# FLUID INCLUSION RESEARCH

Edwin Roedder Editor

Harvey E. Belkin Associate Editor



## Volume 31, 1998



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Volume 31

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#### PREFACE

The purpose of these volumes is to provide entrée into the world literature for the year with English abstracts or annotated citations of all items that either contain fluid inclusion data or are pertinent to some aspect of fluid inclusion work. This covers all types of fluid inclusions (aqueous, organic, silicate melt, sulfide melt, gas, etc.), causes, and mechanisms of trapping (including various types of immiscibility), physical, chemical, and isotopic data, and data on experimental studies of systems pertinent to the interpretation of all types of phase changes occurring in inclusions, as well as to the sources and movement of such volatiles or fluids and their interactions with rocks. These data are generally given without editorial value judgments except in the case of obviously contradictory or obscure statements, where comments or [sic] are added in brackets. Language problems and major shortening make extensive editing necessary on some abstracts, and may still leave the meaning obscure. The extent of coverage varies in part as an inverse function of the availability of the original text to the average Western reader and in part as a direct function of the usefulness of the data. Items that are difficult to obtain, such as theses, and from the Chinese and Russian literature, may be covered in more detail than scientifically more important publications from readily available journals. Pertinent meetings, and the resulting publications, are also listed.

Most items are from the current year, but a few that were not obtained before the necessary editorial cutoff for previous volumes are included. Some items cited as "Indexed under fluid inclusions" came from various computer searches but could not be looked up in time; they may involve only a trivial mention of fluid inclusions or they may be major items since such distinctions are not normally made in computer databases. Compilation of the subject index is one of my most time-consuming chores. The choice of index entries is evolving with each volume, and I would appreciate feedback from the users.

To authors of pertinent articles that have been omitted or are misquoted here through haste or through language difficulties, I extend my apologies and my request to have these things called to my attention; to authors whose original abstracts have been drastically shortened, often by as much as 90%, edited or revised, I offer a reminder that the following "abstracts" are not intended to be abstracts of the whole paper, but only that part most pertinent to inclusion workers. I hope that these cuts have not resulted in erroneous, misleading or confusing statements. The obvious inconsistencies in citation, transliteration, abstracting, editing, cross-referencing, and indexing are strictly a result of lack of editorial time.

I will be glad to learn of unpublished translations of foreign language inclusion literature, and will also be glad to furnish photocopies of the original text of articles or abstracts that have not been translated, or back issues of *Fluid Inclusion Research*, in exchange for partial or full translations for use in future issues. I would particularly like to receive abstracts from pertinent graduate theses and dissertations, as these are exceedingly difficult to locate and represent important contributions that may not appear in the published literature for years.

I am deeply indebted to coeditor Belkin and Business Manager Bodnar for their hard work, and to the U.S. Geological Survey and Harvard University libraries for their cooperation. I also want to thank Joyce M. Angleberger for the excellent typography and editorial help.

Sept. 28, 1999

Edwin Roedder, Editor

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ERRATA

#### **CONTRIBUTORS, VOLUME 31**

Many individuals contribute to the preparation of each volume of Fluid Inclusion Research. Previously we listed Regional Representatives who were asked to help in assuring complete coverage of the world literature by forwarding reprints or citations from their areas to the editors. The concept of Regional Representatives has outlived its usefulness. With the numerous international fluid inclusion meetings and e-mail, I receive much more material from people who are not Regional Representatives than from those who are. I am particularly grateful to those in the following listing who sent me rare volumes, or who translated abstracts, or wrote new abstracts, from the foreign literature. Unfortunately, with the FIR finances as they are, we cannot be as generous with complimentary copies as we used to be, so we can only send a few such copies to the major contributors each year.

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All correspondence concerning editorial matters, and particularly offers of help on abstracting or translation, should be addressed to the Editor:

> Edwin Roedder, Editor Fluid Inclusion Research Department of Earth and Planetary Sciences Harvard University, Cambridge, MA 02138 USA Telephone (978) 281-6193 E-mail roedder@shore.net

#### **VOLUNTEERS NEEDED**

The editors would appreciate any help that can be offered by the readers in issuing future volumes of *Fluid Inclusion Research*. Thus recent volumes have been missing a number of items from the French and German literature because some of our volunteer translators were not able to produce the translations promised. Help is particularly needed in translation and in preparing abstracts on a regular basis from various segments of the literature. These jobs can be partitioned into small units as desired; please contact either of the editors at the following addresses. On an informal basis, it would be most helpful if readers could send to the editors reprints or even just reference citations of pertinent literature. Such help is particularly useful to avoid missing obscure publications, such as theses, or publications in which the presence of inclusion data may not be obvious from title or abstract. If important papers have been missed in previous volumes, they also should be noted.

Edwin Roedder, Editor Department of Earth and Planetary Sciences Harvard University Cambridge, MA 02138 USA E-mail roedder@shore.net Harvey E. Belkin, Associate Editor U.S. Geological Survey Mail Stop 956 Reston, VA 22092 USA E-mail hbelkin@usgs.gov

#### **REPEAT OF EDITOR'S SPECIAL REQUEST TO USERS**

A lot of volunteers put a lot of time into *Fluid Inclusion Research* each year since Volume I was published 31 years ago. Many of these issues contained an editorial plea for feedback from the users concerning how it could be improved in text, format, coverage, or indexing. Unfortunately, I have received almost *no* such feedback. As the preparation is by volunteers and the printing is non-profit operation, I cannot promise gross changes that will increase the load. But, I believe I can speak for the whole crew when I say that we want to make it useful, and hence we need your input.

Edwin, Roedder, Editor Department of Earth and Planetary Sciences Harvard University Cambridge, MA 02138 USA

September 28, 1999



#### NOTICES OF MEETINGS, SYMPOSIA, AND SPECIAL PUBLICATIONS

Edited versions of pertinent abstracts from these meetings will be found in the appropriate volume of Fluid Inclusion Research, 1996, v. 29; 1997, v. 30; 1998, v. 31; 1999, v. 32

#### PAST MEETINGS

- ECROFI XIV, July 1997, Nancy. Abstracts from the meeting program were presented in FIR 30 (1997). Final papers were published in Eur. J. Min., v. 10, 1998; these are given here as many have significant changes in authorship and/or textfrom that of the earlier abstracts.
- IAGC Water-Rock Interaction-9, Taupo. New Zealand, March 30 to April 4, 1998.
- 7th International Kimberlite Conference, Rondebosch, S. Africa, April 13-17, 1998.
- VII Exper. Min., Pet., and Geochem. Meeting (EMPG-VII), Orléans, France, May 14-16, 1998.
- GAC/MAC, Québec, Canada, May 18-20-1998.
- AGU/MS/GS Spring Meeting, Boston, MA, USA, May 26-29, 1998.
- PACROFI VII, Las Vegas, NV, USA, June 1-4, 1998 (68 abstracts).
- IAVCEI International Volcanological Congress '98, Rondebosch, S. Africa, July 11-17, 1998.
- 17th General Meeting of IMA, Toronto, Canada, Aug. 9-14, 1998, with a special session on fluid and melt inclusions.
- 8th Annual V.M. Goldschmidt Conf., Toulouse, France, Aug. 30-Sept. 3, 1998, with a special session on hydrothermal reactions.

European Union Socrates - Intensive Program, Modern Trends in fluid-phase petrology, Siena, Italy, Sept. 12-18, 1998.

GSA Annual, Toronto, Canada, Oct. 26-29, 1998.

- Second APIFIS Int'l. Symposium Mineral Forming Fluids and Ore Genesis was held Oct. 28-30, 1998, in Tashkent, Uzbekistan. The Abstracts Volume (165pp), F.A. Usmanov and He Zhili, eds., published by The Acad. Sciences of Uzbekistan, contains 69 items, some in English, some in Russian, and a few in both languages. In this volume of FIR, translations are given of 20 of the most pertinent Russian abstracts, and of the titles of all other possibly pertinent items, published in Russian, translated by Dr. D.A. Brown. Abstracts originally published in English are also given, where pertinent.
- International Symposium "Mineral Forming Fluids and Ore Genesis, in conjunction with II Symposium APIFIS (Asian and Pacific International Fluid Inclusion Society) Oct. 28-30, 1998, Tashkent, Uzbekistan (abstracts in this volume).
- The Society for Luminescent Microscopy and Spectroscopy continues to issue Newsletters (the latest is volume 11, no. 1, Spring, 1999) that include excellent color reproductions of cathodoluminescence views, and news of interest to anyone using this technique, which is very pertinent to assigning origins to fluid inclusions. Membership information: Jinny Sisson; email (jinny@rice.edu).

AGU Fall, San Francisco, Dec. 6-10, 1998.

Workshop on fluids and fractures in the lithosphere, Nancy, March 26-27, 1999.

European Union of Geosciences 10th Biennial Meeting, Strasbourg, France, March 28 to April 1, 1999.

Mineralogical Society (UK) meeting on Hydrocarbon-bearing Inclusions in Crustal Rocks--Study Methods, Applications, and Case Histories, April 7-8, 1999, National Univ. of Ireland, Galway. Keynote speakers: Aplin, Bodnar, Burruss, Parnell, Piperon and Rankin.

GAC/MAC Joint Meeting, Laurentian Univ., Sudbury, Ontario, Canada, May 26-28, 1999.

AGU Spring, Boston, May 31 to June 4, 1999.

ECROFI XV, June 21-24, 1999, Potsdam, Germany. Mss to be published in Chemical Geology.

- IUGG '99, The 22<sup>nd</sup> General Assembly of the Int'l. Union of Geology and Geophysics, including IAVCEI, Univ., Birmingham, July 19-30, 1999.
- SGA/IAGOD 5th Biennial Conf., Society for Geology Applied to Mineral Deposits. "Mineral Deposits: Processes to Processing," Aug. 22-25, 1999, including a special session entitled "Fluid inclusions and ore formation processes.

9th Goldschmidt Conference, Cambridge, MA, USA, Aug. 22-27, 1999

Sept. 13-15, 1999, Symposium 100th Anniv. D.S. Korzhinski, Moscow

Sept. 21-25, 1999, Third Int'l. Symposium on applied isotope geochemistry, Orléans

#### **FUTURE MEETINGS**

GSA Annual, Denver, CO., USA, Oct. 25-28, 1999, including a two-day SEG short course on Techniques in Hydrothermal Ore Deposits. Web site--http://www.geosociety.organization. Telephone 1-303-447-2020.

AGU Fall, San Francisco, CA, USA, Dec. 13-17, 1999; email (meetinginfo@kosmos.agu.org)

- Melts Workshop, March 16-18, 2000, Grenoble, cosponsored by COPCSE; Nicholas Arndt, email (arndt@ujfgrenoble.fr)
- Geoscience 2000, April 17-20, 2000, Univ. of Manchester: Fluids in the crust. Ms. Maxine Winter; email (geo2000@geolsoc.org.uk)
- Short Course "Fluid inclusion in diagenetic and low-grade metamorphic systems" by R. Goldstein, Univ. Pavia, Italy, end May, 2000. Deadline for subscription Feb., 2000. Further information at URL (http://manhattan.unipv.it/Maggio2000/Versione%20Inglese/corso%20inglese.htm)
- Symposium Geology and Ore Deposits 2000: The Great Basin and beyond, Reno/Sparks, NV, USA, May 15-18, 2000; Geol. Soc. of Nevada, SEG, etc. Registration phone (775) 323-4569; email (gsnsymp@unr.edu)
- COPLSE, Workshop on melt inclusions, "Early 2000," Rhone Valley, France. Organization Committee: N. Arndt, J. Blichert-Toft, A. Sobolov, E. Hauri, J. Touret; email (Nicholas.Arndt@univ-rennes1.Fr)
- GeoCanada 2000, May 29-June 2, 2000, Calgary, Alberta, Canada; Jeremy P. Richards, Univ. Alberta; email (Jeremy.Richards@ualberta.ca)
- AGU Spring, Washington, D.C., USA, May 30-June 3, 2000; email (meetings@kosmos.agu.org)

Geofluids III, Barcelona, July 12-14, 2000; URL (http://www.ub.es/geoquimi/geofluids.htm)

IAVCEI General Assembly 2000, July 18-22, 2000, Bandung, Indonesia; email (iavcei@vsi.dpe.go.id)

31<sup>st</sup> Int'l. Geol. Congress, Aug. 6-17, 2000. Rio de Janeiro, Brazil; email (31igc@31igc.org.br). To include a symposium on modern microbeam techniques applied to fluid and solid species.

Goldschmidt 2000, Oxford. UK, Sept. 3-8, 2000; email (Gold2000@campublic.co.uk)

AAPG Int'l. Conf., October, 2000, Bali Indonesia; Session on fluid history and thermal analysis: Implications for oil exploration; email (P.Eadington@dpr.dsiro.au)

GSA Annual, Reno, NV, USA, Nov. 13-16, 2000.

4th Int'l. Conf. Mineralogy and Museums, Dec. 4-8, 2000, Melbourne, Australia; email (bbirch@mov.vic.gov.au).

AGU Fall, San Francisco, CA, USA, Dec. 15-19, 2000; email (meetings@Kosmos.agu.org)

Goldschmidt Conf. May 24-27, 2001, Roanoke, VA, USA. Contact R. Bodnar, VPI&SU; email (bubbles@vt.edu).

10th Water-Rock Interaction Symposium, June 10-15, 2001, Villasimus, Sardinia; email (wri10@unica.it) or (1fanfani@vaxca1@unica.it)

GSA Annual, Boston, Ma, USA, Nov. 5-8, 2001.

IMA 2002, Edinburgh, Scotland, Sept. 9-13, 2002. K. Murphy, Min. Soc., 41 Queen's Gate, London SW7 5HR; email (IMA@minersoc.demon.co.uk). See web site--http://www.minersoc.org

GSA Annual, Denver, CO, USA, Oct. 28-31, 2002.

11th IAGOD Quadrennial Symposium, S. Africa, 2002; email (ehammerb@geoscience.org.za)



#### **ABSTRACTS AND CITATIONS, 1998**

#### **Editorial Notes and Caveats**

Some items from previous years that were not available earlier are included; there will be more of such back date items in this and future issues as a result of the faster publication schedule. Items for which a full English translation has become available during the year are included, even if the item was previously abstracted from its original language. The first author's address (and email address, if available) are given as of the publication date only. Given names or only initials are listed as in the original. Differences in the transliteration procedures that are used in various Western journals for Cyrillic author's or place names have resulted in different spellings of what is probably the same name (e.g., Tsaryeva vs. Tsareva; Petersilé, Petersilie, and Petersilje; Ye vs. E; ...iy vs. ii, etc.).

To avoid problems in the use of various bibliographic databases, I have maintained such spellings as they appeared in the original publications. Similar problems occur with diacritical marks in author's names. (In alphabetizing here, these marks are ignored. Note, however, that some journals delete all umlauts, and others delete the umlaut but add an "e" to the author's name [e.g., ö becomes oe], so the same author could appear at different places in the following alphabetized listing.) Names starting with "van," "Van," "de," "De," etc., are alphabetized under V (or D), in part with a cross-reference entry under the family name, except when the author's preferences are known; names starting with "Mc" or "St" are alphabetized exactly as spelled. The differences in custom between Spanish and Portugese peoples in the sequence of listing (and hence alphabetization) of double surnames presents numerous possibilities for error in alphabetization. Even worse problems exist for Chinese names, which have been alphabetized here according to what *I believe* is the family name, regardless of the order of printing in the original

In a few abstracts, the use of "temperature of formation" is assumed to refer to FI temperatures. Also, in a few items, cross-references are made to other items in this volume or to particularly pertinent items in previous volumes that have been recognized, but most such have probably been missed. In numerous cases, two (or even three) similar abstracts by the same author (or authors) are printed here, even though they may be nearly duplicates; this is done because differences in data or interpretation may be present. Complete duplicates are merely cited. The software used in pre-paring these abstracts results in some changes in alphabetization from the normal sequence used in scientific bibliographies. To avoid missing items, please note the following examples: O'Hara comes before Oban; Le Guern comes before Leaman.

ABE, T. and TSUKAMOTO, K., 1998, An attempt to visualize the concentration/temperature field around silicate crystals growing at high temperature (abst.). 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A81. First author at Dept. of Earth Sci., Faculty of Sci., Yamaguchi Univ.

Such visualization has been realized successfully by high resolution laser interferometry for crystal growth at room T, but not as yet for high-T crystal growth. However, we had the prospect of visualizing this crystal growth process by means of our sample holding method used in our previous in-situ observations. In this study, we employed a Mach-Zehnder interferometer for the test on the crystal growth of forsterite in the system Fo-An-Silica at T up to 1400°C.

This attempt at such high T has been successful and thus the concentration gradient can quantitatively be analyzed by processing the interference fringes. It was demonstrated first that the gradient of concentration becomes large with the increase of  $\Delta$ Ts and inverse in growth and dissolution. This method is now being applied to the subjects mentioned above. However, the fringes were distorted with the curved meniscus of the thin film of the solution, which impedes a more detailed analysis of the concentration gradient. This problem is now being addressed. (From authors' abstract by E.R.)

ABIDIN, H.Z., NOYA, Y. and MANGGA, S.A., 1998. Paleothermal characteristics of the Masupa gold prospect, East Kalimantan, Indonesia: Ninth Regional Congress on Geol., Mineral and Energy Resources of Southeast Asia—GEOSEA '98 17-19 Aug. Kuala Lumpur. Malaysia, Program and abstracts, p. 119, Mineral Resources paper 22. Authors at Geological Research and Development Centre, Jalan Diponegoro No. 57. Bandung 40122, Indonesia.

A few samples of quartz and calcite minerals from the Ongkang and Kiwi orebodies, Masupa Ria gold prospect, have been sampled for FI study. Most of the FI were L-rich and consist of two phases. L H<sub>2</sub>O and a V bubble with L/V=9.1. Consistent L/V ratios indicate that boiling has not occurred. The FI are negative crystal and elongate in shape. No visible  $CO_2$ was detected in any of the FI.

At the Ongkang body, PFI in quartz from stage 2 alteration have  $T_h$  values ranging from 262-278°C and sal values range from 0.3 to 10.4 wt.% NaCl eq. One of the above FI has the lowest  $T_e$  (-48.7°C) and positive  $T_f$  (1.5°C), which may indicate the presence of CaCl<sub>2</sub> 6H<sub>2</sub>O hydrate. The  $T_h$ 

and sal value from stage 4 alteration are 350°C and 1.0 wt.% NaCl eq., respectively.

Th values, which are recorded in calcite from Ongkang in stage 2 alteration, range from 296 to 300°C with the sal values ranging from 1.4 and 3.0 wt.% NaCl eq.

These T<sub>h</sub> values are lower than the PFI in quartz and are consistent with the deposition of calcite later than quartz. The S FI within calcite has lower T<sub>h</sub> values, i.e. 287°C with the sal value of 1.9 wt.% NaCl eq. The lower T<sub>e</sub> and T<sub>f</sub> values (-41.2°C and -0.8°C, respectively) of one PFI in calcite is again indicative of salts such as CaCl<sub>2</sub> in addition to NaCl. Both P and S FI in calcite from the Ongkang body represent decreasing T and sal with time.

At the Kiwi orebody, a PFI in quartz has  $T_h$  value of 317°C and the sal value is 1.9 wt.% NaCl eq. The  $T_h$  values of the SFI in quartz range from 215 to 234°C with sal values range from 1.2 to 6.4 wt.% NaCl eq. The lower  $T_c$  (-65.1°C) and positive  $T_f$ (2.5°C) values of FI (SFI) in quartz is due to the presence of CaCl<sub>2</sub> 6H<sub>2</sub>O hydrate. Th values of PFI in calcite are very consistent and range from 220 to 222°C while the SFI have lower  $T_h$  values, i.e. 215 and 217°C. Sal values for both P and SFI are 0.7 to 1.6 and 1.9 and 1.2 wt.% NaCl eq., respectively. Again, the  $T_h$  values of FI in calcite are lower than those in quartz indicating late deposition.

At the Ongkang orebody, the lower range of sal values (0.3 to 1.9 wt.% NaCl eq.) are indicative of the absence of magmatic component in the hydrothermal F. The F is possibly due to mixing of the cooler hydrothermal F and less saline groundwater. Gold has been deposited in relation to the higher T<sub>h</sub> value (350°C) when the Ongkang silica cap was formed.

At the Kiwi orebody, on the other hand the F is characterized by an increase in sal F as T declined. The hydrothermal F is mixed with cooler, more saline groundwater. Gold mineralization has been deposited at significantly lower  $T_h$  (180-200°C). (From authors' abstract by E.R.)

AGRINIER, Pierre and JENDRZEJEWSKI, Nathalie, 1998. Improved determinations of carbon and water contents in basaltic glasses by FTIR spectroscopy (abst.): EOS, Trans., 79 (45) Fall Meet, Suppl., p. F986. Authors at Lab. Geochimie Isotopes Stables, IPGP, 2 Place Jussieu, Paris 75251 Cedex 05, France, Metropolitan: email (piag@ccr.jussieu.fr)

Traditionally, the Beer-Lambert law is used to determine [OH-] and [CO<sub>3</sub>-] in glass from infrared spectrum data. This method practically requires the measurement of the thickness and the density of the glass, both

of which are sources of uncertainty. The weaknesses in the practical applications of the Beer-Lambert law have been overcome by an empirical analysis of the IR spectra. Using a large set of natural MORB glasses, whose chemistries span over all the varieties of basaltic glass, we show that there exists a good linear relationship between abs1750 (=mean absorbance in the 1750-1800 cm<sup>-1</sup> domain minus mean absorbance in the 2150-2200 cm<sup>-1</sup> domain) and the density-thickness product. (From authors' abstract by E.R.)

AISSA, D.E., MARIGNAC, Christian, CHEILLETZ, Alain and BOI-RON, M.-C., 1998, Gold-bearing arsenopyrite from the Koudiet el Ahrach Deposit (Edough, Annaba): Bulletin-Office Nat'l. de la Geologie, v. 9, no. 1, p. 3-20.

At the Koudiat el Ahrach occurrence (Edough metamorphic basement, NE Algeria), stibnite, pyrite, pyrrhotite, sphalerite, galena and gold-bearing arsenopyrite are found in epithermal quartz veins. Gold distribution within crystals is very irregular and it is very difficult to establish a correlation with elements bearing arsenopyrite. The vuggy quartz is strongly zoned, with abundant FI, mainly P, allowing a description of the variation in F composition and T during quartz growth. Melting of ice occurs in the very restricted range of  $0-13^{\circ}$ C, while the Te is recorded around -21°C, thus indicating a low-sal NaCl-dominated. F Th are in the range of 180-270°C, and densities 0.795-0.854 g/cm<sup>3</sup>. From one growth zone to the other, changes in both sal and Th are the rule. Mixing trends between a very low-sal F and a more saline F are apparent. Mixing occurs either with an increase or a decrease in Th. (From authors' abstract by E.R.)

AKANDE, S.O. and ERDTMANN, B.D., 1998, Burial metamorphism (thermal maturation) in Cretaceous sediments of the southern Benue Trough and Anambra Basin, Nigeria: AAPG Bull., v. 82, no. 6, p. 1191-1206.

Organic matter reflectance, illite crystallinity, and FI techniques have been used to evaluate burial metamorphic conditions for the lithostratigraphic successions that accumulated during the Cretaceous in the southern Benue trough and Anambra Basin of southern Nigeria. These successions were invaded by intrusives, volcanic rocks, and vein-type leadzinc minerals, especially in the Albian-Cenomanian section of the Abakaliki Anticline. FI P-corrected T from vein quartz in the Albian shales range from 170 to 250°C. The results of this work show that thermal maturation in the Cretaceous successions increases from the post-Santonian (Campanian-Maastrichtian) Anambra Basin into the older Benue trough where strong diagenetic to "anchimetamorphic" (i.e., very low grade metamorphism) conditions were reached. The data suggest that these sediments at the present outcrop levels originally were buried at higher maturity levels. Maximum erosion appears to have taken place on the axis of the Abakaliki Anticline. The presence of bitumen in fractures and pores of the exposed Maastrichtian units in the Anambra Basin suggests that the matured sediments generated some unknown quantity of petroleum. This finding, coupled with reported G finds and some oil in previous exploration wells of the Anambra Basin, enhances the possibilities of Cretaceous targets in the downdip regions. (From authors' abstract by E.R.)

ALBAREDE, F., 1998, Reconciling mantle rare gas geochemistry with tomographic evidence of whole mantle convection (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 34-35.

ALDERTON, D.H.M., 1998. The genesis of tellurium-rich epithermal precious-metal deposits: Examples from western Romania (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-301. Author at Geol. Dept., Royal Holloway (Univ. of London), Egham, Surrey TW20 0EX, UK; email (d.alderton@gl.rhbnc ac.uk)

Au-Ag-Te mineralization in the southern Apuseni Mountains of western Romania is hosted by mid-Miocene (14 Ma) andesite stocks and lava flows formed in a continental margin subduction setting. Mineralization is found in quartz (plus Ca-Mn carbonate and barite) veins and in hydrothermal breccias and is associated with adularia-sericite/smectite and propylitic alteration assemblages. The ore mineralogy is complex, but dominated by pyrite, base metal sulfides, precious metal tellurides, gold, and Sb- and Asbearing sulfosalts. Fl studies suggest that mainstage mineralization occurred at around 250°C from dilute Na-Ca-K-Cl brines. Evidence for sporadic boiling can be found.

Hydrogen and oxygen isotopic analyses of minerals and FI suggest that the mainstage mineralizing F had a composition of  $\delta^{18}O=6.8$  to 9.9 and  $\delta D=-29$  to -76 (per mil SMOW). Sr isotopic analysis of the wallrock alteration assemblages indicates that interaction between hydrothermal F and sediments of continental derivation was extensive. A scenario for F evolution which is supported by the Fl and the stable and radiogenic isotope study would be that the mainstage mineralizing F was dominated by magmatic water which had interacted with local sedimentary lithologies. Furthermore, it appears likely that this F was exsolved from a magmatic body of unknown character which existed at depth below the associated andesitic rocks. Later carbonates and barite were formed at lower T from F with an increased component of meteoric water.

In most epithermal gold-silver deposits there is clear evidence for an overwhelmingly dominant component of meteoric F in the hydrothermal system. Tellurium-rich epithermal deposits appear significantly different and were formed from F which were dominantly magmatic in character. (Author's abstract)

ALLEN, J.M., ASLUND, T., SUNYOTO, W. and SOEBARI, L., 1998. The Wabu gold skam, Irian Jaya, Indonesia (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A3-A4. First author at John Allen & Associates, P.O. Box 32-290, Devonport, Auckland, New Zealand; email (jmallen@jma.co.nz)

The mineralising event is defined by deposition of loellingite, followed by abundant Fe and As sulphides (pyrrhotite, arsenopyrite, pyrite), and finally minor base metal sulphides. Gold and Bi-Te-S minerals are intimately associated, and primarily occur as I within sulphides. Au and Bi are inferred to have been co-precipitated with sulphides, from hydrothermal F that were undersaturated with respect to metallic Au and Bi-Te-S phases, and to have exsolved from sulphide hosts on cooling and recrystallisation. About 2% of known skarn is gold mineralised, restricted to zones of F flow constrained by less permeable lithologies: marble, hornfels and porphyry dykes. Intense, zoned retrograde silicate-carbonate alteration clearly defines proximal mineralisation and F outflow zones. In contrast, alteration is weak in distal gold zones, where association of alteration and mineralisation is indistinct. FI in skam garnet, quartz and carbonate record mixing of an Na-K brine of presumed magmatic derivation, with a S CaCl<sub>2</sub>-bearing F of low sal that is inferred to have evolved during reaction of magmatic F with carbonate metasediments to form skarn. I in prograde garnet and pyroxene are Na-K-(Ca) brines recording high F T (70-80% NaCl+KCl; Th=400-600°C). I in quartz overlapping with mineralisation, and in late calcite, are CaCl2-rich and compositions trend toward the S F with which they are inferred to have incompletely mixed; they record high dilution and low T (CaCl<sub>2</sub>NaCl=0.4-1.5; Th 100-450°C). There is limited evidence that sulphide deposition and gold mineralisation occurred at the interface between dilute magmatic F and S CaCl2 bearing F. (From authors' abstract by H.E.B.)

ALTAMURA, R.J., DEINES, P. and GOLD, D.P., 1998. Stable isotope  $(\delta^{18}O/^{16}O \text{ and } \delta D)$  studies of Mesozoic quartz veins from the Lantern Hill fault, southeastern Connecticut (abst.): The Geological Society of America 33<sup>rd</sup> Annual Meeting, Northeastern Section, March 19-21, 1998, Portland, Maine, v. 30, no. 1, p. 2, ISSN 0016-7592. Authors at Dept. of Geosci., Pennsylvania State Univ., University Park, PA 16802.

Oxygen and hydrogen isotopic data were obtained for quartz and F in its 2-phase aq I in veins that compose the Lantern Hill (LH) quartz vein complex near North Stonington, CT. The LH complex is comprised primarily of an array of parallel veins within the core of a N-S trending normal fault zone that transgresses Upper Proterozoic "basement rocks" of the Avalonian terrane. In contrast to the core zone, wall rocks are dissected by older generations of quartz veins that exhibit a stockwork pattern. Based on a strict criteria that considers cross-cutting relationships, orientation, thickness and texture, a sequence of 9 vein sets were delineated. The main stage of deposition is recorded by an array of parallel veins in the core of the fault zone. Typically mesothermal Au-quartz lodes occur within reverse faults, the LH lode occurs within a normal fault and is essentially "barren" with regard to Au (0.015 ppm). An estimated 24 million m<sup>3</sup> of quartz suitable for use as industrial silica is present to a depth of 170 m

Oxygen isotopic compositions of quartz were obtained by laser-based isotope analysis. Where early- and main-stage quartz yielded  $\delta^{18}O/^{16}O$  measurements between 6.24‰ and 7.04‰, late-stage veins yielded values up to 10.8‰. The mean isotopic compositions of hydrothermal solutions that would have been in equilibrium with such quartz was calculated to be -0.71% with a range from -0.49 to -1.85%. Temperature data used were obtained by Fl analysis of the quartz veins.

The hydrogen isotopic composition of the F in equilibrium with quartz was obtained through the measurement of microliters of aq F extracted from P FI trapped in the quartz. Mean  $\delta D$  was determined to be -27%.

During isotopic exchange between hydrothermal F in the fault and wall rocks, wall-rock feldspars were converted to sericite, and silica was released into solution. F originally more negative in  $\delta^{18}O/^{16}O$  followed a geothermal trend to become more positive. In this model meteoric waters (-10% 518 O/16 O and -27% SD) exchanged with metamorphosed 1-type granites and became less negative with respect to 518O/16O, but changed little with respect to \deltaD.

Emplacement of the vein complex into the LH fault zone occurred during the Middle Triassic at the time of the embryonic opening of the Atlantic Ocean. (Authors' abstract)

ALTHAUS, T., NIEDERMANN, S. and ERZINGER, J., 1998, Noble gases in ultramafic mantle xenoliths of the Persani Mountains, Transylvanian Basin, Romania (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 43-44. Authors at GeoForschungsZentrum Potsdam, Projektbereich 4.2, Telegrafenberg, D-14473 Potsdam, Germany.

We have studied abundances and isotopic compositions of all noble G in samples of whole rock xenoliths, mineral separates thereof, single crystals and host basalts. We have found clear evidence for a mantle origin in He, Ne and Ar isotopic compositions, whereas Kr and Xe did not show any deviation from the atmospheric ratios. (From authors' abstract by E.R.)

AMÁNTOV, V.A., ORLÓVA, M.P. and SÓTNIKOV, G.G., 1998, Diamond-bearing rocks in various structures and situations in the tectonosphere of Russia (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 37-38 (in Russian).

AMTHAUER, Georg and ROSSMAN, G.R., 1998, The hydrous component in andradite garnet: American Mineralogist, v. 83, p. 835-840. Authors at Div. of Geological and Planet. Sci., California Inst. of Tech., Pasadena, CA 91125, USA

Twenty-two andradite samples from a variety of geological environments and two synthetic hydroandradite samples were studied by Fourier transform IR spectroscopy. Their spectra show that H enters andradite in the form of OH. Amounts up to 6 wt% H2O occur in these samples; those from low-T formations contain the most OH (From authors' abstract by E.R.)

ANDERSON, A.J., MAYANOVIC, R.A. and BAJT, Sasa, 1998, Microbeam XAFS study of aqueous chlorozinc complexing to 430°C in fluid inclusions from the Knaumühle granitic pegmatite. Saxonian granulite massif, Germany: Canadian Mineralogist, v. 36, p. 511-524. First author at Dept. of Geol., St. Francis Xavier Univ., P.O. Box 5000, Antigonish, Nova Scotia B2G 2W5

The synchrotron X-ray microprobe (X26A) at the National Synchrotron Light Source (NSLS), Brookhaven Nat'l. Laboratory was used to collect zinc K-edge absorption spectra from saline (ca. 36 wt% NaCl eq.) FI in quartz from the Knaumühle granitic pegmatite, in the Saxonian Granulite Massif, Germany, at T ranging between 30 and 430°C. XAFS spectra were also obtained from one FI that was experimentally re-equilibrated at a high P of hydrogen. The T of the FI was controlled during analysis with a programmable heating stage. Analysis of the XAFS data shows that ZnCl42 is the dominant aq zinc species in the FI up to the average Tt (430°C). Furthermore, the mean Zn-Cl bond length decreases uniformly from 2.31±0.01Å at room T to 2.26±0.02Å at 430°C. The predominance of the tetrahedral chlorocomplex, rather than ZnC12°, at high T is most probably due to the high chloride concentrations of the I brine. (Authors' abstract)

ANDERSON, A.J., MAYANOVIC, R.A. and CHOU, I.-M., 1998, Micro-beam XAFS measurements of zinc complexes in highly saline FI to 400°C before and after experimental re-equilibration at high hydrogen pressure (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 55-56.

ANDRÉ, A.S., LESPINASSE, M., BOIRON, M.C., CATHELINEAU, M., CUNEY, M. and LEROY, J., 1998, Evolution of fluid circulations and P-T regimes in the St. Sylvestre massif by the use of fluid-inclusion planes (abst.) Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998, p. 63 (in French, translation by E.A.J. Burke). Authors at UMR G2R (7566) LIHP Nancy 1, BP 239, 54506 Vandœuvre Cedex.

The end of the Hercynian orogenesis is marked in the Central Massif (France) by an intense hydrothermal activity, which is partly responsible for the formation of mineral occurrences (Au, U) and for hydrothermal altera-

tions. The F percolations are already well-known in the zones mineralized with U (sector of Margnac, Pény), but the lateral extension of these F and of the geothermal paleofields on the scale of the St. Sylvestre massif, however, is not well-known; this encourages a study of the 3-dimensional evolution of F circulations. The paleomigrations of F have been characterized by the analysis of FIP, thus allowing for the elaboration of detailed relations between tectonic phases and F migrations. Three major episodes could be identified along the following chronology: - Planes N20: aqueous-carbonic F, Th = 350-410°C for minimum Pt of

60-90 Mpa (depth 4-6 km).

 Planes NW-SE: biphase aq-carbonic F, Th= 350°C for minimum P of 40-50 Mpa, and aq I with varying sal (0.9-12.8 wt.% eq. NaCl).

- Planes EW: ag F with 4 6 wt.% eq. NaCl. Th = 220-230°C at P of 10-20 Mpa (estimated depth 1-2 km)

The results suggest a process of isostatic uplift of the massif, connected with an erosion stage, which is in agreement with the isotopic and thermal data of Scaillet et al. (GCA v. 60, 1996).

The composition of the aq-carbonic F (±CH4 + N2) remains similar in the whole profile, but their concentration decreases from east to west, ending at zero. This variation in concentration seems to be strongly connected with the position of these aq-carbonic F in relation to the intrusive body of fine-grained granite (g2) which outcrops to the east of the profile and which dips to the west. (Authors' abstract)

ANDREEVA, I.A., NAUMOV, V.B., KOVALENKO, V.I. and KO-NONKOVA, N.N., 1998, Fluoride-sulfate and chloride-sulfate salt melts of the carbonatite-bearing complex Mushugai-Khuduk, Southern Mongolia: Petrologiya, v. 6, no. 3, p. 307-315 (in Russian, translated in Petrology, v. 6, no. 3, p. 284-292). First author at Inst. of Geol. of Ore Deposits, Petrog., Mineral. and Geochem., Russian Acad. of Sci., Staromonetnyi per. 35, Moscow, 109017 Russia; email (vik@igem.msk.su).

Inclusions of mineral-forming media were studied in fluorite from the celestite-fluorite rock of the alkaline carbonatite-bearing Mushugai-Khuduk complex (Southern Mongola). It was found that the late igneous stages of rock formation were characterized by the presence of salt M (density of 1.7-1.8 g/cm3 and H2O contents of 4.7-6.0 wt.%), salt M-solutions (density of 1.3-1.5 g/cm3 and H2O contents of 30-40 wt%), and highly concentrated solutions (density of 0.7-1.0 g/cm3 and H2O contents of 70-85 wt%). The calculated composition of the salt M is the following (wt%): 26-35 CaO, 5.7-9.9 SrO, 1 2-1 9 BaO, 2.7-11 Na2O, 3.7-3.9 K2O, 29-33 SO3, 0.1-10.9 Cl, 2.1-5.5 F, 4.7-6.0 H2O, and 2.1-4.5 CO2. The T of the salt M (670-600°C), M-solutions (550-370°C), and concentrated solutions (430-265°C) were determined. The cooling of the salt M resulted in the crystallization of fluorite, calcite, barite, halite, and a series of unusual sulfate minerals with high contents of CaO, Na2O, K2O, BaO, SrO, and F within the I. The possibility of carbonatite M segregation during the differentiation of alkaline magmas is now accepted by many petrologists. The data obtained from the study of salt M I together with experimental results suggest that the same process may also produce sulfate-dominated M with high concentrations of fluorine and chlorine. (Authors' abstract)

ANDRESEN, Bjørg, MUNZ, I.A., JOHANSEN, Harald and JOHAN-SEN, Ingar, 1998, Compositional and isotope data on hydrocarbon fluid inclusions-A tool for better understanding of light hydrocarbon migration and trapping (abst.): American Chemical Society 215th National Meeting Program, Dallas, TX, March 29-April 2, 1998, paper no. 015. Authors at Inst. for Energy Tech., P.O. Box 40, N-2007 Kjeller, Norway.

A reproducible method is developed for the determination of component and stable isotope composition of CO2 and C1-C5 G components from bulk FI extracts. The method is tested on hydrocarbon FI from some North Sea samples and compared to data on reservoir G from the same area. The obtained data will be discussed in combination with data from in situ analytical techniques such as microthermometery, PVT constraints and fluorescence spectroscopy. (From authors' abstract by E.R.)

ANOVITZ, L.M., BLENCOE, J.G., JOYCE, D.B. and HORITA, Juske, 1998, Precise measurement of the activity/composition relations of H2O-N2 and H2O-CO2 fluids at 500°C, 500 bars. Geochim. et Cosmo. Acta, v. 62, no. 5, p. 815-829. Authors at Geochem. Group, Chemical and Analytical Sci. Div, Oak Ridge Nat'l Laboratory, Oak Ridge, TN 37831-6110, USA.

The activity/composition relations of H2O-N2 and H2O-CO2 F have been measured at 500°C, 500 bars. The results are more accurate, and much more precise, than any currently available, especially for H2O-poor compositions. The data suggest that H2O-CO2 F exhibit large positive

deviations from ideality at 500°C, 500 bars, in marked contrast to values predicted by available EOS. These results indicate that more accurate models for both  $H_2O$ - $N_2$  and  $H_2O$ - $CO_2$  F are needed. (From authors' abstract by E.R.)

ANOVITZ, L.M., LABOTKA, T.C., BLENCOE, J.G. and SINGH, J., 1998, Activity-composition and phase relations of H<sub>2</sub>O-CO<sub>2</sub>-NaCl fluids at 500°C, 500 bars (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-319. First author at M.S. 6110, Bldg. 4500-S, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6110; email (anovitzlm@oml.gov)

H<sub>2</sub>O-CO<sub>2</sub>-NaCl samples were reacted at 500°C, 500 bars and a(H<sub>2</sub>O)=0.425, 0.437, 0.560, 0.606, 0.678 and 0.798. Results indicate that all these activities lie in the V-NaCl two-phase region and that the last value is close to the three-phase (V+brine+halite) field. Data from this experiment suggest that the V corner of the three-phase field lies near  $X(H_2O)=0.730$ , X(NaCl)=0.032. (From authors' abstract by H.E.B.)

APPOLD, M.S. and GARVEN, Grant, 1998, The hydrodynamics and geochemistry of MVT ore genesis in southeast Missouri (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 11. First author at Dept. of Earth and Planetary Sci., Johns Hopkins Univ., Baltimore, Md 21218 USA.

Coupled mathematical models for brine migration and geochemical reactions during flow are described here to illustrate the complex yet elegant control of basin hydrodynamics on the giant MVT ore system [i.e., Viburnum Trend] in southeast Missouri. Ore formation was concentrated in southeast Missouri because of the regional flow patterns, aquifer pinchouts, and favourable conditions for chemical deposition of Pb-Zn sulphides due to F mixing and cooling. Until recently, the mechanisms thought to cause ore mineralisation have remained untested in a hydrodynamic sense and only a few have been theoretically evaluated with geochemical reaction path type calculations based on thermodynamic modeling.

Numerical simulations, based on the finite element method, test steady and transient flow models for brine migration across the entire sedimentary basin. We solve the partial differential equations governing simultaneous F flow, heat transfer, and chemical mass transport for saturated porous media. Our mathematical models suggest that ore formation is constrained hydrologically to time scales less than a few million years, otherwise brines resident in the foreland basin are "flushed" by meteoric recharge across the Permian confining layer and the heat pulse associated with basin-scale F flow arrives too late to elevate brine T along the flow path and establish thermal conditions recorded by FI data. We show examples of reactive flow to test geochemical models of ore deposition 1) metal and reduced sulphur transport in a regional brine that deposits ore while cooling, and 2) metal transport in a regional brine which mixes with local F containing reduced sulphur within the Viburnum Trend. The pros and cons of both scenarios are discussed in light of the hydrodynamic setting. (From authors' abstract by E R.)

AQUILINA, Luc, BAUBRON, J.-C., DEFOIX, Denis, DÉGRANGES, Philippe, DISNAR, J.-R., MARTY, Bernard, and ROBÉ, M.-C., 1998, Characterization of gases in sedimentary formations through monitoring during drilling and core leaching (Balazuc borehole, Deep Geology of France Programme): Applied Geochem., v. 13, no. 6, p. 673-686. First author at BRGM, Direction de la Recherche, 1039 rue de Pinville, 34000 Montpellier, France.

Continuous analysis of the drilling F and core sampling show good agreement. Although higher concentrations are obtained in the drilling F, the drilling to core ratio shows a relatively constant value. These higher concentrations are due to crushing of the rock during drilling and the influence of the sediments surrounding the borehole. The characterization of the G with depth indicates 3 different zones: (1) the Jurassic carbonates, with high CH4 and CO2 concentrations; (2) the Triassic upper sandstone and middle evaporitic units, with average concentrations of He, CO2, N2 and low CH4, and (3) the Triassic lower sandstone unit and the Carboniferous silts, with high He, N1 and low CO2 and CH4 concentrations. These trends indicate that diffusion is not a major process at Balazuc and that the formations remained relatively independent from each other. Nitrogen and CO2, which are the main constituents, show a reverse correlation. The He record in the continuous measurement is correlated to a major F transfer in the formations of the lower part of the borehole, along the Uzer fault. (From authors' abstract by E.R.)

AQUINO, J.S. and MORRISON, G.W., 1998, The relationship between epithermal and porphyry Cu-Au mineralisation in the Dizon deposit, Philippines (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 12. First author at RTZ Exploration, 296 Far East Asia Village, Visayez Ave., Quezon City.

Epithermal mineralisation hosted in alsic (advanced argillic) alteration is popularly thought to be cogenetic with adjacent porphyry copper mineralisation in many major districts. In the Dizon deposit, open pit mining has exposed geological relationships that bear on the timing and genesis of porphyry and epithermal mineralisation in such a system.

Dizon is a gold-rich porphyry copper-gold deposit hosted in an Early Miocene andesite-diorite stratovolcano. The alsic alteration carries no mineralisation of its own at this point, but the rock is still ore because the quartz in the porphyry veins has protected the enclosed sulfides from leaching during alsic overprint. The alsic alteration is part of a blanket that covers 50 km<sup>2</sup> and at least three discrete porphyry systems in the Dizon area. In the mine itself, there is a sharp base to the blanket which clearly overprints the potassic, SCC and propylitic alteration zones.

FI and isotopic data suggest the porphyry system formed from high sal magmatic F at >650 to 350°C. It was eroded by at least 1 km before the alsic blanket developed. The epithermal system was formed by the boiling of low sal F at 390 to 130°C <300 m below the present upper surface of the blanket. The Pb in the epithermal system is from a more enriched source than that in the porphyry system.

The simplest explanation of the relationships, chemical differences and F data, is that the porphyry and epithermal systems are related to two discrete magmatic-hydrothermal events and two discrete igneous episodes. The alsic alteration is not genetically related to the porphyry system, but part of a much more extensive blanket formed by degassing of younger dacitic intrusions, localised by a prominent set of cross-cutting faults. The broader relationship between the dacitic and dioritic intrusions is not entirely clear. They could be two completely separate igneous events, or early and late phases of one evolving magmatic complex. The narrow time interval (approx. 700,000 years) and 1 km of erosion between the dioritic and dacitic igneous events is similar to developments in many active island arc stratovolcanoes, including Mt. Pinatubo, which is only 5 km from Dizon. (From authors' abstract by E.R.)

ARANOVICH, L.Y. and NEWTON, R.C., 1998, Reversed determination of the reaction: Phlogopite+quartz=enstatite+potassium feldspar+H<sub>2</sub>O in the ranges 750-875°C and 2-12 kbar at low H<sub>2</sub>O activity with concentrated KCI solutions: American Mineralogist, v. 83, p. 193-204. Authors at Dept. of the Geophys. Sci., Univ. of Chicago, 5734 S. Ellis Ave., Chicago, ILL 60637 USA.

This study requires revision in estimates of  $H_2O$  activity of granulite facies metamorphism. An important consequence of the expanded  $H_2O$ activity range of granulites is that alkali chloride solutions of only moderate concentrations [XH<sub>2</sub>O=0.5-0.7], which are the values observed in actual FI in many kinds of igneous and metamorphic rocks, are a feasible alternative to the V-absent conditions considered necessary by many workers based on previous low estimates of  $aH_2O$ . Participation of concentrated brines in deep-crust/upper mantle metamorphic processes enables alkali metasomatism and other kinds of chemical transport in an aq F without large-scale melting of the crust. (From authors' abstract by E.R.)

AREHART, G.B. and HULSTON, J.R., eds., 1998, Water-Rock Interaction, Proceedings of the 9th Int'l. Symposium on Water-Rock Interaction-WRI-9, Taupo, New Zealand, 30 March-3 April, 1998. A.A. Balkema, Rotterdam, ISBN 90 5410 942 4.

ARMSTRONG, R.N., ROBERTS, S. and WHITE, N.C., 1998a, Inclustons and the included: An investigation of porphyry forming magmas from the SW USA (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated). First author at School of Ocean & Earth Sci., Univ. of Southampton, Southampton Oceanography Centre, Empress Dock, European Way, Southampton, SO14 3ZH.

The role of the magmatic system in the formation of such deposits is still not fully understood. No information on the actual late stage magmatic M composition has been forthcoming. In this study, data is presented from the analysis of MI hosted within quartz phenocrysts obtained from two actively mined porphyry copper deposits, Morenci (Arizona) and Chino (New Mexico). The use of MI presents an unparalleled opportunity to investigate the late stage chemistry of a magmatic system. Volatile and metal

The MI analysed were hosted within bipyramidal quartz phenocrysts; these I were remelted with varying success. Major element data as obtained by EPMA showed high SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and K<sub>2</sub>O contents and low total Fe and MgO. Measured Cl contents are up to 6920 ppm, which is typical for such calc alkaline systems. Copper values are variable (7.5 to 478.4 ppm), but in general terms elevated for a calc-alkaline system. These high Cu contents probably reflect the time of entrapment of the MI, relative to the magmatic systems overall evolution.

Biotites included within the bipyramidal quartz phenocrysts represent preserved micro phenocrysts, magmatic in origin, and were probably crystallised in an oxidised magma type. Furthermore, the presence of biotites indicates the magma was water-saturated prior to quartz crystallization. Copper values measured for these biotites are extremely variable with some exceptionally high copper contents being recorded (0.001 to 4.655 wt% as measured by SIMS). Low sulphur contents (below the EPMA detection limits), and the absence of a positive correlation between Cu and S suggests that sulphide is not the copper-carrying species. (Authors' abstract)

ARMSTRONG, R.N., ROBERTS, S. and WHITE, N.C., 1998b, Quartz phenocryst morphologies in mineralised porphyry deposits. An insight into the MVP exsolution process? (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated). First author at School of Ocean & Earth Sci., Univ. of Southampton, Southampton Oceanography Centre, Empress Dock, European Way, Southampton, SO14 3ZH.

Many mineralised porphyry systems contain bipyramidal quartz phenocrysts (B-quartz form) in their central plutons. The occurrence of such phenocrysts has been investigated by past workers, but often dismissed as insignificant to the mineralising process. Observations from phenocrysts of the Younger Granodiorite Porphyry from the Morenci deposit (Arizona) provide a record of magmatic volatile exsolution. The phenocrysts, although now presenting a bipyramidal habit, record several phases of growth in the form of growth zones and included mineral species. The preservation of these features, and indeed their formation, is dependent on two key parameters. I. The degree of undercooling of the M ( $\Delta T$ ), and the temporal dependency of this process; and 2. The M/magmatic water content, and its variation through time. Petrographic observations demonstrate that the degree of water saturation through the late stages of M evolution was variable, with the M prior to initial quartz being water-saturated as indicated by the presence of included biotites. A resorbed/spherical growth core to the larger phenocrysts is indicative of large ∆T and probable water saturation. Some of these spherical cores have FI trapped at their margins. Repeated zones of bipyramidal form suggest low AT conditions and a nonsaturated M with regards to H2O. It is also tentatively suggested that the preservation of bipyramidal quartz forms may be evidence of crystallization-induced volatile overpressuring. The quantification of this process could provide a potential pathfinder for mineralised porphyry systems. (Authors' abstract)

ARMSTRONG, R.N., ROBERTS, S. and WHITE, N.C., 1998c, The ore-forming potential of calc alkaline magmatic systems: The melt inclusion chemistry of a copper rich andesite from Hahajima, Japan (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). First author at Dept. of Geol., Univ. of Southampton, Southampton Oceanography Centre, Empress Dock, European Way, Southampton SO14 3ZH.

Silicate MI provide a method of directly sampling the volatile and ore metal content of magmatic systems. Plagioclase-hosted MI of a copper rich andesite from Hahajima, Japan, contain significant levels of copper (up to 2000 ppm), an average water content of 3.26 wt%, and a CI/H<sub>2</sub>O ratio of 0.06. This high copper content can be attributed to the presence of Cusulfide blebs. Simple geochemical modelling demonstrates that the parental M to the andesite was not enriched in copper, and that the presence of sulfides is a consequence of the changing intensive parameters of the magmatic system, namely the  $fO_2$  and fS. The measured volatile contents of these MI appear to be typical of that of an arc andesite. The data tests the existing theoretical models of porphyry copper formation, and highlights some of the processes that occur which prevent the majority of calcalkaline magmas producing mineralised systems. (Authors' abstract)

ARMSTRONG, R.N., ROBERTS, S. and WHITE, N.C., 1998d, The

ore-forming potential of porphyry copper systems: Utilising melt-inclusion chemistry (abst.): Geoscience 98, Geol. Soc. Biennial Meetings, Keele Univ., 14-18 April, 1998, p. xyz.

ARTYKOV, A.A., 1998, The rare-metal magnesian skarns of stockwork rype in Uzbekistan (abst.) Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, 78-80 (in Russian).

AUDÉTAT, Andreas, GÜNTHER, Detlef and HEINRICH, C.A., 1998a, Formation of a magmatic-hydrothermal ore deposit: Insights with LA-ICP-MS analysis of fluid inclusions: Science, v. 279, p. 2091-2094. First author at Inst. for Isotope Geol. and Mineral Resources, ETH Zentrum NO, CH-8092 Zurich, Switzerland; email (audetat@erdw.ethz.ch)

The physical and chemical mechanism of ore precipitation in the Yankee Lode tin deposit (Mole Granite, Australia) was quantified by direct trace-element microanalysis of FI. Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) was used to measure element concentrations in a series of FI representing the F before, during, and after the deposition of cassiterite (SnO<sub>2</sub>). Tin precipitation was driven by mixing of hot magmatic brine with cooler meteoric water. At the same time, a separate magmatic V phase selectively transported copper and boron into the L mixture. [Fig. 1]. Authors' abstract)

See also Barnes and Rose, this volume (E.R.). See figure in the Illustrations appendix.

AUDÉTAT, Andreas, GÜNTHER, Detlef, and HEINRICH C.A., 1998b, The magmatic-hydrothermal evolution of a tin granite: The Mole granite, Australia (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 8. Authors at Inst. for Isotope Geol., ETH Zentrum/NO, 8092 Zürich, Switzerland.

Using advanced F- and MI techniques we tried to reconstruct the magmatic-hydrothermal evolution of an intrusion from the very beginning to the very end.

The Mole Granite was chosen because it represents a typical member of tin granites, is strongly mineralized and shows a well-developed regional zoning from Sn-deposits in the center, through W-deposits near its margins, and basemetal deposits in the adjacent country rocks. Particular attention has been paid to the study of Fl and recrystallized M I, using I petrography, microthermometry, high-T melting experiments and quantitative analyses by LA-ICP-MS and electron microprobe. Quantitative reconstruction of the F evolution in several vein deposits and in miarolithic cavities, together with analyses of different generations of M I leads to an integrated picture of the relationship between the magmatic and hydrothermal evolution of

A first generation of silicate-rich M I occurs on concentric growth zones within quartz phenocrysts and contains between 2 and 100 times higher concentration of Cl, F, B, Li, Cs, W, Sn, Bi, Sb, As and Ag than whole-rock analyses, whereas most other elements do not differ from the bulk analyses by more than a factor of 2. A second generation of M I can be found together with P V I (and probably highly saline brine I) in quartz crystals in miarolitic cavities as well as in magmatic topaz. These I reveal extremely low first melting T (<500°C), and Th between 700°C and 740°C Their composition reflects an extreme degree of fractionation, with a further enrichment of the above listed elements by up to one order of magnitude. A third generation of M I coexists together with V- and brine I in outgrown embayment structures in the same quartz phenocryst as generation I and have a composition close to the whole rock.

FI studies demonstrate that in the W- as well as Sn-deposits of the Mole Granite ore mineral precipitation was driven by mixing of a boiling. 400-600°C magmatic F with 200-300°C meteoric groundwater. In all cases the F mixture was additionally enriched in Cu, B, Li, (+As, Mg and possibly REE) due to the condensation of magmatic V into it. The fractionation of these elements into the V phase has been quantified by analyzing coexisting V- and brine I in several boiling assemblages.

The zonation from Sn-dominated deposits in the granite interior to Wdominated deposits near its contacts seems to reflect an increase in the votatile content of the magma towards the top of the magma chamber. Experimental results and petrographic observations in the Mole Granite suggest that the typical association of mineralization of Sn, W, Bi, Li, and REE with F-rich environment can more readily be explained by an increase in the F-content of the fractionating melt, rather than by fluor-complexing of these elements in the fluid. (From authors' abstract by E.R.)

5

AVÉ LALLEMANT, H.G., GOTTSCHALK, R.R., SISSON, V.B. and OLDOW, J.S., 1998, Structural analysis of the Kobuk fault zone, northcentral Alaska Geological Society of America, Special Paper 324, p. 261xxx, 1998. First author at Dept. of Geol. and Geophys., Rice Univ., Houston, Texas 77005-1892.

The east-west-trending Kobuk fault zone in the hinterland of the Brooks Range fold and thrust belt, north-central Alaska, consists of several poorly exposed, megascopic anastomosing faults. Rock slices between these faults are deformed by numerous meso- and microscopic faults along which only minor displacements occurred. Kinematic analysis of the small-scale faults and analysis of Fl in quartz veins emplaced synkinematically along these structures indicate that the Kobuk fault zone underwent at least four phases of deformation. The first structures (F1) were the result of northward thrusting that started in early Middle Jurassic time. F2 faults are related to north-south extension during the mid-Cretaceous. F3 faults are related to right-lateral strike-slip displacements that occurred during Late Cretaceous and Tertiary time. A fourth phase (F4: north-south extension) is indicated by the FI study. This deformational history, however, does not apply to the entire fold and thrust belt; at the same time that lateral displacements (F3) occurred along the Kobuc fault system, northward thrusting took place in the foreland portion of the Brooks Range fold and thrust belt, indicating that plate convergence was right-oblique resulting in displacement partitioning. (Authors' abstract)

AWWILLER, D.N. and SUMMA, L.L., 1998, Constraining maximum paleotemperature using quartz cement abundances; applications to the hydrocarbon systems of South American fold and thrust belts (abst.): AAPG Bull., v. 82, no. 10, p. 1888.

Accurate predictions of oil vs. G in fold and thrust belts are strongly linked to a good understanding of the relative timing between maturation and thrust emplacement. Unfortunately, the information obtained from conventional paleothermometry techniques (e.g., Fl, vitrinite reflectance, apatite fission track) is often not sufficient to fully constrain thermal histories. To address this problem, Exxon is currently applying technology that uses quartz cement volumes, predicted from simple precipitation kinetics, to help constrain the time spent near maximum T. This information is usually not obtainable from other paleothermometry techniques. To date, we have used this technique on the Maracaibo basin of western Venezuela, the Llanos and Catatumbo basins of Colombia, and the Santiago basin of Peru It is particularly appropriate for Late Cretaceous and Paleogene reservoirs of the region, because these reservoirs are typically quartzose, quartz cement is the main pore-filling cement, and they have appropriate thermal histories. In general, the quartz cement paleothermometry is most effective for quartzose sandstones that encompass a broad range of grain sizes and contain little detrital or authigenic clay. The optimum time-temperature window in fold-and-thrust settings ranges from approximately 5 My at 160-170°C to 80 My at 100-110°C. Outside these bounds, quartz cement paleothermometry may be useful, but some sandstones with typical grain size and sorting parameters tend to be either completely cemented or not cemented at all. (Authors' abstract)

AYERS, John, 1998. Trace element modeling of aqueous fluid---peridotite interaction in the mantle wedge of subduction zones. Contrib. Mineral. Petrol., v. 132, p. 390-404. Author at Dept. of Geol., P.O. Box 105B, Vanderbilt Univ., Nashville, TN 37235 USA; email (john.c.ayers@vanderbilt.edu)

Recently measured partition coefficients for Rb. Th, U. Nb. La (Ce), Pb, Sr, Sm, Zr, and Y between Iherzolite assemblage minerals and H2O-rich F (Ayers et al. 1997: Brenan et al. 1995a,b) are used in a two-component local equilibrium model to assess the effects of interaction between slabderived aq F and wedge lherzolite on the trace element and isotopic composition of island arc basalts (IAB). The model includes four steps representing chemical processes, with each process represented by one equation with one adjustable parameter, in which ag F: (1) separates from eclogite in the subducted slab (Rayleigh distillation, mass fraction of F released F<sup>fluid</sup>), (2) ascends through the mantle wedge in isolated packets, exchanging elements and isotopes with depleted lherzolite (zone refining, the rock/F mass ratio n); (3) mixes with depleted lherzolite (physical mixing, the mass fraction of F in the mixture  $X^{fluid}$ ): (4) induces melting to form primitive IAB (batch melting, mass fraction of melt Fmelt). The amount of mantle lherzolite processed by the F in step (2) determines its isotopic and trace element signature and the relative contributions of slab and wedge to primitive LAB. The average composition of LAB can also effectively be modeled with no contribution from the slab other than H2O (i.e., skip model step 1): n=27, X<sup>fluxd</sup>=0.21, F<sup>mett</sup>=0.17 with r<sup>2</sup>=0.992. The IAB may retain the slab

signature for elements such as B and Be that are highly incompatible and that have very low concentrations in the depleted mantle wedge. The relatively high equilibrium Dmineral/fluid values measured by Ayers et al. (1997), Brenan et al. (1995a) and Stalder et al. (1998) suggest that large amounts of fluid (>5 wt%) must be added to lherzolite in the IAB source. (From author's abstract by E.R.)

AYORA, C., CENDÓN, D.I., TABERNER, C., FANLO, I., GARCÍA-VEIGAS, J. and PUEYO, J.J., 1998, Water-rock reactions in evaporite basins: Their role in the formation of potash deposits: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 289-292. First author at Institut de Cièncas de la Terra, CSIC, Barcelona, Spain.

The chemical evolution of several potash-forming and potash-free evaporite basins has been reconstructed using mineral associations, solute content analysed in FI and numerical simulation of evaporation scenarios. The sulphate depletion of brine is responsible for the type of potash deposit, K-sulphates or sylvite. Both dolomitization and the addition of a Carich solution into the basin account for the ratios between the major solutes analysed. Early diagenetic replacement of anhydrite by polyhalite could explain the variable and depleted amount of potassium found in FI. These processes took place to different extents in the basins of the same age, and within the same basin, and therefore cannot be attributed to global changes in the oceans' composition. (Authors' abstract)

BACH. Wolfgang and NIEDERMANN, Samuel, 1998, Atmospheric noble gases in volcanic glasses from the southern Lau Basin: Origin from the subducting slab?: Earth and Planet. Sci. Letters. v. 160, p. 297-309. Authors at GeoForschungsZentrum Potsdam, Dept. 4.2, Telegrafenberg, D-14473 Potsdam, Germany.

Noble G concentrations and isotopic compositions have been determined for four submarine volcanic glasses from the Valu Fa Ridge (VFR) in the southern Lau Basin. The samples are the least differentiated ones from this area, and they display enrichments in F-mobile elements similar to the nearby island arc. "Her"He ratios are slightly below average MORB (6.8-7 8 times atmospheric), whereas Ne, Ar, Kr. and Xe have isotopic compositions very similar to air. Together with previously published data from VFR and other spreading segments in the Lau Basin, our data show a systematic latitudinal variation of increasing Ne, Ar, Kr, and Xe abundances from north to south as well as Ne and Ar isotopic compositions changing from MORB-like to atmosphere-like in the same direction. Moreover, isotopic compositions and noble G abundances of the lavas correlate strongly with Ba/Nb ratios and H2O concentrations. Based on these observations and mass balance arguments, we propose that the atmospheric noble G come from the subducting oceanic crust and are not due to shallow contamination with air dissolved in seawater or assimilation of old crust. Our data suggest that the noble G released from the subducting slab are atmospheric and thus contain little or no solar He and Ne. In addition to the fact that ratios of He to heavy noble G are small in aged ocean crust, He has possibly fractionated from the other noble G due to its higher diffusivity, and thus He transport from the subducting slab into the mantle wedge is probably insignificant. We propose that the 'Her'He ratios lower than MORB observed in the VFR lavas result from radiogenic ingrowth of He in a highly depleted, and hence degassed, mantle wedge after the enrichment of U and Th released from the downgoing slab. (Authors' abstract)

BADÁLOV, S.T., 1998a, Geochemical prerequisites for diagnosing possible non-traditional kinds of gold mineralization (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 91-93 (in Russian).

BADÁLOV, S.T., 1998b. Principal sources of water and energy and their significance in ore-forming systems (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 16-19 (in Russian).

**BAI, T.B.** and van GROOS, A.F.K., 1998. Phase relations in the system MgO-NaCl-H<sub>2</sub>O: The dehydroxylation of brucite in the presence of NaCl-H<sub>2</sub>O fluids: American Mineralogist, v. 83, p. 205-212.

BA1, Wancheng and QING, Min, 1998: Prospecting and appraising indexes based on the quartz inclusion in Xiaoqinling gold field of China (abst.) Second APIFIS Int'l, Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 95-97 (in English). Authors at Gold Geol. Inst. of MMI, Langfang, Hebei, China;

email (xkuichen@public.lfptt.he.cn)

The Xiaoqinling gold ore field consists of more than 1200 goldbearing quartz veins, of which only 10% have been evaluated or prospected. The paper proposed evaluating indexes based on study of I in quartz, infrared spectroscopic features and the Td of I in wall rock.

There are 4 types of infrared spectra of quartz in Xiaoqinling gold ore field, differing in the relative peaks for  $H_2O$  and  $CO_2$ . Types I and II are high-grade ore quartz vein, types III and IV are poor ore and non-ore quartz vein.

Indexes of evaluation of "infrared spectra relative density" are given, involving the value of  $D_2$  and  $D_2/D_1$  of non-ore quartz and gold-bearing quartz [but  $D_1$  and  $D_2$  are not defined; E.R.]

The detonation [sic; decrepitation] T (Tb) and its variation is one of the indexes which are more reliable to evaluate the degree of gold-bearing of quartz vein.

The variation of infrared spectra parameter of I [i.,e.,  $D_2$  and  $D_2/D_1$ ] in vertical direction, along with the values of Tb, can predicate quantitatively denudation degree of ore body. (From authors' abstract by E.R.)

BAILLY, Laurent, MILESI, J.-P., LEROY, Jacques and MARCOUX, Eric, 1998, The Au-Cu-Zn-Sb epithermal mineralisations of the Baia Mare district (north Romania): New mineralogical and microthermometric results: Earth and Planet. Sci., v. 327, p. 385-390 (in French; Engl. abridged version 1998). First author at BRGM, DR/MGG, BP 6009, 45060 Orleans cedex, France.

The Au-Cu-Zn-Sb epithermal mineralisations of the Baia Mare district (north Romania) and their Mio-Pliocene calc-alkaline volcanic host rocks are linked to the presence, at depth, of the Baia Mare batholith, recognised by geophysical and field studies. The sal and T evolution of FI from Baia Sprie and Sasar deposits are interpreted as being linked to the thermal evolution of the underlying laccolith. The global evolution, however, shows many irregularities related to brittle tectonic activity and phreatomagmatism during mineral deposition. (Authors' abstract)

BAIN, J.H.C., WITHNALL, I.W., BLACK, L.P., ETMINAN, H., GOLDING, S.D. and SUN, S.-S., 1998. Towards an understanding of the age and origin of mesothermal gold mineralisation in the Etheridge Goldfield, Georgetown region, north Queensland: Australian J. of Earth Sci., v. 44, p. 247-263. First author at Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601, Australia.

Fl data indcate T<sub>h</sub> in the range 230-350°C. (From authors' abstract by H.E.B.)

BAKER, T., 1998, Alteration, mineralization, and fluid evolution at the Eloise Cu-Au deposit, Cloncurry District, northwest Queensland, Australia. Econ. Geol., v. 93, p. 1213-1236. Author at Nat'l. Key Centre for Economic Geol., School of Earth Sci., James Cook Univ. of North Queensland, Townsville, Queensland 4811, Australia.

The Eloise deposit is hosted by Proterozoic rocks of the Mount Isa inlier. The deposit is characterized by very high grade, chalcopyritepyrrhotite-rich mineralization hosted by mafic silicate alteration. The system has a distinct chemistry, with enriched Cu. Au, Ag, Co. Ni and Zn.

F1 in pre-, syn- and late- to post-mineralization veins indicate an evolving F history. P I and associated hornblende-biotite assemblages in premineralization veins indicate a high-T F ( $450-600^{\circ}$ C), and sal estimates suggest it was an ultrasaline brine (32-68 wt% total salts). F1 in stage III quartz in mineralized veins display a wide range of Th (~100-500°C) and gangue assemblages (actinolite-chlorite-muscovite) suggest mineralization was a cooler event ( $200-450^{\circ}$ C). I associated with the mineralization have a lower sal (30-47 wt% total salts) than do premineralization I, and variable F1 types occur within the same clusters, which may reflect F mixing. The ultrasaline nature of the F and preliminary sulfur isotope results ( $0.4-2.0\%_0$ ) suggest the ore F was predominantly magmatic. Metals were carried as chlorocomplexes and H<sub>2</sub>S was the dominant sulfur species. Important factors in ore deposition were a decrease in T and sal, and sulfidation of Fe-silicates. Eloise is interpreted to be a structurally controlled, distal, magmatic, hydrothermal vein deposit. (From author's abstract by E R.)

DM identified include halite, Fe-Mn-Cl-Si, FeCl2-2H2O, unknown sylvite, pyrosmalite and ankerite/dolomite. (E.R.)

BAKER, Timothy, LANG, J.R., and MORTENSEN, J.K., 1998. Hydrothermal fluids associated with intrusion-related Au-deposits with lithophile affinities: Examples from the Tombstone plutonic suite. Yukon (abst.): Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 9. Authors at Mineral Deposit Research Unit, Univ. of British Columbia, Dept. Of Earth and Ocean Sci., Vancouver, BC, Canada; email (t.baker@eos.ubc.ca)

Intrusion-related Au-mineralization characterized by a lithophile metal assemblage of Bi-As-W-Mo±Sn is recognized in several magmatic provinces, and includes significant examples at Kori Kollo, Bolivia (64 Mi@2.26 g/t Au), Salave, Spain (~15 Mt@2 g/t), Kidston, Australia (94 Mt@1.48 g/t) and Fort Knox, Alaska (158 Mt@0.83 g/t). Deposits in this group are genetically associated with reduced 1-type intrusions emplaced on the inner (cratonic) side of continental margin arcs or in continental collision settings. Most deposits are hosted by intermediate to felsic, sub-alkalic stocks or plutons. Mineralization styles most common are sheeted veins or breccias, both with low sulfide contents (arsenopyrite and pyrite). Alteration zones are characterized by narrow envelopes of sericite, K-feldspar, albite, quartz and/or carbonate around veins.

The defining metal assemblage for the belt is Au-W-Bi, with variable As-Sb-Mo-Sn and locally significant Pb-Zn-Ag. Intrusion-related mineralization in this belt is zoned from sheeted Au-quartz vein systems within the intrusion, to W±Au skarns at the intrusion contacts, to sediment-hosted Au and Pb-Zn-Ag veins both within and outside extensive contact aureoles which surround the intrusions.

FI studies have focused on regional definition of F types present in addition to more detailed studies of individual deposits. Two major FI types are recognized: (1) low sal (0-6 wt% NaCl eq.) carbonic FI (Type 4), and (2) halite-bearing (30-40 wt% NaCl eq.) aq FI (Type 3). Secondary L-rich aq I (Type 1) occur locally whereas V-rich aq I (Type 2) are absent. Type 41 are ubiquitous, have CO2:H2O which varies from area to area, commonly display evidence of immiscibility and homogenize between 220 and 350°C. Eutectic T are typically depressed by 1 to 4°C below that of pure CO2 indicating the presence of additional gaseous phases. Type 3 I are locally present, and may contain sylvite, carbonate and sulfide in addition to halite. The majority of 1 homogenize via halite dissolution (between 200 and 400°C). At the Mike Lake prospect, however, Type 31 homogenize via V loss and coexist with P Type 4 V-rich I, suggesting immiscibility between the two F. Pressure estimates based on FI suggest depth of emplacement may be a significant control on F composition and evolution in the intrusion-related Au-deposits; low P systems (~0.5 kbar) contain abundant high sal F in addition to ubiquitous carbonic F: high sal F occur locally in intermediate P systems (~1-2 kbar), and generally Type 3 inclusions are absent in high P systems (>2 kbars). (From authors' abstract by E.R.)

BAKER, Tim and THOMPSON, J.F.H., 1998. Fluid evolution at the Red Chris porphyry Cu-Au deposit, northwest British Columbia (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-367. Authors at MDRU, Dept. of Earth and Ocean Sci., Univ. of British Columbia. 6339 Stores Rd., Vancouver, B.C. V6T 1Z4; email (tim.baker@eos.ubc.ca)

The Red Chris Cu-Au deposit (522.7 Mt @ 0.35% Cu and 0.27 g/Au), northwestern British Columbia, is hosted by a pre-accretionary (203.8±1.4 Ma), homblende monzonite to quartz monzodiorite porphyry which forms part of a suite of dikes and stocks that intrude late Triassic volcanic stratigraphy. Trace element geochemistry suggests that the intrusion has a composition which falls on the boundary between alkalic and calc-alkalic compositions, although alteration and mineralized quartz stockworks are more typical of calc-alkalic systems. The deposit is characterized by distinct zones of alteration which have variable metal ratios and distinct F characteristics. Early potassic alteration is characterized by orthoclase±albite±quartz±biotite with chalcopy-

rite+bomite+magnetite+hematite, and high T multiphase FI (Th>650°C). The high sal nature of these I (>40 wt.% NaCl eq.) and their coexistence with V-rich I, suggest a magmatic origin probably the result of immiscibility during late stage volatile saturation in the M. Cu and Au were coprecipitated during this and associated mineralization was a later event and has a Cu:Au ratio of 2:1 (%Cu:g/t Au). Zones of QSC alteration contain rare high sal FI, which are more dilute (30-40 wt.% NaCl eq.) and lower T (Th=300-450°C) than those associated with potassic alteration, and low sal (0-10 wt.% NaCl eq.), low T (Th=100-250°C) FI that show evidence for boiling. Zones of chlorite-carbonate alteration contain low evidence for boiling. In addition to abundant S V-rich I (Th=200-250°C), which are particularly common in Au-rich zones (1:0.28 % Cu:g/t Au). The low sal, iow T F associated with carbonate-rich alteration may be of either meteoric or magmatic origin. Sulfur isotopes from all alteration zones have a narrow range (sulfides:  $8^{34}$ S -3.6-0.6; sulfates  $8^{34}$ S 12.5-16), which suggest a magmatic origin for sulfur and T of ~350-550°C. (Authors' abstract)

BAKKER, R.J., 1998, Improvements in clathrate modelling II: the H2O-

CO<sub>2</sub>-CH<sub>4</sub>-N<sub>2</sub>-C<sub>2</sub>H<sub>6</sub> fluid system: <u>in</u> Henriet, J.-P. and Mienert, J. (eds), Gas Hydrates: Relevance to World Margin Stability and Climate Change: Geological Society, London, Special Publications v. 137, p. 75-105. Author at Geologisch-Paläontologisches Institut, Universität Heidelberg, Im Neuenheimer Feld 234, D-69120 Heidelberg, Germany.

Clathrate stability conditions have been modelled for the  $H_2O$ - $CO_2$ -CH<sub>4</sub>-N<sub>2</sub>- $C_2H_6$  F system based on all available experimental data. Optimum Kihara parameters are estimated for pure CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub> and C<sub>2</sub>H<sub>6</sub> G hydrates from using the most accurate calculation of other parameters involved in clathrate modelling, like fugacities, G solubilities in H<sub>2</sub>O, and thermodynamic constants. For mixed G hydrates of CO<sub>2</sub>-CH<sub>4</sub>, CH<sub>4</sub>-N<sub>2</sub>, and CH<sub>4</sub>- $C_2H_6$  excess Gibbs free energy functions are introduced to obtain a good fit to experimental data. The excess Gibbs free energy is described according to a modified Margules equation, which depends on mole fraction and T. (Author's abstract)

BAKKER, R.J., and DIAMOND, L.W., 1998, Reequilibration of synthetic CO<sub>2</sub>-H<sub>2</sub>O fluid inclusions in quartz (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 10. First author at Geologisch-Paläontologisches Institut, INF 234, D-69120 Heidelberg, Germany; email (ronald.bakker@urz.uni-heidelberg.de)

Changes in FI composition and volume following entrapment are of primary concern in attempts to reconstruct paleo-fluid properties from natural inclusion-bearing samples. It has been convincingly demonstrated by high T experiments that molecular H<sub>2</sub> may diffuse into and out of FI in quart2, according to the imposed fugacity differentials between the I and their external environment. However, recent experimental investigations designed to test the post-entrapment behaviour of aq FI in quart2 under conditions of differential pressure ( $\Delta P=P_{inclusion} - P_{external}$ ) and differential fugacity of water ( $\Delta f_{H2O}=f_{H2Oinclusion} - f_{H2Oexternal}$ ) have led to a controversy regarding the exchange of H<sub>2</sub>O: Bakker & Jansen (Nature 345: 58-60, 1990; GCA 55: 2215-2230, 1991) reported loss of H<sub>2</sub>O from homogeneous CO<sub>2</sub>-H<sub>2</sub>O FI subjected to - $\Delta P$  and - $\Delta f_{H2O}$ , implying that H<sub>2</sub>O migrated out of the 1 *against* the imposed  $\Delta f_{H2O}$  stermer et al. (CMP 119: 1-15, 1995) showed that H<sub>2</sub>O migrates into or out of homogeneous H<sub>2</sub>O-salt I at  $\Delta P = 0$ , *down* the imposed  $\Delta f_{H2O}$  gradients.

Our working hypothesis to resolve these contradictions is to suppose that two independent, additive forces drive diffusion of H<sub>2</sub>O through the quartz host at a given T one is a response to the gradient in chemical potentials associated with  $\Delta f_{H2O}$ , and the other is a response to wetting of the defects and cracks induced by  $\Delta P$ . The effects of these forces are coupled inasmuch as gain or loss of H<sub>2</sub>O may change internal pressure. We assume that T and time play similar kinetic roles, and that CO<sub>2</sub> and NaCl remain immobile.

In order to test these ideas, we have performed two types of hydrothermal reequilibration experiments using synthetic CO<sub>2</sub>-H<sub>2</sub>O Fl in quartz, with the aim of discriminating the effects of  $\Delta f_{H20}$  and  $\Delta P$ . Starting inclusions with X<sub>H20</sub>=0.6 were synthesized at 600°C, 500 MPa from silver oxalate and water and retrieved from the run conditions isochorically. After performing microthermometry and photographic documentation these I were reequilibrated at 600°C for 30 days as follows:

(1) Pure H<sub>2</sub>O was used as an external P medium to generate  $\Delta P$ =+100 MPa and  $\Delta f_{H2O}$ =-32 MPa. The 1 acquired equidimensional, negative-crystal shapes and Th<sub>COML+V→L</sub> values increased slightly while Th<sub>TOT(L+V→L</sub>) decreased. From these observations we infer that H<sub>2</sub>O migrated into the Fl down the imposed  $\Delta f_{H2O}$  gradient, to reach a maximum X<sub>H2O</sub> of 0.65. The calculated increase in I volume associated with this process is 7.6%. Either the imposed  $\Delta P$  had no effect on H<sub>2</sub>O exchange, contrary to our working hypothesis, or its effect was overriden by the magnitude of the  $\Delta f_{H2O}$  gradient. The deduced increase in volume is consistent with the summed effects of the  $\Delta P$  and  $\Delta f_{H2O}$  gradients. FI that had partially decrepitated during first microthermometric heating reequilibrated differently.

(2) Pure H<sub>2</sub>O was used as an external pressure medium to generate  $\Delta P=0$  and  $\Delta f_{H2O}=-111$  MPa. The inclusions acquired flat, negative-crystal shapes and Th<sub>COIL-V-t1</sub> values increased slightly. Until total homogenisation data are available these changes are attributed to either (i) H<sub>2</sub>O loss and/or volume increase, i.e. *against* the imposed  $\Delta f_{H2O}$  gradient and imposed zero  $\Delta P$ , or (ii) H<sub>2</sub>O gain *down* the imposed  $\Delta f_{H2O}$  gradient, with increase in volume driven by the increase in internal pressure (Authors' abstract)

BAKKER, R.J., and GRIMMER, Jörg, 1998. Major fault zones in the Cantabrian Zone (NW Spain): Possible migration paths for petroleum (abst.) Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 11. Authors at Geologisch-Palaontologisch Institut, INF 234, D-69120 Heidelberg, Germany: email (ronald bakker@urz.uni-heidelberg.de; jgrimmer@ix.urz.uniheidelberg.de)

Fl appear to have mainly a P nature in most [fault zone] cements, and the populations consist mainly of all L I. Only a small percentage show the presence of a small V bubble within the liquid. These properties indicate formation conditions at shallow depths and T<50°C for all types of cement. In an early and late type of vein mineralization two types of P water-rich I were observed, i.e. sweat water and 16 eq.wt% NaCl, and intermediate sal. Within an intermediate cement Fl show fluorescence, indicating the presence of petroleum F.

The results illustrate the presence of at least three different types of F which must have been circulating in these fault zones at shallow depths. These rocks illustrate the twofold characteristic of thrust, i.e. migration path versus seal for F. (From authors' abstract by E.R.)

BAKSHEEV, Ivan, PROKOFIEV, Vsevolod, and USTINOV, Vladimir, 1998, Genesis conditions of the Berezovsk gold deposit, Middle Urals: Evidence from fluid inclusion and isotopic data (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 12. First author at Dept. of Geol., Moscow State Univ., 119899 Moscow, Russia; email (mineral@geol.msu.ru)

The Berezovsk mesothermal Au deposit is related to the beresite association and controlled by the systems of granitoid-porphyry and lamprophyre dykes. We studied individual PFI from gangue quartz and scheelite from ladder veins of the deposit and oxygen isotopic composition of these minerals. Quartz and scheelite are formed by CO<sub>2</sub>-rich NaCl-MgCl<sub>2</sub> solutions (T<sub>ounce</sub> -28 to -37°C). Sal of the solutions ranges from 7.3 to 17.0 wt% eq NaCl, T 270-350°C, P 1.4-3.5 kb.

Earlier gangue quartz-I forms close intergrowths with scheelite; later quartz-II forms close intergrowths with fahlore and aikinite which are typical minerals for the productive assemblage. Th of FI from quartz-I range from 320 to 350°C, of scheelite from 310 to 335°C, and of quartz-II from 270 to 300°C. Quartz-I has a higher concentration and wider range of CO<sub>2</sub> than that for quartz-II. They are 3.1-6.3 and 3.1-5.3 mole/kg of solution, respectively. C<sub>CO2</sub> and C<sub>CH4</sub> from the quartz-I FI have a direct correlation. Sal of F responsible for the quartz-I formation is lower than that for quartz-II. They are 9.2-15.1 and 9.4-17.0 mole/kg of solution, respectively. Pressure at the quartz-I formation was ~2.5 kb, at the quartz-II formation ~2 kb.

A direct correlation between  $\delta^{16}$ O of quartz-1 and scheelite at the Berezovsk deposit and other mesothermal Au deposits has been established, including Bestyube, Dzhelambet-Centre, Stepnyak, Dzhelambet-North. (all in North Kazakhstan) Berezovsk, and Shershnevsk, (in Urals), and Muruntau, Middle Asia, Glenorchy, New Zealand, and Hollinger, North America. It indicates the equilibrium crystallization of these minerals. (From authors' abstract by E.R.)

BALDASSARO, P.M., and BODNAR, R. J., 1998, Unusual low temperature phase behavior in the system H<sub>2</sub>O-NaCl-FeCl<sub>2</sub> (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 13. Authors at Virginia Tech, Fluids Research Lab, Blacksburg, Virginia 24061-0420

The low T phase behavior of the system H<sub>2</sub>O-NaCl-FeCl<sub>2</sub> was examined using synthetic FI. The contents within capsule remained reduced [by added solid buffer, FeO) during the experiment.

Borisenko (1977, Geologiya i Geofizika, 18(8): 16-27) reported a Te of -37.0°C for the system H<sub>2</sub>O-NaCl-FeCl<sub>2</sub>. However, in this study, L was observed at -40°C for a composition of 7 wt% FeCl<sub>2</sub> and was also observed at -48.2°C for a composition of 18 wt% FeCl<sub>2</sub>.

For compositions between 0-25 wt% FeCl<sub>2</sub>, anomalous reproducible phase behavior was observed. Above 25 wt% FeCl<sub>2</sub>, I displayed a different type of unusual phase behavior. This concentration is high enough that a significant volume of L should be produced at first melting. However, the I did not freeze, even when cooled to -197°C. No glass phase similar to that reported by Roedder (1984, Rev. Mineral.:12, 644 pp.) for other systems was observed. Upon heating, either slowly or quickly, no phase transitions were detected, as would be expected when the glass transforms into the crystal phase that is stable at that composition. (From authors' abst. by E.R.)

BALL, M.C.N., 1998, Geology of the McDame gold camp. Cassiar, British Columbia. implications for lode-gold: Doctoral thesis, Queen's Univ, Kingston, Ontario. Canada, 351 pp. Indexed under FI (E.R.).

BALLENTINE, C.J. and LOLLAR, B.S., 1998, Using noble gas isotope and abundance information to place constraints on basinal fluid origin, relative timing, transport mode and mass balance: He-N<sub>2</sub> rich gases in the mid-continental USA (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 102-103.

BARANOVA, N.N. and ZOTOV, A.V., 1998. Stability of gold sulphide species (AuHS<sup>0</sup><sub>(aq)</sub>) and Au(HS)<sub>2</sub><sup>\*</sup><sub>(aq)</sub>) at 300, 350°C and 500 bar. Experimental study (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p.116-117.

BARGAR, K.E. and KEITH, T.E.C., 1997, Estimated temperatures for geothermal drill holes at Medicine Lake volcano, northeastern California, based on fluid inclusion and hydrothermal mineralogy studies. U.S. Dept. of the Interior, U.S. Geological Survey, Open-file report 97-716, 116 pp. First author at U.S. Geological Survey, M/S 910, 345 Middlefield Rd., Menlo Park, CA 94025, U.S.A.

Medicine Lake volcano, a Pleistocene to Holocene Cascade shield volcano in the northeastern part of California, is one of the most promising geothermal energy prospects in the Pacific Northwest. At present, [most] data (T, chemistry, etc.) obtained from the drill holes is proprietary. However, [some] drill-core samples have been made available for scientific investigations, and provide reasonable estimates of late Pleistocene to present-day T of F circulating through rocks.

More than 600 rhyolitic to basaltic drill-core specimens from the 12 drill holes (ranging in depth from about 340 to 1.370 m) were collected for this investigation. Volcanic glass and open spaces of fractures, vesicles, and between breccia fragments in core specimen from drill holes located both outside and within the caldera show the effects of hydrothermal alteration. The alteration is more pervasive and reflective of higher T in the two intracaldera drill holes. Forty-five hydrothermal minerals were identified from these drill holes. Many clay minerals, zeolites, carbonates, silica minerals, etc., undoubtedly formed at zeolite-facies T (<-200°C), but the presence of minor garnet, epidote, actinolite/tremolite, prehnite, and talc suggest previous higher (about 200-400°C) sub-greenschist- to greenschistfacies T.

T<sub>h</sub> of Fl in hydrothermal quartz, calcite and wairakite from one core range between 178 and 373°C. Another shows T<sub>h</sub> measurements in hydrothermal quartz and calcite between 125 and 225°C. However, the presence of garnet, epidote, prehnite, actinolite/tremolite and talc indicate that past T have been substantially higher.

Minimum FI T<sub>h</sub> values within the lower half of the ML 45-36 drill hole suggest that current T near the bottom of this drill hole are approximately 200°C and many plot above the theoretical reference boiling-point curve drawn to the present ground surface. These L-rich Fl with high T<sub>h</sub> values reflect P that were greater than at present. During the late Pleistocene the surface is estimated to have been at least 150 m higher than at the present time due to the presence of glacial ice.

Dozens of tiny (<0.5 to  $\sim$ 5 µm), mostly rod-shaped, bacteria-like moving particles were trapped inside a L-rich, P Fl. The I occurs within a hydrothermal guartz crystal that formed on a fracture in rhyolitic lava from 856 m depth in drill hole ML 45-36. The movement appears to be due to Brownian motion. If the particles are the remains of thermophilic microorganisms, the Fl studies indicate that they must have been trapped at T above 200°C. (From authors' abstract by E.R.)

BARKER, A.J. and ZHANG, Xing, 1998, The role of microcracking and grain-boundary dilation during retrograde reactions: in Treloar, P.J. & O'Brien, P.J. (eds), What Drives Metamorphism and Metamorphic Reactions? Geological Society, London, Special Publications. v. 138, p. 247-268

BARKER, C.E., BONE, Yvonne and LEWAN, M.D., 1998, Fluid inclusion and vitrinite-reflectance geothermometry compared to heat-flow models of maximum paleotemperature next to dikes, western onshore Gippsland Basin, Australia: Int'l J of Coal Geol, v. 37, no. 1-2, p. 73-111.

Nine basalt dikes, ranging from 6 cm to 40 m thick, intruding the Upper Jurassic-Lower Cretaceous Strzelecki Group, western onshore Gippsland Basin, were used to study maximum Tmax reached next to dikes. Tmax was estimated from Fl and vitrinite-reflectance geothermometry and compared to T calculated using heat-flow models of contact metamorphism. Thermal history reconstruction suggests that at the time of dike intrusion the host rock was at a T of 100-135°C. Fracture-bound Fl in the host rocks next to thin dikes (<3.4 m thick) suggest T<sub>max</sub> systematically increases toward the dike margin to at least 500°C. The estimated T<sub>max</sub>

next to the thickest dike (thickness (D)=40 m) suggests an extended zone of elevated Ry, to at least a distance from the dike contact (X) of 60 m or at X/D>1.5, using a normalized distance ratio used for comparing measurements between dikes regardless of their thickness. In contrast, the pattern seen next to the thin dikes is a relatively narrow zone of elevated Rv-r. Heat-flow modeling, along with whole rock elemental and isotopic data, suggests that the extended zone of elevated Ryst is caused by a convection cell with local recharge of the hydrothermal F. The narrow zone of elevated Ryr found next to thin dikes is attributed to the rise of the less dense, heated F at the dike contact causing a flow of cooler groundwater toward the dike and thereby limiting its heating effects. The lack of extended heating effects suggests that next to thin dikes an incipient convection system may form in which the heated F starts to travel upward along the dike but cooling occurs before a complete convection cell can form. Close to the dike contact at X/D<0.3, Ryr often decreases even though FI evidence indicates that Tmax is still increasing. Further, FI evidence indicates that the evolution of water V or supercritical F in the rock pores corresponds to the zone where Ryr begins to decrease. The generation of the water V or supercritical F near the dike contact seems to change vitrinite evolution reactions. These metamorphic conditions, closer to the dike than X/D=0.3 make vitrinite-reflectance unreliable as a geothermometer. The form of the R., r profile, as it indicates Tmax, can be interpreted using T profiles estimated from various heat-flow models to infer whether the dike cooled by conduction, incipient convection, or a convection cell. A contact aureole that consists of decreasing Ryer or Tmax extending out to X/D<2 and that has a Tconand >>Tmagma+Thos/2 appears to be a signature of simple conductive cooling. Incipient convection is indicated by a Ryd profile that decreases to background levels at X/D<1. A convection cell is indicated by a wave-like form of the Ryd profile and consistently high Ryd that may not decrease to background levels until beyond distances of X/D>1.5. (Authors' abstract)

BARKER, Colin and SULLIVAN, G.E., 1998, Non-hydrocarbon gases in the deep Smackover Formation, Mississippi salt basin, at the location of the Mary Higgins well, Mobile County, Alabama (abst.): American Association of Petroleum Geologists 1998 annual meeting, Salt Lake City, UT, May 17-20, 1998.

The Smackover Formation is an important G-producing interval in the Mississippi Salt Basin, but inorganic components frequently reduce the economic value of the G. Fl in overgrowths and fracture-filling calcite cements provide samples of G that were present in the system at various times in the past. We have analyzed the composition of G in Fl from 27 different depths in the Conoco Mary Higgins well. This well is located on the eastern shoulder of the Wiggins (sic) Arch and penetrated the entire Smackover Formation over the depth range from 19,177 to 19,400 feet. The carbonates of the Smackover Formation directly overlie basement, and this is intruded at 19,456 feet by a 3-inch rhyolite dike that contains calcite fracture-filling cements. The reservoir interval extends from 19,100 to 19,335 feet. (Authors' abstract)

BARNES, H.L. and ROSE, A.W., 1998, Origins of hydrothermal ores Science, v. 279, p. 2064-2065. Authors at Dept. of Geosci., Pennsylvania State Univ., University Park, PA 16802 USA; email (barnes@geosc.psu.edu).

A review, dealing in particular with Audétat et al. (this issue) (E.R.)

BASUKI, Agung, SUPARKA, Emmy and SUNARYA, Yaya, 1998, Gold deposit in Cikidang area, West Java, Indonesia: Ninth Regional Congress on Geol., Mineral and Energy Resources of Southeast Asia—GEOSEA '98 17-19 Aug, Kuala Lumpur, Malaysia, Program and Abstracts, p. 118, Mineral Resources paper 19. First author at PT.Aneka Tambang (Persero).

The Cikidang gold deposit in West Java is typical of the lowsulphidation epithermal deposit, consisting of several veins of disseminated- and clusters- of native gold, quartz-adularia-calcite assemblages, showing various textures such as colloform banding, vein breccia, comb textures, and rare massive texture. Hydrothermal alteration is widespread in the Cikidang veins; advanced argillic alteration extends from 1 m up to 10 m around the veins, which gradually changes to propylitic alteration.

Fl evidence indicates the mineralized F T range from 165 to 205°C and have sal of 0.028 to 1.07 eq. wt.% NaCl. Besides, the mineralization horizon of the Cikidang vein is located in precious metal horizon whilst the erosional level falls between 200-250 m depths beneath the paleo surface. The age of the mineralization is about Pleistocene time. (From authors' abstract by E.R.)

BAYUK, I.O, and CHESNOKOV, E.M., 1998, Correlation between elas-

tic and transport properties of porous cracked anisotropic media: Physics and Chemistry of the Earth, v. 23, no. 3, p. 361-366. Indexed under FI (E.R.).

BEAUDOIN, Georges and THERRIEN, René, 1998, The Kokanee range Ag-Pb-Zn hydrothermal system: 3D modelling of crustal-scale fracture-controlled hydrothermal fluid flow (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A12. Authors at MEDEF, Dpt. de Géologie et de Génie Géologique, Univ. Laval, Québec, Qc G1K 7P4; email (beaudoin@ggl.ulaval.ca)

The Kokanee Range Ag-Pb-Zn vein field (southeastern B.C.) formed during Eocene crustal extension and unroofing of the Valhalia metamorphic core complex.

In Slocan Group slates, vein minerals oxygen isopleths are concentric about the "Main Lode" with a NE-SW deflection, and abut on the Slocan Lake Fault. No systematic oxygen isotope zonation is found in the Nelson batholith. The oxygen isotope regional zonation in Slocan Group slates reveals the pattern of fracture-controlled hydrothermal F flow, F mixing, and F-rock exchange. Oxygen isotope and sal data indicate mixing between a deep-seated, metamorphic F and an upper crustal F dominated by evolved meteoric water. FI data show no T gradient. F-rock exchange is recorded in the oxygen isotope composition of Slocan Group slates which display a regional depletion consistent with the vein oxygen isopleths.

Our objective is to simulate the oxygen isotope compositons and zonations observed in the Kokanee Range Ag-Pb-Zn vein field. The hypotheses are that the oxygen isotope compositions and zonations are produced by infiltration of a deep-seated F ( $\delta^{18}O=8\%$ ) along the Slocan Lake fault at the base of the continental crust. A hydraulic head gradient forces the F to flow toward higher crustal levels where the F enters the fractures in the Slocan Group states (818O=18%). Fractures in the Slocan Group states are connected to the Slocan Lake Fault and filled with evolved meteoric water ( $\delta^{18}O=3\%$ ). Isothermal conditions are assumed at the T recorded by FI (350°C). We use a finite-element model, FRAC3DVS, which simulates 3D-isothermal F flow and advective-dispersive transport in discretelyfractured porous media. The model has been modified to allow calculation of oxygen isotope compositions during equilibrium and kineticallycontrolled exchange between the F and the rock mass. The porous matrix is discretized with 3D elements and is intersected by vertical and inclined (45°) interconnected planar fractures that schematically reproduce the fracture pattern in Slocan Group slates. Material properties and boundary conditions are adjusted to reproduce the Kokanee range data and to derive useful parameters describing F flow and mass transport in the hydrothermal system. (From authors' abstract by H.E.B.)

BEBIE, J., SEWARD, T. M.and HOVEY, J.K., 1998. Spectrophotometric determination of the stability of thallium (I) chloride complexes in aqueous solution up to 200°C: Geochim. et Cosmo. Acta. v. 62, no. 9, p. 1643-1651.

BECHTEL, A., PERVAZ, M. and PÜTTMANN, W., 1998. Role of organic matter and sulphate-reducing bacteria for metal sulphide precipitation in the Bahloul Formation at the Bou Grine Zn/Pb deposit (Tunisia): Chem. Geol., v. 144, p. 1-21. First author at Mineralogisch-Petrologisches Inst. der Univ. Bonn. Poppelsdorfer Schloβ, 53115 Bonn. Germany.

The origin of the Bou Grine Zn/Pb deposit of Tunisia was investigated during a geochemical study of the Cretaceous Bahloul Formation. The inorganic and organic chemical compositions of the bituminous marls and limestones, as well as the light stable isotope ratios of organic carbon and carbonates were measured. Closely spaced samples were collected along two profiles. at different distances from the enrichments in Zn and Pb. which are best developed near the Bou Grine diapir. The organic geochemical data suggest sulphide precipitation at the Bou Grine deposit by sulphate-reducing bacteria (SRB) SRB utilized hydrocarbons derived both from the Bahloul sediments and from external source rocks. Production of S(-II) by the bacteria was most probably limited by the availability of sulphate, although sulphate was available to the bacteria in high concentrations in close proximity to the Triassic salt dome. Ground waters evolved to hypersaline basinal brines by dissolution of salt and anhydrite at the contact of the diapir. These brines would have been capable of leaching metals from the sedimentary sequences adjacent to the salt dome. The Triassic series has often been advocated as the source of the metals, and the Cretaceous sediments themselves are carriers of metallic elements. Ore deposition apparently resulted when metal-bearing solutions that migrated upward into the roof zone of the diapir mixed with S(-II)-bearing solutions. Those formed when SRB oxidized the high amounts of hydrocarbons

within the Bahloul sediments and in the brines, using SO<sub>4</sub><sup>2</sup> from sulphaterich waters in the anhydrite caprock as an oxidant. (Authors' abstract)

BEHRENS, H., WITHERS, A. and ZHANG, Y., 1998, *In situ* IR spectroscopy on hydrous albitic and rhyolitic glasses and its implications for water speciation and water species reactions in silicate glasses and melts (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p.139-140.

BELEVANTSEV, V.J., GUSHCHINA, L.I. and OBOLENSKII, A.A., 1998, Antimony in hydrothermal solutions: Analysis and generalization of data on antimony (III) chloride complexes: Geochemistry Int'l., v. 36, no. 10, p. 928.

BELKIN, H.E., de VIVO, Benedetto, TÖRÖK, Kálmán and WEB-STER, J.D., 1998, Pre-eruptive volatile content, melt-inclusion chemistry, and microthermometry of interplinian Vesuvius lavas (pre-A.D. 1631): J. of Volcanol. and Geothermal Research, v. 82, no. 79-95. First author at U.S. Geological Survey, MS 956, Reston, VA 20192 USA.

Silicate-MI from lavas and pyroclastics from a selected suite of pre-A.D. 1631 interplinian Mt. Somma-Vesuvius lavas and scoria have been experimentally homogenized and studied by microthermometry, electron microprobe (EMPA) and S-ion mass spectrometry (SIMS) to examine preeruptive volatile content and magma evolution. The MI have a bubble about 0.06% their volume, [misprint; of approximately 1 vol.%] uncommonly contain non-condensable G but do not contain any dense F phases. Clinopyroxene-hosted I yield Th from 1170 to 1260°C, most between 1220 and 1240°C; plagioclase-hosted I have Th from 1210 to 1230°C; these values are typical for the Vesuvius environment. The dominant factor controlling major element variability in the I is clinopyroxene fractionation; MgO varies from 5 to 3 wt%, SiO2 varies from 60 to 48 wt%, total alkalis vary from 15 to 4 wt%, and CaO varies from 13 to 5 wt%. H2O varies from 2.7 to 0.6 wt% and is decoupled from incompatible element evolution suggesting V saturation during trapping. Chlorine and F vary from 1.0 wt% to 0 and 0.63 to 0 wt%, respectively. Bulk rock and limited matrix glass analyses show that the lavas lost about half of their F and Cl content except for the A.D. 472-1631 lava which contains similar CI abundances as the bulk rock. SO3 varies from 0.5 to 0 wt% and, compared with matrix glass and bulk rock, demonstrates that the lavas have lost essentially all sulfur. The samples can be classified into three age groups, >25,000 yr B.P., 25,000-17,000 yr B.P., and A.D. 472-1631. There is a systematic increase in some components, e.g., total alkalis, SO3, CI, Li, B, and Sr with the youth of the sample and a decrease in others. e.g., Zr and Y. However, on average these samples seem less evolved than later A.D. 1631-1944 lavas. (Authors' abstract)

BENISON, K.C. and GOLDSTEIN, R.H., 1998, Climate signals from the mid Permian Nippewalla Group of Kansas (abst.): Abstracts with Programs—Geological Society of America, v. 30, no. 3, p. 2. Indexed under FL

BENISON, K.C., GOLDSTEIN, R.H., WOPENKA, Brigitte, BUR-RUSS, R.C., and PASTERIS, J.D., 1998a, Fluid inclusions in halite indicate extremely acid Permian lakes and groundwaters (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 14. First author at Univ. of Kansas, Lawrence, KS.

During the mid Permian, saline lakes, pans, and mudflats deposited bedded halite and red-bed sediments over an area of at least 200,000 km<sup>2</sup> of the North American midcontinent. Laser Raman microprobe (LRM) analyses of Fl in bedded and displacive halite from the Opeche Shale of North Dakota and the Nippewalla Group of Kansas show peaks for bisulfate (HSO<sub>4</sub><sup>-1</sup>), in addition to peaks for sulfate (SO<sub>4</sub><sup>2-1</sup>) and water. LRM analyses of standard solutions of widely ranging pH in the subsystems of NaCl-Na<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>SO<sub>4</sub>-HCl-H<sub>2</sub>O indicate that only waters with pHs below 1 are characterized by Raman spectra with one or more bisulfate peak. Therefore, bisulfate peaks in LRM spectra of Fl in natural halite are evidence for highly acid (pH < 1) Permian lake waters and groundwaters. Fl leachate analyses by ICP-AES and ion chromatography show that these were Na-K-Mg-Ca-Cl-SO<sub>4</sub>-rich brines with relatively high concentrations of Al, Si, and Fe, also characteristic of modern acid waters. This marks the first identification of ancient acid lake systems.

Natural acid lake and groundwater systems throughout southern Australia may be modern analogs for ancient acid waters. Both the modern Australian and the Permian acid systems are characterized by shallow sa-

line lakes in red siliciclastic sediments. This discovery of ancient acid waters should have far-reaching implications for better understanding the ecology of lake systems, water budgets of past climates, chemical evolution of lake waters and groundwaters, and formation of red beds. (Authors' abstract)

BENISON, K.C., GOLDSTEIN, R.H., WOPENKA, Brigitte, BUR-RUSS, R.C. and PASTERIS, J.D., 1998b. Anatomy of an ancient, extremely acid saline lake system; the Mid Permian Opeche shale of North Dakota (abst.): American Association of Petroleum Geologists 1998 annual meeting, Salt Lake City, UT, USA, May 17-20, 1998.

See previous item.

BENISON, K.C., GOLDSTEIN, R.H., WOPENKA, Brigitte, BUR-RUSS, R.C. and PASTERIS, J.D., 1998c, Extremely acid Permian lakes and groundwaters in North America: Nature, v. 392, p. 911-914. First author at Dept. of Geol., The Univ. of Kansas, Lawrence, Kansas 66045, USA

Evaporites hosted by red beds (red shales and sandstones), some 275-265 My old, extend over a large area of the North American mid-continent. They were deposited in non-marine saline lakes, pans and mud-flats, settings that are typically assumed to have been alkaline. Here we use laser Raman microprobe analyses of FI trapped in halites from these Permian deposits to argue for the existence of highly acidic (pH<1) lakes and groundwaters. These extremely acidic systems may have extended over an area of 200,000 km<sup>S</sup>. Modern analogues of such systems may be natural acid lake and groundwater systems (pH-2-4) in southern Australia. Both the ancient and modern acid systems are characterized by closed drainage, arid climate, low acid-neutralizing capacity, and the oxidation of minerals such as pyrite to generate acidity. The discovery of widespread ancient acid lake and groundwater systems demands a re-evaluation of reconstructions of surface conditions of the past, and further investigations of the geochemistry and ecology of acid systems in general. (Authors' abstract)

See figure in the Illustrations appendix.

BERNIKOV, N.V. and KARSAKOV, L.P., 1998, Fluid inclusion studies in Precambrian complexes of the Russian Far East: Geol. of Pac. Ocean, v. 13, p. 675-688. Authors at Inst. of Tectonics and Geophys., Far East Div., Russian Acad. of Sci., Khabarovsk.

The paper review and revises the main results of research into the I in minerals from the metamorphic and igneous rocks from the Russian Far East (Authors' abstract)

BERNARDO, Cesare and CINZIA, Maineri, 1998, Fluid-present anatexis of metapelites at El Joyazo (SE Spain): Constraints from Raman spectroscopy of graphite (abst ): Plinius, v. 20, p. 181-182. First author at Dipto. di Mineralogia e Petrologia-Univ. di Padova; email (bernardo@dmp.unipd.it).

The garnet-biotite-sillimanite anatectic xenoliths in the Neogene dacite dome of El Joyazo (SE Spain) contain four types of graphite (I to IV), distinguished on the basis of grain-size and texture. Structural characterization of graphite by Laser Raman spectroscopy (LRS) shows systematic differences in the degree of ordering among the four types: only one (III) is fully compatible with the granulite facies conditions (the others represent lesser metamorphism]. LRS results together with petrologic observation suggest that it is possible that high M fractions can be generated by closedsystem, F-present melting of a metasedimentary protolith. Although this contradicts the accepted hypotheses, it is a possible end-member model in uncommon anatectic settings characterized by rapid heating rates and lowgrade source rocks. (From authors' abstract by E.R.)

BEURLEN, Hartmut, da SILVA, M.R.R., and de CASTRO, Cláudio, 1998, Fluid inclusion microthermometry in Be-Ta-(Li-Sn) bearing pegmatites from the Borborema Province, northeast Brazil (abst.): Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 15. First author at Depto. Eng. de Minas, UFPE, Rua Acad. Hélio Ramos s.n., 50.740-530, RECIFE-PE, BRA-ZIL.

FI in Be-Ta-Li-Sn bearing pegmatites reported in the literature are hypersaline aq brines, low sal aq or aq carbonic F. The evolution of volatile F in equilibrium with the different phases of pegmatite crystallization do not follow a universal model. Several heterogeneous Be-Ta-(Li-Sn) pegmautes were sampled systematically along cross sections to study the Fi in the different pegmatite zones (1- muscovite rich contact zone, II- homogeneous or graphic pegmatite. III- blocky feldspar zone and IV- quartz core). The observed FI (mainly in quartz) are mainly S or PS, grouped along healed fractures with chaotic orientation. FI were either low sal aq or aq-carbonic (frequently in trails with silicate dxl, especially muscovite) or rarely pure carbonic F. Some well-formed drusy crystals provided PI for study. Microthermometric data [on these samples] show that the various pegmatite phases were in equilibrium with low sal, aq or aq-carbonic F, with insignificant N2 or CH4, and with common silicate (and probably other) dm. The F apparently evolved from carbonic [CO2 (50%) F] in equilibrium with graphic pegmatite and early minerals (beryl, manganotantalite, blue tourmaline of zones II and III)] to low-carbon aq F (in the core of quartz crystals at the limit between zone III and the quartz core) to CO2-free aq F in the border of these crystals and in minerals of the replacement bodies (apatite, euclase). In one single quartz crystal a thermal gradient of 150°C from the smoky core (Th 290 C, low CO2, low sal, aq) to the hyaline border (Th 144°C, aq, moderate sal) was measured. The sal in this crystal oscillates in successive growth zones suggesting formation in an open system. A similar evolution from aq carbonic to low sal aq F has also been observed in several pegmatite provinces throughout the world. (From authors' abstract by E.R.)

BIGGE, M.A., MACLEOD, G., APLIN, A.C. and LARTER, S.R., 1998, Confocal scanning laser microscopy and its application to the evaluation to palaeo reservoir conditions using fluid inclusions (abst.) American Chemical Society 215th National Meeting Program, Dallas, TX, March 29-April 2, 1998, paper no. 050. Authors at Dept. of Fossil Fuels and Environmental Geochem.: NRG, Univ. of Newcastle upon Tyne, Tyne & Wear, NE1 7RU, UK.

The Leek field is a North Sea oil field adjacent to the North Viking Graben and flanked by three separate potential source kitchens all within the oil window. The field provides a good example of the applicability of the new Confocal Scanning Laser Microscope (CSLM) palaeopressure evaluation technique. Analysis of Fl and formation F was carried out using a variety of chemical and microscopic techniques.

Crush leaching of cleaned reservoir samples to derive a pure FI petroleum fraction followed by GC/GC-MS provides both bulk and molecular geochemical data allowing source typing and maturity determination. Confocal scanning laser microscopy of petroleum FI in combination with microthermometry has been used to obtain accurate petroleum I GOR and thus (combined with PVT modeling) enabled the evaluation of minimum formation palaco P through time. We describe the petroleum F and P history of the reservoir. (Authors' abstract)

BLAMEY, N., 1998. Chemical controls on gold solubility in the Witwatersrand Basin. South Africa (abst.): New Mexico Geol., v. 20, no. 2, p. 49-50. Author at New Mexico Inst. of Mining and Tech., Socorro, NM 87801-4796; email (nblamey@nmt.edu)

In order to test the hypothesis that gold was more soluble than 0.1 ppm. one needs to determine the T of the F. the oxygen and hydrogensulfide fugacity material, and the sal of the F. The bedding parallel fractures are host to FI with estimated 2.3 molar NaCl, based on the freezing depression of ice. Based on the G analysis, the oxygen and hydrogen sulfide fugacities have been calculated giving log values for oxygen fugacity of -27 to -30. Sal has a profound effect on the determination of gold solubility using Henry's Law of constants, thereby increasing the solubility of gold thio-complexes by nearly three orders of magnitude. The data show that metamorphic F trapped by the S FI had the potential to dissolve 0.1 to 10 ppm of gold.

Perhaps gold solubility during metamorphism may be the key to understanding why the Witwatersrand Basin has exceeded all other gold deposits in terms of reserves in that there existed an efficient transport mechanism and an effective trap. (From author's abstract by E.R.)

BLENCOE, J.G., ANOVITZ, L.M. and SEITZ, J.C., 1998a, A Helmholtz free energy model for supercritical H<sub>2</sub>O-CO<sub>2</sub> mixtures (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-319.

BLENCOE, J.G., ANOVITZ, L.M. and SEITZ, J.C., 1998b, A new method for modeling the thermodynamic mixing properties of highiemperature H<sub>2</sub>O-CO<sub>2</sub> fluids (abst.): EOS Trans AGU, 79(17), Spring Meet. Suppl., p. S375. First author at Chemical and Analytical Sci. Div., Oak Ridge Nat'l. Laboratory, PO Box 2008. Bldg. 4500-S. MS 6110, Oak Ridge, TN 37831-6110, email (blencoejg@ornl.gov)

Widely applied semi-empirical thermodynamic models for high-T H<sub>2</sub>O-CO<sub>2</sub> F fail to provide reliable excess properties. Superior results are

BLYTH, A.R., FRAPE, S.K., BLOMQUIST, Runar and NISSINEN, Pasi, 1998, Combining fluid inclusion studies with isotopic investigations of fracture calcite to assess the past thermal and F history of the Olkiluoto research site, Finland (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-88. First author at Univ. of Waterloo, Waterloo, Ontario, Canada N2L 3G1; email (arblyth@sciborg.uwaterloo.ca)

A FI study, combined with isotope geochemistry of several generations of fracture calcite from the Olkiluoto research site, Finland, has been used to better understand the past thermal and F history in the crystalline rock environment. Typically, fracture mineral investigations use oxygen and carbon isotopes from calcite and an estimate of the isotopic composition of the water that precipitated the calcite to perform  $\delta^{18}O$  geothermometry calculations to estimate past T conditions. By combining FI information with calcite isotopes, one can directly measure the T at which the calcite formed and can better determine past F compositions.

Isotopic, petrologic and FI studies at the Olkiluoto research site in Finland were undertaken as part of an investigation within the Finnish nuclear waste disposal program. The study revealed that four F were recorded by fracture calcites. From petrologic evidence, the first F precipitated crystalline calcite at 150 to 250°C with a 813C signature of -22 to -14 PDB and a 818O signature of 11.8 to 14.4 SMOW. These closed fracture fillings were found at depths >500 m and were formed from a high T, low sal, Na-CIF. The next F precpitated crystalline calcite with clay at 70-210°C with a 813C signature of -8 to 7 PDB and a 818O signature of 15.4-21.6 SMOW. These closed fracture fillings were found at depths <500 m and were formed from a moderate to high T, low to moderate sal, Na-Cl F, likely of magmatic origin. The last group of calcites to form record the presence of two distinct F types. The platy (a) calcite formed at 98-238°C with a 813C signature of -13.9 to -5.4 PDB and a 818O signature of 12.3-19.6 SMOW, from a high T, low sal, Na-Cl F of possible magmatic origin. The platy (b) calcite formed at 66.7-98°C with a 813C signature of -13 to -6.3 PDB and a 818O signature of 15.1 to 20.1 SMOW, from a low T, high sal, Ca-Na-Cl F of possible basinal brine origin. (Authors' abstract)

BOARD, W.S. and FRIMMEL, H.E., 1998, Fluid evolution and mineralising potential in the external Gariep Belt (abst.). Special Abstracts Issue Gondwana 10: Event Stratigraphy of Gondwana, published in J. of African Earth Sci., v. 27, no. 1A, p. 29-30. Authors at Dept. of Geological Sci., Univ. of Cape Town, Rondebosch 7701, South Africa.

Regional orogenic F in the external zone of the Gariep orogenic belt differ from pre-orogenic F associated with rift-related base metal sulphide mineralisation by having a considerably lower sal and different chemistry. Based on our data, no significant mineralising potential can be ascribed to these orogenic F.

Most of the FI analysed are secondary. Four types of FI were observed at room T: (1) two-phase, undersaturated aq; (2) three-phase, undersaturated CO2-bearing aq; (3) monophase CO2-rich; and (4) four-phase, saturated CO2-bearing aq 1 with dxl. Aq Fl are the most abundant. The coexistence of types (2) and (3) is interpreted to be a result of L immiscibility during entrapment. The triple point of CO2-rich I varies between -56.6 and -58.4°C. For the lower value, preliminary Raman spectrometric data indicate the presence of additional CH4. Aq I of the D1/D2 veins from the northern part of the PNZ have Th-220-240°C comparable to those obtained for the southern part (Th-230°C). These Th values are generally higher than those obtained from the D1/D2 veins (Th-190-210°C) from the central part. Aq I within D3 veins from the central part yield slightly lower Th values (180-200°C) than the D1/D2 veins there. Aq 1 in D5 veins yielded the lowest Th values (155-170°C). The D4 veins (restricted to the central part of the PNZ) have aq Th values (~240-250°C) that are higher than those of the D1/D2 veins in this area, in agreement with their relationship to contact metamorphism around the Kuboos Pluton

F sal in the  $D_1/D_2$  to  $D_3$  veins are very similar, generally varying between 0-11 wt% NaCl eq., with two samples having higher sal (14 9-15.3 wt% NaCl eq.). Very low sal were obtained for the Schakalsberge Thrust (0-2.6 wt% NaCl). Eutectic T are generally in the range <-35 to <-60°C, indicating the presence of CaCl<sub>2</sub> and MgCl<sub>2</sub> in addition to NaCl. Type (4) 1 were only encountered in the silicic footwall breccia that underlies the main ore bodies at Rosh Pinah and this was the only type of 1 present within the sample. The triple point of the CO<sub>2</sub>-rich 1 of -60.8°C indicates the presence

of other species in addition to  $CO_2$  (most likely  $H_2S$  and/or  $CH_4$ ). The sal determined from clathrate melting T (~20.2 wt% NaCl eq.) indicates that these F are far more saline than the orogenic F.

The pre-orogenic F sampled [by crush-leach] at the Rosh Pinah mine differ in the distribution of the dissolved ions from the regional orogenic F (Fig. 1). An NaCl-CaCl<sub>2</sub>-H<sub>2</sub>O (with minor MgCl<sub>2</sub>) system is confirmed for the orogenic F, whereas those from the mine are dominated by MgCl<sub>2</sub> and CaCl<sub>2</sub>. Only in orogenic F from the northern part of the PNZ was Br detected. Very low Cl/Br and Na/Br ratios indicate that the F sampled were from an evaporitic horizon (Kesler et. al., 1995, Geology, v. 25, p. 641-644). No variation in ionic composition as a function of orogenic F generation were observed. (From the authors' abstract by H.E.B.)

See figure in the Illustrations appendix.

BOBROV, A.B., SIVORONOV, A.A., MALYUK, B.I. and PAVLUN, M.M., 1998. Economic gold mineralization in the Ukrainian shield: extended abstract, Int'l. Liaison Group on Gold Mineralization Newsletter 26, p. 61-64. First author at Dept. of Geol., Lviv State Univ., Grushevskogo 4, 290005, Lviv, Ukraine.

The Ukrainian shield consists of six distinct rock complexes but economic gold mineralization is known in relation to only three of them.

 <u>Charnockite-granulite complex</u> characterized by supracrustal plutonic formations metamorphosed under granulite conditions

2) <u>Tonalite-greenstone complex</u> represented by volcano-sedimentary, volcanic and plutonic formations progressively metamorphosed under conditions from amphibolite and epidote-amphibolite to greenschist facies. FI studies suggest a metamorphic-hydrothermal origin for the mineralization, related to the latest events of the rhyodacite-plagiogranite association and development of post-magmatic F systems. Depositional environments were characterized by rather wide T intervals, 200-400°C, and moderate P of 200-250 MPa. In the case of vein deposits, available data suggest the absence of any significant mineralogical and geochemical zonation.

3) <u>Granitoid-meta-terrigenous complex</u> comprising mainly metasedimentary formations. Gold occurs as grains of the native metal 1-100  $\mu$ m in size with a predominance of fine fractions (44-74  $\mu$ m), and a fineness of 934-978. Preliminary Fl studies suggest rather high T but low-P environments in the range of 250-450°C and 150-200 MPa respectively. (From authors' abstract by E.R.)

BODNAR, R.J., 1998a, Fluid inclusions systematics in porphyry copper deposits (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A30. Author at Dept. of Geological Sci., Virginia Tech, Blacksburg, Va 24060; email (bubbles@vt.edu)

It is well known that porphyry copper deposits are associated with both an early magmatic F that exsolves from the crystallizing magma, and a later F of dominantly meteoric origin that convects through the pluton late in its history. FI in porphyry copper deposits provide a record of this magmatic/hydrothermal F system and its evolution during mineralization and alteration. Previous models for porphyry copper genesis called upon the early magmatic F to introduce the metals into the system and cause earlyhigh T (potassic) alteration. Later alteration (phyllic) (and perhaps copper deposition) was thought to be associated with lower T meteoric waters. More recently, however, results of FI studies have shown that the low to moderate sal, moderate T F associated with phyllic alteration in many deposits are of magmatic origin.

In order to better understand the types of FI that should be produced during cooling of a porphyry copper pluton, the room T phase ratios of FI as a function of time and position within the overall porphyry system have been calculated. The results of these calculations show consistent variations and also predict previously unrecognized 1 types. For example, the model calculations predict a zone of halite-saturated V above the cooling pluton early in its crystallization history. This zone evolves to a L plus V zone as the pluton cools and the crystallization front moves to greater depths. Additionally, the PTX conditions along the sides of the pluton are such that it is possible for magmatic F to migrate from the pluton into the overlying rocks without intersecting the two-phase field to produce FI at shallow depth that have low sal, moderate Th, and show no evidence of immiscibility. In the past such FI were interpreted as being of meteoric origin, but results of recent studies of porphyry systems and these model calculations indicate that they could be of magmatic origin. A discussion of how the distribution of these I types in time and space can be used in exploration for porphyry deposits will be presented. (Author's abstract)

BODNAR, R.J., 1998b, A model for the temporal and spatial evolution of

magmatic fluid inclusions in porphyty copper deposits (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 16. Author at Fluids Research Laboratory, Virginia Tech, Blacksburg VA 24061

As a first step in a larger effort to develop a quantitative fluid flow model describing the evolution of magmatic fluids in porphyry copper systems, the characteristics of fluid FI trapped during crystallization of a porphyry copper-type "Burnham melt" have been calculated. Following the Burnham model for crystallization of a granodioritic magma emplaced at sub-volcanic levels, the PVT properties of a magmatic F with a composition of 10 wt% NaCl have been calculated. The model assumes hydrostatic P conditions from the surface down to the 400°C isotherm, and lithostatic P conditions below that depth.

Results of this study suggest a systematic evolution in magmatic FI properties during crystallization of porphyry-related magmas. The predicted PVT behavior of FI is consistent with the V plume model of Henley and McNabb. The model further suggests that late-stage, moderate sal, moderate T FI are a natural consequence of magmatic F evolution, supporting earlier suggestions that similar F associated with phyllic alteration in porphyry deposits are of magmatic origin. (From author's abstract by E.R.)

BODNAR, R.J., 1998c, Fluid evolution in porphyty copper deposits (abst.) Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 180-181. Author at Fluids Research Laboratory, Virginia Tech, Blacksburg, VA 24061-0420, USA, email (bubbles@vt.edu).

The porphyty copper deposits provide some of the best examples of the effects of F-assisted mass and energy transport in the earth's crust. FI that trap the earliest magmatic F may have a broad range of room T phase ratios depending on a variety of factors including (1) the degree of crystallization of the intrusion. (2) the depth of emplacement and (3) the composition of the magmatic F.

Using the Burnham model (Burnham, 1979) for crystallization of a granodioritic magma emplaced at shallow levels in the earth's crust, the time-space evolution of Fl in a typical porphyry copper deposit have been calculated using the P-V-T-X properties of H2O-NaCl. In this model, the P regime at T<400°C is assumed to be hydrostatic, and lithostatic at greater T (depths), thus approximating the brittle-ductile transition in this environment. During the earliest stages of crystallization, a L+V zone exists immediately above the pluton - I trapped here would produce coexisting halite-bearing and V-rich I that would both homogenize at the same T, and this T in turn would equal the Tr (Fig. 1). Copper transported in the original magmatic F would be partitioned into the high sal L phase. This higher density phase would flow downward along the sides of the pluton, whereas the copper-poor V would move upwards into the shallower volcanic system. Above the L+V zone, a small V+halite zone exists - I trapped here would be V-rich with occasional 'halite' I surrounded by variable amounts of V (Fig. 1). This zone would show relatively low copper grades (in the early yeins), but may contain significant amounts of precious metals. Above the V+halite zone is a zone of moderate T. moderate sal F.

As crystallization proceeds, the halite+V zone gradually migrates downwards and eventually is replaced by a V-only zone directly above the crystallizing pluton. I trapped at this point in time-space would be V-rich and homogenize at T well below the T<sub>t</sub> (Fig. 1). This zone evolves into a Lonly zone at shallower depths without crossing a phase boundary or entering a field of immiscibility. These F are capable of transporting copper and gold from the pluton into overlying volcanic rocks and may account for the common occurrence of enargite-gold mineralization in volcanic rocks associated with deeper porphyry copper type mineralization. This empirical model for the time-space distribution of F1 types in porphyry copper deposits provides a basis for interpretation of F1 from porphyry systems, and may be used in exploration for other mineralized systems. (From author's abstract by E.R.)

See figure in the Illustrations appendix.

BODNAR, R.J., 1998d, Fluid inclusions in Allan Hills 84001 and other Martian meteorites: Evidence for volatiles on Mars (abst.): Workshop on the Issue Martian Meteorites: Where do we stand and where are we going?. Houston, Texas, Nov. 2-4, 1998, LPI Contribution, 1998, no. 956, p. 3-5. Author at Fluids Research Laboratory. Dept. of Geological Sci., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061-0420, USA; email (bubbles@vt.edu).

Introduction: The important role that volatiles play in planetary evolution is well known. On Earth, volatiles have and continue to play key roles in the development and properties of the crust, hydrosphere, and atmostphere. More recently, the recognition that the mantle contains small but ubiquitous quantities of volatile components has led to an improved understanding of mantle rheology and chemistry and the recycling of volatiles in the Earth system. And, of course, volatiles, especially water, are considered to be a prerequisite for the origin and evolution of life as we know it.

The recent announcement that evidence for life had been discovered in the ALH 84001 Martian meteorite [1] combined with the highly successful Mars Pathfinder Mission has led to renewed interest in the geochemical evolution of Mars. Much of the scientific effort in this area has been devoted to characterizing the volatiles present in the SNC meteorites and, by inference, the volatiles present on Mars when the rocks formed. Here, the occurrence of "free" volatiles (i.e., volatiles occurring in the F state, and not as minor components of minerals and/or glasses) in the ALH 84001 and Nakhla meteorites is reported, along with possible implications.

**Background:** FI are microsamples of F (L or G) trapped in rocks and minerals either at the time of their original formation or at some later time as F flow through rocks along fractures [2]. The presence of FI in terrestrial rocks is the rule rather than the exception. Indeed, the rock sample that contains no I that are visible at high magnification (>1000×) is rare, and many minerals such as milky quartz may contain up to  $10^9$  FI per cubic contimeter

The precursor of the martian meteorites is thought to be ultramafic igneous extrusive and/or intrusive rocks that were blasted from the surface of Mars during an impact event. Similar igneous rocks on earth commonly contain Fl along with the more abundant silicate, sulfide, and carbonate MI. As such, it is reasonable to expect that the SNC meteorites should contain Fl that represent F trapped in the rocks while they were on the surface of mars. A review of the recent literature failed to find any references to Fl in these well-studied samples, and a systematic search of available SNC meteorite samples was undertaken.

Observations: FI have been found in two thin sections of SNC meteorites: one in Nakhla (NSNM 5891-3) and one in ALH 84001,146.

Nakhla (NSNM 5891-3). The I in the Nakhla sample is tubular and -8 µm long. The I is one of several dozen I forming a healed fracture that cuts through an orthopyroxene crystal. Most of the I along the fracture are dark with noticeable microfractures extending from the I into the surrounding mineral, indicating that the I have decrepitated (exploded) owing to P buildup within the I. This behavior is common for high-density L FI in terrestrial samples. A few other I along the fracture were clear (transparent) but did not contain a visible bubble. This is because either the I were empty. contained only L with no V bubble, or contained a bubble that was motionless and hidden in a corner of the I. The bubble in the one unambiguous FI in this fracture plane was in constant, slow motion, proving that the I did indeed contain a L phase.

Although it was not possible to conduct the types of tests normally used to determine FI compositions because of the manner in which the sample was prepared, the difference in index of refraction between the L and the V bubble is consistent with the I containing L and V CO<sub>2</sub>, although it is possible that the I contained L water and water V.

ALH 84001.146. The second sample that contained L I with moving bubbles was ALH 84001.146. The I in this sample were spherical to negative-crystal shaped, about 1-2  $\mu$ m in diameter, and not along an obvious fracture (Fig. 1). The fact that the I are not along a fracture is important because it suggests that the I are P (i.e., trapped during growth of the enclosing pyroxene). The F in the I thus represents the magnatic F that exsolved from the crystallizing M as the igneous rock formed on Mars. As such, the I can provide valuable information about degassing early in Mars history. As with the I in Nakhla, no direct chemical tests could be conducted on these I, but the optical behavior of the I suggests that they contain L and V CO<sub>2</sub>.

Implications: The occurrence of (presumably)  $CO_2$  FI in both the Nakhla and ALH 84001 meteorites suggests that  $CO_2$  was migrating through these igneous rocks at some time [during?] or after their formation on Mars. If the  $CO_2$  was present at or near magmatic T, pyroxene (enstatite) would not be stable in the presence of  $CO_2$ , and would react to form a carbonate and a silica-rich phase [3]. This is consistent with a high-T origin for the carbonates in the SNC meteorites, as originally proposed by Harvey and McSween [4]. This interpretation also suggests that the carbonates were present in the rocks before they were ejected from the martian surface. However, by analogy with terrestrial samples, the carbonates did not necessarily have to form as a result of the impact event but, rather, may have formed as a result of natural high-T igneous metasomatic processes before the impact.

See figure in the Illustrations appendix.

BOGARD, D.D. and GARRISON, D.H., 1998, Relative abundances of argon, krypton, and xenon in the Martian atmosphere as measured in Martian meteorites: Geochim. et Cosmo. Acta, v. 62, no. 10, p. 1829-1835. Authors at Planetary Sci., NASA Johnson Space Center, Houston, Texas 77058, USA.

We determined the concentrations of trapped Ar, Kr, and Xe in impact-M glasses from Shergotty, Y793605, and two I of EET79001 not previously analyzed. When combined with literature noble G data on a single glass I in EET79001 and a glass vein in Zagami, these data give more accurate estimates of the composition of Martian atmospheric G trapped in these glasses. For the geological recent composition of the Martian atmospheric we infer <sup>129</sup>Xe<sup>1132</sup>Xe, <sup>36</sup>Ar<sup>1132</sup>Xe, and <sup>34</sup>Kr<sup>1132</sup>Xe ratios [that] differ from those measured by Viking by factors of 2.5 and 1.8, respectively. The <sup>36</sup>Ar<sup>1132</sup>Xe and <sup>34</sup>Kr<sup>1132</sup>Xe ratios in ALH84001 are considerably less than those in impact glasses and suggest preferential adsorption (in carbonate?) of Xe over Ar and Xe over Kr by factors of -11 and -2.6, respectively. We suggest that noble G dissolved in water may have largely determined the trapped noble G abundance pattern in ALH 84001. (Authors' abstract)

BOIRON, M.-C., BARAKAT, Ahmed, CATHELINEAU, Michel, BANKS, David, DURISOVA, Jana, and MORAVEK, Petr., 1998, 3D geometry reconstruction and P-V-T-X conditions of microfissural ore fluid migration in crystalline rocks: The example of the Mokrsko Au-bearing granodiorite (Bohemian massif) (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 17. First author at CREGU and UMR G2R 7566, BP23, 54501 Vandoeuvre-les-Nancy Cedex, France.

Study of the 3D geometry and P-V-T-X conditions of F migration in crystalline rocks shows that the circulation of F may occur through a dense and regular network of extensional structures. Integrated studies including 3D reconstruction of the geometry of F pathways using video-image analysis. SEM with CL, P-V-T-X properties of F, studies of FI (microthermometry, Raman spectroscopy and bulk ion chemistry) have been made, and appear beneficial for developing a genetic model of F circulation and ore formation in the case of gold mineralisation.

The Mokrsko-Celina ores result from the superimposition of three main stages of F migration. The early stage is characterized by F belonging to the C-H-O-N system probably resulting from interactions with metamorphic rocks under high P-T conditions (T=450-550°C and P=250-400 MPa). [The intermediate stage], responsible for fissure sets filled by pyrthotite, chalcopyrite and galena. from F under relatively high P and high T (300-420°C and 100-200 MPa). The last stage is characterized by aq I having low sal (<8 wt% eq. NaCl), and trapped at low P (<70 MPa) and T (220-280°C). Gold particles occur in microfissures affecting earliest sulfides intimately associated with Bi-minerals and chlorites (±carbonates). Thus it was enriched or introduced at the end of the main ore stage.

Quartz from an early thick quartz vein and from the main veinlets has been analysed by crush leach techniques. In both samples, the dominant anion is Cl, SO<sub>4</sub> being minor but significant. F from the quartz veins are dominated by Na, Ca and sometimes appreciable Fe, Mn. Br/Cl from quartz veinlets ranges from 0.0013 to 0.0021 while the thick quartz veins have Br/Cl around 0.0040. There is no difference in the I/Cl ratios between the Fl from the two types of quartz. F from the pre-ore stage quartz vein display a halogen signature similar to those obtained on other magmatic F. The halogen ratios of the F from the quartz veinlets are quite similar to those observed for the F associated with gold mineralization in Iberia (Boiron et al., 1996, GCA 60:43-57) and can be interpreted as indicating they were derived from deep percolation of surface waters which equilibrated with crustal rocks under high P-T conditions. (From authors' abstract by E.R.)

BONEV, I.K., 1998, Nature and origin of the twisted quartz crystals ("Gwindels") and of quartz with white strips ("Fadenquarz") (abst.): 17th General Meeting Int'I. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A84. Author at Geological Inst., Bulgarian Acad. Sci., Sofia; email (bonev@geology.acad.bg)

The famous twisted quartz crystals, "Gwindels," known since the last century and seen in many mineralogical museums, are still an unsolved crystallographic enigma. These bilateral tabular mosaic crystals are developed mainly in the a direction. Found in Alpine veins in the Swiss Alps and the Subpolar Ural, they [are] always associated with normally-shaped crystals. Their most twisted portions form a central zone (0001) resembling an area of local non-destructive plastic deformation of the brittle guartz.

Morphologically similar are the specific non-distorted crystals with "white strips," "Fadenquarz," known also from the Alpine veins in the Alps, Caucasus and Arkansas. Their narrow milk-white central (0001) Faden-zone contains abundant Fl. The proposed explanations of their growth mechanism are geologically unrealistic.

In some hydrothermal skarn-ore deposits druses of parallel doublyterminated crystals were found. Narrow "white strips" trace their central zones. Microscopic, X-ray and microprobe studies established inside them fine relics of seed (0001) calcite plates disintegrated by dissolution. The *a* and *c* axes of both minerals are parallel, clearly indicating epitaxial relationships in the (0001) plane.

The Alpine Fadenquarz shows all features of the same mode of bilateral epitaxic growth on thin (0001) paperspar-calcite seeds, later completely dissolved, with rapid healing of the so-formed notches.

Paperspar can be easily plastically distorted and may act as a seed for twisted quartz, though usually no calcite relics or Fl are preserved in the dissolved and healed seed area. The numerous slightly divergent quartz nuclei forming the rough mosaic of the distorted central zone gradually pass into the outer zones of more perfect and undistorted large straight crystals. (Author's abstract)

BORROK, D.M., KESLER, S.E., BOER, R.H. and ESSENE, E.J., 1998, The Vergenoeg magnetite-fluorite deposit, South Africa: Support for a hydrothermal model for massive iron oxide deposits: Econ. Geol., v. 93, p. 564-586. First author at Dept. of Geol., Univ. of the Witwatersrand, P.O. WITS, Johannesburg 2050, South Africa.

Vergenoeg is a fluorite-bearing massive iron oxide deposit that is genetically related to granites of the Bushveld Complex. It consists of a pipeshaped body containing P fayalite, fluorite, apatite, ilmenite, and magnetite that cuts Rooiberg rhyolites and is surrounded by stratiform bodies of felsite and fragmental hematite-fluorite debris. With the exception of its abundant fluorite, Vegenoeg is similar to massive iron oxide deposits such as Kiruna, Pea Ridge, and Cerro Mercado, all of which are related to felsic magmatism.

Fluorite at Vergenoeg lacks I that might represent an immiscible ironrich M but contains abundant aq I. I petrography, heating-freezing measurements, and G analyses indicate that the P mineral assemblage at Vergenoeg formed from a high-T (>500°C), high-sal (>67 wt% NaCl eq) F that coexisted with a V phase rich in CO<sub>2</sub>. Stable isotope analyses of P fayalite and titanian magnetite from deep in the Vergenoeg pipe yield calculated water compositions for these T that are typical of magmatic water ( $\delta^{18}OH_2O=7$ -8% at 500°C). Alteration of the P fayalite-fluorite-ilmenite assemblage is widespread. FI related to these alteration assemblages homogenize at 150 to 500°C and have sal of 1-35 wt% NaCl eq. Stable isotope analyses of hematite and I waters in fluorite suggest that these F consist of a mixture of magmatic and meteoric water.

These observations suggest that Vergenoeg mineralization formed from hydrothermal F of magmatic origin. Comparison of the FI record at Vergenoeg to the more fragmentary record at other massive iron oxide deposits supports a magmatic hydrothermal model for this class of deposit (From authors' abstract by E.R.)

Dm include halite, sylvite, hematite. Fe chloride, and unidentified. Some of the Fe chlorides may have been trapped as a solid I. (From authors' text by E.R.).

See figure in the Illustrations appendix.

BORTNIKOV, N.S., SAZONOV, V.N., VIKENTN'EVA, O.V., VIKENT'EV, I.V., MURZIN, V.V., NAUMOV, V.B. and NOSIK, L.P., 1998. Role of the magmatogenic fluid in the formation of the mesothermal Berezov gold-quartz deposit: Doklady Akademii Nauk, v 363, no. 1, p. 82-85 (in Russian, translated in Doklady Earth Sci., v. 363, no. 8, p. 1078-1081). First author at Inst. of Geol. of Ore Deposits, Petrog., Mineral, and Geochem., Russian Acad. of Sci., Staromonetnyi per. 35, Moscow, 109017, Russia.

The Berezov deposit is a classic example of mesothermal gold-quartz deposits. Hydrothermal mineralization includes the following types: pyritic copper (±cobalt), quartz-tourmaline-scheelite, and gold-sulfide-quartz.

Our investigations showed that the mineral-forming F consists of H<sub>2</sub>O and CO<sub>2</sub>. At room T, FI consist of three phases (H<sub>2</sub>O<sub>1</sub>+CO<sub>21</sub>+CO<sub>2g</sub>). CO<sub>2</sub> homogenizes into L at 8-27.8°C. I completely homogenize at 280-295°C

however, they often explode prior to homogenization. The presence of syngenetic I filled with mainly  $CO_{2g}$  indicates that quartz crystallized from the F that split into two (L and G) phases. Therefore, the Th of the Fl is considered to be the true T of the mineral formation. The solution sal, calculated on the basis of the melting T of G-hydrate (from -2.0 to 6.0°C), varied from 7.6 to 18.2 wt% NaCl eq. Fluid P, calculated by the isotherm and isochor intersection [9], is 0.9-2.5 kbar.

Thus, obtained results indicate that the near-vein metasomatites and ores of the Berezov ore field were formed from a two-phase F consisting of L (H<sub>2</sub>O+CO<sub>2</sub>) and G (CO<sub>2</sub>) phases. The F isotopic composition evolved because of separation of the volatile components and interaction with host rocks. Sulfur and carbon were mainly derived from the magnatic chamber with subordinate contributions from the host rocks. (From authors' text by E.R.)

BOULLIER, A.M., FIRDAOUS, K. and ROBERT, F., 1998, On the significance of aqueous fluid inclusions in gold-quartz vein deposits from the southeastern Abitibi Sub Province (Quebec, Canada): Econ. Geol., v. 93, p. 216-223.

FI have been studied in a quartz-epidote-actinolite vein within a Proterozoic diabase dike cross-cutting the Donalda gold-quartz vein Nº1, near Noranda, Quebec. Two types of FI were recognized: the first type is represented by two-phase aq FI characterized by low Te (<-45°C), variable Tmice (-33 to -6°C) and high Th (L-V(L)>200°C). The second type is represented by two or three-phase (±solid) aq FI characterized by low Te (<-45°C), highly variable Tmice (-52.8 to -2.4°C), low Th (L-V(L)<130°C) and halite dissolution (<200°C) T. This second FI type is also described with H2O-CO2 and CO2 FI in Archaean gold-quartz veins of the southeastem Abitibi and has a chemical composition (Ca-Na-Cl-bearing with variable sal) comparable to that of brines and groundwaters found in the Superior Province. This study demonstrates that these low Th aq F showing variable sal are unrelated to gold deposition, but should rather be correlated with younger brines and groundwaters which percolated downwards in the continental crust. In these gold-quartz veins, only the high Th aq F may be linked to gold-bearing F. (Authors' abstract)

BOYCE, J.W., GROVE, Marty and REID, M.R., 1998, Diffusivity of Ar in quartz, and the geometry, density, and distribution of radiogenic Arbearing glass inclusions in quartz phenocrysts from the Bishop Tuff, Calfornia, USA (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F964. First author at Dept. of Earth and Space Sci., Univ. of California, Los Angeles, 3806 Geol. Bldg., Los Angeles, CA 90095-1567, US; email (boyce@ess.ucla edu)

Glass I in quartz phenocrysts from the -760 ka Bishop Tuff, Long Valley, that yield  $^{40}Ar/^{39}$ Ar apparent ages >1 Ma older than the eruption age. Assuming no accumulation of Ar in the magma and that Ar solubility in quartz is not rate-limiting, the data imply that quantitative Ar-loss from the MI would be achieved in <10<sup>4</sup> years, or less than 1% of the magma residence time inferred from the Ar data. Thus, to the extent that Ar permeability through quartz is limited by diffusion operating at rates similar to those predicted by the ionic porosity model, it appears unlikely that glass I would quantitatively retain Ar under magmatic conditions unless relatively high Ar concentrations were maintained within the magma chamber. (From authors' abstract by E.R.)

BRAKE, S.S., RESSEL, M.W., CONNORS, K.A., NOBLE, D.C. and WEISS, S.I., 1998, Auto-alteration of dikes of the Matalla-Sta. Rosa Center, Peru. the Carlin Trend and Bare Mtn., NV, by closed-system crystallization of CO<sub>2</sub>- and S-bearing magmas (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-377. First author at Dept. of Geography, Geol. and Anthropology, Indiana State Univ., Terre Haute, IN 47809.

Matalla-Santa Rosa is one of several centers of late Neogene (5 Ma) magmatism, exposed over a vertical range of 2 km, near the Cobriza district, central Peru. Rocks are intermediate to silicic, calc-alkalic and moderately potassic; some have lamprophyric textures. Vertical dikes that intrude unaltered clastic marine strata radiate outward from the upper part of a weakly K-silicate-altered porphyry stock. Dikes range from completely "fresh", consisting of unaltered. P feldspar, biotite, etc., to rocks composed of K-feldspar. Na-plagioclase, Mg-chlorite, quartz, muscovite, carbonate, nutile and sulfides. These *auto-altered* dikes have no associated alteration halos or veinlets, showing that their mineralogical and other features were produced by reaction with their own contained volatiles. Chemical analysis of these thoroughly auto-altered dikes indicates no gain or loss of major or minor elements. One dike contains porous lenses of <1 to 2+ cm in

diameter, oriented parallel to its margins, composed of carbonate, pyrrhotite, quartz and minor chalcopyrite. Euhedral crystals of low-T quartz in these lenses and groundmass quartz contain both high-sal and V-dominated FI; V homogenizes between 280°C and 340°C and halite dissolves at 350-450°C.

Similar features are seen at Lantern and Genesis in the Carlin trend, where mineralogically similar and compositionally unmodified Eocene dikes containing 2 or 3 carbonate phases and pyrite, locally cut virtually unaltered Jurassic dikes. Miocene dikes at Bare Mtn., SW NV, locally have textures and mineralogy similar to those of the Matalla-St. Rosa and Lantern dikes and contain high-sal and V-dominated Fl. <sup>40</sup>Ar/<sup>30</sup>Ar analysis shows that relict phenocrystic homblende from one such dike contains excess argon not degassed on cooling.

The auto-altered Matalla-St. Rosa and Lantern dikes contain, respectively, 2.75 and 3.30 wt.% CO<sub>2</sub> and 420 and 900 ppm S: these elements were largely fixed in mineral phases on cooling and crystallization. However, considerable amounts of some other elements were lost on crystallization, based on values for auto-altered rocks versus those of glassy counterparts (e.g., H<sub>2</sub>O, 1.27 and 0.49 wt.% [sic]; Cs, 2 and 6 ppm; As,  $\geq$ 13 and 25 ppm; Sb, 0.4 and 2.5 ppm, respectively). Auto-alteration reflects emplacement at significant depth such that most volatile constituents were unable to escape from supercooled M or from the M when it crystallized under subsolidus conditions. Auto-altered dikes may provide a guide to sedimentary rock-hosted gold and other mineral deposits (*see also* Ressel et al., this meeting). (Authors' abstract)

BRANTLEY, S.L., FISHER, D.M., DEINES, P., CLARK, M.B. and MYERS, G., 1997, Segregation veins: Evidence for the deformation and dewatering of a low-grade metapelite: <u>in</u> Deformation-enhanced Fluid Transport in the Earth's Crust and Mantle, edited by M.B. Holness, 1997, p. 267-xxx. ISBN 0 412 75290 5.

Discusses, in detail, the FI evidence of segregation vein formation. (H.E.B.)

BRAUER, N.A., BODNAR, R.J., and LAW, R.D., 1998, Fluid inclusions as a monitor of progressive grain-scale deformation during cooling of the Papoose Flat pluton, Eastern California (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ of Nevada, p. 18. Authors at Virginia Tech, Fluids Research Lab, Blacksburg, VA 24061-0420.

Analyses of FI and microstructures within the Papoose Flat pluton were used to investigate the T of F circulating with the pluton during cooling. Based on previous microstructural analyses, the interior of this late Cretaceous granitic to granodioritic pluton has been divided into three domains: i) a central core characterized by magmatic microstructures, ii) a middle domain of high T (>500°C) solid-state deformation, and iii) an outermost domain characterized by relatively low T (<500°C) solid-state deformation. Weakly developed solid-state microstructures overprint the dominant magmatic microstructures in samples from the core domain. The existence of solid-state microstructures in all three domains indicates that deformation continued during and after crystallization of the interior of the pluton.

Two phase, low sal (< 26 wt% NaCl eq.), L-rich aq FI predominate within both quartz and feldspar grains in all samples. The assemblages are thought to mark the positions of healed microcracks which have been partially overprinted by migrating grain boundaries, and indicate that discrete microcracking events occurred during plastic deformation.

Th overlap for all three microstructural domains. The mineral assemblages of the contact aureole and the pluton indicate trapping P between 3.8 and 4.2 kb. Ninety-eight percent of the calculated FI Tt at 3.8-4.2 kb are below the granite solidus of 650°C. Seventy-six percent of the Tt's fall within the more restricted range of 350-500°C, i.e. at T which are lower than the commonly cited brittle-ductile transition T for feldspar at natural strain rates, but above those for quartz. The similar, relatively low Tt's indicate that the majority of I preserved in all three domains were trapped during the late low strain magnitude stages of solid-state deformation. The most common FI Tt's (400-500°C) in all three microstructural domains are similar to the deformation T indicated by microstructures and crystal fabrics in the outer part of the pluton; these Tt's are lower than T associated with contemporaneous solid state and magmatic flow in the pluton interior. The similar Tt's within the pluton core and margin must indicate that the final inclusion-trapping event migrated inward from the margin to the core of the pluton as it cooled, because FI would rapidly equilibrate to a density appropriate for the PT conditions of their host minerals. (From authors' abstract by E.R.)

BRENAN, J.M., RYERSON, F.J. and SHAW, H.F., 1998, The role of aqueous fluids in the slab-to-mantle transfer of boron, beryllium, and lithium during subduction: Experiments and models: Geochim. et Cosmo. Acta, v. 62, no. 19/20, p. 3337-3347. First author at Dept. of Geol., Univ. of Toronto, Toronto, Ontario MSS 3B1, Canada.

The low atomic mass elements B, Be, and Li are viewed as sensitive tracers of the involvement of subducted materials in the genesis of island arc magmas. In order to better assess the role of dense aq F in the slab-tomantle transfer of these elements during subduction, measurements have been made of partition coefficients for B, Be, and Li between aq F and minerals likely to be present in the basaltic portion of the downgoing slab, namely clinopyroxene and garnet. Experiments at 900°C and 2.0 GPa reveal that the average clinopyroxene-F partition coefficient for Be (~2) exceeds that for either Li (~0.2) or B (~0.02) and values are  $100 \times (B, Li)$  to  $1000 \times (Be)$  larger than partition of coefficients for garnet. Clinopyroxene-F partition coefficients were found to vary with the alumina content of run-product clinopyroxenes, but this variation is interpreted to reflect the specific exchange reaction that governs the incorporation of these elements into the pyroxene structure, and not mineral-F disequilibrium.

The element pairs B-Be, B-Nb, and Li-Yb are considered to be essentially unfractionated during the partial melting process, as evidenced by their coherent behaviour in apparently cogenetic lavas and the similarity in their measured mineral-M partition coefficients. A comparison of clinopyroxene-F partition coefficients for these elements with clinopyroxenesilicate M values reveals that B/Be, B/Nb, and Li/Yb ratios will be significantly fractionated in coexisting aq F with respect to the residual solid. The elevated ratios of B/Be, B/Nb, and Li/Yb in island arc lavas relative to MORB are thus considered to be consistent with an origin by F-mediated slab-to-mantle transport. A quantitative model of slab dehydration accompanied by progressive water loss and changes in residual mineral mode reveals that source regions with B/Be and B/Nb appropriate for producing the Izu and Kurile IAB suites can be generated using available estimates for the composition of altered oceanic crust, although B abundances at the high end of published values are required. Because the highest values of B/Be and B/Nb are produced in the mantle wedge at relatively shallow depths, some additional process, such as subduction-induced flow of a hydrated mantle wedge, is required in order to transfer enriched material to depths appropriate for the formation of magmas beneath the volcanic front.

Calculations indicate that by the time the slab reaches a depth of 200 km. B/Be and B/Nb in the dehydration residue has been reduced to ~5-12% of initial values. Thus, the preferential loss of B during dehydration is viewed as a viable mechanism to prevent the excess B acquired during near-surface alteration of oceanic crust from being cycled into the mantle, thereby maintaining the distinction in B/Be and B/Nb for mantle and crustal reservoirs. (Authors' abstract)

BRENNAN, S.T., 1998. Fluid and thermal history of El Abra limestone, NE Mexico (abst.) Geological Society of America Annual Meeting 1998. Abstracts, v. 30, no. 7, p. A-60. Author at Dept. of Geosci., SUNY Binghamton, Vestal Pkwy. E., Binghamton, NY 13902; email (bg20824@binghamton.edu)

El Abra Limestone is a mid-Cretaceous carbonate platform deposit which is currently an exhumed petroleum reservoir. Based on careful petrographic and CL observations coupled with stable isotope and FI analyses, the complex diagenetic history of this formation could be resolved. The first major diagenetic event was the precipitation of calcite cement from either a meteoric-marine mixing-zone F, or a marine F that was increasing in T. These cements were cross-cut by a later calcite cement that was precipitated from formation waters or an oil-field brine. Secondary hydrocarbon FI cross-cut these calcite cements. The hydrocarbon FI have homogenization values that range from 50 to 125 °C, and there is no evidence of thermal reequilibration. UV epi-fluorescence reveals that the hydrocarbon FI have different compositions, which indicates several fracturing and migration events in this resevoir. Hydrocarbon FI are cross-cut by S aq I. Aq FI homogenization values range from 95 to 160°C. However, these I were thermally reequilibrated, indicating that the reservoir was heated to T of 160°C or higher after both the hydrocarbon and aq F entered the reservoir. Bitumen-lined stylolites cross-cut all the described diagenetic features. The bitumen and the heating event indicate that the hydrocarbon F may have been thermally degraded within in the reservoir. The results of this study and previous studies of this region can be combined to constrain the timing of hydrocarbon migration, maximum burial, heating, and hydrocarbon degradation. El Abra Limestone was cemented prior to the Paleocene to Eccene. During the Paleocene to Eccene the reservoir was charged with hydrocarbon and aq F. The thermal degradation event was between 50 and

30 Ma. The reservoir cooled below 100°C approximately 30 Ma and El Abra Limestone has been at or near the surface since at least the Pleistocene. (Author's abstract)

BRENNAN, S.T., and GOLDSTEIN, R.H., 1998, Fluid and thermal history of an exhumed petroleum reservoir (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 19. First author at Univ. of Kansas, Dept. of Geol., 120 Lindley Hall, Lawrence, KS, 66045.

The purpose of this study is to determine the F and thermal histories of an exhumed petroleum reservoir, El Abra Limestone of the Sierra el Abra, by integrating the record of FI and carbonate diagenesis from one quarry in the Sierra el Abra.

There are three types of cements in this reservoir, calcite precipitated during burial, fracture-filling calcite, and stylolite-related megaquartz. In both calcite cements, Fl are S and 90% are hydrocarbon in composition (HC-Fl). 70% of the HC-Fl are L-rich and fluoresce one of three colors: blue-white, yellow-white or dark-blue. Some non-fluorescent HC-Fl are brownish, single phase. S in calcite or P in megaquartz. Others are color-less, two-phase and are dominated by either L or G. The gas-rich HC-Fl homogenize to G, and the liquid-rich HC-Fl homogenize to L. The HC-Fl have not been altered by leaking or stretching. Aq Fl are two-phase and liquid-rich with Th values ranging from 95 to 160°C, and Tm ice values that range from -1.6 to  $-0.4^{\circ}$ C. The aq Fl have been stretched, indicating that the reservoir has been heated to T possibly as high as 160°C. Planes of S aq Fl cross-cut the planes of HC-Fl, indicating entrapment of aq Fl after the reservoir had been charged with oil.

The FI and diagenetic observations indicate a complex F history. Based on other studies in this region the general timing of the thermal and F events can be determined. Illite to smectite transformation data and apatite fission track data indicate that the reservoir was heated to between 80 and 120°C approximately 50 Ma and was cooled below 100°C approximately 30 Ma. Therefore, hydrocarbons first entered the reservoir from approximately 61-50 Ma, the reservoir was then buried and heated, perhaps to at least 160°C. During or after this burial, the HCs were degraded and stylolites formed. The reservoir then cooled to T<100°C 30 Ma. Therefore, based on evidence from this and other studies, the timing of hydrocarbon migration, maximum burial, heating and hydrocarbon degradation, can be constrained. (From authors' abstract by E.R.)

BRIGGS, G.A., ELLIOTT, W.C., VANKO, D.A. and HAYNES, J.T., 1998. Plagioclase-hosted rhyolite glass inclusions in Ordovician Kbentonites in the southern Appalachian Basin (abst.): The Geological Society of America 47<sup>th</sup> Annual Meeting, Southeastern Section, March 30-31, 1998. Charleston, WV, v. 30, no. 4, p. 5, ISSN 0016-7592. First author at Dept. of GeoL. Georgia state Univ., Atlanta, GA 30303.

Rhyolite glass I occur within calcic plagioclase (An<sub>53</sub> to An<sub>77</sub>) in two middle Ordovician K-bentonites in the southern Appalachian basin. These K-bentonites are equivalent stratigraphically to the well known Deicke and Millbrig K-bentonites. In this study, six K-bentonites were analyzed petrographically including microprobe and CL. Two were equivalent to the Deicke and four were equivalent to the Millbrig. Based on the data presented here, the chemistry of glass I distinguishes the Deicke from the Millbrig.

Based on CL intensity, the plagioclase hosts for these glass I were P pyroclastic minerals. For the most part, P plagioclase grains were angular, and ranged in size from 0.23 mm to 0.54 mm. The glass I within the P plagioclase hosts are mostly oblong with rounded ends and corners They are 10-50 µm in size. The glass I were interpreted to represent the major element composition of the original eruptive M forming these Kbentonites. A standard thin section of the Deicke-equivalent K-bentonite at Hinds Creek Quarry, Tennessee, contained an unusually high amount of glass I in plagioclase (>20 glass I/per plagioclase grain). Otherwise, glass I are scattered widely in other Deicke and Millbrig bentonites. In both the Deicke and Millbrig, the average SiO2 and Al2O3 contents of the glass I were -73 wt% and 12 wt% respectively. The glass I in the Deicke have higher Fe and Mg compared to the glass I in the Millbrig K-bentonite This difference in the major elemental compositions of the glass I is consistent with an overall difference in pyroclastic mineralogy between the Deicke and Millbrig K-bentonites. (Authors' abstract)

BRODHOLT, J.P., 1998, Molecular dynamics simulations of aqueous NaCl solutions at high pressures and temperatures: Chem. Geol., v. 151, p. 11-19. Author at Dept. of Geological Sci., Univ. College London, Gower St., London, WCIE 6BT, UK.

Molecular dynamics simulations have been performed on aq NaCl solutions over a range of concentrations, P and T. At 300K and 1 bar, simulated solution densities are in very good agreement with the experimental data at concentrations from 0.2 m to 5.2 m. Simulated densities at 1 and 5 kbars with a 1.74 m concentration solution are also in very good agreement with the experimental data. At 300K and 1 bar the solution is a true strong electrolyte with Na<sup>+</sup> and Cl<sup>+</sup> ions being completely separated. As T increases NaCl pairs tend to form as a direct response to the decreasing dielectric constant. At very low values of the dielectric constant, higher order NaCl complexes are formed. Two simulations at 1 kbar and at T in the two phase region show evidence for phase separation as all the ions cluster together into a small volume of the simulation box. This phase separation vanishes when the P is increased to 5 kbars. (Author's abstract)

BROOKER, R.A., 1998, The effect of CO2 saturation on immiscibility between silicate and carbonate liquids: An experimental study: J. of Petrol., v. 39, no. 11 & 12, p. 1905-1915. Author at Dept. of Geol., Arizona State Univ., Tempe, AZ 85287, USA.

Experiments as 1250°C and 25 kbar are used to illustrate the maximum extent of the silicate-carbonate immiscible L field in a multicomponent system and the effects of  $CO_2$  undersaturation. The results demonstrate the dramatic expansion of the two-L field as  $PCO_2$  is increased to approach Ptotal. The response of the system to  $CO_2$  undersaturation is used to reconcile differences between previous data sets, which apparently indicated an expansion of the two-L field from 0.7 to 7 kbar, followed by a substantial contraction to 25 kbar. This effect appears to be the result of comparing  $CO_2$ -saturated and -undersaturated data. The fully expanded,  $CO_2$ -saturated, multicomponent two-L field at 25 kbar may approach the M compositions formed at mantle P, and an immiscible origin for carbonatites in the mantle cannot be excluded on the basis of the experimental data. (Author's abstract)

BROOKER, R.A., WARTHO, J.-A., CARROLL, M.R., KELLEY, S.P. and DRAPER, D.S., 1998, Preliminary UVLAMP determinations of argon partition coefficients for olivine and clinopyroxene grown from silicate melts. Chem. Geol., v. 147, p. 185-200. First author at Dept. of Geol., Wills Memorial Bldg., Bristol Univ., Bristol BS8 1RJ, UK.

An ultra-violet laser ablation microprobe (UVLAMP) has been applied for the first time to investigate argon partition coefficients for olivines and clinopyroxenes grown from silicate M at 1 bar argon P. These preliminary measurements yield crystal/M partition coefficients ranging from 0.138 ( $\pm 0.01$ ) to 0.013 ( $\pm 0.003$ ) for olivine and 0.589 ( $\pm 0.003$ ) to 0.0016 ( $\pm 0.0005$ ) for clinopyroxene. The higher values may indicate submicroscopic MI, or some other heterogeneous distributions of 'nonequilibrium' argon in the crystals. The lower values are probably more representative of true partition coefficients and fall at least an order of magnitude below the previously reported experimental data. The possibility of anomalous, high argon contents for crystals in previous studies is discussed in terms of surface adsorption, 'trapped' argon and early partial melting. (Authors' abstract)

BROWN, P.E., 1998, Fluid inclusion modeling for hydrothermal systems: in Techniques in Hydrothermal Ore Deposits Geology: Reviews in Economic Geol., v 10, p. 151-171, edited by J.P. Richards and P.B. Larson for Society of Economic Geologists, Inc. Author at Dept. of Geol. and Geophys., Univ. of Wisconsin, Madison, WI 53706 U.S.A.

The purpose of this chapter is, first, to briefly introduce microthermometry, the most common analytical technique used to gain information from FI and second, to discuss how to model and interpret the analytical data. (From authors' abstract by H.E.B.)

BRUCE, Susannah, 1998, The genesis of mineralising brines in the South West Massif Central, France (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated). Author at School of Earth Sci., Univ. of Leeds, Leeds, LS2 9JT; email (susannah@carth.leeds.ac.uk)

The Paleozoic nappe sequences of the SW Massif Central in southern France are crosscut by an E-W trending fault system that is host to Pb-Zn-F-Ba mineralisation. This includes the Albigeois Fluorite district which, with an estimated 7 mt of past production and current reserves, is one of the world's largest fluorite producers. Despite variations in mineralogy and large contrasts in host rock lithology, the deposits were apparently formed from similar F. In each case the F are dominated by a high sal component (20-26 wt% NaCl eq.) which, coupled with common halogen and  $\delta^{1K}O$ systematics, would suggest that they have been derived through similar processes (Bruce et. al., Min. Mag., v. 62A, 1998).

The base metal-fluorite mineralisation of the SW Massif Central is associated with multiple generations of gangue quartz that are regional in extent and occur in a variety of different lithologies. The earliest phase of quartz deposition (Quartz 1) is usually barren and is accompanied by the intense and pervasive silicification of local wall rocks. Three subsequent generations (Quartz 1a, 2 and 3) are associated with sphalerite+galena, sphalerite+siderite and fluorite, respectively. Oxygen isotope analyses of the gangue quartz indicate that the ore-forming brines have undergone isotopic modification through exchange with country rocks in the hydrothermal system. The isotopic composition of F responsible for the initial deposition of quartz varies markedly with geographical location and host-rock lithology (-10.5 to +6%/VSMOW) but in each case is almost constant within individual samples. In contrast, mean 818O signatures of F in equilibrium with subsequent generations of quartz vary only slightly between deposits (Quartz 1a: +3.0 to +10.5%; Quartz 2: +1.5 to +5.5% Quartz 3: -2.0 to +5.0% VSMOW) but values differ more significantly (up to 5‰) within individual samples. This would suggest that the isotopic compositions of the earliest F in the system were locally buffered whereas brines responsible for the precipitation of later generations of quartz did not equilibrate isotopically with local host rocks but instead have retained an isotopic signature from further back along the flow path. It is thought that the initial silicification of local wall rocks by the earliest brines prevented further isotopic buffering of F entering the fracture system.

Processes of brine formation have been investigated through the analysis of halogen ratios in Fl leachates from the same generations of gangue quartz. Results show that Br/Cl ratios decrease through the paragenetic sequence from values that are greater than that of seawater to values equivalent or less but are too high for a magmatic input to be likely (Banks *pers com.*). In addition, the absolute concentration of chloride ions is relatively constant for all F and below that at halite saturation. The trend toward decreasing bromide at constant sal may be explained by the progressive 'flushing out' out of high Br bitterns from an evaporite horizon by a less saline F or by the incongruent dissolution of halite by an infiltrating F with concomittant Br depletion as the F passes through.

In each case a hypothesised surface-derived water would serve to dilute and gradually deplete the high Br reservoir (be it a bittern or a brine produced during incongruent dissolution of halite) such that successive brines exhibit decreasing concentrations of bromide. However, in order to maintain constant sal, the ratio of mixing would have to be sustained both spatially and through time. As this would seem rather difficult to achieve, it is possible that an independent process is operating to keep the sal constant such as one linked to F density. (Author's abstract)

BRUCE, S., BANKS, D., MUNOZ, M., COURJAULT-RADÉ, P., TOLLON, F., BOYCE, A., and FALLICK, A., 1998. The genesis of mineralising brines in the South West Massif Central. France (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998. Extended Abstracts, p. 238-239.

BUCHHOLZ, P., HERZIG, P., FRIEDRICH, G. and FREI, R., 1998, Granite-hosted gold mineralization in the Midlands greenstone belt. a new type of low-grade gold deposit in Zimbabwe: Mineralium Deposita, v. 33, p. 437-460. First author at Lehrstuhl für Lagerstättenlehre, Inst. für Mineratogie, Technische Univ. Bergakademie Freibert. Brennhausgasse 14, D-09596 Freiberg, Germany.

Two types of FI were found (in a very small sampling), Type I (without) and Type 2 (with) CO<sub>2</sub>. Type I: Th CO<sub>2</sub> 27-30°C, Th CO<sub>2</sub>-H<sub>2</sub>O 270-310°C, Tm CO<sub>2</sub>-58.1 to -56.6, Tm clathrate 3.4 to 7.3°C. Type 2: Th 190-260°C, Tm -5.4 to -0.99°C, Te  $\ge$ -7.8°C. (E.R.)

BUEHN, B. and RANKIN, A.H., 1998, Geochemistry and daughter mineralogy of late-stage carbonatitic fluids: Implications for REE, Ba, Sr, U and base metal mineralization processes associated with carbonatites (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 20. First author at Institut für Geowissenschafen, Universität Giessen, Germany,

Associated with the Kalkfeld carbonatite complex, Namibia, we have identified a particularly well preserved and varied assemblage of Fl in recrystallized quartzites adjacent to the main carbonatite complex. The l show an extensive range of compositions and densities from moderate to high sal aq NaHCO<sub>3</sub>-NaCl brines and low density CO<sub>2</sub> F through to high density daughter-mineral-rich 'melt' l containing up to 90% solids. We interpret these assemblages mainly as a consequence of heterogeneous entrapment of high density carbonatite M, brines and CO<sub>2</sub> V phase. Mi-

crothermometric data are difficult to acquire and interpret due to bulk decrepitation of the samples at around 350 to 400°C.

Those positively identified (SXRF&SEM-EDAX) include nahcolite, halite, sylvite, calcite, apatite, fluorite, cryolite, sulphides and arsenides of Fe, Cu, Pb and Zn, rouvilleite Na<sub>3</sub>Ca<sub>2</sub>CO<sub>3</sub> and burbankite (Ca,Na)<sub>3</sub>(Sr,REE,Ba)<sub>3</sub>(CO<sub>3</sub>)<sub>5</sub>. Thorium and uranium have also been detected in significant amounts by micro-XRF but it is difficult to ascribe these to specific dm.

The REE patterns of the burbankite daughters mimic the strong LREE enrichment patterns typical of carbonatites. Total REE contents of this mineral phase are of the order of 10%. In many 'melt' I this phase can occupy over 50% of the I volume suggesting that the evolved carbonatitic 'melts' are considerably enriched in REE. Ba and Sr. The widespread occurrence of fluorine-bearing dm suggests that the 'melt' is strongly enriched in fluorine, supporting the idea that the high REE solubilities inferred (several wt%) are primarily a consequence of REE-F complex formation. In the Kalkfeld complex, BaSO<sub>4</sub>, SrSO<sub>4</sub> and the REE mineralization is relatively minor but in other complexes (e.g. Bayan Obo, China and Kangunkunde, Malawi), where the surrounding country rocks are enriched to ore grade, they are commonly associated with fluorite. The present results demonstrate the importance of residual carbonatite magmas in the genesis of this important paragenetic association.

Aqueous-rich I are characterized by the water-soluble daughter phases NaCl, KCl and NaHCO<sub>3</sub>. The common occurrence of Cu-Fe-Zn-Pb sulfide dm suggests that this aq phase is capable of preferentially transporting significant quantities of base metals in carbonatitic environments, primarily as chloride complexes. The generation and focusing of these late-stage, low density, aq "carbothermal" F evolved from a REE-bearing carbonatite magma not only explains why many carbonatites are enriched in base metals (sometimes spectacularly as in the case of Palabora, RSA), but also why this phase of mineralization is often paragenetically distinct from the more common REE-Ba-Sr-F mineralization.

The salt-poor CO<sub>2</sub>-H<sub>2</sub>O fluids represented by CO<sub>2</sub>-rich, end-member, FI, are clearly associated with the metal-bearing carbothermal and carbonatitic F, but their precise role in mineralization and metasomatic (fenitisation) processes is presently unclear. (From authors' abstract by E.R.)

BÜHN, B. and RANKIN, A.H., 1998. Composition and significance of alkali- and halogen-rich natural carbonatite melts trapped in fluid inclusions (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A32. First author at Univ. Giessen, Germany, and Kingston Univ., UK; email (Bernhard.Buehn@geo.uni-giessen.de)

Carbonatites generally have low alkali contents due to exsolution and expulsion of a F phase at late stages of crystallization. The existence of fentized aureoles around most carbonatites shows that these M do not represent initial M compositions and therefore cannot directly prove the generally supposed alkali-rich nature of mantle-derived carbonatite M.

The alkali-poor Kalkfeld carbonatite complex (Namibia) has expelled a F into quartzitic country rocks which is interpreted to represent an alkaliand halogen-rich carbonatite M. Most FI have high densities and consist of abundant dm like nahcolite, halite, sylvite, burbankite, cryolite, rouvilleite, Ca-Mn-Fe-carbonate, fluorite and Fe-Cu-Zn sulfides (+alkali feldspars/feldspathoids) In addition, both a CO2 phase and a Na-K-Ca aq phase is present in very variable proportions of a melt-CO2-H2O system. This peculiar F and mineral assemblage is the result of [i.e., is indicated by] magma entrapment in quartz crystals, which has preserved the composition of an unexsolved carbonatite M including alkalis and halogens. This assemblage therefore comprises all fugative and solid components otherwise separated by carbonatitic melt-mineral-fluid fractionation and/or immiscibility. We have investigated this M system through a geochemical characterization of individual mineral phases, individual I and the bulk carbonatite M system by microthermometric, SEM-EDX, Synchrotron-XRF, ICP-AES and ICP-MS techniques. The M represent a very rare case where an unexsolved carbonatite M can be investigated, and therefore add to the understanding and direct characterization of carbonatitic M-F systems. (Authors' abstract)

BUICK, Roger, DUTKIEWICZ, Adriana and RASMUSSEN, Birger, 1998, Primordial petroleum: Live oil in fluorescent fluid inclusions in Archean and early Paleoproterozoic sandstones from Australia. South Africa and Canada (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-290. First author at School of Geosci., Univ. of Sydney, Sydney NSW 2006 Australia, email (buick@es.su.oz.au) Some Archean and early Paleoproterozoic sandstones contain radioactive detrital heavy minerals enveloped by bituminous nodules, testifying to the former presence of F hydrocarbons. In the same rocks, fluorescent Fl occur within healed microfractures confined to individual quartz grains. Their fluorescent L is oil, as shown by FTIR analysis which confirms the presence of aliphatic molecules. The microfractures hosting the fluorescent I formed during sediment burial, before point contacts between grains were expunged by pore space occlusion, and were sealed shortly thereafter by quartz cement. As the host quartz grains are often surrounded by metamorphic sericite which does not occur in the I-bearing microfractures, hydrocarbon migration occurred prior to peak metamorphism, which in all cases took place within a few hundred million years of deposition. Thus the entrapped oil was evidently generated from early Precambrian source rocks and represents the oldest known L hydrocarbon.

The occurrence of oil in Archean rocks confirms that hydrocarbon generation and migration was a widespread phenomenon in early Precambrian sedimentary basins and suggests that some of these might still be petroliferous. Its survival for billions of years through regional metamorphic events in which T rose to around 300°C indicates that current kinetic models of oil destruction are inappropriate for certain pressurzed closed systems, that time is not a necessary controlling parameter for petroleum degradation and that the upper T limit for oil stability is higher than generally accepted. Its existence suggests that the productivity of the Archean marine biota may have been comparable to its modern equivalent. If molecular fossils of the organisms from which the oil was derived (biomarkers) can be extracted from the FI, it may also reveal something about the composition of this primordial biosphere. (Authors' abstract)

BUKATA, A.R., KOTZER, T. and CORNETT, R.J., 1998. Fractureinfilling calcite as a proxy for the palaeohydrogeology of a fractured granitic gneiss, an integration of stable isotopes, fluid inclusions and U-series dating (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-225. First author at WEGP, Trent Univ., Peterborough, ON K9J 7B8; email (abukata@trentu.ca)

In many cases, such as the selection of hazardous waste disposal sites, it is important to characterize not only the current hydrogeology, but also the long-term geologic stability of the regional hydrogeology. Fractureinfilling calcite was examined as a proxy for the palaeohydrogeology in the fracture-flow dominated granitic gneiss aquifer on the Chalk River properties of Atomic Energy of Canada Ltd. The study examined the stable isotopes of carbon and oxygen, Fl, and U-series dating of the calcite in an attempt to constrain the long-term hydrogeology of the area.

Calcite was sampled from fractures initially characterized as sealed or open based on visual inspection of the core and whether the fractures were water-bearing or not. Calcites from sealed fractures have an isotopic signature systematically different from calcite in open fractures. The  $\delta^{18}$ O signature of sealed-vein calcites have lower values (~10 to~20 per mil) and display litle trend with depth. Calcite from open fractures display systematic trends from higher  $\delta^{18}$ O (~25) at surface, to lower  $\delta^{18}$ O (~15 per mil) at depth. The overlap in values suggests post-depositional alteration, by either re-dissolution or by two separate calcite precipitation events.

The Fl indicate that the calcite precipitated from groundwaters ranging from freshwater to sal of up to ~10% NaCl eq. by mass. The minimum formation T (Th) cover a wide range (<50 to >200°C), and there is evidence of recrystallization in some of the calcites. This indicates calcite precipitation from one of five sources: 1) modern meteoric recharge water: II) hydrothermal metamorphic water, III) glacial recharge water: IV) Champlain Sea water; or V) a mixture of the above. Uranium series dating by alpha spectrometry and trace element analyses are currently underway to further resolve the origin of the groundwater from which the calcites are precipitating. (Authors' abstract)

BUREAU, Hélène and KEPPLER, Hans, 1998. Complete miscibility between silicate melts and hydrous fluids in the upper mantle: Experimental evidence and geochemical implications: Earth and Planet. Sci. Letters. v. 165, p. 187-196. Authors at Bayerisches Geoinstitut, Univ. Bayreuth, 95440 Bayreuth, Germany.

The phase relationships between silicate M and hydrous F were studied by direct visual observation in an externally heated diamond-anvil cell. Complete miscibility of silicate M and water was observed for a wide range of M compositions, including nepheline, jadeite, dacite, haplogranite and Ca-bearing granite. Some evidence for complete miscibility was also observed in the system basalt-H<sub>2</sub>O. The critical T in all systems decrease rapidly with P. At 15 kbar, the critical T for nepheline is around 550°C, for jadeite around 800°C and for granitic compositions it is close to 900°C. In general, the critical T appear to increase with silica content in the system.

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Our results suggest that there is complete miscibility between silicate M and water in most of the upper mantle, except at very shallow depths. This means that a water-saturated solidus cannot be defined any more in the deeper parts of the upper mantle. Very silica-rich MI found in spinel lherzolites associated with FI are probably the result of the unmixing of a supercritical F containing comparable amounts of water and silicate components. The decomposition of amphibole in a subducted slab occurs at conditions where the miscibility gap between F and silicate M is not yet closed, while the decomposition of phengite and lawsonite occurs far beyond the critical curve. Accordingly, the F released by the breakdown of these minerals should have very different properties. Highly mobile, hydrous F containing little dissolved silicate should be produced by amphibole breakdown, while the decomposition of lawsonite and phengite will lead to much more silicate-rich and less mobile F phases. (Authors' abstract)

BUREAU, H., MÉTRICH, N., PINEAU, F. and SEMET, M.P., 1998, Magma-conduit interaction at Piton de la Fournaise volcano (Réunion Island): A melt and fluid inclusion study: J. of Volcanol. and Geothermal Research, v. 84, p. 39-60. First author at Laboratoire Pierre Sue. CEA-CNRS, CE Saclay, 91191 Gif sur Yvette, France.

Major-element, Cl, S, F, analyses have been performed on a wide selection of MI trapped in olivine (Fo81-87) from scoria and crystal-rich lapilli samples of Piton de la Fournaise volcano. As a whole, they display a transitional basaltic composition. The MI (8-9 wt% MgO, 0.62-0.73 wt% K2O) are in equilibrium with olivines (Fos1-85) in the samples from the Central Feeding Zone and the South-East Feeding Zone and show a slight alkaline affinity. The MI in olivines (F085-87) from the North-West Rift (NWR) contain 9.3-9.7 wt% MgO and 0.54-0.58 wt% K2O, with a more tholeiitic tendency. In oceanitic lavas and crystal-rich lapilli, the olivine xenocrysts are recognisable by the presence of one or more S shear plane fracture(s) filled up with CO2 and alkali-rich basaltic MI. In dunite nodules, olivines present also contain several S shear plane fracture(s) filled up with CO2 and high-SiO2 MI. Secondary CO2-rich FI in olivine (F085-87) from the NWR samples indicate PCO2 up to 500 MPa whereas, P CO2 ranges from 95 MPa to few tenths of bars in the other samples. Both the P MI and the S FI strongly suggest that the olivine crystallises and accumulates over a wide depth range (15 km). It is envisioned that cumulative pockets with low residual porosity are repeatedly percolated with a CO2-rich F phase, possibly associated with basaltic to SiO2-rich M, and are finally disrupted and entrained to the surface when vigorous magma transfer occurs. The SiO2rich residual M in early-formed dunitic or gabbroic bodies may have acted as contaminant agents for the more alkali character of magmas vented through the central feeding system, where a well-developed cumulative system is thought to exist. Finally, the existence of S F and MI in olivines implies that the dunitic bodies are weakened on the micrometric scale. (Authors' abstract)

BUREAU, H., PINEAU, F., MÉTRICH, N., SEMET, M.P. and JAVOY, M., 1998, A melt and fluid inclusion study of the gas phase at Piton de la Fournaise volcano (Réunion Island): Chem. Geol., v. 147, p. 115-130. First author at LGIS, Univ. D. Diderot-IPGP, 4, place Jussieu, 75252 Paris Cedex 05, France.

We have studied carbon, water, sulphur and chlorine contents in M and FI trapped in olivines from diverse feeding systems of Piton de la Fournaise volcano (Réunion Island, Indian Ocean). As a whole, water concentrations (0.59-1.10 wt%) are intermediate between those of tholeiites and alkali basalts. Sulphur concentrations (400-1700 ppm) are comparable to those observed in MORB whereas chlorine concentrations (200-300 ppm) are typical of alkali basalts. Carbon contents range from a few to 520 ppm C. We also observe sulphide globules that indicate saturation of the M with sulphur compounds. The combined study of dissolved carbon contents in MI and of CO2-rich FI indicates that the trapped M may be saturated with a F phase from at least 500 MPa total P to the surface. The CO2 and H2O contents in the trapped M, their major element compositions and the composition of the host olivines reveal a complex crystallization and entrapment history. In general, we observe that the less differentiated MI appear to have been trapped at greater depth. Magmas fed to both the Summit Crater and the southeast rift zone must be stored at shallow levels before eruption to account for the observed distributions of water and carbon concentrations and their low values. These indicate that a large proportion of the volatiles that are present at greater depths are lost before venting. The North-West feeding system corresponds to magma that was much less degassed before venting. The range of concentrations of H2O and CO2 found in samples of a single eruption cannot be reconciled with

continuous degassing of a single magma batch. We therefore propose that most olivines occurring in the lavas have trapped M batches at different stages of their volatile evolution and/or that olivines included M of differing mantle provenances. This also implies that M entrapment occurred at different depths. Carbon and water evolution in parental magmas is calculated to be from 1270 to 2770 ppm C and from 0.7 to 1.1 wt% water, respectively. The volatile contents of parental magmas allow computation of the following volatile fluxes for the average magma production rate of 0.1 m<sup>3</sup>/s observed in the last 50'years: CO<sub>2</sub>, 88×10<sup>3</sup> tons a<sup>-1</sup>; S. 123×10<sup>2</sup> tons a<sup>-1</sup>, Cl, 2.6×10<sup>2</sup> tons a-1, and (magmatic) H<sub>2</sub>O, 62×10<sup>3</sup> tons a<sup>-1</sup>. With literature values of the degree of melting, water and carbon contents in the mantle source would be between 350 and 1100 ppm and between 63 and 277 ppm C, respectively. Because no permanent emanations nor strong degassing during eruption is observed at the surface, it is thought that most G are intercepted at an interface in the building system. (Authors' abstract)

BURGESS, R., JOHNSON, L.H., MATTEY, D.P., HARRIS, J.W. and TURNER, G., 1998, He, Ar and C isotopes in coated and polycrystalline diamonds: Chem. Geol., v. 146, p. 205-217. First author at Dept. of Earth Sci., Univ. of Manchester, Manchester, M13 9PL, UK.

Helium, Ar and C isotopic measurements have been undertaken on different qualities of industrial grade and polycrystalline diamond from localities in Africa and Brazil. These include coated and cloudy diamonds which contain abundant volatile-rich micro-I and framesites and carbonados which consist of aggregates of micro-sized diamond crystals interspersed with mineral I. In an attempt to release selectively the P trapped He from the diamonds, they were analysed using an in vacuo crushing technique. The He data are combined with Ar, K and U data obtained from <sup>40</sup>Ar-<sup>39</sup>Ar stepped-heating studies of irradiated fractions of the diamonds and bulk carbon isotope data obtained from the crushed residues. Results indicate that coated and cloudy diamonds best preserve a mantle signature with <sup>3</sup>He/<sup>4</sup>He values of 1-7 Ra and  $\delta^{13}$ C of -5 to -6‰. Coated diamonds have uniformly high He and Ar concentrations of  $10^{-6} - 10^{-5}$  cm<sup>3</sup> g<sup>-1</sup>. Framesites have lower <sup>3</sup>He/<sup>4</sup>He values 0.1-3 Ra and bimodal 813C values with modes at -6 and -20%. Carbonados show both the lowest 813C values <-25% and <sup>3</sup>He/4He of <0.1 Ra. U and K concentrations show a progressive increase from coats<framesites<carbonados. While it is tempting to attribute low 813C, low 3Her He and high U to the influence of subducted crustal material, it is likely that implantation of 'He by U. Th-rich minerals adjacent to the micro-diamonds is also a possible cause of the low He isotope ratios. (Authors' abstract)

BURGESS, R. and TURNER, G., 1995. Halogen composition of mantle fluids in diamond (abst.): Sixth Int'l Kimberline Conference, Russia, 1995. Extended Abstracts, p. 89-91. Authors at Dept. of Earth Sci., Univ. of Manchester, Manchester, M13 9PL, U.K.

The halogen content of the mantle F trapped in cubic diamonds is estimated to be 2-5 wt% Cl. 60-120 ppm Br and 1-3 ppm I and the concentration of <sup>40</sup>Ar is (1-3) X  $10^{-2}$  mJ/g. This represents about a factor 5000 enrichment relative to present-day upper mantle values (MORB source). To achieve this level of enrichment the F phase must be present at a level of about 200 ppm. (From authors' abstract by H.E.B.)

See also Burgess and Turner, FIR 28. p. 18 (E.R.).

BURNARD, P.G., FARLEY, K.A. and TURNER, G., 1998, Multiple fluid pulses in a Samoan harzburgite. Chem. Geol., v. 147, p. 99-114. First author at Dept. of Earth Sci., Univ. of Manchester, Manchester M13 9PL, UK.

Noble G trapped in Fl in residual mantle xenoliths from Samoa have a wide range in  ${}^{4}\text{He}{}^{40}\text{Ar}^{*}$  which anti-correlates with enrichments in non-atmospheric Ar, Ne and Xe isotopes and with the concentration of  ${}^{40}\text{Ar}^{*}$  trapped in the mineral. These correlations cannot be due to post-eruption loss of He from the I, but are likely due to mixing of a He-depleted mantle F and an unfractionated, plume-derived. F that has entrained significant atmospheric noble G. Mixing of the two F occurred within the mantle or at the base of the Samoan lithosphere. Helium loss at depth is implied. (Authors' abstract)

BURNARD, P.G., HU, R. and TURNER, G., 1998, Helium, argon, heat and gold: Noble gas studies of the Ailaoshan gold province, China (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998. Extended Abstracts, p. 259-260. First author at Dept. of Earth Sci., Manchester Univ., Manchester, M13 9PL, UK.

Analyses of He and Ar in ancient mineralising F, using Fl in pyrite as 'bottles' for the palaeofluids, can be used to trace atmospheric (meteoric).

crustal and mantle contributions to the F and heat budget of extinct hydrothermal systems. The results demonstrate the palaeofluids were a mixture between a mantle-derived, magmatic F and two different groundwaters. (From authors' abstract by E.R.)

BURNS, S.J., MATTER, Albert, FRANK, Norbert and MANGINI, Augusto, 1998, Speleotherm-based paleoclimate record from northerm Oman: Geology, v. 26, no. 6, p. 499-502. First author at Geologisches Inst., Univ. Bern, CH-3012, Bern, Switzerland.

U-Th dating and stable isotope measurements of speleothems from Hoti Cave in northern Oman yield paleoclimate information from the region extending to 125 ka. (From authors' abstract by E.R.)

CAMPBELL, A.R., WILSON, S.A., and DUNBAR, N.W., 1998, Solid inclusions of halite in quartz: Evidence for the halite trend (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 21. First author at Dept. of Earth and Environmental Sci., New Mexico Tech.

High-sal Fl are common in ore deposits associated with high-T magmatic F. In halite and sylvite bearing Fl, microthermometry has, in some cases, documented a decreasing sal.. This has been called the "Halite Trend" (Cloke and Kessler, 1979) and is attributed to halite precipitation from the ore F in response to cooling. The halite contains some K in addition to Na. Quan et al (1987) point out that although there is geochemical evidence for halite precipitation, solid I of halite, whose formation would cause the halite trend, have not been reported in the literature.

Vein quartz from the Capitan Mountains, NM hosts halite and sylvite bearing Fl. These samples exhibit the halite trend on an NaCl-KCl-H<sub>2</sub>O triangular diagram. In order to account for this trend the precipitating salt would have had an approximate composition of (Na<sub>80</sub>K<sub>20</sub>)Cl. Halite precipitation is also supported by an increasing Br/Cl ratio from the chemical analysis of the inclusion fluid. No solid inclusions of salt are seen using a transmitted light microscope. However crystals of halite and sylvite have been have been observed with electron microprobe imaging.

The salt crystals were examined by backscatter electron imaging (BSE) for compositional variation and by secondary electron imaging (SE) for topographic relief. Salt crystals were observed in three distinct settings. 1) Salts in direct contact with the host quartz with little topographic relief between the two. These crystals appear to be solid 1. 2) Salts located within small pits. These are thought to be either solid 1 which have partially dissolved during sample preparation, or dm within FL 3) Radially symmetric lobed salts proximal to a fracture. They sit atop the surface of the quartz and cause bubbling of the carbon coat. These are thought to be precipitated salts from newly decrepitated 1 due to the vacuum in the microprobe.

Quantitative microprobe analysis of the salt crystals from all three settings show a wide range of compositions in the NaCl-KCl binary. A large number of salt crystals have compositions of around 80 mol% NaCl. This corresponds to the precipitating halite composition predicted from the microthermometry. The existence, and composition of, the solid I presented here provides evidence for halite precipitation as the origin of the halite trend. (Authors' abstract)

CAMPBELL, L.S., 1998, Replacement textures in the Bayan Obo REE-Nb-Fe deposit, Inner Mongolia, China, in relation to ore genesis (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). Author at School of Geological Sci., Kingston Univ., Penrhyn Road, Kingston upon Thames, Surrey, KTI 2EE, U.K.,

Textures provide abundant evidence of influx of acidic, F-bearing fluids (e.g.,  $CaCO_3+2HF=CaF_2+CO_2+H_2O$ ). Fl of  $CO_2$  and  $H_2O$  (2-phase or 3-phase) occur in fluorite and apatite.

The study supports a carbonatite-derived hydrothermal replacement model for the mineralization, implying that F-REE complexation was important for REE transport. (From author's abstract by E.R.)

CAMPRUBÍ, Antoni, CANALS, Angels, CARDELLACH, Esteve, SHARP, Z.D. and PROL-LEDESMA, R.M., 1998, Thermal and geochemical evolution of La Guitarra epithermal deposit, Temascaltepec. Mexico: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90-5410-942-4, p. 525-528. First author at Dept. de Cristal-lografia, Mineralogia i Dipósits Minerals, Univ. de Barcelona, Spain.

La Guitarra is a polymetallic and multi-stage. low-sulfidation epithermal vein system. The Ag-Au ore is mainly displayed in silica bands. Stage-I fluids show sal from 5 to 12 wt% NaCl eq., T from 162 to 212°C;  $\delta^{18}O_w$  from 1.2 to 5.2‰; XFeS in sphalerite from 0 to 25%. Stage-II (Agbearing stage): sal from 4 to 6 wt% NaCl eq.; T from 161 to 210°C;  $\delta^{18}O_{\rm w}$ from -2.0 to +6.0%; X<sub>Fe5</sub> in sphalerite from 0 to 16%. Time-space distributions of the above variables convey to magmatic and meteoric F recognition. Coupled with mineralogical evidences of boiling, those characteristics point to a mixing-boiling model for ore deposition. (Authors' abstract)

CANNELL, James and DAVIDSON, G.J., 1998, A carbonate-dominated copper-cobalt breccia-vein system at the Great Australia Deposit, Mount Isa Eastern succession: Econ. Geol., v. 93, p. 1406-1421. Authors at Geol. Dept., Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania 7001, Australia.

Great Australia is a small Cu-Co deposit in the Eastern succession of the Mount Isa inlier, northern Queensland. It may be viewed as a carbonate-rich member of the globally distributed, oxide-dominated, Fe-Cu-Au±rare earth element (REE)±U deposit group. It is also a gold-poor variant of a group of small- to medium-sized, carbonate-dominated vein replacement deposits in the surrounding Cloncurry copper gold field, known as Mount Freda-style deposits. Chalcopyrite-bearing S FI from ore type 1 quartz contain high-T (450±60°C), high-sal (45±10 wt% NaCl eq), high  $fO_2$  F that are interpreted to be syn-ore. Oxygen isotope values of  $\delta^{18}O_{quartu}$ (11.3-13.4‰) indicate that  $\delta^{18}O_{fluid}$ = 8.3 to 1.3 per mil, consistent with a magmatic to metamorphic source. Calcite carbon isotope values require  $\delta^{13}C_{fluid}$ =-0.3 to -3.7 per mil, best explained by a mixture of carbonate sedimentary carbon and magmatic carbon. (From authors' abstract by E.R.)

Three types of 1 in ore type 1 show phases as listed in Table 3, including chalcopyrite, halite, hematite, pyrite, sylvite, and unknown. (E.R.) See figure in the Illustrations appendix.

CAO, Z.M. and HUANG, Y.N., 1998, Tellurium-bearing fluid: Behavior and mechanics of the enrichment and dispersion (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A31. First author at Dept. of Min. Res. and Eco. Chengdu Univ. of Tech., P.R. China; email (czm@cdit.edu.cn)

Samples were collected from the Dashuigou telluride lode deposit in the mineralizing belt of Te-Au-Ag. By various test methods, such as isotopes, FI (Laser microprobe with Raman spectrum), experimental simulation (285°C, 300°C), it suggests that the Te-bearing F originated from the upper mantle. Some conclusions follow such as: 1. Telluride occurs in the Kangdian axis and Dadu River gold ore belts. This suggests that the regional geochemical field be characterized by enrichment in tellurium 2. A transcrustal fracture near the ore district could be a pathway for Degasification (H2Te) of the mantle. Existence of a high content of CO2, H2, BO3. F', Na+, etc. indicates that the ore F was rich in mineralizer. 3. Preliminary enrichment in tellurium was got in the residual magmatic M. 513Cco2 (5.7‰, mean value of 6 samples) and <sup>3</sup>He/<sup>4</sup>He (1.21 x 10<sup>-5</sup>, mean value of 3 samples) values for the dolomite associated with Te mineralization are similar to those for degasification of the upper mantle. Migration of tellurium could be related to HCO3. The oxyphile character of tellurium enable it to migrate in the form of fluoride or bicarbonate complex and to precipitate with Bi, Au and Ag to form tetradymite-dolomite veins. 4. Tellurium underwent transition from a mineralizer to an ore-forming element. Tellurium acting as mineralizer played an important role in the formation of the precious metals (Au, Ag, Pt, and Pd) deposits. Au and PGE occur in the form of metallic telluride other than metallic sulfides. The /Te2, /S2, /CO2 and the T controlled the precious metal mineral facies in the hydrothermal ore deposits. Perhaps a limited recharge of tellurium in the source region was responsible for the predominance of native gold over Au and Ag telluride. Changing from a mineralizer to an ore-forming element. Te was bound together with Bi in residual magma forming tetradymite. 5. Accumulation of tellurium depends upon both pre-enrichment of vaporous H2Te in an unmixing system and shielding effect of the structural trap. Vice versa, tellurium may be dispersing. (Authors' abstract)

CARROLL, M.R., KOHN, S.C. and WOOD, B.J. (eds), 1998, Colston Research Society Conference, The Degassing History of the Earth, Bristol, UK, 29-31 August, 1996; Chem. Geol., v. 147, no. 1/2, p. 1-200.

CARTIGNY, Pierre, HARRIS, J.W. and JAVOY, Marc, 1998. Eclogitic diamond formation at Jwaneng: No room for a recycled component Science, v. 280, p. 1421-1424. First author at Laboratoire de Géochimie Stables, Univ. de Paris VII, Institut de Physic'de Globe de Paris (IPGP), 4 Place Jussieu, 752521 Cedex 05, France.

Eclogitic diamonds have a large range of  $\delta^{13}C$  values, whereas peri-

dotitic diamonds do not. Paired  $\delta^{15}$ N- $\delta^{13}$ C-N variations in 40 eclogitic diamonds from the Jwaneng kimberlite in Botswana show that neither the influence of recycled biogenic carbon nor the global and primordial heterogeneity of mantle carbon are likely for the origin of the large  $\delta^{13}$ C range; the data instead support a fractionation process. It is proposed that carbonatilic mantle M from which diamonds crystallize undergo different evolutions before diamond precipitation, when percolating through either a peridotite or an eclogite. These different evolutions, reflecting the presence or absence of olivine, can account for their respective  $\delta^{13}$ C distributions. (Authors' abstract)

CARTIGNY, Pierre, JENDRZEJEWSKI, Nathalie, PINEAU, Franoise, PETIT, Eddy and JAVOY, Marc, 1998, Major volatiles (C, N and Ar) in vesicles trapped in the Indian Ocean Basaltic glasses: Constraints on the Indian Ocean characteristics (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F878. First author at Lab Gochimie Isotopes Stables IPGP 2 Place Jussieu, Paris 75251, France; email (pcharti@ugcvax.dnet.gwdg.de)

A detailed study of C N isotopes together with C, N and Ar contents has been undertaken on the G vesicles in South West Indian Ridge (SWIR) basalts recovered between the Rodriguez Triple Junction and 49E. Results obtained on this new sample are compared with results from the Central and South East Indian ridges.

Reconstructed initial MORB C/N,  $N_2/Ar$ ,  $\delta^{13}$ C and  $\delta^{15}$ N are about 200, 80, -5 per mil and -61 per mil respectively, in perfect agreement with the initial Pacific and Atlantic MORB estimations. (From authors' abstract by E.R.)

CASSIDY, K.F., 1992, Archaean granitoid-hosted gold deposits in greenschist to amphibolite facies terrains: A high P-T to low P-T depositional continuum equivalent to greenstone-hosted deposits: PhD thesis, Univ. of Western Australia, 296 pp (unpublished).

As quoted by Witt and Vanderhor (this volume) in connection with Fl studies of Yilgam Craton Au deposits, Australia.

See also next item (E.R.).

CASSIDY, K.F., GROVES, D.I. and MCNAUGHTON, N.J., 1998, Late-Archean granitoid-hosted lode-gold deposits, Yilgarn Craton, western Australia: Deposit characteristics, crustal architecture and implications for ore genesis: Ore Geol. Reviews, v. 13, p. 65-102. First author at Centre for Strategic Mineral Deposits (formerly Key Centre), Dept. of Geol. and Geophys., The Univ. of Western Australia, Nedlands, WA 6907, Australia.

Granitoid-hosted lode gold deposits constitute a sub-group of late-Archean lode-gold deposits in the Yilgam Craton of Western Australia. They share a number of common characteristics, including: (1) a strong structural control on a variety of scales: (2) in most instances, the presence of mineralisation in adjacent supracrustal sequence; (3) wallrock alteration and vein assemblages consistent with the addition of SiO<sub>2</sub>, K<sub>2</sub>O, CO<sub>2</sub>, S±Na<sub>2</sub>O, but dependent on the P-T conditions of the host environment and ore F; (4) a metal association comprising Au, Ag, As, Bi, Te, W±Mo and low concentrations of Cu, Pb and Zn; and (5) deposition from a lowmoderate sal, near-neutral H<sub>2</sub>O-CO<sub>2</sub>±CH<sub>4</sub> F over a T and P range from 250 to  $\approx$ 600°C and  $\approx$ 1 to 4 kbar, which corresponds to a range of crustal environments from lower greenschist to upper amphibolite facies. (From authors' abstract by E.R.)

Includes an extensive tabulation of many parameters for the deposits Lady Bountiful, Mt. Pleasant, Granny Smith, Porphyry, Great Eastern Lawlers, and Westonia. This includes ore solutes. T by FI. T by mineral equilibria, P. X<sub>CO2</sub> and sal (E.R.).

See also previous item.

CATHELINEAU, Michel, BANKS, David, BOIRON, M.C., AYT OUGOUGDAL, Mohamed, and YARDLEY, Bruce, 1998, Chemistry of brines migrating at the basement-sedimentary cover contact: The example of Soultz (Rhine Graben) (abst.): Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions. June 1-4, Univ. of Nevada, p. 22. First author at CREGU and UMR 7566, BP 23. 54501 Vandoeuvre-lès-Nancy Cedex, France; email (cathelin@cregu.cnrsnancy.fr, D.Banks@earth.leeds.ac.uk)

The coarse-grained Triassic sandstones have undergone a silica diagenesis and are then crosscut by fractures filled with barite. The sequence of F trapping is the following: i) P aq I in quartz overgrowths, which have sal around 7-10 wt% eq. NaCl and Th in the 120-130°C range, ii) S aq I, with sal of 17-20 wt% eq. NaCl and Th between 150-190°C, in FIP crosscutting the quartz overgrowths, iii) P and PS aq FI with sal of 2-12 wt% eq. NaCl and Th similar to present day T 115-130°C and hydrocarbon (HC) rich I in barite veins.

In quartz veins from the top of the granite, low Tm ice around -25 to -30°C have been found but in barite Tm ice are between 2 and 14 wt% eq. NaCl with two distinct modes at 6.5 and 11 5 wt% eq. NaCl.

The late barites in the basement and its sedimentary cover contain aq FI with a narrow range of sal from 9-12 wt% eq. NaCl, which were trapped at T similar to those of the present day, and characterized by : i) a regular increase in the Na/K ratio with depth, e.g., with increasing T. The values range from 8 to 25 and bracket the ratio of the present day T. ii) a relatively wide range of Br/Cl ratios from 0.003 to 0.008 indicating the contribution of a Br enriched end-member in T percolating through the sediments. iii) Na/Li ratios around 25/40, slightly lower than those of the present day T. Na-Cl-Br systematics show that some of the paleofluids are typical of bastnal brines which have acquired their chemical features by strong interaction with evaporitic layers.

The fracture system in the Soultz granite and its cover rocks has acted as a pathway for flows of different sal F at different times, evolving towards compositions similar to those present at depth today. The large variations in Cl contents among the studied F suggest complex, long-lived and heterogeneous mixing processes. Sal changes are decoupled from T changes suggesting that mixing occurs on the heating part of the F cycle. This case study provides significant reference data on the chlorine contents in F percolating or stored within basement rocks. (From authors' abstract by E.R.)

CATHELINEAU, M., CUNEY, M., COULIBALY, Y., BOIRON, M.C. and AYT OUGOUGDAL, M., 1998, Paleopercolations in the igneous rocks of Charroux Civray (abst.): Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998, p. 87-88 (in French, translation by E.A.J. Burke). Authors at CREGU et UMR 7566, BP23, 54501, Vandœuvre-lès-Nancy Cedex.

The principal episodes of migration of F in the Hercynian basement of the Vienne region (France), the chemical characteristics of paleofluids, and the P-T evolution after the emplacement of the magmatic rocks have been estimated from a detailed study of FIP in these rocks, and also in the minerals in macroscopic faults in the basement and in the Mesozoic sedimentary cover. Two main events have been recognized which can be attributed to two major geodynamic events:

 Late-Hercyman retrograde-metamorphic F associated with magmatic heat flows have produced: alterations with (epidote, prehnite)quartz-chlorite(hematite)±carbonates (dolomite, calcite)±adularia±laumontite; veins with (quartz)-chlorite-phengite; quartzmuscovite; quartz-sulfides-illite. They belong to the systems H<sub>2</sub>O-N<sub>2</sub>, H<sub>1</sub>O-CO<sub>2</sub> (especially in FIP) and H<sub>2</sub>O-salts, and they have been trapped in a wide P-T field: 130 to 500°C, 0.5 to 3.5 kbar.

2) The brines, probably connected with Mesozoic distensions related with the opening of the Atlantic Ocean and/or the Gulf of Gascogne, have plugged the faults in the basement with a paragenesis of hematiteadularia/dolomite/quartz/fluorite/barite±sulfides (Cu, Zn)/calcite. These veins predominate in the igneous rocks and have a very constant paragenetic sequence. The brines (several hundred g/l of salts) in dolomite and fluorite have geochemical characteristics (Br/Cl. trace elements) close to those of F in sedimentary basins, and of F in F-Ba-Pb-Zn deposits on the northerm and south-castern borders of the Central Massif. The brines circulated at T of maximally 75 to 110°C.

Finally, later and less frequent vein fillings with (kaolinite)-calcite have been formed from low-T F (<  $50^{\circ}$ C), related with minor episodes of circulation

Knowledge of F paleopercolations in an igneous body is of essential importance to understand actual and future circulations. If a past percolation (even of recent date) is concerned, the F is not accessible directly any more, and the identification of the percolated structures is then difficult. The only signs of the passing of a F are the eventual perturbations it caused during its migration: i) the presence of newly formed minerals which indicate a supersaturation of the F with regard to a mineral species, or of dissolutions which, however, are more difficult to use; ii) trapped F in the form of I in the newly formed minerals in the fillings of the conduits, or F in healed cracks of the rock. The structures that have been percolated during the F event may also have been formed during deformation events, as well anterior to as contemporaneous with the percolation. (Authors' abstract)

CATHELINEAU, Michel, GUERCI, Alain, BANKS, David, BOIRON, M.-C., and AYT OUGOUGDAL, Mohammed, 1998, Numerical modelling of water-rock interaction using reconstructed fluid composition: a multi-characterization of alpine fissure fluids. (abst.): Program and Ab-
stracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 23. First author at CREGU and UMR 7566, BP 23, 54501 Vandœuvre-lès-Nancy Cedex, France; email (cathelin@cregu.cnrs-nancy.fr)

The major alpine water-rock interactions observed in and around alpine fissures from granites, e.g. quartz dissolution, crystallization of the main fissure fillings (quartz-chlorite), and later alteration of the previous alteration minerals by an ankerite-muscovite assemblage, have been reproduced using FI data and the geochemical code EQ3/6. (From authors' abstract by E.R.)

See also Cathelineau et. al., FIR v. 29, p. 29 (E.R.).

CENDÓN, D.I., AYORA, Carlos and PUEYO, J.-J., 1998. The origin of barren bodies in the Subiza potash deposit, Navarra, Spain: Implications for sylvite formation: J. of Sedimentary Research, v. 68, p. 43-52. First author at Institut de Ciències de la Terra (Jaume Almera), CSIC, Barcelona, Spain.

"Barren bodies" are meter-size lens-like features in sylvite beds where sylvite is absent or depleted. They are commonly found when mining potash deposits. Most barren bodies are believed to be formed by selective dissolution of sylvite, due to the circulation of diagenetic or later F. Contrary to this commonly favored post-depositional interpretation, barren bodies of the Subiza mine, Navarra, Spain, are thought to be the result of synsedimentary processes. This potash deposit contains a 100 m thick Upper Eocene succession of alternating claystone and evaporites (sulfate, halite, and sylvite). The evaporites accumulated in an elongated basin forming one of the depocenters of the 250 km long South Pyrenean foreland basin. Along the margin of the basin, slope instability, promoted probably by tectonism, created mass wasting, forming mounds 0.5-2 m high and tens of meters in extension. As evaporation progressed, two stratified brines formed. Halite precipitated at the air-brine interface and sank to the bottom of the basin with terrigenous clays. Sylvite, however, precipitated from the lower brine. The mounds extended into the upper brine, thus sylvite did not precipitate over these upper zones. With progressive deposition the lower brine covered the mounds, the sylvite beds overlapping the mounds. The mineralogical and petrographical features of the barren bodies and their surroundings are continuous. Analyses of P FI from the halites of the barren bodies show a Mg-K-Cl rich composition. This corresponds to a P brine and is unlike the Na-Cl rich brines expected from replacement processes. The thickness of the sylvite-forming brine (<1 m) inferred from the mounds is inconsistent with the thickness required to form centimeter-thick beds of sylvite in a closed basin. Alternatively, the existence of a more restricted sub-basin, open to a halite-forming basin similar to that observed in saline ponds, is proposed. Numerical simulations of the evaporation processes under these conditions give results that match the mineral associations observed and the solute content of the FI. (Authors' abstract)

CENDON, D.L. PUEYO, J.J., AYORA, C., TABERNER, C. and PI-ERRE, C., 1998, Geochemical evolution of Suria evaporite sequence: Implications for the chemistry of the Eocene ocean (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 294-295. First author at Inst. de Ciències de la Terra, CSIC, Lluis Solé i Sabaris, s/n, 08028 Barcelona, Spain.

The evaporation of recent seawater explains the major elements trends found in Fl. However, some addition of Ca is required to explain the high Ca and low SO<sub>4</sub> values analysed. This excess of Ca changes throughout evaporation and is attributed to dolomitization and not to global changes in seawater composition. (From authors' abstract by E.R.)

CEPEDAL, A., MARTIN-IZARD, A., FUERTES, M. and PEVIDA, L.R., 1998, Evidence of multiple episodes of igneous and hydrothermal activity at El Valle copper-gold deposits, Belmonte de Miranda, Asturias (Spain) (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, A-29. First author at Dept, of Geol., Univ. of Oviedo, Spain; email (mcepedal@asturias.geol.uniovi.es)

El Valle copper-gold deposit is located in the northern part of the Iberian Peninsula in a narrow NE-SW oriented zone called Rio Narcea Belt. The zone is dissected by NE-SW. SE-NW and E-W fault systems and has an extended history of reactivation. Along with geological and geochemical data, preliminary K/Ar ages suggest that the El Valle ore deposit was formed by overprinting of several hydrothermal events.

The FI study shows a highly-saline magmatic F with Th between 580 and 620°C, which was contaminated in volatiles by carbonated host rocks, sometimes rich in organic matter. This F evolved into two immiscible F: one CO<sub>2</sub> and/or CH<sub>4</sub> rich and the other a high sal aq F. Evidence of boiling processes has been found at T between 360 and 420°C and around 1 kbar of P. These processes could be related to the main sulfide mineralization stage. This F evolved into a very low sal aq F with Th ranging from 270 to 360°C.

After extensive erosion, reactivation of the northeast-trending fracture zone caused widespread brecciation and favored the intrusion of porphyritic (285±4 Ma) to diabasic (263±7 Ma) dikes which crosscut all lithologies. At least two hydrothermal events took place. The first sericitized, silicified and carbonatized the monzogranite, and chloritized, silicified and serpentinized the skarn. The second hydrothermal phase produced carbonatization, argillization, silicification and hypogenic oxidation. The intense silicification along fractures and breccia zones resulted in the formation of hematitic jasperoid quartz. The FI study shows a very low sal aq F with lower Th (180-195°C and 120-165°C) suggesting late epithermal events overprinting on the mesothermal skarns.

Lastly, meteoric alteration produced a new generation of oxidation along fractures and breccias. (From authors' abstract by H.E.B.)

CESARETTI, N.N, and DOMINGUEZ, E., 1998. Fluid inclusions and porosity in Pozo Escondido, Yacoraite formation: Diagenetic and oleogenetic indicators: Revista de la Asociación Geológica Argentina, v. 52, no. 3, p. 361-378. Authors at Depto. de Geologia, Univ. Nacional de Sur, San Juan 670-8000 Bahia Blanca, Argentina; email (ghcesar@criba.edu.ar).

Hydrocarbon and saline FI were studied in quartz and anhydrite cements and overgrowths in the upper chalk and sandstone sections of the Yacoraite Formation, Lomas de Olmedo second order basin. The analyzed samples were taken from the drill holes in Pozo Escondido oil field: PE x-1, e-2, e-4 and PEE x-1. Lomas de Olmedo basin starts with a rifl emplacement in the Early Jurassic. In Late Jurassic-Early Cretaceous the basin grows recording fluvial deposits associated with minor volcanics in an environment of extensional faulting. The main basin subsidence occurs during Cretaceous; at this time, the rock of the Yacoraite Formation were deposited. Clastic continental and evaporitic sediments were formed at the end of this basin history. Tertiary and Quaternary folding, faulting and uplift are also recorded. Sandstone and carbonate porosity evolution was studied. P, intergranular, moldic and vuggy porosity was reduced by authigenic quartz overgrowths and cementations of anhydrite and bitumen. Porosity was increased by dolomitic re-emplacement and fracturing. Highly selective porosity conservation was caused by the amount of pore F in some sandstone layers. A mature mesogenesis was reached according to the textures and 10-20% selective porosity values. A direct ratio was found between actual porosity. FI abundance and extractable organic matter. Paraphinic and asphalt hydrocarbon FI were recognized by their light blue and yellow-greenish fluorescence. Reddish asphalt FI with low cloudy points predominate in the stratigraphically lower levels; by contrast light hydrocarbons with high cloudy points, propane, ethane and methane are found in the FI coming from upper levels. A brine composed by NaCI-MgCl<sub>2</sub>-Na<sub>2</sub>SO<sub>4</sub>-NaHCO<sub>3</sub> and NaCO<sub>3</sub> was the diagenetic formation water (17% NaCl eq sal). Based on FI, 121-137°C, with an anomalous value of 154°C, was the interval of T reached during diagenesis. The analyzed samples fall in the oil and G generation window. The amounts of TOC (total organic carbon) and EOM (extractable organic matter) define a source and reservoir rock in the upper chalk section and a reservoir rock in the upper sandstone section. The diagenetic evolution indicates that an increase in the T and P in the pore F. This fact produces maturation of organic matter in the carbonatic section, generating CO2 and carboxyl which in turn caused carbonate dissolution and anhydrite and dolomite precipitation. In the upper sandstone section the fractionated maturation resulted in bitumen filling the pores and S fluorescent asphalt FI in microfractures of quartz. These microfractures were the hydrocarbon migration pathways. (Authors' abstract)

See also next item (E.R.)

CESARETTI, N.N., PARNELL, J. and DOMÍNGUEZ, E.A., 1998, Past and present oil migration pathways in the Yacoraite Formation, Argentina: AAPG Bull., v. 82, no. 10, p. 1900-1901. First author at Dep Geologia. Univ. Nacional del Sur, San Juan 670-8000 Bahia Blanca, Argentina.

Pores, microfractures and fractures were all migration pathways for organic F in the Yacoraite Formation (Cretaceous-Paleocene) in the NW Cretaceous. Lomas de Olmedo Oil Bain in Salta, Argentina. Four drill cores from Pozo Escondido (x-1, e-2, e-4) and Escondido Este (x-1) (64° west long. 24° south latitude) were studied for the distribution of hydrocarbons. Different migration pathways functioned to varying degrees during

the basin history.

Lomas de Olmedo is an early Jurassic rift basin whose main subsidence happened during the Cretaceous. The end of the subsidence is recorded by the Yacoraite Formation, the most important oil bed. It [consists of] quartz sandstones, mudstones, boundstones and grainstones that act as a reservoir and source rocks.

In sandstones pore size was partially reduced first by quartz overgrowths, then by anhydrite cementation, and finally by bitumen as droplets and grain-coatings in the reservoir rocks. In the chalk level the pore sizes were increased by dolomitization and reduced by anhydrite cementation and bitumen precipitation.

Microfractures functioned only in the past. In the chalk level they crosscut some quartz grains in a very fine grained carbonate matrix. These microfractures are considered to have been P migration pathways. In the sandstone level the microfractures crosscut detrial quartz grain and predated silica cementation. The microfractures were generated by high F P caused by migration of the oil present in the pores and were sealed by silica cementation in the presence of oil. These microfractures are considered to be S migration pathways. In both cases the microfractures host asphaltic hydrocarbon FI. Fractures function in the chalk level at the present time. They are open and clean and were generated by dilation. These fractures host the oil produced from the well.

The predominant mechanism of S migration in the sandstone level was as globules or bubbles of oil driven by water movement. Both aq and hydrocarbon Fl are observed. The distorted oil globules could be attributed to a greater buoyant force than the P inside the globule, forcing the globules to move through pore throats. When this P exceeded the mechanical strength of the rocks, microfractures in quartz were developed and S oil migration was induced.

Present day migration is probably linked to open pores and fractures, mainly in the limestone level which hosts the present naphtenic oil and has no evidence of bitumen cement.

In this basin there is a relationship between oil maturation and the migration pathways. Initially a heavier oil migrated through the pores and microfractures. Then the heavier fraction (asphaltic bitumen) remained in the pores and the lighter fraction moved through the microfractures. After cementation reduced the porosity, fractures became the pathways for the present naphtenic oil migration. (Authors' abstract)

See also previous item (E.R.).

CHABIRON, Aliouka, ALYOSHIN, Alexei, CUNEY, Michel, GOLU-BEV, Viatcheslav, VELITCHKIN, Vasili and POTY, Bernard, 1997. Composition of melt inclusions and REE pattern in rhyolites of the Strel'tsovka uranium ore field (Eastern Transbaikalia, Russia) as indicators of magma composition (abst.): in N. P. Laverov, ed., Principal Genetic Problems Related to Mineral Deposits of Magmatic Affiliation. IGEM-RAS Symposium, Moscow, April 8-10, 1997 [Betekhtin Symposium], p. 232-233 (in Russian: Engl. translation from: English Version of the Abstracts of the Oral presentations of the Papers of the Russian Participants, p. 46-47). ISBN 5-88918-002-9. First author at Centre de Recherche sur la Géologie des Matieres Premieres Minerales et Energetiques. BP 23, 54501 Vandœuvre-lês-Nancy Cedex, France.

The Mo-U deposits of the Strel'tsovka are associated with an Upper Jurassic--Lower Cretaceous volcanic caldera and feature unique reserves. Uranium mineralization was formed immediately after volcanic activity and is genetically linked with acid volcanism from the point of view of some researchers. MI trapped in quartz phenocrysts of rhyolites were analyzed by electron microprobe and electron scanning microscope (SEM). Rhyolites exhibit high REE content (up to 2.3 times the chondrite) with fractionated LREE, non fractionated HREE patterns and strong Euanomaly typical of alkaline magmatism. The average composition of glass before rehomogenisation (on the basis of 24 analyses of 23 magmatic I) is the following one: SiO2-69.79%; Al2O3-4.12%; K2O-5.75%; Na2O-5.11%; F\*1.96%; FeO-1.11%; TiO2-0.11%; MnO-0.06%; MgO-0.01%; CaO-0.02%. Such composition corresponds to F\*rich alkaline acid magmatism (high alkali and agpaitic index and low Mg, Ti contents). Initial F content was probably higher because fluorite, parisite and Frich mica crystals have been observed in the MI. U content determined by fission tracks varies from 13.4 ppm to 23.6 ppm and fluorite. (Authors' abstract)

CHANG, Hailiang and HAN, Youke, 1998, H<sub>2</sub>S-containing and organic fluid inclusions in Bancanghe gold deposit of Huanglin area. Hubei province: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1071-1074 (in Chinese). CHANG, Hailiang and HUANG, Huilan, 1998, Melt-fluid inclusions in topaz from the Jianfengling pegmatoid in Linwu County, Hunan Province: Acta Petrologica et Mineralogica (Yanshi Kuangwuxue Zazhi). v. 17, no. 1, p. 81-86 (in Chinese; Engl. abst.). Authors at Yichang Inst. of Geol. and Mineral Resources, Yichang 443003.

The Jianfengling pegmatoid, situated in the upper part of the Jianfengling granite body in Hunan Province, South China, consists mainly of quartz, topaz and zinnwaldite. Three types of I have been found in topaz from the pegmatoid body: (a) silicate MI, (b) F (G-L) I and (c) M-FI. Described here are characteristics of these I as well as their distribution, phase state, composition, molecular textures of the polymerized silicate M. Th and homogenizing behavior during the heating, cooling and quenching processes. It is considered that the M-FI are products of random capturing of the unmixed magma (M) and L (F) at the end of magmatic evolution. Therefore, the study of M-FI is of great significance in the discussion of the magmatic evolution process. (Authors' abstract)

CHAPMAN, L.H. and WILLIAMS, P.J., 1998, Evolution of pyroxenepyroxenoid-gamet alteration at the Cannington Ag-Pb-Zn deposit, Cloncurry District, Queensland, Australia: Econ. Geol., v. 93, p. 1390-1405. Authors at Nat'l, Key Centre in Economic Geol., School of Earth Sci., James Cook Univ., Townville Q4811, Australia.

The Cannington deposit, hosted by sillimanite-K feldspar zone gneisses, contains distinctive Fe-rich silicate host rocks formed during a complex history of postpeak metamorphic alteration.

The metasedimentary origin and skam-like features suggest that carbonate-bearing or calc-silicate precursors could have been present at least locally.

Hydrous Fe-K-CI-rich assemblages characterized by homblende, biotite, pyrosmalite, and dannemorite occur in veins and as alteration of pyroxene-pyroxenoid-garnet rocks. Very high sal, Na-K-Fe-Mn-Pb-rich P FI occur in quartz of this stage. Later sulfide-magnetite-fluorite mineralization was associated with further retrograde hydration that produced phyllosilicates such as greenalite. The spatial relationship exhibited by anhydrous alteration assemblages and metals implies that the deposit was at the very least significantly reconstituted during postpeak metamorphic alteration, or that metals were transported to the deposit as a later part of the same alteration system that produced the Fe-(Mn-Ca)-rich assemblages. (From authors' abstract by E.R.)

Dm phases found, by EDM/SEM, include halite, sylvite, pyrosmalite, and Pb-K chloride (E.R.)

CHAREF, A. and SHEPPARD, S.M.F., 1998. Saline diapirism, pulsating hydrothermalism and Zn-Pb deposits: The N. Tunisian basin (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 302-303.

CHARLOU, J.L., FOUQUET, Yves, BOUGAULT, Henri, DONVAL, J.P., ETOUBLEAU, Joel, JEAN-BAPTISTE, Philippe, DAPOIGNY, Arnaud, APPRIOU, Pierre and RONA, P.A., 1998, Intense CH<sub>4</sub> plumes generated by serpentinization of ultramafic rocks at the intersection of the 15°20'N fracture zone and the Mid-Atlantic Ridge: Geochim et Cosmo. Acta, v. 62, no 13, p. 2323-2333. First author at Dept. Géosci. Marines, IFREMER Centre de Brest, Plouzané, France CH<sub>4</sub> concentrations in the bottom waters [are high] where serpentinized rocks outcrop. No <sup>3</sup>He anomaly is associated with methane, ruling out any P mantle component. CH<sub>4</sub> output from ultramafic outcrops is believed to reflect ongoing serpentinization. These results associated with many other CH<sub>4</sub> anomalies measured in the water column above ultramafic outcrops found between 12°N and the Azores most likely reflect serpentinization processes extending along the whole slow-spreading Mid-Atlantic ridge. (From authors' abstract by E.R.)

CHAUVET, A., NOMADE, S., BARBANSON, L., CHARONNAT, X. and TOURAY, J.C., 1998. Mineralogical and textural analysis. and fluidinclusion study of the gold-bearing mineralizations of the Cévennes (French Central Massif) (abst.): Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998. p. 91 (in French, translation by E.A.J. Burke). Authors at UMR 6530, Univ. Orléans, BP 6759, 45067 Orléans Cedex 2.

Textural and mineralogical studies, and a FI analysis have been carried out on the gold-bearing veins of Alteyrac/Pont-de-Rastel and on the reworked mineralizations of the paleoplacer of Bulidou (Stephanian Basin of Ales) in order to characterize the formation processes of these mineralizations. The results show that the origin of the mineralization is due to the emplacement, in a ductile/brittle environment, of guartz veins associated

with sulfidic and metallic parageneses. The study also gives evidence for three stages in the formation of these veins, corresponding with an evolution of the chemistry of the mineralizing F, from an aq-carbonic end member rich in iron and arsenic, to an ag end member rich in antimony and lead. The gold would be located within the sulfides emplaced during the last pulses of stage 1 and during stage 2. This evolution is similar for all studied mineralizations. However, some fundamental differences distinguish the mineralizations of Bulidou from the in situ veins:

The Bulidou deposit shows a well-developed opening stage (stage 2), with formation of geodes. This stage is characterized by triphase aqcarbonic Fl with a high degree of filling. Equilibration T of arsenopyrite are 350 to 450°C, the metallic phases are rich in Pb.

The formation of the Alteyrac/Pont-de-Rastel veins is only controlled by processes of faulting, brecciation and filling. Evidence of outright opening is rare, and quartz geodes have never been found. The FI are biphase with a low degree of filling. The formation T of arsenopyrite are lower than in Bulidou, and the metallic phases are enriched in Sb.

These results suggest that the in situ mineralizations of Alteyrac/Pontde-Rastel are not the source of the sedimentary mineralizations in the Bulidou conglomerate. It has been shown, however, that those two types of deposit result from the same mineralizing process The observed differences can be explained, either by an emplacement at different structural levels, or by a diachronic mode of emplacement. (Authors' abstract)

CHAZALLON, Bertrand, CHAMPAGNON, Bernard, PANCZER, Gérard, PAUER, Frank, KLAPPROTH, Alice and KUHS, W.F., 1998. Micro-Raman analysis of synthetic air clathrates. Eur. J. Mineral, 1998, no. 10, p. 1125-1134 First author at Laboratoire de Physico-Chimie des Materiaux Luminescents, UMR 5620, Université Claude Bernard Lyon I, 43 Boulevard du 11 novembre 1918, F-69622, Villeurbanne, France; email (chazallon@silly.uni-mki.gwdg.de)

Raman spectroscopy measurements on synthetic air clathrates, prepared at different P and T, are presented. The G fractionation for clathrates formed at -2 and -20°C is determined from the integrated vibron mode intensities of nitrogen and oxygen molecules. An increasing fractionation in favour of oxygen with increasing P is found. An asymmetric peak shape for the O<sub>2</sub> vibron mode was observed in air clathrates prepared at 300 bar and -2°C. The asymmetry of the N2 vibron mode in the same sample is much less pronounced. (Authors' abstract)

See also FIR 30, p. 35-36 (E.R.).

CHEN, Honghan, LI, Sitian, SUN, Yongchuan and ZHANG, Qiming, 1998. Two petroleum systems charge the YA13-1 gas field in Yinggehai and Qiongdongnan basins, South China Sea: AAPG Bull., v. 82, no. 5A, p. 757-772.

Restoring burial history, correlating maturities and biomarkers of Gcondensate source rocks, measuring FI, and stable carbon isotope data show that two petroleum systems charge the YA13-1 G field in Yinggehai and Qiongdongnan basins in the South China Sea (From authors' abstract by ER)

CHEN, Peirong, LU, Jianjun, WANG, Rucheng, et al., 1998. Fluid inclusion study on the first example of all alone Te deposit. 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998 Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1011-1014 (in Chinese);

CHEN, Ruging, LU, Huanzhang and GUHA, Jayanta, 1998. Coal inclusions in minerals: Genetic implications (abst.) GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A31. Authors at Sciences de la Terre/CERM, Univ. du Québec à Chicoutimi, Chicoutimi, QC, G7H 2B1; email (jguha@ugac.uquebec.ca)

Organic matter such as bitumen and kerogen associated with endogenic metallic deposits has been cited in existing literature as derived from petroleum, bacteria or mantle methane. The present investigation of coal 1 in minerals found in the Yaogangxian tungsten deposit, related genetically to the late Yanshan granite (167-178 Ma. K-Ar dating) in the Hunan Province in China, indicates that organic matter in the form of solid (dusty coal), L (coal-type hydrocarbon) and V (coal-type G) were derived from coal macromolecule during coalification and trapped by crystallizing minerals such as fluorite, quartz and wolframite

The coal I can be subdivided into three types. (1) Organic I vitrinite. exinite and altered vitrinite possibly due to hydrothermal alteration producing a decoloration of the vitrinite. (2) Organic-inorganic l: vitrinite/exinite+dusty quartz I, at times showing the original grain boundary of coal now composed of quartz and vitrinite, and (3) Inorganic I: pelite dusty quartz, carbonate and clay mineral I. Inorganic matter adhering to organic matter is released from coal macromolecule during coalification and is transported to the site of mineralization. In addition numerous aq FI, with Th ranging from 190-270°C and sal between 1-7 wt% are closely associated with coal I in healed fractures. G chromatographic data show that there are several species of hydrocarbons such as methane, ethane, propane, propylene, acetylene, isobutane, normal butane, isopentane, normal pentane and hyxane in P aq I. The dry-wet ratio of light hydrocarbon is very high (0.972-0.998) which is characteristic of coal-type G.

From the above data and the regional setting it can be shown that the metamorphism of a Late Triassic coal-bed, 650 m above the underlying granite body, into homfelsed anthracite during magmatohydrothermal activity released organic matter which may have played an important role in the localization of the tungsten mineralization. This study illustrates the possibility of coal seams being an additional source of organic matter in hydrothermal processes. (Authors' abstract)

CHEN, Shizhong, ZHOU, Jiyuan and CUI, Binfang, 1998, Characteristic fluid inclusions and geophysical-chemical ore-forming conditions of Hongshan cryptoexplosive breccia-porphyry copper deposit in Huichang Jiangxi: Volcanology & Mineral Resources, v. 19, no. 3, p. 205-213 (in Chinese; Engl. abst.). Authors at IGMR, Nanjing. 210016.

The Hongshan deposit is regarded as a typical cryptoexplosive brecciaporphyry copper deposit. Based on the study of geochemistry and experimental geochemistry of this deposit, we give general ore-forming geochemical conditions of Hongshan copper deposit. (Authors' abstract)

FI data presented and discussed (H.E.B.)

CHEN, Xueming, LIN, Zong and XIE, Fuchang, 1998. Geological and geochemical characteristics of the Bainiuchang superlarge silver polymetallic deposit of superimposed mineralization, Yunnan Province Scientia Geologica Sinica (Dizhi Kexue) v. 33, no. 1, p. 115-124 (in Chinese; Engl. abst.)

The main orebodies are in the forms of both stratiform and veins of various dimensions, and the mineralogical composition is very complex. The decrepitation T of the Fl range from 60 to 410°C, and the contents [of] salts range from 3.1 to 10%. The  $\delta^{34}$ S values of sulfides in orebodies are about -4 to 5.5% but 18.6 to 23.4% in strata. The lead is normal and anomalous lead. Majority of mineralization hydrothermal solution are from seawater and rainfall. (From authors' abstract by E.R.)

CHEN, Yanjing, LI, Xin, JING, Jun, GAO, Xiuli, CHEN, Huayong, WU, Xidan and WU, Dehua, 1998, Study of oreforming fluid for the Wangfeng gold deposit of Xinjiang and its genetic implication: Acta Geologica Sinica (Diqiu Xuebao), v. 19. no. 2, sum 49, p. 195-203 (in Chinese. Engl. abst.). First author at Dept. of Geol., Peking Univ., Beijing, PRC

Studies on wall rock alteration and FI show that the ore-forming process includes three stages which are marked by the mineral assemblages of quartz-pyrite, polymetallic sulfides, and quartz-carbonate respectively. Their mineralizing T are concentrated in the ranges 360-520°C. 240-360°C, and 120-240°C, respectively. The middle stage contributed most to the mineralization. With the value of 8180% ranging 1.15-2.70, the ore-forming F are most likely to be hybrid F by metamorphic solution and meteoric solution. Chemical composition of FI shows that the oreforming F was derived from a shallow level source and was beneficial for gold mineralization. The ratio of CO2/H2O is usually >0.026, which is also favorable for gold mineralization. The calculated trapping P of I demonstrates that the mineralization should occur at the depth of 5 6-1.2 km. mainly at about 1.9 km. The ore-forming process concedes with the crustal extension elevation, consequently agrees with the mineralization during collisional orogenesis. Hence, the collision orogenesis at the end of Paleozoic resulted in the formation of the Wangfeng gold deposit: and more gold deposits like Wangfeng may be found along the Bingdaban fault belt. Infrared spectroscopic analysis of quartz shows that the densities of absorption spectra for CO2(D2) and the ratios of D2 over the densities for H2O (D1) (D2/D1) are generally high, which suggests the mineralization should have been strong. D2>0.55 and D2/D1>>0.26 are indicators to gold enriched samples (Authors' abstract)

CHEN, Y.J., CHEN, H.Y., WANG, H.H., LI, X., HU, S.X., FU, S.G. and JIN, C.Y., 1998, Fluidization, metallogenic mechanism and type of the Bankuan gold deposit. China: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 533-536.

First author at Dept. of Geol., Peking Univ., Beijing, P.R. China.

Auriferous quartz veins in the Bankuan gold deposit occur in the interlayer broken zone of the basal conglomerate of the Tietonggou Group and at the unconformity between the Tietonggou Group and the crystalline basement. The composition of Fl indicates that the nature and composition of ore-forming F changed drastically soon after they reached the Tietong-gou Group from the crystalline basement, resulting in gold precipitation. Therefore the Bankuan deposit is assigned to the conglomerate or unconformity strata-bound type deposit. 137 thermometric data [decrepitation or homogenization?] are concentrated in three ranges 400-340°C, 320-220°C and 200-160°C, representing a three-stage metallogenesis. (Authors' abstract)

Includes analyses (methods unspecified) of 9 Fl samples for K, Na, Ca, Mg, HCO<sub>3</sub>, F, Cl, SO<sub>4</sub>, CO, CH<sub>4</sub>, CO<sub>2</sub> and H<sub>2</sub>O (E.R.).

CHEN, Zhensheng, RICIPUTI, L.R., MORA, C.I., FISHMAN, N.S. and DRIESE, S.G., 1998. SIMS analysis of oxygen isotopes in authigenic K-feldspar and quartz from the Mount Simon Sandstone: Evidence of regional fluid-flow (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-316. First author at Dept. of Geological Sci., Univ. of Tennessee, Knoxville, TN 37996; email (zchen@utkux.utcc.utk.edu)

The widespread occurrence of apparently contemporaneous (~400 Ma) authigenic quartz (qz) and K-feldspar (Kfs) in the Cambrian Mount Simon Sandstone, IL, IN and WI, suggests that formation of these cements may have resulted from regionally migrated basinal F through the PaleoIllinois Basin SIMS was used to measure oxygen isotope compositions of individual Kfs and qz grains/overgrowths to better understand F composition, T and movement through the basin. 818O values were determined on 5-10 individual grains/overgrowths for Kfs and qz cements in samples from 4 Mt. Simon cores (IL, IN) from depths of 655 to 1570 m and 2 outcrop samples from WI. Individual analyses for qz and Kfs in each sample span a range of 3-7%, and there is a geographic trend in average values: Kfs 818O values increase from 13±2% in the southernmost, most deeply buried sample to 24±2‰ in the northernmost outcrop sample, and average qz δ<sup>18</sup>O values increase northward from 22±2‰ to 28±1‰ The δ<sup>18</sup>O values of cements or overgrowths remain constant or decrease slightly (2-3‰) in the last precipitated cement.

Basinal reconstruction/thermal modelling suggest that Tf, at the time of cement precipitation, decreased northward from <90°C to <45°C. However, qz Fl data suggest that (1) F were hotter (100-130°C) than predicted based on depth of burial alone and (2) F T were relatively constant or may even have increased northward across the basin, consistent with transfer of heated diagenetic F towards basin margins. The relatively large  $\delta^{18}$ O variations both within and between samples are (1) difficult to reconcile with T limits estimated from burial curves, (2) consistent with Fl data that indicate higher F T, and (3) suggest that both qz and Kfs formation spanned a period of changing F composition and T. The geographic trend in SIMS  $\delta^{16}$ O values are most consistent with coupling of a south to north F-flow vector and changing precipitation T. (Authors' abstract)

CHEN, Zongqing, 1998, Relation between reservoir mineral inclusions and oil-gas generation-capping, migration and accumulation in the southern part of the Lichuan Synclinorium, Western Hubei: Acta Geologica Sinica (Diqiu Xuebao), v. 72, no. 4, p. 367-376. Author at Sichuan of Petroleum Geological Exploration and Development, Chengdu, Sichuan 610051.

In light of the correlation of the reservoir mineral I with the calculated hydrocarbon yield, if the source bed is good, organic I are rich, and vice versa. Likewise, whether the conditions of relevant cap rocks are good or not can be judged to a certain degree according to the amount of organic I in adjacent reservoirs combined with the merits of the petroleum generation conditions. The P-corrected I T<sub>h</sub> evidently show that the oil-G migration in various reservoirs took place in the Jurassic after the Indosinian movement. The P accumulations of oil-G for various reservoirs did not all occur according to the age priority, but generally petroleum accumulation was completed in Jurassic time. (From author's abstract by E.R.)

CHENG, H., EDWARDS, R.L., MURRELL, M.T. and BENJAMIN, T.M., 1998, Uranium-thorium-protactinium dating systematics: Geochim. et Cosmo. Acta. v. 62, no. 21/22, p. 3437-3452. First author at Minnesota Isotope Laboratory, Dept. of Geol. and Geophys., Univ. of Minnesota. Minneapolis, Minnesota 55455, USA.

Minneapolis. Minnesota 55455, USA. With precise <sup>234</sup>U. <sup>230</sup>Th, and <sup>231</sup>Pa data available. <sup>230</sup>Th and <sup>231</sup>Pa ages can now be tested rigorously for concordancy. If the material is not concordant, the isotopic characteristics of this material may be examined in some detail. These models may help constrain the nature of diagenetic processes, and in some situations it may be possible to determine or constrain the true ages with materials that have behaved as open-systems. (From authors' abstract by E.R.)

CHI, Guoxiang, KONTAK, D.J. and WILLIAMS-JONES, A.E., 1998, Fluid composition and thermal regime during Zn-Pb mineralization in the Lower Windsor Group. Nova Scotia, Canada: Econ. Geol., v. 93, p. 883-895. First author at Geological Survey of Canada, Quebec Geosci. Centre, P.O. Box 7500, Sainte-Foy, Quebec, Canada G1V 4C7.

Various geochemical studies indicate that the deposits were formed by F expelled from the basin, but [the source(s) and path of the fluids] remain unclear. This paper addresses these problems. The compositions and T of the F were evaluated from FI data, whereas host-rock T were estimated from vitrinite reflectance measurements.

The ore-forming F are characterized by: (1) variable, but generally high sal-(mainly between 15 and 30 wt% NaCl eq), (2) variable, but generally detectable, amounts of bivalent cations (mainly Ca<sub>2</sub><sup>\*</sup>), (3) significant concentrations of hydrocarbon species, and (4) high T (mainly between 150 and 250°C). NaCl/(NaCl+CaCl<sub>2</sub>) wt, ratios in Fl show a broad districtscale variation: mainly <0.6 for the Jubilee deposit and several showings on Cape Breton Island, and mainly >0.4 for the Gays River and Walton deposits in mainland Nova Scotia. CH<sub>4</sub>/higher hydrocarbons ratios of the G components are greater for the Gays River deposit (3.8-9.7) than the Jubilee deposit (0.7-1.3). Fl Th do not show a negative correlation with the distance between the deposits and the central part of the Maritimes basin, as might be expected if the F for different deposits were derived from the same source region.

The background T prior to mineralization were estimated from mean vitrinite reflectance ( $R_0$ ) in host rocks which were relatively far from the deposit, and were probably least affected by the mineralizing events, and from Th of FI in preore minerals. These T are in the range of 70 to 155°C, which are significantly lower than those of the ore-forming F. The paleogeothermal gradients estimated from the background T and burial depths are ca. 65°C/km. Vitrinite reflectance values in host rocks adjacent to the deposits indicate that these rocks were heated by the mineralizing F to variable degrees, but thermal equilibrium between the F and rocks was not attained in most cases. This thermal relationship suggests focused and short-lived, rather than pervasive and long-lived, F flow

The regional variation of F composition and thermal patterns supports a model in which the ore-forming F of individual deposits were derived from separate sources; F flow was focused along confined conduits and individual mineralizing systems were unconnected hydrologically Under paleogeothermal gradients of ca. 65°°C/km, F with T of ca. 250°C could have been generated in sub-basins proximal to the deposits. Sudden release of overpressured F from the basal part of the proximal sub-basins, characterized by high F rate and short duration, is proposed as the mechanism of ore-forming F flow. (From authors' abstract by E.R.)

See also Kontak and Sangster, and Savard and Chi, this volume (E.R.).

CHI, G, and LAVOIE, D., 1998. Porosity evolution and evidence of hydrocarbon migration in the Kamouraska and Riviere Ouelle formations. Humber Zone, Québec; a fluid inclusion approach: Eastern Canada and national and general programs. Current Research--Geological Survey of Canada, 1998. p. 19-24.

Indexed under FI.

CH1, Guoxiang and SAVARD, M.M., 1998, Basinal fluid flow models related to Zn-Pb mineralization in the southern margin of the Maritimes Basin, Eastern Canada, Econ. Geol., v. 93, p. 896-910. Authors at Geological Survey of Canada, Quebec Geosci, Centre, 2535 Blvd, Laurier, P.O. Box 7500, Sainte-Foy, Quebec, Canada G1V 4C7.

Mentions FI temperatures of ~250°C (p. 208) (E.R.)

CHI, Guoxiang, SAVARD, M.M., SAMI, Terry and LEIGH, Ken, 1998. The Polaris Mississippi Valley-Type Zn-Pb deposit—Implications of fluid inclusion and C, O, Sr isotopes studies on giant sulfide accumulation (abst.) GAC/MAC Meeting Quebec 1998. Abstract Volume 23, p. A32. First author at GSC-Quebec, Centre Géoscientifique de Québec, 2535 Laurier, Ste-Foy, QC G1V 4C7; email (gchi@gsc.nrcan.gc.ca)

With 22 mt of ore grading 14% Zn and 4% Pb, Polaris is among the largest MVT deposits in the world. The deposit consists of a single ore body with maximum dimensions of 800 m long x 300 m wide x 150 m thick. The genetic reason of such a large amount of Zn and Pb sulfides in a

limited space is unknown. We address this problem using FI (n=600) and C, O, Sr isotopes (n=90) studies of various paragenetic phases present in and around the Polaris deposit

The dolomitized host rocks form an alteration halo around the ore body. Five types of dolomite have been distinguished, including three replacive dolomites (RD) and two pore-filling dolomites (PD). The paragenetic order is RD1, RD2, RD3, PD1, and PD2. Sphalerite and galena precipitation largely overlaps with RD3 and PD1. FI were studied in RD3, PD1, PD2, and sphalerite. The overall ranges of Th and last Trnice are from 67 to 141°C and from -46.7 to -27.0°C, respectively, which indicate warm basinal brines with high Ca/Na ratios. G chromatography analysis of FI indicates very low concentrations of light hydrocarbons (<0.06 mol%). No systematic variation in Trnice or Th is observed between different minerals. Th values of FI in PD1 (25 samples, 520 1) around the ore body do not show a clear isotherm pattern. C, O, and Sr isotopes were analyzed for all dolomites and early diagenetic calcites (DC). The overall ranges of 818OVPDB values are from -7.7 to -5.1% for DC, -9.4 to -5.3% for RD1, and -10.7 to -7.9% for RD2 - PD2. 813C values of dolomites (-2.4 to -3 1‰, mainly -1.5 to 0.5‰) are similar to those of DC (mainly -2.8 to -0 1‰). \*\*Sr/86Sr values range from 0.707966 to 0.708588 for DC. 0 709995 to 0.711259 for RD1, and 0.708222 to 0.709481 for RD2 - PD2. The isotopic values of RD2, RD3, PD1, and PD2 are tightly clustered. and have largely overlapping domains. All dolomite isotope values are similar throughout the dolomitized aureole, or do not vary in any identifiable pattern. It is remarkable that there is no systematic spatial and temporal variation in F T and composition in the ore-related phases. The geochemical homogeneity, and perhaps the giant and compact features of the deposit, reflects a highly evolved mineralizing regime (high w/r ratio), suggesting a long-lived, focused basinal F flow system. (Authors' abstract)

CHIODINI, Giovanni and MARINI, Luigi, 1998, Hydrothermal gas equilibria: The H2O-H2-CO2-CO-CH4 system: Geochim. et Cosmo. Acta, v. 62, no. 15, p. 2673-2687.

CHOI, S.H., 1998, Geochemical evolution of hydrothermal fluids at the Daejang Cu-Zn-Pb vein deposit, Korea. Resource Geol., v. 48, no. 3, p. 171-182. Author at Dept. of Earth and Environmental Sci., Chungbuk Nat'l Univ., Cheongju 361-763, Korea; email

(cshoon@cbucc.chungbuk.ac.kr).

The Daejang mine is located within the Cretaceous Gyeongsang basin. Mineral paragenesis can be divided into four stages (stages I, II, III and IV) by major tectonic fracturing. Stages I, III and IV are economically barren, Stage II. at which the precipitation of major ore minerals occurred, is further divided into three substages with paragenetic time based on minor fractures and discernible mineral assemblages: substage lia, marked by deposition of quartz and Fe-sulfides: substage 11b. by introduction of basemetal sulfides within carbonates and some quartz: substage llc. by quartz and carbonates with various sulfosalts.

FI data indicate a complex geochemical evolution of hydrothermal F. Both CO2-rich and H2O-rich F were trapped in FI at stage I and substage Ila. It is suggested that a compositionally heterogeneous F was formed by F boiling and CO2 immiscibility at T of about 400 to 300°C. Composite lodes of base-metal sulfides, carbonates and quartz at substage llb were deposited in open spaces created by fracturing. The fracturing event prompted rapid decreases in P and T of residual F and resulted in retrograde F boiling at about 200 bars and 300-250°C during substage IIb. The progressive loss of CO2 by CO2 effervescence and retrograde boiling from substage IIa and IIb F resulted in pH increase and related increase in carbonate activity, causing deposition of abundant carbonates. The change in pH also caused the decrease of stability of hydrogen sulfide with Cu. Zn and Pb chloride complexes (as main transporting agents at Daejang) and resulted in the precipitation of base-metal minerals. Deposition of Ag- and Sb-bearing sulfides and sulfosalts of substage IIc occurred at T of about 250 to 150°C from a dominantly ag F with low sal (down to 3.0 eg. wt% NaCl). At this substage, aq F formed by mixing with cooler and less saline meteoric groundwater. There is a systematic decrease in calculated δ18Owater values with the mineralization stage (and decreasing T) in the Daejang hydrothermal system, from values of about 11% for stage 1. through about 4‰ for stages II and III, to about -3 per mil for stage IV. The result of stable isotope and FI studies are interpreted to indicate progressive less evolved and/or unexchanged meteoric water influx of an early hydrothermal system formed by highly evolved meteoric waters. (Author's abstract)

CHOI, S.-H., SO, C.-S., VOUM, S.-J. and SHELTON, K.L., 1998, Geo-

chemistry and genesis of hydrothermal Cu deposits in the Gyeongsang Basin, Korea: Masan mineralized area: N. Jb. Miner. Abh., v. 173, no. 2, p. 189-206.

Mineralization at these hydrothermal vein-type deposits consists primarily of copper, plus Au, Zn, Pb and Fe. It can be separated into two distinct stages (stage I, ore-bearing quartz veins; stage II, barren calcite veins) which developed along pre-existing fracture zones. Stage I ore minerals comprise pyrite, arsenopyrite, pyrrhotite, chalcopyrite, electrum, magnetite, sphalerite, galena and hematite. FI data show that stage I ore mineralization was deposited between initial high T (near 330°C) and later lower T (near 200°C) from F with sal between 1.4 and 6.9 wt% eq. NaCl. The relationship of sal and Th suggest that ore mineralization at Majin was deposited mainly due to F boiling, whereas ore deposition at Woongnam resulted from cooling and dilution via influx of cooler, more dilute meteoric waters. Evidence of F boiling suggests P decreasing from about 140 to 60 bars. This corresponds to a depth of about 550 m in a hydrothermal system that changed from lithostatic toward hydrostatic P conditions.

Sulfur isotope compositions of early sulfides of stage 1 are consistent with an igneous source of sulfur with a 834Sz value near 2.0 per mil. Calculated 8<sup>14</sup>SH2S values show a tendency to decrease with paragenetic time during stage 1, from about 2.5% to -3.0%. This pattern, coupled with FI evidence and the occurrence of hematite in later stage I veins, indicate progressively increasing oxidizing conditions. Measured and calculated hydrogen and oxygen isotope values of ore-forming F indicate meteoric water dominance, with values approaching unexchanged meteoric water with increasing paragenetic time.

Equilibrium thermodynamic interpretation of solubility data for copper chloride complexes, and the evolution of the Masan hydrothermal F indicate that increasing pH and JO2 concomitant with cooling ore F were the main causes of copper precipitation. (From authors' abstract by E.R.)

CHOMIAK, B.A. and NORMAN, D.I., 1998, Q.M.S. analysis of individual F.I.P. fractured under observation: (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-81 Authors at Environmental Sci. Dept. New Mexico Tech. Socorro. NM 87801; email (bchomiak@nmt.edu.us)

One serious drawback of using a quadrupole mass spectrometer (QMS) to analyze FI volatiles extracted in a vacuum liine is the inability to observe the objects being analyzed. Claims that crushing minerals liberates the volatiles from one I, or just a few I, at a time are unsubstantiated.

We have designed an apparatus which is capable of fracturing individual FI planes (FIPs), in a vacuum chamber with a viewport designed for use with a microscope. A spherical diamond punch. 0.03 mm in diameter, is used to fracture FIPs at the surface of a standard FI section, 150 to 250 microns thick. Steadily increasing stress is applied with the punch until fracturing is observed. The resulting puff of volatiles are recorded by the QMS in peak-hopping mode. We have analyzed Hansonburg fluorite that has I with about 0.5 mol.% gaseous species and measured H2O, CO2, CH4, CnHn. N2. Ar. H2S and He. The latter four species are not detected in all analyses. The major difficulties with this device are 1) a low signal-tobackground ratio, 2) adsorption of volatiles, and 3) calibration. Peak heights of major G species (CO2, CH4, N2) are typically only ten times background. The water signal can be lost by adsorption unless the device and the QMS are heated. Instrument calibration is hampered by our lack of FI standards.

The principal benefit of this device is that minerals with complex F entrapment histories can be analyzed for volatile species on a FIP basis. The bulk or semi-bulk analyses of such material obtained by crushing now can be interpreted with end member compositions of the major volatile species in mind. (Authors' abstract)

CHOU, I.-M. and ANDERSON, A.J., 1998. Direct observation of low T melting in the system petalite-quartz-H2O using a hydrothermal diamondanvil cell: Methods and geological implications (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 327. First author at 955 National Center, U.S. Geological Survey, Reston, VA 20192 USA

An unexpected low-T immiscible M phase was observed in a hydrothermal diamond-anvil cell (HDAC) at T as low as 400°C near 142 MPa. These new results are relevant to our understanding of the late evolutionary stages in lithium-rich rare element pegmatite formation. (From authors' abstract by E.R.)

CHOU. I-Ming and BASSETT, W.A., 1998. Minerals in hot water and hot fluids in minerals: Visual observations and in-situ characterization of

samples through diamond windows (abst.): 17th General Meeting Int'l Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A135.

CHOU, I.-M, BLANK, J.G., GONCHAROV, A.F., MAO, H.-K. and HEMLEY, R.J., 1998, In situ observations of a high-pressure phase of H<sub>2</sub>O ice: Science, v. 281, p. 809-812. First author at 955 Nat'l. Center, U.S. Geological Survey, Reston, VA 20192, USA.

A previously unknown solid phase of H<sub>2</sub>O has been identified by its peculiar growth patterns, distinct P-T melting relations, and vibrational Raman spectra. Morphologies of ice crystals and their P-T melting relations were directly observed in a hydrothermal diamond-anvil cell for H<sub>2</sub>O bulk densities between 1203 and 1257 kg/m<sup>3</sup> at T between -10 and 50°C. Under these conditions, four different ice forms were observed to melt: two stable phases, ice V and ice VI, and two metastable phases, ice IV and the new ice phase. The Raman spectra and crystal morphology are consistent with a disordered anisotropic structure with some similarities to ice VI. (Authors' abstract)

CHRISTENSON, B.W., WOOD, C.P. and AREHART, G.B., 1998, Shallow magmatic degassing Processes and PTX constraints for paleofluids associated with the Ngatamariki diorite intrusion, New Zealand, in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 435-438. Authors at Wairakei Research Centre, Inst. of Geological and Nuclear Sci., New Zealand.

A study of the alteration halo surrounding a diorite intrusion in the Ngatamariki geothermal system is being conducted to ascertain the nature of the reservoir F extant at the time of diorite emplacement. Preliminary results show that hot, highly saline (>30 wt% NaCl) F were in equilibrium with a low density, volatile-rich phase within, and immediately adjacent to the diorite, and that these F interacted with convecting meteoric F during formation of the extensive alteration halo. T in this system range from 250°C in the alteration halo to >500°C in the diorite, and evidence points to the existence of repeated P transients across the brittle-plastic transition during subsolidus cooling of the intrusion. (Authors' abstract)

CHUPIN, S.V., CHUPIN, V.P., BARTON, Jr., J.M. and BARTON, E.S., 1998, Archean melt inclusions in zircon from quartzite and granitic orthogneiss from South Africa: Magma compositions and probable sources of protoliths: Eur. J. Mineral., 1998, no. 10, p. 1241-1251. First author at Inst. of Mineral. and Petrog., SB RAS, 630090, Novosibirsk, Russia; email (chupin@uiggm.nsc.ru)

Results are presented of analyses of MI in >3.0 Ga zircon grains from three lithologies in South Africa: the Orange Grove Quartzite of the Witwatersrand Supergroup, quartzite of the Beit Bridge Group and the S-type Singelele orthogneiss, the latter both of the Central Zone of the Limopoo Belt. In each case, the presence of MI indicates that the zircon is magmatic in origin. No MI occur in metamorphic overgrowths in some grains. MI in detrital zircon grains from the two quartzite units indicate that both tonalitic-trondhjemitic and granitic magmatsm at that time is among the earliest recognized in southern Africa. I in zircon grains from the Singelele orthogneiss are compositionally similar to the host rock, showing that they are a magmatic phase rather than a xenocrystic phase. (Authors' abstract) Scene FIR 30 c. 282 (2015 B).

See also FIR 30, p. 38-39 (E.R.).

CLARK, S.K., REAGAN, M.K. and PLANK, T., 1998, Trace element and U-series systematics for 1963-1965 tephras from Irazu Volcano. Costa Rica: Implications for magma generation processes and transit times: Geochim, et Cosmo. Acta, v. 62, no. 15, p. 2689-2699. First author at Depts of Geol., Univ. of Iowa, Iowa City, Iowa 52242, USA.

Compositional differences between two groups of tephra can be explained by variations in the degree of melting and in the compositions of F involved in magma genesis. Low-Ra magmas were generated by dehydration partial melting of gamet-bearing mantle that had been enriched previously by a slab F. High-Ra magmas were generated by a similar mechanism, but involved an additional mantle-derived F. Trace element compositions of the high-Ra magmas suggest that this F was similar to a carbonatite. The T and P during melting were appropriate for carbonatitesilicate M miscibility, and the carbonatitic F was consumed or partly consumed during melting. The lower concentrations of many highly incompatible trace elements in the high-Ra samples resulted from a higher degree of partial melting of its mantle source caused by F-silicate M miscibility. The approximately equal HFS element and Ba concentrations in the lowand high-Ra samples, and the relatively high REE, Sr, and P<sub>3</sub>O<sub>5</sub> concentrations in the high-Ra samples reflects the addition of these elements to the high-Ra magma from the F. Ra-Ba-Th geochronometry suggests that the enrichment event occurred between a few centuries and eight millennia before the eruption. (From authors' abstract by E.R.)

CLEMENS, J.D. and DROOP, G.T.R., 1998, Fluids, P-T paths and the fates of anatectic melts in the Earth's crust: Lithos, v. 44, p. 21-36. First author at School of Geological Sci., CEESR, Kingston Univ., Penrhyn Rd., Kingston-upon-Thames, Surrey KT1 2EE, UK.

This paper presents a model for the longevity and physical behaviour of anatectic M in the Earth's crust. (From authors' abstract by E.R.)

CLINE, J.S. and HOFSTRA, A.H., 1998. Ore fluid evolution at the Getchell Carlin-type gold deposit, Nevada, USA (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A30. First author at Geosci. Dept., Univ. of Nevada, Las Vegas; email (jcline@nevada.edu)

Getchell is a large, low-grade, sediment-hosted Carlin-type deposit. Gold occurs as submicron particles in As-rich pyrite. The main ore stage includes gold+As-rich pyrite+quartz+orpiment+fluorite: orpiment and fluorite precipitated late in this event. The late ore stage contains realgar+calcite+pyrite+Au.

P and S aq FI from main ore stage quartz yield P corrected T of 180-220°C. Fluorite trapped P aq 1 at 155-200°C and S aq 1 at 115-155°C. Fluorite also trapped S, three-phase 1 that record the influx of a 240°C CO<sub>2</sub>rich F. CO<sub>2</sub>-H<sub>2</sub>O phase equilibria constrain trapping to a minimum of -330 bars and provide a P correction for ore stage I. Realgar trapped S, single--phase I. Aq I in calcite are typically necked; sparse S I with consistent phase ratios were trapped at 115-155°C.

Quadrupole mass spectrometer G analyses show that ore-stage F in quartz, fluorite, and orpiment are generally H<sub>2</sub>O-dominant, but contain significant concentrations of CO<sub>2</sub> and H<sub>2</sub>S. Trace amounts of hydrocarbons (HC) and N<sub>2</sub> may be present. Late ore calcite 1 are H<sub>2</sub>O-dominant and contain minor to moderate CO<sub>2</sub>, minor HC, and occasionally, traces of N<sub>2</sub> and H<sub>2</sub>S.

I F in main ore stage quartz, fluorite, and orpiment have the highest  $\delta D_{H20}$  (-50 to -97‰) and  $\delta^{18}O_{H20}$  (+12 to 0‰) values. I F in late ore realgar have low  $\delta D_{H20}$  (-133 to -151‰) and  $\delta^{18}O_{H20}$  (-13.6 to -17.0‰) values characteristic of meteoric water. I F in late ore stage calcite exhibit a wide range of  $\delta D_{H20}$  (-74 to -125‰) and  $\delta^{18}O_{H20}$  (14 to 2‰) values.

The high  $\delta D_{H20}$  and  $\delta^{18}O_{H20}$  values of main-ore stage F provide clear evidence for a deep-sourced ore F at Getchell that is either metamorphic or magmatic in origin. Mixing of the deep-sourced F with cooler, variably exchanged meteoric water may have reduced ore F T. diluted ore F CO<sub>2</sub> and H<sub>2</sub>S concentrations, and produced the lower isotope values of late ore stage F. The low  $\delta D_{H20}$  and  $\delta^{18}O_{H20}$  values of S realgar I may record the collapse of cool, dilute meteoric water into the system. (Authors' abstract)

CLOCCHIATTI, R., MASSARE, D. and THELLIER, B., 1998. Displacement kinetics of glass inclusions by thermodiffusion: a direct method of crystal- growth measurement (abst.): Reunion des Sciences de la Terre, Brest. 31 March-3 April, 1998, p. 93 (in French, translation by E.A.J. Burke). First author at Laboratoire Pierre Süe, CEA-CNRS 91191 Gif-sur-Yvette, France.

The knowledge of growth kinetics in natural silicate L is fundamental for the understanding of magmatic processes. This knowledge is especially essential for the modelling of the evolution and the solidification of magma reservoirs.

Glass I, microscopic specimens of magmas, have permitted following and measuring the speed of growth of olivine crystals in tholeitic L trapped in feldspars (Jambon et al., Chem. Geol. v. 96, 1992). The method proposed here is based on the measurement of the displacement speed of an I subjected to a temperature gradient of 30-60°C/mm in a T domain between 1135 and 1175°C. The I is displaced towards the hot pole by a dissolution process, whereas a phenomenon of crystallization occurs at the cold pole. The G bubble, initially present in the I, is displaced towards the cold pole. Where it will be immobilized and then enfolded by the crystal growth. The stretching and the tracks left by the G bubble allow measurement of this displacement. The dissolution-crystallization process causes a progressive modification of the I morphology, changing it from an initially globular form to a negative-crystal cavity.

An I in an olivine grain (Foo1.81), subjected to a gradient of  $40^{\circ}$ C/mm is displaced at a speed of  $4 \cdot 10^{.9}$  m/sec at 1175°C, and at a speed of  $2 \cdot 10^{.9}$  m/sec at 1135°C. The speed of migration depends principally from the T gradient, but it is also affected by the physico-chemical properties of the

#### host mineral and of the I. (Authors' abstract)

CLOCCHIATTI, R., SCHIANO, P., OTTOLINI, L. and BOTTAZZI, P., 1998, Earlier alkaline and transitional magmatic pulsation of Mt. Etna volcano: Earth and Planet. Sci. Letters, v. 163, no. 1-4, p. 399-407. First author at Laboratoire Pierre Sue, CEA-CNRS-UMR 9956, Centre d'Etude Nucléaire de Saclay 91191, Gif-sur-Yvette, France.

The observation of glass I with alkalic and transitional compositions in single olivine crystals from Aci Castello hyaloclastites indicates that small volumes of alkalic M preceded tholeiite eruptions during the onset of Mt. Etna volcanism. The gradual shift in composition from alkalic to transitional M is explained by simple partial melting of a compositionally uniform source, with the degree of melting increasing by a factor of 3-4 during this early melting process. Such variation controls both the chemical and mineralogical signatures of emitted lavas. The source shows trace-element and isotopic signatures which may be representative of a HIMU-type plume for Etnean lavas. (Authors' abstract)

CMÍRAL, Martin, FITZ GERALD, J.D., FAUL, U.H. and GREEN, D.H., 1998, A close look at dihedral angles and melt geometry in olivinebasalt aggregates: A TEM study: Contrib. Mineral. Petrol., v. 130, p. 336-345. Authors at Research School of Earth Sci., Australian Nat'l. Univ., Canberra ACT 0200, Australia; email (Martin.Cmiral@anu.edu.au).

In the past, geometry of partial M in polycrystalline olivine (and other materials) has been characterised by dihedral (wetting) angles which depend upon surface free energy. However, since olivine (like most other crystalline materials) is distinctively anisotropic, the simple surface energy balance defining the dihedral angles is not valid and M geometry is more complicated than can be expressed by a single dihedral angle value. We show the simple dihedral angle concept to be invalid via transmission electron microscope images. Olivine-basalt interfaces are frequently planar crystal faces (F-faces) which are controlled by the crystal structure rather than the surface area minimisation used in the simple dihedral angle concept. Nevetheless, the dihedral angles may provide useful insights in some situations. They may give a rough estimation of the wetting behaviour of a system, or be used to approximate the M distribution if F-faces are not present (possibly at large grain size and very low M fraction). Our measurements, excluding F-faces, give a range of dihedral angle values from 0 to 10° which is significantly lower than reported previously (20-50°). The nature of 0° angles (films and layers up to 1 µm in thickness) is unclear but their frequency compared to dry grain boundaries depends on grain size and M fraction (e.g. 70% for grain size 43 µm and M fraction 2%). (From authors' abstract by E.R.)

COLLINGS, M., SHERMAN, D.M. and RAGNARSDOTTIR, K.V., 1998, Complexation of Cu<sup>2+</sup> in hydrothermal (25-175°C) NaCl brines: Results from in situ EXAFS spectroscopy (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 345-346.

COLLYER, T.A., KOTSCHOUBEY, B., KHAN, H. and HIERONY-MUS, B., 1998. The hydrothermal tricolor quartz vein from São Geraldo Do Araguaia. State of Pará - Brazil, origin and application (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto. Canada, Abstracts and Programs, p. A66. First author at Inst. of Economic-Social Development the State of Pará.

The outer zone is mainly composed of smoky quartz, and the intermediate zone is constituted of irregularly banded and undulated tricolor cluster quartz. The inner part consists of clay with enclosing angular quartz fragments.

The l of the border quartz zone showed the H<sub>2</sub>O-CaCl<sub>2</sub>-NaCl system. sal range 20.6 to >23.2 wt% NaCl and T range 488-492°C. In the crystals bicolored zone have been identified the presence of the H<sub>2</sub>O-CaCl<sub>2</sub>-NaCl and H<sub>2</sub>O-FeCl<sub>2</sub>-NaCl systems and sal ranging from 13.8 to 17.3% and 19.9 to >23.2 wt% NaCl, respectively. In the red zone the H<sub>2</sub>O-FeCl<sub>2</sub>-NaCl system shows a sal range from 8.68 to 10.1 wt% NaCl and T ranging from 267 to 199°C. (From authors' abstract by E.R.)

COMPAGNONI, R., CONTE, R., FACCHINELLI, A., ORIONE, P., ROSSETTI, P. and TROSSARELLI, C., 1998. The rodingite of Bellecombe (Val D'Aosta, Italy): A petrographic and fluid inclusion study (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada. Abstracts and Programs, p. A77. Authors at Dip. di Scienze Mineralogiche e Petrologiche-Università di Torino-Via Valperga Caluso, 35-10125 Torino, Italy. The studied rodingite occurs as an alignment of boudins, ca. 1 m long and 20-50 cm thick in an antigorite serpentinite of the Piemonte Zone, W. Alps. A FI study was performed on coarse grained vesuvianite (Ves) crystals of different colour and composition:  $T_{horn}=285.4^{\circ}C\pm17$  (n=51),  $T_{em}=-26.4^{\circ}C\pm5$ ,  $T_{fm}=-9.8^{\circ}C\pm3$ , consistent with an aq F with 12.8 wt% NaCl eq. and a density of 0.88 g cm<sup>-3</sup>. A Ft-IR study gave absorption bands referable to H<sub>2</sub>O, to CH-bonds of possible aromatic hydrocarbons, but no evidence of CO<sub>2</sub>. A Mass Spectroscopy analysis on gases released upon decrepitation suggests the presence of H<sub>2</sub>, CH<sub>4</sub>, C<sub>2</sub>H<sub>6</sub>, C<sub>3</sub>H<sub>8</sub>, H<sub>2</sub>O and molecules with A.M.1>90. In conclusion, the FI study indicates that the Bellecombe rodingite formed during the Alpine greenschist facies metamorphic event and suffered at T≥285°C, during the post-climactic retrograde history, an important influx of hydrocarbon-bearing aq F of still unknown origin. (From authors' abstract by E.R.)

COOKE, D.R., BULL, S.W., DONOVAN, Serena and ROGERS, J.R., 1998, Metasomatism and base metal depletion in volcanic rocks from the McArthur Basin, Northern Territory—implications for base metal mineralization: Econ. Geol., v. 93, p. 1237-1263. Authors at Centre for Ore Deposit Research, Geol. Dept., Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania 7001, Australia.

Evidence for the leaching of base metals by oxidized, saline brines has been recognized from dolerites of the McArthur basin. Many chemical components were removed, including an almost 100% depletion of Cu. Pb, and Zn. The F responsible for potassic alteration were non-gassy, low-T ( $\approx 100^{\circ}$ C) saline (>20 wt% NaCl eq.) Na-K-Ca-Mg-rich brines. The high sal and the presence of hydrocarbons are consistent with brine derivation from the overlying evaporitic carbonates during diagenesis. Carbonoxygen (carbonate) and oxygen (silicate) isotope analyses are consistent with the formation of dolomite veins and potassic alteration in the Settlement Creek Volcanics during interaction with low-moderate T ( $\approx 100^{\circ}$ C) evolved meteoric waters±seawater ( $\delta^{18}O_{(flud)}\approx-1\%; \delta^{13}C_{(flud)}\approx-7\%)$ , which descended through the overlying carbonate horizons, becoming progressively more saline and enriched in <sup>18</sup>O as they interacted with the partially lithified sediments.

The F responsible for metal leaching and potassic alteration of the Tawallah Group dolerites are interpreted to have been low T, hematitestable, saline brines with a high base metal transporting capacity due to their oxidized nature and low H<sub>2</sub>S contents. The metals acquired by these brines could have been transported significant distances through a suitable aquifer (e.g., well-sorted hematitic sandstone), and the resultant metalliferous brines were probably involved in the formation of at least some of the stratiform Pb-Zn, MVT, and breccia-hosted Cu deposits. (From authors' abstract by E.R.)

Daughter phases found include halite, opaque, unknown (green biotite?), anatase, red-brown hydrocarbon, rutile, and hematite (E.R.).

COOPER, A., WOOD, B.J. and RAGNARSDOTTIR, K.V., 1998. The properties of carbonated fluids in the systems Na<sub>2</sub>CO<sub>3</sub>-H<sub>2</sub>O and K<sub>2</sub>CO<sub>3</sub>-H<sub>2</sub>O to 1000°C and 20 kbar (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p.347-348. Authors at Dept. of Earth Sci., Univ. of Bristol, Bristol BS8 1RJ, UK.

The results show that carbonate M can exist in a variety of P, as low as 1.5 kbar and as high as 18 kbar. Their presence can account for metasomatism observed in a variety of settings, where no traces of water are observed and cast doubts on any suggestions that  $CO_2$ -rich F exist as metasomatic agents. (From authors' abstract by E.R.)

COSTAGLIOLA, P., BENVENUTI, M., LATTANZI, P. and TANELLI, G., 1998, Metamorphogenic barite-pyrite (Pb-Zn-Ag) veins at Pollone, Apuane Alps, Tuscany: Vein geometry, geothermobarometry, fluid inclusions and geochemistry: Mineral, and Petrol., v. 62, p. 29-60. First author at Museo di Mineralogia e Litologia dell' Università, Firenze, Italy.

The southern sector of the barite-pyrite-(Pb-Zn-Ag) deposit of Pollone consists mainly of stratiform, supposedly syngenetic, barite-pyrite orebodies, whereas the northern area is characterized by a barite-pyrite-(Pb-Zn-Ag) vein system. At Pollone, arsenopyrite and chlorite geothermometers show broadly comparable results, and suggest local metamorphic peak T between 320 and 350°C. Phengite geobarometry indicates minimum P of about 3.5 kbar. Fl data and mineral equilibria suggest that the mineralizing F were initially hotter than the country rocks (about 450°C at 3.5-4.0 kbar). Rocks in direct contact with the orebodies are depleted in Rb and enriched in Sr in comparison to similar rocks elsewhere in the area. This is attributed to the presence of Rb-poor muscovite and Sr-rich barite. Rb-depleted muscovites suggest mineral-F interaction in a rock reservoir characterized

by a different (modal) mineralogical composition than the Pollone host rocks. The progressive decrease of Sr in barite with increasing distance from the orebodies may be explained with a T decrease along the infiltration paths of mineralizing F (i.e., from the vein into the wall rocks). The similar O-isotope composition of quartz from veins and host rocks is explained with the overall homogeneous O-isotope composition of the Alpi Apuane basement rocks. This indicates a limited interaction between mineralizing F and the rocks exposed at Pollone. Remobilization of syngenetic orebodies was conceivably of minor importance in the production of metamorphogenic veins. F cooling along a major tectonic lineament is thought to be responsible for barite deposition. (From authors' abstract by E.R.)

COUTINHO, M.G.N. and ALDERTON, D.H.M., 1998, Character and genesis of Proterozoic shear zone-hosted gold deposits in Borborema Province, northeast Brazil: Trans. Instn. Min. Metall. (Sect. B: Appl. earth sci.), v. 107, Sept-Dec, 1998, p. B109-Bxxx.

The vein mineralogy is dominated by quartz and pyrite in association with Fe-Ti oxides, base-metal sulphides and rarer phases that contain Ag, Bi, Cd, Mo, Te and Se. The presence of tourmaline and K-feldspar in the veins suggests the influence of granites in the hydrothermal system.

Fl studies have revealed the presence of a dominant F phase with a low sal (ca 6 wt.% NaCl eq.) and variably enriched in CO<sub>2</sub> (up to 35 mol%). T<sub>h</sub> are in the range 250-350°C. The data are compatible with immiscibility of H<sub>2</sub>O-CO<sub>2</sub>-NaCl F, at a P of ca 2 kbar. Oxygen and carbon isotopic analysis of quartz and Fl indicates that at some localities meteoric waters were incorporated into a metamorphic or magmatic F-dominated hydrothermal system. (From authors' abstract by E.R.)

CRAW, D., KOONS, P.O., CHAMBERLAIN, C.P. and POAGE, M., 1998, Rock-exchanged fluid oxygen isotope ratios in active collisional mountain belts, Pakistan and New Zealand: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 765-769. First author at Geol. Dept., Univ. of Otago, Dunedin, New Zealand.

Rock-exchanged oxygen isotope ratios [and Fl data] for vein-forming F have been estimated using laser ablation oxygen isotope data on quartz veins from two active mountain belts. Meteoric water penetrating into a tectonic thermal anomaly at Nanga Parbat, Pakistan, is fully equilibrated with the host rocks because of enhanced isotopic exchange between low density dry steam and hot rock. Isotopically exchanged F in the Southerm Alps. New Zealand. rise almost to the surface at the crest of the mountains. Rise of these deep-sourced F is due to enhanced permeability resulting from strain partitioning and dilatation during oblique collisional tectonics. (Authors' abstract)

CRAWFORD, A.J., KAMENETSKY, V.S., WOLFE, Rohan and DANYUSHEVSKY, L.V., 1998, Melt inclusions: A new tool for monitoring volatiles and chalcophile metals in evolving magma suites (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 99. Authors at Centre for Ore Deposit Research, School of Earth Sci., Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania.

We have built a modified and upgraded version of the heating stage apparatus, first designed by Prof. A.V. Sobolev at Vernadsky Inst. of Geochemistry in Moscow, which provides optical control of homogenisation and phase transformations in an  $fO_2$ -controlled environment. MI are heated until the instant of disappearance of the shrinkage bubble, which is taken to be equivalent to the point of trapping of the MI. The M is rapidly quenched from this Th using a blast of He (because of its very low thermal inertia), and invariably produces a crystallite-free glass. Such quenched glassy I can then be exposed by polishing, and analysed by various microanalytical techniques, including electron microprobe. FTIR, laser Raman spectroscopy and laser ablation ICP-MS.

A major target of our research has been to examine the evolution of volatiles and metals during crystallization of magmas that host economic porphyry Cu-Au deposits, and similar, but barren, intrusions in known porphyry districts. Abundant FI data document the coexistence of hypersaline L (brines) and V in porphyry deposits. Most metals partition preferentially into the brine, from which they may be precipitated to form ore. High T and sal of ore-forming F suggest that there should be a continuum from originally low-volatile silicate M through hydrous silicate M and hydrous saline M to late-stage water-rich F. Extensive FI research has been unable to address the early, high-T stages of magmatic F exsolution from porphyry deposit magmas. In contrast, the MI record of intrusive porphy-

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ries (mineralised or barren) is untapped, apart from a few studies which documented silicate/salt M immiscibility in granites We have commenced this attack with a MI study of the Balut dyke from the Dinkidi porphyry Cu-Au deposit in Luzon. This dyke is a late stage transitional alkaline monzodiorite pegmatite strongly implicated in the Cu-Au mineralisation at Didipio. Fresh magmatic homblende and clinopyroxene phenocrysts preserve numerous MI. I contain different proportions of silicate glass, silicate dxl (e.g., mica and amphibole), opaque minerals (e.g., haematite, magnetite, and chalcopyrite), salt crystals (e.g., Na and K chlorides and sulfates), a V bubble and L H2O. Preliminary ICP-MS-determined bulk compositions have significant quantities of Na, K. S, Cl, and precious- and chalcophile metals. These I record the latest stage in the evolution of such magmas, when an immiscible metal- and volatile-rich salt-silicate component separates from the cooling magmatic system and evolves into hydrothermal hypersaline brines and solutions. Further studies on this occurrence and several other major porphyry Cu-related intrusive rocks are in progress, and should provide important new constraints on the late magmatic evolution of F, brine segretation, and partitioning of the chalcophile and base metals An optimal outcome from this work would be the demonstration that 'fertile' potentially mineralising magmatic systems have certain diagnostic compositional features clearly different from barren systems. (From authors' abstract by E.R.)

CROCKET, J.H., 1998, PGE in Hawaiian basalt: Implications for PGE mobility in volcanic fluids (abst.): 17th General Meeting Int'I. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A6. Author at School of Geog. and Geol., McMaster Univ; email (crocketj@mcmail.cis.mcmaster.ca)

Gold, Pd, Ir, Os and Pt were determined by radiochemical neutron activation in fresh and altered basalt, and fumarolic condensates from Kilauea volcano, Hawaii. The objective was to evaluate the mobility of these metals in basaltic rock in response to surficial hot water-rock reactions, and to evaluate transport properties as reflected in fumarolic condensates. The presence of ralstonite, a fluorine-bearing mineral, suggests the possibility that halogen complexes may transport noble metals in Kilauea magmas. (From author's abstract by E.R.)

CUNNINGHAM, C.G., RASMUSSEN, J.D., STEVEN, T.A., RYE, R.O., ROWLEY, P.D., ROMBERGER, S.B. and SELVERSTONE, J., 1998, Hydrothermal uranium deposits containing molybdenum and fluorite in the Marysvale volcanic field, west-central Utah: Mineralium Deposita, v. 33, p. 477-494. First author at U.S. Geological Survey, 954 Nat'l, Center, Reston, VA 20192, USA; email (cunningham@usgs.gov).

Uranium deposits containing molybdenum and fluorite formed in an epithermal vein system that is part of a volcanic/hypabyssal complex. Uranium-bearing, quartz and fluorite veins were deposited by a shallow hydrothermal system. The veins, which filled open spaces along the high-angle fault zones and flat-lying fractures, were deposited within 115 m of the ground surface above the concealed rhyolite stock. Hydrothermal F with T near 200°C,  $\delta^{18}O_{H20}$ —15.  $\delta D_{H20}$ —130. log  $fO_2$  about -47 to -50, and pH about 6-7, permeated the fractured rocks; these F were rich in fluorine, molybdenum, potassium, and hydrogen sulfide, and contained uranium as fluoride complexes. The hydrothermal F reacted with the wallrock resulting in precipitation of uranium minerals. (From authors' abstract by E.R.)

Homogenization T and sal of 132 Fl were measured in 18 quartz and fluorite samples. Fl Th for all samples show a peak at about 200°C. Quartz Fl T are generally hotter (190-260°C) than most of the fluorite Fl T, there is overlap in the 200-250°C range. The median Th of Fl in green and purple fluorite is 190-200°C, clear fluorite is slightly less at 170-180°C, and quartz is hotter at 210-220°C. Coexisting V and L-rich I in fluorite were found in the near-surface samples and indicate boiling occurred at these levels. Fl T in minerals deeper in the mine are hotter than those near the present ground surface. The inclusion F are generally dilute. The median sal is 0.0-0.5 wt% NaCl eq. for quartz and for green and clear fluorite, and slightly higher, 0.5-1.0 wt% NaCl eq., for purple fluorite. A small, generally rhombic dm was noted in fluorite of different colors: it did not dissolve upon heating to Th. Carbon dioxide as L or clathrates was not found in any samples. (From authors' text by E.R.).

D'ALESSANDRO, W., GIAMMANCO, S., PARELLO, F. and VA-LENZA, M., 1997, CO<sub>2</sub> output and  $\delta^{13}C(CO_2)$  from Mount Etna as indicators of degassing of shallow asthenosphere. Bull Volcanol, v. 58, p. 455-458. First author at Istituto di Geochimica dei Fluidi (CNR), via Torino 27/D, 1-90133 Palermo, Italy.

An estimated average CO<sub>2</sub> output from Etna's summit craters has recently been determined. The volume of magma involved is approximately 20 times greater than the volume of magma erupted annually during the period 1971-1995. On the basis of C-isotopic data of CO<sub>2</sub> collected in the Etna area and of new hypotheses on the source of Mediterranean magmas, significant contributions of CO<sub>2</sub> from non-magmatic sources to the total output from Etna are unlikely. Such large outputs of CO<sub>2</sub> and also of SO<sub>2</sub> from Etna could be due to an anomalously shallow asthenosphere beneath the volcano that allows a continuous escape of G toward the surface, even without migration of magma. (From authors' abstract by E.R.)

DANYUSHEVSKY, L.V., 1997, High-Ca boninites: A result of the interference of mantle plumes into the affairs of subduction zones?: J. of the Czech Geological Society, MAEGS-10, v. 42, no. 3, p. 7-x. Author at Dept. of Geol., Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania, 7001, Australia.

Experimental studies of MI in olivine phenocrysts from Tongan and Troodos boninites have demonstrated that their P M had high MgO (2)-24 wt%) and moderate H<sub>2</sub>O (around 2 wt%), and crystallization T of 1350-1389°C at about 1 kbar. A high-P experimental study has demonstrated that such M are in equilibrium with a harzburgite mantle residue at 15-17 kbar and 1430-1470°C. (From authors' abstract by H.E.B.)

DANYUSHEVSKY, L.V. and FALLOON, T.J., 1998, Melt inclusion and high-P experimental constraints on primary magmas and mantle melting (abst.); EOS, Trans., 79 (45) Fall Meet. Suppl., p. F1003. Authors at School of Earth Sci., Univ. of Tasmania, GPO Box 252-89, Hobart, TAS 7001, Australia; email (L.Dan@utas.edu.au)

Our studies from the northern Tonga forearc, the Troodos Ophiolite and the Lau Basin backarc spreading centres show that the major element compositions of the parental magmas reflect high degrees of melting coupled with high P of magma separation. Preservation of these high P signatures in MI, trapped during low-P crystallization, requires a very effective channelling mechanism operating at significant depths in the mantle (down to 60 km). The fact that major elements of MI from these suites did not identify components of a melting column suggests that aggregation was complete before the onset of crystallization. (From authors' abstract by E.R.)

DARLING, R.S., 1998, Modeling magmatic phase equilibria with synthetic H2O-KCI fluid inclusions: An interactive laboratory exercise for undergraduate petrology students (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-132, Author at Dept. of Geol., State Univ. College at Cortland, Cortland, NY, 13045; email (darlingr@cortland.edu)

The low T phase behavior of H<sub>2</sub>O-KCI FI is nearly identical to that shown by simple binary magmatic systems. Because this phase behavior can be observed at reasonable classroom or laboratory T, study of the H<sub>2</sub>O-KCI system offers petrology students a visual, interactive learning experience of an important magmatic process that cannot be directly observed.

Using synthetic H2O-KCI FI (sealed in quartz) of known composition (5, 10, 15, 20, 22.5 and 25 wt % KCl) and a microscope equipped with a heating and cooling stage, students conduct experiments in which they observe and control: 1) eutectic melting of ice and sylvite, and 2) liquidus melting of ice or sylvite These phase changes are observed and T recorded while the stage is warmed from sub-eutectic T (<10.7°C). Using this data, petrology students construct their own phase diagram of the water-rich portion of the H2O-KCI system and, at the same time explore questions on the: 1) relationship between cutectic and liquidus T and bulk composition. and 2) applications of the phase rule at various T. During initial cooling of the H-O-KCl inclusions, students observe metastable (supercooled) brine, followed by nucleation of ice and sylvite. Cooling at any point on the liqundus nicely demonstrates euhedral crystal textures analogous to those produced during magmatic crystallization whereas warming on the liquidus demonstrates anhedral crystal textures analogous to those produced during magmatic melting.

The main advantage of this laboratory technique is that all of the important phase changes analogous to simple binary magmatic systems can be visually observed and controlled by the student. Consequently, every point, line and space on a phase diagram has direct relevance to the student and results in a more meaningful understanding of phase diagrams and their application to igneous rocks. (Author's abstract)

DARLING, W.G., 1998a, Hydrothermal hydrocarbon gases: 1, Genesis and geothermometry: Applied Geochemistry, v. 13, no. 7, p. 815-824. Author at British Geological Survey, Wallingford, Oxfordshire 0X10 8BB, UK.

Various sources for hydrothermal CH4 have been proposed over the years. While C isotope studies have narrowed the possibilities, enough higher hydrocarbon G data now exist both to supplement the isotopic data and to permit additional deductions regarding origins. Comparison of typical C1-C6 data for G of various origins (from sedimentary and crystalline rocks, and hydrothermal systems) reveals certain characteristics. Apart from isotopic differences, hydrothermal hydrocarbons differ from sedimentary hydrocarbons mainly in possessing tendencies toward a relative excess of CH4, higher normal/iso ratios for butane and pentane, and relatively high amounts of C6 G. Despite these differences, consideration of the evidence indicates that hydrothermal hydrocarbon G in most cases originate like sedimentary basin G by thermal degradation of organic matter in the relatively shallow subsurface. The principal characteristic of these hydrothermal G. "excess" CH4, appears to have a geothermometric function. The following empirical relationship has been derived. r°C=57 log(CH4/C2H6)+96.8, which fits moderately well a range of geothermal fields worldwide. This G geothermometer may be particularly applicable during geothermal exploration in areas where there is little direct knowledge of subsurface conditions. (Author's abstract)

DARLING, W.G., 1998b, Hydrothermal hydrocarbon gases: 2. Application in the East African Rift system: Applied Geochernistry, v. 13, no. 7, p. 825-840. Author at British Geological Survey, Wallingford, Oxfordshire 0X10 8BB, UK.

Hydrocarbon G are ubiquitous in the hydrothermal systems of the East African Rift System (EARS), though often found at very low concentrations in the 'volcanic' eastern branch as compared to the 'sedimentary' western branch. Study of the chemical and isotopic compositions of these hydrocarbons from sites in Kenya, Ethiopia, Djibouti and Uganda reveals considerable homogeneity over hundreds of km of the various rift units Consideration of C and He isotopic evidence points to a predominantly crustal thermogenic origin for the hydrocarbons, there being no evidence of mantle inputs in either the MORB or 'hotspot' sectors of the EARS. Temperature information from geothermal wells has been utilised to investigate the relationship between reservoir T and ratios of CH4 to C2H6. The general C1/C2 geothermometric relationship proposed in Part 1 of this study holds reasonably well, and is shown to give results equal to or better than the 'inorganic' G geothermometers presently in use, both in the wellfields and undeveloped high-enthalpy geothermal areas. Results from lowenthalpy hot spring systems are less well correlated with apparent deep T. but consistent with data from similar systems elsewhere in the world. (Author's abstract)

DAVIDSON, G.J., 1998, Alkali alteration styles and mechanisms, and their implications for a 'brine factory' source of base metals in the riftrelated McArthur Group, Australia: Australian J. of Earth Sci., v. 44, p. 33-49. Author at CODES SRC, Univ. of Tasmania, P.O. Box 252-79, Hobart, Tasmania 7001, Australia.

McArthur Group alkali metasomatism occurred in several phases. none of which fit a classic model of alkali-mineral zonation towards an evaporitic basin centre as previously proposed. They comprise (i) troughmargin alteration along the Emu Fault zone, formed by gravity-driven meteoric-evaporitic brines sourced from adjacent shelves, and focused up to 3.5 km out into the adjacent deeper water clastic succession of the Barney Creek Formation: these formed zoned albite-microcline assemblages. variably overprinted by B-bearing illite: (ii) ore-related alteration at the HYC Zn-Pb-Ag deposit, which overprinted trough-margin alteration in places, adding disseminated ankerite, adularia and base-metal sulfides to some feldspathised beds; (iii) early diagenetic alkali metasomatism that was associated with descending/advecting brines sourced from overlying evaporite sequences, and transmitted through porous clastic sediments (e.g., parts of the Lynott Formation, Mara Dolomite and Tatoola Sandstone): and (iv) extensive inversion-related K-feldspar metasomatism of volcaniclastic beds towards the basin centre. The descending/advecting brine model (iii) has implications for sedimentary Zn-Pb ore genesis in the basin, because it offers a mechanism to efficiently deliver batches of saline F into the deep diagenetic environment, resulting in alkali alteration and metal leaching, and the production of ideal Zn-Pb-transporting ore F A variation in the flux of saline diagenetic water, caused by eustatically and tectonically driven aridity cycles in sedimentary facies, could have imposed strong episodicity on the formation of related Zn-Pb deposits. This speculative model is relevant to metals exploration on the premise that each 'brine factory' potentially gave rise to a related cycle of Zn-Pb ore deposition at the same or an overlying stratigraphic level. (Author's abstract)

DAVIS, M.J. and IHINGER, P.D., 1998, Heterogeneous crystal nucleation on bubbles in silicate melt: American Mineralogist, v. 83, p. 1008-1015. Authors at Dept of Geol. and Geophys., Yale Univ., New Haven, CT 06511, USA.

Experiments reported herein document heterogeneous crystal nucleation on bubbles in supercooled lithium disilicate M. Crystalline lithium disilicate (Li<sub>2</sub>Si<sub>2</sub>O<sub>3</sub>) nucleated and grew on small bubbles (~1 µm) with a one-to-one correspondence between the number of bubbles and crystals (ranging from <10<sup>2</sup> to 10<sup>5</sup> bubbles/mm<sup>3</sup>). Crystals grew on large bubbles (>100 µm) only in samples fused in N<sub>2</sub>, suggesting a chemical control on nucleating efficiency. Bubbles ~1 µm in diameter served as nucleation sites for polycrystalline lithium disilicate spherulites; bubbles smaller than 1 µm served as nucleation sites for the more common ellipsoidal crystalline form. This difference in behavior might be due to the additional surface area available for crystal nucleation on the 1 µm bubbles.

Findings suggest superliquidus thermal history can influence crystal nucleation via bubble formation induced by supersaturation, and has implications for natural samples and experimental studies. Heterogeneous crystal nucleation on bubbles may serve as an efficient nucleation mechanism in natural degassing magmas and aid in the formation of fine-grained groundmasses common to many volcanic rocks. We have documented a new mechanism of spherulite formation in highly supercooled silicate M, similar to conditions thought to exist during devitrification of natural glasses. The ability of crystals to nucleate on bubbles can be exploited in the production of commercial glass-ceramic materials. (Authors' abstract)

De CORTE, K., CARTIGNY, P., SHATSKY, V.S., SOBOLEV, N.V. and JAVOY, M., 1998, Evidence of fluid inclusions in metamorphic microdiamonds from the Kokchetav massif, northern Kazakhstan: Geochim. et Cosmo. Acta, v. 62, no. 23/24, p. 3765-3773. First author at Dept. of Geol. and Soil Sci., Univ. of Ghent, Krijgslaan 281 S8, B-9000 Ghent, Belgium.

Microdiamonds from garnet clinopyroxenites of the Kokchetav massif (northern Kazakhstan) and associated alluvial diamonds have been investigated using infrared spectroscopy. All diamonds have high nitrogen contents (from 747 up to 4488±20% at. ppm) and are of type lb-laA. Nitrogen data are consistent with a diamond formation over a narrow T range. Microdiamonds from garnet clinopyroxenites are characterized by water and carbonate I, similar to those occurring in fibrous coated diamonds from kimberlite, which suggest that diamonds grew from a C-H-O fluid. In contrast, alluvial microdiamonds do not contain any carbonate I and H<sub>2</sub>O is absent or present in only minor amounts. Alluvial diamonds are considerably more N-rich but have a similar range of nitrogen aggregation states. It is suggested that alluvial diamonds belong to a separate diamond population compared with the microdiamonds from garnet clinopyroxenites.

The Kokchetav microdiamonds are distinct from kimberlitic fibrous diamonds in that they contain abundant lb centres, have high nitrogen contents and show different populations depending on host rock type. These characteristics support a metamorphic origin for the microdiamonds from the UHPM rocks of the Kokchetav massif. (Authors' abstract)

de RONDE, C.E.J., 1998, Chemistry of 3.2 Ga seafloor hydrothermal vent fluids: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 19-24. Author at Inst. of Geological and Nuclear Sci., Lower Hutt, New Zealand.

Ancient (ca. 3.2 Ga) seafloor hydrothermal vents, known as the Ironstone Pods, have been identified in the Barberton greenstone belt of South Africa Ironstone Pod hydrothermal F end-member concentrations (Mg=0) of various dissolved components, derived from bulk FI crush-leach experiments. include: C1 (730 mmol/I), Br (2.59), I (0.058). Na (822), NH<sub>4</sub> (114), K (21.5), Ca (42.6), and Sr (0.15). This hydrothermal F also contains up to 1.07 mol% CO<sub>2</sub>, 0.03 mol% N<sub>2</sub>, 0.02 mol% CH<sub>4</sub>, 262 ppm COS, and minor amounts of C<sub>2</sub>-C<sub>4</sub> hydrocarbons. Hydrothermal end-member Ca, Sr and NH<sub>4</sub>, in particular, and to a lesser degree K, I and CO<sub>2</sub>, commonly plot on, or very close to, modern vent F trends. By contrast, end-member Na and Br concentrations are distinct (higher) from modern vent F. High I and NH<sub>4</sub> concentrations are consistent with contributions from sediments and/or organic matter. (Author's abstract)

Th mainly in 100-200°C range: Tmee. -3 to -40 (E.R.)

De Ros LUIZ, Fernando, 1998, Heterogeneous generation and evolution of diagenetic quartzarenites in the Silurian-Devonian Furnas formation of the Parana Basin, southern Brazil: Sedimentary Geol., v. 116, no. 1-2, p. 99-128. Author at Uppsala Univ., Inst. of Earth Sci., Uppsala, Sweden.

Silurian-Devonian sandstones of the Furnas Formation in the intracratonic Parana Basin, southern Brazil, display strongly heterogeneous distribution of quartz, kaolinite and illite authigenesis. The sandstones were affected by extensive dissolution/kaolinization of detrital feldspar, mica and clay under an eodiagenetic meteoric regime. Circulation of hot F through fractures related to the uplift and magmatism along the regional Ponta Grossa Arch promoted heterogeneous kaolinite and feldspar illitization and quartz cementation. This is supported by intense illitization of kaolinite at shallow depths, by K/Ar dating of the illite, whose age coincides with the magmatism, and by high FI Th in quartz overgrowths from outcrop-samples. The progressive destruction of feldspar-generated diagenetic quartzarenites with poorly connected pore systems and low reservoir potential [sic]. Evidence yielded by this study suggests that the application of simplified "isochemical" models of diagenetic processes within the system SiO2-Al2O3-K2O-H2O may have very limited validity, applying basically to the deep-burial mesodiagenesis of some sandstones in rapidly subsiding basins. (Author's abstract)

ZHANG, Dehui and WEI, Liu, 1998, The fluid inclusions researches on the Yinshan polymetallic deposit, Jiangxi Province, China (abst.). 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A34. First author at China Univ. of Geosci., Beijing, 100083 P.R. China; email (Zyb@cug.edu.cn)

Yinshan, a large-scale Cu-Pb-Zn-Au-Ag polymetallic deposit, is in Jiangxi Province, China. FI research shows:

- In polymetallic ore veins, some FI of halite dm-bearing have been discovered.
- The FI may be divided into two groups: high saline (30-45 wt% NaCl eq) and low saline (2.86-14.4 wt% NaCl eq).
- 3. There are L-CO2-bearing I in polymetallic ore veins
- 4. Th of Fl range from 95 to 520°C.
- The plot of T<sub>h</sub> vs sal shows two groups of data and the curvilinear correlation between T<sub>h</sub> and sal.
- 6. Sal and Th decrease southwesterly and upwards.

From the points mentioned above, the conclusions can be drawn as follows: the high sal indicate that the hotter hydrothermal F was mostly magmatic [which mixed with cool dilute F]. It is inferred that it is possible there is a concealed igneous body and a concealed porphyry copper deposit at depth of the deposit. (From authors' abstract by E.R.) (Editor's note: authorship incorrectly transcribed as "Dehui, Z. and Wei, L"in original)

DELLA-PASQUA, Fernando, KHIN Zaw, MERNAGH, Terry, RYAN, Chris and VARNE, Rick, 1998. Composition of primary melt and fluid inclusions in olivine phenocrysts from Lombok, Indonesia: Implications for magma genesis and metal enrichment (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 112. First author at School of Earth Sci., Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania 7001, Australia.

M and Fl from a suite of primitive samples on the island of Lombok, Indonesia, were investigated to 1) define the chemical affinities of the parental magma and 2) assess the role of CO<sub>2</sub> and trace element composition on magma genesis and metal enrichment.

Olivine phenocrysts in ankaramite from Lombok are the earliest crystallising silicate phase. Thus, P I in these phenocrysts preserve information about the prevailing magmatic conditions during the early stages of crystallization. Four types of such I were found: L (melt), S (solid), V (vapour), and a combination of the three (L±V±S). S-type I consist mostly of chromian spinel. Very rarely however, immiscible F bubbles are accidentally attached to these Cr-spinel crystals and become trapped by a growing olivine phenocryst to form S+V±L P I.

A DILOR MICRODIL-28® Laser Raman Spectroscope (LRS) at the AGSO, Canberra, was used to scan for N<sub>2</sub>, CO<sub>2</sub> and CH<sub>4</sub> F species in the F bubble of S+V $\pm$ L type I. These analyses confirm the trapping of a CO<sub>2</sub>rich F phase by the growing olivine (Fo<sub>88.90</sub>) phenocrysts. However, N<sub>2</sub> and CH<sub>4</sub> were not detected. No CO<sub>2</sub> was detected in the shrinkage bubbles within MI.

MI (L-type) in magnesian olivine phenocrysts are typically crystalline. These I were homogenised, using a heating stage, and then quenched to a homogeneous glass to determine their major and trace element composition. Electron microprobe analyses of homogenised MI indicate that the ankaramites magma formed by the aggregation of silica undersaturated M fractions. Preliminary Proton Induced X-ray emission (PIXE) microanalysis of the crystalline MI showed elevated concentrations of Cu, S and Ca, and significant Ni and Se. The homogenised MI showed trace Sr and Y, but very low concentrations of ore elements (Cu–40 ppm). No Cu was

#### observed in the V-rich I.

The presence of S+V±L type I in olivine phenocrysts is of fundamental significance for magma genesis because: 1) it indicates that, at least locally, some zones of the magma were F saturated during early stages of crystallization, 2) it supports a mechanism where ankaramitic M are generated as P M by mantle partial melting in the presence of CO<sub>2</sub>, 3) it suggests that a CO<sub>2</sub> F phase must play an important role in the genesis of primitive ankaramitic magmas, 4) the presence of such immiscible F at magmatic T (>900°C) provides a potential medium for the early partitioning of metals into a volatile phase within the host magma, 5) with increasing degree of crystallization the exclution of this F phase is likely to increase as magma evolves to more felsic composition, and 6) demonstrate the presence of mantle-derived CO<sub>2</sub>.

In summary, these results suggest that the ankaramite magma was saturated in CO<sub>2</sub>-bearing F early in its evolution. This interpretation can be extended to other ankaramite suites such as Ulakan (Bali) and Merelava (Vanuatu arc), where similar S+V±L P I are found. Combined M and FI data may be used to ascertain the mineral potential and the barren/fertile nature of magma types. (From authors' abstract by E.R.)

den BROK, S.W.J. (Bas), 1998, Effect of microcracking on pressuresolution strain rate: The Gratz grain-boundary model: Geology, v. 26, no. 10, p. 915-918. Author at Instut für Geowissenschaften, Johannes Gutenberg-Universität, Becherweg 21, 55009 Mainz, Germany.

Different, but reasonable and well-accepted assumptions made about grain-boundary structure during pressure-solution (PS) creep may easily have an effect of more than 10 orders of magnitude on the calculated PS deformation rate. Understanding of grain-boundary structure during PS creep is therefore extremely important. Experimental evidence is presented in support of a grain-boundary model previously proposed by A.J. Gratz on the basis of observations on naturally deformed rocks. The model predicts that sudden increases in stress or F P may lead to microcracking and subsequently many-orders-of-magnitude increase in PS deformation rate. (From author's abstract by E.R.)

den BROK, Bas, PASSCHIER, Cees and SIEBER, Michel, 1998. Fibre growth in wet salt aggregates in a temperature gradient field: Mineralogical Magazine, v. 62, no. 4, p. 527-532. Authors at Inst. für Geowissenschaften, Becherweg 21, D-55099 Mainz, Germany.

Intense fibrosity develops in wet porous NaCl crystal aggregates (grain size 250-500  $\mu$ m) held in a T gradient field (0.5-4°C/mm) at T between 20 and 50-60°C *In situ* microscopic observation of the process shows that fibre growth is associated with T-gradient driven motion of tiny G (ar. water V) bubbles present in the saturated intercrystalline aq NaCl solution. Gas bubbles move through the intercrystalline pore F into the cold direction. They only move if they are next to a NaCl crystal; bubbles that are 'free' do not move. Each bubble is 'pushed' into the cold direction by a growing crystal fibre of the same diameter as the bubble itself. Fibres apparently grow due to oversaturation of the NaCl solution at the hot side of the G bubble. Crystals dissolve at the cold side of the G bubbles, apparently by undersaturation of the NaCl solution there. Thus, bubbles dissolve their way through NaCl-crystals and aggregates. Intense fibrosity develops within weeks. (Authors' abstract)

Also of pertinence to the movement of FI in salt if it is used as a medium for nuclear waste storage (E.R.).

den BROK, Bas, ZAHID, Mohsine and PASSCHIER, Cees, 1998. Cataclastic solution creep of very soluble brittle salt as a rock analogue: Earth and Planet. Sci. Letters, v. 163, p. 83-95. First author at Institut für Geowissenschaften, Johannes Gutenbert-Universität, 55009 Mainz, Germany.

Until about the late 1960s, macroscopically ductile deformation of quartz was seen as a microscopically cataclastic process by most geologists (cf the origin of the name 'mylonite'). Undulatory extinction, subgrains, recrystallised grains and even crystallographic preferred orientations were interpreted as due to water-assisted brittle deformation processes. Nowadays, by contrast, the occurrence of these optical microstructures is considered as conclusive and unequivocal evidence for dislocation creep. The abundance of these microstructures in naturally deformed rocks lead to the conclusion that dislocation creep is the most important ductile deformation mechanism within the Earth's crust. We studied whether a water-assisted brittle deformation mechanism could, in principle, be able to produce apparent 'crystal plastic' microstructures, and how. To this end we performed a long-term deformation experiment using soluble brittle salt (NaCIO<sub>3</sub>) as an analogue for quartz. A single crystal of NaCIO<sub>3</sub> was uniaxially stressed for 44 days at room T in the presence of a saturated NaClO<sub>3</sub> solution under atmospheric P. The crystal was microscopically studied *during* the experiment. It slowly deformed by cataclastic creep. First, irregular free face dissolution structures developed at highly stressed portions of the crystal. These locally developed into very fine channel-like structures, mostly oriented sub-parallel to crystallographic planes. Most of the channels developed into slits and finally into fractures. Fracture walls migrated by solution transfer leading to changes in shape of the crystal fragments. The resulting polygonal deformation microstructure could easily be mistaken for a dynamically recrystallised 'crystal plastic' microstructure. Therefore, care should be taken to use such optical microstructures as conclusive evidence for dislocation creep. This is important because the occurrence of these microstructures is the strongest argument for dislocation creep in crustal rocks. (Authors' abstract)

DENEELE, D., SAUVAGE, A.C., DUBOIS, M., BUATIER, M., LO-PEZ, M. and POTDEVIN, J.L., 1998, Fluid-rock interaction. 1. Mineralizations with nacrite and barite in karst cavities of the Lodève Basin, a fluid-inclusion study (abst.): Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998, p. 101 (in French, translation by E.A.J. Burke). First author at Université de Lille I, URA 719, 59655 Villeneuve d'Ascq.

Nacrite is a rare mineral of the kaolinite group: its conditions of formation (T, P, F composition) are not well-known. The mineral has been found in the fillings of karst cavities in Cambrian dolomite of the Lodève Basin (France). Nacrite is associated with newly formed quartz, dolomite, and barite 1, which seem to be at least partly contemporaneous with it. The FI in barite crystals have been studied to characterize the F which formed these mineralizations.

The large majority of the P I are monophase L. coexisting with rare biphase I. On cooling the specimen, the T<sub>e</sub> is between -65 and -60°C (system H<sub>2</sub>O-NaCl-CaCl<sub>2</sub>), and the ice melts between -29.2 and -5.9°C. Hydrates (hydrohalite) have been observed, they melt around -20°C, although some of these continue to be present at higher T. The ice-melting T imply that the F is highly saline (up to 25 wt.% eq. NaCl). This sal was probably caused by interactions with evaporite levels in the sedimentary cover.

Taking into account the stretching phenomenon (inelastic and irreversible deformation of the crystal around the I), the  $T_t$  of the I in barite are between 80 and 100°C. These would also represent the  $T_f$  of nacrite, relatively low in comparison to the estimated data in literature. (Authors' abstract)

DENNIS, P.F., 1998, The stable isotope composition of fluid inclusions in speleotherms: Palaoprecipitation, palaeothermometry and climate change (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A31. Author at Stable Isotope Laboratory, School of Environmental Sci., Univ. of East Anglia. Norwich, NR4 7TJ, UK.

The speleotherm archive is unique containing a high-resolution palaeotemperature, palaeoprecipitation and palaeogroundwater isotopic composition record. Most speleotherms contain up to 0.1 wt% of water in the form of Fl that were trapped in the host calcite at the time of growth. This relict seepage water is closely related to the mean annual meteoric precipitation composition of the cave site during the time of speleotherm growth. Provided the speleotherm grew in thermal isotopic equilibrium, then measurement of both the 1 and host calcite compositions can be used to define the palaeoprecipitation isotope composition and cave palaeotemperature. There are, however, considerable technical problems associated with the extraction and measurement of small, submicro-litre volumes of 1 water and measuring both the hydrogen and oxygen isotopic compositions to the better than  $\pm 2(\delta^2H)$ % and  $\pm 0.2(\delta^{18}O)$ % precisions that are required for palaeoclimate work.

In this paper I present results from a series of experiments on synthetic I that demonstrate that reliable and robust recovery of I water is possible without modification of its isotopic composition. Using these techniques FI data obtained from Holocene speleotherms covering a known climate range from northern Norway to southern Europe are used to show that the I accurately record the range of modern meteoric precipitation compositions reported for this region. Finally, high-resolution (approximately 100 years) FI isotopic records from several speleotherms from western England are presented.

The techniques used in this work have wider applications in other areas of Fi study including low T hydrothermal veins, diagenetic studies, etc. (Author's abstract)

DEVIDAL, J.-L., GIBERT, F., KIEFFER, B., PIN, C. and MONTEL,

J.M., 1998, A new method for solubility measurement: Application to NdPO4 system in H<sub>2</sub>O-NaCI-HCI hydrothermal fluids (abst.): Mineralogical Magazine, v 62A, V M Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 375-376. Authors at UMR 6524 Magmas et Volcans Université Blaise Pascal, 5 rue Kessler, 63000 Clermont Ferrand, France.

Of pertinence to nuclear waste storage (E.R.).

DIAMOND, L.W., 1998, Underpressured paleofluids and future fluid flow in the host rocks of a planned radioactive waste repository: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 769-773. Author at Inst. of Mineral. and Petrol., Univ. of Bern, Switzerland.

Low-permeability marls at Wellenberg, Central Helvetic Alps, are the host rocks of a planned radioactive waste repository for Switzerland. Fl in the marls indicate that, during Oligo-Miocene Alpine metamorphism, twophase CH4-H2O-NaCl F formed in-situ with P that evolved from lthostatic to subhydrostatic. The underpressures resulted from porosity being created by nappe folding under hydrodynamically closed conditions. Free F in boreholes exhibit the same two-phase state, the same compositions, and locally the same underpressured (now subhydrostatic) regime as the paleofluids. Whereas other workers have explained the modern underpressures as transient effects of post-glacial rebound, the new correlations suggest the P anomalies are relicts of Alpine tectonics. The implications are that zones of the marls have remained hydrodynamically closed for ~20 Ma, and that therefore they are likely to remain closed into the distant future, potentially providing a suitable environment to isolate waste. (Author's abstract)

DIETRICH, A., LEHMANN, B., WALLIANOS, A. and TRAXEL, K., 1998, Contrasting melt inclusion and bulk rock geochemistry of Bolivian tin porphyry systems suggest a two-stage magmatic evolution (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). First author at Inst. für Mineralogie und Mineralische Rohstoffe, TU Clausthal, Germany.

The Miocene tin porphyry systems of Llallagua, Chorolque, Oruro and Cerro Rico in the Andean tin belt of Bolivia, are related to subvolcanic stocks/domes. The rocks consist of phenocrysts of quartz, feldspars and biotite, and of 50-60% of fine-grained groundmass. The central parts of the systems are affected by strong tournalinisation and silicification, overprinted by and passing outwards into sericitic alteration. A weak propylitic alteration is locally developed in distal parts of the systems. Tin mineralisation occurs as disseminated cassiterite and (dominantly) in quartztournaline-cassiterite-sulfide veins. Llallagua is the largest hard rock tin mine in the world, whereas the famous Cerro Rico was one of the richest silver mines before it became an important tin producer.

MI occur in quartz phenocrysts, and are round to negative crystalshaped with diameters ranging in between a few to 50 gm [µm?]. A shrinkage bubble is most times developed. The MI were studied by electron (EPMA) and proton (PIXE) microprobes. Major element composition of the MIs is characterised by low CaO. Na<sub>2</sub>O and high K<sub>2</sub>O concentrations, indicating that quartz crystallization occurred after main plagioclase crystallization and synchronous or prior to K-feldspar formation. Shandindices around 1.1 show a peraluminous composition of the MI. High Ta, low TiO<sub>2</sub> and low Zr concentrations of the MI correspond to the fractionation trend of Tertiary granitic/rhyolitic rocks of the tin belt. The high degree of magmatic fractionation of the MI is similar to tin granites/rhyolites, but is in sharp contrast to the bulk rock geochemistry of the porphyries. The magmatic tin enrichment up to 83 ppm Sn in the MI, with complementary depletion in TiO2, correlates with the Sn-TiO2 fractionation trend of Tertiary magmatic rocks of the tin belt (Fig. 1). The bulk rock tin contents in the tin porphyries show a scatter distribution resulting from hydrothermal overprint.

The sharp contrast between bulk rock and MI geochemistry leads to a two-stage magmatic evolution of the Bolivian tin porphyries which explains the anomalous situation of tin mineralisation associated with relatively little fractionated rhyodacitic rocks. The model requires the existence of an unexposed magma chamber of highly fractionated M and the exsolution of tin-rich F from this M during interaction with andesitic/basaltic M portions. From authors' abstract by E.R.)

See figure in the Illustrations appendix.

DINGWELL, D.B., 1998. The glass transition in hydrous granitic melts: Physics of the Earth and Planetary Interiors, v. 107, no. 1-3, p. 1-8.

The influence of water on the glass transition T of hydrous granitic M is estimated on the basis of a variety of available sources of data that provide phenomenological data for the L-glass transition and for which the relaxation timescale can be accurately estimated. These sources include (a) dilatometric micropenetration viscosity determinations (b) T-dependent spectroscopic investigations of hydrous M and (c) densities of synthetic FI in glasses. All available evidence on the glass transition T of hydrous granitic M, when corrected for equivalent timescales, yields a single consistent trend of decreasing Tg with increasing water content that has powerful applications in the rheology and kinetics of processes involving latestage silicic intrusives and eruptive products. The brittle-ductile transition in hydrous silicic L can be accurately predicted using this trend. Combination of the presently derived relationship for the influence of water on the glass transition of granitic M with presently available data for the high T viscosities of such systems permits the estimation of the T dependence of the viscosity of hydrous M over the entire range of T relevant to granite petrogenesis. Such a comparison reveals that the viscosity-T relationships of hydrous granitic M are not Arrhenian, as is assumed by all existing calculational schemes for the prediction of hydrous M viscosities. The increasing deviation of viscosity-T relationships of hydrous granitic M from Arthenian with increasing water content is broadly consistent with similar trends accompanying the addition of excess alkalies to metaluminous granitic M base compositions. In detail, however, the influence of water on the deviation of viscosity-T relationships of hydrous granitic M from Arrhenian is not as strong as would be predicted from a molar companison of the effects of H2O vs. alkali oxide or alkaline earth oxide added to these M The answer to this apparent discrepancy may lie in the incomplete dissociation of water in the M structure. (Author's abstract)

DINGWELL, D.B. and HESS, K.-U., 1998, Melt viscosities in the system Na-Fe-Si-O-F-CI: Contrasting effects of F and CI in alkaline melts: American Mineralogist, v. 83, p. 1016-1021.

DIPPLE, G.M., 1998, Reactive dispersion of stable isotopes by mineral reaction during metamorphism: Geochim. et Cosmo. Acta, v. 62, no. 23/24, p. 3745-3752. Author at Dept. of Earth and Ocean Sci., Univ. of British Columbia, Vancouver, BC V6T 1Z4, Canada.

The process of reactive dispersion is introduced whereby reaction in one chemical system imparts hydrodynamic dispersion to another apparently unrelated reactive transport system. Reactive dispersion is illustrated with a one-dimensional finite difference model for coupled heat flow. F flow, mineral reaction, and oxygen isotopic exchange during contact metamorphism of siliceous dolomite. Infiltration-driven decarbonation reactions impart isotopic heterogeneity to an initially homogeneous system. The effect on F composition is explored using a breakthrough curve that tracks F composition through time. The corresponding effects on rock composition are illustrated with plots of isotopic alteration vs. distance, Reactive dispersion is especially efficient during infiltration of H<sub>2</sub>O into carbonate rocks because <sup>18</sup>O is strongly fractionated between CO<sub>2</sub> and H<sub>2</sub>O and because mineral reactions may buffer the CO2-H2O content of F. The spatially heterogeneous isotopic alteration predicted to develop during decarbonation reactions in a homogeneous protolith is similar in magnitude and distribution to that observed downstream of the isotopic depletion front in contact metamorphic aureoles. (Author's abstract)

DIVAEV, F.K., POLICKOVSKY, V.S., [also spelled Polykovski, elsewhere] IVANOVA, N.A., and YUDALEVICH, Zinoviy A., 1998, The gas composition and temperature of fluids related to diamond bearing carbonatites, western Uzbekistan (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions. June 1-4, Univ. of Nevada, p. 24. First author at Inst. Mineral Resources, T.Shevchenko Str, 11-a, Tashkent, 700060, Uzbekistan, fax:3712-406812.

Diamond-bearing carbonatites of Southern Nuratau are represented by casenites, ringites, melilitic carbonatites, and rarely slovites, which form dikes and diatremes in enclosing aleuroshists and show no connection to any intrusive massifs. The mineral and chemical composition, the structure and the carbon isotopic composition of carbonatites indicate a mantle genesis for these rocks.

FI in crystals of carbonate and apatite have dimension 0.001-0.03 mm. They are G/L, and contain 5-35% G. Sometimes there are from 1 to more than 4 trapped solid minerals in the FI. The chemical composition of the FI ( $CO_2$ =61.1%, CO=4 8%,  $CH_4$ =6.4%,  $N_2$ =16.7%,  $H_2S$ =1.7%,  $H_2O$ =9.3%, average of 5 analyses) is dominated by carbon compounds, with little water, and is taken as evidence for low oxygen fugacities during formation of diamond-bearing carbonatites.

The T regime of F is characterized by several intervals [Th determinations?]: late magmatic - ≥640°C to 480°C, autometasomatic - 440°C to 380°C, and hydrothermal - 380°C to 90°C.

FI research on diamond-bearing carbonatites confirms petrologic conclusions about the magmatic genesis of these rocks under the low oxygen fugacity conditions of the earth's upper mantle. We estimate the prospects of carbonatites in Western Uzvekistan as a new source of diamonds as quite good. (From authors' abstract by E.R.)

DIVAEV, F.K. and POLYÓVSKY, V.S., 1998, Thermochemical characteristics of fluids and the origin of the diamond-bearing carbonatiles of the southern Nuratau (abst): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 39-41 (in Russian).

See Translations.

DOBES, Petr, 1998, Migration of paleofluids in granitoids: A study of fluid inclusions in rocks and veins of the Melechov massif (abst.): Geosci. Research Reports for 1997, p. 30-31 (in Czech).

DOBES, Petr and ZAK, Karel, 1998. The Bohemian quartz lode and adjacent vein mineralizations in western part of the Bohemian Massif: An example of fluid circulation in a shear zone (abst.): Geosci. Research Reports for 1997, p. 48-49 (in Czech).

DOBES, Petr, ZAK, Karel, LEACH, David, and VIETS. John, 1998a, The Bohemian quartz lode and adjacent vein mineralization in the Bohemian massifi an example of fluid circulation in a shear zone (abst.): Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 25. First author at Czech Geological Survey, Klárov 3, 118 21 Prague 1, Czech Republic.

The Bohemian Massif contains Late-Variscan to Post-Variscan hydrothermal minerals and vein-type mineralization (Ag-Pb-Zn, U, Au, fluorite-barite) located predominately in or close to zones of intensive regional shearing or faulting near boundaries of crustal blocks that experienced different uplift histories during the Late-Hercynian period.

The Bohemian Quartz Lode (BQL) is more than 55 km long and up to 50 m wide and is located in a major NW-SE shear zone along the western margin of the Bohemian Massif.

The vein bodies are hosted in gneisses. Quartz in the BQL is of polycyclic origin and shows patterns of dissolution, recrystallization and cataclasis, but quartz in the parallel Zhor vein show weaker patterns of recrystallization. The Mutenin deposit consists of three massive or brecciated silver-bearing quartz-carbonate veins. The Michalovy Hory ore district consists of a swarm of about 30 steeply dipping, hydrothermal quartzcarbonate veins containing fluorite, barite and a complex suite of Pb-Zn, Ag-Bi-Co-Ni, U minerals.

FI in all the minerals have variable L:V ratios, interpreted as the result of continued healing and necking of 1 at low T after nucleation of the V phase rather than boiling. Th ranged from 118 to 208°C, Te and Tm indicate the mixing of low and high sal F of variable Na-K-Mg-Ca-Cl composition. The low Te observed in the latest quartz of the BQL may indicate the presence of LiCl in the F. [Tabular data deleted].

Measured  $\delta^{18}$ O of quartz,  $\delta$ D of hydrothermal kaolinite and sericite, and Th all show that the hydrothermal F of the late phases of BQL and of adjacent mineralization had  $\delta^{18}$ O values from -5 to +5‰ and  $\delta$ D between -60 and -70‰ (SMOW) and were neither magmatic nor metamorphic. (From authors' abstract by E.R.)

DOBES, Petr, ZÁK, Karel, LEACH, David and VIETS, John, 1998b. Late to post-Variscan hydrothermal activity along the Bohemicum/Moldanubicum boundary (Bohemian Massif) (abst.): Proc. of the Int'l. Conf. "Palaeozoic Orogenesis and Crustal Evolution of European Lithosphere" published in Acta Universitatis Carolinae-Geologica 1998, v. 42, no. 2, p. 227. First author at Czech Geological Survey, Klarov 3, 118 21 Prague 1, Czech Republic; email (dobes@cgu.cz)

This study compares the paleofluid evolution in the Bohemicum and Moldanubicum Units These crustal blocks experienced different metamorphic conditions and different uplift and/or subsidence histories during the Variscan and Late-Variscan periods. In the high-grade metamorphosed Moldanubicum Unit, F types evolved from early retrograde-metamorphic high- $\delta^{18}$ O F of H<sub>2</sub>O-CO<sub>2</sub>-CH<sub>4</sub> type to high- $\delta^{18}$ O medium sal aq F, that were later replaced by aq F with lower  $\delta^{18}$ O values and highly variable sal (case study—Au-bearing deposit Kasperske Hory, Durisova et al., 1997). In the Bohemicum Unit, where the influence of the Variscan metamorphism was negligible, low T aq F of variable sal were recorded (case study—epither-mal Pb-Zn deposit Stribro, Dobes et al. 1995). Presence of high- $\delta^{18}$ O F was not observed in this unit The most intensive F circulation occurred along the tectonic boundary of the two units, where many vein-type hydrothermal mineralizations can be found (Pribram ore region, mineralizations which occur parallel to the Bohemian Quartz Lode). These veins are located predominately in or close to zones of intense regional shearing or faulting. In this boundary zone, F types evolved from aq high- $\delta^{18}$ O, medium to high sal F, important for sulfidic deposition, to low sal aq F characterized by lower  $\delta^{18}$ O values that dominated during formation of uraninite-bearing veins.

For this study, a combination of optical microthermometry and ion chromatography data on FI and stable isotope data were obtained for minerals of several mineralizations: Uranium mineralization of the Dylen and Vitkov deposits, post-U carbonate-sulfidic mineralization of the Dylen and Vitkov deposit, sulfidic (polymetallic) mineralizations and U mineralization of the Pribram ore region, a complex suite of Pb-Zn, Ag-Bi-Co-Ni and U minerals of the Michalovy Hory ore district, barren regional quartz lodes (Bohemian Quartz Lode, Zhor quartz vein), and Cu-carbonate mineralization of the Mutenin deposit.

At least three types of F can be distingushed for the mineralization studied:  $H_2O$ -rich,  $H_2O$ -CO<sub>2</sub>, and  $H_2O$ -CH<sub>4</sub> F.  $H_2O$ -CO<sub>2</sub> and  $H_2O$ -CH<sub>4</sub> F with low sal have been found only in pre-U minerals of the Dylen deposit and the Vitkov deposit, respectively. The  $H_2O/CO_2$  or  $H_2O/CH_4$  ratios in I are highly variable and indicate the trapping of heterogeneous F under conditions of partial immiscibility between CO<sub>2</sub> or CH<sub>4</sub> and  $H_2O$  at T to 350°C and P to 1.5 kbar.

For all other mineralization types, aq F with mixtures of chlorides of variable Na-K-Mg-Ca-Li composition are typical. Th of I vary generally from 300°C to <100°C. Sal (from 0.5 to about 25 wt% NaCl eq.) with solute compositions that differ largely between various mineralizations but also within different stages of the individual deposits. Based on F composition and stable isotopes, different types of deeply circulating and shallow circulating aq F, controlled by the F-rock interactions at different T, can be distinguished. Shallow circulating F are Na-K-rich with low to moderate sal, while F deeply circulating in relatively cool crust are characterized by high sal and high CaCl<sub>2</sub> content, probably the result of interaction of F with plagioclase.

Water-gas immiscibility, interaction with the host rocks. F mixing and T decrease seem to be the most important mineral deposition mechanisms. Mechanisms of F movement probably include F movement from zones of lithostatic to zones of hydrostatic P, seismic pumping, and thermal convection.

F types recorded in the Czech part of the Bohemian Massif are similar to those recorded by Reutel (1992) in the western margin of the Bohemian Massif in Germany. (Authors' abstract)

DOMBROWSKI, A., HOERNES, S. and OKRUSCH, M., 1998. Fluid flow along deep crustal shear zones within metaturbidites of an ancient accretionary prism. Damara orogen. central Namibia (abst.): 17th General Meeting Int'i. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs. p. A76. First author at Mineral. Inst., Univ of Würzburg.

The Khomas trough in central Namibia comprises metamorphosed deep-sea turbidites within an ancient accretionary prism setting at an active continental margin. Extensive scapolitization of metapelites and metapsammites occurred leading to the formation of two conspicuous marker horizons. Scapolites are of mizzonitic compositions with an EgAn content of 54-67%. F sal calculated from scapolite compositions revealed values of 0.16-0.43 XNaCl in the coexisting F with an average of 0.22. FI studies revealed corresponding F sal of 10-20 wt% NaCl eq. While in the southern scapolite-bearing sequence the XNaCI values are quite uniform, in the northern horizon differences of 0.18 X<sub>NaCl</sub> are preserved within a single sample. Thus, F compositions must have changed at least within the northern scapolite-bearing sequence of the Khomas Trough and F/rock ratios must have been considerably low otherwise chlorine gradients would have been smoothed out. Stable isotope studies confirm F-rock interaction with saline pore F of the sediment pile from where they were expelled during progressive deformation. F migration along prominent shear zones caused extensive scapolitization of predominantly pelitic sequences in the northern Khomas Trough. (From authors' abstract by E.R.)

DOMINY, S.C. and CAMM, G.S., 1998. Geology and hydrothermal development of Bostraze--Balleswidden kaolin deposit, Cornwall, United Kingdom: Trans. Instn. Min. Metall. (Sect. B. Appl. earth sci.), v. 107, Sept-Dec. 1998, p. 148-157.

The development of the kaolin deposits of Devon and Cornwall is still relatively poorly understood. The earliest  $F(350\pm100^{\circ}C)$  were released

from the crystallizing granite and led to hydraulic fracturing and progressive feldspar alteration of the biotite granite host rock. This stage was characterized by quartz-tourmaline-cassiterite-bearing veins and pervasively greisenized wallrocks. A network of microcavities within the granite feldspar hosted the early smectite/illite assemblage. A later, low-T  $(100\pm50^{\circ}C)$  and less saline stage associated with active faulting produced the kaolinitic alteration assemblage and epithermal quartz veining. The stable oxygen and hydrogen isotopic composition of the clays suggests that they were formed from waters that had similar characteristics to modern groundwaters and to the composition of meteoric F that predominated during the late Mesozoic and Caenozoic. The isotopic and mineralogical nature of the clays implies widespread recrystallization and isotopic reequilibration of kaolinite in a near-surface system. These findings support the theory that the kaolinite deposits are the product of both supergene and hydrothermal processes. (From authors' abstract by E.R.)

DOREMUS, R.H., 1998, Diffusion of water and oxygen in quartz: Reaction-diffusion model: Earth and Planet. Sci. Letters, v. 163, p. 43-51. Author at Materials Sci. & Engineering Dept., Rensselaer Polytechnical Inst., Troy, NY 12180, USA.

A mechanism of diffusion of isotopically tagged water in crystalline quartz by molecular diffusion and network exchange is compared to previous experiments. Three experimental factors are explained by this mechanism. (1) The apparent diffusion coefficient is proportional to the fugacity of the water V in the G phase. (2) The ratio of apparent diffusion coefficients at 800°C in deuterium-hydrogen exchange to <sup>18</sup>O-<sup>16</sup>O exchange is 4.7 (10)<sup>5</sup>. (3) Below 700°C the measured diffusion coefficients become time dependent. This diffusion-exchange mechanism is valid for a wide variety of crystalline and amorphous oxides. (Author's abstract)

DRAGUSANU, C., SUGISAKI, R. and MURARIU, T., 1998, Gas analysis of crushed minerals from pegmatites of the Romanian Carpathians (abst.): 1998 Annual Meeting of the Geochemical Society of Japan (Kyushu University), Oct. 9-11, 1998, p. 127 (in Japanese).

DRESCHER, J., KIRSTEN, T. and SCHÄFER, K., 1998, The rare gas inventory of the continental crust, recovered by the KTB Continental Deep Drilling Project: Earth and Planet. Sci. Letters, v. 154, p. 247-263. Authors at Max Planck Institut für Kernphysik, POB 103980, D-69029 Heidelberg, Germany: email (kirst@kosmo.mpi-hd.mpg.de).

The rare G inventory of the continental crust as mirrored in the continental metamorphic rocks from the "KTB" deep drilling site in NE Bavaria, Germany, has been investigated through systematic isotope analysis of 47 whole-rock samples and 10 mineral separates from the drill core. The measured concentrations confirm a very low crustal inventory of noble G relative to the atmosphere ( $\leq 0.2\%$ ). The presence of a mantle helium component is identified by <sup>3</sup>He excess leading to a range of 2 X 10<sup>-8</sup>  $\leq$  <sup>3</sup>He/<sup>4</sup>He  $\leq$  6.5 X 10<sup>-6</sup> for the He isotopic ratio. Excesses of <sup>21</sup>Ne and of heavy xenon isotopes demonstrate the presence of nucleogenic and fissionogenic G. The acquired data have enabled us to estimate loss rates of <sup>41</sup>He, <sup>21</sup>Ne<sub>met</sub>. <sup>40</sup>Ar and <sup>136</sup>Xe<sub>fiss</sub> from typical crustal rocks. The global extension of these rates to the continents yields degassing fluxes of (2-3) X 10<sup>10</sup> atoms m<sup>-2</sup> s<sup>-1</sup> for <sup>40</sup>Ar, in good agreement with theoretical estimates from atmospheric models and from accumulated G in crustal F. (Authors' abstract)

DRIESNER, T., SEWARD, T.M. and TIRONI, I.G., 1998, Molecular dynamics simulation study of ionic hydration and ion association in dilute and 1 molal aqueous sodium chloride solutions from ambient to supercritical conditions: Geochim. et Cosmo. Acta, v. 62, no. 18, no. 3095-3107.

DRISTAS, J.A., HANSTEEN, Thor, DEGUILLÉN, A.O. and KUNIS, Soledad, 1998, Glass and CO<sub>2</sub>-dominated fluid inclusions in diopside-rich xenoliths and clinopyroxene phenocrysts from a comenditic trachyte La Pampa province, Argentina (abst.): Terra Nostra, 1998, no. 5, 16th Latin American Conf. on Geosci., 14-16 Oct., 1998, Bayreuth, Germany. First author at Dep. Geologia, Universidad Nacional Del Sur, San Juan 670, 8000 Bahia Blanca, Argentina.

The main volcanic suite in La Pampa province is represented by rocks of rhyolitic to dacitic composition, trachytic rocks are firstly described in this study. We have investigated glass and FI in diopside xenoliths and clinopyroxene phenocrysts from comenditic trachyte in order to put constraints on their genesis and ascent history.

Xenoliths and diopside phenocrysts contain abundant glass and CO<sub>2</sub> dominated P FI. A few PMI contain an opaque dxl of titaniferous magnetite. Host minerals on the wall of the glass I have not been observed [sic]. Therefore, the glass composition is assumed to represent quenched relicts of an original rhyolitic magma. Microprobe analyses of glass I indicate a rhyolitic composition. The densities of CO<sub>2</sub> Fl in diopside suggest entrapment P of 4.1-4.8 kbar at 900-1000°C. High-T microthermometry show the formation of a new phase (probably K-feldspar) in the MI at 700-750°C [on heating or cooling?]. (From authors' abstract by E.R.)

DUAN, Zhenhao, MOLLER, Nancy, and WEARE, John. 1998. Theoretical prediction of phase separation, PVT properties, enthalpy and fugacity of supercritical fluids H<sub>2</sub>O-CO<sub>2</sub>-CH<sub>4</sub>-N<sub>2</sub> up to 2000 k and 100 kbar (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 26. Authors at Dept. of Chem. 0340, Univ. of California, San Diego, La Jolla, CA 92093-0340.

See FIR v. 29, p. 46 (E.R.).

DUAN, Zhenhao, WEARE, Nancy and WEARE, J.H., 1998, The predicting power of a molecular dynamics equation of state for supercritical fluids up to 2000 K and 100 kbar (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-186. Authors at Dept. of Chemistry, Univ. of California, San Diego, CA.

Based on the intermolecular forces, we developed an EOS for predicting the thermodynamic properties (free energy, phase equilibria, fugacity, PVT properties, enthalpy, etc.) of H<sub>2</sub>O, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>, H<sub>2</sub>S, O<sub>2</sub>, H<sub>2</sub>, Ar and their mixtures in the supercritical region up to 2000 K and 100 kbar. This EOS is very simple with only two parameters for each component and each binary. It predicts thousands of data points from many different labs in the world. (Authors' abstract)

DUBESSY, J., PIRONON, J., LAMB, W., McSHANE, C., POPP, B. and THIÉRY, R., 1998, Analysis of methane at low concentration in fluid inclusions with Raman spectroscopy (abst.): Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid inclusions, June 1-4. Univ. of Nevada, p. 27. First author at CREGU, UMR 7566. BP-23, 54501-Vandœuvre-lès-Nancy Cedex, France.

The aim of this work is to develop a method for precise determination of isochores of Fl of the H<sub>2</sub>O-NaCl-CH<sub>4</sub> system with low methane concentration for application to diagenetic F. This approach is based on a combination of Raman spectrometry and thermodynamic modelling.

Calibration of the ratio of Raman scattering cross-sections of the water stretching mode and the symmetric stretching vibrational mode of methane as a function of T and sal was carried out on synthetic Fl have been prepared according to the method of Lamb et al (1996, GCA 60:1895-1898) in fluorite at 400°C and 5 kbar. Spectra were obtained at different T on a micro-Raman spectrometer (Labram, ©Dilor) equipped with a heating stage (© Chaix-Meca).

The stretching band of water shows [figure deleted] a decrease of its full width at half height and a shift of its maximum intensity wavenumber. The symmetric stretching Raman band of methane is shifted down by nine wavenumbers with respect to its value for low G density but remains constant. The intensity increase of the methane band is related to its increase in concentration in the aqueous phase during increasing T to the Th. A computer code allows the calculation of the concentration of methane in the L aq solution coexisting with the vapor inside synthetic fluid inclusions as a function of temperature.

The application of Raman data for the calculation of the isochore of natural FI of the H<sub>2</sub>O-NaCl-CH<sub>4</sub> system is made following the different steps: 1) measurement of the salinity ( $m_{NaCl}$ ) of the aqueous phase from microthermometric data; 2) determination of the methane molality ( $m_{CH4}$ ) from the Raman data and the calibration curve established for  $m_{NaCl}$ ,  $m_{CH4}$  and  $T=T_h$ . 3) calculation of the pressure (Ph) at the Th for the considered isopleth using the Duan model; 4) calculation of the isochore in the single phase region assuming that it is parallel to the isochore of an hypothetical FI with the same sal and same Th. (From authors' abstract by E.R.)

DUBLYANSKY, Yuri, 1998a, Traces of epigenetic hydrothermal activity in the Yucca Mountain volcanic tuffs: Fluid inclusions and gas chemistry evidence (abst.). Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada (abstract distributed at meeting but not published in the volume). Author at Inst. of Mineral. and Petrog., Russian Acad. of Sci., Siberian Branch 2 Akademika Koptiuga Ave., Novosibirsk, 630090, Russial, email (dublyan@uiggm.nsc.ru).

Composite opal-quartz-calcite veinlets were sampled in the exploratory

tunnel excavated in welded tuffs of the Yucca Mountain unsaturated zone. Veinlets typically exhibit several episodes of mineral deposition, recorded by alternating layers of: (1) botrioidal opal; (2) drusy quartz (crystals up to 2-4 mm); and (3) calcite (massive to spary; crystals up to 1.5 cm). Optical studies revealed four basic types of FI in calcite: (1) all-G; (2) G-rich with variable but generally high V/L ratio (~0.4-0.8); (3) G-L with low V/L ratio (~0.1 and less); and (4) all-L (with some 5-7 morphological subtypes).

G-rich and all-G I: I were broken open in glycerol and the change of the bubble volume was measured. Subsequently, the bubble was immersed in selective sorbents in order to remove: (1)  $CO_2$ ; (2) CH<sub>4</sub>+other hydrocarbons, and (3)  $O_2$ . The content of a G was estimated from the bubble volume decrease. The rest of the G that was not dissolved in sorbents was attributed to a mixture N<sub>2</sub>+noble G.

Large bubbles, occupying 40-80% of vacuoles in the Yucca Mountain subsurface calcites have been interpreted elsewhere as the air-water-carbon dioxide phase trapped during the growth of calcite from films of percolating rainwater. Our results [mainly  $CH_4$  and lesser  $N_2$ ] do not corroborate these early interpretations. On crushing, most bubbles decreased in volume which implies P<1 atm. The G chemistry is not compatible with the environment of aerated unsaturated zone. G-rich I in the Yucca Mountain calcite were trapped from a F carrying both dissolved and gaseous methane. This implies crystallization from deep-seated methane-rich thermal water in the saturated zone.

G-L I: all together, we obtained 82 T<sub>h</sub> from 6 calcite samples, with a significant part of the data coming from I assembled in groups and having consistent V/L ratio. 89% of the data are bracketed by 35°C and 55°C, which suggests crystallization of calcite at T exceeding the present day unsaturated zone T. This result is in accord with previous (though meager) FI data obtained by the DOE for calcites recovered from boreholes at -200-400 m. Calcite FI T suggest a paleothermal gradient of 150-160°C/km. which is ten times the value of the present-day gradient in the unsaturated zone of 12-15°C/km.

Conclusion: textural and Fl data suggest deposition of calcite encountered in the Yucca Mountain exploratory tunnel was from deep-seated low-T thermal F. Both thermometric and G chemistry data are incompatible with the vadose-zone setting. (From author's abstract by E.R.)

DUBLVANSKY, Yuri, 1998c, Fluid inclusions in calcite samples from the ESF. Nevada Test Site. Nevada: Report assembled for the Office of the Attorney General of the State of Nevada, July, 1998, Washington, D.C., 16 pp

A report on a study performed by the author. June 15-19, 1998. at Virginia Tech, Blacksburg, Va. (E.R.)

DUBLYANSKY, Y.V. and REUTSKY, V.N., 1998, Epigenetic quartzopal-calcite crusts in the Yucca Mountain subsurface: Fluid inclusions and stable isotopic evidence of hydrothermal origin (abst.): Geological Society of America Annual Meeting 1998, Abstracts. v. 30. no. 7, p. A-79 Authors at Inst. of Geol., Geophys. and Mineral., 3. Koptiuga Ave., Novosibirsk, 630090, Russia; email (dublyan@uiggm.nsc.ru)

Studied calcite encrusts open fissures and loosely cements broken fragments of welded tuff Tiva Canyon. Crusts often contain layers of drusy quartz and opal up to 3 mm thick. Two-phase FI suitable for thermometry were observed in six out of twelve calcite samples collected from the first 300 m of the tunnel excavated under Yucca Mountain.

Most samples yielded Th of 35-70°C, in one sample the earliest part of the crust showed T in excess of 70-80°C.

All-gas I were studied from one sample; they appeared to contain a low-density G (upon crushing oil entered the I). Less-than-atmospheric P indicates entrapment at elevated T. Being submerged in bromine water, bubbles released from I decreased in volume by -80%, which indicates the presence of hydrocarbons (alkanes) in them. Raman spectroscopy revealed strong fluorescence of inclusion's content, suggesting the presence of cyclic aromatic hydrocarbons (C6 and higher). Fluorescence decreased under prolonged laser excitation, indicating decomposition of hydrocarbons. The host calcite did not fluoresce.

Gas chromatographic analyses of calcite, quartz and opal from crusts, as well as bedrock (uffs revealed presence of methane, acetylene, heavier hydrocarbons (C3 to C6), plus several unidentified heavy hydrocarbons.

Stable isotopic profiles taken across 0.5-1.5 cm crusts revealed quite constant values of oxygen, bracketed by a 1.5 permil interval (-10.5 to - 12.0 PDB). Carbon in most samples gradually decreases from -2 to -6 permil PBD along growth direction. More complex behavior was found in one sample, the earliest part of which revealed unusually 'light' oxygen (-19.5 permil PDB) and 'heavy' carbon (0.6 permil PDB).

Presence of drusy quartz, elevated FI T, chemistry of G trapped in I, and extremely uniform stable isotopic features of calcite indicate formation of quartz-opal-calcite crusts at Yucca Mountain in association with ascending hot and at times G-charged F. Observed features are not compatible with the aerated vadose zone setting and the 'rainwater' origin postulated for these formations. (Authors' abstract)

DUCEA, Mihai and SALEEBY, Jason, 1998, Crustal recycling beneath continental arcs. Silica-rich glass inclusions in ultramafic xenoliths from the Sierra Nevada, California: Earth and Planet. Sci. Letters, v. 156, no. 1-2, p. 101-116. Authors at California Inst. of Tech., Div. of Geological and Planet. Sci., Pasadena, CA 91125, USA.

We describe silica-rich (up to 69.5% SiO2) glass I trapped as grain boundary films and within-grain pockets in ultramatic xenoliths hosted by Pliocene basalts from the Sierra Nevada, California The ultramafic xenoliths are lherzolites which equilibrated in the Sierra Nevada upper mantle at 1150-1180°C and 1 4-1.8 GPa. The glass I have trachytic compositions. similar to previously described silicic M from mantle xenoliths. We have determined the Sr and Nd isotope compositions of the grain boundary films using a leaching technique, and calculated the glass isotopic compositions. The glass <sup>87</sup>Sr/<sup>45</sup>Sr (0.7077-0.7085) and <sup>143</sup>Nd/<sup>144</sup>Nd ratios are higher than in the ultramafic xenoliths and distinct from the host basalt ratios Glasses are characterized by Nb depletions, enrichment of light rare earth elements. and the presence of negative Eu anomalies, indicating a crustal origin for the M source. The Nd isotope ratios are inconsistent with an oceanic crust as the source for these former M. The source rocks must have been continental materials recycled in the mantle, either foundered lower crust or subducted sediment. Low Rb/Sr and high Sr/Nd ratios observed in the glasses are suggesting a lower crustal source. The Sierra Nevada lowermost crust (amphibole-bearing gamet pyroxenites and other dense Mesozoic cumulate mafic-ultramafic rocks), as defined by studies of older, Miocene xenolith-bearing volcanic rocks from the same area (Ducea et al., J. Geoph. Res., 1996), has isotopic compositions similar to the glass I. Geologic and geophysical evidence indicate that the Sierra Nevada has lost its eclogitic arc root, probably by foundering in the mantle. We propose here that the silica-rich glasses were formed by low percent partial melting of the dense, cold Sierran batholithic lowermost crust during root delamination. Further tests need to be aimed at addressing the viability of the main alternative to our interpretation, i.e., derivation of glasses from melting subducted sediments. (From authors' abstract by E.R.)

DUGDALE, A.L., and HAGEMANN, S.G., 1998. Multi-phase vein system at the Bronzewing gold deposit, western Australia: Evidence for homogeneous T-X conditions during ductile shear zone development and formation of the vein system (abst.): Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ of Nevada, p. 28. Authors at Dept. of Geol. and Geophys., Centre for Strategic Mineral Deposits, Univ. of Western Australia, Nedlands-Western Australia 6907, Australia.

The Bronzewing gold deposit, in the Eastern Goldfield Province of the Yilgarn craton in Western Australia is hosted in greenschist facies tholeiitic metabasalts. Gold mineralization is confined to type 2 shear and extensional veins of white buck quartz that contain three types of FI (1) mixed aq-carbonic 1 with highly variable CO<sub>2</sub> and CH<sub>4</sub> content (7-93 and 1-15 mol%, respectively) and sal (0.1-21 eq. wt% NaCl). Aq:carbonic ratios are variable within trails and clusters: (2) aq 1 of variables al (7 to 17 eq. wt% NaCl); and (3) carbonic 1 that contain up to 30 mol% CH<sub>4</sub>. All three FI types are observed in the same traits and clusters, therefore, they form an assemblage, possibly trapped during phase immiscibility.

Extensional veins are of two types: (1) composite open space-fill veins, and (2) buck veins that are locally laminated and contain wallrock fragments (implosion breccias). Both shear and extension veins are mostly observed in the proximal alteration zone of the Bronzewing lode-gold deposit. They are an integral part of the ductile shear zone system and contain variable amounts of quartz, carbonate, albite, scheelite, and the majority of pyrite, pyrrhotite and gold. FI trapped in these veins are (1) mixed aqcarbonic 1 with highly variable CO2 and CH4 content (10-97 and 0-41 mol%, respectively) and sal (0.1-21 eq. wt% NaCl). Aq:carbonic ratios are largely constant, although. locally, the ratio can be variable within individual trails or clusters; (2) aq 1 of highly variable sal (0.1 to 23 eq wt% NaCl), and (3) carbonic I with compositions that range from CH1-rich (up to 85 mol% CH4) to nearly pure CO2. All three I types are observed in the same trail or cluster in most samples, hence they form an assemblage and, therefore, are interpreted to have been trapped contemporaneously. This suggests possible widespread F immiscibility at the time of trapping.

Further investigations should constrain the extent of phase immiscibility and its effect on the precipitation of sulfides and gold. (From authors' abstract by E.R.)

DÚNIN-BARKÓVSKAYA, E.A. and KIM, M.A., 1998, The crystallomorphological features of auriferous arsenopyrite from the gold-sulphidearsenic ores of the Kokpatas Deposit (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 144 (in Russian).

DÚNIN-BARKÓVSKAYA, E.A., LÉBEDEVA, S.E. and TSOI, L.A., 1998, Thermobarogeochemical investigations at IGG Akad. Nauk Uzbekistan (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 30-35 (in Russian).

See Translations.

DÚNIN-BARKÓVSKAYA, E.A., SMIRNOVA, S.K., KOZLOV, V.V., TSOI, L.A. and LEBEDEVA, S.E., 1998. The fluid regime of the formation of the major productive mineral associations and parageneses of goldore, rare-metal, and fluorite deposits of Uzbekistan (abst.). Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 69-72 (in Russian).

DUTKIEWICZ, Adriana, RASMUSSEN, Birger and BUICK, Roger, 1998, Oil preserved in fluid inclusions in Archaean sandstones: Nature, v. 395, 29 Oct. 98, p. 885-888. First author at CSIRO Div. of Petroleum Resources. P.O. Box 136, North Ryde New South Wales, 1670, Australia.

Oil is generally thought to be geologically young, as it is thermodynamically unstable when subjected to elevated T over long periods in open systems. Indeed, almost all petroleum production comes from rocks younger than 400 My. Although the oldest known oil occurs in rocks 1,650 My old, suitable source rocks were abundant in older geological successions and circumstantial evidence suggests that some of these generated hydrocarbons early in their history. Here, we report the discovery of oil preserved in FI in sandstones dating back ~3.000 My. Most I lie within healed microfractures confined to individual detrital guartz grains, indicating that their oil was emplaced before Archaean or palaeoproterozoic metamorphism sealed all voids and thus came from older (in some cases Archaean) sources. The FI apparently acted as inert P vessels that protected the oil from subsequent degradation by circulating F and mineral catalysts. Because of its great age, this oil can potentially yield valuable information about the size and diversity of the early biosphere, particularly if it contains molecular fossils (biomarkers) of the primordial organisms from which it was derived. (Authors' abstract)

DUTROW, B., FOSTER, C.T., Jr. and TRAVIS, B., 1998, Deciphering signatures of fluid infiltration using 3D thermal and textural modeling (abst.): 17th General Meeting Int<sup>\*</sup>I. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A76. First author at Dept. of Geol., LSU; email (dutrow@geol.lsu.edu)

We developed an approach linking sophisticated thermal models of intruding plutons with texture models in metamorphic rocks in order to relate metamorphic textures to pluton geometry and host rock permeability, features which control heat and F flow around the intrusion. Thermal and flow fields are calculated for a specific pluton geometry and permeability distribution using a 3D heat and mass transfer code. This calculation provides P, T, X, t data for specific locations in the aureole. In turn, these data are used as input for textural modeling calculations to simulate development of rock textures at these host rock locations. Calculations with and without pore F convection, completed for conditions approximating metamorphism in Maine, USA, show that two distinct distributions suggest that rocks from NW Maine more closely resemble the convective case (From authors' abstract by E.R.)

DUVAL, B.C., RIVIERE, Catherine, DURAND, Bernard, ROURE, Francois, SCHNEIDER, Frederic and ESCHARD, Remi, 1998. Optimizing the interplay between industry and academic partners: "hub" function of a research institute and application to petroleum geoscience and education (abst.): AAPG Bull., v. 82, no. 10, p. 1910-1911.

A consortium will evaluate and predict reservoir qualities in subthrust conditions by reconstructing their burial and thermal history and using fine-tuned petrophysics and FI technologies. These characterizations are studied along regional transects across the foreland and foothill parts of selected basins. (From authors' abstract by E.R.)

DZIGGEL, A., KLEMD, R. and STEVENS, G., 1998, Gold mineralization at Turk mine, Zimbabwe: Geochemical and statistical investigation of the hydrothermally overprinted host rock. Univ. of the Witwatersrand, Johannesburg, Economic Geol. Research Unit Information Circular No 327, 16 pp.

Indexed under FI

EDRAKI, Mansour and ASHLEY, P.M., 1998, Magnetite skarn at the Biggenden mine, Southeast Queensland (abst.): Geological Soc. of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 130. Authors at Div, of Earth Sci., Univ. of New England, Armidale, NSW 2351.

The development of skarn has followed contact metamorphism and has replaced all rock types. Skarn mineralogy indicates that there was an evolution from prograde through to various retrograde assemblages.

FI in prograde skam calcite and gamet yield high  $T_h$  (500-550°C) and high sal (~30 wt.% NaCl eq.). FI in the sulphide-stage quartz and calcites homogenise between 300 and 400°C and have lower sal. The  $\delta^{18}$ O and  $\delta^{13}$ C values of carbonates show the typical trends of depletion characteristic of skam deposits, which results from infiltrating magmatic/meteoric waters. The water/rock ratio has been calculated at 5-10 during skam formation. (From authors' abstract by E.R.)

EDWARDS, K.J. and VALLEY, J.W., 1998. Oxygen isotope diffusion and zoning in diopside: The importance of water fugacity during cooling. Geochim. et Cosmo. Acta, v. 62, no. 13, p. 2265-2277. Authors at Dept. of Geol. and Geophys., Univ. of Wisconsin, Madison, WI 53706, USA.

The oxygen isotope ratio of diopside correlates with crystal size in many high grade marbles, permitting the intracrystalline self-diffusion rate of oxygen in diopside to be empirically evaluated. Measurements and calculations to predict differences in  $\delta^{18}$ O between large and small [75 µm to 1.5 mm] diopside grains lead to the following conclusions. (1) Natural diopsides in this study exhibit variations in oxygen isotope ratios between grains of different size, which are related to the peak T, cooling rate, and water fugacity during cooling. Diffusion distances are properly modeled by the size of an entire grain; there is no evidence for subdomains. (2) In slowly cooled high grade metamorphic terrains, water fugacity can be highly variable from rock to rock during cooling. For many rocks, water fugacity is the most important constraint on the degree of oxygen isotope retrograde exchange. (From authors' abstract by E.R.)

EGGENKAMP, H.G.M., 1998. The stable isotope geochemistry of the halogens C1 and Br. A review of 15 years development (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 411-412.

EGGINS, S.M., RUDNICK, R.L. and McDONOUGH, W.F., 1998, The composition of peridotites and their minerals. A laser-ablation ICP-MS study: Earth and Planet. Sci. Letters, v. 154, no. 1-4, p. 53-71. Authors at Research School of Earth Sci., The Australian Nat'l. Univ., Canberra, ACT 0200, Australia.

We have analyzed the major- and trace-element contents of minerals and whole rocks for two peridotite xenoliths from SE Australia (one fertile, the other infertile) using both solution chemistry (ICP-MS) and microbeam techniques (EMP, LA-ICP-MS). The incompatible lithophile trace elements are contained mainly in solid mineral phases at upper-mantle conditions, with no significant concentrations occurring on grain boundaries or in FI. (From authors' abstract by E.R.)

EGLE, Susanne, de WIT, M.J. and HOERNES, Stephan, 1998, Gondwana fluids and subsurface palaeohydrology of the Cape Fold Belt and the Karoo Basin, South Africa (abst.): Special Abstracts Issue Gondwana 10: Event Stratigraphy of Gondwana, published in J. of African Earth Sci., v. 27, no. 1A, p. 63-64. First author at Dept. of Geochem., Univ. of Vienna, Austria.

The objectives of our investigations are: (1) to discern the origin of the F; and (2) to determine the link of regional, synorogenic crustal hydrology to regional tectonics and mineralisation.

Basin-scale examination of stable isotopes and FI, as well as structural and petrological investigations, were carried out on a variety of quartzcalcite veins of different relative ages and on their low-grade sedimentary host rock.

Microscope studies of multiple cross-cutting FI trails confirm pulsa-

tory release of F. All FI reveal large amounts of aq low-sal F (0.87 wt% NaCl eq.) with varying amounts of CO<sub>2</sub>. In addition, methane was identified in vein samples of the Collingham Formation (Ecca-Group). FI in the samples of the Cape and Karoo Supergroups display a well-defined peak of Th at 150-170°C with F P between 1.1 and 2.0 kbar. Quartz-calcite geothermometry reveals Tt between 230-260°C, which are in the upper range of the observed Th. Methane-water geothermometry yields a similar Tt of 235°C. Th within the confines of the DR-3 U deposits are about 270°C, with estimated Tt between 300-350°C and F P between 0.4 and 1.0 kbar. Thus, samples from within the Beaufort Group at the most northerly extent of one of our traverses, have higher T than those found 50 km to the south in stratigraphically lower sequences of the basin.

Hydrogen isotope measurements on FI of vein-quartz scatter widely within the range of -94.4<(D<-54.3‰ (SMOW), with a mean of 74.7‰. [(D= $\delta D$ ?] Such low (D values indicate a major contribution from meteoric sources. Calculated oxygen isotope composition of the F vary between -4 and 2‰ SMOW, suggesting a mixture of meteoric water with F which were generated by diagenetic dehydration reactions and devolatilisation during low-grade metamorphism, reaching P-T conditions of the lower greenschist-facies.

There is a clear correlation between the light stable isotope signatures of the vein-quartz and their immediate host rock isotopic compositions. The latter are, without exception, depleted in <sup>18</sup>O with respect to veinquartz. There is a large scatter in  $\delta^{13}$ C values of vein-calcite (-18.7 to 8 5‰ PDB). The scatter in  $\delta^{13}$ C values of the host rock carbonate most likely reflects the P signature of the sedimentary environment and variable volumes of organic matter.

Synthesis of the geochemical results with numerical basin modelling, yield a consistent model for the subsurface Gondwana hydrology during Cape Orogeny close to the Permo-Triassic transition, in which Karoo basinal F are internally rock-buffered but locally focused along north verging listric thrusts.

We speculate that the F responsible for the near-surface mineralisation of the DR-3 U deposits (and local Au rich sulphide enrichment) are associated with heat transport from, "blind" thrusts cutting-up through the deeper section of the southern Karoo Basin; and that these thrusts root in the central section of the Cape Fold Belt. The F observed in the sedimentary sequences of the Cape Fold Belt and the Karoo Basin may be called "tectonic brines". The presence of large volumes of water during Cape Orogeny at such depths, as well as the presence of large amounts of U suggest that the DR-3 U occurrence is one of the few examples of mesothermal ore deposits within a compressional regime (From authors' abstract by E R.)

ELLENDORFF, Barbara, SCHMIDT, Kai, and SIEMANN, M.G., 1998, Comparison of LA-ICP-MS and ion chromatography methods in the analysis of single fluid inclusions in evaporites (abst.): Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions. June 1-4, Univ. of Nevada, p. 29. Authors at Fachgebiet Mineralogie. Geochemie, Salzlagerstätten, Technische Universität Clausthal. Adolph-Roemer-Straße 2A, D-38678 Clausthal-Zellerfeld, Germany: email (ellendorff@immr.tu-clausthal.de)

The two methods for the chemical analysis of single FI are compared in their accuracy and precision using  $1 > 250 \,\mu\text{m}$  in diameter and synthetic standards. The first method is based on the microextraction of single FI as described by Lazar and Holland (1988). The brines are diluted and analyzed by ion chromatography (IC). In a single measurement, major and trace elements (Na, K, Mg, Ca, Cl, SO<sub>4</sub>, Li, Br) of brines and host crystal can be analyzed accurately.

As a new method for the analysis of single FI, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) is employed. Different approaches of calibration are discussed. Beside glass standard materials microwells filled with calibration solution are tested.

LA-ICP-MS enables the determination of considerably smaller I [than microextraction] and a number of additional trace elements (e. g., B, Rb, Sr) can be studied. (From authors' abstract by E.R.)

ERNST, W.G. and LIU, Jun, 1998. Experimental phase-equilibrium study of Al- and Ti-contents of calcic amphibole in MORB: a semiquantitative thermobarometer: American Mineralogist, v. 83, no. 9-10, p. 952-969. Indexed under Fl.

ESCHENBACHER, A.J., KYLE, P.R., LOWENSTERN, J.B., and DUNBAR, N.W., 1998. Melt inclusion investigation of the volatile behaviour of fractionating, alkaline magma, Mount Erebus. Ross Island. Antarctica (abst.): Program and Abstracts. PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 30. First author at Dept. of Earth and Environmental Sci., New Mexico Inst. of Mining and Tech., Socorro, New Mexico, 87801.

Mount Erebus is an active, intraplate, alkaline volcano. At present, activity takes the form of a convecting, anorthoclase-phonolite lava lake that is emitting significant amounts of CO<sub>2</sub>. The Mount Erebus phonolites are most likely products of progressive fractional crystallization from basanite and phonotephrite compositions similar to the lavas exposed on the flanks of the volcano and adjacent areas.

MI in phenocrysts from basanite, phonotephrite and phonolite were analyzed by Fourier transform infrared (FTIR) spectroscopy to determine CO<sub>2</sub> and H<sub>2</sub>O concentrations. MI in olivine from basanite contain 0.85±0.08 to 1.70±0.15 wt% H<sub>2</sub>O and 2704±222 to 6045±431 ppm CO<sub>2</sub> dissolved as carbonate. 1 in plagioclase from phonotephrite contain 0.09±0.01 to 0.85±0.09 wt% H<sub>2</sub>O and 677±114 to 869±174 ppm CO<sub>2</sub>. MI in anorthoclase from phonolite contain 0.14±0.01 to 0.38±0.04 wt% H<sub>2</sub>O and 533±54 to 843±118 ppm CO<sub>2</sub>. These data are consistent with a fractionation trend from basanite to phonolite that is accompanied by continuous degassing and production of a progressively more H<sub>2</sub>O-rich G.

 $H_2O$  contents of phonolite and phonotephrite correspond to saturation P of 5 to 20 bars and 5 to 100 bars respectively. The concentration of  $CO_2$  in the basanite indicates that it must have begun degassing a  $CO_2$ -rich G at a P no less than 2.9 kbar, corresponding to a depth of -9 km (Authors' abstract)

ESSARRAJ, Samira, BOIRON, M.-C., CATHELINEAU, Michel, BANKS, D.A., EL BOUKHARI, Abdelmajid and CHOUHAIDI. M.Y., 1998, Brines related to Ag deposition in the Zgounder silver deposit (Anti-Atlas, Morocco): Eur. J. Mineral., 1998, no. 10, p. 1201-1214. First author at Faculté des Sciences et Techniques, BP 618, Marrakech, Morocco, email (boiron@cregu.cnrs-nancy.fr)

The Zgounder ores occur in sets of quartz-calcite veinlets, crosscutting the Middle-Precambrian volcanosedimentary formations of Sirwa (Anti-Atlas, Morocco). Two major stages of mineralization are distinguished:

i) A first stage is characterized by the deposition of quartz (biotite) together with As-Co minerals. This stage is also characterized by a variety of  $H_2O-CO_2$ -CH<sub>4</sub> F with moderate densities, interpreted as F equilibrated with metasediments. These F are trapped under rather high T (around 400-450°C) and a rather wide range of P attesting to probable P fluctuations from hydrostatic to lithostatic conditions. In addition to P and T drops, aqcarbonic F have probably undergone episodic immiscibility, the latter process likely being related to the deposition of metals.

ii) The second stage corresponds to the major (Cu-Zn)-Ag(Hg) ore deposition and clearly postdates the As-Co assemblage Silver deposition occurs after the crystallization of quartz-sphalerite-chalcopyrite veins, but both Cu-Zn and Ag(Hg) ore-bearing F are NaCl-CaCl<sub>2</sub> brines (24 to 40 wt.% NaCl eq.+CaCl<sub>2</sub>). Brines occur as several Fl types (L+V±halite cube), and were trapped under minimum T of around 160-200°C. The ion chemistry of the Fl determined by crush-leach analysis shows that brines display typical features of sedimentary F which interacted with evaporites: Na/K ratio ranges from 10 to 12, Na/Ca from 1.9 to 2.4, Na/Li from 220 to 445. Cl/Br from 300 to 380 and Cl/SO<sub>4</sub> from 1100 to 2100. F at the origin of the Zgounder Ag mineralization are thus Na-Ca brines unrelated to the earlier As-Co ores. Dilution and slight cooling are the two main driving mechanisms for silver deposition, as in several other examples from Anti-Atlas or Canada. (Authors' abstract)

See also FIR 30, p 55-56 (E.R.)

ETOH, J., TAGUCHI, S., IZAWA, E. and WATANABE, K., 1998. Texture. fluid inclusion and origin of bladed-quartz (abst.): Abstracts with Programs, 48th Annual Meeting of the Society of Resource Geology. Tokyo, June 17-19, No. O-49 (in Japanese).

EVANS, M.A., 1998. Hydrologic structure of the Central Appalachians during the late Paleozoic Alleghanian Orogeny (abst.): Abstracts with Programs—Geological Society of America, v. 30, no. 4, p. 11. Indexed under Fl.

EVANS, M.A., EGGER, J., HAIGHT, J. and ELMORE, R.D., 1998. Examining the relationship between remagnetization and orogenic fluids: Central Appalachians (abst.): Geological Society of America Annual Meeting 1998. Abstracts. v. 30, no. 7, p. A-126. First author at Dept. of Geol. and Planetary Sci., Univ. of Pittsburgh, Pittsburgh, PA 15260; email (mae6+@pitt.edu) One of the most commonly invoked remagnetization mechanisms for chemical remnant magnetization's (CRMs) is the migration of orogenic F. However, in spite of its popularity, the orogenic F hypothesis has not been rigorously tested. Preliminary work in the central Appalachians suggests that a relationship between orogenic F and remagnetization is not straightforward.

However, the F histories of the Oriskany and the two limestone units differ significantly. Stable isotope and Fl data from veins indicate that low sal (7-15 wt % NaCl eq.), high T (155-225°C minimum) F migrated through the Oriskany after folding. In contrast, F in the Helderberg and the Trenton were restricted to in-situ high-sal, low T brines. Although the results from the Oriskany are consistent with remagnetization by orogenic F, such F are not directly related to the synfolding remagnetizations in the Helderberg and Trenton. (From authors' abstract by H.E.B.)

### EVERETT, Catherine, 1998, Genesis of Lower Carboniferous-aged Irish Zn-Pb-(Ba) deposits: An example of a deeply circulating hydrothermal system: SEG Newsletter, No. 35, 1998, p. 8-9. Author at Dept. of Geol. and Geophys, Yale Univ., New Haven, CT.

New evidence has been discovered in Ireland which supports the hypothesis that ore F circulated through and reacted with weakly metamorphosed, altered, and strongly fractured Silurian sedimentary basement rocks. Fl and stable isotope data from basement-hosted quartz-carbonate veins reveal the presence of a basement-equilibrated, high-T (>200°C), moderate sal F which is strikingly similar to the high T ore F found in Fl in the Irsh basemetal deposits. There is also evidence for infiltration into the basement of low T surface F (both brines and either seawater or meteoric water). Hydrothermal alteration in the Old Red Sandstone is highly localized and probably was produced by highly focused F flow along faults by basement-equilibrated high-T F. These results, in conjunction with previous Pb, S, C, O, and H isotope studies, imply that hydrothermal F flow within the basement rocks of Ireland was fundamental to the formation of the Irish deposits. (From author's abstract by E.R.)

FABRE, Cécile, BOIRON, M.-C, DUBESSY, Jean, and MOISSETTE, Alain, 1998a, Laser ablation - optical emission spectroscopy (LA-OES): new improvements for the analysis of individual fluid inclusions, minerals and glasses (abst): Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 31. Authors at CREGU and UMR G2R 7566, BP23, 54501 Vandoeuvre-les-Nancy Cedex, France.

The principle is the following: a Nd-YAG laser is coupled with an optical emission spectrometer which analyzes the emission lines of the elements present in the plasma resulting from the interaction between the laser and the material.

A variety of improvements permit Na, Li, K and Ca emission lines to be obtained simultaneously for each shot. Calibrations of element ratios have been carried out on synthetic glasses and synthetic Fl in quartz. Reproductibility for net intensity of Na, Ca, Li emission lines in glasses is in the range 5 to 15%. In Fl, RSD element ratios are between 8 and 15%. (From authors' abstract by E.R.)

FABRE, C., BOIRON, M.-C., DUBESSY, J. and MOISSETTE, A., 1998b. Laser-ablation optical-emission spectrometry: methodological developments applied to the analysis of individual fluid inclusions (abst.): Réunion des Sciences de la Terre. Brest, 31 March-3 April, 1998, p. 111 (in French, translation by E.A.J. Burke). Authors at CREGU-UMR 7566, BP 23, 54501 Vandœuvre-lès-Nancy Cedex; email (fabre@cregu.cnrsnancy.ft)

FI are prime objects for the reconstitution of paleocirculations and for the understanding of F-rock interactions. A new analytical method is based on the optical-emission spectrometry of a plasma produced by a pulsed laser, on spots of the scale of a few micrometers. The L in the FI is reached after ablating the surface with the laser. The ions in the L phase can be recognized by the characteristic radiations of their electronic transitions. Our work shows that it is possible to detect Na. K. Li. Ca. Mg. Sr. Ba, Cu, and Cs in Fl with a size in the order of several tens of micrometer. The detection limit varies between 10 and 100 ppm, depending on the element. Plasmas produced from a glass or from an aq solution have the same average T. For this reason, the calibration of the intensity ratios of the emission peaks of two elements is done with synthetic glasses for which the reproducibility of the intensity ratios is in the order of 5%. [sic]. Such calibration curves have been obtained for the ratios Na/Li. Na/K, and Na/Ca. The determination of the ratio of two cations in a natural FI is based on the statistical analysis of the absolute intensities of the emission peaks of these

elements, for which the RSD is in the order of 10%.

This method allows thus to analyse ions in natural FI. The challenge formed by the analysis of the cation contents in an aq phase is on the way to be met: the analysis of quantities of matter lower than 10<sup>-12</sup> kg will then be possible. (Authors' abstract)

FALLARA, Francine, SAVARD, M.M. and PARADIS, Suzanne, 1998, A structural, petrographic, and geochemical study of the Jubilee Zn-Pb deposit, Nova Scotia, Canada, and a new metallogenic model: Econ. Geol., v. 93, p. 757-778. First author at Geological Survey of Canada-Québec, Centre Géoscientifique de Québec, P.O. 7500, Sainte-Foy. Québec, Canada G1V 4C7.

Quotes I data from Chi et al., 1995 (FIR 28, p. 22). (E.R.)

FAN, Hongrui, JIN, Chengwei and SHENG, Yuanchao, 1998, Oreforming fluid geochemistry of the Hatu gold deposit in Xinjiang, northwest China: Mineral Deposits (Kuangchuang Dizhi), v. 17, no. 2, p. 135-149 (in Chinese; Engl. abst.) Authors at Inst. of Geol., Chinese Acad. of Sci., Beijing 100029.

The Hatu gold deposit is located in western Junggar of Xinjiang, adjacent to Kazakhstan, lying in north limb of Dalabute synchinorium of Junggar Hercynian folding belt. Wall rocks of the deposit are lower Carboniferous basalt-pyroclastic rocks. Orebodies are controlled by fault system of the old crater. Two ore types, quartz vein and altered rock, have been found in the mine. The ore veins contain abundant FI, which are mainly two phase G-L NaCl-H2O and three phase NaCl-CO2-H2O with L CO2. Oreforming F are rich in CO2, N2, Na\*, K\*, CI and SO42, but merely contain simple ore-forming elements characterized by Au-As-Ag-Sb. Ore-forming F are of low sal. In the main mineralizing stage, sal is  $4.1 \text{ wt\%} \sim 6.3 \text{ wt\%}$ NaCl eq., density 0.88 g/cm<sup>3</sup>,  $fO_210^{-35} \sim 10^{-31}$  Pa, and Eh 0.60~0.80 eV. The F in the I have a wide range of Th from 160 to 360°C, but the best T range for gold deposition is from 230 to 260°C. Quartz from auriferous veins has 818O values ranging from 15.4% to 17.5%. Calculated 818O and δD values for the ore-forming F range from 6.0% to 11.7% and -86% to -111% respectively, suggesting derivation from later volcanic F mixed with meteoric water. F immiscibility and F-rock interaction may be the main causes for gold deposition in the mine. (Authors' abstract)

FAN, Hongrui, XIE, Yihan and WANG, Yinglan, 1998a, Geochemistry of water/rock reaction system of vein gold deposits: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998; Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1043-1046 (in Chinese).

FAN, Hongrui, XIE, Yihan and WANG, Yinglan, 1998b, Fluid-rock interaction during mineralization of the Shanggong structure-controlled alteration-type gold deposit in western Henan province, central China: Acta Petrologica Sinica, v. 14. no. 4, p. 529-541. Authors at Inst. of Geol., Chinese Acad. of Sci., Beijing 100029.

The Shanggong gold deposit is contained within a ductile shear zone in weak-metamorphosed rocks of the middle Proterozoic Xiong'er Group. The ores occur as veins or as lenticular bodies within altered basalticandesitic host-rocks. During Frock interaction, the ore-forming components were not equally mobile. Inner alteration zones are characterized by additions in components such as Au, Ag, As, Sb and Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, Na<sub>2</sub>O, and by decreasing in REE. Fl data suggest that T and P during first stage of Frock interactions were 365-300°C and 285 MPa-200 MPa, and 325-240°C and 160 MPa-100 MPa in gold deposition stage. Primary F were associated with a homogeneous H<sub>2</sub>O-CO<sub>2</sub>-NaCl F containing 0.18-0.24 X<sub>CO2</sub> and 9.5-6.3% NaCl, and changed to aq F with 5.9-1.6% NaCl during gold mineralizing stage. Frock interactions were main reason for gold deposition. (Authors' abstract)

FANLO, Isabel and AYORA, Carlos, 1998. The evolution of the Lorraine evaporite basin Implications for the chemical and isotope composition of the Triassic ocean: Chem. Geol., v. 146, p. 135-154. First author at Cristalografia y Mineralogia Dpto., Ciências de la Tierra, Edificio Geologicas, C/Pedro Cerbuna, 12, E-50009-Zaragoza, Spain.

During the Upper Triassic times about 75 m of halite with minor anhydrite was deposited in the Lorraine basin. Samples of halite and sulfates were systematically collected from a borehole intersecting the sequence. The chemical evolution of the original brine was investigated by X-ray microanalysis of PI trapped in halite. The original brines were of the Na-Mg-K-Ca-Cl type, being consistent with the mineral association of halite and minor anhydrite. Their solute content can be reproduced by evaporation of present day ocean composition in an open basin. However, some

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modifications are required. The inflow of a small excess of CaCl2 into the basin (1.2 to 1.9% of the total recharge) is required to explain the low SO4 values analyzed in FI. The same inflow helps to explain more satisfactorily the low Na and high Cl contents. The back-reaction of brine with previous Ca-sulfate that forms polyhalite could explain the low and variable K values analyzed. The excess of Ca with respect to present day seawater, and the formation of SO4-poor evaporite sequences is the rule rather than the exception in the geological record. We have not been able to assess the ultimate origin of the Ca excess in the basin. Nevertheless, the great variation of the SO4 content within short vertical distances (centimeter scale), suggests that these variations are due to processes taking place within the evaporite basin rather than to changes in the composition of the ocean at a global scale. The isotopic composition of sulfur and oxygen was determined using samples of sulfates from the same borehole. The  $\delta^{34}S$  values of 2) samples analyzed show a narrow variation:  $\delta^{34}S = 15.5 \pm 0.4\%$ . The  $\delta^{18}O$  values of eight samples analyzed show a wider range of variation:  $\delta^{18}O = 13.0 \pm 1.1\%$ . None of the processes which modify the  $\delta$  values, such as sulfate reduction or additional sulfate sources (continental, recycling of sulfates from the margins), were clearly identified. The values of  $\delta^{34}S_{sw} = 15.7$  to 14.5% and  $\delta^{18}O_{sw} = 13.7$  to 12.2‰ for the sulfate dissolved in the Triassic ocean explain the  $\delta$  values of the sulfates interbedded in the halite of the Lorraine basin, and most analyses reported in the literature. (Authors' abstract)

FAURE, K., MATSUHISA, Y., METSUGI, H. and MIZOTA, C., 1998, Water-rich quartz and adularia veins of the Hishikari epithermal Au-Ag deposit, southern Kyushu, Japan: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 537-540. First author at Dept. of Geochem., Geological Survey of Japan, Tsukuba, Japan.

Thermogravimetric, manometric, and Fourier transformation infra-red analyses indicate that quartz and adularia from epithermal veins contain orders of magnitude more water than would be expected in crystalline nonhydrous minerals. The water is contained within structural sites such that it is released only at specific thermal energies, and not merely loosely bound to mineral surfaces or trapped within FI. Petrographic studies reveal that the veins contain minor amounts of chalcedonic quartz, and that quartz and adularia contain abundant mineral I, possibly clay minerals. The chalcedonic quartz and mineral I are most likely the source of the water. Results from this study show that chemical and isotopic analyses of water extracted from whole-rocks, ostensibly from FI, should be interpreted with caution. Ubiquitous recrystallisation and replacement textures in the Hishikari veins attest to a complex history that may hamper the determination of the original composition of F and origin of metals. (Authors' abstract)

FEDOROV, I.I., BAGRYANTSEV, D.G., CHEPUROV, A.A., OSORGIN, N.Yu., POKHILENKO, L.N. and CHEPUROV, A.I., 1998, Experimental investigation of the volatiles captured by crystallizing diamonds: Geokhimiya, 1998, No. 4, p. 446-421 (in Russian, translated in Geochem Int'l., v. 36, no. 4, p. 361-366). Authors at Inst. of Mineral. and Petrog., Siberian Div., Russian Acad. of Sci., Universitetskii pr. 3, Novosibirsk, 630090, Russia.

Chromatography was applied to determine the composition of the postcrystallization gaseous phase after diamond syntheses from the  $Fe_{0.36}Ni_{0.64}$ -C system at high P-T parameters. The compositions of volatiles captured by diamonds and other high-P phases (recrystallized graphite. Fe-Ni alloy) upon their crystallization are determined. The captured G are more oxidized than their parent medium. A discrepancy regarding the extent of gaseous-phase oxidation should be taken into account when applying data from natural samples to reconstruct the parameters of diamond genesis. It is shown that the G speciation, when determined chromatographically, differs substantially from speciation calculated for the P-T parameters of runs. Presumably, the difference in speciation arises from assumptions commonly used in the thermodynamic modeling of F equilibria at high P-T parameters. (Authors' abstract)

FENG, Bengzhi and ZENG, Qindong, 1998, Ore-forming conditions of mantle fluid originated, Haigou gold deposit, Jilin 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v 17 Supplement, p. 969-972 (in Chinese).

FENG, Shouzhong, 1998a. Geological features and metallogenic mechanism of Zhengcha Pb-Zn mineral deposit, Jilin, China: J of Guilin Inst. of Tech., v. 18, no. 2, p. 112-123 (in Chinese, abstract translated by H.-Z. Lu). Author at Jilin Inst. of Geol. and Mineral Resources, CNNC, Changchun, Jilin, China.

The Zhengcha Pb-Zn ore deposit is located in a folded Proterozoic graphic [graphitic?] marble and plagioclase amphibolite beds and lenses. The Mesozoic granite porphyry and diorite are intruded into the Proterozoic graphic marble and plagioclase amphibolite and form skarn and ore bodies. Pb, S, H, O and C isotopes have been studied, as well as the FI. Two types of FI. halite bearing and aq I have been found in calcite and quartz of the ore body. Th for dm bearing I range from 420 to 280°C with higher sal of 36-63 wt.% NaCl eq. Th for aq I range from 150 to 400°C with sal from 3 to 12 wt.%. The bulk composition of FI is rich in K, Na, F and CI. The G composition is mainly H<sub>2</sub>O and CO<sub>2</sub>. &D and 8<sup>18</sup>O<sub>H2O</sub> of FI are in the mixture region of meteoric water. The sources of metal, sulfur and F are possibly from the intrusions and the hostrocks.

FENG, Shouzhong, 1998b, The geological characteristics and genesis of Ermi copper deposit, Jilin province, China: J. of Guilin Inst. of Tech., v. 18, no. 4, p. 323-329 (in Chinese, abstract translated by H.-Z. Lu). Author at Jilin Inst. of Geol. and Mineral Resources, CNNC, Changchun, China.

The Ermi copper deposits are mainly in the eastern part of the Mesozoic quartz diorite and granitic porphyry intrusions in the Ermi volcanic basin. The ore bodies, as vein, veinlet, veinlet-disseminated and disseminated types, occur at the inner and outer contact zone between quartz diorite and andesite volcanic rocks. The copper deposits could be classified into four ore stages according to the mineral paragenesis and alteration assemblage. The sulfur isotope data of sulfide of quartz diorite and copper quartz vein quartz are very similar, possibly indicating the same source. FI studies show the Tf ranges from 161 to 364°C. The origin of this deposit is associated with the intrusions.

FENG, Zengzhao, ZHANG, Yongsheng and JIN, Zhenkui, 1998, Type, origin, and reservoir characteristics of dolostones of the Ordovician Majiagou Group, Ordos, North China Platform: Sedimentary Geol., v. 118, no. 1-4, p. 127-140.

Dolostones are well developed in the Ordovician Majiagou Group in the Ordos area. North China Platform. These dolostones can be divided into four types: mud-sized to silt-sized crystalline dolostones not associated with gypsum and halite beds (type I), mud-sized to silt-sized crystalline dolostones associated with gypsum and halite beds (type II), mottled silt-sized to very fine sand-sized crystalline dolostones (fine saccharoidal dolostones) (type III), and mottled coarse silt-sized to fine sand-sized crystalline dolostones (coarse saccharoidal dolostones) (type IV). Type I dolostones consist of mud-sized to silt-sized dolomite crystals. Laminar stromatolites, ripple marks, mud cracks and birdseyes are common. Such dolostones are not associated with gypsum and halite beds, but lath-shaped pseudomorphs after gypsum are common. The ordering of dolomites averages 0.59, and molar concentration of CaCO<sub>1</sub> averages 51.44%. 813C averages -0.8 per mil (PDB Standard), 818O averages -2.9 per mil. SCe averages 0.83. The above characteristics suggest that type I dolostones result from penecontemporaneous dolomitization of lime mud on supratidal flat environments by hypersaline sea water. Type II dolostones mainly consist of mud-sized to silt-sized dolomite crystals. They are commonly well laminated but show no desiccation structures. Such dolostones are intercalated within laminated gypsum and halite beds or are intermixed with them. Such dolostones resulted from dolomitization of lime mud by hypersaline sea water in gypsum and halite precipitating lagoons. Type III dolostones consist of coarse silt-sized to very fine sand-sized dolomite crystals. They commonly underlie type I dolostones and grade downwards to dolomite-mottled limestones and pure limestones. The ordering of dolomites averages 0.63, and molar concentration of CaCO3 averages 55.64% ol'C averages -0.2 per mil, ola averages -3.3 per mil, oce averages 1.24. Such dolostones resulted from reflux dolomitization by hypersaline sea water. Type IV dolostones consist of coarse-silt-sized to finesand-sized dolomite crystals. In such dolostones, stylolites are cut by dolomite crystals. Fl are present, and Th commonly ranges from 104 to 203°C. The ordering of dolomites averages 0.85, and molar concentration of CaCO1 averages 50.65%. δ13C averages 0.6 per mil, δ18O averages -7.4 per mil. and &Ce averages 1.16. Such dolostones resulted from deep burial dolomitization. In the Ordos area, type I and II dolostones modified by palaeokarstification are the major G reservoir rocks of the Ordos Gas Field at present. Type IV dolostones show good reservoir characteristics and may also be potential reservoir rocks. (Authors' abstract)

FENG, Zhongyan and CHANG, Zhaoshan: Studies on fluid inclusions associated with skam deposits in Taihang Mountains, China (abst.): Sec-

Four stages of skarn formation of these many Fe-Cu-Pb-Zn deposits are recognized. Minerals and conditions of formation of each stage in several different skarn deposits based on FI studies are as follows:

(1) Early skarn stage: gamet, pyroxene, etc. show Th 570-580; sal (wt%) 43-65; and composition of the L phase (μg/l0g) [sic] Na<sup>+</sup> 11.9-115.2, K<sup>+</sup> 0.5-1.6, Ca<sub>2</sub><sup>+</sup> 3.3-78.4, Mg<sub>2</sub><sup>+</sup> 15.2-161, F- 0.1-3.2, Cl<sup>+</sup> 11.7-163.8, SO<sub>4</sub><sup>2-</sup> 93.2-262.8.

(2) Hydrosilicate-iron oxides stage: epidote, amphibole, quartz, magnetite, hematite show Th 345-422; sal (wt%) 33-40; composition of the L phase in the 1 (μg/10g) Na\* 15.3-20, K\* 2.0-3.9, Ca<sub>2</sub>\* 2.0-3.3, Mg<sub>2</sub>\* 0.3-0.9, F\* 0.1-5.7, Cl' 11.7-52.9, SO<sub>4</sub><sup>2\*</sup> 31.8-93.15.

(3) Hydrosilicate-base metal sulfides stage: chlorite, serpentine, sericite, calcite, pyrite, chalcopyrite, galena, sphalerite, etc., show Th 230-260; sal (wt%) 16-17; composition of the L phase (µg/10g) Na<sup>\*</sup> 15.3-47.9, K<sup>\*</sup> 2.3-3.9, Ca<sub>2</sub><sup>\*</sup> 3.3-41.4, Mg<sub>2</sub><sup>\*</sup> 6.0-9.0, F<sup>\*</sup> 0.1-3.2, Cl<sup>\*</sup> 11.7-163.8, SO<sub>4</sub><sup>2\*</sup> 93.2-262.8.

(4) Late stage: calcite shows Th 179-220 and sal (wt%) 10±. In some skarn deposits FI studies also yield information about P XCO<sub>2</sub>/XH<sub>2</sub>O, composition of the V phase in the I, δD, δ<sup>18</sup>O and fO<sub>2</sub>. (From authors' abstract by E.R.)

FERNÁNDEZ-MARTÍNEZ, J. and VELASCO, F., 1996, The Troya Zn-Pb carbonate-hosted sedex deposit, northern Spain: Society of Economic Geologists, Special Pub. No. 4, p. 364-377. Authors at Departamento de Mineralogía y Petrología, Universidad del País Vasco, Apdo. 644, E-48080 Bilbao, Spain.

Three exhalative pulses of mineralization are recognized indicating different episodes of F expulsion during basinal dewatering. The deposit was produced by brines generated within the sedimentary sequence. F1 studies indicate sal of 14-26 wt.% NaCl eq. and T in the range of 100-175°C, consistent with those calculated according to the sulfur isotope fractionation between mineral pairs. A homogeneous source involving a warm deep brine is indicated. (From authors' abstract by E.R.) 1-63

FERRILL, D.A., 1998, Critical re-evaluation of differential stress estimates from calcite twins in coarse-grained limestone: Tectonophysics, v. 285, p. 77-86. Author at Center for Nuclear Waste Regulatory Analyses, Southwest Research Inst., 6220 Culebra Road, San Antonio, TX 78283-5166 USA.

Comparison of two techniques to estimate differential stress magnitude based on calcite twinning reveals significantly different calculated values of differential stress for limestone experimentally and naturally deformed at low T. This inequality may be due to fundamental differences between the rock type (marble versus limestone) and deformation T (above and below 200°C) for samples used in technique calibration versus samples used in testing and application. A technique that was empirically derived from marble experimentally deformed at 200-800°C yields values of differential stress that are factors of 2 to 9 times larger than maximum differential stress measured during experimental deformation of limestone at low T (<200°C). Differential stress estimates from naturally deformed rocks differ by factors of 4 to 20, depending on the stress estimation technique used. Calcite tends to develop thin twins when deformed at T < 200°C, and thick twins when deformed at T > 200°C. Because of the T dependence of calcite-twin morphology, and possible effects of strain, grain size, and porosity, twin-based differential stress estimates should be used cautiously and particular attention given to deformation T. (Author's abstract)

Of pertinence to the interpretation of FI in deformed calcite (E.R.).

FIELD, M.P., KERRICH, Robert and KYSER, T.K., 1998. Characteristics of barren quartz veins in the Proterozoic La Ronge domain. Saskatchewan. Canada: A comparison with auriferous counterparts: Econ. Geol., v. 93. p. 602-616. First author at Inst. of Marine and Coastal Sci.. Rutgers Univ., 71 Dudley Road. New Brunswick, NJ 08901, USA.

The Star and Island Lake plutons of the Central metavolcanic belt, La Ronge domain, host a variety of barren and auriferous quartz veins in northeast-trending shear zones, with competency contrasts in the plutons, which may be attributed to the northeast-trending boundary of igneous phase changes, or the presence of northeast-trending dikes. Veins range from 30 cm to 2 m wide, up to hundreds of meters long, and exhibit a discontinuous pinch and swell nature common to most shear zone-hosted mesothermal quartz veins. Barren veins are paragenetically simple, quartz being the dominant hydrothermal mineral with sparse microcline of variable origin. Muscovite, a common gangue mineral in auriferous veins, is rare in barren veins; in barren veins its occurrence is correlated with slightly elevated gold values.

Macro- and microfractures, preserved as veins and planar arrays of FI, are a result of episodic brittle failure. Regionally, veins have a bimodal distribution of  $\delta^{18}$ O quartz values with barren and auriferous veins occupying both populations. Petrographically, FI in barren veins are identical to those described in auriferous veins. Th values and wt% NaCl and bulk CO<sub>2</sub> are also similar, however, an important distinction is that auriferous veins may have up to 30 mol% CH<sub>4</sub>, a phase absent in barren veins. Distinct mineral paragenesis and CH<sub>4</sub> content may represent different redox states of barren and auriferous F. Lack of reduced carbon species in barren veins may reflect an oxidizing F with few reduced sulfur ligands capable of transporting gold. (From authors' abstract by E.R.)

FISCHER, T.P., GIGGENBACH, W.F., SANO, Yuji and WILLIAMS, S.N., 1998. Fluxes and sources of volatiles discharged from Kudryavy, a subduction zone volcano, Kurile Islands: Earth and Planet. Sci. Letters, v. 160, p. 81-96. First author at Dept. of Geol., Arizona State Univ., Tempe, AZ 85287-1404, USA.

The Kudryavy volcano, a 996-m-high basaltic-andesite cone on the northeastern shore of Iturup Island in the Kuriles, erupted last in 1883 and has since been in a persistent state of high-T, >900°C fumarolic activity. Its flux of SO2, measured by COSPEC, is 73±15 t/d, or 416 Mmol/a. In combination with the chemical composition of the parent G supplying the high-T vents and the isotopic compositions of He and C, it allows the evaluation of contributions from major source components, such as the mantle, the crust, and subducted sediments and carbonate. The 3Her He ratio of 6.7 RA corresponds to a 84% mantle origin and a flux of 2200 mol/a of mantle He. At a He concentration of 2200 mol/Mt. the mass of mantle material required to generate this flux is 1.0 Mt/a. The same mass produces a flux of 0.025 mol/a of <sup>3</sup>He and of 50 Mmol/a of mantle CO<sub>2</sub> at a CO<sub>2</sub>/<sup>3</sup>He ratio of 2×109. In conjunction with the C-isotopic composition of furnarolic CO2 of -7.2‰, about 12% of the CO2 are derived from the mantle, 67% from marine carbonate in subducted, altered oceanic crust, 21% are of subducted organic sedimentary origin. The flux of 280 Mmol/a of carbonate-derived CO2 requires 0.41 Mt/a of oceanic crust with a CO2 content of 3 wt%, and 0.35 Mt/a of sedimentary material to supply the organic CO2 flux of 86 Mmol/a. Nitrogen from the mantle contributes at most 2% to the total N2 flux of 5.4 Mmol/a. Assuming N to be derived from the subducted sediments, its concentration there is 460 mg/kg. The total volume of mantle and subducted material required to maintain the flux of volatiles over the 100 a period of high-T fumarolic activity of Kudryavy is 0.07 km Steady-state release of volatiles from the depth of arc magma generation to the fumaroles and continuously high heat flow from the mantle are main process supporting the long-term high-T degassing at Kudryavy. In this steady-state system, the calculated volatile fluxes are balanced over time by volatiles originating from subducted sediments, hydrothermally-altered oceanic crust below the Kudryavy volcano and the mantle wedge. This has significant implications for volatile cycling from the Earth's crust and mantle to the atmosphere. (Authors' abstract)

FOGLIATA, A. and GONZALEZ, M.M., 1998, Study of fluid inclusions of the wolframiferous quartz veins from Mazan Range, La Rioja, Argentine: IV Meeting of Mineralogy and Metallogeny, [IV Réunion de Mineralogia y Metalogenia "MINMET"] Sept. 23-25, 1998, Bahia Blanca, Argentia, p. 71-75 (in Spanish, Engl. abst.).

The FI of the tungsten-bearing quartz vein of Yanacoya deposits. Sierra de Mazán, La Rioja, are studied. Wolframites occur associated with Paleozoic granitic rocks. As accompanying minerals appear cassiterite and scarce pyrite. FI in quartz veins have variable compositions, but three main types are recognized. Th determined confirm that hypothermal F are related to tungsten mineralization. (Authors' abstract)

FOGLIATA, A.S., GONZÁLEZ, M.M., and MAS, Graciela, 1998. Fluid inclusions of the La Descubridora tin deposit. Evidence of fluid evolution (abst.): Program and Abstracts. PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions. June 1-4, Univ. of Nevada, p. 32. First author at CONICET- Univ. Nac. de Tucumán, M. Lillo 205, 4000- S.M. de Tucuman, Tucumán, Argentina; email (fogliat@csnat.untmre.edu.ar; gonzalez@criba.edu.ar; gmas@criba.edu.ar)

La Descubridora consists of hydrothermal high temperature quartz, veins hosted in Silurian-Ordovician granitic rocks. Most veins contain quartz, muscovite, pyrite, chalcopyrite and arsenopyrite, quartz has discontinous undulatory extintion with cassiterite both within the quartz mass, or

with S muscovite in the alteration zones. FI in anhedral quartz veins range from <2 to 14  $\mu$ m. Type I are monophase (L or V) aq PS and S. Type II have two phases: Type IIa are L+V, either isolated or in clusters (P) or as S trails, and Type IIb are V+L, isolated, and condense a low density CO<sub>2</sub> V phase on cooling. Type III are P isolated H<sub>2</sub>O+CO<sub>2</sub> with three phases.

Secondary Type IIa FI have a mean Th of 222°C, and P and PS ones have mean Th of 328°C (Fig. 1). The mean Th for Type IIb and III inclusions is also near 328°C, and all FI have around the same sal of 6 wt% NaCl eq. The  $CO_2$ -H<sub>2</sub>O I fall in the homogeneous area on the empirical solvus for  $CO_2$ -H<sub>2</sub>O with 6 wt% NaCl eq.

A broad span of isochores is a consequence both of varying CO<sub>2</sub> ratios and of a range of T among all types of I and show a range of P varying from 400 to 1400 bars. The unmixing mechanism which yields monophase and aq FI is assumed to have occured between 275°C and 300°C, in the two-phase field. (From authors' abstract by E.R.)

FOLEY, N.K. and FLOHR, M.J.K., 1998, Ancient gossan formation at the Bald Mountain VMS deposit, Maine: A natural analogue of the modern oxidation of tailings piles? (abst.): The Geological Society of America 33<sup>rd</sup> Annual Meeting, Northeastern Section, March 19-21, 1998, Portland, Maine, v. 30, no. 1, p. 19, ISSN 0016-7592. First author at MS 954, U.S. Geological Survey, Reston, VA 20192; email (nfoley@usgs.gov)

The Bald Mountain Cu-Zn-Au-Ag deposit is a weakly metamorphosed volcanogenic massive sulfide (VMS) body occurring within an early Paleozoic volcanic belt. Below a unit of glacial till, supergene Cu and overlying Fe-oxide, Au-, and Ag-bearing gossan stages are superimposed on underlying massive sulfide zones that display well-preserved mineralogical textures (Slack and others, 1997). These characteristics make the gossan zone at Bald Mountain an ideal candidate for identifying chemical and biomineralogical processes that control natural degradation of a massive sulfide body, which presently occurs within a transitional ecoregion characterized by humid-temperate to polar and warm-continental to subarctic conditions (Bailey, 1989). Natural degradation of sulfide tailings piles (e.g., Flohr and Hammarstrom, 1997).

The geometry of the supergene Cu and Au-Ag gossan zones argues against an Ordovician seafloor weathering origin for the gossan (Slack and others, 1997). Fl data for P, two-phase (I-v) I in quartz intergrown with goethite yield T up to  $-85^{\circ}$ C, thus indicating that the formation of the porous and boxwork goethite gossan took place at T considerably warmer than those found in modern surficial environments. Stabilities of some of the S sulfate minerals suggest a pH range of 4-6 for the most recent F involved in the life cycle of this VMS system. (From authors' abstract by H.E.B.)

FONAREV, V.L. TOURET, J.L.R. and KOTELNIKOVA, Z.A., 1998. Fluid inclusions in rocks from the Central Kola Granulite area (Baltic Shield): Eur. J. Mineral., 1998, no. 10. p. 1181-1200. First author at Inst. of Experimental Mineral., Russian Acad. of Sci., Chemogolovka, Russia.

Metamorphic rocks of the Archean Central Kola granulite area. Baltic Shield, contain two major Fl types: gaseous and salt-bearing aq (brines). Most of the abundant gaseous I are CO<sub>2</sub>-rich, containing up to 5-35 mol% N<sub>2</sub>. Almost pure N<sub>2</sub>-bearing (with occasionally up to 7.9 mol% CH<sub>4</sub>) and CH<sub>4</sub>-rich I also occur. Brine I contain CaCl<sub>2</sub> (up to 21.8-28.3 eq. wt%)- or NaCl (9.9-30.5 eq. wt%)-rich F. Late, low-sal aq I (mostly pure H<sub>2</sub>O, containing occasionally up to 6.1 eq. wt% NaCl) have also been observed.

N<sub>2</sub>-rich and CO<sub>2</sub>-rich F with maximum N<sub>2</sub> contents occur only in BIF and closely related enderbites, together with CaCl<sub>2</sub>-bearing brine I. Other F types occur in all other investigated samples (pelitic gneiss and plagiogneiss, enderbites).

The increase of N<sub>3</sub> content (from 5 up to 35 mol%) in the CO<sub>2</sub>-rich F causes a regular decrease of both homogenization (T<sub>h</sub>, always to L) and final T<sub>m</sub>, from -17 to -45.4°C and -57.7 to -61.7°C, respectively. In pure to almost pure (<5 mol% N<sub>2</sub>) CO<sub>2</sub> I, density variations for synchronous (syngenetic) I (GSI=groups of synchronous I) are essentially due to post-trapping changes, either volume changes (notably volume decrease, leading to a density increase of the enclosed F) and/or leakage (density decrease).

The Central Kola granulite area has been submitted to three metamorphic events: M1 ( $670\pm20^{\circ}C$ ,  $51\pm0.5$  kbar), M2 ( $565\pm15^{\circ}C$ ,  $40\pm0.5$  kbar) and lower-grade M3. From the location of the 1 in minerals equilibrated at a given metamorphic stage, and from comparison between 1 isochrores and mineral P-T data, it is inferred that N<sub>2</sub>-, CaCl<sub>2</sub>-, and most CO<sub>2</sub>-rich 1 are related to the M1 event. Some P, lower-density CO<sub>2</sub> 1 in M2 garnet represent M2 F. They indicate CO<sub>2</sub> P at M2 conditions lower than metamorphic P (by about 1,1 kbar), whereas some isochores for M1 and M21 (V=46.7)

and 5.12 cm<sup>3</sup>/mole, respectively) correspond to F P higher than metamorphic P. This is explained by a combination of partial H<sub>2</sub>O leakage and volume decrease of the 1 during post peak-metamorphic conditions. The overall interpretation leads to a model of cyclic alternation of stable (quiet) subisobaric cooling periods (post M1 and M2), followed by short episodes of decompression during uplift (leading to M2 and M3, respectively). (Authors' abstract)

See also FIR 30, p. 60 (E.R.)

FORTUNA, John, 1998, Late porphyry- related gold mineralization at the Kingking porphyry Cu-Au deposit, Mindanao, Philippines: SEG Newsletter, 1998, no. 35, p. 5. Author at Dept. of Geological Sci., Univ. of Michigan. Ann Arbor, MI.

Gold is deposited with copper in the potassic zone of most porphyry copper deposits, but can be remobilized during retrograde alteration or by later, unrelated hydrothermal events. Gold at the Kingking porphyry Cu-Au deposit in the Philippines is in guartz-pyrite veins on the periphery of the high-copper zone. These veins are enclosed in sericite-clay-chlorite alteration and cut main-stage quartz-chalcopyrite-bornite veins in deeper parts of the deposit. The gold-quartz-pyrite veins previously were interpreted to be of epithermal origin, based on lack of Cu-sulfides and the location of Kingking at the south end of the eastern Mindanao epithermal gold belt. Quartz in the main-stage quartz-chalcopyrite-bornite veins contains isolated P L-rich I with halite, sylvite, hematite and chacopyrite dm. and V. The I homogenize at 650 to 700°, have sal of 70+ wt.% NaCl equivalent, and define a halite trend. Quartz in the gold-quartz-pyrite veins contains identical PI with the same dm and similar sal. These I homogenize at slightly lower T (550-660°C) and fall on the same halite trend. Close similarity of F in the two vein types suggests that Au-bearing quartzpyrite veins are part of the porphyry system, and formed at slightly lower T and slightly later than main-stage copper mineralization. The combination of high gold grades and lack of copper values in these gold-quartz-pyrite veins is unusual, however, and suggests that conditions during retrograde alteration of porphyry systems permit significant movement of gold, with no copper. (Author's abstract)

FOURNIER, Patricia, OELKERS, E.H., GOUT, Robert and POK-ROVSKI, Gleb, 1998, Experimental determination of aqueous sodiumacetate dissociation constants at temperatures from 20 to 240°C: Chem. Geol., v. 151, p. 69-84. First author at Laboratoire de Géochimie. CNRS UMR 5563, Univ. Paul Sabatier, 38 rue des Trente Six Ponts, 31400 Toulouse, France.

Dissociation constants of sodium acetate ion pair (NaCH<sub>3</sub>COO<sup>0</sup>) were determined at the L-V saturation P by Raman spectroscopy at T from 20 to 240°C and by potentiometry at T from 25 to 172°C. Large differences were found between these two experimentally determined data sets. These parameters are used to assess the formation of these complexes at T and solution compositions typical of natural F. (From authors' abstract by E.R.)

FRANK, M.R., CANDELA, P.A. and PICCOLI, P.M., 1998a, Estimated copper concentrations in magmatic vapor and brine in a sulfur-bearing brine-vapor-haplogranitic melt-intermediate solid solution-pyrrhotite system at 800°C and 100 MPa (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-371. Authors at Laboratory for Mineral Deposits Research, Dept. of Geol., Univ. of Maryland, College Park, MD 20742; email (frank54@geol umd.edu)

The transport and deposition of some ore metals by a magmatic volatile phase (MVP) has long been accepted. The MVP may be a low-sal V, a high-sal brine, or both. Experimental studies in sulfur-free systems have shown Cu prefers the high-chloride brine over the V (Candela and Holland, 1984, GCA, v. 48, 373; Williams et al., 1995, CMP, v. 130, p. v. 121. 388). Recent studies of FI from natural settings have shown that Cu preferentially partitions into the V relative to the brine in natural (sulfurbearing), sub-solidus V-brine systems (Audétat et al., 1998, Sci., v. 279, 2091). Therefore, we performed experiments in the system brine-Vhaplogranitic M-intermediate solid solutions (lss)-pyrrhotite (Po)-quartz at 800°C. 100 MPa and at an oxygen fugacity buffered by Ni-NiO. Both V and brine FI were trapped in a silicate glass and quartz. FI that trapped the magmatic V phase contain: 1) a large V bubble, 2) liquid, and 3) one or more opaque dxl. FI that trapped magmatic brine contain: 1) a V bubble, 2) liquid. 3) multiple halite/sylvite dxl. and 4) two opaque dxl. Both types of FI may contain at least two types of opaque dxl. one is tetrahedral and the other is magnetic, platy, and hexagonal, these crystals are assumed to be Iss and Po, respectively (both minerals are present in the capsule at the end

of a run) The Po crystals can be manipulated inside each FI by an external magnet, allowing for a detailed examination of their geometry. Opaques in V FI are dominated by Iss with rare Po. Brine FI have more Po, but less Iss relative to V FI. Order of magnitude, model Cu concentrations in the FI due to dm alone were calculated from the relative volume of an opaque dxl and its host, given measurements of the dimensions of the crystals and the host FI. V (n=38) and brine (n=36) Fl contain 0.8±(0.2) × 104 (20) and  $0.2\pm(0.1) \times 10^4$  (2 $\sigma$ ) ppm Cu, respectively, producing a partition coefficient (D'/bcu) on the order of 4 for Cu between a coexisting V and brine. Cu concentrations in the M (measured by EPMA)=27±(2) (2o) ppm, yielding model values of DV/metCu =3±(1) × 102 (20) and Db/me =0.7±(0.4) × 10<sup>2</sup> (2 $\sigma$ ). These preliminary results differ from those of sulfur-free experiments, but closely approximate findings from natural systems, suggesting sulfur may play a role in the complexation and transport of Cu in the high-T, low to moderate /(O2) realm of magmatichydrothermal systems. (Authors' abstract)

FRANK, M.R., CANDELA, P.A. and PICCOLI, P.M., 1998b. Kfeldspar-musocvite-andalusite-quartz-brine phase equilibria: An experimental study at 25 to 60 MPa and 400 to 550°C: Geochim. et Cosmo. Acta, v. 62, no. 23/24, p. 3717-3727. Authors at Laboratory for Mineral Deposits Research, Dept. of Geol., Univ. of Maryland, College Park, MD 20742, USA.

Felsic magmas may evolve one or more water or chlorine-rich F phases which can transport heat and solutes into associated hydrothermal systems and can contribute to alteration and ore deposition. The composition of a subcritical, V-undersaturated high-sal L phase (brine) in equilibrium with K-feldspar-muscovite-quartz and muscovite-andalusite-quartz was determined for P and T ranging from 25 MPa and 400°C to 60 MPa and 550°C. Values of log<sub>10</sub> (KCI/HCI) have been obtained. Comparison of our results with previous studies conducted at higher P and with lower-sal aq phases show that the mineral stability fields in the K-feldspar-muscovite-andalusite-quartz system shift to lower KCI/HCI values with increasing sal and decreasing P. (From authors' abstract by E.R.)

FRANTZ, J.D., 1998, Raman spectra of potassium carbonate and bicarbonate aqueous fluids at elevated temperatures and pressures: comparison with theoretical simulations: Chem. Geol., v. 152, p. 211-225.

FREZZOTTI, M.L., DALLAI, L., GIORGETTI, G. and SHARP, Z.D., 1998. Fluid inclusion and stable isotope evidence for F migration during metamorphism in the Priestley metamorphic complex (O'Kane Canyon, North Victoria Land, Antarctica) (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A32. First author at Dip. di Scienze della Terra, Univ. of Siena: email (frezzotti@dst.unis.it)

Fl, F-mineral equilibria and stable isotope studies have been used to derive P, T, composition and origin of F during low-P high-T metamorphic events.

Fl are preserved in veins in two localities. Two veins (MR17 and 18) were sampled in a C-bearing metapelite belonging to the upper-greenschist facies; two veins (MR19 and 25) were sampled in lower-amphibolitic facies C-bearing marbles and metapelites. A single grouping of structurally controlled early Fl have been recognized in each vein set. In lower-amphibolitic facies rocks, trapped F are H<sub>2</sub>O-CO<sub>2</sub>-CH mixtures (Fluid A: 50 mol% CO<sub>2</sub> and 4 mol% CH<sub>4</sub>) in marbles, and H<sub>2</sub>O-CO<sub>2</sub>-N<sub>2</sub> mixtures (Fluid B: 50 mol% CO<sub>2</sub> and 10 mol% N<sub>2</sub>) in schists. Entrapment of F with different compositions occurred during vein formation, at about 500-550°C and 3-3.5 kbars F.P. These I underwent re-equilibration during cooling that resulted in density increase, without change in composition. In lower-grade schists, veins were formed from a single H<sub>2</sub>O-CO<sub>2</sub>-CH<sub>4</sub> F phase (Fluid C 30-60 mol% CO<sub>2</sub> and 4 mol% CH<sub>4</sub>) at 350-400°C and 2 kbars F.P. (From authors' abstract by E.R.)

FRICOVÁ, A., 1997, Fluid inclusion study of the Jilové gold deposit near Prague: Unpubl. M.Sc. thesis, Charles Univ., Fac. of Sci., Prague, 131 pp.

The Variscan vein Au-bearing Jilové deposit, within the Central Bohemian Metallogenic Zone with about 15 t of total gold, is a mesothermal gold deposit. The early F, which deposited the main generation of quartz, was of H<sub>2</sub>O-CO<sub>2</sub>-NaCl-CaCl<sub>2</sub> type. Quartz precipitated at 350-300°C and 1.5-2.0 kbar. The F heterogenization process became more frequent with the decrease of F T to 270-250°C.

In gold-associated quartz and carbonates H<sub>2</sub>O-NaCl and H<sub>2</sub>O-CO<sub>2\*</sub> NaCl F were trapped separately in PS to S Fl trails. In all the cases the degree of fill was constant, but the CO<sub>2</sub>-content was significantly higher (30-40 mol%) than in the early mineralization stages (10-20 mol%). The total T<sub>h</sub> of Fl fall in the interval of 190-250°C. Fl in individual samples were trapped at different P conditions, ranging from nearly 0.1 kbar (hydrostatic load) to 1.3 kbar (predominant lithostatic load).

Sal of all the types of Fl varies between 1 and 8 wt.% NaCl eq. No significant differences in sal of Fl trapped in individual minerals of all mineralization stages were found. (From author's abstract by P. Dobes).

FRIMMEL, H.E., DEANE, J.G. and CHADWICK, P.J., 1996, Pan-African tectonism and the genesis of base metal sulfide deposits in the northern foreland of the Damara orogen, Namibia: Society of Economic Geologists, Special Pub. no. 4, 1996, p. 204-217, First author at Dept. of Geological Sci., Univ. of Cape Town, Rondebosch 7700, South Africa.

Two types of carbonate-hosted base metal sulfide mineralization can be distinguished. The Berg Pb-Zn(-V)-type mineralization is related to relatively low-T (c. 240°C) basinal brines that circulated along growth faults through the rift graben filling, where they leached Pb and Zn probably from early-rift, c. 750 Ma volcanic rocks and subsequently precipitated galena and sphalerite in structural traps. In contrast, the Tsumeb-type Pb-Zn-Cu mineralization is related to collision tectonics. It was formed by less saline, but hotter (c. 450°C), orogenic F that were expelled from the highergrade metamorphic areas. (From authors' abstract by H.E.B.)

FI data are presented (H.E.B.).

FULIGNATI, P., GIONCADA, A. and SBRANA, A., 1998. The 79 AD Vesuvius magma chamber: A SEM-EDS study of daughter minerals in hypersaline fluid inclusions from cognate syenites: N. Jb. Miner. Mh., 1998, no. 9, p. 403-416.

Daughter minerals in multiphase hypersaline FI in sanidine crystals were investigated through SEM-EDS analyses. The samples studied are cognate xenoliths of feldspatoid-bearing syenites ejected in 79 AD eruption of Vesuvius, representing the magmatic mush crystallized at the wall of the magma chamber. The hypersaline FI indicate that an immiscible F phase exsolved from the M. This study permitted identification of two dm associations: a chlorides-bearing association and a fluorite-bearing association. It is proposed that the two associations reflect the chemical variations of the F phase during exsolution, in response to the different M/F partition coefficients for chlorine and fluorine. The presence of tungsten in chloridesbearing FI stresses the importance of chlorides-bearing brines in the transport of ore metals. (Authors' abstract)

FURONG, Huang, 1998. Concentration and geochemical behaviour of tellurium in Guantian pyrite deposit: Acta Geologica Sinica (Diqiu Xuebao). v. 19. no. 1, sum 48, p. 50-58 (in Chinese; Engl. abst.). Author at Geological Inst. for Chemical Minerals, MCL, Zhuozhou, Hebei.

A review of the geochemistry of tellurium, with some FI data presented (H.E.B.).

GÁL, Á., 1976, Mineralogical investigations on grown-up quartz crystals originated from Brad-Sacaramb epithermal ore occurrences (Romania). MS thesis, Univ. of Babes-Bolyai, Cluj-Napoca, Romania, 47 pp (in Romanian). Author at Dept. of Mineral., Eötvös L. Univ., H-1088 Budapest, Muzeum krt 4a, Hungary.

The LS type, epithermal style Au-Ag-Te-polymetallic mineralizations appear in a volcanic complex, which is elongated in NW-SE direction. The mineralizations occur along E-W faults in form of impregnations and veins. The main minerals are: pyrite, sphalerite, galenite, greenockite, chalcopyrite, bournonite, meneghinite, arsenopyrite, boulangerite, fahlore, antimonite, mackinawite, pyrrhotite, krautite, etc., among the gangue minerals quartz, calcite, barite, etc. Mineralogical investigations, including crystallomorphology, and Fl studies had been made on grown-up quartz crystals originated from the Basin of Brad-Sacaramb from 7 localities (Velea Morii Veche, Musariu, Carpen, Sacaramb, Bocsa, Hondol-Baiaga).

In those crystals which show the "+" and "-" rhombohedron face in equal shape, size, boiling phenomena often occurred. In those crystals exhibiting only "+" rhombohedron, the Fl pattern does not suggest visible boiling phenomena. Main Fl parameters for L+V I: Th=148-314°C, Tm<sub>1ce</sub>=-2.8 to -0.6°C, sal=0.7-4.5 wt.% NaCl eq. (Author's abstract, abbreviated by I. Gatter)

GALLUP, D.L., 1998. Geochemistry of geothermal fluids and well scales, and potential for mineral recovery: Ore Geol. Reviews, v. 12, p. 225-236. Author at Unocal, 1300 N. Dutton Avenue, Santa Rosa, CA 95401, USA.

Although the potential use of geothermal brines for simultaneous energy and mineral production is significant, only a few mineral recovery systems are currently in commercial operation. Selected metal concentrations reported in F and scale deposits that are of interest to economic geologists include the following.

Metal	Fluid Range, mg/kg	Scale Range, wt%
Ag	0-1.4	0 - 89
As	0-114	0-12
Au	0-0.08	0 - 6.4
Cu	0 - 8	0 - 21
Zn	0 - 1160	0-15.9
Pb	0 - 650	0 - 55.8
Pd	0 - 0 002	0 - 0.0024
P.	0 - 0.05	0-0.016

(From author's abstract by E.R.)

GAO, Sanmei, 1994, Study of geology and fluid inclusions in the Francoeur and Lac Fortune gold deposits, Québec: Thesis, Université du Québec à Chicoutimi, March, 1994, 99 pp.

The Francoeur and Lac Fortune gold deposits are located in the Rouyn-Noranda area, Québec. The major host lithologies include volcanic rocks of the Blake River Group, sedimentary rocks of the Timiskaming and Cobalt groups, synvolcanic and late-tectonic intrusive rocks.

The Francoeur deposit occurs along the east-west striking Francoeur-Wasa shear zone, bordered to the north by gabbro-diorite stock. Hydrothermal alteration is well developed, and is commonly limited to the shear zone. The major products of alteration are zoned. A typical sequence of alteration zones from the orebody outward changes from the assemblage albite-pyrite, through carbonate-hematite, to muscovite-chlorite. Gold mineralization is related to hydrothermal wall rock alteration, especially to the formation of the albite-pyrite assemblage. The ore is mostly located in altered mylonites, in which gold is disseminated, closely associated with pyrite.

The Lac Fortune deposit occurs in a small shear zone parallel to the Francoeur-Wasa shear zone. It is characterized by the development of quartz-carbonate veins. Hydrothermal alteration is less well developed than in the Francoeur deposit. The alteration minerals mainly occur in the wall rock or near the contact zone between the wall rock and quartz-carbonate veins, with chlorite-carbonate-fuchsite being the principal assemblage. The minerals of the quartz-carbonate veins were formed mainly by open space filling or direct precipitation of ore material from hydrothermal F. Goldbearing minerals, including coarse free gold and Pb-Bi tellurides, are scattered in the quartz-carbonate veins.

Three groups of FI related to the gold mineralization of the Lac Fortune and Francoeur deposits are recognized. They are aq I, CO<sub>2</sub>-rich I and H<sub>2</sub>O-CO<sub>2</sub> 1. The aq I are in the H<sub>2</sub>O-CO<sub>2</sub>-NaCl system, with additional CaCl<sub>2</sub> and CH<sub>4</sub>. The Th appear higher on average in the Francoeur deposit than in the Lac Fortune deposit. The Th range from 110 to 360°C for the FI from the Lac Fortune deposit, and from 150 to 578°C for those from the Francoeur deposit. The sal ranges from 5 to 9 wt.% NaCl eq. for the FI from the Lac Fortune deposit, and from 2 to 9 wt.% NaCl eq. for those from the Francoeur deposit. The ore-forming F in both deposits are rich in CO<sub>2</sub> with low sal.

In the Lac Fortune deposit, the F preserved in the  $H_2O-CO_2$  I represents the P ore-forming hydrothermal F. This  $H_2O-CO_2$  F with low sal separated in the process of mineralization to form an aq F with relatively high sal and a non-saline  $CO_2$ -rich F. The T and P of the F range respectively from 110-360°C and 3200-5100 Pa at the site of mineralization. Phase separation (unmixing) of the mineralized F is an important mechanism of gold deposition.

In the Francoeur deposit, the mineralized F are compositionally  $H_2O-CO_2$ -NaCl F. The minimum T and P are 150-578°C and 4000-5000 Pa at the site of mineralization. F-rock interaction played an important role in the gold precipitation.

The different mineralization mechanisms and styles may be caused by the difference of physicochemical conditions of the ore-forming F. T of the mineralized F is the major controlling factor in both gold deposits.

In the Lac Fortune gold deposit, because the mineralized F had a relatively low T, phase separation played an important role in the gold precipitation and an open-space filling type of gold deposit was formed. In the Francoeur deposit, however, the mineralized F, with relatively high T, resulted in an extensive alteration of wall-rock; F-rock interaction played an important role in the gold deposition and produced a replacement type of gold deposit. (Author's abstract) GARANIN, V.K., KUDRIAVTSEVA, G.P. and POSSOUKHOVA, T.V., 1998, Diamonds from the M.V. Lomonosov deposit (Arkhangelsk Diamondiferouse Province, Russia) (abst.): 17th General Meeting Int'l Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A15. Authors at Geological Dept., Moscow State Univ., Russia; email (mineral@geol.msu.ru)

Most of the crystals, according to their absorption spectra, contain many nitrogen impurity's defects. The concentration of A-defects makes up (30-40) x  $10^{19}$  cm<sup>-3</sup>. The low concentration of A-defects was determined in microdiamonds. The content of IIa-type diamonds is low. N<sub>2</sub>, CO<sub>2</sub> and H<sub>2</sub>O (up 70%) are the main Fl. (From authors' abstract by E.R.)

GARLAND, M.I., HENDERSON, G.S., WICKS, F.J. and HASLETT, T.L., 1998, Characterization of inclusion suites in sapphire using Raman spectroscopy (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-382. First author at Geol Dept., Univ. of Toronto, 22 Russell St., Toronto, Ontario, MSS 3B1, email (garland@afml.geology.utoronto.ca)

Characterization of the mineral I suites within gem corundum crystals may yield direct information about the type of growth environment and the genetic history of the corundum.

Sapphires from deposits in southwestern Montana show different I suites. Rock Creek sapphires contain micro-sized, rutile crystals in crystallographically controlled zones. Amorphous carbon, hematite, goethite, and diaspore occur throughout the sapphire host, and calcite was present in dehydrated Fl. Dry Cottonwood sapphires contain labradorite associated with muscovite and randomly dispersed rutile grains. The type of I and association with the host mineral indicate that the western Montana sapphires formed in metamorphic environments specific to each deposit. (From authors' abstract by H.E.B.)

GARRIDO, M. and DOMÍNGUEZ, E., 1998. Fluid inclusions from the porphyry copper type deposit "La Voluntad", Neuquen Province, Argentina: Revista Geològica de Chile, v. 24, no. 1, p. 91-108 (in Spanish, Engl. abst.).

In La Voluntad porphyry copper deposit the mineralization is related to a Permian tonalite intruded in Lower Paleozoic metamorphites. Triassic rhyolitic volcanic rocks unconformably cover the tonalite. The mineralization-alteration proceeded in two stages. During the first, a low intensity pervasive potassic alteration with disseminated pyrite and chalcopyrite and scarce molybdenite was developed. During the second, a high intensity fracture-related phyllic alteration was overprinted on the early potassic alteration. The mineralization consists of pyrite, chalcopyrite, bornite, molybdenite, sphalerite, arsenopyrite and scarce wolframite.

The Fl in the first F indicates T between 400-410°C, high sai and boiling. These F are related to veins containing molybdenite with potassic alteration envelopes and with veins with chalcopyrite, pyrite, molybdenite, aresenopyrite with phyllic envelopes. The F in the next stage are of lower T (360°C), lower sal (5-6 wt % NaCl eq.) and without boiling. Veins with pyrite, molybdenite, sphalerite with phyllic envelopes are related to these F The F in the evanescent stage are of 334°C, of low sal, and related to sterile quartz veins. (From authors' abstract by E.R.)

GARRIDO, M., DOMÍNGUEZ, E. and SCHALAMUCK, I., 1998, Origin of the hydrothermal fluids of the Tajo vein, Paramillos de Uspallata, Mendoza: IV Meeting of Mineralogy and Metallogeny. (IV Réunion de Mineralogia y Metalogenia "MINMET") Sept. 23-25, 1998. Bahía Blanca, Argentina, p. 105-110 (in Spanish, Engl. abst.).

The Tajo Pb-Ag-Zn lode belongs to the Paramillos de Uspallata District. New Fl data on quartz, sidente and sphalerite confirm that hydrothermal F have T between 160 and 260°C and low to medium sal (5-19% wt. eq. NaCl).  $\delta^{34}$ S on galena and sphalerite are compatible with a magmatic origin.  $\delta^{18}$ O siderite and quartz are higher than for pure magmatic water. It is concluded that the hydrothermal system is a mixture of magmatic and meteoric water and could be linked to the carbonate base metal gold deposits located around porphyry copper deposits. (Authors' abstract)

GASSYMOVA, F.L., and MELNIKOV, F.P., 1998. Polycyclic aromatic hydrocarbons (PAH) in diamonds and other minerals from the kimberlite pipes of Mir and Udachnaya-vostochnaya (abst.): Program and Abstracts. PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 33. First author at Azerbaidzan, Geological Institute SA.

Exposed hydrocarbon I in zircon (Mir pipe) are similar in their chemi-

cal compound to hydrocarbon in such minerals as olivine from the Udachnaya pipe (Daldyno Alakitski area) and gamet from the Mir pipe (Malo-Botuobinski area). Aromatic hydrocarbons with molecular structure of alkilabocarbons, alkilphenantren and piren predominate. Values  $\delta^{13}$ C of zircons are similar to values  $\delta^{13}$ C of hydrocarbons in olivines from the Udachnaya pipe (Galimov et al., 1988) and in gamets from the Mir pipe (Botkunov et al., 1985). These values include the range of values of isotopes of carbon diamond of eclogitic paragenesis.

Taking into consideration that Tf of diamond and its complementary rocks is about 1000°C, P.A.H. are to change into graphite plus hydrogen. This conclusion conforms to the discovering hydrogen and some other G I (CH<sub>4</sub>, H<sub>2</sub>O) in diamonds and in different magmatic minerals.

According to I.I.Kulakova, P.A.H. are formed by the reactions: mCH<sub>2</sub> =P.A.H.+kH<sub>2</sub>; nCO<sub>2</sub>+mCH<sub>4</sub>=P.A.H.+kH<sub>2</sub>O; and nCO+mH<sub>2</sub> =P.A.H.+kH<sub>2</sub>O. Possibly, the source of hydrocarbon for these processes and for the process of diamond formation was the same. (From authors' abstract by E.R.)

GATTER, I., 1997a, The perspectivity of gold ore at the Recsk-Paradfilrö ore field in the light of the Fl studies. Földtani Kutatás v. XXXIV, no. 2, p. 16-19 (in Hungarian). Author at Dept. of Mineral., Eötvös L. Univ., H-1088 Budapest, Muzeum krt 4a, Hungary.

The results of detailed Fl studies had been made on outcrops at the Recsk-Paradfurð HS type epithermal ore field are as follows: the ore forming F show fluctuating tendencies in time and space, according to the occurrence of the various quartz generations. The main data for Ql (veinlet): Th 230-290°C, sal 0.75-4.5 wt.% NaCl eq., Q2 (small symmetric veins): Th 180-260°C, sal 0.5-3.25 wt.% NaCl eq., Q3 (euhedral crystals): Th 210-270°C, sal 1.5-4 wt.% NaCl eq. and finally the Q4 (sucrose quartz): Th 220-300°C, sal 1.5-2.5 wt.% NaCl eq. The Th vs. sal plot is complex, cooling, boiling, and re-heating tendency can be traced.

The main boiling horizon of the system and the places of high lateral thermal gradient on the  $T_h$  distribution plot coincides with the main places of the early mining activity. (Author's abstract)

GATTER, L. 1997b, On the fluid inclusion characteristic of the calcite crystals from Esztramos Hill: Top. Min. Hun., v. V, p. 109-116., Miskolc (in Hungarian with Engl. abst.). Author at Dept. of Mineral., Eötvös L. Univ., H-1088 Budapest, Muzeum krt 4a, Hungary.

Fl studies had been made on grown-up calcite crystals originated from calcite vein filling fissures and carstic cavities of Mesosoic limestone of Esztramos Hill. The T<sub>h</sub> of L+V I do not exceed 120°C, the presumably T<sub>1</sub> of room T L phase I are 60-70°C. The sal of F is 0.18 to 0.35 wt.% NaCl eq. respectively, suggests the predominance of the meteoric water. The calcite formed under epi-telethermal conditions, in deep carstic environment. (Author's abstract)

GAUNT, J.M. and GIZE, A.P., 1996, Application of basin evolution modeling to date ore deposition: An example: Society of Economic Geologists. Special Pub. No. 4, p. 546-554. First author at Trevelyan, Avenue Road, Falmoutn, Cornwall, TR11 4AZ, England.

The Cow Ark-Marl Hill Moor district lies on the flank of the present basin inversion axis. Here Fe-Pb-Zn-S mineralization occurs within a complex multi-generation vein sequence hosted by Dinantian limestones. The mineralization is present as two distinct episodes. iron-disulfide dominated Period 1 and galena dominated Period 2, paragenetically separated by multiple vein carbonates and hydrocarbon Fl generations. The mineralizing F were impure NaCl-MgCl<sub>2</sub>-CaCl<sub>2</sub>-H<sub>2</sub>O brines with sal >15 wt.% NaCl eq. and T<sub>h</sub> of 85-115°C and 95-130°C for Periods 1 and 2 respectively. (From authors' abstract by H.E.B.)

GENGE, M.J. and GRADY, M.M., 1998. Melted micrometeorites from Antarctic ice with evidence for the separation of immiscible Fe-Ni-S liquids during entry heating: Meteoritics & Planetary Sci., v. 33, no. 3, p. 425-434.

Indexed under FI.

GHAZI, A.M., SHUTTLEWORTH, Steve and KRESMER, Daniel, 1998, Chemical characterization of individual fluid inclusions by laser ablation ICP-MS (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F952. First author at Dept. of Geol., Georgia St. Univ., Atlanta, GA 30303. US: email (mghazi@gsu.edu)

Primary FI in halite from the Permian Paradox and the Palo Duro Basins have been analyzed for Mg. K. Ca, Rb and Sr concentrations. In addition to the laser ablation quadrupole ICP-MS work performed at Georgia St. Univ., data is being obtained using the Merchantek LUV266 and Finnigan MAT Element Sector Field ICP-MS at Washington Univ. in St. Louis. Quantification is by a set of artificial capillary tube FI standards of known composition of Mg, K, Ca, Rb and Sr. Halite samples were selected for analysis because they contained FI in similar volumes to the microcapillary tube FI. Thus it was possible to analyze the natural I under analytical conditions identical to those for the microcapillary tube I. Uncertainties in the analysis of individual FI range from 4 [sic]. (From authors' abstract by E.R.)

GIBERT, François, GUILLAUME, Damien and LAPORTE, Didier, 1998, Importance of fluid immiscibility in the H<sub>2</sub>O-NaCI-CO<sub>2</sub> system and selective CO<sub>2</sub> entrapment in granulites: Experimental phase diagram at 5-7 kbar, 900°C and wetting textures: Eur. J. Mineral, 1998, no. 10, p. 1109-1123. Authors at UMR6524/CNRS and Université Blaise Pascal, 5 rue Kessler, 63038 Clermont Ferrand, France; email (gibert@opgc.unibpclermont.fr)

New experimental data on F immiscibility in the H<sub>2</sub>O-NaCI-CO<sub>2</sub> system at 900°C and 5-7 kbar have been obtained using the synthetic FI technique. The main result is a significant enlargement of the immiscibility field as P decreases from 7 to 5 kbar. Combined with previous data, our experiments show that immiscibility is probably a widespread phenomenon in low-P granulite-facies rocks. Because CO2-rich F and NaCl-rich ag F have very contrasting wetting behaviour. F unmixing could result in a selective entrapment of the CO2-rich component in granulites (Watson & Brenan, 1987). To check this hypothesis, we performed an experiment in which polycrystalline quartz was heat-treated in the presence of small volume percentages of the two immiscible F. The observed pore geometry is characterized by a combination of large, isolated CO2-rich bubbles, and an interconnected network of NaCl-H2O-filled channels along quartz edges. A model combining unmixing and the subsequent escape of the aq F by porous flow could therefore explain the CO2-rich FI in low-P granulites. (Authors' abstract)

See also FIR 30, p. 67 (E.R.).

GIBERT, F., PASCAL, M.-L. and PICHAVANT, M., 1998, Gold solubility and speciation in hydrothermal solutions: Experimental study of the stability of hydrosulphide complex of gold (AuHS<sup>o</sup>) at 350 to 450°C and 500 bars: Geochim. et Cosmo. Acta, v. 62, no. 17, p. 2931-2947. First author at CRSCM-CNRS, la rue de la Ferollerie, 45071 Orleans, France.

The solubility of gold was measured in aq KCl (0.5 m) solutions under oxygen, sulfur, and slightly acidic pH buffered conditions between 350 and 450°C at a constant P of 500 bars. Two buffer assemblages were used to constrain  $fO_2$ ,  $fS_2$ , and consequently  $fH_2$  and  $aH_2S$ : respectively, pyritepyrrhotite-magnetite (Py-Po-Mt) and pyrite-magnetite-hematite (Py-Mt-Hm). The measured solubility of gold at equilibrium with Py-Po-Mt and Qtz-KF-Mus is 52±8 ppb at 350°C, 134±17 ppb at 400°C and 496±37 ppb at 450°C. With Py-Mt-Hm and Qtz-KF-Mus the solubility of gold is increased to 198±9 ppb at 400°C and 692±10 ppb at 450°C. These results are consistent with the aq complex AuHS° being the dominant goldbearing species. The equilibrium constants ( $\log K_{R10}$ ) for the reaction: Au<sub>4s1</sub> + H<sub>2</sub>S<sub>(aq)</sub> = AuHS° + ½ H<sub>2(g)</sub> are significantly higher than those derived by Benning and Seward (1996) and the possible causes of the discrepancies are discussed.

The equilibrium constant for AuHS<sup> $\circ$ </sup> shows that this species plays an important role in the deposition of gold in natural environments. Cooling, H<sub>2</sub>S loss, pH change, and oxidation seem to be effective mechanisms for gold precipitation, depending on the local ore forming conditions. (From authors' abstract by E.R.)

GIL', A.V. and GERTMAN, Yu.L., 1998. A geological-genetic model of the gold-productive ore-genetic system as exemplified by the Kaul'dy deposit (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 129-131 (in Russian)

See Translations.

GILES, A.D. and MARSHALL, Brian, 1998, Woodcutters Pb-Zn-Ag deposit, Northern Territory: Geometric, fluid-inclusion and isotopic constraints on genesis (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 166. Authors at Univ. of Tech., Sydney, P.O. Box 123, Broadway, NSW 2007, Australia.

Woodcutters Pb-Zn-Ag deposit consists of bedding-parallel bands of galena, sphalerite and pyrite within Early Proterozoic rocks (carbon-

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ate/pelite units with intercalated tourmalinite, banded iron formation and thin tuffaceous layers). The overall deposit comprises stratigraphicallycontrolled replacements, plus 'feeder' mineralisation associated with pre-D1 faults.

There are six inclusion-populations. Type I solid I in colloform *sp* predated the syn-D1 remobilization of Pb-Zn sulphides. Type II decrepitated S I occur in *sp* and gangue (*qtz* and dolomite); they pre-date remobilization, because they are preserved in the strained phases but form grain-boundary arrays in recrystallised phases. Type III decrepitated growth-zone primaries occur in syn-D1 veins. Types IV, V, and VI inclusions overprint all veinsystems and D1/M1-recrystallized *sp* and gangue in banded ore. Microthermometry on the nucleated V phases of Types V and VI inclusions yield sal of 0.85-21.8 and 2.03-15.8 wt% NaCl eq., respectively; Th values (uncorrected for P) range from 88-270°C and 245-320°C, respectively.

T calculations on coexisting sulphide pairs demonstrated disequilibrium in the Pb-Zn-Fe ore and most of the pyritic 'ore', but one sample of pyritic 'ore' has possibly reequilibrated under lower greenschist facies metamorphism (~425°C).

Early FI were destroyed by decrepitation, late FI record 'non-genetic' F events. (From authors' abstract by E.R.)

GILG, H.A., 1996, Fluid inclusion and isotope constraints on the genesis of high-temperature carbonate-hosted Pb-Zn-Ag deposits: Society of Economic Geologists, Special Pub. No. 4, p. 501-5014. Author at Lehrstuhl für Angewandte Minéralogie und Geochemie, TU München, Germany.

Three endmember types of high-T carbonate-hosted Pb-Zn-Ag deposits have been distinguished: garnet skarns, pyroxene skarns and skam-free replacement deposits. A review of FI and H-C-O-S-isotope data suggests that T and P are not key parameters responsible for differences between the three sub-types. The origin and composition, especially the oxidation-sulfidation state and CO<sub>2</sub> content, of hydrothermal F, however, is variable and can be related to mineralogical and chemical composition of the ore. The oxidation state of the ore-forming F is mainly controlled by the amount of sulfur-rich, oxidizing magmatic G in the F and the extent of wall rock buffering. Sal are variable and correlate positively with the average Agcontent of the sulfidic ores. High concentrations of CO<sub>2</sub> in ore F (>0.5 mol%) are characteristic for skam-free replacement deposits and are related to reaction with sedimentary carbonates. (From author's abstract by E.R.)

GIONCADA, A., BOTTAZZI, P., CLOCCHIATTI, R., MASSARE, D., OTTOLINI, L., SBRANA, A. and SCHIANO, P., 1998, Parent liquids of the Vulcano lavas (Eolian Islands, Italy): constraints obtained from studies of glass inclusions (abst.): Réunion des Sciences de la Terre. Brest, 31 March-3 April, 1998, p. 121 (in French, translation by E.A.J. Burke). First author at 1D S.T. Università di Pisa, via S. Maria 53, 56126 Pisa, Italy

The study of petrogenetic processes responsible for the genesis of Vulcano lavas is difficult because of the amount of mechanical mixtures, the assimilation of crustal material, and the alteration of the strata. To minimalize these effects, the present study has been done on glass I in olivine with the highest Mg contents. Two P L, trapped in the form of glass I in olivine (Fo91-88), have been identified in shoshonitic basalts of the Sommata (formation dated at about 50 ka) and in the ejects of the last eruption of the Fossa (1888-1890). These L have a number of common characteristics: 1) they have been trapped in olivine with the same composition, associated with the same spinel, 2) they have similar T<sub>1</sub> (1180-1160°C), 3) they have high Ca/Al ratios, indicating they have been formed by the fusion of a source rich in pyroxenes; 4) their distribution spectra of trace elements are similar; 4) they are rich in sulfur and chlorine. On the other hand, the Fossa L are enriched in incompatible elements, and they have a small Eu anomaly. They are strongly enriched in Ba, and they have trace-element ratios with different degrees of incompatibility. Na/K. Zr/Nb and La/Nb. which distinguish them from the Sommata L. The two compositions of Vulcano liquids, until now unknown at the surface in the form of lavas, represent the parent magmas of the two series defined by the evolved members (De Astis et al., J. Volc. Geoth Res., v. 102, 1997) The study of the trace elements suggest that these L were derived from different fusion degrees of a single homogeneous source. (Authors' abstract)

GIONCADA, A., CLOCCHIATTI, R., SBRANA, A., BOTTAZZI, P., MASSARE, D. and OTTOLINI, L., 1998. A study of melt inclusions at Vulcano (Aeolian Islands, Italy): Insights on the primitive magmas and on the volcanic feeding system: Bull Volcanol. v. 60, p. 286-306. First author at Dipartimento di Scienze della Terra, Università di Pisa, via S. Maria, 53, 1-56126, Pisa, Italy: email (gioncada@dst.unipi.it)

This work presents the results of a microthermometric and EPMA-

SIMS study of MI in phenocrysts of rocks of the shoshonitic eruptive complex of Vulcano (Acolian Islands, Italy). Different primitive magmas related to two different evolutionary series, an older one (50-25 ka) and a younger one (15 ka to 1890 A.D.), were identified as MI in olivine Foss-91 crystals. Both are characterized by high Ca/Al ratio and present very similar Rb/Sr. B/Be and patterns of trace elements, with Nb and Ti anomalies typical of a subduction zone. The two basalts present the same T of crystallization (1180±20°C) and similar volatile abundances. The H2O, S and CI contents are relatively high, whereas magmatic CO2 concentrations are very low. probably due to CO2 loss before low-P crystallization and entrapment of MI. The mineral chemistry of the basaltic assemblages and the high Ca/AI ratio of MI indicate an origin from a depleted, metasomatized clinopyroxene-rich peridotitic mantle. The younger primitive M is characterized with respect to the older one by higher K2O and incompatible element abundances, by lower Zr/Nb and La/Nb, and by higher Ba/Rb and LREE enrichment. A different degree of partial meltiing of the same source can explain the chemical differences between the two magmas However, some anomalies in Sr. Rb and K contents suggest either a slightly different source for the two magmas or differing extents of crustal contamination. Low-P degassing and cooling of the basaltic magmas produce shoshonitic L. The MI indicate evolutionary paths via fractional crystallization, leading to trachytic compositions during the older activity and to rhyolitic compositions during the recent one. The bulk-rock compositions record a more complex history than do the MI, due to the syneruptive mixing processes commonly affecting the magmas erupted at Vulcano. The composition and T data on MI suggest that in the older period of activity, several shallow magmatic reservoirs existed; in the younger one a relatively homogeneous feeding system is active. The shallow magmatic reservoir feeding the recent eruptive activity probably has a vertical configuration, with basaltic magma in the deeper zones and differentiated magmas in shallower, lowvolume, dike-like reservoirs. (Authors' abstract)

GIULIANI, Gaston, 1997a, Genesis of Brazilian and Colombian emerald deposits: l'Habilitation a Diriger des Recherches, Inst. National Polytechnique de Lorraine, France (in French, Engl. abst.): Centre de Recherches Pétrographiques et Géochimique.

Brazilian emeralds represent an original Precambrian mineralization style. The main deposits are located in the States of Bahia (Carnaiba and Socotó), Minas Gerais (Mina Belmont and Capoeirana) and Goiás (Santa Terezinha). They are hosted in lower Proterozoic volcano-sedimentary series with intercalations of mafic or ultramafic rocks (M-UMR). Two types of mineralizations are definied.

 type 1, those associated with pegmatites intruding M-UMR formations (Socotó, Camaíba, Mina Belmont and Capoeirana) with an emerald grade comprised between 12 and 165 g/t;

 - type 2, those devoid of pegmatites but linked to ductile shear zones crosscutting M-UMR formations (Santa Terezinha), with an emerald grade varying between 50 and 800 g/t.

Type 1 deposits result from the circulation of hydrothermal F that developed infiltrational metasomatism of M-UMR around pegmatite veins. The M-UMR (serpentinite, talc-schist) are transformed to phlogopitite and the pegmatite to plagioclasite. The phlogopitites display several zones separated by metasomatic fronts, the whole forming a metasomatic column. Emerald crystallized in the inner zones, either in the plagioclasite or in the phlogopitite zones associated with phlogopite, apatite and quartz. A sharp metasomatic front underlines the disappearance of emerald and the appearance of the Cr-bearing spinel. Talc-actinolite-tremolite-spinel and serpentine-dolomite assemblages could be found within the outer zones which are emerald-free.

Hydrothermal alterations correspond to an alkaline (K. Na) metasomatism, resulting from the removal by a F phase of chemical elements from both pegmatite and M-UMR. A chemical mass balance on the metasomatized M-UMR indicates a supply of alkalis and hygromagmaphile elements such as Al, Si, K, Rb, Be, Nb, Cs, F, P, S by the fluid, whereas Mg, Ca, Cr, V, Th, and REE are leached from the host-rocks.

Type 2 deposits are stratiform and emerald is located within phlogopitites and phlogopitized carbonate-talc schists Talc schists provided the main sites for thrusting and the formation of sheath folds. Emerald-rich zones are commonly found iin the core of sheath folds and along the foliation: control by the regional stretching lineation is obvious. Two types of ore are distinguished: 1) a carbonate-rich ore composed of dolomite, talc, phlogopite, quartz, chlorite, tremolite, spinel, pyrite and emerald: chemical mass balance shows an increase of Be, Cr, Ni and F, 2) a phlogopite-rich ore composed of phlogopite, quartz, carbonates, chlorite, albite, talc, pyrite and emerald; chemical mass balance on the metasomatised talc-schist indi-

cates a supply by the fluid of Na, K, S, V and F.

Hydrothermal fluids associated with type 1 deposits belong to the  $H_2O$ -(NaCl-CaCl<sub>2</sub>-Fe, Mg)  $Cl_2 \pm KCl$ ) - ( $\pm CO_2 \pm N_2 \pm CH_4$ ) system. Total sal varies between 12 and 37 wt.% NaCl eq. and minimal T<sub>1</sub> are scattered between 235 and 560°C. Fluids related to type 2 deposits belong to the  $CO_2-N_2 \pm CH_4$ -H<sub>2</sub>O-NaCl system. Sal varies between 1 and 22 wt.% NaCl eq. and minimal T<sub>1</sub> vary from 300 to 500°C. Fluids in emeralds have a similar total composition with H<sub>2</sub>O contents >90 to 95% of the total fluid content in the mineral, whatever its age of formation and tectonic setting. Nevertheless, fluids in the Santa Terezinha emeralds have high-CO<sub>2</sub> contents up to 14 wt% of the whole fluid phase.

Brazilian emeralds related to type 1 have a systematic  $\delta^{18}$ O interdeposit variability (+6.3< $\delta^{18}$ O<+12.1‰). The  $\delta^{18}$ O for the fluids is buffered by the hosting ultramafic rocks during the fluid-rock metasomatic interaction. The  $\delta$ D values of channel water in emerald and the calculated  $\delta^{18}$ O H<sub>2</sub>O of phlogopite for Carnaiba and Socotó deposits are compatible with waters of both magmatic and metamorphic origins. Nevertheless, sulfur isotopic compositions obtained for molybdenite indicate a magmatic origin for sulfur [and suggest] a magmatic origin for the mineralizing fluid and beryllium.

The O and H isotopic data for Santa Terezinha are consistent with both magmatic (evolved crustal granites) and metamorphic fluids, but a metamorphic origin is proposed. (From author's abstract by E.R.)

### GIULIANI, Gaston, 1997b, Genesis of Colombian emerald deposits: l'Habilitation a Diriger des Recherches, Inst. National Polytechnique de Lorraine, France (in French, Engl. abst.): Centre de Recherches Pétrographiques et Géochimique.

The genesis of Colombian emeralds cannot be from a classic pegmatite model. The presence of halite-bearing FI within emerald and the presence of trapiche crystals appear unique. New studies favour a "hydrothermal-sedimentary" genetic model. It takes into account the role played by organic matter (OM) contained in the Early Cretaceous black shale (BS), in sulphate-hydrocarbon redox reactions, to explain the uncommon features of Colombian emerald.

- Stage 1 is characterized by decollement planes which focused the circulation of hydrothermal F inducing albitisation (albitite layers) and calcitisation of the BS. This metasomatism led to leaching of major (Si, AI, K, Ti, Mg, P), trace (Ba, Be, Cr, V, C, B, U) and REE elements from the enclosing BS; this stage was accompanied by the development of a vein system filled by fibrous calcite, bitumen and pyrite. Albitite layers are well preserved in the eastern zone as stratiform levels, whereas they are found as angular fragments within polygenic hydrothermal tectonic breccia in the western zone.

- Stage 2 is marked by the formation of hydrothermal tectonic breccias along faults in the eastern zone, thrust faults and thrust-related anticlines in the western zone. It is characterized by extensional vein sets and hydraulic breccia development filled by muscovite, albite, rhombohedral calcite and dolomite, pyrite, bitumen and finally by the precipitation in drusy cavities of fluorite, apatite, parisite, dolomite, emerald and quartz.

Microthermometric, Raman-probe and SEM analysis demonstrate the presence of H2O-NaCl-CaCl2-KCl-CO2-N2-rich brines trapped in emerald, carbonates and pyrite. The Tt of fibrous calcite from state 1 and rhombohedral carbonates and emerald from stage 2 are estimated respectively at 150-200°C and 300°C. Oxygen and carbon isotope compositions of quartz and carbonates in all the deposits are consistent with values of metamorphic waters or basinal formation waters. Emeralds also show a strong enrichment in 18O (+15.5<818O H2O<+23.6‰) and the 8D values of channel water are inconsistent with a magmatic water origin. The 834S values of H<sub>2</sub>S in solution in equilibrium with pyrite from emerald deposits range from 14.8 to 19.4‰, whereas sedimentary pyrite from the enclosing black shales yields a 8<sup>34</sup>S suggesting an evaporitic origin compatible with Jurassic or Early Cretaceous evaporites isotopic signatures. Cation analysis of FI in quartz, emerald and fluorite by crush-leach technique confirms that F are predominantly Na-Cl-Fe-Ca-K-SO4 brines, derived from the dissolution of evaporites (CI/Br>10.000).

The emerald deposits are characterized by the synchronous deposition of large quantities of pyrite from reduction of evaporitic sulphates. The presence of OM in the BS and hydrothermal bitumen in the carbonatespyrite veins suggests thermochemical sulphate reduction (TSR). Four main conditions are necessary to establish that TSR reaction was effective:

 OM is now present in the ore body, this is the case in Colombian deposits where hydrothermal bitumen is found

2- OM was present when the different stages of the hydrothermal system developed and at the time of ore formation: in fact, hydrothermal bitumen precipitated during stages 1 and 2 and is found as solid 1 within P FI hosted by emerald.

3- Two types of OM are present: in our case, original, i.e. OM in the BS and hydrothermal, i.e. bitumen in the veins.

4- The chemical change in the altered OM is compatible with TSR. Rock-Eval analyses on both sedimentary and hydrothermal OM, coupled with hydrogen-carbon isotope data, show that organic hydrogen was consumed during the reduction.

TSR reaction produced bitumen derived locally from the transformation of OM from sediments by medium T hydrothermal F, up to 300°C. (From author's abstract by E.R.) See also next item (E.R.).

GIULIANI, G., FRANCE-LANORD, C., COGET, P., SCHWARZ, D., CHEILLETZ, A., BRANQUET, Y., GIARD, D., MARTIN-IZARD, A., ALEXANDROV, P. and PIAT, D.H., 1998, Oxygen isotope systematics of emerald: Relevance for its origin and geological significance: Mineralium Deposita, v. 33, p. 513-519. First author at ORSTOM, Institut Français de Recherche Scientifique pour le Développement en Coopération and CRPG-CNRS, UPR 9046, BP 20, 54501 Vandœuvre-lès-Nancy Cedex, France; email (giuliani@crpg.cnrs-nancy.fr)

Oxygen isotopic composition of emerald from 62 occurrences and deposits in the world reveals a wide range in  $\delta^{18}O$  (SMOW) between 6.2 and 24.7‰. The  $\delta^{18}O$  values for each deposit are restricted and can be used to determine the origin of emerald from the world's most important producers. The  $\delta^{18}O$  value of emerald appears to be a fingerprint of its origin, especially for gems of exceptional quality from Colombia (eastern emerald zone,  $\delta^{18}O = 16.8\pm 0.1\%$ , western emerald zone,  $\delta^{18}O = 21.2\pm 0.5\%$ ). Afghanistan ( $\delta^{18}O = 13.5\pm 0.1\%$ ), Pakistan (Swat-Mingora districts,  $\delta^{18}O = 15.7\pm 0.1\%$ ), Brazil (Santa Terezinha de Goiàs,  $\delta^{18}O = 12.2\pm 0.1\%$ ; Quadrilatero Ferrifero,  $\delta^{18}O = 6.9\pm 0.4\%$ ) and Zimbabwe (Sandawana,  $\delta^{18}O = 7.5\pm 0.5\%$ ). Furthermore, the <sup>18</sup>O-composition of emerald appears to be a good marker of its geological environment because the data suggest that host-rock-buffering of F  $\delta^{18}O$  is considerable during F-rock interaction. (Authors' abstract)

### GIULIANI, G., FRANCE-LANORD, C., ZIMMERMANN, J.L., CHEILLETZ, A., ARBOLEDA, C., CHAROY, B., COGET, P., FON-TAN, F. and GLARD, D., 1997. Fluid composition, $\delta D$ of channel H<sub>2</sub>O, of lattice oxygen in beryls: Genetic implications for Brazilian, Colombian, and Afghanistani emerald deposits: Internat'I. Geol. Review, v. 39, p. 400-424. First author at ORSTOM, Institut Français de Recherche Scientifique pour le Développement en Coopération and CRPG-CNRS. UPR 9046. BP 20, 54501 Vandœuvre-lès-Nancy Cedex, France; email (giuliani@crpg.cnrs-nancy.fr)

The F composition. bD of channel H2O. and b18O lattice oxygen have been determined in beryl and emerald from a variety of geological environments and used to constrain the origin of the parental F from which beryl has grown. Step-heating analyses performed by quadrupolar mass spectrometry were used to quantify the composition of the F phases in beryl from granitic pegmatites and greisens and emerald from Brazil, Colombia. and Afghanistan. An important conclusion is that beryl and emerald have a similar F composition, with concentrations of H2O being greater than 90% of the total water [fluid?] in the mineral irrespective of the age of formation (2.0 Ga to 32 Ma) and tectonic settings. However, the Brazilian Santa Terezinha shear-zone emerald deposit contains abundant CO<sub>3</sub>, up to 13 wt% of the total F. A second conclusion is that the channel H2O content for some Brazilian emeralds is higher than the range defined for beryl in the literature, especially for those related to the shear-zone type (2.99<H2O<3.16 wt%) and the pegmatite type from the Pombos, Pela Ema, and Pirenópolis deposits (2.78<H O<3.01 wt%). Colombian emeralds have very low H2O contents (1.30<H2O<1.96 wt%), among the lowest in the world

Brazilian. Colombian, and Afghanistani emeralds have contrasting and restricted ranges of  $\delta^{18}$ O values. In Brazil, emeralds related to pegmatites have a systematic  $\delta^{18}$ O inter-deposit variability (6.3< $\delta^{18}$ O<12.1‰). The calculated  $\delta^{18}$ O of the F was buffered by the host ultrabasic rocks during Frock interaction. Emerald and cogenetic phlogopite related to shear-zone-type deposits have a quite restricted  $\delta^{18}$ O range (12.0< $\delta^{18}$ O<12.4‰), the calculated  $\delta^{18}$ O<sub>120</sub> is interpreted to represent the original isotopic composition of the hydrothermal F. Relative to Brazil, the  $\delta^{18}$ O of Colombian and Afghanistani emeralds shows strong enrichment in  ${}^{18}$ O

(13.4<8<sup>18</sup>O<23.6‰), and the high calculated 8<sup>18</sup>O of the F suggests extensive reaction with <sup>18</sup>O-rich sedimentary or metasedimentary rocks. In Brazil, the 8D composition of channels in emerald and the calcu-

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lated  $\delta^{18}O_{H2O}$  for phlogopite are compatible with both magmatic and metamorphic origins. A magmatic origin is supported for emeralds associated with the pegmatitic Socotó and Carnaiba deposits (mean  $\delta D$ =-37.8±8‰) and a metamorphic origin is suggested for the Santa Terezinha shear-zone type (mean  $\delta D$ =-32.4±3‰). A metamorphic origin is proposed for Colombian emeralds. Afghanistani emeralds have a  $\delta D$  composition of channels (mean  $\delta D$ =-46.3±1.3‰) that is compatible with both magmatic and metamorphic origins. (From authors' abstract by E.R.)

See also previous item (E.R.).

GLEESON, S.A., WILKINSON, J.J., BOYCE, A.J., FALLICK. T.E. and STUART, F.M., 1998a, On the origin of anomalously low delta D fluids in quartz-hosted fluid inclusions, southwest England, UK (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-88. First author at T.H. Huxley School of Earth and Environmental Sci., Imperial College, London SW7 2BP, UK; email (s.gleeson@earth leeds.ac uk)

A detailed FI study in post-Variscan

quartz±carbonate±sulphide±anhydrite veins hosted by Palaeozoic basement (Porthleven, Cornwall) and Permo-Triassic sediments (Western Approaches) has identified two F types. A high sal (20-27 wt % NaCl), low T (80-150°C) brine has been identified in base metal mineralised veins hosted by Palaeozoic rocks onshore and in sulphate bearing veins within the offshore succession. A second, honer (200°C) more dilute (0-5 wt.%) F has been identified in E-W trending veins in Porthleven.

Directly measured  $\delta D$  values of the saline brines range from -39 to -103 to a relatively small range in estimated  $\delta^{18}O(1.6-6.8)$ . Similarly, the dilute E-W F have  $\delta D$  values ranging from -41 to -78, with associated  $\delta^{18}O$  values of -1.8 to 6.8 These data show there are no systematic variations in  $\delta D$  between quartz veins. Within veins where individual quartz bands have been sampled, non-systematic temporal fluctations are evident. There is no significant correlation between  $\delta D$  and  $\delta^{18}O$ , sal, T, or any element found in either F.

The low  $\delta D$  values encountered in this study cannot be accounted for by physical fractionation processes and, thus, are anomalous. Four possible origins for these data in this study will be outlined and discussed: analytical artifacts, post-entrapment changes in FI; F sources and water/rock interactions. It is suggested that none of the conventional explanations for low  $\delta D$  values can easily explain the range and fluctuations of the data and other potential mechanisms to produce the observed fractionation will be suggested. (Authors' abstract)

GLEESON, S.A., WILKINSON, J.J., BOYCE, A.J., FALLICK, A.E. and STUART, F.M., 1998b. On the origin of anomalously low δD fluids in quartz hosted fluid inclusions, Southwest England, U.K. (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998. St. Andrews, Scotland (unpaginated). First author at Royal School of Mines. Imperial College, London SW7 2BP, U.K.

Anomalously low  $\delta D$  compositions, apparently unrelated to high latitude meteoric precipitation, have been reported from a range of environments and have most commonly been attributed to organic interaction processes.

A detailed FI study in post-Variscan

quartz±carbonate±sulphide±anhydrite±fluorite veins hosted by Palaeozoic basement (Porthleven. Cornwall) and Permo-Triassic sediments (Western Approaches) has identified two broad F types. A high sal (20-27 wt% NaCl), low T (80-150°C) brine has been identified in base metal mineralised veins hosted by Palaeozoic rocks onshore and in sulphate bearing veins within the offshore succession. A second, hotter (200°C) more dilute (0-5 wt%) F has been identified in a distinctive E-W trending veins in the Porthleven area. Halogen compositions suggest the brines originated as either seawater or a mixture of seawater and meteoric water evaporated past the point of halite precipitation and the dilute F originated as a slightly evaporated mixture of seawater and meteoric water

Directly measured  $\delta D$  values of the saline brines range from -39 to -103‰ for a relatively small range in estimated  $\delta^{18}O$  (1.6-6.8‰). Similarly, the dilute E-W F have  $\delta D$  values ranging from -41 to -78‰, with associated  $\delta^{18}O$  values of -1.8 to +6.8‰. These data show there are no systematic variations in  $\delta D$  between quartz veins, however, where individual quartz bands within a single vein have been sampled, non-systematic fluctuations in composition through time are evident. There is no significant correlation between  $\delta^{18}O$  and  $\delta D$  for either F type suggesting that in both F systems the two isotopes are decoupled. Similarly, there is no systematic relationship between  $\delta D$  and sal, T, or any element found in either F. Four possible origins for the anomalously low  $\delta D$  F in this study [are] discussed analytical artifacts; post-entrapment changes in FI; F sources and water/rock interactions. It is suggested that none of [these] conventional explanations [are adequate, and] range and fluctuations of the data and lack of correlation with F components observed and an alternative mechanism will be suggested. If an unrecognised process is responsible for fractionation of FI  $\delta D$ , care must be taken in invoking the involvement of meteoric waters in ore deposits formed in areas of high latitude, i.e. with low  $\delta D$ meteoric waters. Such interpretations must be supported by data from other techniques. (From authors' abstract by E.R.)

GLEESON, S.A., YARDLEY, B.W.D. and MUNZ, I.A., 1998. Downward infiltration of fluid into the high-grade basement of south Norway I Brines (abst.): Mineralogical Magazine. v. 62A, V. M. Goldschmidt Conf.. Toulouse 1998, Extended Abstracts, p. 527-528.

GOEBEL, E.D., 1996, The pathway for MVT hydrothermal fluids within the Tri-State mining district from stratigraphic plotting of conodont alteration indices: Society of Economic Geologists, Special Pub. No. 4, p. 413-418, Author at Univ. of Missouri-Kansas City, Dept. of Geosci., 710 E. 52<sup>nd</sup> St., Kansas City, MO 64110-2499 USA.

Based on stratigraphic plotting of conodont alteration index data for the Tri-State district conodont elements have been appreciably affected by heat from hot advecting MVT hydrothermal F. Sphalerite in the Tri-State district has T<sub>h</sub> of ~70 to 135°C. Heat from the advecting hot F is thought to have increased conodont alteration index values to 2-3 (60-140°C and 110-200°C) where conodont alteration index values from burial alone would likely have been no higher than 1.5 (50-90°C). Previous vitrinite reflectance studies west of the Tri-State district in the Cherokee basin identify local warm spots through which advecting hydrothermal F vertically penetrated Pennsylvanian rocks. Such relict heating anomalies in stratified rocks serve to constrain the paleo-plumbing system in each area. (From author's abstract by E.R.)

GOEDE, Albert, McCULLOCH, Malcolm, McDERMOTT, Frank and HAWKESWORTH, Chris, 1998, Acolian contribution to strontium and strontium isotope variations in a Tasmanian speleothern. Chem. Geol., v. 149, p. 37-50. First author at Dept. of Geography and Environmental Studies, Univ. of Tasmania, GPO Box 252-78, Hobart 7001, Tasmania, Australia.

Of pertinence to the interpretation of speleothern FI. (E.R.)

GOLDEN, K.M., ACKLEY, S.F. and LYTLE, V.I., 1998. The percolation phase transition in sea ice: Science, v. 282, p. 2238-2241 First author at Dept. of Mathematics, Univ. of Utah. Salt Lake City, UT 84112, USA

Sea ice exhibits a marked transition in its F transport properties at a critical brine volume fraction  $P_c$  of about 5%, or temperature  $T_c$  of about  $-5^{\circ}$ C for sal of 5 parts per thousand. For T warmer than  $T_c$ , brine carrying heat and nutrients can move through the ice, whereas for colder T the ice is impermeable. This transition plays a key role in the geophysics, biology, and remote sensing of sea ice. Percolation theory can be used to understand this critical behavior of transport in sea ice. The similarity of sea ice microstructure to compressed powders is used to theoretically predict  $P_c$  of about 5%. (Authors' abstract)

Of pertinence to the interpretation of FI in ice. (E.R.)

GOLDFARB, R.J., PHILLIPS, G.N. and NOKLEBERG, W.J., 1998. Tectonic setting of synorogenic gold deposits of the Pacific Rim: Ore Geol. Reviews, v. 13, p. 185-218. First author at U.S. Geological Survey, Box 25046. Denver Federal Center, Denver, CO 80225, USA

More than 420 million oz. of gold were concentrated in circum-Pacific synorogenic quartz lodes. These ores have many features in common and can be grouped into a single type of lode gold deposit widespread throughout clastic sedimentary-rock dominant terranes. The auriferous veins contain only a few percent sulphide minerals, have gold silver ratios typically greater than 1:1, show a distinct association with medium grade metamorphic rocks, and may be associated with large-scale fault zones. Ore F are consistently of low sal and are  $CO_2$ -rich.

The abundance of gold-bearing quartz-carbonate veins throughout the Gondwanan. North American and Eurasian continental margins suggests the migration concentration of large F volumes during continental growth. Such volumes could be released during orogenic heating of hydrous silicate mineral phases within accreted marine strata. The common temporal association between gold veining and magmatism around the Pacific Rim retlects these thermal episodes. (From authors' abstract by E.R.)

GOLÓVKO, A.V., SHAKIROV, N.I., KOZLÓV, V.V. and IGNÁTIKOV, E.N., 1998, A gold-sulphide show in the Karashokho Diatreme (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 109-110 (in Russian).

GOLOVKO, A.V., TOLMACHEVA, E.V. and ORLOVA, M.P., 1998, T-P-geochemical investigations into the shonkinites of the various facies in the Karashakho pipe (western Uzbekistan) (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 43-44 (in Russian).

See Translations.

GOLÓVKO, A.V., YAKÓBENKO, N.E., SHAKÍROV, N.I. and KORÓBOV, V.A., 1998, Features of the composition and origin of the shonkinites in the Karashokho Diatreme (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 41-42 (in Russian).

See Translations.

GONZÁLEZ, M.M., 1997, The fluid inclusions on gold quartz of La Candelaria, Córdoba Province: Analysis of their origin and their application on mining prospecting: Doctoral thesis Dec. 11, 1997, Dept. de Geologia, Universidad Nacional del Sur. Bahia Blanca, Argentina, 336 pp. (in Spanish, abstract in Engl.). Author at Biblioteca Central, Universidad Nacional del Sur.

The metamorphic Precambrian rocks of the Candelaria District host several economically important mesothermal gold deposits (e.g.: La Higuerita. La Bragada, Paso del Molle, etc.). According to the structural setting, ore mineralogy and wall rock lithologies, three different types of veins can be distinguished in the Candelaria District. - type A: plastically deformed segregation veins with different grades of concordance with the host rocks; they have been probably generated during syn-metamorphic processes; type B: quartz veins associated to pegmatites dikes; and – type C: quartz veins developed in zone of intense fracturing. Those veins do not show any ductile deformation. They are centrimetric to decimetric in width and contain P sulphides.

Gold mineralization in the Candelaria area is spatially associated with shear-hosted quartz veins. Structures which host mineralization are typically no larger than 100 m long and 2-5 m wide, with grades <20 g/t Au. Systematic FI studies using petrographic and microthermometric analysis have been carried out on the different quartz veins in order to characterize the P-V-T-X conditions of the F circulation in the fault network.

The results of this study are based on the analysis of the Fi and the distribution of deformed quartz-rich veins and lenses.

The development of different quartz generations with clearly distinguishable types of FI, initial CO<sub>2</sub> rich and progressively higher H<sub>2</sub>O content, implies that F had been trapped under variable P-T conditions. Considering all these chemical and physical characteristics, it is proposed that the gold mineralisations of the Candelaria District formed from CO<sub>2</sub>-rich hydrothermal systems, which were active during the reactivation of the NNE-SSW shear zone under extensional conditions. The genesis of the deposits favours the metamorphic-hydrothermal mobilization and concentration model. (Author's abstract)

GONZÁLEZ, M.M., and MAS, G.R., 1998a, Fluid inclusions and quartz textures in the auriferous veins of La Higuerita mine. La Laguna area, Cordoba, Argentina (abst.): Program and Abstracts. PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions. June 1-4. Univ. of Nevada, p. 34. Authors at UNS-CONICET, Universidad Nacional del Sur, Departamento de Geologia, San Juan 670, 8000 Bahia Blanca, Argentina; email (gonzalez@criba.edu.ar, gmas@criba.edu.ar)

Quartz veins, cutting muscovite schist, consist of quartz+pyrite, galena and chalcopyrite. Pervasive wallrock alteration produced by infiltration and percolation of F consists of sericite, chlorite and epidote.

FI are essentially  $H_2O$  and/or  $CO_2$  with variable sal, and some have a solid phase (halite). Three types are <u>Type I</u>: One  $CO_2$ -rich phase at T(room); cooling results in a separate bubble that homogenizes to L between 4 and 12°C; associated with healed fractures and growth planes; considered PS. <u>Type II</u>: two phases at T(room)- L+V. or two immiscible L. <u>Subtype IIa</u>: PS L+V; associated with type I, on cooling nucleate a low density  $CO_2$  bubble between -35 and -55°C; L-V is about 3:1 <u>Subtype IIb</u>: Two immiscible L (H<sub>2</sub>O+CO<sub>2</sub>). <u>Subtype IIc</u>: Aq L+V. in PS planes; V around 20%. <u>Type III</u>: Three-phase (H<sub>2</sub>O+CO<sub>2</sub>); P and PS; highly variable phase ratio; ThCO<sub>2</sub> to either the L or V phase suggests trapping of a het-

erogeneous effervescent fluid.

The Th H<sub>2</sub>O+CO<sub>2</sub> is between 250° and 400°C, always to the L, with a mean T of about 360°C. Sal of the aq phase, from the T of CO<sub>2</sub> clathrate dissociation, is 7.4 to 12.9 wt% NaCl eq.

Bulk densities range from 0.45 to 0.95 g/cm<sup>3</sup>. The spread of densities, besides the initial heterogeneity, may reflect pressure variations during deformation over a fluctuating P-T path, possibly according to the "fault-valve-cycle". Microthermometric analyses of the 1 reveal a CO<sub>2</sub> rich F, with highly variable density and variable H<sub>2</sub>O. Furthermore, the distinct Fl compositions indicate that these CO<sub>2</sub> rich F (CO<sub>2</sub>>>H<sub>2</sub>O) represent an unrecognized category of ore forming F. Fl from these gold quartz veins provide estimates of P and T of the F dynamic process that were active during mineralization, namely, about 360°C and 2 kb. (From authors' abstract by E.R.)

GONZÁLEZ, M.M. and MAS, G., 1998b. Fluid inclusions and hydrothermal chlorites. Comparison between two geothermometers and its use in prospecting: "La Bragada" mine, Cordoba, Argentina: IV Meeting of Mineralogy and Metallogeny. (IV Réunion de Mineralogia y Metalogenia "MINMET") Sept. 23-25, 1998, Bahia Blanca, Argentina, p. 115-120 (in Spanish, Engl. abst.) Author at (Gonzalez@criba.edu.ar)

The present study was undertaken to use two geothermometers at La Bragada mine to constrain the T-P path provided by Fl and the Tf of hydrothermal chlorites by means of Al<sup>IV</sup> substitution. Microthermometric data combined with a chlorite geothermometer suggest that the T-P conditions of vein formation during gold mineralization was around 350°C and Ikbar, corresponding to the regional [brittle?] deformation. (Authors' abstract)

GOODMAN, E.D., SUMMA, L.L., RICHARDSON, M., KOCH, P.S., GREEN, A.R. and NORTON, I.O., 1998, Structural framework of northern South America and hydrocarbon systems analysis of eastern Venezuela basin; an integrated approach (abst.): AAPG Bull., v. 82, no. 10, p. 1918-1919.

The complex history of northern South America's margins poses special challenges for understanding hydrocarbon systems evolution. We used an integrated plate-to molecular-scale approach to begin unraveling this complex history and, in the process, validated this approach as a means of studying hydrocarbon systems in other complex tectonic settings. Probable Jurassic hypersaline-lacustrine and Albian marine carbonate source rocks were identified using samples of reservoired oils, seeps, organic-rich rocks and FI. The detailed geochemistry (biomarkers, isotopes, etc.) of these hydrocarbons was integrated with Exxon's global database to understand the characteristics and distribution of these oils and their postulated source rocks. Biomarker analysis of oils from FI, trapped in Miocene sandstones overlying the proposed graben fill, helped to constrain the distribution of the inferred, Jurassic, lacustrine source and to demonstrate the existence of effective vertical migration pathways. Our thermal models suggest tremendous volumes of hydrocarbons were lost from mid-Tertiary "Carapita Basin" due to lack of effective traps and seals and quenching during subsequent uplift. Mixing of the later charge, light oils with heavier Cretaceous oils has resulted in fields with variable oil qualities. Other post-emplacement processes such as late G migration into oil-filled reservoirs, deep burial of oil accumulations, biodegradation, and water washing have also significantly affected hydrocarbon quality. (From authors' abstract by E.R.)

GRAHAM, C.M., VALLEY, J.W., EILER, J.M. and WADA, Hideki, 1998, Timescales and mechanisms of fluid infiltration in a marble: An ion microprobe study: Contrib. Mineral. Petrol., v. 132, p. 371-389. First author at Dept. of Geol. and Geophys., Univ. of Edinburgh. Edinburgh EH9 3JW, UK.

Using a recently developed ion microprobe technique, a detailed oxygen isotope map of calcite grains in a coarse-grained marble has been constructed. supported by trace element (Mn, Sr, Fe) analysis and CL imaging, in order to constrain scales of oxygen isotope equilibrium, timescales and mechanisms of metamorphic F infiltration, and F sources and pathways. Results are compared with a previous study of this sample (Wada 1988) carried out using a cryo-microtone technique and conventional oxygen isotope analysis. The marble, from the high T/low P Hida metamorphic belt in north-central Japan, underwent granulite facies followed by amphibolite facies metamorphic events, the latter associated with regional granite intrusion. The Cl imaging indicates two types of calcite, a yellow luminescing (YLC) and a purple luminescing (PLC) variety. The YLC, which occupies grain boundaries, fractures, replacement patches, and most of the abundant deformation twin lamellae, post-dates the dominant PLC calcite

and maps out F pathways. Systematic relationships were established between oxygen isotope and trace element composition, calcite type and texture, based on 74  ${}^{18}$ O/ ${}^{16}$ O and 17 trace element analyses with 20-30  $\mu$ m spatial resolution The YLC is enriched in Mn and Fe, and depleted in  ${}^{18}$ O and Sr compared to PLC, and is much more 18O-depleted than is indicated from conventional analyses. Results are interpreted to indicate infiltration of <sup>18</sup>O-depleted (metamorphic or magmatic) F (initial  $\delta^{18}$ O = 9-10.5‰) along grain boundaries, fractures and deformation twin lamellae. depleting calcite grains in Sr and enriching them in Mn and Fe. The sample is charactensed by gross isotopic and elemental disequilibrium, with important implications for the application of chromatographic theory to constrain F fluxes in metacarbonate rocks.

Areas of PLC unaffected by "short-circuiting" F pathways contain oxygen diffusion profiles of ~10%/~200 µm in grain boundary regions or adjacent to fractures/patches. When correction is made for estimated grain boundary/fracture and profile orientation in 3D, profiles are indistinguishable within error. Modeling of these profiles gives consistent estimates of Dt (where D is the diffusion coefficient and t is time) of  $-0.8 \times 10^{-8}$  m<sup>2</sup>, from which, using experimental data for oxygen diffusion in calcite, timescales of F transport along grain boundaries at amphibolite facies T of -103 to ~10<sup>4</sup> years are obtained. These short timescales, which are much shorter than plausible durations of metamorphism, imply that rock permeabilities may be transiently much higher during F flow than those calculated from time integrated F fluxes or predicted from laboratory measurements. The preservation of 18 O/16 O profiles requires either rapid cooling rates (-100-600°C/My), or, more plausibly, loss of grain boundary F such that a dry cooling history followed the transient passage of F. The 818O trace element correlations are also consistent with volume diffusion-controlled transport in the PLC. F transport and element exchange occurred by two interrelated mechanisms on short timescales and on different lengthscales - longdistance flow along cracks, grain boundaries and twin lamellae coupled to -200 µm-scale volume diffusion of oxygen. (Authors' abstract)

GRAUPNER, T., SPOONER, E.T.C., KEMPE, U., BRAY, C.J., and KREMENETSKY, A.A., 1998: Characterization of hydrothermal fluids from the giant Muruntau Au-quartz vein ore field. Uzbekistan: Initial results (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 100-102 (in English). Authors Graupner and Kempe at Inst. of Mineral. Freiberg Univ. of Mining and Tech., Brennhausgasse 14, 09596 Freiberg. Germany: Spooner and Bray at F. Gordon Smith Fluid Inclusion Laboratory. Dept. of Geol., Univ. of Toronto, 22 Russell St., Toronto, Ontario M5S 3B1, Canada, Kremenetsky at IMGRE, ul. Veresaeva 15, Moscow 121357, Russia

The Muruntau Au ore field and the Myutenbai deposit, and a number of prospects have been studied, using samples of quartz and scheelite.

The F chemistry study included analysis of FI by microthermometry. laser Raman spectrometry and integrated volatile/cation-anion chromatographic analysis of trapped F using a method slightly modified from that of Channer and Spooner (1994). In order to establish petrographic evidence for a FI chronology, nine samples from different textural settings have been investigated using FI mapping.

CO2 is the major G component in all investigated G-bearing I. In addition, highly variable amounts of CH4 and (to a lower degree) variable amounts of N2 were found by laser Raman spectrometry. CH4 concentrations range from 2.5 to 39.5 mol%. N2 concentrations are between <0.5 and 10.0 mol%. These results are in good agreement with G chromatographic analysis showing volatile components in the following order of abundance: H2O>>CO2>CH4+N2>COS>C2+ and C3-hydrocarbons.

Using ion chromatography, Na' and CI' were determined to be the principal ions in all samples. In addition, minor amounts of K\*. Mg2 Ca2\*. Br' and SO42\* are detected in most sample leachates. Areas showing FI with variable volumetric ratios of carbonic and aq L, and indicating heterogeneous trapping of F were found in Muruntau "central" quartz veins and in the quartz nodule sampled in the adjacent wall rock, but were not observed in the investigated Myutenbai samples. There is good evidence that the low- and high-XCO2 FI were formed by H2O-CO2 F immiscibility.

Non-aq volatile data for samples from low-grade mineralized "flat" ore veins at the margins of the investigated ore bodies with (non-aq) G composition dominated by S CO2-rich I also fit into the phase separation trend suggested for the "central" ore veins samples and show CO2/CH4 ratios of between 1.37 and 3.29 for quartz and scheelite samples.

The consistency of highly phase separated F and high-grade mineralization in Muruntau "central" quartz veins and the lack of phase separation evidence in all investigated Myutenbai samples supports considerable

variations in the geochemical conditions during F evolution for both deposits. According to our results, it is suggested that deposition of gold in Muruntau "central" quartz veins may have been caused by CO2-H2O phase separation. (From authors' abstract by E.R.)

GRAY, J.E., GENT, C.A., SNEE, L.W. and THEODORAKOS, P.M., 1998, Age, isotopic and geochemical studies of the Fortyseven Creek Au-As-Sb-W prospect and vicinity, southwestern Alaska: U.S. Geological Survey Professional Paper, 1998, p. 17-29. Indexed under FI.

GRISHINA, Svetlana, PIRONON, Jacques, MAZUROV, Mikhail, GORYAINOV, Sergey, PUSTILNIKOV, Anatoly, FON-DER-FLASS, German and GUERCI, Alain, 1998, Organic inclusions in salt. Part 3. Oil and gas inclusions in Cambrian evaporite deposit from East Siberia. contribution to the understanding of nitrogen generation in evaporites. Org. Geochem., v. 28, no. 5, p. 297-310. First author at United Inst. of Geol., Geophys. and Mineral., 630090, Novosibirsk, Russia.

Halite in Cambrian KCI-deposits from the southern part of the Siberan platform, which have been thermally overprinted by dolerite intrusions. commonly contains I dominantly composed of CO2 and less commonly. host I composed of hydrocarbons. Four types of hydrocarbon I have been identified in samples taken from locations devoid of dolerite intrusions. These are (1) monophase gaseous I (i.e. N2, CH4 or N2-CH4). (2) aliphatic oil I, (3) two-phase (L1 + L2) hydrocarbon-brine 1 and, (4) N2-hydrocarbon 1. The area where the N2-rich I occur is associated with ammonium-free Kchlorides. By comparing different types of K-salt environments, the origin of the nitrogen could be identified. First, ammonium ions are produced by deamination of organic matter and stored in K-chlorides, and thereafter N2 is released from NH<sub>4</sub>-K minerals by oxidation in zones rich in iron oxides and/or by 40K radiolysis. (Authors' abstract)

GROSSMAN, J.N., ALEXANDER, C.M.O'D., WANG, J., ZANDA, B., BOUROT-DENISE, M., HEWINS, R.H. and VU, Y., 1998, The lack of potassium-isotopic fractionation in Bishunpur Chondrules (abst.): 61st Meteoritical Society Meeting July 27-31, 1998. Trinity College, Dublin, Ireland, published in Meteoritics & Planetary Sci., v. 33, no. 4 Supple., p. A64-A65. First author at U.S. Geological Survey. Reston, Va 20192. U.S.A

Volatile elements can provide some of the best constraints on the nature of the chondrule formation process and of chondrule precursors. Volatile-poor chondrules may have formed either from volatile-poor material or by partial evaporation of volatile-rich material during melting. Volatiles may also have been affected by S processes, such as parent-body (aq) alteration of chondrules.

Rayleigh-type evaporative loss of K from synthetic chondrules produces rapid increases in 841K, even at modest levels of evaporation [1]. In [1], the mesostasis in three low-FeO chondrules were analyzed, and none showed any resolvable (<2‰) fractionation of K isotopes. Yu et al. [1] assumed that entry of K into the chondrules after accretion was minimal and, therefore, that evaporative loss of K did take place, but probably in a dust-enriched environment, thus allowing isotopic exchange between G and M

Here we attempt to rule out that S entry of volatiles into chondrules erased evidence of P K-isotopic fractionation. We identified I of glass inside olivine crystals in six Bishunpur chondrules. As in Semarkona [2], several of these I have extremely low Na/AI ratios compared to their chondrule mesostasis. There is evidence that volatiles, including K, entered certain chondrules after solidification, probably during aq alteration [3] The glass I, especially alkali-poor ones, offer the best hope of finding material that escaped any such alteration. These I as well as normal chondrule mesostasis were analyzed by ion probe as described in [1].

Five of the chondrules were type I (olivine, Fac,1), with mesostasis Na<sub>2</sub>O contents of 0.2-9 wt% (the latter being an unusual type I chondrule). The sixth chondrule had Fao olivine and mesostasis with 2-4 wt% Na2O. One type I chondrule and the sixth chondrule had glass I that were significantly lower in alkalis than surrounding mesostasis.

The analysis of 17 areas of mesostasis and glass I are plotted in Fig. 1. The fraction of K remaining assumes initial L-chondrite-like K/Al ratios for all the chondrules. None showed any significant K isotopic fractionation, confirming the results in [1].

From the analyses, it seems likely that Bishunpur chondrules lacked any K-isotopic fractionation even before parent-body alteration occurred. This is consistent with direct condensation models of chondrule L [4], although we doubt that such models can explain many of the properties of

real chondrules (e.g., relict grains and fast cooling rates). Type I chondrules could have formed from volatile-poor material such as high-T condensates, which would not be expected to show K-isotopic fractionation, although the correlation of chondrule grain size with volatile content may argue against this [5], depending on the effect of S alteration. If type I chondrules experienced evaporative loss of volatiles, the combined effects of enhanced evaporation rates due to fairly high PH<sub>2</sub> and exchange with the surrounding G while molten must have reduced the amount of isotopic fractionation in chondrules to levels we are unable to detect. This does not require that volatiles recondensed into chondrules to any great extent during cooling: they were simply able to exchange with the M. Indeed, the zoning profiles of glass in many type I chondrules requires that most observed S entry of volatiles happened after solidification and incorporation into a parent body. What is certain, however, is that chondrules did not experience simple Rayleigh-type loss of volatiles. (Authors' abstract)

See figure in the Illustrations appendix.

GROVES, D.I., GOLDFARB, R.J., GEBRE-MARLAM, M., HAGE-MANN, S.G. and ROBERT, F., 1998, Orogenic gold deposits: A proposed classification in the context of their crustal distribution and relationship to other gold deposit types: Ore Geol. Reviews, v. 13, p. 7-27. First author at Centre for Teaching and Research in Strategic Mineral Deposits, Dept. of Geol. and Geophys., Univ. of Western Australia, Nedlands. WA 6907, Australia.

The so-called 'mesothermal' gold deposits are associated with regionally metamorphosed terranes of all ages. The resulting gold-bearing quartz veins are emplaced over a unique depth range for hydrothermal ore deposits, with gold deposition from 15-20 km to the near surface environment, so the term 'mesothermal' is not applicable to this deposit type as a whole. Instead, the unique temporal and spatial association of this deposit type with orogeny means that the vein systems are best termed *orogenic gold deposits*. Most ores are post-orogenic with respect to tectonism of their immediate host rocks, but are simultaneously syn-orogenic with respect to ongoing deep-crustal, subduction-related thermal processes and the prefix *orogenic* satisfies both these conditions. On the basis of their depth of formation, the orogenic deposits are best subdivided into *epizonal* (<6 km), *mesozonal* (6-12 km) and *hypozonal* (>12 km) classes. (From authors' abstract by E.R.)

Includes a table with F compositions for orogenic and six other types of gold deposits. (E.R.)

GUAN, Shiping and LI, Zongwei, 1998, Geochemistry of ore-forming fluids of Pb-Zn deposits in east margin of Kangdian geoaxis, southwest China: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1087-1090 (in Chinese).

GUILHAUMOU, Nicole, CORDON, Sophie, DURAND, Claudine and SOMMER, Frédéric, 1998, P-T conditions of sandstones silicification from the Brent Group (Dunbar, North Sea): Eur. J. Mineral., 1998, no. 10, p: 355-366. First author at Ecole Normale Supérieure, Laboratoire de Géologie, URA 1316 du CNRS, F-75230 Paris Cedex 05, France; email (guilhaum@lgs.jussieu.fr)

Silicification is one of the diagenetic phenomena that causes a drastic decrease of porosity in sandstone reservoirs. In several important hydrocarbon fields located in the Brent Province of the northern North Sea, silicification is found together with illitisation. The present paper attempts to define P and T conditions of silicification in the Dunbar Field (Greater Alwyn, Great Britian). SEM CL observations were performed on sandstones. Raman FTIR microanalyses and microthermometric measurements were done on single 1 precisely related to the quartz overgrowth generation. Two main types of aq and hydrocarbon-bearing FI are observed and can be related to the beginning of the main silicification phase: (1) Trapping of FI with highly variable methane contents in rehealed cracks; (2) Trapping of contemporaneous aq and hydrocarbon Fl, mainly at the boundary between detrital grains and overgrowth. Two phase aq F1 homogenize between 105 and 110°C in the Frontal Panel area and between 100-105 and 105-110°C in the West Flank area depending on the well. Sal are between 2.5 and 4 w1.% eq. NaCl.

Raman microspectrometric analyses and observation of earlier heterogeneous trapping suggest that the brine is methane-saturated in all samples with no other G species detected. FTIR microspectrometry of hydrocarbon-bearing FI show that they contain light aliphatic mature oils ( $C_R$ - $C_m$ alkane eq.) with variable amounts of dissolved CO<sub>2</sub>. Their Th vary between 80 and 90°C, depending on the well. Since the trapped brines are in the methane-saturated H<sub>2</sub>O-NaCl( $\pm$ KCl) system. Th of aq I are equal to Tt. The Tt are 15-20°C lower than the present-day Tf, this argues against a present-day resetting of the I. The deduced P values are near 400 $\pm$ 20 bars.

Using basin modeling (GENEX) to match observed organic matter maturation parameters, the T obtained from FI correspond to a burial depth of 2.3 to 2.5 km sub-seafloor for the Frontal Panel and 2.4 to 2.8 km subseafloor for the West Flank. The P values obtained from FI are higher than those derived from modeling which may indicate the existence of overpressures in the reservoir at the time of cementation. (Authors' abstract)

GUILHAUMOU, N., DUMAS, P., CARR, G.L. and WILLIAMS, G.P., 1998, Synchrotron infrared microspectrometry applied to petrography in micrometer-scale range: Fluid chemical analysis and mapping: Applied Spectroscopy, v. 52, no. 8, p. 1029-1034. First author at CNRS, URA 1759, Dept. de Géotectonique-Université Pierre & Marie Curie, 75252 Paris, Cedex 05, France.

The potentiality of synchrotron infrared microspectrometry was investigated for in situ analysis of FI and volatiles of particular geological interest. Thanks to the intrinsic high brightness of the synchrotron infrared source, areas as small as a few µm<sup>2</sup> can be probed, providing a highcontrast analysis of small I in geological materials. We have identififed organic components in such small volumes in their L and gaseous phase, thus allowing a deeper analysis of oil-water I entrapped in diagenetic cements. Such detailed analysis opens up new perspectives in petroleum reservoir evolution studies. The high signal-to-noise ratio of spectra obtained in small volume allows a fast and accurate chemical manning of the I components. Drastic refraction effects preclude, at the present state, a quantitative analysis of either the volume or the thickness of the individual I. Traces of volatiles such as CO2 and H2O are easily detected in the vitreous and gaseous part of the glass M Fl. We have also profiled the hydroxyl concentration near a wall, and calculated the hydrogen diffusion coefficient in anhydrous minerals such as diopside. (Authors' abstract)

GUNN, V.K., BARKER, A.J., NESBITT, R.W. and SCHMIDT, L.B., 1998, New insights into the fluid flow and mineralisation history of the Zinkgruvan Pb-Zn-Ag deposit, Sweden (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated). First author at School of Ocean and Earth Sci., Univ. of Southampton, Southampton Oceanography Centre, Southampton SO14 3ZH.

Zinkgruvan is an early Proterozoic Pb-Zn-Ag deposit. It has traditionally been interpreted as a Broken Hill-type stratiform deposit (Hedström et al., Econ. Geol., v. 84, 1989). The Pb-Zn-Ag mineralisation is contained within a package of poly-deformed and highly metamorphosed rocks. The localised presence of wollastonite and forsterite is indicative of low-P conditions, and on this basis provisional estimates of peak metamorphism are. P=<5 kbar,  $T=700-750^{\circ}C$  Late stage F infiltration [Fi data?] gave rise to variable retrogression of peak metamorphic assemblages, and the sphalerite and galena ores preserve features from both the prograde and retrograde events.

Preliminary investigation suggests evidence for significant K\* metasomatism, although the relationship between this and the ore has still to be determined. (From authors' abstract by E.R.)

GUO, Naiyan and YU, Xiaoguo, 1998: Organic inclusion study of YC 13-1 gas field in the Qiong Dongnan Basin, South China Sea (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 150 (in English). Authors at Exploration and Development Research Center of China Nat'l. Offshore Oil Corp., Hebei, China 074010.

In this paper we try to obtain information about the origin, migration and accumulation of G field by the study of type, distribution, homogenous T and components of organic 1 in diagenetic quartz of the reservoir in the YC 13-1 G field, the biggest offshore G field in China. Sandstone samples were studied by Th, LRM, GC and GC-MS.

Organic 1 in authigenic quartz of sandstone in LS<sub>3</sub> are characterised by large amount, high evolution level and rich in CO<sub>2</sub>. The organic 1 can be classified into five types. Iiquid, three phasic, gaseous, mixture phasic and solid hydrocarbon 1. From the first to the third stages the change of the organic 1 type implies the quick filling of hydrocarbons in the reservoir. The filling suggests that the F media in the reservoir of the Lingshui Formation is a strong reduce water column with a medium saline and high sulphur content deposited in marine environment. The biomarker distribution of the 1 and condensates is totally different. The hydrocarbons in the 1 with high maturity originated from marine source rock with terrigenous

plant input and low pristane/phytane ratio. The G originated from two source rocks, marine and coaly, the former is P source rock. The type distribution, homogenous T and components of organic I in authigenic quartz sandstone suggest that G migration began at Pliocene, in YC 13-1 G field. At that time the strata buried depth was about 3000 to 3300 m. [and] G reservoir had not yet formed. The large-scale migration occurred in the end of Pliocene to Quaternary, with its depth about 34 to 390 m. (From authors' abstract by E.R.)

GURENKO, A.A., HANSTEEN, T.H. and SCHMINCKE, H.-U., 1998, Evolution of magmatic volatiles during Miocene seamount to shield stage of Gran Canaria (Canary Islands): Evidence from OI- and Cpx-hosted melt and fluid inclusions (abst ): Mineralogical Magazine, v 62A, V.M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 551-552. Authors at GEOMAR Research Center. Wischhofstrasse 1-3, D-24148 Kiel, Germany.

We have studied volatile components (H<sub>2</sub>O, CO<sub>2</sub>, F, Cl, S) and S<sup>6+</sup>/S<sub>tot</sub> ratios in F and naturally quenched glass 1 in Ol and Cpx phenocrysts from Miocene basaltic hyaloclastites drilled during ODP Leg 157. Our goal is to understand the behaviour of magmatic volatiles from magma generation to eruption during the seamount to shield stages of Granodiorite Canaria - a well studied oceanic intraplate volcano. (From authors' abstract by E.R.)

HAGGERTY, S.E., 1998, Diamonds in space and time (Meyer, 1989) (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A12. Author at Geosciences., Univ. of Massachusetts, Amherst, email (haggerty@eclogite.geo.umass.edu)

Diamond precipitation is redox controlled by oxidation of CH4 or reduction of CO2 at >180 km. (From author's abstract by E.R.)

HALL, D.L., STERNER, S.M., SHENTWU, W., WAGNER, P.D., HADLEY, S. and HAY, B.P., 1998, Applying fluid inclusions to petroleum exploration and production problems (abst.): American Chemical Society 215th National Meeting Program, Dallas, TX, March 29-April 2, 1998, paper no. 049. First author at Fluid Inclusion Technologies, 2217 N. Yellowood Ave., Broken Arrow, OK 74012.

Mechanical crushing of rock samples, followed by bulk analysis of evolved organic and inorganic FI volatiles by quadrupole mass spectrometry using a rapid, automated sampling system, allows nearly continuous stratigraphic mapping of paleofluids in the subsurface. These data can be used to document petroleum migration through specific stratigraphic intervals, evaluate petroleum type and quality, establish a time-integrated effectiveness for potential seals, infer nearby undiscovered petroleum, delimit petroleum-bearing intervals and assess reservoir compartmentalization and connectivity. Examples will be presented from the Gulf of Mexico and the Western Canadian Sedimentary Basin. (Authors' abstract)

HALLIDAY, A.N., LEE, D.-C., CHRISTENSEN, J.N., REHKÄM-PER, Mark, YI, Wen, LUO, Xiaozhong, HALL, C.M., BALLENTINE, C.J., PETTKE, Thomas and STIRLING, Claudine, 1998. Applications of multiple collector-ICPMS to cosmochemistry. geochemistry. and paleoceanography: Geochim. et Cosmo. Acta, v 62, no. 6, p. 919-940. Authors at Dept. of Geological Sci., Univ. of Michigan, 2534 C.C. Little Building, Ann Arbor, Michigan 48109-1063. USA.

Multiple collector-inductively coupled plasma mass spectrometry (MC-ICPMS) is a new technique for the measurement of isotopic compositions at high precision. MC-ICPMS is likely to become the method of choice for many isotopic measurements because it is a more user friendly and efficient method for the acquisition of high precision data. It is also much more versatile, permitting elements to be measured that were previously considered intractable, and allowing the acquisition of data in stu, all with a single mass spectrometer. The limiting factor on the sensitivity is the transmission which is  $\leq 2\%$  for all instruments thus far designed. (From authors' abstract by E.R.)

HALTER, W.E., WILLIAMS-JONES, A.E. and KONTAK, D.J., 1998a. Modeling fluid-rock interaction during greisenization at the East Kemptville tin deposit: Implications for mineralization. Chem. Geol., v. 150, p. 1-17. First author at Dept. of Earth and Planet. Sci., McGill Univ., 3450 Univ. str., Montreal, Quebec, Canada H3A 2A7.

Interaction between a tin-bearing greisenizing F and a leucogranitic rock was modeled in order to evaluate the possible role of alteration induced changes in F chemistry in cassiterite deposition. The interaction was modeled using simple titration and multiple-pass F flow models with the program CHILLER, modified to permit calculations at 450°C and 4.0 kb. The compositions of the mineralizing F and the unaltered leucogranite were based, respectively, on analyses of Fl and whole-rock chemistry, of samples from the East Kemptville greisen-hosted tin deposit, Nova Scotia. The multiple-pass F flow model quantified changes in F composition as a function of its interaction with the wall rock and thus enabled us to assess better the factors that controlled cassiferite precipitation. Important conclusions of the model are that the F and the rock equilibrated at each stage of the alteration and the water/rock ratio remained constant across the alteration halo. We further concluded that phases precipitated close to the ven in an earlier stage of the alteration were re-dissolved with evolution of the mineralizing system. In particular, re-dissolved with evolution of the mineraliower pH, and the chemical potential of SnCl<sup>+</sup> increased away from the vein. This could, in turn, explain the low tin grades at East Kemptville. (From authors' abstract by E.R.)

See also next item (E.R.)

HALTER, W.E., WILLIAMS-JONES, A.E. and KONTAK, D.J., 1998b, Origin and evolution of the greisenizing fluid at the East Kemptville tin deposit, Nova Scotia, Canada: Econ. Geol., v. 93, p. 1026-1051. First author at Dept. of Earth and Planet. Sci., McGill Univ., 3450 Univ. str., Montreal, Québec, Canada H3A 2A7.

The process responsible for greisen-hosted tin mineralization at East Kemptville was investigated using petrographic, chemical, and Fl analyses of samples from a single deep drill hole in the western part of the deposit (Baby zone). Based on their trace element chemistry, the greisens intersected in the hole appear to have all formed from a single leucogranite protolith. Alteration developed as symmetrically zoned halos around central fractures as a result of the interaction of a fluoride-rich orthomagmatic F with evolved leucogranite. During alteration, K feldspar was first replaced by albite. With further alteration, albite was replaced by muscovite resulting in the formation of quartz-sericite greisen. Ore minerals are locally present in this zone. Closer to veins, muscovite is replaced by topaz and quartz, producing a quartz-topaz greisen with which the most intense mineralization is associated. This latter greisen is enriched in F, Fe, S, Zn. and Sn, suggesting that these elements were added by the mineralizing F. Next to the vein, dissolution of pyrrhotite, sphalerite, and cassiterite characterizes quartz-greisen in which the concentration of ore-forming elements (Sn. Fe, S, F, Zn. Cu) is lower than in the quartz-topaz greisen. Microthermometric measurements of FI in quartz from the various alteration zones show that this alteration sequence was formed by only one greisenizing event and that T was approximately constant (450°C). The F responsible for greisen formation was an NaCl-brine, containing subordinate and variable concentrations of Fe. Mn and K

Measured Te of FI are lowest in quartz-topaz greisen as a result of an increase in the Fe concentration due to pyrrhotite dissolution. Oxygen fugacity, which was calculated from the CO<sub>2</sub>/CH<sub>4</sub> ratio in G released by crushing FI-rich samples, displays a corresponding minimum since pyrrhotite dissolution releases Fe2<sup>°</sup>. The distribution of pyrrhotite and the FI data indicates that pyrrhotite was precipitated close to the vein during early stages of the alteration and reprecipitated farther out as alteration progressed. This suggests that alteration zones moved away from the vein and widened with time.

The sal of Fl varies between 27 and 41 wt.% NaCl eq. and increases linearly with increasing distance from the vein, even in the absence of Nabearing phases. It therefore follows that sodium was transported toward the fracture (vein) down a chemical potential gradient. This occurred through compensated infiltration, i.e., a regime in which flow was dominantly parallel to the fracture but individual aliquots of F followed complex paths back and forth between the fracture and the rock.

Cassiterite precipitated in quartz-topaz greisen in response to a pH increase of the mineralizing F due to its interaction with the wall rock. Other components affecting cassiterite solubility were either constant (T) or acted against its precipitation ( $fO_2$  and  $a_{Cl}$ .) (Authors' abstract)

See also previous item (E.R.).

HANOR, J.S., 1996, Controls on the solubilization of lead and zinc in basinal brines: Society of Economic Geologists, Special Pub. No. 4, p. 483-500. Author at Dept. of Geol. and Geophys., Louisiana State Univ., Baton Rouge, LA 70803 USA.

There is general consensus that basinal brines have acted as transport agents for lead and zinc in the formation of many carbonate-hosted ore deposits. There has been less agreement, however, on what specific properties of brines permit some of them to act as solvents for these metals. Alternative hypotheses for solubilization have included metal complexing

by chloride, bisulfide, or organic ligands. Several properties of basinal F combine to increase the solubility of galena and sphalerite in a non-linear manner by many orders of magnitude as sal increases at fixed T and  $a_{H2S}$ . These include: (1) a decrease in pH with increasing sal as a result of rockbuffering; (2) the progressive predominance of MeCl<sub>4</sub><sup>2-</sup> complexes, whose activities increase in the proportion of 10,000 to 1 with increasing activities of chloride; (3) and the strongly non-ideal behavior of chloride which results in activity coefficient terms which are significantly greater than unity in very saline waters. Field evidence argues against either organic or bisulfide complexing of lead or zinc as an important control on metal solubility. Data suggest that a threshold chlorinity of roughly 100 g/l (equivalent to a sal of 170 g/L) exists, below which sedimentary F are typically poor solvents for Pb and Zn and above which metals in concentrations of interest in problems of sedimentary ore genesis can be accomodated in solution. (From author's abstract by E.R.)

HANSTEEN, T.H., KLÜGEL, Andreas and SCHMINCKE, H.-U., 1998, Multi-stage magma ascent beneath the Canary Islands: Evidence from fluid inclusions: Contrib. Mineral. Petrol., v. 132, p. 48-64. Authors at GEOMAR, Abteilung Vulkanologie und Petrologie, Wischhofstraße 1-3, D-24148 Kiel, Germany; email (thansteen@geomar.de)

Gabbroic and ultramafic xenoliths and olivine and clinopyroxene phenocrysts in basaltic rocks from the Canary Islands contain abundant CO2dominated F1. I densities are strikingly similar on a regional scale. Histogram maxima correspond to one or more of the following P: (1) minimum 0.55 to 1 0 GPa (within the upper mantle); (2) between 0.2 and 0.4 GPa (the Moho or the lower crust); (3) at about 0.1 GPa (upper crust). Fl in several rocks show a bimodal density distribution, the lower-density maximum comprising both texturally early and late I. This is taken as evidence for an incomplete resetting of I densities, and simultaneous formation of young I. at well-defined magma stagnation levels. For Gran Canana, P estimates for early 1 in harzburgite and dunite xenoliths and olivine phenocrysts in the host basanites overlap at 0.9 to 1.0 GPa, indicating that such magma reservoir depths coincide with levels of xenolith entrainment into the magmas. Magma chamber P within the mantle, inferred to represent levels of mantle xenolith entrainment, are 0.65-0.95 GPa for El Hierro. 0.60-0.68 GPa for La Palma, and 0.55-0.75 GPa for Lanzarote. The highest-density FI in many Canary Island mantle xenoliths have probably survived in-situ near-isobaric heating at the depth of xenolith entrainment. Lower crustal ponding and crystallization prior to eruption may be the rule rather than the exception, independent of the tectonic setting. (From authors' abstract by E.R.)

HAO, Fang, LI, Sitian, SUN, Yongchuan and ZHANG, Qiming, 1998, Geology, compositional heterogeneities, and geochemical origin of the Yacheng gas field, Qiongdongnan basin, South China Sea: AAPG Bulletin, v 82, no. 7, p. 1372-1384.

Overpressuring and a thermal anomaly near the No. 1 fault are revealed by FI Th and vitrinite reflectance. (From authors' abstract by E.R.)

HARLOV, D.E., HANSEN, E.C. and BIGLER, Christopher, 1998, Petrologic evidence for K-feldspar metasomatism in granulite facies rocks: Chem. Geol., v. 151, p. 373-386.

HARMER, R.E. and GITTINS, J., 1998. The case for primary. mantlederived carbonatite magma: J. of Petrol., v. 39, no. 11 & 12, p. 1895-1903. First author at Council for Geosci., Private Bag X112, Pretoria 0001, South Africa.

There is much debate about whether carbonatite magmas are derived in 'secondary' fashion through the advent of L immiscibility operating in the crust on evolved nephelinitic magma, or whether they are derived in the mantle by direct partial melting of a carbonated peridotite. This paper briefly summarizes the ESr-ENd data for carbonatites in general and evaluates the isotopic relationships between carbonatites and alkaline silicate rocks in several well-studied complexes from Africa. Available data for carbonatites younger than 200 Ma have a range in Esr-ENd that is less than that found in oceanic basalts despite the fact that carbonatites traverse lithospheres that are much more complex than those in the oceans. By contrast, for the Napak, Kerimasi, Shombole, Dorowa, Shawa and Spitskop complexes the alkaline silicate rocks show greater variablity and have more enriched ESr-ENd (higher ESr. lower ENd) values than their associated carbonatites. In general, the carbonatites have isotopic compositions that are closer to the more primitive silicate rocks, such as melilitites and olivine nephelinites, than to more evolved nephelinites and phonolites. In the case of the Napak Complex, the enriched component was introduced from the

lower crust whereas for the Dorowa and Shawa complexes of SE Zimbabwe, the component was derived from the sub-continental lithospheric mantle. These relationships indicate that the carbonatites must have existed as discrete magmas in the mantle and argue against a derivation by L immiscibility in the crust. Although a contrast in isotopic composition does not rule out an immiscibility relationship at mantle depths and early in the evolutionary history of a melilititic or nephelinitic magma, there is little experimental support for it. Existing experimental data indicate that immiscibility between carbonate and silicate L is favoured at low, crustal, F but that immiscibility is unlikely to occur in realistic mantle M or their derivatives at mantle P. Many experimental data exist to show that magnesian carbonatite L form as the near-solidus M of carbonated mantle peridotite at depths in excess of 75 km. We conclude that the calcitic and dolomitic carbonatite magmas discussed in this paper are best considered as being derived from P carbonatite magmas generated in the mantle by partial melting of carbonated peridotite. (Authors' abstract)

HARMS, E. and SCHMINCKE, H.U., 1998, Volatile composition of the Laacher See phonolite magma (East Eifel, Germany, 12900 BP): Implications for syneruptive S, F, Cl and H<sub>2</sub>O degassing (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F936. First author at GEOMAR forschungszentrum für Marine Geowissenschafte, Abt. Vulkanologie und Pétrologie, Wischhofstr. 1-3, Kiel 24148, Germany; email (eharms@geomar.de)

We quantified the syneruptive volatile loss by comparing volatile concentrations in glass I in phenocrysts and partially degassed host matrix glass. Glass I (150-1490 ppm S) and host matrix glasses (150-820 ppm S) both document a strong S-decrease from the least to the most differentiated M fractions which is probably due to crystallization of hauvne (sodalite phase with max. 4.8 wt% S. modal content 0.5-1.5 vol%), showing that most S was lost from the M prior to eruption. The sulfate/total sulfur ratio of the pre-eruption M increased with proceeding magmatic differentiation from c. 8 to 71%, as indicated by S k a wavelength shift measurements in glass I. This suggests the release of sulfate-rich M during Plinian and sulfide-rich M during phreatomagmatic phases. F and Cl are enriched in glass 1 (690-4060 ppm F, 1770-4400 ppm Cl) and matrix glasses (680-3660 ppm F, 2130-4330 ppm CI) during the magmatic evolution. The most differentiated M fractions (max. 13 wt% Na2O) represented as matrix glass only are extremely F-enriched (5080-8780 ppm) and Cl depleted (460-2820 ppm) suggesting that virtually all F was retained in the M. whereas some CI was lost during pre- and/or syn-eruptive degassing. The H2O concentrations in glass I vary statistically during magmatic differentiation (2.5-5.7 wt%). Host matrix glasses are H2O-depleted (0.2-2.8 wt%) compared to most glass I. (From authors' abstract by E.R.)

HAURI, E.H., 1998, Water and other volatiles in the Hawaiian plume: A SIMS study of melt inclusions (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 585-586 Author at DTM, Carnegie Inst. of Washington, Wash., D.C. 20015, USA.

We have addressed the origin of water in the sub-Hawaiian mantle by examining MI within olivine phenocrysts from Loihi, Kilauea, Mauna Loa and Koolau. We also measured the D/H ratios of magmatic water contained within these MI. (From author's abstract by E.R.)

HE, Ying, ZHU, Xingguo and XU, Peicang, 1998, The isotopic compositions of CO<sub>2</sub> for single fluid inclusions in volcanic rocks from Shengli oilfield. China: Scientia Geologica Sinica (Dizhi Kexue) v. 33, no. 3, p. 380-383 (in Chinese; Engl. abst.). First author at Dept. of Geol., Northwest Univ., Xi'an 710069.

The isotopic compositions of CO<sub>2</sub> [presumably of C] for single F1 in volcanic rocks from the Shengli oil-field have been analyzed with the LRM spectrum analysis method. There are significant differences in isotopic compositions of CO<sub>2</sub> for the single I between non CO<sub>2</sub> and CO<sub>2</sub> gas-field [(-10.22±0.99)‰ for non CO<sub>2</sub> gas-field and (-4.18±0.45)‰ for CO<sub>2</sub> gas-field, PDB]. The results are identical with the isotopic compositions of CO<sub>2</sub> for the group of 1 in volcanic rocks analyzed with the cracking method (from -14.6 to -10.2‰ for non CO<sub>2</sub> gas-field and from -5.5 to -4.8‰ for CO<sub>2</sub> gas-field. PDB), and corresponds to the isotopic compositions of CO<sub>2</sub> for natural G (from -11.8 to -5.4‰ for non CO<sub>2</sub> gas-field and from -5.3 to -4.4‰ for CO<sub>2</sub> gas-field. PDB). Therefore, the natural CO<sub>2</sub> may be derived from the volcanic rocks derived from mantle.

HE, Zhili, 1998. A brief review of decrepitation method development during the past 50 years (abst.): 17th General Meeting Int'l. Mineralogical Association. Aug 9-14, 1998. Toronto. Canada, Abstracts and Programs, p. A35. Author at #FK Dept. of Geol., Univ. of Sci. and Tech., Beijing, email

### (licylxj@public.bta.net.cn)

A review of the history of decrepitation studies in Canada, USSR and China. (From author's abstract by E.R.)

HE, Zhili and MEL'NIKOV, F.P., eds., 1998, APIFIS Newsletter, Special Issue, in conjunction with the Second APIFIS Symposium, Tashkent, Uzbekistan, Oct. 28-30, 1998, 118 pp. (in Russian and English).

This reprints the abstracts from the 165-page Abstract Volume for this meeting, each in same language as in original (Smirnova and Kozlov, 1998, this volume). (E.R.)

HE, Zhili and XIE, Yuling, 1998, Discussion about some problems in studies of superlarge ore deposits and prospecting (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 15-16 (in English). Authors at Beijing Univ. of Sci. and Tech., 100083 Beijing, China.

The research of FI obtained from minerals indicates that there is no significant difference between the superlarge and large, middle and small Au-quartz deposits in ore-forming F. It seems that there is no unique oreforming F to form the superlarge gold deposit. Generally speaking, some superlarge ore deposits are polygenetic and compound ore deposits. (From authors' abstract by E.R.)

## HEATH, Emily, MACDONALD, Ray, BELKIN, Harvey,

HAWKESWORTH, Chris and SIGURDSSON, Haraldur, 1998, Magmagenesis at Soufriere volcano, St. Vincent, Lesser Antilles Arc: J. of Petrol, v. 39, no. 10, p. 1721-1764. First author at Environmental Sci Div., IEBS, Lancaster Univ., Lancaster LA1 4YQ, U.K.

There is conflicting evidence as to the pre-eruptive water contents of Soufriere magmas; compositions of clinopyroxene phenocrysts and MI suggest H<sub>2</sub>O>3 wt%, whereas various projections onto phase diagrams are more consistent with relatively anhydrous magmas. Primary magmas at Soufriere were generated by around 15% melting of mid-ocean ridge basalt type mantle sources which had been modified by addition of F released from the slab containing contributions from subducted sediments and mafic crust. (From authors' abstract by E.R.)

HEDENQUIST, J.W., ARRIBAS, Antonio, Jr., and REYNOLDS, T.J., 1998, Evolution of an intrusion-centered hydrothermal system: Far Southeast-Lepanto porphyry and epithermal Cu-Au deposits, Philippines: Econ. Geol., v. 93, no. 4, p. 373-404. First author at Mineral and Fuel Resources Dept., Geological Survey of Japan, 1-1-3 Higashi, Tsukuba 305, Japan; email (jeffrey@gsj.go.jp).

There are many examples of spatially associated porphyry and epithermal ore deposits; a genetic connection has been suggested for some and argued against for others. Nowhere is this spatial association better demonstrated than in the Mankayan district of northern Luzon, Philippines, where the Lepanto high-sulfidation epithermal Cu-Au deposit is superadjacent to the Far Southeast porphyry Cu-Au orebody, together they contain >3.8 Mt Cu and >550 t Au.

Quartz diorite porphyry dikes intruded Miocene basement rocks of metavolcanic and volcaniclastic rocks to a 300 m elevation. These intrusions postdate the Pliocene volcanic breccia and dacite porphyry that host much of the epithermal ore. K silicate alteration, consisting of biotitemagnetite and minor K feldspar, is centered on the quartz diorite porphyry. Vitreous, anhedral quartz veins are associated with this early alteration and contain C-rich and hypersaline L I with maximum Th of 450 to 550°C (and 50-55 wt % NaCl eq. sal). Lithostatic P estimates indicate a paleosurface at a ≥1.500 m elevation. Advanced argillic alteration formed over the top of the porphyry and consists of quartz-alunite, dated at 1.42±0.08 Ma (n=5), synchronous with K silicate alteration. The lower limit of extensive quartz-alunite alteration is at a \$600 m elevation. The chlorite-sericite alteration is cut by veins of euhedral quartz that locally fill reopened anhedral quartz veins. The euhedral quartz veins contain anhydrite-white micapyrite±chalcopyrite±bornite and have halos of sericite. FI provide evidence for boiling on inception of this fracturing event (Th=350°C, 5 wt % NaCl eq.) and indicate a depth of 1.500 to 2.000 m below the paleowater table. This brittle-fracture event was followed by cooling and dilution of the hydrothermal F

The elevation of the enargite Au epithermal ore and its host of silicic alteration increases as the unconformity between the basement and dacite breccia rises from a 700 to 1.200 m elevation with increasing distance from the porphyry. Published data on enargite-hosted FI (Th=295-200°C, 4-2 wt.% NaCl eq.) indicate that the T and sal both decrease with increasing distance from the porphyry. Epithermal ore consists of stage 1 euhedral

pyrite-enargite-luzonite, and subsequent stage 2 Au is accompanied by tetrahedrite-chalcopyrite-sphalerite plus telluride and selenide minerals.

The dated minerals were also analyzed for their 818O and 8D compositions, and their associated hydrothermal water values were calculated Water in isotopic equilibrium with biotite averaged +6.3 and -45 per mil. respectively, typical of hypersaline L exsolved from felsic magma. The acidic water that deposited the alunite formed when magmatic V (7‰  $\delta^{18}$ O and -25‰ 8D) was absorbed by local meteoric water (-10‰ 818O and 70‰ δD) in a proportion of ≈9:1 magmatic to meteoric. Lateral flow to the northwest and progressive mixing with ground water diluted the magmatic component to 1.1 at a distance of 4 km from the porphyry. At the depth of the porphyry deposit, the later water isotopically stable with sericite was dominantly magmatic (5.7% 818O and -43% 8D) in the core. The marginal sericitic alteration (1.5% 818O and -51% 8D water values) indicates a maximum 20 to 30% component of local meteoric water. Pyrophyllite in both the porphyry and epithermal deposits formed from water with an isotopic composition similar to that which formed the sericitic alteration. The late euhedral quartz veining and sericitic alteration appear to have been associated with the majority of Cu and Au deposition. In addition, mineralogic, paragenetic, isotopic, and FI evidence suggests that this water precipitated the enargite and Au within the epithermal deposit.

Our results reinforce guidelines for exploration of such deposits. Advanced argillic (quartz-alunite) and K silicate alteration at Lepanto-Far Southeast are coupled in origin and result from V and hypersaline L separation. Thus, exploration programs for buried porphyry deposits should document carefully the geologic, morphologic, and temporal characteristics of exposed areas of advanced argillic alteration and its origin. Epithermal ore at Lepanto-Far Southeast reflects a paleohydrologic regime dominated by lateral F flow, with a marked control by intersection of the Lepanto fault and a lithologic unconformity. Recognizing evidence for lateral flow is critical, as paleohydrology controlled the distribution of alteration and mineralization in many high-sulfidation epithermal deposits. (From authors' abstract by E.R.)

HEDENQUIST, J.W., REYES, A.G., TAGUCHI, S. and SIMMONS, S.E., 1998, Styles of hydrothermal systems in volcanic arcs: Causes of diversity of alteration and mineralization (abst.): GeoScience 98, Geol Soc., Biennial Meetings, Keele Univ., 14-18 April, 1998, p. 141.

The characteristics of hydrothermal alteration in volcanic arcs are related to several factors, including: depth to the degassing magma, formation by neutral pH or acidic waters, porosity- or fracture-controlled flow. relief, etc. Deep, neutral-pH upflow in the Broadlands systems, New Zealand, forms a 1×3 km-size zone of high-T alteration in the porous volcanic rocks, with a halo of argillic alteration. In this low-relief setting, a steamheated acid-sulfate water that forms in the vadose zone causes only a thin (10s m), sporadic cap of advanced argillic alteration. By contrast, the Hatchobaru system in Japan has its neutral-pH upflow strongly channelled by faults, causing a much smaller zone of high-T alteration, 0.3×1 km, despite a similar upflow to Broadlands. The moderate relief of several 100 m results in a perched water groundwater table that allows advanced argillic alteration to form as much as 500 m below the surface. The Bacon-Manito system. Philippines, has an even higher relief, resulting in advanced argillic alteration extending down along faults as much as 1000 m within an otherwise neutral-pH style of alteration. In addition, the shallow depth of degassing magma results locally in hypogene acid CI-sulfate water creating high-T (>400°C) advanced argillic alteration along fractures as deep as 2 km. Interpretation of alteration styles depends on reconstruction of the volcanic edifice; knowing both allows the paleohydrology of the system to be deduced, which is necessary for effective mineral exploration, as will be illustrated with epithermal and porphyry ore deposit examples (Authors' abstract)

HEDENQUIST, J.W. and RICHARDS, J.P., 1998, The influence of geochemical techniques on the development of genetic models for porphyry copper deposits: Chapter 10 in Techniques in Hydrothermal Ore Deposits Geology: Reviews in Economic Geology. v. 10, p. 235-236, Richards, J.P. and Larson, P.B., eds. First author at Mineral and Fuel Resources Dept., Geological Survey of Japan, 1-1-3 Higashi, Tsukuba, 305-8567, Japan.

A very thorough review of the application of various geochemical techniques, including FI, to further an understanding of the conditions of formation of porphyry copper deposits, with extensive (~200) references. (E.R.)

HEIMBACH, J.M., and SPENCER, R.J., 1998. Fluid inclusion and stable isotope geochemistry of a Cambrian to Ordovician carbonate-hosted zinc deposit, southeastern Yukon, Canada (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions. June 1-4, Univ. of Nevada, p. 35. Authors at Dept. of Geol. and Geophysics, The Univ. of Calgary.

The carbonates are composed of micrite with early cement and coarse grained replacement dolomite. Sulfides include syndepositional, laminated pyrite and coarse-grained replacement sphalerite and pyrite.

The  $\delta^{13}$ C values of micrite with early cement range from -0.48 to 2.63‰ (PDB), within the ranges of Cambran to Ordovician limestone. FI Th are from 150 to 200°C. The dolomite is in equilibrium with a F of composition between 7 and 12‰ (SMOW). Dolomite formed at relatively high T, from a distinctly different F than the calcite. Pyrite  $\delta^{34}$ S values point to low T (syndepositional) biogenic sulfate reduction of a Cambran sulfur reservoir.

Coarse-grained replacement sphalerite and pyrite  $\delta^{44}$ S values are from 17.17 to 18.74‰ (CDT), depleted by 15‰ relative to Cambrian seawater. They are derived from a hydrothermal F (140 to 150°C sphalerite FI Th), so these data can not be explained by bacterial sulfate reduction. The  $\delta^{34}$ S values around 17 ‰ indicate that the sulfur is from a Devonian. Jurassic, or Cretaceous sulfur reservoir. (From authors' abstract by E.R.)

HEINRICH, C.A., AUDÉTAT, FRISCHKNECHT, R., GÜNTHER, D. and ULRICH, T., 1998. Metal fractionation between magmatic brine and vapor, and the link between porphyry-style and epithermal Cu-Au deposits (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998. St. Andrews, Scotland (unpaginated). Authors at Institut für Isotopengeologie und Mineralische Rohstoffe, Departement Erdwissenschaften, ETH Zentrum NO 8092 Zürich, Switzerland.

Laser-ablation ICP mass-spectrometry was used to measure the major and trace element composition of individual FI enclosed in natural quartz samples from a range of magmatic-hydrothermal ore deposits, in order to explore the behavior of ore-forming components during F phase separation ("boiling") in high-T saline F systems. Here we report data from 13 samples showing unambiguous textural and microthermometric evidence for coeval trapping of a L brine and a coexisting V phase of lower density and lower sal. The microanalytical data reveal two groups of elements, which show drastically different geochemical behavior during F phase separation. Na, K, Fe, Mn, Zn, Rb, Cs, Pb and other trace elements (characteristically Cl-complexed) fractionate into the brine, whereas Cu, As and Au (probably as HS-complexes) selectively fractionate into the coexisting V phase.

We suggest that the process of brine/V separation is the key to explain the common spatial and temporal association of porphyry-style Cu(-Au) and epithermal Au(-Cu-As) deposits. Physical separation of a buoyant V phase in the deeper porphyry environment segregates a fraction of the Cu, As and Au from the large excess of chalcophile elements (notably Fe) remaining in the dense brine. V separation thus permits selective transport of high concentrations of bisulfide-complexed metals into the low-T epithermal environment, where they are precipitated by interaction with groundwater close to the earth's surface. (Authors' abstract)

HEINRICH, C.A., AUDÉTAT, A., ULRICH, T. and GÜNTHER, D., 1998, Liquid-vapor partitioning of trace-elements in boiling hydrothermal systems: Laser-ablation ICPMS data from natural fluid inclusions (abst): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 593-594. Authors at Dept. Erdwissenschaften, ETH Zentrum NO, Zürich, Switzerland.

New micro-analytical data, from L and V I trapped simultaneously in quartz in a variety of ore-deposits, now provide unambiguous and quantitative evidence for strong fractionation of a range of elements between coexisting F in 'boiling' hydrothermal systems. The thermodynamic explanation and the geological consequences of our observations are still speculative, but it is inevitable that the physical separation of brine and V has a profound influence on metal transport and ore deposition, especially for the behaviour of Cu, As and Au at the transition between 'porphyry' and 'epithermal' environments. (From authors' abstract by E.R.)

HELGESON, H.C., OWENS, C.E., KNOX, A.M. and RICHARD, Laurent, 1998, Calculation of the standard molal thermodynamic properties of crystalline, liquid, an G organic molecules at high temperatures and pressures: Geochim. et Cosmo. Acta, v. 62, no. 6, p. 985-1081. Authors at Dept. of Geol. and Geophys., Univ. of California, Berkeley, California 94720, USA.

The thermodynamic properties of a wide range of organic solids, L. and G at high T and P have been calculated. They are a requisite for characterizing hydrothermal metastable equilibrium states involving these species and quantifying the chemical affinities of irreversible reactions of organic molecules in natural G, crude oil, kerogen, and coal with minerals and organic, inorganic, and biomolecular aq species in interstitial waters in sedimentary basins. (From authors' abstract by E.R.)

HERMS, Petra and SCHENK, Volker, 1998, Fluid inclusions in highpressure granulites of the Pan-African belt in Tanzania (Uluguru Mts): A record of prograde to retrograde fluid evolution: Contrib Mineral. Petrol, v. 130, p. 199-212. Authors at Mineralogisch-Petrographisches Institut, Universität Kiel, Olshausenstrasse 40, D-24098 Kiel, Germany.

The high-P granulites of the Uluguru Mountains are part of the Pan-African belt of Tanzania, the metamorphic evolution of which is characterized by an anticlockwise P-T path. Mineral assemblages that represent distinct metamorphic stages are selected for FI studies in order to deduce the F evolution in metapelites and pyroxene granulites from the prograde to the retrograde stage. FI data improve the petrologically derived P-T path and confirm the anticlockwise evolution. F1 in quartz enclosed in garnet porphyroblasts in metapelites preserve prograde F of CO2-N2 composition and later-trapped pure CO2. During isochoric heating at T near the peak of metamorphism, deformation and recrystallization led to F homogenization vielding N2-poor CO2 composition in metapelites. Near-peak CO2-N2 FI in quartz of metapelites and CO2 l in garnet-pyroxene granulites are characterized by perfect negative crystal shape. Garnet formed in veins and as coronas around orthopyroxene represent the near-isochoric/isobaric cooling stage which is characterized by high-density CO2-rich Fl. Up to 15 mol% N2 in some P CO2 I in corona garnet indicate small-scale F heterogeneity during the static garnet growth. The fact that high-density FI are preserved suggests a shallow dP/dT slope of the uplift path. Nevertheless, some FI decrepitated or re-equilibrated and low-density CO2 I were trapped in the garnet-pyroxene granulite while N2-CH4 I formed in the metapelites. Different F compositions in metapelite and metabasite argue for an internal control of the F composition by phase equilibria. In shear zones where the pyroxene granulite was transformed into scapolite-biotite schist, CO2-N2 and low-density N2-CH4 FI indicate several stages of tectonic activity and suggest F influx from the nearby metapelites. High- and low-sal aq l observed beside CO21 in garnet-pyroxene granulites, in vein quartz and shear zones could be of high-grade origin but are mainly re-equilibrated or retrapped along healed microfractures during lower-grade stages (Authors' abstract)

HEZARKHANI, Ardeshir and WILLIAMS-JONES, A.E., 1998, Controls of alteration and mineralization in the Sungun porphyry copper deposit, Iran: Evidence from fluid inclusions and stable isotopes: Econ. Geol., v. 93, p. 651-670. Authors at Dept. of Earth and Planet. Sci., McGill Univ., 3450 University St., Montreal, Québec, Canada H3A 2A7; email (ardeshir@geosci.lan.mcgill.ca).

The Sungun porphyry copper deposit is associated with dioritegranodiorite to quartz monzonite. Copper mineralization was accompanied by both potassic and phyllic alteration. Molybdenum was concentrated at a very early stage in the evolution of the hydrothermal system and copper somewhat later. Early hydrothermal alteration produced a potassic assemblage (orthoclase-biotite) in the central part of the stock, propylitic alteration occurred contemporaneously with potassic alteration, but in the peripheral parts of the stock, and phyllic alteration occurred later, overprinting the earlier alteration. The early hydrothermal F are represented by high-T (340-500°C), high-sal (up to 60 wt.% NaCl eq.) L-rich FI [see Fig. 13], and high-T (320-550°C), low-sal, V-rich I. These F are interpreted to represent an orthomagmatic F which boiled episodically, the brines are interpreted to have caused potassic alteration and deposition of group I and II quartz veins containing molybdenite and chalcopyrite. Propylitic alteration is attributed to a L-rich, lower T (240-330°C), Ca-rich, evolved meteoric F. Influx of meteoric water into the central part of the system and mixing with magmatic F produced deep albitization (transition alteration) and shallow phyllic alteration. This influx also caused dissolution of early formed copper sulfides and remobilization of Cu into the sericitic zone where it was redeposited in response to a boiling-induced decrease in T (From authors' abstract by E.R.)

See figure in the Illustrations appendix.

HITZMAN, M.W., ALLAN, J.R. and BEATY, D.W., 1998, Regional dolomitization of the Waulsortian limestone in southeastern Ireland, Evidence of large-scale fluid flow drive by the Hercynian Orogeny: Geology, v. 26, no. 6, p. 547-550.

The Lower Carboniferous Waulsortian limestone has been affected by late diagenetic, regional burial dolomitization over an area of 7000 km<sup>2</sup>

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extending 170 km northeastward from the Hercynian front. The dolostone is composed of two components: (1) a very fine crystalline replacive component, and (2) a coarse-crystalline, baroque component that fills vuggy porosity developed within the replacive dolostone. FI within the coarsecrystalline component of the regional dolostone indicate that the dolomitizing solutions were warm (<100°C) and moderately saline (10-13 wt.% NaCl eq.). The replacive dolomite displays systematic decreases in crystal size and degree of xenotopic texture northward. Both components of the regional dolostone display a regular northward increase in mean  $\delta^{18}$ O values; the replacive dolomite has  ${}^{87}Sr/{}^{86}Sr$  values that decrease northward. These laterally variable characteristics suggest that regional dolomitization resulted from large-scale, north-directed F flow of heated brines developed in response to topographic uplift associated with collapse of the continental margin south of Ireland during the Hercynian (Variscan) orogeny: (Authors' abstract)

HITZMAN, M.W. and BEATY, D.W., 1996. The Irish Zn-Pb-(Ba) orefield: Society of Economic Geologists, Special Pub. no. 4, 1996, p. 112-143. First author at Dept. of Geol. and Geological Engineering, Colorado School of Mines, Golden, CO 80401, USA.

Fl studies indicate that the hydrothermal F had T between 150 and 240°C and sal between 10 and 23 wt.% NaCl eq. when it reached the sites of sulfide precipitation. Limited Fl data suggests that the water pulled into the system from above was significantly cooler (<120°C) and less saline (<10 wt.% NaCl eq.). Sulfide precipitation occurred as the metal-rich, sulfur-poor, mildly acidic hydrothermal F reacted with carbonate sediments causing an increase in F pH. Sulfur isotope studies indicate that sulfide precipitation was increased due to the mixing of hydrothermal F with the cooler, sulfate-rich water. (From authors' abstract by H.E.B.)

HO, Tent and AKIHIRO. Yamasaki, 1998, Solubility of liquid CO2 in synthetic sea water at temperatures from 278 K to 293 K and pressures from 6.44 MPa to 29.49 MPa, and densities of the corresponding aqueous solutions. J. Chem. Eng. Data, v. 43, p. 2-5.

HOISCH, T.D. and MATHIS, L.J., 1998, Phase equilibria of massive wollastonite rocks from the Big Maria Mountains, southeastern California (abst.): Abstracts with Programs—Geological Society of America, v. 30, no. 6, p.10.

Indexed under FI.

HOLLOWAY, J.R., 1998, Graphite-melt equilibria during mantle melting: constraints on CO<sub>2</sub> in MORB magmas and the carbon content of the mantle: Chem. Geol., v. 147, p. 89-97. Author at Dept. of Chem. and Geol., Arizona State Univ., Tempe. AZ 85287-1404, USA: email (jholloway@asu.edu)

Melts produced under F-absent, graphite-saturated conditions have tightly constrained oxidation states and CO2 contents. A model is presented for the generation of mid-ocean ridge basalt (MORB) magma by Fabsent partial melting of graphite-saturated upper mantle. The model results in M ferric/ferrous ratios and oxygen fugacities which are consistent with observed values in glassy MORBs and oceanic peridotites. Increasing the degree of partial melting causes decreases in the ferric/ferrous ratio of the M, the oxygen fugacity, and the concentration of CO2 in the M. Sensitivity analysis indicates that the initial ferric-iron concentration in the source region has the greatest effect on the results. For the range of probable initial values, the oxygen fugacity of the graphite-saturated P MORB magma at 1GPa is 2.5 log10 units below the Ni-NiO buffer. and the CO2 content of the M ranges from 900 to 1800 ppm (mass). The amount of source region carbon consumed during partial melting is between 40 and 80 ppm. The dissolved CO<sub>2</sub> in MORBs represents a flux of 3.5 to  $7 \times 10^{10}$ kg/year which is significantly greater than estimates based on the measured CO: content of glassy MORB samples. (Author's abstract)

HOPKINSON, L., ROBERTS, S., WILKINSON, J. and HERRING-TON, R., 1998. The nature of crystalline silica from the TAG hydrothermal mound, 26°N Mid Atlantic Ridge (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998. Univ. Greenwich. UK (unpaginated). First author at Dept. of Geol., Univ. of Southampton, Southampton Oceanographic Centre, Empress Dock-European Way, Southampton, SO14 3ZH.

The various types of silica, and their water contents, are discussed (E.R.)

HOPP, T., TRIELOFF, M. and FALTER, M., 1998. The carrier phases

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and the isotopic composition of argon in mantle xenoliths from Reunion Island (abst.): Max-Planck-Institut für Kernphysik Heidelberg, Tätigkeitsbericht 1997/1998, p. 300-301 (in Engl.).

A variety of metasomatic processes induced argon of distinct isotopic composition into mantle xenoliths found in Réunion magmas. These argon components and their host phases were identified revealing the history of the interaction of the rocks with their magmatic environment within the mantle. This study also refined the argon isotopic composition of the Réunion mantle plume source. (Authors' abstract)

HOPPLE, J.A., HANNON, J.E. and COPLEN, T.B., 1998. Comparison of two stable hydrogen isotope-ratio measurement techniques on Antarctic surface-water and ice samples: Chem. Geol., v. 152, no. 3-4, p. 321-323. First author at U.S. Geol. Surv., 810 Bear Tavern Rd., West. Trenton, USA.

A comparison of the new hydrogen isotope-ratio technique of Vaughn et al. [Vaughn, B.H., White, J.W.C., Belmotte, M., Trolier, M., Cattani, O., Stievenard, M., 1998. An automated system for hydrogen isotope analysis of water. Chem Geol. (Isot. Geosci. Sect.), 152, 309-319].[see also Vaughn et al., this volume] for the analysis of water samples utilizing automated on-line reduction by elemental uranium showed that 94% of 165 samples of Antarctic snow, ice, and stream water agreed with the 2<sub>H</sub> values determined by H<sub>2</sub>-H<sub>2</sub>O platinum equilibration, exhibiting a bias of 0.5‰ and a 24& [sic] variation of 1.9‰. The isotopic results of 10 reduction technique samples, however, gave 2<sub>H</sub> values that differed by 3.5‰ or more, and were too negative by as much as 5.4‰ and too positive by as much as 4.9‰ with respect to those determined using the platinum equilibration technique. (Authors' abstract)

HORITA, Juske and HOLLAND, H.D., 1998, Brine inclusions in halite and the origin of the Middle Devonian Prairie evaporite of western Canada—Reply: J. of Sedimentary Research, v. 68, no. 1, p. 230-231. First author at Chemical and Analytical Sci. Div., Oak Ridge Nat'l Laboratory, P.O. Box 2008, MS6110, Oak Ridge, TN 37831-6110, USA.

A discussion of the problems in interpretation of Fl data from evaporites, and an evaluation of the work of Kovalevich et al. (1997). (E.R.)

HOTTA, T., NAKASHIMA, K. and MATSUEDA, H., 1998, Petrological and fluid inclusion studies on a Tertiary granitoid discovered from the Otoge caldera (abst.): Abstracts with Programs, 48th Annual Meeting of the Society of Resource Geology, Tokyo, June 17-19, No. P-33 (in Japanese)

HOU, Zengqian and ZHANG, Qiling, 1998. CO<sub>2</sub>-hydrocarbon fluids of the Jade hydrothermal field in the Okinawa trough: Fluid inclusion evidence: Science in China (Series D), v. 41, no. 4, p. 408-415 [in English]. Authors at Inst. of Mineral Deposits, Chinese Acad. of Geological Sci., Beijing 100037, China.

The Okinawa trough is a spreading back-arc basin featuring emitting hydrothermal solutions (black chimney type) and modern sulfide precipitation on the sea floor. The study of Fl in water-rock interaction products in the Jade hydrothermal field indicates that the deep hydrothermal system beneath the sea floor is fairly rich in G and there are two independent and coexisting F-CO<sub>2</sub>-hydrocarbon F and salt aq F. On the whole, the composition of CO<sub>2</sub>-hydrocarbon Fl is similar to that of the Fl in natural G fields. The dominant composition of the I in [sic, of] aq F is H<sub>2</sub>O with CO<sub>2</sub> and CH<sub>4</sub> being oversaturated. The salt aq F of the Jade hydrothermal system might be emitted through a black chimney, whereas CO<sub>2</sub>-rich F discharge CO<sub>2</sub> bubbles and CO<sub>2</sub> hydrate through fissures. Hydrocarbons in G phase or in F might be enclosed somewhere under the sea. Large storage of CO<sub>2</sub>-CH<sub>4</sub>-H<sub>2</sub>S G or F and reaction of this G or F with salt water will lead to commercial sulfide deposits. (Authors' abstract)

#### HU, Ruizhong, BI, Xianwu, HE, Mingyou, LIU, Bingguang,

TURNER, G. and BURNARD, P.G., 1998. Mineralizer constraint on gold mineralization of Ailaoshan gold belt Science in China (Series D), v. 41, supp., p. XX [in English]. First author at Inst. of Geochem., Chinese Acad. of Sci., Guiyang 550002, China.

After determining that sulfur is the main mineralizer of ore-forming F of Ailaoshan gold mineralization belt in West Yunnan Province of China, the S. He and Ar isotope compositions and geological events related to gold mineralization are studied. It is revealed that the ore-forming F of the belt is a mixture of high T S-rich deep-seated F and low-T S-depleted meteoric groundwater. That the gold mineralization occurred in early Himalayan period resulted dominantly from the mantle degassing which was associ-

ated with the crust extension at that time. The forming and evolving process of ore-forming F can be determined as: S-rich deep-seated F ascended and added to S-depleted meteogenic F cycling in shallow fracture systems of the belt in early Himalayan period  $\rightarrow$  the S-depleted meteogenic F converted to the mixing F containing sufficient S $\rightarrow$ gold in surrounding rocks was extracted by the mixing F, and then precipitated at a suitable place to form the gold deposits. (Authors' abstract)

FI data presented (H.E.B.).

HU, Ruizhong, BURNARD, P.G., TURNER, G. and BL, Xianwu, 1998, Helium and argon isotope systematics in Fl of Machangqing copper deposit in West Yunnan Province, China: Chem. Geol., v. 146, no. 1-2, p. 5-63. Authors at Chinese Acad. of Sci., Inst. of Geochem., Guiyang, China.

This paper reports the helium and argon isotope compositions of FI hosted in pyrites from Machangqing alkali-porphyry copper deposit in West Yunnan province, China. There is an excellent positive correlation between <sup>4</sup>He/<sup>36</sup>Ar and <sup>40</sup>Ar/<sup>36</sup>Ar, and between <sup>40</sup>Ar/<sup>4</sup>He and <sup>3</sup>He/<sup>4</sup>He in the I-trapped F. This indicates that the ore-forming F can be considered as a mixture of two endmember components, a modified mantle F and crustal F. From the noble G results and combined noble G and stable isotope behavior, the authors conclude that the former is a high-T magmatic F differentiated from Machangqing alkali-porphyry and enriched in volatiles such as sulfur and carbon. The crustal F is likely a low-T meteoric F enriched in crustal radiogenic helium but with atmospheric argon isotopic composition. The sulfur and carbon concentrations in the low T F are probably too low to produce a distinct C or S isotope signature the mixing between high and low T F can only be traced using noble G. In addition, the positive relationship between <sup>3</sup>He/<sup>4</sup>He and 8<sup>34</sup>S reflects the evolutionary physicochemical conditions of the mixed F. (Authors' abstract)

HU, Ruizhong, TURNER, G., BURNARD, P.G. and BI, Xianwu, 1998, Helium isotope compositions of Machangqing copper deposit in Western Yunnan, China: Chinese Sci. Bulletin (Kexue tongbao), v. 43, no. 1, p. 69-72 (in English). First author at Inst. of Geochem., Chinese Acad. of Sci., Guiyang 550002, China.

Helium isotopic composition of IF in pyrites from Machangqing copper deposit, China, has been measured. The measurements, with <sup>3</sup>He/<sup>4</sup>He ratios ranging from 0.46-2.08 Ra, indicate that the helium in ore-forming F is a mixture of crust and mantle, and are consistent with the fact that the parental magma responsible for the formation of ore-forming F of the deposit is of crust-mantle provenance. (Authors' abstract)

HU, Shumin and ZHANG, Ronghua, 1998, Direct measurement of high temperature and pressure fluids: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1059-1066 (in Chinese).

HUA, Renmin, 1998, Hydrothermal deposits--different ancient geothermal systems: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 977-980 (in Chinese).

HUANG, Y. and FAIRCHILD, I.J., 1998. Annual trace element records in speleothems from Grotta di Ernesto. NE Italy (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998. Extended Abstracts, p. 661. Authors at Dept. of Earth Sci., Keele Univ., Staffordshire ST5 5BG, UK.

Natural soda straw stalactites often display periodic visible bands, typically 0.05-0.5 mm wide, comparable with likely linear annual extension rates of the structures. Such bands are found to represent thickenings of the walls of the structures at growth steps. However, soda straw stalactites from Grotta di Ernesto, NE Italy display both growth step and thin I rich bands (3-5  $\mu$ m), the latter being similar to those in stalagmites. On the thin section. I rich layers appear to preserve tip shapes and positions during its extension. (From authors' abstract by E.R.)

HUANG, Zhilong and XIAO, Huayun, 1998, Source of CO<sub>2</sub> in lamprophyre of Laowangzhai gold deposit, Yunnan province: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998; Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1075-1078 (in Chinese).

HURAI, Vratislav, GAZDACKO, L'ubomír, FERENCÍKOVÁ, Elígia, MAJZLAN, Juraj and REPCOK, Ivan, 1998, Origin of the ore-forming fluids in the Gretla, Jedl'ovec and Rudnany siderite vein deposits (Spišskogemerské rudohorie Mts.): Mineralia Slovaca, v. 30, p. 423-430 (in Slovak [?]; Engl. abst.). First author at Geologická sluzba SR, Mlynská dolina 1, 817 04 Bratislava.

Several compositionally contrasting types of F have been revealed in hydrothermal siderite veins of the Spišsko-gemerské rudohorie Mts. Siderite precipitated at minimum T between 155-190°C from moderately saline aq solutions, containing CO<sub>2</sub> V Low sal aq solutions with a highdensity CO<sub>2</sub> L are correlated with a greenschist facies metamorphism (200-300°C, 1-3 kbar). The F are associated with quartz-pyrite-tourmaline assemblage and have been superimposed to the siderite. The latest, quartzsulphide mineralization crystallized from low T (90-120°C) brines containing sulphates and chlorides of divalent cations. The brines are thought to be genetically linked with leaching Permo-Triassic evaporitic sequences by meteoric waters.

Carbon and oxygen isotope ratios of the siderite-forming F have been derived from Fl microthermometry and stable isotope data, using Rayleigh fractionation model. The  $\delta^{13}$ C (-9.5 to -13.5% PDB) values of the siderite-forming F indicate a metamorphic CO<sub>2</sub> liberated during oxidation-hydration of organic matter in surrounding metasedimentary rocks. However, it cannot be ruled out that the original isotopic signature of the siderite was modified during cryptic metasomatism connected probably with an isotopic exchange during superimposed greenschist-facies metamorphism. A cryptic metasomatism of the siderite is documented by a domain texture revealed by BSE imagery, showing earlier Fe-rich siderite replaced by later MgO-enriched and FeO-depleted siderite. (Authors' abstract)

HURAI, Vratislav, SIMON, Klaus, WIECHERT, Uwe, HOEFS, Jochen, KONECNÝ, Patrik, HURAIOVÁ, Monika, PIRONON, Jacques and LIPKA, Jozef, 1998, Immiscible separation of metalliferous Fe/Tioxide melts from fractionating alkali basalt: P-T-fO<sub>2</sub> conditions and twoliquid elemental partitioning: Contrib, Mineral, Petrol., v. 133, p. 12-29. First author at Geological Survey, Mlynská dolina 1, 817 04 Bratislava, Slovak Republic.

Globules of iron-dominated (59-69 wt.% FeOtor) and titaniumdominated (43.5 wt.% TiO2 oxide M have been detected in igneous xenoliths from Pliocene-to-Pleistocene alkali basalts of the Western Carpathians. FI and mineral composition data indicate immiscible separation of the high-iron-oxide M (HIM) [, from a high-silica melt] at magmatic T. The HIM separation occurred during clinopyroxene (augite) accumulation in an alkali trachybasalt and continued during crystallization of amphibole (kaersutite) and K-feldspar (anorthoclase), the latter coexisting with trachyte and alkalic rhyolite residual M. Some HIM was also expelled from sub-alkalic rhyolite (70-77% SiO2) coexisting with An27-45 plagioclase and quartz in granitic (tonalite-trondhjemite) xenoliths. Oxygen fugacities during HIM separation range from -1.4 to 0.6 log units around the QFM buffer. A close genetic relationship between HIM-hosted xenoliths and mantle-derived basaltic magma is documented by mineral 818O values ranging from 4.9 to 5.9‰ V-SMOW. 8D values of gabbroic kaersutite between -61 and -86‰ V-SMOW are in agreement with a presumed P magmatic water source. Most trace elements, except Li, Rb and Cs, have preferentially partitioned into the HIM. The HIM/Sc M partition coefficients for transition elements (Sc, V, Cr, Co, Ni) and base metals (Zn, Cu, Mo) are between 2 and 160, resulting in extreme enrichment in the HIM. La and Ce also concentrate in the silicic M, whereas Tb-Tm in the HIM. Hence, the immiscible separation causes REE fractionation and produces residual silicic M enriched in LREE and depleted in HREE. The weak fractionation among Tb-Tm and Yb. Lu can be attributed to recurrent extraction of the HIM from the magmatic system, while flat HREE chondritenormalized patterns are interpreted to indicate no or little loss of HIM. (Authors' abstract)

HUSTON, D.L., 1998. The hydrothermal environment: J. of Australian Geol & Geophys., v. 17, no. 4, p. 15-30. Author at Australian Geological Survey Organization., GPO Box 378, Canberra, ACT 2601, Australia. Fl discussed as a source of data (H.E.B.)

HUTCHEON, Ian, 1998, The controls on the origin and distribution of H<sub>2</sub>S and CO<sub>2</sub> in clastic and carbonate rocks of the western Canada sedimentary basin: Reservoir, v. 25, no. 1, p. 6. Indexed under FI.

IMAI, Akira, SHIMAZAKI, Hidehiko and NISHIZAWA, Tomoko, 1998, Hydrogen isotope study of fluid inclusions in vein quartz of the Hishikari gold deposits, Japan: Resource Geol., v. 48, no. 3, p. 159-170. First author at Geological Inst., Univ. of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan; email (akira@geol.s.u-tokyo.ac.jp)

# Volume 31, 1998
The origin of mineralizing F responsible for the Hishikari vein-type epithermal Au deposits was studied on the basis of the hydrogen isotopic ratio ( $\delta D$ ) of the IF from vein quartz and adularia. The origin of hydrothermal F was estimated by combination of the present  $\delta D$  values and the oxygen isotopic ratios ( $\delta^{16}O$ ) previously reported by Shikazono and Nagayama (1993).

The water in the FI was extracted by means of decrepitation of quartz at 500°C. Hydrogen was obtained by reduction of the collected water with Zn shot at 450°C. The δD values were determined by mass spectrometer.

The  $\delta D$  values of IF obtained from quartz range from -61 to -114%. These are significantly lower than the  $\delta D$  value of the thermal water presently venting from the Hishikari deposits and that of local meteoric water.

Hydrogen isotopic fractionation between water and amorphous silica, which might have initially precipitated from the hydrothermal F at least partly. Is not a probable cause of this isotopic depletion, while some water might have been released from the initial hydrous amorphous silica during recrystallization to quartz observed presently. Thus, a part of ore F for the Hishikari deposits is supposd to have been originated from the water having anomalous  $\delta D$  values of <-100‰.

Such D depletion cannot be caused by simple oxygen-shift of meteoric water or by contribution of magmatic volatiles. The  $\delta D$  values of water released from the shale samples of the Shimanto-Supergroup, a major host to the Hishikari veins range from -132 to -148%. Therefore, the anomalous  $\delta D$  values of IF from some vein quartz and adularia suggest that the water released from hydrous minerals of the sedimentary basement rocks by dehydration or the groundwater isotopically exchanged with sedimentary torks at elevated T during circulation, partly contributed to the hydrothermal F responsible for the Hishikari deposits. (Authors' abstract)

IMAI, Hideki, TAKAHASHI, Mikio and YAMAGUCHI, Mitsuo, 1996, Relation between volcanic-hosted precious- and base-metal deposits and geothermal systems: Resource Geol., v. 46, no. 2, p. 73-94. First author at 1-53, Haramachi, Shinjuku-ku, Tokyo 162, Japan.

Volcanic-hosted epithermal deposits which widely occur in "Green Tuff" regions in Japan are classified into adularia-sericite type and acidsulfate type based on ore and alteration mineral assemblages. The latter type deposits sporadically coexist with the former type in one area. The separated F by boiling from the original hydrothermal solution genetically related to adularia-sericite type deposits would be responsible for the mineralization of acid-sulfate type.

Many geothermal systems are found in Quaternary volcanic regions composed mainly of andesitic rocks, nearly coincident with the "Green Tuff" regions. Most of these geothermal areas are characterized by hot-water system composed of NaCl-bearing hot-water with CO<sub>2</sub> and H<sub>2</sub>S G. In Sengan (Matsukawa) district, however, V-dominated F is found, associated with hot-water system. The F is also composed of H<sub>2</sub>O V with small amounts of CO<sub>2</sub> and H<sub>2</sub>S. The alteration minerals which characterize these two types of geothermal areas are different. The former is associated with sericite, chlorite, albite, zeolite and kaolinite, while the latter area with kaolinite, alunite, pyrophyllite and sericite. The V-dominated geothermal F are considered to be separated from the hot-water systems through boiling processes.

We speculate that epithermal deposits of the adularia-sericite type were formed from hot-water geothermal F, while those of the acid-sulfate type were formed from V-dominated geothermal F. (From authors' abstract by E.R.)

INVERNIZZI, C., VITYK, M., CELLO, G. and BODNAR, R., 1998. Fluid inclusions in high pressure/low temperature rocks from the Calabrian Arc (southern Italy). The burial and exhumation history of the subductionrelated Diamante-Terranova unit: J. Metamorphic Geol., v. 16, p. 247-258. First author at Dipartmento Scienze della Terra, Università'di Camerino, Camerino, Italy 62032; email (chiarai@camserv.unicam.it)

The Diamante-Terranova Unit (DfATU), in the Calabrian Arc of southern Italy, is part of an ophiolitic sequence involved in a high P/low T event (P=8 kbar, T=400°C) followed by re-equilibration at greenschist facies conditions (P=3 kbar; T=300°C). The rocks contain two types of quartz-calcite veins—an earlier generation of deformed, folded and faulted veins formed during or before subduction, and a later set of planar, undeformed veins formed during exhumation of the DIATU. The earlier folded quartz-calcite veins contain regularly shaped aq I as well as I with a highly irregular dendritic texture. The later planar veins contain only regularly shaped aq I similar to those in the earlier veins. In both vein types, all I are demonstrably S in origin. Regularly shaped I from both vein types are low sal (0-5 wt.% NaCI). Most contain L and V and homogenize to the L (Th 135-180°C), whereas others contain only L at room T. Both the two-phase and monophase I occur in the same fractures and are thought to record the same trapping event, with the monophase I remaining metastable L at room T. No microthermometric data could be obtained from the dendritic 1 in the earlier folded veins. I with the highly irregular dendritic texture found in the earlier veins are similar to those produced experimentally during laboratory-induced deformation of synthetic I in quartz under conditions of internal underpressure, simulating either isobaric cooling or isothermal compression. The occurrence of I with the dendritic texture in the earlier folded veins, and their absence from the later planar veins, suggests that the earlier veins formed before or during subduction and were folded and faulted in a compressional environment and their contained FI were modified to produce the dendritic texture. During later uplift of the DIATU, planar veins containing regularly shaped aq I formed and some of the F forming these veins were also trapped as S1 in the earlier folded veins. The results of this study provide convincing evidence that I with a highly irregular dendritic morphology represent early I that have survived prograde conditions in a high P/low T 'implosion' texture is preserved over geological time, even after being overprinted by internal overpressure conditions generated during retrograde decompression. We suggest that I that have survived prograde metamorphism are common in high P/low T rocks, but are often not identified as such due to their morphology which makes their recognition difficult. (Authors' abstract)

IRWIN, J.J., 1998, Evidence for sources of salinity and dissolved gases, fluid mixing and phase separation, from laser microprobe analysis of Cl, K, Br, I, Ar, Kr, and Xe in fluid inclusions: Chapt. 12 in Reviews in Econ. Geol., v. 7, Applications of Microanalytical Techniques and Understanding Mineralization Processes, M.A. McKibben, W.C. Shanks III, and W.I. Ridley, eds, p. 217-231. Author at Cadence Mineral Resources, Inc., 2658 Beliview Ave., West Vancouver, B.C., Canada V7V 1E4.

Argon, Kr, and Xe were extracted from Fl by laser microprobe decrepitation of minute portions of samples and measured in a low blank, high sensitivity mass spectrometer. Neutron irradiation [before extraction] along with synthetic Fl of known composition enables measurement of Cl, K. Br, and I along with <sup>36</sup>Ar, <sup>40</sup>Ar, <sup>84</sup>Kr, and <sup>129</sup>Xe in less than 10<sup>th</sup> cc of F. A table listing 25 data sets, from Bingham, Ascension Island, Butte,

A table listing 25 data sets, from Bingham, Ascension Island, Butte, Salton Sea, Hansonburg, Creede, Mother Lode, Stripa and elswhere provides data. Simultaneous analysis of noble G and halogens in FI provides unique information useful for defining and delineating F reservoirs in each of these ancient hydrothermal systems and quantifying mixing and boiling related to mineral precipitation. (From author's text by E.R.)

IRWIN, J.J. and ROEDDER, E., 1995. Diverse origins of fluid in magmatic inclusions at Bingham (Utah, USA), Butte (Montana, USA), St. Austell (Cornwall, UK), and Ascension Island (mid-Atlantic, UK), indicated by laser microprobe analysis of C1, K, Br, I, Ba+Te, U, Ar, Kr and Xe: Geochim, et Cosmo, Acta, v. 59, p. 295-312.

See Irwin, 1998 (previous item). This item was omitted in FIR v. 28 (E.R.).

ISAKSEN, G.H., POTTORF, R.J. and JENSSEN, A.I., 1998, Correlation of fluid inclusions and reservoired oils to infer trap fill history in the South Viking Graben, North Sea: Petroleum Geosci., v. 4, no. 1, p. 41-55.

Organic geochemical correlations between Fl and associated oils and oil-shows in Mesozoic reservoirs in the Sleipner area demonstrate generation from the same source rock organic facies (type II) for I in wells 15/9-1 and 15/9-19. For well 15/9-9 the oil show is from a mixed type II/III source rock, whereas the Fl is from a type II source. All Fl are less thermally mature than the associated free oils and are thought to represent the earliest hydrocarbon yield from the source rocks. GC/MS/MS analyses of the Fl proved essential for resolving biomarker compounds and correlating them to reservoired F. Among the biomarkers, bisnorhopane contents in the Fl are consistently lower than in the associated reservoired oil. The expected dilution effect of bisnorhopane as progressively more hydrocarbons are generated from kerogen maturation is not observed. The difference in bisnorhopane amounts in Fl and oils is primarily due to varying relative hydrocarbon yields, through time, from different source rocks. (Authors' abstract)

ISHIYAMA, D., SATO, H., MIZUTA, T., KIMURA, J. and WOOD, S.A., 1998, An experiment on quantitative chemical analysis of an individual fluid inclusion using laser ablation-ICP-MS. Abstracts with Programs, 48th Annual Meeting of the Society of Resource Geology, Tokyo, June 17-19, No. O-52 (in Japanese)

ISHIYAMA, Daizo, NOMIYAMA, Kunihiro, MIZUTA, Toshio, MA-TSUBAYA, Osamu and SATO, Masaru, 1998, Characteristic features of fluid associated with magma/carbonate-rock interaction at the Kamineichi dolomitic skarns in the contact aureole of the Miyako Granitic Body, Iwate Prefecture, Japan: Shigen Chishitsu (Resource Geology)—Japanese edition, Engl. abst. v. 48, no. 2, p. 61-76. First author at Dept. of Earth Sci. and Tech., Fac. of Engineering and Resource Sci., Akita Univ., Akita 010-8502, Japan.

Some dolomitic skams in the Kamineichi area, lwate Prefecture, were formed by contact metamorphism associated with emplacement of the Miyako granodiorite in Early Cretaceous age. The characteristic features of the F forming the dolomitic skams were investigated on the basis of mineral assemblages of the dolomitic skams, Th and sal of Fl in calcite and quartz, and carbon and oxygen isotopic ratios of calcite and dolomite.

The Tf of dolomitic skarns was estimated to be around 530°C from the mineral assemblage and chemical composition of calcite coexisting with dolomite. The Th of Fl in calcite range from 300 to 500°C with a peak around 460°C, and from 100 to 325°C with a peak around 220°C. The sal of the IF are divided into 30 wt.% eq. NaCl and from 8.4 to 3.7 wt.% eq. NaCl. Based on the Tf of dolomitic skarns around 530°C and Th of Fl in calcite around 460°C, the formation P was estimated to be from 1.0 to 0.7 kb. The F of 30 wt.% eq. NaCl around 0.7 kb and 550°C. The trap T of F having the Th around 220°C is estimated to be around 280°C at 0.7 kb. The F was predominant in hydrothermal stage, in which ore minerals such as pyrrhotite and chalcopyrite were precipitated in the dolomitic skarns of the area.

Mass balance calculations of the 818O and 813C depletion resulting from equilibrium decarbonation at 500°C indicate that the observed depletions of  $\delta^{18}$ O and  $\delta^{13}$ C in calcites with higher oxygen isotopic ratios (23.3 to 24.6%) could have arisen from Rayleigh-type or Single stage decarbonation of fresh dolomite rocks. Mass balance calculations also indicate that the depletions of  $\delta^{18}$ O in calcites with lower oxygen isotopic ratios (13.6 to 17.8‰) may have resulted from the isotope exchange between the H2O-dominant F and the dolomitic limestone experienced those decarbonation at T from 530 to 300°C. The concentration of CO2 in skarnforming F was relatively high at an early stage of contact metamorphism which was responsible for the formation of skarn minerals such as forsterite, diopside and spinel. While the concentration of CO2 in F decreased, when the oxyygen isotopic exchange between F and dolomitic limestone took place below 530°C. Boron was transported with chlorine in H2O-dominant F derived from magma, and borate minerals such as kotoite, ludwigite, warwickite, szaibelyite and suanite in the Neichi dolomite skarn were formed by interaction between the dolomite and the dilute F. (From authors' abstract by E.R.)

ISHIYAMA, Daizo, SATO, Hinako, MIZUTA, Toshio, KIMURA, J.-I. and WOOD, S.A., 1998a, An experiment on quantitative chemical analysis of an individual fluid inclusions using a LA-ICP-MS (abst.) Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no 7, p. A-370. First author at Inst. Applied Earth Sci., Akita Univ., Akita 010-8502, Japan; email (ishiyama@ipc.akita-u.ac.jp)

The chemical analyses of synthetic solutions of an individual FI formed in paraffin were carried out to evaluate the accuracy of the chemical analyses for an individual FI in natural minerals using LA-ICP-MS. The solution prepared contains Rb, Sr, Ba and U. The concentration of the synthetic solution is 10 ppm. The synthetic FI in paraffin with different volumes of 10 microliter and 0.08 microliter were analyzed. These volumes correspond to spherical FI which the radii are about 1 mm and 200 micrometers, respectively. The concentration of these elements in the synthetic FI were measured using solid standard. The values measured were normalized assuming the concentration of Sr is 10 ppm. The concentration of Rb, Ba and U is 10.2, 9.1 and 10.0 ppm for the FI having the volume of 10 microliter, respectively. The ranges of concentration of Rb. Ba and U are 7.4 to 13.2. 9.8 to 14.6 and 4.1 to 6.4 ppm for the FI having the volume of 0.08 microliter, respectively. The concentration was measured within errors from 40 to 150% for Rb. Ba and U in the synthetic Fl with 0.08 microliter volume, although the volume is larger than that of typical FI in natural minerals.

To clarify the availability of this method for natural FI, the FI in sphalerite of Pb-Zn veins and rhodochrosite veins of the Matahachi deposit, Jokoku mine in southwestern part of Hokkaido Island, Japan. The F in FI of sphalerite is thought to be hydrothermal solution responsible for the formation of these veins, although the FI show S features. The Ba/Sr mole ratios of F in FI in sphalerite ranges from 0.08 to 0.54 for rhodochrosite veins. The ranges of mole concentration of chlorine were estimated to be 510 to 1000 millimole/kg H<sub>2</sub>O for rhodochrosite veins based on the data of NaCl eq. sal from Fl in the sphalerite. The data measured in this study are distributed in the area near mixing line between Japanese present thermal water containing 20% of volcanic G and seawater on the mCl versus (Ba/Sr) mol diagram. This relationship suggests that the mixing between hydrothermal solution associated with volcanism and seawater have to be considered for the formation processes of the rhodochrosite veins. (Authors' abstract)

ISHIYAMA, Daizo, SATO, Hinako, MIZUTA, Toshio, KIMURA, J.-I. and WOOD, S.A., 1998b, An experiment on quantitative chemical analysis of an individual fluid inclusion using a LA-ICP-MS (abst.): Abstracts with Programs, 48th Annual Meeting of the Society of Resource Geol., Tokyo, June 17-19, No. 0-52 (in Japanese).

See previous abstract (E.R.).

ISHIZUKA, Osamu and IMAI, Akira, 1998. "Brown Ore" from the Fukasawa Kuroko deposits, northeast Japan: Its characteristics and formation process: Resource Geol., v, 48, no. 2, p. 53-73. First author at Geological Inst., Univ. of Tokyo, Hongo, Tokyo 113-0033, Japan.

Brown-colored sulfide ore (brown ore) occurs in the easternmost part of the Tsunokakezawa No. 1 orebody of the Fukasawa kuroko-type deposits, northern Honshu, Japan. As this type of ore also occurs in the marginal or uppermost part of several other kuroko deposits in Japan, the formation of brown ore appears to be repeated in the process of kuroko formation The brown ore is characterized by its higher Ag concentration (up to around 200 g/t) than ordinary black ore (Zn-Pb ore) of volcanogenic massive sulfide deposits. The brown ore from the Fukasawa deposits can be divided into following three ore types based on its texture and mineral composition: pyritic brown ore, principal brown ore and "diseased" brown ore. P precipitation textures such as framboidal- and colloform-textures and compositional zoning within sulfide grains are significant in the brown ores. This seems to be due to lack of overprinting high T mineralization resulting in preservation of P features. The Ag-Au mineralization is widely observed within the brown ores. Silver and gold are especially concentrated in the barite veinlets in the principal brown ore, which are supposed to be fillings of conduit of hydrothermal solution precipitated in the latest stage of hydrothermal activity. This mineralization seems to occur at waning stage of brown ore formation by ore solution at a lower T (around 250°C) than that of main part of brown ore (around 270°C) [Th data]. Relatively low F T and contribution of oxic ambient seawater may be responsible for the development of the Ag-Au mineralization in the brown ore. The occurrence of framboidal-rich pyritic brown ore having negative δ<sup>14</sup>S values (less than -10‰) and filamentous texture of sphalerite, seeming remnant of bacteria, indicate the presence of intensive microbial activity in the hydrothermal area for brown ore formation.

Formation environment of each ore type of the brown ore is supposed to be as follows: Pyritic brown ore is likely to have formed on the sea-floor around redox boundary at T (around 240°C) lower than ordinary black ore. Principal brown ore seems to have been formed beneath the shell of the pyritic brown ore at T around 270°C. Footwall of the brown ore is disseminated tuff breccia corresponding to feeder zone of hydrothermal F Overprinting chalcopyrite mineralization is not observed in the brown ore except in limited part of "diseased" ore, which occurs just above the disseminated tuff breccia. [Sal varies from 2-5 wt.%, with mean ~3-3.5%]

Based on the features distinct from the ordinary black ore, the brown ore can be regarded as a product in the marginal part of submarine hydrothermal system, where T and flow rate of hydrothermal solution was relatively low and microbial activity was intensive. The brown ore seems to well preserve its P features after its deposition and might show the initial feature of some part of the ordinary stratiform black ore. (Authors' abstract)

ISMAÎLOV, M.I., 1998. The in-depth mineral facies of the skarns of the Middle and Southern Tien-Shan and their associated mineralization (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30. 1998. Tashkent, Uzbekistan, Abstracts vol., p. 76-78 (in Russian).

ISMAÍLOV, M.I., BABAZHÁNOV, A.A. and LÉBEDEVA, S.E., 1998. The rare-metal deposits of Western Uzbekistan based on thermobarogeochemical data from ore quartz (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 85-86 (in Russian). See Translations.

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**IWAMORI**, Hikaru, 1998, Transportation of H<sub>2</sub>O and melting in subduction zones. Earth and Planet. Sci. Letters, v. 160, p. 65-80. Author at Dept. of Earth and Planetary Sci., Nagoya Univ., Chikusa, Nagoya, Japan; email (hikaru@geol.s.u-tokyo.ac.ip)

Here I present a numerical model in which the aq F migrates by permeable flow and interacts chemically with the convecting solid, including melting. The calculation results suggest that nearly all the  $H_2O$  expelled from the subducting slab will be hosted by serpentine and chlorite just above the slab, and is brought down by up to 150 km, depending on the T along the slab. Further studies with various subduction parameters, and M segregation processes which are not included in this study, are required to compare the model results with the observed distribution and chemistry of arc magmas. (From author's abstract by E.R.)

IZRAELI, F., SCHRAUDER, M. and NAVON, O., 1998. On the connection between fluid- and mineral-inclusions in diamonds: 1998 Kimberlite Symposium (further details unavailable). First author at lnst of Earth Sci., The Hebrew Univ., Jerusalem, 91904. Israel.

FI were found in fibrous diamonds, but the relation between these diamonds and the common, single crystal diamonds is not clear. Here we report new findings on a fibrous diamond found by S.F. Haggerty within an eclogitic xenolith and on octahedral diamonds with central, internal clouds of I (cloudy diamonds). These findings help in bridging the gap between F and mineral I in diamonds.

F (water and carbonates) are evident in the IR spectra of 8 of the 10 cloudy diamonds. The clouds are  $\sim 1$  mm in size, occupy the central zone of the diamonds, and consist of millions of sub-micrometer 1.

In addition to water and carbonate, the IR spectra of the clouds reveal the presence of garnet, clinopyroxene, phlogopite, and an unidentified silicate (with a main peak at  $\sim 1010$  cm<sup>-1</sup>) in the different diamonds.

The unique feature of the cloudy diamonds is the mutual occurrence of both mineral and FI. Except from their microscopic size, the mineral I are similar to other mineral I in diamonds. The F span a wide range of compositions, much wider than that of the F trapped in fibrous diamonds. Three types of F may be distinguished (although I containing mixtures of these types were also observed).

 Silica-rich composition that is broadly similar to that of fibrous diamonds;

2. Water-rich composition that is also rich in KCI; and

3. Carbonate-rich F. Some I may actually contain carbonate minerals, but the wide range of compositions and the presence of water suggest that some were trapped as F. The trapping of microscopic F<sup>-</sup> and mineral-I in individual clouds (and most probably within a single micro-I) indicates that diamond, garnet, and pyroxene were in equilibrium with a F during the growth of the diamond. (From authors' abstract by E.R.)

JACKSON, S.E., PEARSON, N.J. and GRIFFIN, W.L., 1998. The laser ablation microprobe (LAM)-ICP-MS: Applications to ore systems and mineral exploration (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention. Townsville, July 1998. p. 219. Authors at Key Centre for Geochemical Evolution and Metallogeny of Continents, School of Earth Sci., Macquarie Univ., Sydney, NSW.

Laser ablation microprobe (LAM)-ICP-MS is firmly established as a fast, sensitive and reliable technique for in situ determination of trace elements in minerals and their I. The technique couples the high resolution sampling capabilities of a pulsed UV laser with the extraordinary detection capabilities of the ICP-MS. Current instrumentation is capable of simultaneously determining 30-40 elements in spots of ca. 30 µm diameter at detection limits down to low ppb level for many elements. Minimal sample preparation is required and a typical analysis takes less than 2 minutes. Using the depth profiling capability of the laser, it is also possible to assess the homogeneity of the ablation volume and so determine whether elements are concentrated homogeneously in the lattice structure, or whether they are chemically zoned or occur in I. The technique already has very useful isotopic applications (e.g., U/Pb dating) and, with the recent advent of multicollector ICP-MS instrumentation, an age of rapid, in situ, high precision isotope ratio analyses (e.g., U/Pb, Re/Os, Sm/Nd, Lu/Hf, Rb/Sr) is dawning. LAM-ICP-MS has the capability of sampling and analysing individual FI in the ore and associated minerals (From authors' abstract by E.R.)

JAMBON, A., GILLET, P., CHAMORRO, E. and COLTICE, N., 1998. Helium and argon poor magmas from the undegassed mantle (abst.) Mineralogical Magazine, v 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 705. JARGALAN, Sereenen and MURAO, Satoshi, 19998, Preliminary study on the characteristics of Tsagaan tsakhir uul gold deposit, Bayankhongor, southern Mongolia: Bulletin of the Geological Survey of Japan, v. 49, no. 6, p. 291-298. First author at Dept. of Geochem., Grad. School of Sci., Tohoku Univ.

Highly prospective gold mineralization is represented by several localities of quartz vein sets and veinlet zones, occurring both in Cambrian granodiorites and Proterozoic migmatized schists. Wall rock alteration is developed weakly as silicification, sericitization, albitization, chloritization and pyritization. In the area three types of quartz veins are observed: (1) metamorphic quartz veins; (2) mesothermal quartz veins; (3) epithermal quartz veins. Mesothermal quartz veins are richest in gold content. Within mesothermal veins gold is often associated with pyrite, chalcopyrite, galena and is also found as free grains in quartz. Gold content in quartz veins show a wide range between 0.1 and 749.6 g/t. Most of the FI observed in quartz are two phase L>V and range between 0.3 µm and 10 µm in size. The Th of mesothermal veins ranges from 160 to 356°C. Not many facts are known for the epithermal veins in this district but our study has indicaled that the Th of the quartz vein range from 107 to 120°C The apparent sal of Fl in mesothermal quartz ranges between 1.74 and 6.74 wt.% NaCl eq., with an average 4 18 wt.% NaCl eq. Based on this preliminary study, we have concluded that at Tsagaan tsahir uul the mineralizing F for mesothermal system was CO2-bearing and of low sal, and that effective deposition of gold within the system happened at T from 160 to 260°C, although the obtained T show wider range. (From authors' abstract by E.R.)

JARMOLOWICZ-SZULC, Katarzyna, 1998a, Studies on the filling of pore space in the Rotliegendes sedimentary rocks, SW Poland; Fluid inclusions, luminescence, isotopes (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ of Nevada, p. 46. Author at Polish Geological Inst., 00-975 Warsaw, ul. Rakowiecka 4.

The Paproc region represents a G reservoir in the Rotliegendes and Zechstein rocks. Cements - carbonate, quartz and sulphate - from five deep drillings were studied.

Both water and hydrocarbon I were found, the second type showing a sort of dull blue fluorescence and being present only in anhydrites. Due to the position of one phase G I, time constraints may be set on G migration. HC I homogenize at -104°C which suggests methane with some nitrogen admixture. Homogenization of two phase water I occurs between 100 and 130°C for anhydrite and 90 and 120°C for carbonates. F sal varies between 2 and 10 wt% eq. NaCl.

lsotope data for carbonates show the maximum frequency as follows:  $\delta^{13}C$  in the interval of -5 to -3‰ and  $\delta^{18}O$  from -12 to -7‰, which suggests an enrichment of the carbonate cement in lighter isotopes. The oxygen data point to T generations of carbonate cements - high T of 90 to 125°C and low T of 45 to 60°C. The higher range has been also pointed out by the two phase Fl, while the lower by one phase ones. Present day bottom values are close to 100°C. (From author's abstract by E.R.)

JARMOLOWICZ-SZULC, Katarzyna, 1998b, Quartz cements in the Cambrian sandstones, Zarnowiec region, N. Poland: A fluid inclusion study: Geological Quarterly, v. 42, no. 3, p. 311-318 (in English). Author at Polish Geological Inst., Rakowieca 4, 00-975 Warszawa, Poland.

FI studies were conducted in quartz cements of the Cambrian sandstones from two boreholes in the Zamowiec region (northern Poland). The research based on the microscope observations of I aiming at their petrography and fluorescence characteristics as well as it comprised the routine microthermometric runs. The CL studies resulted in determination of generations of quartz cementing the sandstones. Two types of FI have been found--aq and hydrocarbon ones. They are connected with two generations of the quartz cements in the sandstones under discussion. The aq I yield Th of about 100°C and sal of about 8% wt. NaCl eq. The hydrocarbon I studied display three T groups ranging from 71 to 110°C. An attempt of interpretation of the entrapment conditions of coeval oil and aq I was made resulting in p-T values. Due to the limited number of FI in the cements the representativeness of the data is, however, rather poor. (Author's abstract)

JAVANMARDI, Jafar and MOSHFEGHIAN, Mahmood, 1998. Simple method for predicting gas-hydrate-forming conditions in aqueous mixedelectrolyte solutions: Energy & Fuels, v. 12, p. 219-222.

JEAN-BAPTISTE, P., BOUGAULT, H., VANGRIESHEIM, A., CHARLOU, J.L., RADFORD-KNOERY, J., FOUQUET, Y., NEED-HAM, D. and GERMAN, C., 1998, Mantle <sup>3</sup>He in hydrothermal vents and plume of the Lucky Strike site (MAR 37\_17\_N) and asociated geothermal heat flux: Earth and Planet, Sci. Letters, v. 157, no. 1-2, p. 69-77.

JELSMA, H.A., HUIZENGA, J.M. and TOURET, J.L.R., 1998, Fluids and epigenetic gold mineralisation at Shamva Mine, Zimbabwe; a combined structural and fluid inclusion study: J. of African Earth Sci., v. 27, no. 1, p. 55-70.

JENKIN, G.R.T., LEWIS, Helen and FEELY, Martin, 1998, Upper Triassic granite-hosted base-metal deposition related to rifting? Testing paleo-hydrology in the Galway Granite. W. Ireland (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). First author at Dept. Geol. and Geophys., Univ. of Edinburgh, EH9 3JW.

Authors use published FI data (E.R.).

JI, Hongbing and LI, Chaoyang, 1998a, Geochemical characteristics and source of ore-forming fluid for Jinman copper deposit in Western Yunnan Province, China: Acta Mineralogica Sinica, v. 18, no. 1, p. 29-37. Authors at Inst. of Geochem., Chinese Acad. of Sci., Guiyang, 550002.

The Jinman copper deposit, in western Yunnan, is a silver-bearing, high-grade vein-type copper deposit. The Th of the FI hosted in hydrothermal quartz and calcite range from 140 to 280°C and from 9 [sic] to 204°C, the calculated P range from 600 to 1200 bar, and the sal of oreforming F varies from about 5 to 20.8 wt.% NaCl eq. in the two stages of mineralization. The 834S values of the various sulphides are consistent with isotope equilibrium fractionation, i.e.,  $\delta^{34}S_{P_2} > \delta^{34}S_{ep} > \delta^{34}S_{Be}$ . The ratios of total sulfur (TS) over total organic carbon (TOC) range from 0.16 to 5.54 in ore, with no correlation of any kind. On the basis of "Ohmoto model" calculation, the ratio of redox (R') ranges from 2.16 × 10"17 to 1.55  $\times 10^4$  for dissolved sulfur species in ore-forming F from early to late in two stages of mineralization.  $\delta^{13}C_{C02}$  corresponds to mantle source CO<sub>2</sub>; δ13CCH4 corresponds to CH4 from contemporary geothermal source. Most of the points of 8180H2O and 8DH2O fall on or between the lines of reaction between meteoric water and clastic rocks, while a small part of the points fall near the reaction line of magmatic water with clastic rocks. Most of the points of ore-forming F fall within the mixing region between meteoric water and plutonic (or magmatic) F in S13C-S18O space, and some of these points on the mixing line with P=1. (From authors' abstract by E.R.)

JI, Hongbing and LI, Chaoyang, 1998b, Geochemistry of Jinman copper vein deposit, West Yunnan province, China—II. Fluid inclusion and stable isotope geochemical characteristics: Chinese J. of Geochemistry, v. 17, no. 1, p. 81-90 (in English). Authors at Open Laboratory of Ore Deposit Geochem., Inst. of Geochem., Chinese Acad. of Sci., Guiyang, 550002.

The Jinman deposit is a Ag-bearing copper vein deposit located at the north margin of the Lanping-Simao back-arc basin in West Yunnan. The filling-replacement stage and the boiling-exhalative precipitation stage of mineralization took place at T1-140-280°C and T2=94-204°C under P of (600-1200) × 105 Pa. The sal of ore-forming solutions ranges from 5 w1.% - 20.8 wt.% (NaCl). Sulphide 834S (CDT) values are in the range of -9.6% to 11.03‰ with a range of 22.66‰ showing an apparent "pagoda"-shaped distribution in histogram. Meanwhile, the 834S values of the various sulphides are consistent with the characters of isotope equilibrium fractionation, i.e., 834Sp >834Scp>834SBn. The TS/TOC ratios of the ores are widely variable between 0.16 and 5.54 with no correlation of any kind can be established According to the model of Ohmoto, the oxidation-reduction ratios of sulfur species in ore-forming solutions at the two mineralization stages were calcluated to be R<sup>1</sup>=2.16 × 10<sup>-17</sup> and R<sup>2</sup>=1.55 × 10<sup>4</sup> δ<sup>13</sup>C<sub>CO2</sub> (PDB) values obtained from FI in calcite and quartz are between -8.12% to -3.18%, averaging -5.26%, which are comparable with the isotopic composition of mantle-derived CO2. I in quartz yield 813CCH4 (PDB) between -32.11% and -22.04% (averaging -26.69%), similar to that of methane in modern geothermal G. For the ore-forming solutions, δ<sup>18</sup>O<sub>H2O</sub> (SMOW) values are between -10.57‰ and 9.77‰ and δD<sub>H2O</sub> (SMOW) are between -51‰ and -135‰. Considering the effect of isotope exchange during water-rock reactions, most of the data are plotted along or close to the line defined by the reaction of meteoric water with clastic rocks, while a small part of the points fall near the reaction line of magmatic water with clastic rocks. In S13C vs. S18O diagram, the oreforming solutions are plotted for the most part into the mixing area between the meteoric F and the deep-seated F and partially on the mixing line of P=1. (Authors' abstract)

JI, Kejian and GUO, Xinsheng, 1998, Source of hydrothermal fluid in Shizuoyuan W-Au deposit, Hunan, China: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998; Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1047-1050 (in Chinese).

JIYUAN, Z., BINGFANG, C. and YAN, L., 1998: The feature and origin of Yuxi silver mine in Hami, Xinjiang Province, China (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 136 (in English). First two authors at Nanjing Inst. of Geol. and Mineral Resources, Nanjing 210016, P.R. China; last author at Chengdu Inst. of Tech., Chengdu 610059, P.R. China.

The Yuxi As-Pb-Zn ore deposit has formed by epithermal mineralization, superimposed mineralization and supergene oxidation. The geochemistry, S and Pb isotope, rare earth element (REE), initial ratio of 87Sr/86Sr. S, Se, Co and Ni ratios studies indicate that the minerals originated from biotite plagiogneiss, dolomitic marble and granite. The C, H, O isotopic analytical results suggest the media comes from mixed groundwater of rain water, formation stored water and mineral crystallization water. The syn-ductile and brittle-ductile shear mineralization suggest that the heat is mainly the crustal shearing heat. The I compositions show that the ore-forming solution is of HCO3-Cu2+-K+ or HCO3-Ca2' type. The Ag. Pb and Zn were transported in the forms of sulfur-hydrogen and carbonic acid complex compounds. The changes of P, T, pH value and Eh value produced by the change of mechanical properties in the transportation channel-way caused the minerals to deposit. The ore-forming T. sal, P. depth, pH value and Eh value are 118-245°C, 2.43-11.13% (WB), 158.11-736 05\* [sic] 105 Pa, 0.53-2.45 Km, 6.3-6.8, 0.202-0 262v respectively. (From authors' abstract by E.R.)

JOCHUM, K.P., HOFMAN, A.W., BESSETTE, D., STOLL, B. and GRAUP, G., 1998, SY-XRF microprobe trace element study on melt inclusions from the Hawaii scientific drilling project (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F929. First author at Max Planck Institute f. Chemie, Postfach 3060, Mainz 55020, Germany; email (kpj@mpchmainz.mpg..de)

We have analyzed about 15 trace elements in 10-200 µm large MI from 9 picritic basalts from Mauna Kea and Mauna Loa by synchrotron radiation induced X-ray fluorescence (SY-XRF) and also determined the chemical composition of the bulk samples by SSM and XRF. The extremely variable Sr abundances in the I, especially for the Mauna Loa samples, may confirm the hypothesis of an unusual and heterogeneous Hawaiian source. (From authors' abstract by E.R.)

See also Sobolev, this volume (E.R.)

JOHAN, Z., 1998a. Mineralization related to mafic and ultramafic rocks. New genetic concepts 9abst.): Mineral Deposits Study Group, Annual Meeting. 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). Author at BRGM, Orléans, France.

Ophiolitic chromite orebodies within the harzburgitic upper mantle contain a PGM association resulting from a high-T F-rich ore-forming system, characterised by a very low sulfur fugacity. The highest precipitation T of chromite is limited by the upper thermal stability of pargasite (about 1050°C). Olivine and clinopyroxene crystals included in chromite are often associated with droplets of native nickel. The composition of these alloys (low Fe content) indicates an oxygen fugacity ranging from 10<sup>-14</sup> atm. at 1100°C. The F filling negative crystals in massive chromite is an aq solution with 5 wt% NaCl eq. containing CO<sub>2</sub>, CH<sub>4</sub> and minor C<sub>2</sub>H<sub>4</sub>, C<sub>2</sub>H<sub>6</sub>. The extensive crystallization of chromite is due to the appearance of this reducing F phase.

Isoferroplatinum occurring in dunite is interstitial with respect to chromite and silicates, and contains silicate I which are excellent markers of the composition of magmatic L coexisting with the ore-forming system. The I fill negative isoferroplatinum crystals and systematically contain clinopy roxene associated with hydroxyl-bearing silicates (tremolite, muscovite, biotite), albite and accessory apatite, titanite, anhydrite and a residual glass containing 11-15 wt% water. The composition of original magmatic L was calculated using image analysis of I. The L was water-rich (5-10 wt%) and quartz-normative. Its composition is close to that obtained experimentally by high-P partial melting of peridotite under water-saturated conditions.

In the Bushveld stratiform intrusion, Raman spectroscopy of Fl shows CH<sub>4</sub>-rich PGE horizons. The Merensky reef is four times richer in CH<sub>4</sub> than underlying pyroxenites and chromitites. The distribution of REE within the various cumulates of the Upper Critical Zone is remarkable.

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Variations in the REE distribution cannot be explained by magmatic fractionation. The occurrence of REE-bearing minerals in volatile-rich intercumulus indicates REE transportation in F phase. The F induces a strong variation in  $fO_2$ , modifying the Eu<sup>3+</sup>/Eu<sup>2+</sup> ratio and consequently the concentration of Eu in the F phase.

The observations demonstrate the important role of the reducing F phase in the precipitation of chromite and in the concentration of PGE in ophiolitic complexes as well as in Alaskan-type and stratiform intrusions. (From author's abstract by E.R.)

JOHAN, Z., 1998b, Mineralogy of the Bushveld upper critical zone intercumulus: Genetic considerations (abst.). 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A5. Author at BRGM, Orléans, France; email (z johan@brgm.fr)

Raman study reveals the presence of F with a variable CH<sub>4</sub>/CO<sub>2</sub> ratio. The Pothole reef section is characterized by CH<sub>4</sub>-rich F, wherea G chromatography shows the highest CH<sub>4</sub> concentration (0.21-0.25  $\mu$ m/g) at Merensky reef - the pyroxenites and chromitites of the UCZ only contain 0.04-0.10  $\mu$ m/g. CO<sub>2</sub> concentration varies from 1.08 to 3.25  $\mu$ m/g. Within Merensky reef, Cl- and REE-rich apatite has been altered by the late F into REE-poor, OH-rich apatite.

REE distribution in the UCZ rocks reveals the highest REE concentration at the top of Merensky reef. Furthermore, a remarkable cyclic variation is observed in Eu concentration, leading respectively to positive and negative Eu-anomalies. This behaviour, which cannot be interpreted in terms of magmatic evolution, reflects /O<sub>2</sub> variation in the F phase. (From author's abstract by E.R.)

JOHNSON, E.L., ROSIN, S.M., and MANCKTELOW, N.S., 1998, An optical method for measuring <a> axes positions in quartz using fluid inclusion morphology (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-133. First author at Dept. of Geol., Central Michigan Univ, 314 Brooks Hall, Mt. Pleasant, MI 48859; email (e.l.johnson@crnich.edu)

Knowledge of <a> axes orientations is of paramount importance to the understanding of deformation mechanisms in quartz and by extension. quartz-rich rocks. The measurement of <a> axes positions cannot be measured by standard optical (U-stage) techniques since quartz is a uniaxial mineral. Many quartz grains, however, contain abundant FI and in many instances, the FI occupy negative crystal-shaped cavities for which <a> axes positions can be optically determined. We have utilized these negative crystals to locate <a> axes positions using a U-stage. In order to test the validity of this approach, a blind comparison was performed on a deformed quartz aggregate from the Simplon Fault Zone (Central Alps Switzerland) Both <a> and <c> axes positions for this sample were measured using the proposed optical technique and via an X-ray texture goniometer. The locations of <a> axes maxima contoured on a Schmidt net using the two techniques agree closely demonstrating that the optical technique was successful. Advantages of the optical technique are 1) that the technique is simple and requires inexpensive equipment and 2) that <a> axes positions can be determined on a grain-by-brain basis allowing for the detailed study of crystalloraphic orientation differences across grain boundaries in deformed aggregates of quartz. One obvious disadvantage is that only grains containing negative-shaped FI can be used (Authors' abstract)

JONSSON, E. and BROMAN, C., 1998, Fluid inclusion studies of hydrated Mn arsenates and associated minerals from the Lángban mine. Sweden (abst): 17th General Meeting Int'l. Mineralogical Association. Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A32. First author at Dept. of Mineral., Swedish Museum of Natural History, Stockholm, Sweden.

Mineralogical and FI data from the complex Pb-Mn-As-Sb-bearing fissure mineralizations in the Långban mine (59.86°N, 14.27°E), in Varmland, Sweden, suggest formation at low T and P at or close to atmospheric P, from low to moderately high saline F. FI have been studied in allaktite, sarkinite, barite and calcite. Eutectic melting data from FI in the Mn arsenates suggest a F composition different than FI in calcite and barite, possibly dominated by CaCl<sub>2</sub> as a dissolved component. (From authors' abstract by E,R.)

JOUSSELIN, David and MAINPRICE, David, 1998. Melt topology and seismic anisotropy in mantle peridotites of the Oman ophiolite. Earth and Planet. Sci. Letters, v. 164, p. 553-568. Authors at Laboratoire de Tectonophysique, CNRS UMR 5568, Université Montpellier II, Montpellier, France; email (jousse@dstu.univ-montp2.fr)

This paper presents shape measurements of plagioclase and clinopyroxene I, assumed to reflect M topology, in peridotites of the uppermost mantle section of the Oman ophiolite. The plagioclase and clinopyroxene grains are devoid of any intracrystalline deformation in all samples. In contrast, the olivine in these rocks has recorded a high T plastic deformation, with different strengths of the crystallographic preferred orientation (CPO) of the olivine grains. Individual 'melt pockets' are first described by ellipses in two dimensions. They are more elongated when they have a larger area, and they are preferentially oriented parallel to the lineation (the X structural axis) of the sample, with a better defined preferred orientation for samples that have a stronger CPO. In a second step, an average M phase shape is defined in three dimensions for each sample, using the image autocorrelation technique. The average shape is nearly spherical for the samples with weak CPOs, and it is ellipsoidal, with a long axis parallel to X and the short axis parallel to Z (normal to the foliation) for samples with strong CPOs. The long axis of the ellipsoid is 3 times as long as the short axis for the sample with the strongest CPO. We use an anisotropic differential effective medium method to estimate the seismic properties of partially molten upper mantle peridotites. The M pockets were modeled as basalt filled I with the average shape and orientation given by the image analysis. The CPO of the olivine crystals was used to calculate the elastic properties of the anisotropic background medium. The calculated P-wave seismic anisotropies ranged from 5 to 15% with the anisotropy increasing with the CPO strength and M fraction. The maximum P-wave velocities are found along X with velocities above 8 km/s at 0% M and an average 0.5 km/s reduction for 10% of M. The minimum P-wave velocities are found along Z with velocities generally below 7.5 km/s at 0% M and an average reduction of 0.8 km/s for 10% of M. (Authors' abstract)

 KADKO, David and BUTTERFIELD, D.A., 1998, The relationship of hydrothermal fluid composition and crustal residence time to maturity of vent fields on the Juan de Fuca Ridge: Geochim. et Cosmo. Acta, v. 62, no. 9, p. 1521-1533. First author at Univ. of Miami. RSMAS/MAC. 4600
Rickenbacker Causeway, Miami, Florida 33149, USA. The <sup>228</sup>Ra<sup>J26</sup>Ra ratio of hydrothermal F reflect the residence time of

The <sup>228</sup>Ra/<sup>226</sup>Ra ratio of hydrothermal F reflect the residence time of the F within the crust as well as the age-since-melting of the basalt with which the F interact. F residence times from the onset of high-T (200°C) reaction are  $\leq 3$  years which is short compared to the mean life of <sup>228</sup>Ra. The residence times are short relative to hypothesized storage periods for brines within the ocean crust. A potential implication of this result is that postulated, long-lived, high-chlorunity brine reservoirs must be extensively diluted by young, Ra-bearing F that have reacted significantly with hot rock. (From authors' abstract by E.R.)

KAINDL, Reinhard, ABART, Rainer, HOINKES, Georg, and KNOLL, Peter, 1998. Density differences in fluid inclusions from monoand polymetamorphic rocks in the Austroalpine Basement (abst.): Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 37. First author at Inst. for Mineral -Crystallog, and Petrol., Karl-Franzens-Univ., Graz, Austria; email (reinhard, kaindl@kfunigraz.ac at)

The Austroalpine Basement (AAB) is a nappe system comprised of mono- and polymetamorphic metasediments, amphibolites, orthogneisses and subordinately marbles, eclogites and migmatiles. Fl hosted in meta-morphic index minerals were observed in the largely monometamorphic Schneeberg Complex (SC) and in the Radenthein Basement (RB). In both areas garnet-micaschists and homblende shists dominate. The amphibolite facies parageneses are of Cretaceaous age. Only in the basal parts of the SC relics of an older paragenesis are observed.

In the monophase sections of the SC primary and secondary CO<sub>2</sub>-CH<sub>4</sub>-N<sub>2</sub> I ( $X_{CH_4}$ =0.03,  $X_{N2}$ =0.02) with variable densities from 0.8 to 1.17 g/cm<sup>3</sup> occur in the quartz matrix. Only in the basal, polymetamorphic sections primary, low sal H<sub>2</sub>O-NaCl I are observed in garnet cores, which pertain to the pre-Cretaceous paragenesis. High Th<sub>H2O</sub>(L+V L)=325°-372°C yield low densities (0.6-0.7 g/cm<sup>3</sup>). Aq I in "young" matrix quartz have higher sal (>10 eq. wt% NaCl) and densities (>0.8 g/cm<sup>3</sup>). This reflects differences in P-T conditions during I entrapment in the course of the pre-Cretaceous and Cretaceous events.

Within the monophase shists of the RB garnet and kyanite porphyroblasts as well as matrix quartz contain P H<sub>2</sub>O-CO<sub>2</sub>-N<sub>2</sub>-NaCl I. Th of the three-phase I are 23-24°C for I in garnet. For I in kyanite Th<sub>CO2</sub> varies from 0 to 27°C, and for I in matrix quartz it varies from -30 to +30°C. This suggests that the original F densities were best preserved in garnet. Kyanite

and quartz were more susceptible to post metamorphic modification. The composition of the  $CO_2$ - $N_2$  V phase is relatively constant regardless of host mineral and F density. This leads us to conclude that post metamorphic loss of H<sub>2</sub>O may be responsible for these density variations. (From authors' abstract by E.R.)

KALDYSHKINA, T.V., TROSTYÁNSKY, G.D. and SÍLOV, V.P., 1998, A new exogenic genetic kind of manganese ore-shows in Uzbekistan (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 154-155 (in Russian).

KAMENETSKY, Vadim and CRAWFORD, A.J., 1998. Melt-peridotite reaction recorded in the chemistry of spinel and melt inclusions in basalt from 43°N, Mid-Atlantic Ridge: Earth and Planet. Sci. Letters. v. 164, p. 345-352. Authors at School of Earth Sci. and Centre for Ore Deposit Research, Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania, 7001, Australia.

Compositions of spinel and glassy MI in primitive olivine (Fo<sub>89.3.01</sub>) from basalt AII32 D11-177 at 43°N, Mid-Atlantic Ridge fall into two principal groups. The dominant (~90%) Group-I spinel and MI have typical MORB compositions. In contrast, Group-II Cr-spinels are strongly enriched in TiO<sub>2</sub> (2.6-4.1 wt.%), and Group-II MI show significant enrichment in SiO<sub>2</sub> (54.6-58.4 wt.%), TiO<sub>2</sub>, Na<sub>2</sub>O and K<sub>2</sub>O, whereas their CaO contents (9.3-11.1 wt.%) are unusually low. Group II-M are also remarkable in crystallizing high-Mg orthopyroxene (Mg# 91). These mineral associations and M compositions are unusual for MORB, and are interpreted to result from interaction between MORB-like M and harzburgitic peridotite at low P. (Authors' abstract)

# KAMENETSKY, Vadim, CRAWFORD, A.J. and EGGINS, S.M.,

1998, Unusual mineral and melt inclusion compositions in basalts from 43°N, mid-Atlantic ridge: Evidence for melt-peridotite interaction (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 231. First author at Dept. of Geol.. and Center for Ore Deposit Research, Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania, 7001.

The samples are Ol-phyric pillow basalts with quenched pillow rim glasses. Clinopyroxene phenocrysts are also present in D12-7. Olivine phenocryst compositions (Fo up to 92) are among the most magnesian known from MORB. D12-7 olivines are unusually enriched in CaO (up to 0.45 wt%). This enrichment correlates with extremely high CaO/Al2O3 values in MI (up to 1.2; c.f., <0.9 in MORB melts), which are a consequence of high CaO (up to 15.2) and low Al2O3 (12.8-15.5 wt%) contents in the basaltic M (MgO 10-12 wt%). This governs an early Ol-Cpx cotectic: Cr-diopsidic clinopyroxenes in D12-7 have Mg# (90-92), the highest reported from MORB. Spinel I in olivine demonstrate the most unusual features for MORB spinel: Cr# range up to 70 (c.f., <60 in MORB), and TiO; contents in some D11-177 spinels are as high as 2-4 wt% (c.f., <0.7 in MORB). This high Cr# is in agreement with low Al<sub>2</sub>O<sub>3</sub> content in the M as evidenced by MI. High TiO2 abundances in spinel may reflect elevated TiO<sub>2</sub> in parental M recorded in a number of MI (up to 2.4 wt% vs <1.5 wt% TiO2 in common MORB melts). Other peculiar compositional features of these high-Ti MI are: (in wt%) very high SiO2 (up to 58) and Na2O (up to 3.4) and low CaO (9-11), and that they are trapped in low-Ca (CaO 0.18-0.24) olivines. Such compositions are unusual for MORB and are clearly saturated in orthopyroxene, which has been found as 1 in high-Si MI. In summary, the mineral assemblage and MI chemistry in studied basalts are atypical of MORB and may reflect a variety of parental magma compositions ranging from common MORB to more unusual compositions

Melt-peridotite interaction, as it follows from this study, could be an important factor controlling the compositions of MORB P M, their evolutionary paths during ascent, and the effects of high-P fractionation and reequilibration on the compositions of residual peridotites and erupted rocks and glasses. (From authors' abstract by E.R.)

### KAMIJO, Koichi, HASHIZUME, Ko and MATSUDA, J.-L. 1998, Noble gas constraints on the evolution of the atmosphere-mantle system: Geochim. et Cosmo. Acta. v. 62. no. 13, p. 2311-2321. Authors at Dept. of Earth and Planetary Sci., Grad. School of Sci., Osaka Univ., Toyonaka, Osaka 560-0043, Japan.

We present a model on the evolution of atmosphere-mantle system assuming a significant degassing from the less depleted mantle, based on the recent results of the He-Ar systematics proposed by Matsuda and Marty (1995). The degassing fluxes of noble G are represented by the concentrations in the mass flow, which follows the model of Porcelli and Wasserburg (1995a,b). However, we have not assumed the steady-state, and have assumed the mass transfer as an exponential function of time. The degassed amount from the less depleted mantle is related to the mixed amount of mass between the less depleted mantle and the depleted mantle. The amount of mixing is constrained from the K abundances in each mantle reservoir. Consequently, the degassed amount from the less depleted mantle is also constrained.

The following conclusions are obtained from this model. The initial elemental ratio  ${}^{3}\text{He}/{}^{36}\text{Ar}$  is likely to be in cosmic abundances, and the initial concentration of  ${}^{36}\text{Ar}$  in the Earth is constrained to be  ${}^{-1} \times 10^{12}$  atoms/g. The present fraction of  ${}^{36}\text{Ar}$  in the depleted mantle reservoir is calculated to be at most 2.4  $\times 10^{-3}$  of the initial inventory. The  ${}^{40}\text{Ar}/{}^{36}\text{Ar}$  ratio in this reservoir is estimated to be  ${}^{<}(1 \ 3 {}^{-1}, 4) \times 10^{5}$ . The less depleted mantle reservoir also degassed and the present amount of  ${}^{36}\text{Ar}$  is calculated to be at most 1.3  $\times 10^{-1}$  of the initial inventory. The  ${}^{40}\text{Ar}/{}^{36}\text{Ar}$  ratio in the less depleted mantle reservoir is estimated to be  ${}^{<}(3 {}^{-7}\times 10^{4})$ .

To explain the difference between the neon isotopic ratios in the atmosphere and those observed in the mantle rocks, isotopic fractionation during the escape from the atmosphere and/or significant contribution of late accreted materials possessing planetary Ne is necessary. In our model, Ne degassing from both mantle reservoirs would have provided at least 50-90 times the amount of <sup>22</sup>Ne in the present atmosphere. Therefore, the fraction supplied by late-accreted material would be negligible, which is contrary to the model proposed by Porcelli and Wasserburg (1995b). We conclude that isotopic fractionation model during escape from the atmosphere provides the best fit to the observations. (Authors' abstract)

KANEOKA, Ichiro, 1998a, Xenon's inside story: Science, v. 280, p. 851-852.

A review of Xe studies from MORBs, CO<sub>2</sub> well gas, and diamonds (E.R.)

See next item. (E.R.)

KANEOKA, Ichiro, 1998b, Noble gas signatures in the Earth's interiorcoupled or decoupled behaviour among each isotope systematics and problems related to their implication. Chem. Geol., v. 147, p. 61-76. Author at Earthquake Research Inst., Univ. of Tokyo, Bunkyo-ku, Tokyo 113, Japan.

In order to conjecture the degassing state of the Earth's interior, many kinds of noble G systematics are used to characterize the source materials in the Earth's interior. Although some systematics show clear trends, others do not indicate any trends to identify each end-member and relationship The He-Ne systematics indicates mixing of mantle component with the solar 20Ne/22Ne and the atmosphere-derived component. The Ar-Xe systematics seem to show some trends, but the effectiveness of the Ne-Ar systematics seems to be limited to samples derived from the area on regional scale. No clear correlation is observed in the Ne-Xe systematics for samples on global scale. Although such variations are affected by the elemental fractionation of the atmosphere-derived components to some extent, it is not sufficient to explain the range of observed variation. Lighter noble G (He, Ne) seem to not always correlated with heavier noble G (Ar. Kr, Xe), probably due to large difference in their mobilities. Based on the Ar-Xe systematics, the occurrence of recycled materials can be inferred, indicating a possibility of transport of heavier noble G into the Earth's interior together with recycled materials. The thermal state in the Earth's interior on global scale might also control the noble G signatures of magma sources as is the case for the South Pacific Area. (Author's abstract)

See previous item (E.R.)

KASAI, Kaichiro, SAKAGAWA, Yukihiro, KOMATSU, Ryo, SA-SAKI, Munetake, AKAKU, Kohei and UCHIDA, Toshihiro, 1998, The origin of hypersaline liquid in the Quaternary Kakkonda granite, sampled from well WD-1a. Kakkonda geothermal system, Japan: Geothermics, v. 27, no. 5/6, p. 631-645. First author at Japan Metals & Chemicals Co., Ltd. (JMC), 72 Sasamori, Ukai, Takizawa-mura, Iwate, 020-01 Japan.

Hypersaline metal-rich L (ca. 40 wt.% total chloride species) was obtained from a depth of 3708 m in the Kakkonda geothermal system. Sampling of well WD-1a was conducted by reverse circulation after a standing time of about 196 hours (with T recovering to >500°C). Tritium content and the relationship between  $\delta D$  and  $\delta^{1K}O$  showed that the river water that was circulated in the well had mixed with an isotopically heavy F during the standing time. Phase separation occurred during T recovery, concentrating the hypersaline L in the bottom of the well. This original hyper-

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saline L has a sal of about 55 wt.% NaCl eq., consisting of Na-Fe-K-Mn-Ca chloride, rich in Zn and Pb but poor in Cu, Au and Ag. The F originates from the Kakkonda granite and mixed with circulating water from the well in a zone of fine fractures induced by thermal stress during drilling. (Authors' abstract)

KASAI, K., SAKAGAWA, Y. MIYAZAKI, S., AKAKU, K. and UCHIDA, T., 1998, Supersaline and metal-rich brine obtained from the Quaternary Kakkonda Granite by NEDO WD-1a in the Kakkonda geothermal field, Japan. Mineralium Deposita, v. 33, p. 298-301. First author at Japan Metals and Chemicals Co., Ltd. (JMC), 72 Sasamori. Ukai, Takizawa-mura, Iwate, 020-01 Japan.

A supersaline, metal-rich brine (ca. 40 wt.% total chloride salt) was extracted from 3708 m depth of well WD-1a in the Kakkonda Granite by reverse circulation after a standing time about 196 hours. The estimated borehole T exceeds 500°C near the bottom. Tritium content and the relationship between  $\delta D$  and  $\delta^{18}$ O show that the injected borehole F (river water) evidently mixed with an isotopically heavy and ancient F. The phase analysis showed that a G phase separated from a brine and that a brine concentrated in the borehole as the borehole T recovered after cooling by drilling F. We think the original F was trapped in the Kakkonda Granite and mixed with the borehole F through fine fractures induced by thermal stress. (Authors' abstract)

KASIMOVA, F.I., 1995, Meaning of carbon isotopes of hydrocarbon inclusions [in accessory minerals] from kimberlite pipe Mir: Sixth Int'l. Kimberlite Conference, Russia, 1995, Extended Abstracts, p. 705.

Hydrocarbon I were determined in zircon from concentrate kimberlite pipe Mir. With the method of low T spectrofluorimetry their consistence was studied. Consistence of hydrocarbon I in zircon is close to hydrocarbon which were studied earlier in mineral-indicator olivine from pipe Udachnaya (Daldino-Alkitaiskii region) and in garnets from pipe Mir (Malo-Botoubinskii region). Aromatic hydrocarbons with molecular structure of alkinnaphtaline, alkinfenatren and piren prevail.

Hydrocarbon I are determined in minerals-indicators of the following parageneses: in olivines from magnezial and ilmenite ultrabasic rocks, in gamets from ilmenite (magnezial and ferruginous) and magnezial ultrabasic rocks and alkremites: in zircon from ultrabasic magnezial paragenesis.

Meaning of  $\delta^{13}$ C hydrocarbons from I at zircon are close to the meaning  $\delta^{13}$ C hydrocarbons in olivines from pipe Udachnaya and in garnets from pipe Mir; they occupy field of meanings of isotopes of hydrocarbons of diamond of eclogite paragenesis.

So, hydrocarbon 1 for piropes of alkremite paragenesis are P, and for olivines, gamets, zircons of ultrabasic paragenesis are lowned [sic] (Author's abstract)

Hydrocarbon FI were identified in zircon, olivine and garnet. Carbon isotopes determined by low T spectrofluorimetry overlap the isotope field determined from diamond of eclogite paragenesis (H.E.B.)

KASTNER, Miriam, KVENVOLDEN, K.A. and LORENSON, T.D., 1998, Chemistry, isotopic composition, and origin of a methane-hydrogen sulfide hydrate at the Cascadia subduction zone: Earth and Planet. Sci. Letters, v. 156, no. 3-4, p. 173-183. First author at Scripps Inst. of Oceanography, Univ. of California San Diego. La Jolla. CA 92093, USA.

At Ocean Drilling Program (ODP) Site 892, offshore from central Oregon. G hydrate was recovered close to the sediment-water interface at 2-19 m below the seafloor (mbsf) at 670 m water depth. G from a sample of this layer was composed of both  $CH_4$  and  $H_2S$ , and also contains ethane and minor amounts of CO<sub>2</sub>. The facts suggest that the mixing of  $CH_4$  and  $H_2S$  is a geologically young process. Because the existence of a mixed  $CH_4$ -H<sub>2</sub>S hydrate is indicative of moderate to intense advection of a methane-rich F into a near surface active sulfate reduction zone, tectonically active (faulted) margins with organic-rich sediments and moderate to high sedimentation rates are the most likely regions of occurrence. (From authors' abstract by E.R.)

KATAOKA, N., MATSUEDA, H., ISHIYAMA, D. and MATSUBAYA, O., 1998, Genesis of gold mineralizations at the Specogna ore deposits. western Canada (abst.): Abstracts with Programs. 48th Annual Meeting of the Society of Resource Geology; Tokyo, June 17-19, No. P-28 (in Japanese)

Indexed under FI (E.R.).

KENDRICK, M., BURGESS, R., PATTRICK, R.A.D. and TURNER, G., 1998, Noble gas and halogen geochemistry of mineralising fluids from Cu-porphyry in Southern Arizona and Bingham Canyon, Utah (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated). Authors at Dept. of Earth Sci., Univ. of Manchester, Oxford Rd., Manchester, M13 9PL.

Following optical characterisation of FI populations, sequential crush analysis of quartz from these deposits has been carried out. Laser extraction of FI in the Bingham canyon samples are currently being undertaken to target specific populations and these data will be presented at the meeting.

Bulk crushing of four different Laramide porphyries (Ray, Mission, Pinto Valley and Globe Miami) give Br/Cl values in the range  $0.9-1.3 \times 10^{\circ}$ <sup>3</sup> molar, but only Silver Bell with Br/Cl of  $1.5-1.7 \times 10^{\circ3}$  molar, is above the seawater value of  $1.54 \times 10^{\circ3}$  molar. *UCl* values for the five deposits are between  $1-11 \times 10^{\circ5}$  molar, all significantly above the seawater value of  $0.09 \times 10^{\circ5}$ , and Silver Bell again provides the highest values of up to 11 x  $10^{\circ5}$  molar. There is significant variation in halogen ratios between samples from different zones within the porphyries confirming that different F have mixed during the evolution of these deposits.

<sup>40</sup>Ar shows a strong correlation with Cl (and Br and I). The correlation indicates that samples contain a mixture of at least two F components with high <sup>40</sup>Ar content (<sup>40</sup>Ar/<sup>36</sup>Ar>296): a high sal F with <sup>40</sup>Ar\*/Cl of  $\geq 10^{-4}$  molar similar to that measured in magmatic F; and a low sal component with <sup>40</sup>Ar\*/Cl-10<sup>-6</sup> molar typical of crustal F. A third component has low sal and an atmospheric <sup>40</sup>Ar/<sup>36</sup>Ar signature. Noble G elemental ratios (Kr/Ar and Xe/Ar) of this endmember are consistent with air-saturated water and it is therefore most likely to be meteoric F as opposed to air Ar trapped in the sample as blank. Within a given deposit, the <sup>40</sup>Ar\*/Cl value differs depending upon location of samples within the ore body therefore reflecting the relative importance of the different F endmembers. (From authors' abstract by E.R.)

KENT, A.J.R., STOLPER, E.M., WOODHEAD, J., HUTCHEON, I.D. and FRANCIS, D., 1998, Using glass inclusions to investigate a heterogeneous mantle: An example from N- and EMORB-like lavas from Baffin Island (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 765-766. First author at Div. of Geological and Planetary Sci., California Inst. of Tech., Pasadena, CA 91125 USA.

We have analysed olivine-hosted (Fo<sub>84</sub>-Fo<sub>92</sub>) glass I from a suite of picritic rocks from Baffin Island, Canada. Major element compositions of -200 glass I were measured by electron microprobe and REE abundances were measured in a subset of these I by ion microprobe. Our results are also compared to major element and REE data for matrix glasses from the same samples. The new data are consistent with the suggestion that the Baffin Island picrites represent mixtures of M derived from (1) a depleted mantle source, similar to that from which typical MORB are derived, and (2) an incompatible-element enriched, high-<sup>87</sup>Sr/<sup>86</sup>Sr, source (From authors' abstract by E.R.)

KENT, A.J.R., WOODHEAD, Jon, FRANCIS, Don and STOLPER. E.M., 1998, Variations in glass inclusion composition in basalts from heterogeneous source regions: An example from Baffin Island (abst.): EOS, Trans. 79 (45) Fall Meet. Suppl., p. F939 First author at Div. of Geological and Planetary Sci., California Inst. of Tech., Pasadena, CA 91125, US; email (kent5@llnl.gov)

We have investigated, using the electron and ion microprobes, the compositions of over 300 olivine-hosted glass I from the 65 Ma old picrite suite at Baffin Island. Canada. Glass I from individual samples vary considerably in the degree of incompatible element enrichment. We interpret our data as indicating that glass I preserve more of the diversity of M derived from depleted and enriched sources that aggregate to form individual erupted lavas than is sampled by the whole-rock lavas. Thus glass I may provide a means to identify the most depleted and enriched components of the source region. (From authors' abstract by E.R.)

KHALMUKHAMEDOV, T.R., ISLÁMOV, F.I., ZIÍRI, N.M., KONÉEV, R.I., MEKHMANKHODZHÁEV, A.D., ZHURÁEV, A.Zh. and GÉRTMAN, Yu.L., 1998, The formation of gold-ore mineralization in the Kairagach Deposit (abst.) Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 131-133 (in Russian). See Translations.

KHAMRABÁEV, I.Kh. and AKBÁROV, Kh.A., 1998, Evolution of Academician Kh.N. Baimukhamedov's ideas in the study of ore deposits (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 15 (in Russian).

KHAMRABÁEV, I.Kh., AKHUNDZHÁNOV, R., USMÁNOV, A.I. and KOZLÓV, V.V., 1998, Ideas about the genetic association between magmatism and mineralization on the basis of a study of solid micro-inclusions in rock-forming minerals (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 62-64 (in Russian).

See Translations.

KHIN ZAW, 1998, Geological evolution of selected granitic pegmatites in Myanmar (Burma): Constraints from regional setting, lithology, and fluidinclusion studies: Internat'I. Geol. Review, v. 40, p. 647-662. Author at Centre for Ore Deposit Research. School of Earth Sci., Univ. of Tasmania, GPO Box 252-79, Hobart, Tasmania, Australia 7001.

Pegmatite deposits commonly occur in the 1500 km long, N-Strending, tungsten-tin-bearing granitoid belt in Myanmar. The pegmatites are commonly zoned, feldspars and muscovite being more abundant in the center and quartz more common at the margin. The zoning pattern is rather distinct in the pegmatite body, where tourmaline is present. The lightcolored felsic minerals are confined to the core zone and the dark-colored tourmaline crystals to the outer zone.

Numerous FI have been found in quartz, topaz, and beryl. Most of the I are rounded to elliptical, with a variable degree of L filling. All I are aq, two-phase (L and V) I with no dm. Th of 173 FI were measured in this study.

Geothermometric studies indicate that the pegmatites were formed over a Th range of 230 to 410°C. Sal of Fl in pegmatite minerals yielded from 1.0 to 10.8 NaCl eq. wt.%. Topaz and quartz single crystals (several cm across) from the Sakangyi pegmatite provide an opportunity to extract the F trapped in these minerals. The Na/K ratios of the Fl in two topaz samples were 3.0 to 4.9, and those of two quartz samples were 2.9 to 10.5, suggesting the presence of substantial potassium in the pegmatite-forming F was not observed. The post-magmatic, hydrothermal F responsible for the pegmatite veins evidently emanated from cooling S-type granitoids, with which they are spatially associated. (From author's abstract by E.R.)

KHIN ZAW, GEMMELL, B.J., LARGE, R.R., THAIK, A.M., YEAP, E.B. and KHOO, T.T., 1998. The importance of ore fluid chemistry in studies of ore genesis: Examples from Australian and southeast Asian deposits: Ninth Regional Congress on Geol., Mineral and Energy Resources of Southeast Asia—GEOSEA '98 17-19 Aug, Kuala Lumpur, Mafaysia, Program and abstracts, p. 113. Mineral Resources paper 16. First author at Centre for Ore Deposit Research, Univ. of Tasmania, Hobart. Tasmania, Australia 7001.

Ore F research currently undertaken at Centre for Ore Deposit Research. Univ. of Tasmania in collaboration with CSIRO (Commonwealth Scientific and Industrial Organisation) and AGSO (Australian Geological Survey Organisation) has shed light on the understanding of the environment and evolution of hydrothermal processes for the Australian and southeast Asian base metal and gold deposits. These results also provide guidelines for the selection of targets in mineral exploration.

The Hellyer deposit is a mound-style volcanic-hosted massive sulphide (VHMS) deposit in western Tasmania, Australia. Textural, petrographic and microthermometric investigations of FI in the Hellyer stringer system indicate that Type I, P, L-V I are 10-15 µm in size, and yield Th of 170-220°C in early 2A veins, 165-322°C in main-stage 2B veins and 190-256°C in late-stage 2C veins. These data suggest a waxing and waning thermal history. However, the average sal remained between 8-11 NaCl eq. wt.% in all stage 2 veins. LRS analysis indicates the presence of CO2 (<1 mol%) in the Hellyer VHMS system. Semi-quantitative SEM-WDS microprobe analyses of FI decrepitates iindicate that the Hellyer ore F were enriched in potassium and calcium but depleted in magnesium relative to seawater. PIXE analysis of FI in quartz from the mineralised zones also indicates significant base metal concentrations in the Hellyer ore F. Cation composition and higher sal relative to seawater suggest that recycled seawater alone cannot be the sole source of the ore F. The high base metal content and the presence of CO2 in the FI implies that magmatic input of ore metals during seawater leaching of the footwall volcanic pile is a distinct possibility

Gold-copper-bismuth mineralisation in the Tennant Creek goldfield has four major I types in quartz associated with mineralised and barren ironstones: (1) L-V I with low L/V ratios (Type I), (2) L-V I with high L/V ratios or high V/L ratios and characteristic dark bubbles (Type II). (3) L-Vhalite | (Type III), and (4) L-V | with variable L/V ratios (Type V). Type ] inclusions are present in the barren ironstones and unmineralised portions of fertile ironstones, whereas Types II and III inclusions are recognised in fertile ironstones. Type I FI have Th of 100-350°C with a mode at 200-250°C. Type II inclusions in mineralised ironstones have Th of 250-600°C with a mode of 350°C. Type I FI have a sal range of 10-30 NaCl eq wt %. Sal measurements on FI in the mineralised zones gave a range of 10-50 NaCl eq. wt.% with a mode of 35 NaCl eq. wt.%. This research indicates that the Tennant Creek ironstones were formed from a relatively low T and moderately saline F, whereas gold and copper mineralisation was deposited from later hydrothermal F of higher T and sal. G analysis indicates the presence of N2 and CO2, with very minor CH4 in Types II inclusions but no N2 or CH4 G in type I inclusions. Microprobe analysis of the FI decrepitates indicates that the I from Tennant Creek contain sodium and calcium and minor potassium.

The high T ( $\geq$ 350°C), high sal ( $\geq$ 35 NaCl eq. wt.%) and cation composition of the Tennant Creek ore F suggest that the ore F were derived from upward migrating heated basinal brines, although a contribution from a magmatic source cannot be ruled out. Close association of V-rich type Ilb and salt-rich type III inclusions in the mineralised ironstones indicates heterogeneous trapping of ore F. This heterogeneous trapping is interpreted to be due to unmixing (exsolution) of a G-rich (e.g. N<sub>2</sub>) F during the upward migration of the metal bearing brines and/or due to degassing caused by reaction of oxidised ore F and host ironstones. These FI data have important implications regarding the deposition of gold in the ironstones, and can be used, in conjunction with other exploration techniques, in discriminating fertile from barren ironstones.

The Kyaukpahto gold deposit in Myanmar is hosted in turbiditic sandstone. Gold mineralisation is also associated with intense silicification, sericitisation and argillic alteration. Major sulphide minerals are pyrite and arsenopyrite with minor galena, chalcopyrite, and sphalerite. Preliminary Fl study at Kyaukpahto gold deposit reveals three major Fl types in quartz in the ore zone: (1) Type I, two-phase, H<sub>2</sub>O L and VI. (2) Type II, threephase with H<sub>2</sub>O L. V and CO<sub>2</sub> Ll and (3) Type III, two-phase, L-rich I with variable L and V ratios. Primary Type I Fl are 5-15 µm across and yielded Th of 239-310°C and sal of 1.2-10.9 NaCl wt.%. Present geological, mineralogical and Fl characteristics demonstrate that the Kyaukpahto gold deposit is comparable to the Carlin type sediment-hosted gold deposits.

Many gold deposits are widely distributed in peninsular Malaysia and there is a potential for discovery of world class gold deposit in the peninsula. The gold deposits in the peninsula are similar to slate-belt type, structurally controlled mesothermal gold deposits. FI in the mineralised veins from the Selinsing and Bukit Koman deposits contain CH<sub>4</sub> (detected by Laser Raman spectrometry). CH<sub>4</sub> is commonly recorded in mineralised Archean and Slate-belt type mesothermal lode gold deposits in Australia and Canada. The enrichment of CH<sub>4</sub> indicates that there is a possibility of applying FI G to discriminate mineralised mesothermal gold veins from barren vein system in the peninsular Malaysia. (From authors' abstract by E.R.)

KHIN ZAW, HUSTON, D. L., and LARGE, R. R., 1998, A chemical model for the Devonian remobilization process in the Cambrian VHMS Rosebery deposit, western Tasmania: Constraints from metal zonation and fluid inclusion studies (abst.): Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 38. First author at Centre for Ore Deposit Research, Geol. Dept., Univ. of Tasmania, Hobart, Tasmania 7001, Australia.

The Rosebery deposit in western Tasmania is a polymetallic massive sulfide deposit hosted in felsic volcanics of the Cambrian Mt Read Volcanic belt. The deposit underwent upper greenschist facies regional metamorphism and related deformation during the Devonian Tabberabberan Orogeny, resulting in folding, shearing and faulting (thrusting) of the ore lenses. The south-end of the Rosebery deposit has undergone metasomatic replacement related to a post-orogenic Devonian granite intrusion. The Rosebery area has also been intruded by shallow-level post-orogenic granitoid plutons. The granite does not outcrop at Rosebery but the existence of a shallow granite intrusion below the south-end of the orebody has been interpreted from gravity data. Metasomatic mineral assemblages related to the Devonian granite have been recognized transgressing Cambrian VMHS minerals at the south-end of the Rosebery orebody.

Cambrian VHMS mineralization at Rosebery consists of three P sulfide-sulfate zones; a lowermost pyrite-chalcopyrite zone, overlain by a sphalerite-galena±pyrite zone, and further overlain by an uppermost massive harite zone. Three major Devonian replacement zones can be distin-

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guished: (1) a magnetite-biotite±chalcopyrite zone. (2) a pyrrhotite-pyrite zone and (3) a tourmaline-quartz±magnetite zone. Other metasomatic minerals such as fluorite, gamet and helvite are also present (Khin Zaw et al., 1997, Canadian Mineralogist, 35:1-25).

Metal zonation studies indicate that zinc occurs dominantly in a blanket-like enrichment zone in the P sulfide lenses of the Rosebery deposit; silver exhibits a generally similar pattern. Gold is largely concentrated at the top of the ore lenses. In the transgressive pyrrhotite-pyrite replacement zone at the south-end of the Rosebery deposit, zinc is conspicuously depleted but gold concentrations of more than 20 g/t are observed. In contrast, the biotite-, magnetite-, and tourmaline-bearing replacement zones contain low gold grades (generally <5.0 g/t Au). Like zinc, silver is also depleted in the replacement zones but a significant amount of copper is present. Copper concentrations as high as 2% are observed in the biotite-magnetite zone as well as in the pyrrhotite-pyrite zone. This indicates that although zinc and silver were dissolved and removed during the Devonian replacement event, gold and copper were redistributed and recrystallized.

Microthermometry and laser Raman spectroscopy studies of fluid inclusions in minerals from the Devonian replacement zone indicate that the early biotite-magnetite and pyrthotite-pyrite assemblages formed from the interaction of moderate- to high-T ( $\geq$ 330°C), saline (10-25 NaCl eq. wt%), CO<sub>2</sub>-bearing F with the original stratiform lead-zinc mineralization. The later stage tournaline veining and associated replacement assemblages resulted from lower T ( $\leq$ 300°C), less saline ( $\leq$ 10 NaCl eq. wt%) F. The high T, high sal and CO<sub>2</sub>-bearing metasomatic F support the hypothesis of derivation of this F from Devonian granite below the Rosebery deposit.

During the Devonian metasomatic event, gold was most likely remobilized and recrystallized as AuCl<sub>2</sub>-complex because of the high T and high sal of the F. Copper also appears to have been recrystallized during the replacement process, and exhibits minor remobilization. In comparison to copper and gold, zinc, lead and silver have been dissolved and removed probably as chloride complexes. (Authors' abstract)

KILLAWEE, J.A., FAIRCHILD, I.J., TISON, J.-L., JANSSENS, L. and LORRAIN, R., 1998, Segregation of solutes and gases in experimental freezing of dilute solutions: Implications for natural glacial systems: Geochim, et Cosmo. Acta, v. 62, no. 23/24, p. 3637-3655. First author at School of Earth Sci., Univ. of Birmingham, Birmingham, UK..

Low ionic strength waters containing significant calcium and bicarbonate are common in nature, but little literature exists on their behaviour during freezing. Modeling indicates that freezing-induced concentration of solutes (in a closed-system) would lead to progressive increase in calcite saturation index, despite rising partial P of  $CO_2$  ( $P_{CO2}$ ), but the consequences of CaCO<sub>3</sub> precipitation for the distribution of matter between solid, L and G phases required experimental investigation. We studied the effects of variations in the rate of advance of an ice-water interface and in the initial degree of saturation for calcite on the behaviour of the system.

Downward growth of ice in a 24-cm diameter cylindrical vessel was achieved at a constant linear rate of 3 or 8 mm/h by the progressive cooling of an overlying alcohol reservoir, and the expansion of volume accommodated by regular water sampling through side ports, together with a small expansion chamber. Initial air-saturated solutions (initial  $P_{CO2}$  in the range  $10^{-3}$  to  $10^{-5/2}$ ) were prepared to reflect a range from strongly undersaturated to supersaturated for calcite. Comparative blank experiments were run using deionized water.

Ice growth led to enrichment in solutes at the ice-water interface and the creation of a diffusive boundary layer, calculated to be 0.6 mm thick, truncated below by convecting F. The first-formed ice (stage 1), was relatively solute-rich because of initial rapid ice nucleation. Where solutions were not strongly supersaturated for calcite this was followed by formation of a solute-poor (stage 2) ice. Ice-interface water segregation coefficients of stage 2 ice were calculated to be 0.0004-0.003 for various solute ions. The relative magnitude of segregation coefficients ( $Mg^2 > Ca^2 > Sr^2$ ) is attributed to interstitial incorporation (coupled with HCO<sub>3</sub><sup>-</sup>) in the ice lattice, and controlled by ion size. Air bubbles nucleated once nitrogen supersaturation had reached values of 2-2.5 in the boundary layer and were incorporated into ice. These GI had dissolved air compositions modified by the differential diffusion of O<sub>2</sub>. N<sub>2</sub> and CO<sub>2</sub> out of the boundary layer, an O<sub>3</sub>/N<sub>2</sub> ratio of 0.4 being characteristic.

Freezing of solutions strongly supersaturated for calcite led to formation of impure (stage 3) ice in which ions are incorporated in similar proportions to those of the parent aq solution. Stage 3 ice contains both solid CaCO<sub>3</sub> and aq (solute-rich) I, asociated with an irregular ice-water interface. GI were invariably rich in CO<sub>2</sub> up to 63% by volume, yet represented only a small proportion of the CO<sub>2</sub> generated as a byproduct of CaCO<sub>3</sub> precipitation.

These data allow a better understanding of the expected chemical characteristics of ice that has formed from freezing of bulk water, including river icings, basal ice of glaciers, and local refrozen layers in firm and glacier ice. Generation of CO<sub>2</sub>-rich G bubbles by re-freezing is a powerful mechanism for modification of CO<sub>2</sub> compositions of bulk gaseous 1 in ice. (Authors' abstract)

Of pertinence to various FI freezing studies (E.R.).

KLEMD, R., 1998, Comment on the paper by Schmidt Mumm et al. High CO<sub>2</sub> content of fluid inclusions in gold mineralisations in the Ashanti Belt, Ghana: A new category of ore forming fluids?: Mineralium Deposita, v. 32, p. 107-118. Author at FB-Geowissenschaften, Universität Bremen, P.O. Box 330440, D-28334 Bremen, Germany.

See reply by Schmidt-Mumm et al., this volume (E.R.).

KLÜGEL, Andreas, 1998, Reactions between mantle xenoliths and host magma beneath La Palma (Canary Islands): Constraints on magma ascent rates and crustal reservoirs: Contrib. Mineral. Petrol., v. 131, p. 237-257. Author at GEOMAR, Abteilung Vulkanologie und Petrologie, Wischhofstr. 1-3, D-24148 Kiel, Germany; email (akluegel@geomar.de)

Spinel-bearing peridotitic mantle xenoliths from the 1949 eruption on La Palma were modified mineralogically and chemically during prolonged reactions with their host magma. The magmatism that brought the peridotites to the surface caused two distinct generations of xenolith fractures: (1) Old fractures are accompanied by 0.9-2 mm wide diffusion zones where peridotite olivine became less forsteritic through diffusive exchange with the host magma. (2) Young fractures show no selvages and only narrow diffusion zones of <0.02 mm width. Calculations based on a model of Fe-Mg interdiffusion give an age of 6 to 83 years and <4 days for old and young fractures, respectively. A combination of these data with Fl barometry indicates that selvages and veins formed during xenolith transport rather than representing wall-rock reactions or mantle metasomatism. The results provide ample evidence for prolonged storage of the xenoliths in the crust, constraining a multi-stage magma ascent. (From author's abstract by E.R.)

KNOLL, P., PRESSL, M., ABART, R. and KAINDL, R.A., 1998, Quantitative analysis of high density fluid inclusions: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p 843-846. First author at Inst. of Experimental Physics, Karl-Franzens Univ., Graz, Austria.

A combined microthermometric and micro-Raman spectroscopic method for the quantitiative analysis of FI is presented. This method avoids systematic errors due to nonlinear Raman behavior. The improvement on the accuracy of F-composition determination is demonstrated in the N<sub>2</sub>-CH<sub>4</sub> system. At F densities higher than 0.008 mole/cm<sup>3</sup> the accuracy is significantly increased. (Authors' abstract)

KODERA, P., RANKIN, A.H. and LEXA, J., 1998. Evolution of fluids responsible for iron skarn mineralisation: An example from the Vyhne-Klokoc deposit. Western Carpathians, Slovakia. Mineral. and Petrol., v. 64, p. 119-147. First author at Geological Survey of the Slovak Republic, Bratislava, Slovakia,

Vyhne-Klokoc, the largest Fe-skam deposit in the Western Carpathians, is related to the emplacement of a large granodiorite pluton in the central zone of a Neogene stratovolcano. Skarn mineralisation is developed in places where apophyses of the pluton intruded basement carbonates. Granodiorite in the apophyses grades into rocks of granitic composition, involving the replacement of mafic minerals and a concomitant decrease in Fe-content. Ca-magnetite exoskarns (not accompanied by endoskarns) developed in three paragenetic stages. FI data for quartz in granodiorite suggest the existence of aq F immiscibility during the early hydrothermal stages. Three end-members of FI were recognised, with a continuum between all three types. High sal, L-rich, probably S FI (29-68 wt.% NaCl eq., Th 450-570°C, composed of NaCl+FeCl2+KCl) coexist with V-rich Fl with low but variable salt contents (±CO2). Probably late S FI (1-25 wt.%. NaCl eq., composed mainly of NaCl+CaCl2, Th 188-283°C) form the other end-member type of FI trapped in granodiorite quartz. FI from skarn garnets show a large variation in sal (4-23 wt % NaCl eq., composed of NaCl±FeCl2+CaCl2+KCl+MgCl2) and Th (220-370°C), independent of the gamet types, probably reflecting variable amounts of magmatic F and low sal meteoric waters. FI in retrograde quartz, calcite, and sphalerite show progressively more dilute (0-4 wt.% NaCl eq., Th 215-380°C), probably dominantly meteoric F with evidence for boiling at shallow depth. Chlorite

crystallization T, calculated from the chlorite geothermometer, are in good agreement with the Th data for FI in associated skam minerals. Compositional changes in the granodiorite apophyses are the result of subsolidus autometasomatic reactions of accumulated saline magmatic F inside the apophyses with pre-existing mafic mineral phases. Reactions add the iron to the F - the potential source for magnetite skarn. Later mixing with dilute, cooler probably meteoric waters had the effect of decreasing the sal and density of the equilibrated magmatic F, making it more buoyant and capable of moving out from the apophyses into the country rocks, causing metasomatic reactions and precipitating magnetite. An overlap exists between the FI microthermometry data from P FI in garnets and late S FI in the granodiorite quartz indicating the same sources of the hydrothermal F probably mixtures of magmatic and meteoric waters. Based on FI, geological, petrological and mineralogical data, an integrated F evolution model involving magmatic and meteoric F is developed to explain the geological and F controls on Fe-skarn mineralization associated with granodiorite intrusions. (Authors' abstract)

KOEBERL, Christian, REIMOLD, W.U. and SHIREY, S.B., 1998. The Aouelloul Crater. Mauritania: on the problem of confirming the impact origin of a small crater: Meteoritics & Planetary Sci., v. 33, no. 3, p. 513-517.

Indexed under Fl.

KOLDÁEV, A.A., 1998, Thermobarometric studies of gas-liquid inclusions in infiltration minerals of weathering crusts on ultrabasic and mafic rocks (abst.): Second APIFIS Int'1. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 152-154 (in Russian).

KOLDÁEV, A.A. and FLITSIYAN, E.S., 1998, Features of a study of the microelemental composition of the formation of weathering crusts in connection with their origin (based on an instrumental neutron-activation analysis and neutron-activation autoradiography) (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 157-160 (in Russian).

KOLONIN, G.R., MORGUNOV, K.G. and STEPANCHIKOVA, S.A., 1998. Comparison of the experimental and thermodynamic methods of stability constant estimation of the REE chloride complexes at elevated temperatures using NdCl<sup>2+</sup> and HoCl<sup>2+</sup> as examples (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998. Extended Abstracts, p. 803.

KOMATSU, Ryo, IKEUCHI, Ken, DOI, Nobuo, SASAKI, Munetake, UCHIDA, Toshihiro and SASADA, Masakatsu, 1998, Characteristics of the Quaternary Kakkonda granite and geothermal system clarified by fluid inclusion study of deep investigation well, Kakkonda, Japan: J. of the Geothermal Research Soc. of Japan. v. 20, no. 3, p. 209-224 (in Japanese; Engl. abst.). First author at Japan Metals and Chemicals Co., Ltd., 72 Sasamori. Ukai, Takizawa, Iwate, 020-0172.

We performed FI study of an investigation well (WD-1a: 3.729 m in total depth) in the Kakkonda geothermal field, Japan. WD-1a was drilled in the Quaternary Kakkonda granite from 2,860 m through 3,729 m in depth which is the heat source of the Kakkonda geothermal system. The boundary between hydrothermal convection and heat conduction zones was found around 3,100 m by T loggings. We discussed thermal structure in the Kakkonda granite and permeation of meteoric water into the Kakkonda granite. T of the Kakkonda granite shallower than 3,100 m can be evaluated roughly from Th of the L-rich I which has a minimum sal in every depth. Since the Kakkonda granite deeper than 3,100 m is less permeable at greater depths, meteoric water permeates less into the Kakkonda granite. The evidence is as follows: (a) minimum sal of the L-rich I shallower than 3.250 m are close to 0 wt.%, although those deeper than 3.300 m increase. (b) Th of the L-rich I, which has minimum sal, increases just slightly between 2,750 m and 3,250 m, then they increase steeply deeper than 3,300 m. (c) according to the result of G analysis for FI by laser Raman microprobe spectroscopy, CO<sub>2</sub> and H<sub>2</sub>S were not detected shallower than 3.150 m, although they were detected deeper than 3.350 m. We also built a geothermal model of the Kakkonda field based on the FI study, showing thermal structure and F flow in the Kakkonda geothermal system. (Authors' abstract)

KOMOV, I.L., 1998. Diagnostics of captive minerals in inclusions (abst.): 17th General Meeting Int'l. Mineralogical Association. Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A32. Author at State Sci. Centre of Envir. Radiogeochemistry, Kiev, Ukraine; email (CEN-TER@radgeo.freenet.kiev.ua)

Various radiation procedures are used for identifying drns: coloration after X-ray dosage, INNA of drns, and IR spectroscopy. (E.R.)

KONÉEV, R.L., GÉRTMAN, Yu.L., and ZHURÁEV, A. Zh, 1998, Paragenetic analysis of capillary mineral-geochemical systems—classification and assessment of gold-silver mineralization (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 118-119 (in Russian).

KONTAK, D.J., 1998, A study of fluid inclusions in sulfide and nonsulfide mineral phases from a carbonate-hosted Zn-Pb deposit. Gays River, Nova Scotia, Canada: Econ. Geol., v. 93, p. 793-817. Author at Nova Scotia Dept. of Natural Resources, P.O. Box 698, Halifax, Nova Scotia, Canada B3J 2T9.

This paper reports on a detailed FI study of synore (sphalerite, calcite) and postore (calcite, fluorite, quartz, barite) mineral phases at the Gays River Zn-Pb deposit (2.4 Mt, 8.6% Zn, 6.3% Pb), Nova Scotia, Canada. The deposit is hosted by dolomitized bituminous carbonate rocks, and is dominantly of replacement style, with lesser porosity infilling. Paragenetically, constant volume dolomitization of the host rock is followed by euhedral, manganiferous dolomite cement, then sphalerite and galena. Syn- to postore calcite with trace amounts of barite, fluorite, and quartz, occlude the remaining porosity.

FI types include: (1) aq, L-rich±solids, including halite, (2) methane, (3) H<sub>2</sub>O-CO<sub>2</sub>, (4) monophase L and V types, and (5) L petroleum±aq phase. Type 1 inclusions are most abundant, types 2 and 3 are rare, and type 5 are postore. Type 4 I are mostly related to postentrapment changes (e.g., necking). Thermometric data indicate that the mineralizing F were high-sal, NaCl-CaCl<sub>2</sub>-H<sub>2</sub>O brines with 20 to 28 wt.% NaCl eq. Hydrohalite ice-melting relationships indicate considerable variation in the NaCl/(NaCl+CaCl<sub>2</sub>) ratio of the F (0.2-1). Lower sal FI (0-16 wt % NaCl eq.) are restricted to postore calcite and barite. Combined SEM-EDS analyses of decrepitate mounds identify Na, Ca, and Mg as the major solute components. Th for all mineral phases range from 70 to 250°C, but ranges of  $\leq 10-20^\circ$ C occur within isolated groups of I. Homogenization data on L petroleum I and associated aq I in fluorite are 120 to 150°C, whereas three petroleum I in syn- or postore calcite have Th values of 53, 53, and 167°C.

Bulk crush G chromatography indicates that I F contain up to 1.4 mol% combined CO<sub>2</sub> and CH<sub>4</sub> with the most abundant condensable G in sphalerite and galena. Since the high P ( $\leq 2.000$  bars) required to retain this G as dissolved species in the F are incompatible with the local stratigraphy, it is inferred that the G was either picked up along the F path and transported as an immiscible phase or was produced locally in the carbonate bank by thermal degradation of organic material.

The data are interpreted to indicate that a high-T (≤250°C), saline (ca. 25 wt % NaCl) metalliferous F migrated into the carbonate bank where it reacted with reduced sulfur generated by thermochemical sulfate reduction and mixed with an equally saline but lower T F. The variability of the NaCl/(NaCl+CaCl<sub>2</sub>) ratio of the F suggests contamination by dissolution of the host dolostone: this dissolution may also have provided some of the CO<sub>2</sub> component of the G. The P of the mineralizing environment is constrained at ca. 400 bars by the presence of L petroleum, aq and methane I, and their respective isochoric projections. The high T also suggest affinities with the Irish carbonate-hosted base metal deposits. (From author's abstract by E.R.)

See also Savard and Chi, Sangster et al., and Chi et al., this volume (E.R.)

KONTAK, D.J., HORNE, R.J., SANDEMAN, Hamish, ARCHIBALD, Douglas and LEE, J.K.W., 1998. <sup>40</sup>Ar/<sup>39</sup>Ar dating of ribbon-textured veins and wall-rock material from Meguma lode gold deposits, Nova Scotia: Implications for timing and duration of vein formation in slate-belt hosted vein gold deposits. Can. J. Earth Sci., v. 35, p. 746-761. First author at Nova Scotia Dept. of Nat. Res., P.O. Box 698. Halifax, NS B3J 219. Canada: URL (http://www.gov.ns.ca) Results of 15 <sup>40</sup>Ar/<sup>39</sup>Ar age spectra for whole-rock argillite samples

Results of 15<sup>40</sup>Ar/<sup>30</sup>Ar age spectra for whole-rock argillite samples collected from within and adjacent to veins from eight Meguma gold districts in the Meguma Terrane of southern Nova Scotia are presented. The samples give excellent plateau ages from ca. 379 to ca. 403 Ma. The results of this work compare well to previous whole-rock <sup>40</sup>Ar/<sup>30</sup>Ar dating of Meguma Group. However, with respect to the vein samples, there is a marked difference between the <sup>41</sup>Ar/<sup>30</sup>Ar ages of vein-hosted whole-rock

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samples and hydrothermal minerals (amphibole, muscovite, biotite) from the same deposits previously dated, which indicates that whole-rock samples have retained their metamorphic ages and have not been reset by the later hydrothermal event responsible for vein formation, despite being incorporated within the high-T F (approximately 400-450°C). This discrepancy in ages indicates that the wall rocks and veins were in thermal disequilibrium, as the vein T were well above that required to cause diffusion of argon out of mica phases within the whole-rock samples, and implies therefore that the F must have been derived from depth. The results have the following important implications for models of vein formation: (i) vein formation was rapid and is consistent with models of hydrofracturing due to F overpressure, and (ii) the vein-forming F were derived from depth and cannot have been produced by a lateral sccretion processes whereby F and gold are derived from the Meguma Group. (From authors' abstract by E.R.)

KONTAK, D.J. and SANGSTER, D.F., 1998, Aqueous and liquid petroleum inclusions in barite from the Walton deposit, Nova Scotia. Canada: A carboniferous, carbonate-hosted Ba-Pb-Zn-Cu-Ag deposit: Econ. Geol., v. 93, p. 845-868. First author at Nova Scotia Dept. of Natural Resources. P.O. Box 698, Halifax, Nova Scotia, Canada B3J 2T9.

The Walton Ba-Pb-Zn-Cu-Ag deposit is hosted by sideritized carbonates. Barite occurs in a variety of forms and overlaps the deposition of sulfide minerals.

All barite types are characterized by the presence of abundant aq and L petroleum FI that are of dominantly equant shape, of P and S origin, and s100- to 150-µm size. Inclusions are classified as (1) L- and V-rich aq with rare solid phases, (2) mixed CO2 and CH4 (rare), and (3) L petroleum with rare bitumen. It is not possible to establish a chronology for the different F and all types may, in fact, be closely related temporally and spatially. The occurrence of three-phase aq-petroleum l, indicative of heterogeneous trapping, indicates contemporaneity of the aq and petroleum I. The aq I are dominated by high-sal types (20-28 wt % NaCl eq.), but intermediate- and low-sal types also occur. Observations of first melting (eutectics at -55 and -35°C) and final melting (ice and hydrohalite) indicate that F compositions varied in terms of NaCl/(NaCl+CaCl2)(≤0.1-1.0) and NaCl/(NaCl+MgCl2)(0.2-0.84) ratios. Preliminary SEM-EDS analysis of decrepitate mounds confirms the presence of Na, Ca, and Mg and also indicates K. Fe, and Mn in solution. The lack of clathrate phases suggests that, if present, condensed G (e.g., CH4, CO2) occur in only minor to trace amounts in aq I. Th cover a broad range with maximum T of ca. 300°C

L petroleum I, with a blue-white color under ultraviolet light, occur in isolated populations with uniform L/V ratios characterizing a particular group. Th range from ca. 100 to 300°C, similar to the range for aq. I but within a group a much narrower range is recorded. The high Th and rare occurrence of bitumen in the 1 predicates rapid, postentrapment cooling of the area (i.e., within a few kiloyears), otherwise degradation of the petroleum would have occurred in the presence of L petroleum with the petroleum causing reduction of aq sulfate to H<sub>2</sub>S.

Collectively, the FI data indicate that mineralization occurred at ambient conditions of 250 to 300°C and P of ca. 400 bars, as constrained for different I types. The L petroleum is considered to have been generated by thermogenic processes via interaction of the heated, highly saline mineralizing F with organic-rich beds and was subsequently entrained as an immiscible phase within the aq F. Generation of the hydrothermal petroleum at Walton is analogous to the present-day occurrence of L petroleum vented from black smokers on the ocean floor (e.g., Guaymas basin). (From authors' abstract by E.R.)

See also Chi et al., Sangster et al., and Savard and Chi, this volume (E.R.).

KOOI, M.E., SCHOUTEN, J.A., van den KERKHOF, A.M., IS-TRATE, G. and ALTHAUS, E., 1998. The system CO2-N2 at high pressure and applications to fluid inclusions: Geochim et Cosmo. Acta. v. 62, no. 16, p. 2837-2843. First author at Van der Waals-Zeeman Inst., Univ. of Amsterdam, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands.

Postulated F-F immiscibility of 50-50% CO<sub>2</sub>-N<sub>2</sub> mixtures has been checked by high-P experiments (<5 GPa; <400 K) and could be rejected. The implications for the interpretation of high-density Fl (<42 cm<sup>3</sup>/mole) in eclogite and granulite-facies rocks are discussed. only models based on LG-immiscibility are applicable for molar volume calculations also in the very-high-P range. The position of the critical curve for CO<sub>2</sub>-N<sub>2</sub> could be more accurately determined with the help of experimental and FI data. The S<sub>2</sub>-F isopleth and the three-phase (S<sub>1</sub>S<sub>2</sub>F) line have been established for

50.6% N2 composition. (Authors' abstract)

KORMUSHIN, V.A., 1997, The feeler for the thermal influence on fluid inclusions: II Symposium APIFIS (Asian & Pacific Int'l. Fluid Inclusion Society) Program, Tashkent, Uzbekistan, p. 38. Author at Scientific Soc. of Ore-forming Fluid Research in Inclusions of Minerals of Uzbekistan.

It is well known that the thermal influence causes to move G bubbles in FI (1). The nature of this motion is not studied yet. The feeler (2) had been contrived for the thermal pointed influence on micro-objects within the eyeshot of microscope. The feeler is applied for study of FI in thin polished plates, petrographic and immersed preparations with no destruction. It has T register and may influence on FI in the regime of regulated heating as well as create the gradient thermal flow of variable intensity at any horizontal direction. The device is of a little size and convenient in work. The application of the described device will promote the additional information about physico-chemical features of ore forming F [sic]. (Author's abstract)

KOVAL, P.V. and PROKOF'EV, V.Yu., 1998, P-T conditions of crystallization of granitoids in the Mongolia-Okhotsk zone: Evidence from studies of melt and fluid inclusion in minerals: Petrologiya, v. 6, no. 5, p. 497-511 (translated in Petrology, v. 6, no. 5, p. 451-465). Authors at Vinogradov Inst. of Geochem. and Analytical Chem., Siberian Div., Russian Acad. of Sci., ul. Favorskogo 1a, Irkutsk, 664033 Russia.

The crystallization conditions of granitic rocks of the Mongolia-Okhotsk zone were estimated on the basis of data on their geochemistry and 1 in minerals at 1235-540°C and 8000-90 bar at a content of water of 13.9-0.2 wt.%. The range of the physicochemical conditions of granitoid M crystallization (T, P, and water concentration in the M) increased to the highest (possible under crustal conditions) values with decreasing depth facies of the granitoids. The estimates obtained on the batholithic levels of the intrusions usually correspond to the range of the main modal values of the distributions. Extreme values were commonly yielded by small and metalliferous granitoid intrusions of the rare-metal geochemical types. It was demonstrated that granitoids of the rare-metal geochemical types can form by means of the F-magmatic differentiation (metamagmatic transformation) of earlier palingenetic granitoid M in the presence of CO<sub>2</sub>-rich F. F-magmatic differentiation played an important part in the development of metalliferous magmatic systems. (Authors' abstract)

KOVALENKER, V.A., 1998a, Epithermal fluid-magmatic systems: sources of water, composition of ore-forming solutions, and parameters of mineral-formation (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis. Oct 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 112-115 (in Russian).

See following item (E R.).

KOVALENKER, V.A., 1998b. Epithermal fluid-magmatic systems: sources of water, composition of ore-forming solutions, and parameters of mineral-formation (abst.) Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume. p. 115-117 (in English). (English translation of preceding item). Author at Inst. of Geol. of Ore Deposits. Petrog., Mineral, and Geochem. (IGEM) RAS, 109017, Russia, Moscow, Staromonetny 35.

A review of epithermal deposits and the literature on their megatectonic environments and the chemistry of their F, from FI studies (E.R.)

KOVALEVICH, V.M., PERYT, T.M. and PETRICHENKO, O.I., 1998, Secular variation in seawater chemistry during the Phanerozoic as indicated by brine inclusions in halite J of Geology. v. 106, p. 695-712. Authors at Inst. of Geol and Geochem. of Combustible Minerals, Naukova 3A, 290053 Lviv, Ukraine.

Analysis of data on the chemical composition of P FI (brine I) in Pbedded halite from many evaporite formations of northern Pangea shows that during the Phanerozoic the chemical composition of marine brines was oscillating significantly between the Na-K-Mg-Ca-Cl type and the Na-K-Mg-Cl-SO<sub>4</sub> type. We regard those changes as corresponding to the chemical evolution of the Phanerozoic ocean. The changes correlate in time with earlier suggested secular changes in the mineralogies of marine nonskeletal himestones and potash evaporites. In addition to those secular changes of seawater chemistry, the concentrations of K, Mg, Ca, and SO<sub>4</sub> ions in marine brines underwent important changes under the influence of local factors, including rock-water interaction. These S changes did not influence the principal chemical type of the brine characteristic for a given time interval. In the past concentration of the Ca-ion did not exceed the present concentration in marine water by a factor of three, and the increase was synchronous with a decrease in the SO<sub>4</sub> ion concentration. This could be as much as three times lower when compared to the present concentration of that ion in seawater. (Authors' abstract)

# KOVALEVICH, V.M., PERYT, T.M., PETRICHENKO, O.I.,

HORITA, Juske and HOLLAND, H.D., 1998, Brine inclusions in halite and the origin of the Middle Devonian Prairie evaporites of western Canada; discussion and reply: J. of Sedimentary Research, v. 68. no. 1, p. 228-231.

KOZIOL, A.M. and NEWTON, R.C., 1998, Experimental determination of the reaction: Magnesite + enstatite = forsterite + CO<sub>2</sub> in the ranges 6-25 kbar and 700-1100°C: American Mineralogist, v. 83, p. 213-219. First author at Dept. of Geol., Univ. of Dayton, Dayton, Ohio 45469-2364. USA.

KOZLÓV, V.V., 1998: Mineralogy and origin of the Chadak Au-Ag hydrothermal deposit, Uzbekistan (abst.): Second APIFIS Int'l, Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 125-129 (in English). Author at Inst. of Geol, and Geophys., Tashkent, Uzbekistan.

The Chadak deposits, including the Kyzylcheku, Shkol'noe and Bichanzor gold deposits, represent the volcanic-hosted low-sulfidation, adularia-sericite type of gold deposits with 'an anomalous regime' of F evolution, e.g. high T jumps after the main stages of epithermal ore deposition. As a result, wollastonite and garnet-bearing, skam-like assemblages are developed after carbonate in quartz-carbonate-adularia gold bearing veins. The mineralogical, stable isotope and Fl evidences suggest the invasion of high-T F into the buried epithermal vein systems and their progressive mixing with meteoric water, oxidation and cooling. The mineralogy of the vein systems is very complex. The Chadak vein systems developed during four major mineralization events, which represent different F pulses of a different T and composition: I. Au-Ag lode adularia-sericite-type mineralization; II. Skam-like calc-silicate, Ag-Au-Bi-Pb-Zn-Cu - bearing mineralization replaced most of the older gold-bearing quartz-calcite-adularia veins in several vein systems. Vertically, skarn mineralization is located in the calcite-bearing upper part of the vein system. Extensive recrystallization and partial re-deposition of the older Au-Ag ores took place during both prograde and retrograde stages. Th ranges from 100 to 600°C; Ill. Quartzhematite Cu-Bi-bearing mineralization with Th 150-272°C, and 818Owater -8.8% in the F; IV. Quartz-barite-fluorite Pb-Zn-bearing mineralization, with FI Th ranging 210 to 90°C

A study of mineralogy and FI in Au-Ag veins of the Chadak deposit has revealed a complex history of F inputs and mineralization events. The results of our studies demonstrate a change in F regime from low saline, relatively reduced, low CO<sub>2</sub> F, typical for Au-Ag epithermal deposits, to saline, oxidized F enriched in CO<sub>2</sub>, similar to the F from Pb-Zn skam deposits. An invasion of high T brines into the Chadak epithermal system of shallow levels was a result of magmatic and tectonic activation of the ore field. There are no clear evidences for significant difference in time of formation between epithermal Au-Ag and subsequent high-T Ca-silicate mineralizations in Chadak and other deposits with 'an anomalous regime' of F evolution. This type of 'anomalous' deposit may present direct evidence for temporary, spatial and genetic link between some Au-Ag lowsulfidation deposits and other style of mineralization well known in the region: Pb-Zn skarns and porphyry-copper. (From author's abstract by E.R.)

KOZLÓV, V.V., SMIRNÓVA, S.K. and USMÁNOV, A.I., 1998. The use of modern equipment in the thermometry and analysis of the composition of fluid inclusions (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 163-165. (in Russian).

See Translations.

KOZLOWSKI, A., SLABY, E., FILA, E., MARCINOWSKA, A. and ILNICKI, S., 1997, Geochemical constraints of the metasomatic Tourmaline formation in the Izera area. Poland: Abstracts, Int'l. Symposium on Tourmaline, June 20-25, 1997, Ministry of Educ., Czech Republic. First author at Inst. of Geochem., Mineral. and Petrog., Fac. of Geol. of the Warsaw Univ., 02-089 Warszawa, al. Zwirki i Wigury 93, Poland.

Metasomatizing solutions were investigated by means of FI methods in the minerals of albitite, greisens and veins. The parent F of the metasomatites were mainly L, i.e., hydrothermal, pneumatolytic I were found only exceptionally. T of the metasomatic process decreased gradually. Albite and quartz from albitites (leucogranites) crystallized at almost 500-400°C [all Th=pressure corrected]. Different tourmaline associations yielded variable T (530-350°C). Early topaz in greisens crystallized at 530-490°C, main-phase topaz at 500-410°C and the late one at 400-360°C. Fluorite dispersed in greisens and albitites formed at 380-300°C, nest fluorite at 290-230°C and veinlet fluorite at 260-130°C

The solution P (determined from CO<sub>2</sub>-bearing I) changed from ca. 0.9 kbar to ca. 0.5 kbar at the end of the process. For crystallization of the albitite minerals it has typical value of ca. 0.8 kbar, for tournaline, 0.9-0.7 kbar, for topaz, 0.8-0.4 kbar and for fluorite ca. 0.5 kbar. The lower P values during the topaz and fluorite formation could be connected with opening of small fissures and voids.

Carbon dioxide content and sal varied strongly, probably by inflow of separate portions of solutions. The richest in CO<sub>2</sub> were connected with the highest sal, achieving 20 wt%, and occasionally exceeding this value. The solutions initially were of Na-type, subsequently being enriched in Ca and K. The maximum of Ca concentration and minimum of Na occurred during fluorite crystallization. The highest K concentrations were found at the decline of topaz crystallization, when it was partly replaced by muscovite. (From authors' abstract by H.E.B.)

KRAVCHUK, I.F., MALININ, S.D. and SLUTSKY, A.B., 1998, Chlorine in fluid-magmatic systems: Experimental data (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 811. Authors at Vernadsky Inst. of Geochem., Russian Acad. of Sci., 117975, Moscow, Russia.

Experimental studies of chlorine solubility in M of various compositions and its partitioning between the phases were conducted in high-P cells of three types, viz: horizontal two-chamber bomb, G bomb, and cylinderpiston apparatus at T 800-1200°C and P to 15 kb. Natural and model systems of from basaltic to granitic compositions were studied in equilibrium with water-chloride F of various concentrations. (From authors' abstract by E.R.)

KREKELER, M.P.S., HUFF, W.D., BERGSTROM, S.M., KOLATA, D.R. and CINGOLANI, C., 1998, Petrology and volcanology of Middle Ordovician K-bentonites from Cerro Viejo, San Juan Province, Argentina and Paleogeographic implications for the Argentine Precordillera (abst.): The Geological Society of America 32nd Annual Meeting, North-Central Section, March 19-20, 1998, Columbus, Ohio v. 30, no. 2, p. 29, ISSN 0016-7592.

Trace element and REE data from whole rock samples indicate that these beds were derived from highly evolved silicic magmas. K-bentonites overlap in Volcanic Arc Granite (VAG) and Within Plate Granite (WPG) fields in discrimination diagrams. K-bentonites are enriched in LREE, depleted in HREE, and have negative europium anomalies. These data indicate that the K-bentonites originated from subduction zone related volcanism where a large crustal component was mixed with magmas. MI data from P quartz phenocrysts show these beds to be High K rhyolites having 3.6 to 4.6 wt% K<sub>2</sub>O and 73.5 to 75.5 wt% SiO<sub>2</sub>. Total volatiles in the MI range between 2.0 to 4.7 wt%. (From authors' abstract by H.E.B.)

KRÜGER, Yves, and DIAMOND, L.W., 1998, Behavior of synthetic fluid inclusions in the system H<sub>2</sub>O-NaCI-CO<sub>2</sub>-Ag: Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 39. Authors at Mineralogisch-Petrographisches Institut, Universität Bern, CH-3012 Switzerland.

In attempting to quantify P-V-T-X properties in part of the ternary system H<sub>2</sub>O-NaCl-CO<sub>2</sub> we conducted eight syntheses of FI from a 6 wt% NaCl solution and silver oxalate (Ag<sub>2</sub>C<sub>2</sub>O<sub>4</sub>) at 500-700°C and 1400-5000 bar. Under all these conditions we expected homogeneous entrapment of FI with a bulk composition of 9.69 mol% CO<sub>2</sub> and 1.74 mol% NaCl, and we expected that Ag would behave as an inert component. However, the I showed significant deviations from the expected behavior

Clathrate dissociation T (CLA $\rightarrow$ LlQ<sub>AQ</sub>+LlQ<sub>CO2</sub>+VAP) vary by up to 1.3°C and total Th (LlQ+VAP $\rightarrow$ LlQ) vary by up to 25°C. In most I two dxl are observable: (1) chlorargyrite (AgCI) was identified by irradiating the I with ultraviolet light such that the originally transparent crystals turned black due to a photochemical reaction, and (2) nahcolite (NaHCO<sub>3</sub>) was identified by its high interference colors under crossed polarizers and by laser Raman spectroscopy.

We attribute the observations to "loss" of CO<sub>2</sub> from the V phase to nahcolite and to aq HCO<sub>3</sub>. In accord with this idea we detected a distinct Raman peak in the aq phase at 1017 cm<sup>-1</sup> (corresponding to the C–OH stretching vibration, Davis and Oliver, 1972, J Solution Chem. I 329-

339). The quartz host showed no peak at this position, hence we infer that the aq phase indeed has significantly enhanced concentrations of HCO<sub>3</sub>.

I synthesized by the silver oxylate method need to be carefully checked for dxl, for correlations in microthermometric data, and for compatible molar volumes, before reliable P-V-T-X data can be derived for the geologically important CO<sub>2</sub>-H<sub>2</sub>O-NaCl ternary. (From authors' abstract by E.R.)

KUNZ, Joachim, STAUDACHER, Thomas and ALLÈGRE, C.J., 1998, Plutonium-fission xenon found in Earth's mantle: Science, v. 280, p. 877-880. First author at Institut de Physique du Globe de Paris. Laboratoire de Géochimie et Cosmochimie, Centre National de la Recherche Scientifique, URA 1758, 4 place Jussieu, F-75252 Paris Cedex 05. France.

Data from mid-ocean ridge basalt glasses indicate that the short-lived radionuclide plutonium-244 that was present during an early stage of the development of the solar system is responsible for roughly 30% of the fissiogenic xenon excesses in the interior of Earth today. The rest of the fissiogenic xenon can be ascribed to the spontaneous fission of still live uranium-238. This result, in combination with the refined determination of xenon-129 excesses from extinct iodine-129, implies that the accretion of Earth was finished roughly 50 million to 70 million years after solar system (Authors' abstract)

KUROSAWA, M., SHIMANO, S., SASAKI, M., FUJIMOTO, K., SHIMA, K., OSHIMA, H., ISHII, S. and SUENO, S., 1998, Chemical analyses of fluid inclusions by the LAM-ICP-MS and PIXE (abst.): 1998 Annual Meeting of the Mineralogical Society of Japan/Japan Association of Mineralogists, Petrologists and Economic Geologists, Kyushu University, Oct 8-10, 1998, p. 153 (abst. in Japanese).

KUSTÁRNIKOVA, A.A. and USMÁNOV, A.L., 1998, The decomposition of volcanic glass and its effect on mineral-formation in the palaeo-rift basalts of the southern Tien-Shan (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 48-51 (in Russian).

KYLE, R.J., HARRISON, Jeffrey, PENNINGTON, Jay and KAVA-LIERIS, Imants, 1998, Fluid evolution history for the giant Grasberg porphyry Cu-Au system, Irian Jaya, Indonesia (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A98. First author at Dept. of Geological Sci., Univ. of Texas, Austin, Texas, 78712, USA: email (tkyle@mail.utexas.edu)

The Grasberg deposit within the Central Range of the island of New Guinea is one of the world's richest Cu-Au systems with proven reserves of 19 mt of Cu and 1450 t of Au. The Grasberg deposit is the principal orebody of the Ertsberg District which also includes proximal Cu-Au-bearing skarns in mixed carbonate-siliciclastic wall rocks and distal Zn-Pb-Ag replacement zones in carbonate wall rocks. Total production of Ertsberg District porphyry and skarn ores since 1972 is >300 mt of ore averaging 1.7% Cu. 1.1 g/t Au, and 5.4 g/t Ag.

FI studies indicate a change from high T (500+°C), high sal F of "magmatic" origin with characteristic Cu- and Fe-bearing dm in the Grasberg Igneous Complex (GIC) quartz stockwork to lower T and sal F in distal deposits and late-stage minerals. Late-stage quartz-sulfide veins within Kucing Liar contain halite-bearing Fi with Th of 300-450°C. Synchrotron XRF analysis of FI in Grasberg stockwork quartz reveals high concentrations of Cu and Fe, as well as metals (Zn. Pb, Mn) that generally occur peripheral and paragenetically late with respect to Cu. These relationships and other geochemical information indicates that the metals in the GIC mineralizing system were supplied from a deep magmatic source and overprint diverse host rocks at shallow crustal levels. (From authors' abstract by H.E.B.)

LABOTKA, T.C., ANOVITZ, L.M., BLENCOE, J.G. and SEITZ, J.C., 1998, The effects of the mixing properties of H<sub>2</sub>O-CO<sub>2</sub> on the flow of metamorphic fluids (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-319.

LAIER, T. and NYTOFT, H.P., 1998. Isotopically heavy natural gas in Pre-Cambrian crystalline rocks—South Greenland. An example of extreme fractionation due to migration (abst.): American Chemical Society 215th National Meeting Program, Dallas, TX, March 29-April 2, 1998, paper no. 016.

Natural G. C1-C5, I in the Precambrian crystalline rocks of the Ili-

mausaq intrusion, 1100-1300 MA, is isotopically heavy.  $\delta^{13}$ C of methane and ethane being 1.6-5.0% and 9.2-12.5% respectively. The G content in the rocks vary from 50 to 100 mg/kg of rock. The presence of bitumen, 100-150 mg/kg of rock, containing biomarkers typical of Proterozoic organic matter suggest an organic origin of all hydrocarbons in the crystalline rocks. Isotopic fractionation due to diffusive loss of G is thought to be responsible for the isotopically heavy signature of the gases. The systematic variation in G composition, e.g.,  $C_1/C_2$  and  $iC_4/nC_4$  with the  $\delta^{13}$ C value of methane further support this hypothesis. (Authors' abstract)

LANG, J.R., BAKER, Tim and LEWIS, P.D., 1998, Intrusive, stratigraphic, geochemical and structural controls on skarn and massive sulphide manto/chimney ores in the La Negra and Zimapan districts, central Mexico (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A101-A102. First author at Mineral Deposit Research Unit, Univ. of British Columbia, Vancouver, BC, V6T 1Z4; email (jlang@eos.ubc.ca)

Skam alteration evolved similarly in each area. Stage 1 is barren, present only at La Negra and is dominated by spurrite. Stage 2 is pervasive, barren, anhydrous gamet-dominated endo- and exoskam. Stage 3 is well-mineralized, pervasive to fracture-controlled, gamet-pyroxeneamphibole exoskam. Calc-silicates in mantos and chinneys are restricted to the vicinity of dikes. Pervasive alteration of intrusions comprises a potassic assemblage at La Negra and El Monte and a sericitic assemblage at Carrizal. Fl document a decrease in T (700-<200°C) and sal (>50 to <10 eq. wt%), 325-425°C from non-boiling, NaCl-KCl- CaCl<sub>2</sub>-H<sub>2</sub>O brines. Oxygen isotopes decrease from 9-12‰ (Stage 2) to 4-10‰ (Stage 3). Galena Pb isotopes are similar to igneous compositions. (From authors' abstract by H.E.B.)

LARGE, R.R., BULL, S.W., COOKE, D.R. and McGOLDRICK, P.J., 1998, Genetic model for the HYC deposit, Australia: Based on regional sedimentology, geochemistry, and sulfide-sediment relationships: Econ Geol., v. 93, p. 1345-1368. First author at Centre for Ore Deposit Research. Univ. of Tasmania, GPO Box 252-79, Hobart. Tasmania 7001, Australia: email (Ross.Large@utas.edu.au)

The fine-grained, laminated, stratiform zinc-lead ores of the McArthur River (HYC) ore deposit have been the subject of continued debate in regard to the timing of zinc-lead mineralization—sedex or syndiagenetic replacement. Several lines of evidence are used here to demonstrate that a synsedimentary origin is likely for the HYC deposit.

The detailed nature of the layering in the ores suggests that the introduction of metalliferous brines into the basin was not continuous but occurred as a series of pulses interspersed with pelagic sedimentation and turbidite deposition. Preliminary calculations suggest that on the order of 10.000 discrete pulses of brine were required to form each ore lens, and it is suggested these pulses were related to microseismic activity following each major seismic event in the basin.

Solubility considerations indicate that the mineralized brines were most probably sulfate-rich ( $SO_4^2 > H_2S$ ) and capable of transporting up to several thousand ppm zinc and lead at moderate T (150-250°C), and nearneutral pH. Zinc-lead deposition was the result of two possible processes: (1) thermochemical reduction of brine sulfate by organic matter in anoxic basin water, and (2) diffusion of H<sub>2</sub>S from the anoxic water column into the metalliferous brine layer. Sulfur isotope data are best explained if both processes operated together to deposit galena and sphalerite. (From authors' abstract by E.R.)

LARSEN, R.B., 1998, Composition of volatile fluids in granite pegmatites, south Norway: Implications for genesis of high-purity quartz (abst.): 23<sup>rd</sup> Nordic Geological Winter Meeting, 13-16 January, 1998, Abstract Volume, p. 177. Author at Geological Survey of Norway, P.O. Box 3006, N-7002 Trondheim, Norway.

FI studies including more than 650 microthermometric measurements and a few Raman microprobe analyses were conducted on quartz from the intermediate zone of seven pegmatites. All the studied I are P, show an- to euhedral morphologies, are typically 4-8  $\mu$ m in diameter and contain saline solutions and 10-15 vol.% of a carbonic phase. All but one pegmatite have ThCO<sub>2</sub> L-28°C; one, with traces of N<sub>2</sub>, has ThCO<sub>2</sub> = 10°C. Initial melting of ice at or close to -21°C, imply that NaCl is the dominant salt species in the aq phase and clathrate melting T document strongly contrasting sal from 6.4 to 17.4 wt.% NaCl eq., following a crude declining trend from north to south. Preliminary LA-HR-ICP-MS analysis [laser ablation, high resolution-ICP-MS] of quartz from the same pegmatites, show that the total concentration of structural admixtures in quartz increases parallel with the decrease of sal. (From authors' abstract by H.E.B.)

LARSEN, R.B., EIDE, E.A. and BURKE, E.A.J., 1998. Evolution of metamorphic volatiles during exhumation of microdiamond-bearing granulites in the western gneiss region, Norway: Contrib. Mineral. Petrol., v. 133, p. 106-121. First author at Geological Survey of Norway, P.O. B. 3006, N-7002 Trondheim, Norway; email (rune.larsen@ngu.no)

FI in garnet, kyanite and quartz from microdiamond-bearing granulites in the Western Gneiss Region, Norway, document a conspicuous F evolution as the rocks were exhumed following Caledonian high- and ultrahigh-P (HP-UHP) metamorphism. The most important of the various F mixtures and dm in these rocks are: (N2+CO2+magnesian calcite), (N2+CO2+CH4+graphite+magnesian calcite), (N2+CH4), (N2+CH4+H2O). (CO2) and (H2O+NaCI+CaCl2+nahcolite). Rutile also occurs in the N2+CO2 inclusions as a product of titanium diffusion from the garnet host into the Fl. Volatiles composed of N2+CO2+magnesian calcite charcterise the ambient metamorphic environment between HP-UHP (peak) and early retrograde metamorphism. During progressive decompression, the mole fraction of N2 increased in the F mixtures; as amphibolite-facies conditions were reached, CH4 and later, H2O, appeared in the F, concomitant with the disappearance of CO2 and magnesian calcite. Graphite is ubiquitous in the host lithologies and Fl. Thermodynamic modelling of the metamorphic volatiles in a graphite-buffered C-O-H system demonstrates that the oberved metamorphic volatile evolution was attainable only if the fO2 increased from c -3.5(±0.3) to -0.8(±0.3) log units relative to the FMQ oxygen buffer. External introduction of oxidising ag solutions along a system of interconnected ductile shear zones adequately explains the dramatic increase in the /O2. The oxidising F introduced during exhumation were likely derived from dehydration of oceanic crust and continental sediments previously subducted during an extended period of continental collision in conjunction with the Caledonian orogeny. (Authors' abstract)

LARSEN, R.B. and POLVÉ, M., 1998. Trace element distribution in pegmatitic quartz: Petrogenetic applications to granite pegmatites in south Norway (abst.); 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs. p. A147. First author at Geological Survey of Norway.

FI studies and solution ICP-MS analysis of quartz were combined with XRF analysis of feldspar and mica separates from the intermediate and core zones of Late Proterozoic granite pegmatites in South Norway. P FI in quartz contain 6.4-17.4 wt% NaCl and 5 mol% CO<sub>2</sub> and belong to the H<sub>2</sub>O-CO<sub>2</sub>-NaCl-(±N<sub>2</sub>) system. In correlation with mineral compositions, total F sal follow a crude declining trend from N to S. Given these constraints, the trace element distribution in quartz imply that pegmatites formed from progressively more differentiated granitic M toward the south. Compositional changes of FI, feldspar and biotite conform to this model, and it can be concluded that trace element analysis of quartz may provide an important tool in understanding pegmatite forming processes. Results of complimentary in situ laser ablation HR-ICP-MS analysis of REE in quartz are in progress. (From authors' abstract by E.R.)

LAWRIE, K.C. and HINMAN, Mark, 1998. Exploration model for Cobar Au-Cu-Ag-Pb-Zn deposits (abst.): Geological Society of Australia, Abstracts No. 49. 14th Australian Geological Convention, Townsville, July 1998, p. 260. First author at James Cook Univ. of North Queensland.

Cobar deposits comprise multiple epigenetic lodes that are highly discordant to stratigraphy and occur as vertically continuous pipes, lenses and veins of narrow width and short strike length. Metal ratios vary from N to S and also vary significantly between adjacent orebodies, with vertical and lateral zonation common within individual lodes.

Two F components were involved in deposit formation. These are (1) a relatively reduced (pyrrhotite+/or pyrite-stable) F that evolved from nalkane to C<sub>2</sub>H<sub>4</sub>-rich compositions prior to mineralisation, and progressed to hotter, more saline and CH<sub>4</sub>-rich compositions during mineralisation. This F is considered to be of basinal (connate) origin; (2) a more oxidised (pyrite or magnetite-stable) H<sub>2</sub>O-CO<sub>2</sub> F that is high T but has low sal. This F is considered to have been derived from the basement (metamorphic and/or igneous origin). Ore precipitation resulted from the mixing of these two F with contrasting T, redox properties; and compositions including sal. Pb isotope data supports a mixing model: the Pb-Zn end member of the mineralisation spectrum appears to represent basinal-source dominance, whereas Cu-Au mineralisation is basement-source dominant, although still mixed. A meteoric F component may be present in some deposits.

The metal contents of Cobar deposits differ from other sedex deposits due to F sourcing from regions external to as well as within the host basin. Lower F sal, a greater (and higher) F T range, and precipitation due to F mixing also contribute to the complexity of observed metal ratios in Cobar deposits. More 'typical' sedex Pb-Zn-Ag deposits may occur elsewhere within the Cobar Basin. (From authors' abstract by E.R.)

LAWRIE, K.C., JAIRETH, Subhash, A-IZZEDDIN, David and GRACE, Jason, 1998, Gold localisation in a lateral ramp within a reactivated mylonite: The Golden Butterfly deposit, Croydon goldfield, N.Q. (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 261. First author at James Cook Univ. of North Queensland.

Au occurs within numerous quartz veins which are hosted within the Proterozoic Croydon Volcanic Group and granites. Mineralisation is localised within restricted domains along these veins, and generally considered to lie at the intersection of lodes with graphitic zones within granites and volcanics, and/or cross-cutting faults. Au mineralisation is coincident with brittle-ductile shearing of buck quartz, sericitic alteration, and formation of extensional comb quartz textures. FI data for mineralised comb quartz veins shows that F were saline (5-15 wt% NaCl eq.), and of moderate T (max. Th 259°C). Au was most likely transported as a thio complex, and most likely precipitated as a consequence of redox reactions between graphitic wallrocks and relative oxidised hydrothermal F. However, there is evidence for mixing with a cooler, less saline F in some comb quartz veins. (From authors' abstract by E.R.)

LAWRIE, K.C., MERNAGH, Terrance, BLACK, Lance and WY-BORN, Doone, 1998, Au-Cu mineralisation at the Bald Hill prospect, L.F.B., N.S.W. (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 262. First author at Australian Geological Survey Organisation. GPO Box 378, Canberra, ACT 2601.

Bald Hill is a Au-Cu prospect in the Lachlan Fold Belt, hosted in a small pluton. Two zones of mineralisation are recognised within the pluton: a northern Au-Cu zone and a southern Au-dominant zone. Preliminary results from the northern zone show that the main alteration and mineralisation paragenesis is: <u>Pre-ore</u>: Sulphide-poor quartz veins, and silicification and albitisation of groundmass; <u>Syn-ore</u>: Sulphide-bearing quartz veins and disseminated mineralisation.

A reconnaisance Fl study revealed that pre-ore F are  $H_2O$ -CH<sub>4</sub>-bearing (no CO<sub>2</sub> detected). This suggests that the F was reduced. I have Th in the range 300-400°C, are L-rich, with high potassium in the F possibly indicated by small solid mica 1. The syn-ore F has a similar H<sub>2</sub>O-CH<sub>4</sub> composition (no CO<sub>2</sub> detected). In this stage, heterogeneous L-V ratios within individual quartz crystals suggest phase separation occurred at the time of mineralisation. V ratios up to 50% are preserved in P and PS I. High sal are indicated by the presence of halite and other phases within I.

In summary, mineralising F appear to have been reduced, of moderate T and high sal. Ore deposition may have been coincident with phase separation related to de-pressurisation within active brittle-ductile faults that intersect the pluton. It is considered likely that the Bald Hill Au-Cu prospect is related to reduced I-type magmas emplaced at relatively shallow crustal levels, although the host pluton itself may not be the phase of magmatism from which mineralising F were derived. (From authors' abstract by E.R.)

LAYNE, G.D. and SHIMIZU, N., 1998. In situ measurement of lead isotope ratios in minerals and melt inclusions using high resolution-high transmission secondary ion mass spectrometry (SIMS) (abst.): EOS Trans. AGU, 79(17). Spring Meet. Suppl., p. S353. Authors at Woods Hole Oceanographic Inst., MS23, Woods Hole, MA 02543-1541, USA; email (glayne@whoi.edu)

Large format high resolution-high transmission SIMS has been successfully applied to the measurement of Pb isotope ratios in mineral and glass phases which contain very low total Pb concentrations (0.1-2 ppm)-specifically, plagioclase and basalt glass. (From authors' abstract by E R.)

LEACH, D.L., VIETS, J.G., KOZLOWSKI, A. and KIBITLEWSKI, S., 1996. Geology, geochemistry, and genesis of the Silesia-Cracow zinclead district, southern Poland: Society of Economic Geologists, Special Pub. no. 4, 1996, p. 144-170. First author at US Geological Survey, P.O. Box 25046 Federal Center, Denver, CO 80225, USA.

FI in sphalerite are mostly two-phase aq L plus V but organic Lbearing FI are abundant. FI T<sub>h</sub> in sphalerite are between 40 and 156°C and sal range from near 0 to >23 wt.% NaCl eq. FI T<sub>h</sub> increase with depth below the surface and are consistent with a cooling gradient of the ore-F of about 6 to 10°C per 100 meters. T-sal relationships and their variations with depth are interpreted to indicate the mixing of multiple F during ore

formation. Analysis of electrolytes in 1 F show that later ore stage sulfides have significantly more bromide, ammonia, and acetate than sulfides in early ore stages. FI G in sphalerite and galena appear to contain at least two end-member compositions characterized by either  $CO_2$ -CH<sub>4</sub> or  $CO_2$ -H<sub>2</sub>S gas compositions and are consistent with the presence of multiple ore F in the ore-forming environment. (From authors' abstract by H.E.B.)

LEE, Jongman and STERN, R.J., 1998. Glass inclusions in Mariana arc phenocrysts: A new perspective on magmatic evolution in a typical intraoceanic arc: The J. of Geol., v. 106, p. 19-33. First author at Dept. of Geosci., Univ. of Texas at Dallas, Box 830688, Richardson, TX 75083-0688, USA.

Major element compositions of glass I in olivine and plagioclase phenocrysts from representative Mariana arc lavas show that mafic Mariana arc L are tholeiitic and not high-alumina, implying that the high-alumina characteristic of these lavas reflects accumulation of plagioclase. Glass I also show the common occurrence of felsic M previously unrecognized among Mariana arc lavas and indicate that felsic M are important, if cryptic, components of this magmatic system. Primitive, mantle-derived M have not been found. Glass I data indicate that the arc magma systems sampled by erupting lavas are compositionally bimodal, with Fe-rich mafic and high-silica (66-76% SiO2) modes. These observations are most simply interpreted as being due to shallow, compositionally zoned magma chambers. The restriction of felsic glass I to plagioclase phenocrysts indicates that felsic M reside in the upper part of the magma chamber, underlain by Fe-rich mafic M. Plagioclase phenocrysts accumulate between mafic and felsic zones. Glass I from plagioclase and olivine in the same sample are compositionally distinct, indicating that these minerals formed in different M. These data indicate that Mariana arc magmas reside in strongly zoned magma chambers, and that coupled magma mixing and plagioclase accumulation are important for controlling the spectrum of lavas erupted in this typical arc. (Authors' abstract)

LEE, T.J. and BROWN, P.E., 1998a, Mineralization and fluid inclusions in Paddington. West Australia: An Archean shear zone-hosted lode gold deposit (abst.): Geological Society of America Annual Meeting 1998. Abstracts, v. 30, no. 7, p. A76-A77. Authors at Dept. of Geol. and Geophys., Univ. of Wisconsin-Madison, 1215 West Dayton St., Madison. WI 53706; email (tleegold@geology.wisc.edu)

The majority of Archean lode gold deposits lie in S faults spatially associated with large, transcrustal shear zones, which most likely served as the main conduits through which gold-bearing F flowed. However, large gold deposits are rarely located within these transcrustal shear zones. The Bardoc Tectonic Zone is a north-northwest trending transcrustal deformation zone located within the Norseman-Wiluna greenstone belt of the Archean Yilgarn Craton of Western Australia. The Paddington deposit lies directly within this tectonic zone, approximately 30 kilometers north of Kalgoorlie and the Golden Mile. The deposit is contained within low to middle greenschist facies metamorphosed dolerite (Paddington dolerite) and basalt (Paddington volcanics).

 The deposit contains three main generations of veins: 1. early, highly deformed carbonate veins; 2. near-vertical, shear-parallel, quartz-carbonatescheelite-sulfide±mica veins; crosscut by 3. near-horizontal quartzcarbonate-sulfide±tourmaline±gold veins.

The highest gold concentrations are found in sections of the nearhorizontal veins that have undergone later shearing. Such veins are perpendicularly cut by sulfide-rich veinlets, which contain gold. The relationship of gold to these later features suggests that much of the gold was deposited or remobilized after the formation of the flat veins.

Quartz grains in near-horizontal veins contain several generations of F1. Relatively undeformed quartz grains. found in proximity to sulfide and carbonate grains, contain P to early S H<sub>2</sub>O-CO<sub>2</sub>-CH<sub>4</sub> I with highly variable compositions (XH<sub>2</sub>O from 0.1 to 0.9, XCO<sub>2</sub> from <0.1 to 0.8 and XCH<sub>4</sub> from 0.08 to 0.25). These I are also closely and consistently associated with the sulfide-rich veinlets. Secondary H<sub>2</sub>O-CO<sub>2</sub> I with variable H<sub>2</sub>O:CO<sub>2</sub> ratios (XH<sub>2</sub>O from 0.98 to 0.75), high sal aq I (Th from 150 to 330°C), low sal aq I (Th from 140 to 210°C, and nearly pure methane I (Th approximately –83°C) also exist in the near-horizontal veins as separate trails (i.e. aq and H<sub>2</sub>O-CO<sub>2</sub> I do not appear to occur in the same trails).

Samples from smaller gold deposits and prospect pits along the Bardoc Tectonic Zone have also been found to contain multiple distinct generations of carbonic and aq-carbonic 1, in addition to late low T aq 1. (Authors' abstract)

LEE, T.J. and BROWN, P.E., 1998.b Fluid inclusion analysis of a shear

zone hosted lode gold deposit, Paddington, Western Australia (abst.). Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 39. Authors at Dept. of Geol. and Geophysi., Univ. of Wisconsin-Madison, 1215 West Dayton St., Madison, WI 53706; email (tleegold@geology.wisc.edu; pbrown@geology.wisc.edu)

The Paddington deposit lies in the Norseman-Wiluna greenstone belt of the Archean Yilgarn Craton of Western Australia in greenschist facies metamorphosed dolerites and high Mg tholeiitic basalts. The deposit consists of quartz-carbonate veins and vein sets, containing arsenopyrite, pyrite, galena, chalcopyrite, and pyrrhotite along with clustered crystals of scheelite.

Preliminary analyses of Fl in quartz indicate the existence of at least four main types. Primary, low-sal (<5 wt% NaCl), high T ( $T_h$ =310-380°C) H<sub>2</sub>O-CO<sub>2</sub> and variable sal (from <5 to 20 wt% NaCl), high T ( $T_h$ =250-320°C) H<sub>2</sub>O I are both present, generally as isolated I or separate clusters. Secondary low-sal (<5 wt%), low-T ( $T_h$ =140-200°C) H<sub>2</sub>O and S CH<sub>4</sub> I are also common. A few probably S, low sal. relatively low T ( $T_h$ =200-230°C) H<sub>2</sub>O-CO<sub>2</sub> I exist in some samples. Scheelite crystals contain saline, high T aq and (unclear) high T H<sub>2</sub>O-CO<sub>2</sub> I, with some S low T aq I near grain boundaries. Quartz crystals in proximity to scheelite contain high T H<sub>2</sub>O-CO<sub>2</sub> (variable mol% CO<sub>2</sub>) and variably saline H<sub>2</sub>O in "mixed" clusters (i.e. an individual cluster contains both types of I).

The presence of  $H_2O$ -CO<sub>2</sub> 1 along the shear indicates that these F most likely originated at some depth and flowed up through this shear. However, gold mineralization only occurs where both  $H_2O$ -CO<sub>2</sub> and saline  $H_2O$  inclusions occur. Thus gold mineralization may be associated with phase separation (CO<sub>2</sub>-rich vs.  $H_2O$ -rich F), or F mixing (deep-sourced CO<sub>2</sub>-rich F mix with saline, lower T aq F). (From authors' abstract by E.R.)

LEE, W.-J. and WYLLIE, P.J., 1998, Process of crustal carbonatite formation by liquid immiscibility and differentiation, elucidated by model systems: J. of Petrol., v. 39, no. 11 & 12, p. 2005-2013. First author at Div. of Geological and Planetary Sci., California Inst. of Tech., Pasadena, CA 9125, USA: email (wjl@gps.caltech.edu)

Experimental studies on several silicate-carbonate joins provide a framework in the system CaO-Na2O-(MgO+FeO)-(SiO2+Al2O3) (+CO2) which illustrates possible processes for the formation of carbonatites. The two key features are the silicate-carbonate liquidus surface, and the miscibility gap liquidus surface. Crystallizing parental carbonated silicate M may reach a silicate-CO2 eutectic, a silicate-carbonate field boundary, or a miscibility gap. Some hydrous carbonated silicate M may bypass the high-T miscibility gap and reach the silicate-carbonate field boundary. Immiscible carbonate-rich L in model systems simulating magmatic conditions tend to be concentrated near calciocarbonatite compositions (<-80%CaCO3: e.g. nepheline sovite), but may be more alkalic from silicate parents with higher Na/Ca values. An immiscible carbonate-rich L separating from the high-T parent silicate L will cool with the precipitation of silicates only, until it reaches the silicate-carbonate field boundary, where it is capable of precipitating carbonate minerals, which can form carbonatite cumulates. Some parents may reach this boundary by direct crystallization, but most probably traverse the miscibility gap. Along this field boundary, the coprecipitation of calcite drives the L toward residual alkalirich compositions. The carbonate liquidus (>85% CaCO<sub>3</sub>) is a 'forbidden volume' for magmas. V loss from carbonatite magma can introduce alkalis into country rocks, but this does not cause alkali depletion of magma, calcite precipitates to maintain the magma composition. Hydrous magnesiocarbonatite magmas can precipitate cumulate sovites. (Authors' abstract)

LENG, J., SHARMA, A., BODNAR, R.J., POTTORF, R.J. and VITYK, M.O., 1998, Quantitative analysis of synthetic fluid inclusions in the H<sub>2</sub>O-CH<sub>4</sub> system using Raman spectroscopy (abst.): Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 41. First author at Dept. of Geological Sci., Virginia Tech, Blacksburg VA 24061.

Experiments were conducted to test the feasibility of determining the composition of H<sub>2</sub>O-CH<sub>4</sub> synthetic Fl using Raman spectroscopy. Fl in quartz were synthesized following techniques described by Bodnar and Sterner (1987). Aluminum carbide plus H<sub>2</sub>O served as the source for CH<sub>4</sub>. Fl were synthesized at 600°C and 3 kbar in hydrothermal cold-seal vessels. I compositions used to develop the technique had compositions of 0.87, 1.78, 2.93, 3 86, 5.5 and 10.4 mol% CH<sub>4</sub>. Th for the I were: 0.87 mol%=307.8°-308.4°C; 1.78 mol%=307.9°-310.7°C; 2.93 mol%=311.0°-318.2°C, 3 86 mol%=316.1°-320.4°C; 5.5 mol%=321.4°-323.7°C; 10.4 mol%=344.4°-346.0°C. H<sub>2</sub>O-CH<sub>4</sub>. Fl of known composition were analyzed

with a DILOR XY Raman microprobe using the 514 nm line of an Ar<sup>\*</sup> laser. The spectral resolution was ±0.3 cm<sup>-1</sup>. To maximize the signal-tonoise ratio, a collection time of 1024 seconds was selected. All I were analyzed at 350°C in a Chaixmeca heating stage attached to the Raman microprobe. Peak areas for CH<sub>4</sub> and H<sub>2</sub>O were obtained by integrating the spectrum using a common base line for both the CH<sub>4</sub> and H<sub>2</sub>O peaks. The CH<sub>4</sub> peak area ratio was then calculated for each I analyzed. Figure 1 shows the calculated peak area ratios (PAR) of the H<sub>2</sub>O-CH<sub>4</sub> FI as a function of the mole fraction of methane. Each of the data points is an average of 10 to 15 individual I analyses. The data show a systematic variation in the peak area ratios determined from Raman spectroscopy and the CH<sub>4</sub> compositions of the I. (Authors' abstract)

See figure in the Illustrations appendix.

LETNIKOV, F.A., GANTIMUROVA, T.P. and SIZYKH, N.V., 1998, On the estimation of fluid regime for the continental volcanism of the Permian-Miocene in some regions of Eurasia: Geokhimiya, 1998, no. 5, p. 448-455 (translated in Geochm. Internat'l., v. 36, no. 5, p. 389-396). Authors at Inst. of the Earth's Crust, Siberian Div., Russian Acad of Sci., ul. Lermontova 128, Irkutsk, 664033, Russia.

F analyses (H<sub>2</sub>O, CO<sub>2</sub>, CH<sub>4</sub>, CO and H<sub>2</sub>) for the continental volcanics from several regions of Eurasia (Permian to Miocene) are compared. The Karpathians, Great and Lesser Caucasus, Siberian Craton, Transbaikalia, and the Baikal rift zone comprise the regions studied. It was found that in various parts of Eurasia, melting proceeded within similar age intervals under the influence of independent F flows. The initial and final stages of the prolonged episodes of basaltic magmatism are characterized by low F abundance in igneous systems. (Authors' abstract)

See figure in the Illustrations appendix.

LEVIN, S.V., 1998, Digital decrepitation: Geologiya i Razvedka, v. 2, p. 79-81 (in Russian).

LEWIS, A.J., KOMNINOU, A., YARDLEY, B.W.D. and PALMER, M.R., 1998, Rare earth element speciation in geothermal fluids from Yellowstone National Park, Wyoming, USA: Geochim. et Cosmo. Acta. v. 62, no. 4, p. 657-663. First author at Dept. of Earth Sci., Univ. of Leeds, Leeds LS2 9JT, UK.

The waters show little fractionation of REE relative to their host rhyolitic volcanics; it appears that the REE abundances of hydrothermal F resulting from alteration of YNP rhyolites are unaffected by the presence of potential complexing species, i.e., that acid-alteration completely strips REE from the portion of the rocks that it affects without any fractionation across the REE series.

The main control over REE speciation is the relation abundances of potential complexing agents; however, pH and absolute abundances are also important. In the most acidic waters (pH~2.0) the free ion is the major species when sal and SO<sub>4</sub>/Cl are low (60-80% of each REE), and REE complexes with chloride can be significant (up to 5%). For higher SO<sub>4</sub>/Cl values, sulphate complexes dominate (80-90%). For less acid waters (pH 2.8–4.0) fluoride is the main complexing agent in low SO<sub>4</sub>/F fluids, but as the SO<sub>4</sub>/F ratio increases the sulphate species become dominant, especially for the light REE (LREE). (From authors' abstract by E.R.)

LEWIS, Stephanie, HOLNESS, Marian and GRAHAM, Colin, 1998. Ion microprobe study of marble from Naxos, Greece: Grain-scale fluid pathways and stable isotope equilibration during metamorphism: Geology, v 26, no. 10, p. 935-938. First author at Dept. of Geol. and Geophys., Univ. of Edinburgh. Edinburgh EH9 3JW, UK.

In metamorphic terranes, modification of the stable isotope compositions of marbles by F infiltration has been extensively modeled to try to constrain both the magnitudes and time scales of metamorphic F fluxes. We have made a study of key localities on the Aegean island of Naxos (Greece) in which we combined textural observations with micro-scale trace element and stable isotope analysis to test the assumptions upon which modeling of metamorphic F flow is based, and to identify F transport mechanisms. Integration of ion microprobe analyses of <sup>18</sup>O/<sup>16</sup>O, <sup>13</sup>C/<sup>12</sup>C. Mn, and Fe with detailed CL imaging provides evidence that water-rich F were channeled along cracks and grain boundaries within marble, with limited equilibration between the F and rock. Very low values of  $\delta^{18}O_{\rm SMOW}$  (down to 2%) along grain boundaries indicate a meteoric source for F rather than a metamorphic source. in contrast to previous studies. In this example, the simplifying assumptions made previously in chromatographic theory, to constrain metamorphic F fluxes, time scales, and porosities from bulk isotope data, are incorrect. By making micro-scale measurements, we can determine infiltration mechanisms and distinguish separate F-flow events. These observations and measurements provide a basis for constructing more realistic models of metamorphic F flow. (Authors' abstract)

LI, Baohua, CAO, Zhimin, LIU, Yongfeng, et al., 1998. The characteristics of ore-forming fluids in Donglinshan gold deposit: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1015-1018 (in Chinese).

LI, Changeun and HAN, X.L., 1998, Fluid inclusion study of Eocene carbonate rocks in Kashi Depression: Acta Mineralogica Sinica, v. 18, no. 1, p. 46-51 (in Chinese; English abst.). Authors at Hebei Inst. of Sci. and Engineering, Tangshan, 063009.

This paper deals with the diagenesis of Eocene carbonate rocks in the Kashi Depression. The FI characteristics of diagenetic minerals are described. In term of the microthermometry and re-equilibrium data on the FI, the diagenetic T and maximum paleo-geotemperature have been obtained. Based on the above data, the oil-generating strata in this area are evaluated. (Authors' abstract)

LI, Cunyou and SHI, Lida, 1998: The application of  $\alpha$ - $\beta$  peak and other quartz decrepitation parameters to gold vein search (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 97-98 (in English). Authors at Shenyang Inst. of Geol. and Mineral Resources, CASS.

Based on the amount of quartz decrepitation data and gold vein search information, a decrepitation parameter model for gold vein search is established by quartz I decrepitation for the Zhang Quan Zhuang quartz vein type gold deposit in He Bei Province, China. The criteria used are:

Decrepitation T (Td): the more the gold content is, the lower the Td

Decrepitation activity (h): the average of decrepitation activity in the rich ore body levels are lower.

Decrepitation Curve: the decrepitation curves of Zhang Quan Zhuang gold deposit can be divided into four types, some of which are found in gold-rich veins.

4. The Height of Main Decrepitation Peak (Zh): the average height of main decrepitation peak is small for the levels rich in gold and big for the areas poor in gold.

5  $\alpha$ - $\beta$  Peak: the pattern of the  $\alpha$ - $\beta$  peak can be utilized to decide the stripped degree of vein and evaluate the mineralization prospect.

 The Frequency Coefficient (Pc) and The Intensity Coefficient (Qd) of Hydrothermal Activity; the two coefficients are for quantitatively evaluating mineralization. Either big Pc or big Qd indicate the intense mineralization.

Some right conclusions have been reached and 840 kg gold have been found by application of the above decrepitation parameter model. (From authors' abstract by E.R.)

LI, Rongxi, JIN, Kuili and LIAO, Yongsheng, 1998a. Analysis of organic inclusions using micro-FT.IR and fluorescence microscopy and its significance. Geochimica, v. 27, no. 3, p. 244-250 (in Chinese; English abst.). First author at Beijing Graduate School, China Univ. of Mining and Tech., Beijing 100083.

Organic I from the Shaheije Formation of Eogene period in Shengli Oil-Gas Province, eastern China, were studied using Micro-FTIR and fluorescence microscopy as well as by measurement of Th. Two populations of organic I were recognized, the P and S organic I. The former contains sulfur alcohol and organic materials which have relatively long alkyl chains with the carbon atom number of 15-17, whereas the later contains a certain amount of H<sub>2</sub>S besides sulfur alcohol and organic materials which have relatively short alkyl chains with the carbon atom number of 5-6. The Th of the P organic I is 87-91°C and is lower than that of the S I (Th=98-105°C), suggesting that the P I experienced a thermal evolution of lower degrees than the S I. This inference is consistent with the characteristics of the fluorescence spectroscopy and parameters ( $\lambda$  max. Q values) of the organic I. The composition and thermal maturation of organic I suggest that the P I resulted from the migration of the hydrocarbon-generated organic materials within the stratum where they lived, whereas the S organic I are trapped when hydrocarbon migrated secondly out of the source rock to the places where they finally accumulated. (Authors' abstract)

LI, Rongxi, JIN, Kuili and LIAO, Yongsheng, 1998b, Organic inclusions

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in Shengli oil-gas province study and their application in the petroleum exploration (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 150 (in English). First and second author at Beijing Grad. School, China Univ. of Mining and Tech., Beijing 100083; last author at Geological Research Inst., Shengli Petroleum Administration, Dong Ying 257015.

Organic 1 from Sha Hejie formation of Eogene Period in Shengli Oil-Gas Province, East China, were studied using Micro-FT, IR and fluorescence microscopy as well as the TOF-SIMS together with the measurements of Th. Two groups of organic I were recognized-the P and S organic 1. The P organic I contained sulfur alcohols and longer alkyl chains with the carbon atom number of 15-17 compared with the S organic I which contained shorter alkyl chains with the carbon atom number of only 5-6 and a certain amount of H2S besides sulfur alcohols. The P organic 1 experienced a lower degree of thermal evolution with the Th of 87~91°C than that of the S organic I with the Th of 98-105°C, which is consistentwith the characteristics of the fluorescence spectroscopy and parameters (Amax, Q-Values) of the organic I. The composition and thermal maturation of organic 1 show that the P organic I formed during the period of hydrocarbon generation and migrated inside of the stratum where they [formed] while the S organic I are trapped when the hydrocarbon migrated secondly from the source rocks under the stratum to the place where they accumulated. (Authors' abstract)

LI, Xia, JACKSON, Peter, KITTO, P.A. and JIA, Y., 1998, Mineralogical, sulfur isotope and fluid inclusion studies of gold mineralization, Bendigo, Victoria, Australia: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p 553-556. First author at School of Earth Sci., La Trobe Univ., Bundoora, Vic., Australia.

The alteration halo in Bendigo is at least 150 m wide around the core of the Nell Gwynne anticline. Gold occurrences correspond to higher concentration of CH<sub>4</sub> and CO<sub>2</sub> during the whole process of the F evolution. The Th in the mineralised veins have a range of 220-400°C, whereas those in the barren veins are 145-300°C. F immiscibility, including boiling, is responsible for gold deposition in the CH<sub>4</sub>-CO<sub>2</sub>-H<sub>2</sub>O-NaCl system. CH<sub>4</sub>-H<sub>2</sub>O FI exclusively occur in gold-rich laminated veins, spurs and breccia veins rather than in the barren veins. Sal range from 1.5% to 13.5 wt.% equivalent NaCl. The near-primordial values of the sulfur obtained from the ore veins and the highly altered zone may indicate a magmatic source or derivation from the metamorphic terrain. (Authors' abstract)

LI, Xuejun, DU, Yangsong, HU, Jinwen and FANG, Jiangin, 1998. Study on hydrothermal mineralization of the Datuanshan copper deposit of skarn type in Tongling area, Anhui: Acta Geologica Sinica (Diqiu Xuebao), v. 19, no. 2, sum 52, p. 30-38 (in Chinese; Engl. abst.). First author at China Univ. of Geosci., Beijing.

It is shown that the T and P of the metallogenic system decreases gradually, and a regular variation in composition, sal, density and mineralization degree of the ore F takes place with transition of the metallogenic process from post-magmatic hydrothermal period, skarn period to quartz-sulfide period. (Ore transport and deposition) was evidently influenced by pH, Eh and G fugacities of the ore F. The ore F of the principal metallogenic period is rich in Cu. (From authors' abstract by E.R.)

LI, Yiliang, WEI, Chunsheng and ZHENG, Yongfei, 1998. Application of auger electron spectroscopy to geochemistry: Earth Sci. Frontiers. v. 5, no. 2, p. 311-323.

Auger electron spectroscopy has many geochemical applications in the study of near-surface geological materials. It can be employed to analyze the relative atomic concentration of surface components semi-quantitatively. The extreme near-surface sensitivity and very high lateral resolution (<0.1  $\mu$ m m) make it possible to identify the heterogeneity and discrete domains of mineral surface on a submicrometer scale. AES in scanning mode can be used to identify the newly nucleated alteration minerals and to get the chemical composition of the residue from the decrepitated FI film on a nanometer scale. Depth profiles determined by AES are important to studies of chemical weathering. They provide direct evidence for the depth of reaction, and thus changes in the surface chemistry can be monitored as a function of depth within the minerals. When AES is combined with X-ray photoelectron spectroscopy, it can be used to study the mechanism of transportation and reactions on mineral-F interfaces. (Authors' abstract)

of metallogenesis of NNE-trending strike-slip fault-fluid-uranium mineralization in Hunan-Jiangxi border region: Geoscience-J. of Graduate School, China Univ. of Geoscience, v. 12, no. 4, p. 522-531. Authors at China Univ. of Geosci., Beijing 100083

The structural and tectonic evolution of the fault zones and oreforming features of hydrothermal uranium mineralization are detailed. Some uranium deposits are closely related to hydraulic fracturing. With the study of structural style and fractile geometry of the strike-slip fault system, the authors calculate the fractal values (D) of different associated fault patterns of the mine, the models of F flow and hydrothermal U-mineralization and the process of U-metallogenic dynamics. (From authors' abstract by E,R.)

LI, Z.L., ZHANG, W.L. and YANG, R.Y., 1998, The analysis of chemical composition of melt inclusion of beryl in pegmatite and discovery of zinc spinel by electronic probe (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A147. First author at Dept. of Earth Sci., Zhongshan Univ.

The compositions of MI in beryls from pegmatites in Xinjiang, Hunan and Yunnan, China, have been successfully analyzed by the electronic probe by the authors. Minerals such as beryl, zinc spinel, mica, quartz, magnetite, hematite, sidenite, sphalerite and silicate M have been determined from 120 analysis points in the MI. The dm beryl in MI shaped like granular and irregular ranges from 10 x 5 to 40 x 8 µm. Its composition ratio of SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> varies from 3.57 to 3.83, which is similar to that of host mineral beryl. In addition, the dm beryl contains minor components of Fe. Ca, K, Na, Mg, Nb and Ta, etc. The zinc spinel, which appears as solid I or dm in MI of beryl, was first discovered in MI of beryls from Xinjiang and Hunan pegmatites in China. Zinc spinel shaped like hexagon and long strip ranges from 15 x 7 to 60 x 30 µm and is commonly associated with quartz and mica. The contents of Al2O3, ZnO and FeO are in the range of 53.83-58.58%, 31.68-41.71% and 8.98-2.94 [%?], respectively. The minor components of zinc spinels are Mg, Mn, Si, Al, Nb and Ta, etc. Mica shaped like longstrip contains high content of K and Fe, and its composition ratio of SiO2/Al2O3 varies from 1.313 to 1.741. Fe-enriched and aluminosilicate-enriched M are extensively distributed in I. Compared with host mineral and dm beryl, the compositions of silicate M are enriched in Fe, Mg, Zn. Ca. P, Ti. Nb. Quartz is widely scattered in I. and its SiO2 content ranges from 79.28 to 100%. The FeO content of magnetite, hematite and siderite in I ranges from 42.26 to 95.14%. The sphalerite-quartz association only appears in pseudo-secondary I, and the contents of Zn and S range from 65.11 to 63.42% and from 35.41 to 35.36% respectively. [sic] (Authors' abstract)

LIAO, Xiangjun and WU, Dan, 1998. Typomorphic characteristics of quartz from Yuerya gold deposit, eastern Hebei: J. of Guilin Inst. of Tech. (Guilin Gong Xueyuan Xuebao), v. 18, no. 4, p. 330-334. Authors at Hainan Bureau of Geol. and Mineral Resources, Haikou.

The present paper deals emphatically with such typomorphic characteristics of quartz from Yuerya gold deposit as trace elements, REE, I, natural themoluminescence as well as its significance in the study of ore genesis and prospecting. Investigation shows that K<sup>\*</sup>, Na<sup>\*</sup> and Als<sup>\*</sup> are substituted in the lattice of quartz, that K<sub>2</sub>O/Na<sub>2</sub>O of quartz can be used in judging depth of mineralization, that the mineralizing T [FI data] of Yuerya gold deposit is 305~343°C, and that ore-forming F in Yuerya gold deposit originates from the deep crust. (Authors' abstract)

LIIMATAINEN, Jyrki, 1998. Fluid inclusion data from the Osikonmaki gold deposit. Rantasalmi, southeastern Finland: Special Paper, Geological Survey of Finland, v. 25, p. 91-99.

LIN, Wenwei and YIN, Xiulan, 1998a, Inspissation of ore-forming fluids and its forms: Acta Geologica Sinica (Diqui Xuebao), v. 19, no. 2, sum 49, p. 158-165 (in Chinese; English abst.). First author at Inst. of Mineral Deposits, CAGS, Beijing.

It is common for almost all of large- and medium- size hydrothermal deposits to develop widespread hydrothermal alteration, accompanied by inspissation of ore-forming F. F-rock interaction makes initial low-concentration F form the metamorphic zone with water-rich minerals, and cause free-water in solution to solidify in the alteration zone. The interaction between free-water and such components as C and S together with boiling and release of P will stimulate the depletion of free-water and the increase of metallic concentration in residual solution. The inspissation of F can appear in structural zones or pore F. Tectonic-altered rock mapping, experimental simulation indicator element studies and mathematical mod-

eling for the metasomatic profile can help to determine the inspissation ranges of ore-forming F and the dimensions of mineralization. Hence, the theory of F inspissation in water-rock interaction will provide a criterion for deciding the ore-forming metamorphic formation and predicting the reserves of ore deposits. (Authors' abstract)

LIN, Wenwei and YIN, Xiulan, 1998b, Ore-forming fluid conden[sation] theory in water/rock reaction--an application to ore prospecting: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998. Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1051-1054 (in Chinese).

LIN, Xinduo, 1998, Geological characteristics of magma-hydrothermal transitional ore deposits: Geoscience-J. of Graduate School, China Univ. of Geoscience, v. 12, no. 4, p. 485-492. Author at China Univ. of Geosci., Wuhan 430074.

In this paper the author introduces the recent progress of the study on magma-hydrothermal transitional ore deposit and discusses the forming mechanism of the magma-hydrothermal F. The characteristics of magmahydrothermal transitional ore deposits [involve] six aspects--the relation of orebody to magmatic rock, orebody to host rock, ore textures and structures, country rock alterations, ore zoning and mineral FI. (From author's abstract by E.R.)

### LINDAAS, S.E., CHOMIAK, B.A., CAMPBELL, A.R. and NOR-

MAN, D.I., 1998, Enargite-hosted fluid inclusion gases from the Lepanto, Philippines, high-sulfidation Cu-Au deposit (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-20. Authors at Earth & Env. Sci. Dept., New Mexico Tech, Socorro, NM 87801; email (slindaas@nmt.edu)

The Lepanto Cu-Au deposit, located in the Mankayan mineral district of northern Luzon, Philippines, is a 1.3 Ma old high-sulfidation epithermal deposit, hosted in the Cretaceous to Paleocene aged Lepanto metavolcanics. The enargite orebody is localized at the oblique intersection of the Lepanto fault with smaller branch faults. It lies 0.5 km to the west of a copper porphyry and associated hydrothermal breccia pipe. Previously, ore F were thought to have moved westward from the porphyry to deposition sites via the Lepanto fault; the G analyses presented here refine this model.

Using a quadrupole mass spectrometer in crush-fast-scan mode, semibulk analyses of gaseous species were obtained from mixed P and S Fl in 17 samples of enargite. G analyses are best expressed in G ratios when there is F evolution, e.g. during boiling. N<sub>2</sub>/Ar and H<sub>2</sub>S/Ar ratios correlate well, with the higher values recording a larger magmatic component. This magmatic component appears within the breccia pipe and is concentrated in two areas within the main enargite orebody. N<sub>2</sub>/CH<sub>4</sub> ratios decrease systematically outward from the porphyry; however, N<sub>2</sub>/CH<sub>4</sub> ratios are anomalously high in the two loci. Fluid mixing between magmatic, crustal, and meteoric end members can be demonstrated on a temary. N<sub>2</sub>-CH<sub>4</sub>-Ar plot. Although there is a general trend of decreasing CO<sub>2</sub>/CH<sub>4</sub> away from the porphyry, the enargite orebody exhibits a pronounced CO<sub>2</sub>/CH<sub>4</sub> anomaly, suggesting locally strong reducing conditions.

Previous microthermometric analyses of P FI in the same samples (Mancano and Campbell, Geochim, et Cosmo, Acta, v. 59, no. 19) established a general trend of decreasing Th away from the porphyry along the Lepanto fault. Anomalously high Th values in this trend correlate with the loci identified by G analyses. High sal also occur at these loci. The generally low sal of the 1 (0.1-0.9 eq. vt.% NaC1) was explained as a result of phase separation at depth, with V transport of metals, sulfur, and heat, but not salt, to a meteoric reservoir above. The G analyses of the FI indicate an addition of magmatic G to the meteoric F in support of this hypothesis.

The G analyses offer a refinement of the F flow model. The general westward flow is augmented by loci of the upward flow of F occurring along the branch fault intersections with the Lepanto fault. The loci are expressed by more mineralization, higher N<sub>2</sub>/Ar and H<sub>2</sub>S/Ar ratios, locally more reducing conditions and slightly higher sal and Th of Fl. (Authors' abstract)

LINDLEY, I.D., 1998, Mount Sinivit gold deposits: in Geology of Australian and Papua New Guinean mineral deposits, Berkman, D A and Mackenzie, D.H., eds: Australasian Inst of Mining and Metallurgy. v. 22, p. 821-826.

Indexed under FI.

LING, Qicong and CHENG, Huilan, 1998. Discussion on forming proc-

ess and geological characteristics of magmatic skarn in Tongling area, Anhui province: J. of Changchun Univ. of Sci. and Tech., v. 28, no. 4, p. 366-372 (in Chinese; Engl. abst.). Authors at China Univ. of Geosci., Wuhan 430074.

MI have been discovered and T<sub>b</sub> are recorded up to and above 1,000°C. No distinguished difference can be found between magmatic skarn and contact metasomatic skarn in mineral assemblages and chemical composition. The authors suggest that magmatic skarn is the product of the evolution of intermediate-acidic magma in depth. (From authors' abstract by E.R.)

LINNEN, R.L., 1998a, Depth of emplacement, fluid provenance and metallogeny in granitic terranes: A comparison of western Thailand with other tin belts. Mineralium Deposita, v. 33, p. 461-476. Author at Bayerisches Geoinstitut, Universität Bayreuth, 95440 Bayreuth, Germany.

The most important tin mineralization in Thailand is associated with the Late Cretaceous to Middle Tertiary western Thai granite belt. A variety of deposit types are present, in particular pegmatite, vein and greisen styles of mineralization. Most of the deposits contain low to moderately saline aq Fl and aq-carbonic I with variable CH4/CO2 ratios Low sal aq I represent trapped magmatic F in at least one case, the Nong Sua pegmatite, based on their occurrence as PI in magmatic garnet. Aq-carbonic I are commonly S and neither the CO2 nor NaCl contents of these I decrease in progressively younger I, implying that they are not magmatic in origin. Reduced carbon is depleted in the metasediments adjacent to granites and the \deltaD values greisen muscovites are variable, but are as low as -134 per mil, indicative of F interaction with organic (graphitic) material. This suggests that the aqcarbonic FI represent F that were produced, at least in part, during contact metamorphism-metasomatism. By comparing the western Thai belt with other Sn-W provinces it is evident that there is a strong correlation between F composition and P in general. Low to moderately saline aq I and aqcarbonic I are characteristic of mineralization associated with relatively deep plutonic belts. Mineralized pegmatites are also typically of deeper plutonic belts, and pegmatite-hosted deposits may contain cassiterite that is magmatic (crystallized from granitic M) or is orthomagmatic-hydrothermal (crystallized from aq or aq-carbonic F) in origin. The magmatic aq F (those that were exsolved from granitic M) are interpreted to have had low sal. As a consequence of the low sal, tin is partitioned in favour of the M on V saturation. Sub-volcanic systems by contrast are characterized by high Thigh sal F. Owing to the high chlorinity, tin is strongly partitioned in favour of the V and cassiterite mineralization can form by orthomagmatichydrothermal processes. Similar relationships between the depth of emplacement and F composition also appear to apply to other types of granitehosted deposits, such as different types of molybdenum deposits. (From authors' abstract by E.R.)

A comparison of FI and stable isotope data is given (Table 2) between Nong Sua and Pilok deposits.

FI compositions in these two deposits are plotted on  $T_h$ -sal diagrams with amount of CO<sub>2</sub> as the third dimension FI data (from the literature) in other western Thai deposits are summarized (Table 3). (E.R.)

LINNEN, R.L., 1998b. The solubility of Nb-Ta-Zr-Hf-W in granitic melts with Li and Li+F: Constraints for mineralization in rare metal granites and pegmatites: Econ. Geol., v. 93, no. 7, p. 1013-1025. Author at Bayerisches Geoinstitut, Universität Bayreuth, 95440 Bayreuth, Germany

Tantalum mineralization is associated with granites and pegmatites that invariably are rich in lithium. This in part is due to the extreme fractionation that is necessary for M to reach saturation in either a Ta or an Li phase. However, there may be chemical interactions in M that explain this association. Experiments, therefore, were conducted to determine the effect of lith-ium on the solubility of tantalite in water-saturated granitic M. The genesis of tantalum mineralization may be explained by Ta being retained in the M because of high Li-F concentrations. Tantalite crystallization is delayed until an Li±F±P mineral crystallizes, which lowers tantalite solubility and results in a general association of Ta with Li in mineralized granitic rocks.

In contrast to columbite and tantalite, the solubility of wolframite is not affected by the lithium content of the M (with up to 3.8 wt.% Li<sub>2</sub>O in starting glasses) and the solubilities of zircon and hafnon decrease with increasing Li content of the M. (From author's abstract by E.R.)

LISK, M., EADINGTON, P.J. and O'BRIEN, G.W., 1998. Unravelling complex filling histories by constraining the timing of events which modify oil fields after initial charge: in Parnell, J. (ed.) 1998. Dating and Duration of Fluid Flow and Fluid-Rock Interaction. Geological Society, London,

Special Publications, v.144, p. 189-203. First author at CSIRO Div. of Petroleum Resources and Australian Petroleum Cooperative Research Centre, P.O. Box 1130, Technology Park, Bentley, WA6102, Australia.

Complex and multiphase charge histories are a feature of many hydrocarbon discoveries. Previous descriptions of charge history that have relied on the chemical properties of hydrocarbons do not define the geometry of hydrocarbon accumulations prior to the attainment of their present state. In this paper, examples of oil charge studies conducted on hydrocarbon discoveries from the Australian North West Shelf are presented to demonstrate the application of a new technique for the mapping of hydrocarbon charge calted GOI<sup>TM</sup> (Grains containing Oil-bearing FI). In Australian oil fields GOI values in oil leg samples are an order of magnitude higher than in underlying water zones and record the maximum oil saturation experienced through time. Oil I are retained if oil is lost from the pore spaces of the rock, which allows GOI to be used to identify relict oil columns and locate the original oil-water contact. (From authors' abstract by E.R.)

LIU, Bin, 1998, Fluid inclusion characteristics, thermodynamic conditions of formation and P-T-t path of glaucophane eclogates in the North Qilian Mountains (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan. Abstracts volume, p. 47 (in English). Author at Underground Construction & Engineering Dept. of Tongjji Univ.

Glaucophane eclogites of the Caledonian subduction complex in the Zoulangnanshan of North Qilian Mountains are the products of subduction-accretion process during the convergence of the Alashan block with the Central Qilian block. FI data of five (different) deformationmetamorphic stages have shown that almost all P I trapped in the early glaucophane-greenschist forming stage have been decrepitated. Inclusions of the subsequent eclogite-, jadetic pyroxene- and quartzite-forming stage are well developed: I in garnet are mainly FI which contain mainly aq solution. Apart from these aq I many solid I also occur. Many tiny I with pure CO2 and high sal occur in the quartz segregations. For the later glaucophane-schist forming stage many tiny decrepitated T-shaped CO2 l are distributed along cleavages in glaucophane crystals while I trails occur along grain- or subgrain boundaries. For the even later amphibolitegreenschist retrogression stage the dense FI trapped in the earlier stages have been partially or completely decrepitated due to recrystallization: in this stage, besides the introduction of H2O-NaCl-CaCl2 fluid. CO2 fluid was once present, causing the formation of these two types of P I. For the very late ductile shearing-brittle deformation stage H1O-NaCI I of mediumlow sal are dominant

The Tf and P of the FI are calculated using thermodynamic equations relating the FI to the coexisting host minerals. It is suggested that the metamorphic terrain has experienced a counter-clockwise P-T-t path of T-rising and P-rising followed by a clockwise one of T-falling and P-falling. The changing thermodynamic conditions from quick P-rising during progressive metamorphism to quick isothermal decompression has revealed a tectonodynamic (geodynamic) feature of quick burying followed by quick uplifting for the subduction zone. (From author's abstract by E.R.)

LIU, Jiajun, ZHENG, Minghua, ZHOU, De'an, LIU, Jianming, ZHOU, Yufeng, GU, Xuexiang, ZHANG, Bin and LIN, Li, 1998. The components and evolution of the hydrogen and oxygen isotopes of oreforming fluids from La'erma gold ore belt: J. of Changchun, Univ. of Sci. and Tech., v. 28, no. 1, p. 43-49 (in Chinese, Engl. abst.). First author at Inst. of Geochem., Chinese Acad. of Sci., Guiyang 550002.

The La'erma gold ore belt, in the south subzone of western Qinling, includes La'erma and Qiongmo ore deposits and Yaxiang ore occurrence. These stratabound gold deposits are closely associated with submarine exhalative sedimentation and possess many unique features. The gold deposits in the Cambrian silicalite formation composed of black chert and slate are so clearly confined by strata, host rock types and structures that their stratabound character is well accepted.

The hydrothermal minerals such as quartz and barite in the gold ore belt have their  $\delta^{18}$ O values -3.19%-+26.71‰. leading to ore-forming F with  $\delta^{18}$ O of -11.06%-+15.34‰ (from isotope fractionation equations of quartz-water and barite-water).  $\delta$ D of -58.2%--121.5‰ (from F)). It is shown through the above-described isotopic study that the ore-forming solution was mainly derived from the ancient meteoric water. Oxygen and hydrogen isotopic evolution curves for water and rock system indicated that metallogenic F would have boiled while ore-forming materials precipitated.

During the hydrothermal mineralization [sic. of?]. circulating groundwater (meteoric water), ore-forming materials in the silicalite formation were remobilized, migrated and re-enriched, which contributed to the formation of the present ore bodies. (Authors' abstract)

LIU, Jiaqi and ZENG, Yishan, 1998a, Preliminary study on fluid inclusions in hsianghualite: Geol and Mineral Resources of South China, 1998, no. 1, sum 53, p. 56-62 (in Chinese; Engl. abst.). First author at Yichang Inst. of Geol. and Mineral Resources, Yichang 443003.

Preliminary study has been carried out by the authors on the thermobarogeochemical features of FI in hsianghualite [Li<sub>2</sub>Ca<sub>3</sub>[Be<sub>3</sub>Si<sub>3</sub>O<sub>12</sub>]F<sub>2</sub>]. It is concluded that the P-corrected Th, sal, density, P. oxygen fugacity and fugacity of CO<sub>2</sub> are 270-290°C, 34-36 wt.% NaCl, 1.03-1.15 g/cm<sup>3</sup>, 30-60 MPa,  $10^{23}$ - $10^{-35}$  bar and  $10^{23}$ - $10^{4.5}$  bar, respectively. The G phase components of FI in hsianghualite are rich in H<sub>2</sub>O (88-96%) and CO<sub>2</sub> (4-9%), with little CO, CH<sub>4</sub>, H<sub>2</sub>, N<sub>2</sub> and so on. (Authors' abstract)

LIU, Jiaqi and ZENG, Yishan, 1998b, Temperature and pressure geochemistry of fluid inclusions in hsianghualite, Xianghualing area, Hunan province, China: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 985-988 (in Chinese).

LIU, Jinhong, 1998, The classification and significance of the inclusions in gemstones: Jilin Geology (Jilin Dizhi), v. 17, no. 2, p. 65-69 (in Chinese; Engl. abst.). Author at Jilin Au, Ag, Gem, Jade Assoc., Changchun City, P.R.C. 130061.

In this paper, the definitions of I in gemstones are given. They are classified according to sequence, formation, component, phase state, size and so on, which has an important significance for genetic research, appraisal and evaluation.

LIU, Jinhui and ZHANG, Jianli, 1998. Ore-forming mechanism of uraninite in Xiazhuang ore field, north Guangdong and south Jiangxi provinces: 6th National Meeting on Mineral Deposits. Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 981-984 (in Chinese).

LIU, Wei, GUANGMING, Yang and XIA, Q.L., 1998. Fluid inclusion studies on the Dalu bastnaesite ore deposit. Dechang Sichuan Province, P.R. China (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent. Uzbekistan, Abstracts volume, p. 75-76 (in English). Authors at China Univ. of Geosci., Wuhan, 430074, P.R. China: email (zyb@cug.edu.cm)

Microthermometry of FI in bastnaesite indicates three types of I: (1) two-phase L-rich I, (2) two-phase G-rich I, and (3) [9] polyphase M hydrothermal I. Type I inclusions have Th of 385 to 455°C. Type II inclusions have Th of 474-492°C. There is no Th in type III inclusions at 900°C. Type I inclusions have a sal range of 12.5 to 17.4 NaCl eq. wt%.

This research data of FI in bastnaesite suggest that main ore-forming F was a kind of boiling F. The heterogeneous trapping occurred in the mineralizing process of bastnaesite. (From authors' abstract by E.R.)

LIU, Xianfan, GAO, Zhengmin, NI, Shijun, et al., 1998, Origin and migration of ore-forming fluids of micro-disseminated gold deposits of Yunnan, Guizhou and Guangxi provinces' 6th National Meeting on Mineral Deposits. Nanjing, China, Nov. 25-28, 1998. Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 989-992 (in Chinese).

LIU, Xianfan, NI, Shijun, ZHU, Laimin and JIN, Jingfu, 1998, A study on physicochemical conditions of post-mineralization thermal solution and exo-solution in Carlin-type gold deposits: J. of Changchun Univ. of Sci. and Tech., v. 28, no. 4, p. 393-398, 405 (in Chinese, Engl. abst.).

Based on composition. T and sal of 1 of representative minerals to be formed in post-mineralization thermal solution and exo-solution, the authors calculated a series of thermodynamic parameters and the geochemical characteristics and studied the change [of] pattern for low T solution. The results show that the nature of thermal solution of mineralization and post-mineralization stage is weak alkaline, but the exo-solution is weak acid, the H<sub>2</sub>, CH<sub>4</sub> and CO fugacities of post-mineralization thermal solution and exo-solution obviously decrease, especially CH<sub>4</sub> fugacity, comparing with mineralization epoch in exogenic process. Contrartly, S<sub>2</sub> fugacity obviously increase in the exogenic process. For the nature of sulfurbearing atomic group in solution, H<sub>2</sub>S and HS<sup>2</sup> are main constituents of the mineralization stage. but SO<sub>4</sub><sup>2</sup>, KSO<sub>4</sub><sup>+</sup> and NaSO<sub>4</sub> are the most important [components] in post-mineralization thermal solution. Migration forms of gold and mechanism of which P ore transforms into

oxidized ore are affected or controlled by the characteristics and varieties of solution in exogenic process. Hence, the results have significance for discovery and development of ore in Carlin-type gold deposits. (Authors' abstract)

LIU, Yimao, LU, Huanzhang, WANG, Changlie, XU, Youzhi, KANG, Weiqing and ZENG, Ti, 1998, On the ore-forming conditions and oreforming model of the superlarge multimetal deposit in Shizhuyuan: Science in China (Series D), v. 41, no. 5, p. 502-512 [in English]. First author at Guangzhou Inst. of Geochem., Chinese Acad. of Sci., Guangzhou 510640, China.

Eight favorable ore-forming conditions for the Shizhuyuan Wmultimetal deposit are proposed. They are: (i) the geochemistry background special enriching the volatile and W and Sn ore-forming elements; (ii) the existence of M-F system very nch in volatile and ore-forming elements; (ii) supply of sufficient ore-forming material and volatile multisource; (iv) the infiltration and convection water source and driving force partly supplied by the Jurassic reservoir basin; (v) favorable tectonic conditions; (vi) ore-bearing greisen and vein superimposed in the pre-existing skarn rocks; (vii) favorable ore-transport and ore-concentration strata condition; (vii) there were a set of favorable ore-forming structures in Shizuyuan area; (ix) the orebody has good ore-reserve condition. Finally, oreforming models are proposed. (Authors' abstract)

FI data presented (H.E.B.).

LIZORKINA, L.I., 1998, Mineralogical features of ores from the gold-ore deposits of the Auminzatau-Kul'dzhuktau Rise in the Central Kyzylkumy (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 107-108 (in Russian).

LODEMANN, Manuela, FRITZ, Peter, WOLF, Manfred, IVANO-VICH, Miro, HANSEN, B.T. and NOLTE, Eckehart, 1998. On the origin of saline fluids in the KTB (Continental Deep Drilling Project of Germany): Applied Geochemistry, v. 13, no. 5, p. 653-671. First author at GSF-National Research Center for Environment and Health, Inst. of Hydrology, D-85764 Neuherberg, Germany.

Highly saline F were encountered during the German Continental Deep Drilling Project (KTB) from depths ranging between 2 and 3 km to about 9 km. Some 460 m<sup>3</sup> Ca-Na-Cl brines with about 68 gl<sup>-1</sup> total dissolved solids (TDS) and some 270 m<sup>3</sup> associated G, mainly N<sub>2</sub> and CH<sub>4</sub> were pumped to the surface from the main fracture system situated near the bottom of the pilot hole. Geochemical and isotopic data support the hydraulic tests which suggest the presence of an open and large F reservoir at depth.

While Ca and Sr contents of the extracted brines may be the result of water-rock interaction, CI is most likely of external origin. The CI is hypothesized to derive from geotectonic processes rather than to descending infiltration of paleo-seawater (evaporitic brines). The sampled F have probably migrated from a deeper reservoir to their present position since the Cretaceous-Tertiary period due to tectonic activity. However, several isotopic studies have identified an admixture of descending paleowaters down to more than 4000 m depth. The high <sup>36</sup>CI/CI ratio of the F sampled during the long-term pumping test point to a host rock highly enriched in U-Th, unlike the sampled KTB country rocks. The F reservoir is believed to be in contact with the Falkenberg granite massif situated about 2 km to the E of the KTB holes, capable of supplying sufficient neutron flux for considerable subsurface production of <sup>36</sup>CI. The Na-CI-(K', SO4) precursor F of the Ca-Na-CI brines were produced in the course of extensive tectonic processes since the Late Caledonian within the Bohemian Massif. (From authors' abstract by E.R.)

LOKHOV, K.I., NIKITINA, L.P., BELYATSKY, B.V. and LEVSKY, L.K., 1998, Mantle fluid component in the Proterozoic lamproites of the Baltic Shield (abst.): The Ninth Int'l Conference on Geochronology, Cosmochronology and Isotope Geology, Abstracts, published in Chinese Sci. Bulletin, v. 43, Supp., p. 84. Authors at Inst. of Precambrian Geol. and Geochron RAS, St. Petersburg, Makarova Emb., 2, 199034, Russia.

F compositions and Ar isotopes were studied in the bulk samples of lamproites of the two regions of Baltic Shield: Kostomuksha (Central Karelia) and Poria Guba (Kola Peninsula).

The F analyses demonstrated extremely high concentrations of the main volatile components (water and carbon dioxide) in the rocks: up to 5 mm/gram. The rocks are characterized by the following ratios in volatile component: H/C=4-20 and N/C<0.01. Such ratios are characteristic for the hydrated MORB basalts.

For rocks of both regions were obtained mineral Rb-Sr isochrones giving the age estimates of 1200+/-5 m.y. for the Kostomuksha and 1719+/-8 m y. for the Poria Guba rocks. The rocks from both regions demonstrate unusual for Precambrian lamproites isotopic characteristics of Sr and Nd: \_Nd=(9-93) (enriched mantle) and \_Sr down to -20 (depleted mantle). Enriched component in the lamproites could originate due to mixing of depleted (MORB-type) material with enriched EMI1-type mantle source,

Potassium-argon dating of micas (phlogopites) from these rocks given an estimation of the age near 1225+/-15 m.y. for Kostomuksha rocks, and 1760+/-20 m.y. for Poria Guba rocks.

In these micas also were studied distribution and abundance of chemical active volatiles. The values of C<sup>36</sup>/Ar [<sup>36</sup>Cl/Ar?] and N<sup>36</sup>/Ar were estimated. These ratios are lower than in the mantle F, but for an order of magnitude higher, than in typical crustal metamorphic F. This indicates presence of the mantle F component, estimated mixing ratio between crustal and mantle components is from 0.3 to 0.8. Using the data on carbon dioxide concentrations in the micas, and the ratio <sup>40</sup>Ar/<sup>36</sup>Ar>10,000 in the depleted mantle source of these rocks, we estimate that magmatic phlogopites could capture from the F at the time of their formation the amounts of <sup>40</sup>Ar in the range n x 10<sup>-6</sup> ccSTP/g. Estimated value of excess argon is about 10% of the measured amounts of isotope <sup>40</sup>Ar, thus we estimate a real age of the rocks formation to 10% lower than the isotopic K-Ar age; near 1200 m.y. for the Kostomuksha and 1740 m.y. for the Poria Guba rocks. (Authors' abstract)

LOKHOV, K.I., TOKAREV, I.V., LEVSKY, L.K. and KOZLOV, A.V., 1998, Argon and helium isotopes and the main fluid components in the quartz crystals from the subpolar Ural (abst.): The Ninth Int'l Conference on Geochronology, Cosmochronology and Isotope Geology, Abstracts, published in Chinese Sci. Bulletin, v. 43, Supp., p. 84. First author at Inst. of Precambrian Geol. and Geochron. RAS, St. Petersburg, Makarova emb., 2, 199034, Russia.

F compositions and Ar, He isotopes were studied in the samples of quartz crystals of different generations from the hydrothermal rocks of the Subpolar Ural.

Prior to the analyses, the zones in the quartz crystals, which represent different stages of the crystal growth, were selected by optical studies. For the analyses were chosen the areas in the polished sections of the crystals with relative abundant FI, which were believed to be P for given generation of the crystal growth. In the crystals from all of the studied hydrothermal systems it were marked three main quartz generations: early "smoky colored", "rose colored", and the latest "violet colored". For the analyses were selected the crystals, where were present all of the marked generations.

The analyses as of F compositions, so isotopic He and Ar studies were performed by heating T a little higher, than the  $\beta$ - $\alpha$  transition; 650°C. Optic inspection of the heated samples has shown that most part of the FI was employed due to thermal activation. Composition of G released from one aliquot of the sample was analyzed by the mass-spectrometer, providing relative determination of H<sub>2</sub>. CH<sub>4</sub>. N<sub>2</sub>. CO, H<sub>2</sub>O, CO<sub>2</sub>. SO<sub>2</sub>. Isotopic analyses of He and Ar were performed from another aliquot by means of the isotopic static mass-spectrometer.

F composition of the earliest generations is characterized by dominance of water, and H/C>20. In some samples sufficient amounts of nitrogen were detected (up to 10% by volume). In the late quartz generations the ratios H/C are in the range 5-20, and no sufficient amounts of nitrogen were detected.

The highest <sup>40</sup>Ar/<sup>36</sup>Ar ratios: 3000-10000 were detected in the first quartz generation, the lowest: 300-1000 in the latest. The isotopic ratios <sup>3</sup>He/<sup>4</sup>He are lowest ( $1 \times 10^{-8}$ ) in the earliest zones, and highest ( $1.2 \times 10^{-6}$ ) in the latest zones. These data we consider as evidence of participance of the surface waters at the final stages of hydrothermal process. The samples of the early quartz generation with high nitrogen contents are characterized by the high values of the <sup>40</sup>Ar/<sup>36</sup>Ar ratios and low of the <sup>3</sup>He/<sup>4</sup>He, thus detected nitrogen can be of non-atmospheric origin [sic]. (Authors' abstract)

LONG, Xunrong, ZHEN, Minghua, ZHANG, Shouton, et al., 1998. Fluid inclusion research on Mulongtao gold deposits: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 973-976 (in Chinese).

LOVE, D.A., CLARK, A.H., HODGSON, C.J., MORTENSEN, J.K., ARCHIBALD, D.A. and FARRAR, Edward, 1998. The timing of adularia-sericite-type mineralization and alunite-kaolinite-type alteration.

The Mount Skukum epithermal Au deposit exhibits both hypogene alteration and mineralization facies characteristic of the adularia-sericite deposit type, and barren advanced argillic alteration of the alunite-kaolinite type, the two being separated by only 750 m on the present erosional surface.

The  $\delta D$  and  $\delta^{34}S$  values of alunite from the advanced argillic alteration, which average -175±0.5 (1 $\sigma$ ) per mil and 2.93±0.43 (1 $\sigma$ ) per mil, respectively, suggest that this alteration conforms to the hypogene type formed by magmatic SO<sub>2</sub> mixing with meteoric water, an inference that is consistent with mineral associations and textures that imply fairly high T (pyrophyllite stable).

Gold-bearing quartz-calcite(-adularia) veins are hosted by andesitic volcanic strata of the Eocene Skukum Group and by rhyolitic dikes. The mineralized veins conform entirely to the adularia-sericite class and were controlled by strike-slip faults and fracture zones. The ages of alunite and adularia from Mount Skukum indicate a succession from the barren alunite-kaoline-type hydrothermal system to the gold-bearing adulariasericite-type system, both of which formed during ongoing magmatism in the Mount Skukum Volcanic Complex. (From authors' abstract by E.R.)

LOWENSTEIN, T.K., LI, Jianren and BROWN, C.B., 1998, Paleotemperatures from fluid inclusions in halite. Method verification and a 100,000 year paleotemperature record, Death Valley, CA. Chem. Geol., v. 150, p. 223-245. First author at Dept. of Geological Sci. and Environmental Studies, State Univ. of New York at Binghamton, Binghamton, NY 13902, USA.

Maximum Th of Fl (Thmax) in halite (laboratory-grown crystals and modern samples, Death Valley, CA) match maximum brine T during halite precipitation. Maximum brine T during halite precipitation in Death Valley, late April, 1993 (34.4°C) agree with Thmax (34°C) and correlate well with average maximum air T in April (31.3°C) and May (37.6°C). Thmax may be used for paleoclimate interpretations based on the close relationship between saline lake T and average air T from modern settings Lower Th, demonstrably below the T at which halite grew, are interpreted to reflect collapse of some FI walls due to the P difference between the inside and outside of I. By only using Thmax, the problems of anomalously low Th due to possible collapse of FI are avoided Halite samples from 30 stratigraphic intervals 90 to 0 m (100 to 0 ka), Core DV93-1, Death Valley, CA, were used to measure Th of FI. Virtually all Th from Core DV93-1 are below the modern Thmas of 34°C (halite precipitation late April, 1993) Lacustrine halites, deposited in a perennial saline lake 35 to 10 ka, have Thmas between 19 and 30°C, which suggests brine T approximately 4 to 15°C below modern late April values. Ephemeral saline lake halites precipitated 60 to 35 ka have Thmax between 23 and 28°C. 6 to 11°C below modern values. The highest Thmax value in the 100 ka record (up to 35°C) is from a halite sample formed approximately 100 ka in a climate regime somewhat colder than the modern. (Authors' abstract)

LOWENSTEIN, T.K., LI, Jianren, HANNA, Jeffrey, GODFREY, Linda, JORDAN, Teresa, KU, T.-L. and LUO, Shangde, 1998. 80.000year Paleoclimate record from the arid Andes, Salar de Hombre Muerto, Argentina (abst.): Geological Society of America Annual Meeting 1998. Abstracts, v. 30, no. 7, p. A115-A116. First author at Dept Geol. Sci.. State Univ. of New York, Binghamton, NY 13902; email (lowenst@binghamton.edu)

A 40-m long core (HM-2008) from Salar de Hombre Muerto (southeastern Puma plateau, 25 S. latitude, 4100 m elevation) contains evaporites and associated siliciclastics deposited in environments ranked by paleoaridity from driest '1' desiccated mudflat/subaerially exposed salt flat (Holocene) to wettest '4' perennial saline lake (late Pleistocene). Six U series dates, from 82.4 ka to 8.0 ka, give average sedimentation rates of 0.5 m/1000 years. Lacustrine 'wet' phases (paleoaridity index of 3 and 4), represented by perennial saline take halites, occurred during Oxygen Isotope Stage 4 (OIS 4) (82 ka to 64 ka) and OIS 3. Between 26 ka and 8 ka, Hombre Muerto salar contained saline pan/ephemeral saline lake environments (paleoaridity index of 2 and 3). The OIS 4 and OIS 3 saline lake deposits therefore formed in a wetter climate regime than the evaporites coincident with OIS 2. The last evidence for 'wetter' lacustrine environments occurs at core depths of 6.4 m (8.0 ka); overlying massive mudflat sediments accumulated during the driest period of the 80 kyr record. The paleotemperature component of the climate record is given by L-V Th of FI in halite, which record water T during salt crystallization. Maximum Th are used for paleotemperature interpretations because they correlate with maximum brine T and air T. Th<sub>max</sub> from modern halites precipitated in Hombre Muerto range from 15 to 26.4°C Maximum air T at Hombre Muerto are about 28°C. Th<sub>max</sub> values from 16 stratigraphic intervals of core HM-2008 range from 18 to 30°C (1,939 total measurements). Th<sub>max</sub> values from those observed in modern Hombre Muerto halites, indicating brine T during halite precipitation varied surprisingly little over the past 80 kyr. (Authors' abstract)

LU, Anhuai, LÜ, Guxian, WANG, Wenzheng and LAI, Yong, 1998, Continent-continent collision and fluid mineralization in southern Wendeng: Acta Geologica Sinica (Diqiu Xuebao), v. 19, no. 2, p. 185-194. First author at China Univ. of Geosci., Beijing.

The authors discuss the relationship between the evident zonal mineralization distribution from Ag through Au-Ag, Au, Au-Pb-Zn to Au-Cu and collision mechanism, research detailed features of quartz I in collision belt, especially the coupling relation of varying features of H<sub>2</sub>O and CO<sub>2</sub> contents in quartz I to compressive and extensional structures in the collision zone, and further present the recognition about the mineralization of F driven by the collision. (From authors' abstract by E.R.)

LU, G.-Q., 1994. A genetic link between the gold-mercury mineralization and petroleum evolution: A case of the Danzhai gold-mercury deposit: PhD thesis, Univ of Québec at Chicoutimi, 209 pp.

FI examination reveals important information about the ore-forming F. A variety of hydrocarbon I are identified, including: (1) L methane I; (2) bitumen I; (3) paraffin wax I; (4) heavy oil I, and various combinations. L methane I are found in both metallic minerals such as cinnabar and realgar and gangue minerals such as quartz, calcite, dolomite and barite. The heavy oil I are more abundant in carbonate minerals such as calcite and dolomite than in other minerals such as quartz and cinnabar. The spatial relationship between the L methane I and cinnabar and realgar demonstrates that the hydrocarbon I are a significant part of ore-forming F. The Th of aq I range from 130-210°C and the sal detected from 5.2-19.3 wt % NaCl eq. Solid probe mass spectrometry confirms that hydrocarbons, particularly methane. are the most important constituent of the FI. The methane in some I is as high as 69.8 mol%. Some heavy hydrocarbon molecules are also detected by the mass spectra. The spectra of a sample from the second stage of mineralization displays a complete separation indicating a dominant unmixing of the CH4 and H2O phases. Another spectra of a sample from the third stage of mineralization displays a complete separation indicating a marked unmixing of H2O and CO2 phases. (From authors' abstract by H.E.B.)

LU, H. and MATSUMOTO, R., 1998, Synthesis of CO<sub>2</sub> hydrate in various CH<sub>3</sub>CO<sub>2</sub>Na/CH<sub>3</sub>CO<sub>2</sub>H pH buffer solutions: <u>in</u> Henriet, J.-P. and Mienert, J. (eds), Gas Hydrates: Relevance to World Margin Stability and Climate Change: Geological Society, London, Special Publications v. 137, p. 107-111. Authors at Geological Inst., Univ. of Tokyo, Hongo 7-3-1, Tokyo 113, Japan.

CO<sub>2</sub> hydrates were synthesized in CH<sub>3</sub>CO<sub>2</sub>Na/CH<sub>3</sub>CO<sub>2</sub>H buffer solutions with various pH values and different concentrations to investigate whether the change of pH value can influence CO<sub>2</sub> hydrate formation. The results imply that the change in pH value has a minimum influence on the equilibrium condition of CO<sub>2</sub> hydrate. The equilibrium condition of CO<sub>2</sub> hydrate in the various pH buffer solutions is seemingly controlled by the total concentration of the acetic acid and acetate anion, while Na\* cation plays a minimum role. (Authors' abstract)

LU, Yan and ZHOU, Jiyuan, 1998, Analysis of metallized structures and metallogenic prognosis in the Dongbeizhhai gold ore deposit, Songpan County, Sichuan Province, China (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 93-94 (in English). First author at Chengdu Univ. of Tech., Chengdu, P.R. China; second author at Nanjing Inst. of Geol. and Mineral Resources, Nanjing, P.R. China.

The Dongbeizhhai gold ore-deposit is formed by submarine exhalation mineralization into the N-S trending Kuashiya Fault in the Minjiang Meridional Structural System. During subsequent fault movements, when the F get to low P areas of the fault, the gaseous part of the F separated from the L-rich part. T and pH and Eh value of the F were changed quickly, and materials of the F were crystallized into ore.

This structural interpretation has resulted in an increase in demon-

strated reserves (E.R.)

LU, Yuanfa, ZHAN, Mingguo, CHEN, Kaixu and HUANG, Huilan, 1998a, Fluid inclusions in ore-bearing skarns at the Yangla copper mineralized concentration area in Degin, Yunnan, China (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 81 (in English). Authors at Yichang Inst. of Geol. and Mineral Resources, Chinese Acad. of Geological Sci., Yichang 443003, P.R. China.

There are five types of 1 in transparent minerals, such as garnet, diopside, quartz and calcite, from the stratiform skarns, which are monophase Ll, liquid-rich two-phase G-L ones (LV), G-rich two-phase G-L ones (VL), CO<sub>2</sub>-bearing ones (C) and polyphase ones containing dxl halite (S). The F systems in these I are variable, and their Th and sal are high with wide range from 100-620°C, generally >300°C, 8.3 wt% -55.0 wt% NaCl, commonly >20 wt%. The T show a positive correlation with the sal. The densities of most FI are >1.00 g/cm. The trapping P for I are relatively lower (10~25 MPa).

The I in the contact metasomatic skarns are mainly L- and LV-types with few C-type and S-type. The F systems are simple. The Th, sal and densities are relatively lower, generally <250°C, <20.0 wt% NaCl eq. and >1.00 g/cm<sup>3</sup> respectively, and the sal are almost constant when the T decreases to 100°C±. Their minimum trapping P is up to 150 MPa.

The observed variations in T, sal, density, etc. suggest that the F for stratiform skams were derived from two origins (hot, saline solution and cooler, less saline seawater) to which mixing mechanism exhalativesedimentation is regarded as the most reasonable explanation, and that those for contact-metasomatic skams came from granodiorite magma. The systematic I data also indicate that there were at least three structure-heat events at the Yangla mineralized concentration area. (From authors' abstract by E.R.)

See also next item (E.R.).

LU, Yuanfa, ZHAN, Mingguo, CHEN, Kaixu and HUANG, Huilan, 1998b, Fluid inclusions in ore-bearing skams from the Yangla copper mineralization concentrated area of Degen County, Yunnan province: Mineralium Deposita, v. 17, no. 4, p. 331-341.

See also previous item (E.R.).

LUCZAJ, J.A., 1998, Sulfide mineralization and massive dolomitization in eastern Wisconsin: Evidence for a common origin during post-Silurian regional hydrothermal activity (abst.): The Geological Society of America 32nd Annual Meeting, North-Central Section, March 19-20, 1998, Columbus, Ohio v 30, no. 2, p. 57, ISSN 0016-7592. Author at Dept. of Earth and Planetary Sci., Johns Hopkins Univ., Olin Hall, 3400 N. Charles St., Baltimore, MD 21218, email (john.luczaj@jhu.edu)

A variety of epigenetic Mississippi Valley Type (MVT) minerals are present in Paleozoic carbonate rocks throughout Wisconsin and adjacent states. Several problems exist with the current models regarding both massive dolomitization and MVT mineralization in the region, especially in areas far from the ore district in southwestern WI.

Abundant evidence supporting regional-scale hydrothermal activity in shallowly-buried Paleozoic rocks of Wisconsin that are far from the ore district include: (1) MVT mineral assemblages in Precambrian through Devonian rocks, (2) dolomite and sphalerite Th of 70-120°C, (3) mineralized faults and fractures. (4) mineralized breccias. (5) sulfide cemented quartz sandstone aquifers, (6) authigenic K-feldspars with Th >100°C (Liu et al., 1995), and (7) presence of post-Silurian ultramafic igneous intrusions (Carlson and Adams. 1997). Epigenetic dolomitization and sulfide mineralization has affected all of the Paleozoic rocks in eastern Wisconsin, and current hydrogeologic models do not explain elevated T recorded away from the ore district. This pervasive hydrothermal signature may be the result of an elevated regional geothermal gradient related to regional ultramafic igneous activity in the northern Midcontinent. Timing of hydrothermal activity in the region is still in question because dates for authigenic K-feldspars and sphalerite are different. The evidence outlined above suggests that the massive dolomite and trace sulfide mineralization outside the ore district were not formed by unrelated hydrologic processes but, instead, had a common hydrothermal origin. (From authors' abstract by H.E.B.)

LÜDERS, V., PRACEJUS, B. and HALBACH, P., 1998. Formation of massive sulfide ores and barite in the Central Okinawa Trough. Japan. Evidence from studies of fluid inclusions and stable isotopes (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Volume 31, 1998

Fluid Inclusions, June 1-4. Univ. of Nevada, p. 42. First author at GeoForschungsZentrum Potsdam, PB 4.3 Lagerstättenbildung, D-14407 Potsdam, Germany.

Fl and sulfur isotopes were studied in massive sulfide and barite samples from active and inactive smokers, mounds, and stockwork mineralization of the hydrothermal "Jade" field in the Central Okinawa Trough. Ores forming from these F can be chemically characterized by their respective major components: a) Zn-Pb-rich, b) Ba-Zn-Pb-rich, c) Zn-Cu-rich, d) Fe-rich replacements, and e) Zn-Pb-rich impregnations of felsic volcanics (rhyolite). Additionally, barite precipitates in the outer edifice of smokers, within soft sediments adjacent to the vents, and in open spaces of the stockwork zone.

The  $\delta^{34}$ S values of sulfides from stockwork mineralization and chimneys are very homogeneous but sulfides from chimneys always show mean  $\delta^{34}$ S values of about 5‰, whereas stockwork sulfides are heavier (mean  $\delta^{34}$ S-6.8‰). The  $\delta^{34}$ S values of barites are less homogeneous, indicating mixing of the hydrothermal F with ocean water.

Two-phase FI in sphalerite from impregnation (stockwork) ores show preliminary Th between 285°C and 347°C (mean 315°C) and yield sal between 5.0 and 6.5 eq. wt % NaCl, whereas enargite-hosted FI show lower Th of about 270°C and higher sal (~8 eq. wt% NaCl). The Th of P twophase I in barite from the inner fabrics of smokers are considerably lower than those of I in ZnS (mean Th 190°C) but they show sal similar to those of FI in ZnS. Barites from the outer edifice of smokers contain less saline PFI in growth zones (3.7-4.5 eq. wt% NaCl). The Th of these two-phase FI are lower than those of PFI in barite from the inner parts of smokers (128 to 189°C). Additionally, all barite samples contain numerous generations of S I which mostly are arranged along trails cutting through the crystals. These S I are either monophase, i.e. aq I, or two-phase, low-sal aq I. (From authors' abstract by E.R.)

LUETH, V.W. and GOODELL, P.C., 1998, A fluid inclusion study of geodes from Rio Grande Do Sul, Brazil: Implications for the origin of quartz geodes (abst.). Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 43. First author at New Mexico Bureau of Mines & Mineral Resources, Socorro. NM 87801; email (vwlueth@nmt.edu)

Two types of quartz geodes, of similar size and shape, are recognized from the Parana basalts. Mineralogic, morphologic, and Fl characteristics differentiate the two types although they are of similar size and shape.

One group of geodes is characterized by dark gray to black exterior chalcedony and with particular chaledony-quartz stratigraphy. Dark geodes contain pyrolusite and hollandite. FI Th are low (less than 40°C) and sal range between 0.0 and 0.7 eq. wt% NaCl

The other group of geodes is characteristically light-colored and have more abundant and coarser grained quartz. Manganese oxide mineralogy is limited to sparse, bladed pyrolusite crystals covered by drusy quartz. FI Th in quartz range from 140° to 175°C with low sal (0 to 0.7 eq. wt% NaCl).

The light-colored geodes may be the result of: 1) a hydrothermal heating event that occurred during or after geode growth or 2) deeper burial that led to a greater degree of silica diagenesis. (From authors' abstract by E.R.)

LUO, Yi, WANG, Mingtai, LI, Jianhong, et al., 1998. Metallogeny model and geochemistry of ore-forming fluids of uranium deposits in Xuguangu area. Guangdong province: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998. Mineral Deposits (Kuangchuang Dizhi). v. 17 Supplement, p. 1055-1058 (in Chinese).

LUQUE, F.J., PASTERIS, J.D., WOPENKA, B., RODAS, M. and BARRENECHEA, J.F., 1998. Natural fluid-deposited graphite: Mineralogical characteristics and mechanisms of formation: American J. of Sci., v. 298, p. 471-498. First author at Departamento de Cristalografia y Mineralogia, Facultad de Geologia, Universidad Complutense de Madrid, 28040 Madrid, Spain.

This paper focuses on the similarities and differences between metamorphic graphite (formed *in situ* from organic matter) and F-deposited graphite. We discuss the formation of F-deposited graphite in terms of the source of carbon, the characteristics of the C-bearing F (the C-O-H system), the mechanisms of carbon mobilization, and the mechanisms of carbon precipitation. New and existing analytical data are compiled on the physical and chemical characteristics of F-deposited graphite obtained by the following techniques: optical microscopy, differential thermal analysis, thermogravimetry, X-ray diffraction, Raman spectroscopy, and stable iso-

topic mass spectrometry. Our discussions focus on major, that is, volumetrically significant, worldwide concentrations of graphite (Authors' abstract)

LVOV, S.N. and ZHOU, X.Y., 1998, pH measurements in supercritical hydrothermal systems (abst.): Mineralogical Magazine, v. 62A. V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 929. Authors at Center for Advanced Materials, Pennsylvania State Univ., 517 Deike Bldg., University Park, PA 16802 USA.

We have developed a flow-through electrochemical cell (FTEC) and demonstrated that it successfully operates in both subcritical and supercritical aq environments at T up to 400°C. The FTEC consists of a previously developed flow-through external (Ag/AgCI) P-balanced reference electrode (FTEPBRE) and a modified flow-through platinum hydrogen electrode (FTPHE). (From authors' abstract by E.R.)

LYDON, J.W., 1998a, In praise of understanding ore-forming processes: SEG Newsletter No. 32, 1998, p. 19-20.

LYDON, J.W., 1998b. "In praise of understanding ore-forming processes"—Reply to Solomon and Khin Zaw: SEG Newsletter, No. 34, p. 41-42.

MA, Guoliang, LI, Ying, XUE, Chunji and QI, Sijing, 1998, Exhalites in the metallogenetic belt of the Qinling Ranges, China (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A114. First author at Sciences de la Terre, Univ. du Québec à Chicoutimi, 555 Boul. Univ., Chicoutimi, PQ G7H 2B1.

In the ore deposits of Dengjiashan and Qiantongshan, which are located in the south of the ore belt, the lenticular or bedded ores are actually the mineralized silica rocks. Apart from such sulfides as sphalerite, pyrite, minor galena and arsenopyrite, the silica rocks are composed of microcrystalline quartz, albite, scapolite, ankerite and minor tourmaline. Even though there are such sedimentary structure as banded and laminated structures, the dominant structures are lump and mottled structures. Their  $\delta^{18}O$  (SMOW) are 18.6 to 21.3‰, indicating a hydrothermal origin. REE composition is similar to that of sea water, which has low REE content and depletion of C. Studies of FI show that their forming T are 87-200°C, and the sal are around 14 wt% NaCL

By comparing with the modern seafloor hydrothermal sediments, it is concluded that the albitite and silica rocks are exhalites formed during the hydrothermal sedimentation of the ore deposits. (From authors' abstract by H.E.B.)

MacGOWAN, D.B., 1998. Geochemical controls on distribution of liquid, gaseous and critical fluid phases during generation and migration of hydrocarbons (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30. no. 7, p. A-84. Author at Medicine Bow Associates. P.O. Box 323, Laramie. WY 82073, email (macgowan@uwyo.edu)

Heterogeneous F phases are present in many petroliferous basins, particularly those associated with abnormal F P. Indeed, theories of the origin and maintenance of abnormal F P call upon multiple F phases to activate capillary seals in low permeability rocks. It has previously been held that these multiple F phases form when L hydrocarbon and solid kerogen thermally crack to form G. However, empirical models of F phases during the generation and migration of hydrocarbons suggest that, through this T and P range. F phases are distributed through a variety of L, L+G, gaseous and supercritical F phases. Burial history models and kinetic models of the generation of hydrocarbons are coupled with empirical F phasecomposition models to understand the evolution of F phases of hydrocarbons through time-T space. Such models are very useful for understanding F phase properties, such as flow characteristics, as well as the stability of abnormal F P seals deriving from capillarity between multiple-F phases in low permeability rocks, during generation and migration. Several synthetic burial history models were constructed to test the effect of changing thermal gradients, changing subsidence rates and uplift and geopressure regimes on the distribution of hydrocarbon F phases through time. Additionally, time-T models from the Green River Basin, WY and the San Joaquin Basin, CA were also evaluated. These models indicate that over the time-T-P range of hydrocarbon generation and migration. formation F exist primarily as G-L mixtures (multiple phases) or as super critical F (single phase); simple L or G phases appear to be relatively rare. This implies that seals on abnormally-pressured compartments may be geologically ephemeral. (Author's abstract)

MACH, C.J. and THOMPSON, T.B., 1998, Geology and geochemistry of the Kokomo mining district, Colorado: Econ. Geol., v. 93, p. 617-638, Authors at Dept. of Earth Resources, Colorado State Univ., Fort Collins, CO 80523, USA.

The ores of the Kokomo mining district, Colorado, are Ag-Pb-Zn massive sulfide replacement deposits (mantos) hosted by limestone. The sedimentary section is greatly expanded by Cretaceous-Tertiary porphyritic granodiorite and quartz monzonite sills, dikes, and stocks. Hydrothermal alteration is dominated by skarns in calcareous sedimentary rocks.

Fl analyses of quartz and carbonate gangue minerals indicate that T averaged 350°C during the early stages of ore deposition and decreased to about 160°C during the late stages. Ore F sal also decreased through the ore deposition event from 4.6 to <2 wt.% NaCl eq.

Carbonate gangue minerals within the ore zone exhibit  $\delta^{13}$ C and  $\delta^{13}$ C values within the range for magmatic water. Sulfur isotope values of sulfide minerals suggest a magmatic sulfur source.

The Kokomo stable isotope values, FI Th and sal are comparable to data from other Leadville-type (magmatic hydrothermal) carbonate-hosted sulfide replacement deposits in the Colorado mineral belt, including Leadville and Gilman. (From authors' abstract by E.R.)

MAEDA, Hiroyuki, 1998, Volcanic activity, hydrothermal alteration and epithermal gold-silver mineralization in the Ryuo mine area in the Kitami metallogenic province, Hokkaido, Japan: Resource Geol., v. 48, no. 2, p. 105-115. Author at Dept. of Civil Engineering, Fac. of Engineering, Kitami Inst. of Tech., Kitami 090-8507, Japan; email (maeda@rock.civil.kitami-it.ac.jp).

The Ryuo epithermal gold-silver deposit occurs primarily in the felsic volcaniclastic rocks of the Ikutahara Formation and in Ryuo Rhyolite. The Ryuo mineralization age of 7.7-8.1 Ma coincides well with the hydrothermal alteration age (7.7 Ma) of Ryuo Rhyolite hosting ore veins. It is concluded that the Ryuo mineralization was essentially accompanied by felsic volcanic activity during the sedimentation of the Ikutahara Formation, and was closely related both temporally and spatially to the intrusive activity of Ryuo Rhyolite.

Hydrothermal alteration related to the epithermal gold-silver mineralization of the Ryuo deposit is primarily characterized by early regional and vein-related alterations, and late steam-heated alteration. Early regional alteration consists of a smectite halo (smectite+pyrite±quartz±opal-CT±mordenite±clinoptilolite-heulandite series mineral). Early vein-related alteration is primarily marked by potassic alteration. This alteration halo can be subdivided into a K-feldspar halo

(quartz+adularia+pyrite±illite±interstratified illite/smectite±smectite), an illite halo (quartz+illite+chlorite+pyrite±interstratified illite/smectite±smectite) and an interstratified illite/smectite halo (quartz+interstratified illite/smectite+pyrite±smectite). Late steam-heated alteration characterized by kaolinite or alunite locally overprints the early K-feldspar halo.

The style of the Ryuo gold-silver deposit is a low-sulfidation epithermal type. The gold-silver-bearing quartz veins precipitates during boiling of ore F. The origin of the ore F might be meteoric water. The T and sulfur fugacity conditions during precipitation of electrum and acanthite are estimated to be 206-238°C [Th values] and 10<sup>-13.5</sup> to 10<sup>-11.6</sup> atm, respectively. (From author's abstract by E.R.)

MAEDA, S., TAKAGI, H., TAGUCHI, S., SANADA, K., HAYASHI, M., SASADA, M., SAWAKI, T., FUJINO, T. and UCHIDA, T., 1998. Semiquantitative measurements of CO<sub>2</sub> gas in liquid-rich inclusions by laser Raman microspectroscopy: <u>in</u> Water-Rock Interaction, G.B. Archart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 855-859 First author at West Japan Engineering Consultants (WestJEC), Fukuoka, Japan.

The detection limits and F-values for N<sub>2</sub>, CO<sub>2</sub>, CH<sub>4</sub> and H<sub>2</sub>S gases in the laser Raman microspectrometery have been determined utilizing the RAMANOR T64000 microprobe. The major factors which affect the spectrum intensity were also examined using a 25 mol% CO<sub>3</sub> standard, synthesized I. Very wide fluctuations in the spectrum intensity of th G were reduced down to relative error 14% as a result of normalizing the CO<sub>2</sub> using the H<sub>2</sub>O water intensity in the same Fl. This method can be applied to L-rich Fl for the semiquantitative measurements of CO<sub>2</sub> gas. (Authors' abstract)

MAEDA, S., TAKAGI, H., FUJINO, T., TAGUCHI, S., HAYASHI, M., SAWAKI, T., HORIKOSHI, T. and OKU'BO, Y., 1998. Homogenization temperature of fluid inclusions in the primary quartz of host rock along

hydrothermal veins: Abstracts with Programs of "A 20th Anniversary Symposium and 1998 Annual Meeting of Geothermal Research Society of Japan, Oct. 27-29, 1998, Waseda Univ., Tokyo.

MAEKAWA, Tatsuo, 1998, Equilibrium conditions of gas hydrate from mixtures of methane and ethane and outline of experimental apparatus for gas hydrate synthesis in porous sediment: Bulletin of the Geological Survey of Japan, v. 49, no. 10, p. 501-507 (in Japanese; Engl. abst.).

Natural G hydrates of thermogenic origin often include high concentration of ethane as well as methane. The phase equilibrium conditions were experimentally determined for G hydrates synthesized from methane and ethane mixtures. The present results indicate that addition of ethane to G mixture shifts the equilibrium condition to the side of higher T and lower P. An experimental apparatus for G hydrate synthesis in porous media was constructed to study the formation and properties of G hydrates in porous sediments in ocean bed. (Author's abstract)

MAGLAMBAYAN, V.B., ISHIYAMA, Daizo, MIZUTA, Toshio, IMAI, Akira and ISHIKAWA, Yohei, 1998, Geology, mineralogy, and formation environment of the disseminated gold-silver telluride Bulawan deposit. Negros Occidental, Philippines: Resource Geol., v. 48, no. 2. p. 87-104. First author at Dept. of Earth Sci. and Tech., Fac. of Engineering and Resource Sci., Akita Univ., Akita 010-8502, Japan; email (maglamvb@hotmail.com)

The Bulawan deposit is located in the porphyry copper belt of southwest Negros island, Philippines. Propylitic, K-feldspar, sericitic and carbonate alteration types can be distinguished in the deposit. Sericite alteration overprinted the propylitized and K-feldspar alteration zones, at lower T than epidote and chlorite in the propylitized zone. Carbonate alteration is associated with the mineralization in the center of the breccia pipes and along faults.

Mineralization consists of gold-silver telluride ores that are hosted by the carbonate- and sericite-altered dacite porphyry breccia pipes. The Bulawan ores occur mainly as disseminations, but unlike many epithermal gold deposits, lack classical epithermal colloform and crustiform quarz veins.

Fl in quartz and calcite in clasts of propylitized andesite in the breccia pipes homogenize from about 300 to 400°C while Fl in quartz, calcite and sphalerite within the dacite porphyry breccia pipes homogenize between 300 to 310°C. The ores were formed around 300°C from hydrothermal solutions with sal of about 6.6 wt.% NaCl eq. The presence of sylvanite and calaverite as intergrowths with each other, and the Ag content of calaverite as intergrowths with each other. Based on paragenesis, the Bulawan deposit formed in a pyrite-stable environment, with pH between 3.4 and 5.5,  $fO_2$  between  $10^{-32}$  to  $10^{-50}$  atm,  $fS_2$  between  $10^{-8}$  to  $10^{-78}$  atm,  $fTc_2$  between  $10^{-8.9}$  to  $10^{-6.3}$  atm, and total sulfur content about 10<sup>-7.8</sup> molal. The dominant reduced sulfur species in the ore solutions may have been  $H_2S_{(aq)}$ , and the likely aq tellurium species were  $H_2Te_{(aq)}$  and  $H_2TeO_{3(aq)}$ . The ore minerals in the Bulawan deposit were probably formed by mixing of slightly saline and low sal F. (From authors' abstract by E.R.)

MAGLAMBAYAN, V.B., ISHIYAMA, Daiso, MIZUTA, Toshio and ISHIKAWA, Yohei, 1998, Thermal effect by post-ore intrusive rocks to ore textures and fluid inclusions of the Uwamuki No.4 orebody. Kosaka Kuroko deposits, Akita Prefecture, Japan: J.Min. Coll. Akita Univ., Ser A, V VIII, no. 2, p. 49-68. First author at Inst. of Applied Earth Sci., Mining College, Akita Univ., Akita 010-8502, Japan; email (maglamvb@hotmail.com)

The purpose of this study is to clarify the thermal effects by the postore intrusive rock on ore textures and Fl of the stratiform sulfide orebody based on the vertical and horizontal variations on grain size of minerals and Fl data obtained from the samples of the boreholes MR872 and MR864 of the Uwamuki No. 4 orebody in the Kosaka Kuroko deposits.

The highly saline Fl were found in Zone IV near to the Takaderayama rhyolite in MR872 (14.1 wt.% NaCl eq. of Fl in barite) and in the Uwamuki tuff breccia of hanging wall close to the rhyolite in MR864 (halitebearing Fl in quartz). The emplacement of the Takaderayama rhyolite into the Uwamuki tuff breccia caused phase separation of pore water in [of?] seawater origin to occur above 440°C. The very high sal L phase which separated from the low-sal V during phase separation was trapped as the halite-bearing S Fl in phenocryst quartz in the tuff breccias in MR864 and as the S Fl with high sal in barite of Zone IV in MR872.

The thermal effects of the Takaderayama rhyolite probably caused the coarsening of sphalerite and barite crystals around the Takaderayama rhyolite in the Uwamuki No. 4 orebody and the generation of high sal of FI in the ores of the orebody and in the surrounding rocks. (From authors' abstract by H.E.B.)

MAGRO, G., RUGGIERI, G., PANICHI, C., SCANDIFFIO, G., BOIRON, M.C. and CATHELINEAU, M., 1998, Noble gases and carbon isotopic composition of fluid inclusions from the Larderello geothermal field (Italy), preliminary data (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 939. First author at CNR-Istituto di Geocronologia e Geochimica Isotopica, via Maffi 36, Pisa, Italy.

We measured N<sub>2</sub>/Ar ratio and the isotopic compositions of noble G and carbon of  $CO_2$  extracted by undervacuum crushing of Fl in order to: 1) define the origin of the palaeogeothermal F, 2) compare noble G and  $CO_2$ isotopic compositions of the F trapped in the l with present-day discharged F and evaluate if the source of these F has been changed with time. (From authors' abstract by E.R.)

MAINERI, C., COSTAGLIOLA, P., BENVENUTI, M., RUGGIERI, G., CASIGLIA, A., VASELLI, O., LATTANZI, P. and TANELLI, G., 1998, Studies of the "La Crocetta" raw ceramic material mine (Porto Azzuro, Isola D'Elba): Fluid inclusion and C-O isotope constraints of latestage fluids: 78th Nat'l. Congress of SIMP, Monopoli, 1-3 Oct., 1998, published in Plinius no. 20, p. 143-144. First author at Dipartimento di Scienze della Terra, Università di Firenze.

At La Crocetta, intensely alkali metasomized aplites and quartz porphyries are crosscut by calcite and minor pyrite veins that postdate the seriticization. The calcite has FI with 1.5-2.6 wt.% NaCl eq. and  $T_p=200-220^{\circ}C$ . Oxygen and carbon isotopic compositions of late-stage calcites coupled with FI data strongly suggest that the last hydrothermal event at La Crocetta involved a dominantly meteoric F, mixed with a CO<sub>2</sub> magmatic component. (From authors' abstract by E.R.)

MALININ, S.D. and KUROVSKAYA, N.A., 1998, Fluorite solubility in heterogeneous fluids of the system H<sub>2</sub>O-NaCI: Geochemistry International, v. 36, no. 3, p. 278-xxx.

MALLARD, W.G. and LINSTROM, P.J., eds., 1998. NIST Chemistry WebBook, NIST Standard Reference Database Number 69, November, 1998, Nat'l. Inst. of Standards and Technology, Gaithersburg, MD 20899; URL (http://webbook.nist.gov/chemistry)

Charles S. Oakes has called FIR readers' attention to this "book" in which the individual "chapters," separately authored, are not the pages of data on a single molecule but rather the collection of data of a particular type, available for use in calculations. The titles include:

Neutral Thermochemical Data

Negative Ion Energetics Data

Boiling Point Data

Heat of Sublimation Data

Condensed Phase Heat Capacity Data

Proton Affinity Evaluation

Constraints of Diatomic Molecules

Vibrational and Electronic Energy Levels of Polyatomic Transient Molecules

Ionization Energy Evaluation

Thermophysical Properties of Fluid Systems

Ion Energetics Data (four "chapters")

Organometallic Thermochemistry Data

IR and Mass Spectra

Henry's Law Constants

Molecular Vibrational Frequencies

UV/Visible Spectra

Oakes indicates that it provides (online, real time calculation to your specs) thermophysical properties of a variety of F systems over a very wide range of P and T. H<sub>2</sub>O, CO<sub>2</sub>, methane, ethane, propane, N<sub>2</sub>, O<sub>2</sub>, etc. It will even present the (tabulated and graphed) results in units of your choice (including those beloved by engineers in the U.S.)

MANDEVILLE, C.W., WEBSTER, J.D., SASAKI, A., HAURI, E.H., RUNCLE, M., TAYLOR, B.E. and BACON, C.R., 1998. Open-system degassing during the climactic and pre-climactic eruptions of Mount Mazama. Crater Lake, Oregon: Indications of a mantle sulfur source (abst.): EOS, Trans. 79 (45) Fall Meet. Suppl., p. F961. First author at American Museum of Natural History, New York, NY 10024-5192, US; email (cmandy@amnh.org)

Preliminary electron microprobe analyses of plagioclase-hosted glass I

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from climactic pumice all have sulfur concentrations of 80-211 ppm. Lower sulfur concentrations in some I are attributed to M entrapment following previous degassing events. Ion microprobe measurements of sulfur concentration in glass I from andesitic scoria range from 994 to 1620 ppm with average matrix glass sulfur concentration of 102 ppm (determined via Kiba bulk extraction). Negative correlation of  $\delta^{34}$ S values versus sulfur concentration is indicative of sulfur degassing from oxidized magma where SO<sub>4</sub> is the dominant sulfur species in the M and sulfur loss is dominant at SO<sub>2</sub>. A minimum estimate of total sulfur degassing from rhyodacitic and andesitic magma during climactic eruption is 3.1 X 10<sup>13</sup> gS. (From authors' abstract by H.E.B.)

MANGO, Helen, ARMIENTA, A., VILLASENOR, G., LATHROP, A. and ONGLEY, L., 1998, Fluid inclusions indicate lack of relationship between skam orebodies and outlying veins in Zimapan, Mexico (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-77. First author at Natural Sci., Castleton State College, Castleton, VT 05735; email (mangoh@sparrow.csc.vsc.edu)

The ore deposits of Zimapán (Hidalgo, Mexico) consist mostly of Pb-Zn skarns around intrusive bodies. However, there are numerous quartz and calcite veins throughout the region. These veins have been the focus of many prospect pits for several hundred years, although it is not immediately apparent whether or not these veins are related to the ore deposits, and therefore whether they contain any economic mineralization.

FI data suggest that the veins are not closely related to the ore deposits. FI from quartz, calcite and sphalerite within the orebodies of San Carlos and Santa Fe have Th ranging from 208 to  $332^{\circ}$ C (n=29), with an average of 275°C. Calculated sal for these I range from 1 to 28 wt.% NaCl eq; the average is 12.8 wt.% NaCl eq. In contrast, calcite and quartz from veins away from the orebodies contain FI with Th ranging from 88 to 212°C (n=28), averaging 163°C. Sal average 0.2 wt % NaCl eq. Because the vein F are on average over 100°C cooler and are mostly considerably more dilute than those from the ore deposit, it seems unlikely that the F responsible for ore generation were also the source of the veins. Therefore, prospecting along these veins may not be worth the effort.

These data are also useful from an environmental standpoint. The groundwater in the town of Zimapán is contaminated by arsenic, and while arsenic is present in the ores, the mines are kilometers from the town, as well as being either downhill or on the other side of a small mountain range (thus indicating no direct groundwater link). One hypothesis as to the introduction of arsenic into the groundwater system is that water is coming in contact with arsenic-bearing minerals in veins away from the orebodies. However, the FI data suggest that these veins carry any arsenic minerals toon, and so it appears unlikely that these veins carry any arsenic minerals that could contaminate the groundwater. (Authors' abstract)

MANNING, C.E., 1998, Fluid composition at the blueschist-eclogite transition in the model system Na<sub>2</sub>O-MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O-HCI: Schweiz. Mineral. Petrogr. Mitt, v. 78, p. 225-242. Author at Dept. of Earth and Space Sci., Univ. of California. Los Angeles, CA 90095-1567. USA: email (manning@ess.ucla.edu)

The transformation of mafic epidote-blueschists to eclogites in subduction zones liberates water-rich F. Solute activities and concentrations in these high-P F are here estimated for the first time and show that the F evolved from mafic rocks during eclogite formation should be rich in Si and Na, and have significantly higher Al contents than more familiar crustal F. (From author's abstract by E.R.)

MAO, Jingwen, ZHANG, Zuoheng, YANG, Jianmin, ZHANG, Zhaochong, WANG, Zhiliang and YE, Dejin, 1998, Geology and metallogenic geochemistry of the Yingzuishan gold deposit, Gansu province Mineralium Deposita, v. 17, no. 4, p. 297-306. First author at Inst. of Mineral Deposits, Chinese Acad of Geological Sci., Beijing 100037.

The Yingzuishan deposit, a gold deposit recently discovered in the western part of North Qilianshan Caledonian orogenic belt, is 15 km away from the Hanshan large-size gold deposit. The strata in the mine are composed of volcanic, clastic and carbonate rocks of Middle Cambrian Ge'ermogou Group.

The host rock for the gold mineralization mainly comprises silty slate, dacitic cataclastic breccia and andesitic tuffbreccia. Totally 11 orebodies have so far been found, of which the largest one is about 509 m long and 3-5 m wide with an average grade of 9.62 X 10<sup>4</sup>. The orebodies extend 180-200° and dip 37-82°. Silicification, sericitization and ferrodolomitization are developed in the mine.

Mineralization in the Yingzuishan gold deposit displays two episodes,

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endogenetic and exogenetic. The endogenetic comprises two stages of mineralization. Stage I comprises dense massive quartzite formed through replacement of ultrabasic rocks by auriferous hydrothermal solution. Stage II, the principal gold mineralization stage characterized by small auriferous sulfide quartz veins, is commonly superimposed upon stage I. Geochemical studies of the ores and altered rock reveal that silicon, alkaline components, CO<sub>2</sub> and LREE were brought into the metallogenic system during mineralization and alteration.

Th of stage II mineralization range from 320 to 200°C. Raman laser analysis of single I shows the existence of abundant CO<sub>2</sub> in the F. Oxygen isotope data suggest that the ore-forming hydrothermal solution responsible for the gold deposit was mainly derived from the magma of the mantle. (Authors' abstract)

MAPANI, B.E.S. and WILSON, C.J.L., 1998, Evidence for externally derived vein forming and mineralising fluids: An example from the Magdala gold mine, Stawell, Victoria, Australia: Ore Geol. Reviews, v. 13, p. 323-343. Authors at The Univ. of Melbourne, School of Earth Sci., Parkville, Vic. 3052, Australia.

Mineralogical and microfabric studies of the Magdala gold deposit together with isotopic and FI studies have shown that the mineralising F is externally derived. Four types of FI were distinguished on the basis of spatial arrangement and composition using the Laser Raman spectroscopy method. The sal of the FI range from 0.7 to 8.4 wt.% NaCl eq., suggesting that gold was deposited due to the influx of different external F. The association of pyrite-arsenopyrite-pyrrhotite with gold and with PGEs suggests that these F have a lower crustal origin and may have originated from the upper mantle and mixed with F derived from deep seated metasediments. (From authors' abstract by E.R.)

MARESCOTTI, Pietro, 1998, The manganese mineralizations associated with cherts of "Diaspri Di M. Alpe Formation": Mineralogy, chemistry, phase equilibria and genetic significance: Summary of PhD research published in Plinius, no. 19, p. 158-163. Author at Dipartimento di Scienze della Terra, Università di Genova, C. so Europa 26. I-16132 Genova.

Physical and chemical constraints, revealed by a Fl study indicate that the F circulated during the main tectono-metamorphic events, most likely at the peak conditions (275±25°C: 2.5±0.5 kbar).

In few samples FI characterized by a different chemical system has been detected. They show a distinct microthermometric behaviour. On cooling all I freeze around -50°C and form brownish aggregates. On subsequent heating, the first melting (T<sub>e</sub>) is observed around -39°C while final melting (Tm<sub>ier</sub>)takes place between -8.5 and -10.5°C. SEM analyses in open microcavities indicate that Mn, NatK±Ca are present while CI was never detected. Raman microspectroscopy reveals that very low density CH<sub>4</sub> is present in the G bubble, while no CO<sub>2</sub> has been detected. This F is related to a temporally defined episode recorded in an intermediate growth stage of euhedral quartz crystals. My data suggest a fairly complex solution where Mn<sup>3+</sup>, MnOH and MnOH<sub>2</sub> seem the dominant species, while CI apparently is a very subordinate ion. This F migrated through the complex system of microfractures, represented by the syntectonic veins, and possibly represents the mineralizing F which triggered the observed reactions in the wall rock. (From authors' abstract by H.E.B.)

MARIGNAC, C., 1998, The nature of ore-forming fluids and ore deposition conditions in Sn-W deposits from fluid inclusion studies: A review: 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A136. Author at CRPG-CNRS, Nancy, France; email (mangnac@mines.u-nancy.fr)

A review. (E.R.)

MARIGNAC, C., VALLANCE, J., CATHELINEAU, M. and BOI-RON, M.-C., 1998, Fluids associated with the Sn-W mineralization of Vaulry (Biond Massif, Limousin, France) (abst.): Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998, p. 156 (in French, translation by E.A.J. Burke). First author at CRPG-CNRS, Nancy; email (marignac@mines.u-nancy.fr)

The wolframite-cassiterite (+sulfides) mineralizations of Vaulry are hosted by networks of quartz veinlets, oriented N0 to N30°, corresponding to a system of shear and tension joints (N-S shortening) caused by the Blond leucogranite of assumed Westphalian age. The granite contains barren quartz veinlets along the same directions, along an E-W passageway of about 10 km, to the west of the deposit.

In the deposit, the quartz verns have been deformed at the brittleductile limit, still by the N-S shortening. The mineralization is superposed

on this deformation, in connection with a rotation of the shortening direction to N50°E, as indicated by the major direction of FIP in which the mineralizing F circulated, in the veins and in their nearby host rocks. This direction is also ubiquitous in the quartz crystals of the Blond granite, all along the E-W passageway.

The mineralizing F, with low sal (3.7-5.5 wt.% eq. NaCl), have circulated at a T of 350 to 400°C at an estimated P of maximally 120 Mpa, but with strong fluctuations. The repetition of cementing and solution of the drains in the veins repeatedly changed the P from a lithostatic to a hydrostatic regime. Raman microspectrometry showed the sporadic presence of volatiles (essentially CH<sub>4</sub> and N<sub>2</sub>) in very low quantities. These volatiles set the Vaulty deposit apart from the other tungsten deposits of the Variscan chain.

It seems that the mineralization is the result of the mixing of a moderately saline high-T F, containing small quantities of methane and nitrogen, with a colder diluted F (meteoric water?). As similar F circulated on a regional scale (the E-W passageway), it is concluded that the hydrothermal system responsible for this mineralization has a range of several kilometer. (Authors' abstract)

MARKL, Gregor and BUCHER, Kurt, 1998. Composition of fluids in the lower crust inferred from metamorphic salt in lower crustal rocks: Nature, v. 391, p. 781-783. Authors at Institut für Mineralogie. Petrologie und Geochemie, Albert-Ludwigs-Universität, Alberstrasse 23b, 79104 Freiburg, Germany.

Knowledge of the rheological properties of the lower crust and the metamorphic processes that operate there is important for our understanding of orogenic processes and granite genesis. The rheological properties critically depend on whether F are present in the lower crust and, if present, on their composition. FI and phase-equilibria studies of lower crustal granulites have shown that F with low water activities (due to the presence of dissolved components such as CH4, N2, CO2 and chlorides) are present at least episodically in the lower crust. Here we report the occurrence of a solid salt solution (NaCl-KCl) found together with chlorine-rich amphibole and biotite in lower crustal granulites. A desiccation mechanism explains how salt and chlorine-rich minerals formed from an originally water-rich F through a short-lived series of hydration reactions in the granulites, during which chlorine was progressively enriched in the F. Consequently, it would appear that F was present in the lower crust in only small amounts and was not stable over geologically long periods of time, leading to the conclusion that the lower crust is devoid of a free F phase during most of its history. (Authors' abstract)

MARKL, Gregor, FERRY, John and BUCHER, Kurt, 1998. Formation of saline brines and salt in the lower crust by hydration reactions in partially retrogressed granulites from the Lofoten Islands, Norway: American J. of Sci., v. 298, p. 705-757. First author at Institut für Mineralogie, Petrologie, und Geochemie, Albert-Ludwigs-Universität. Alberstrasse 23 b, D-79104 Freiburg, Germany.

Anorthosites, gneisses, and mangeritic rocks from the Lofoten Islands in northern Norway contain CI-rich amphibole (up to 3.5 wt.% CI) and biotite (up to 1.5 wt.% CI) that developed mostly during regional metamorphism at  $\approx$ 600°C and  $\approx$ 9 kb by replacement of older anhydrous granulite facies mineral assemblages. Textural evidence indicates that amphibole and biotite evolved from CI-poor to CI-rich compositions within individual samples. Development of CI-rich amphiboles and biotites within a shear zone demonstrates that the amphibole and biotite developed by reaction between a preexisting granulite facies mineral assemblage and an q F. Mineral-F equilibria indicate that the aq F was variable in composition ranging from X<sub>H20</sub>(=[H<sub>2</sub>O/(H<sub>2</sub>O+CI)] of 0.99 for equilibrium with the most CI-poor amphiboles and biotites to 0.4 to 0.6 for equilibrium with the most CI-rich minerals that coexist with salt. The most saline F correspond to NaCI eq. concentrations of over 25 mol/l.

The range in OH/Cl of amphiboles and biotite in individual samples can be explained by a desiccation model in which small amounts of "normal" low-Cl crustal F infiltrate rocks with granulite facies minerals and is subsequently enriched in Cl by preferential consumption of H<sub>2</sub>O during the resulting hydration reaction. Saline F developed at the extremes of reaction progress and then produced the Cl-rich amphibole and biotite compositions coexisting with halide crystals. (From authors' abstract by E.R.)

MARKL, Gregor and PIAZOLO, Sandra, 1998. Halogen-bearing minerals in syenites and high-grade marbles of Dronning Maud Land, Antarctica: Monitors of fluid compositional changes during late-magmatic fluidrock interaction processes: Contrib. Mineral. Petrol., v. 132, p. 246-268. Authors at Institut für Mineralogie, Petrologie und Geochemie. Albert-Ludwigs-Universität, Albertstrasse 23 b, D-79104 Freiburg, Germany; email (markl@ruf.uni-freiburg.de)

Meta-sedimentary rocks including marbles and calcsilicates experienced a granulite facies metamorphism with peak metamorphic conditions around 830±20°C at 6.8±0.5 kbar, accompanied by intrusion of huge amounts of syenitic (charnockitic) magmas at 4.5±0.7 kbar. The marbles and calcsilicates may represent meta-evaporites as indicated by the occurrence of metamorphic gypsum/anhydrite and Cl-rich scapolite that formed in the presence of saline F with XNaCI in the range 0.15-0.27. The results are interpreted to reflect the reaction of relatively homogeneous magmatic F [in terms of log (/H2O//HF)] derived from the late-magmatic stages of the syenites with both earlier crystallized, still hotter parts of the syenites and with adjacent country rocks during down-T F flow. Fluorine is successively removed from the F and incorporated into F-bearing minerals (close to the syenite into metamorphic fluorite) In the course of this process log(/H2O//HF) increases significantly. Chlorine preferably partitions into the F and hence log(/H2O/fHCI) does not change markedly during F-rock interaction. (From authors' abstract by E.R.)

MARSHALL, D., MEISSER, N. and TAYLOR, R.P., 1998, Fluid inclusion, stable isotope and Ar-Ar evidence for the age and origin of goldbearing quartz veins at Mont Chemin. Switzerland Mineral. and Petrol., v. 62, p. 147-165. First author at Inst. of Mineral. and Petrog. Univ. of Lausanne, Switzerland.

A new Swiss gold occurrence at Mont Chemin, comprising goldbearing quartz veins, displays many characteristics that are typical of mesothermal gold deposits within the Alps and globally. The most notable of these features are. i) the presence of NaCl-H<sub>2</sub>O-CO<sub>2</sub>-bearing F with an XCO<sub>2</sub> of approximately 0.016 and NaCl eq. in the range 4.6 to 10.6 wt.%, ii) greenschist formational T and P in the range 265-285°C and 700-1400 bars; and iii) the proximity of the occurrence to the Rhone-Simplon Line, a deep crustal structure in the Swiss Alps.

Corrected Ar-Ar data for hydrothermal adularia, considered to be contemporaneous with mineral deposition from the gold-bearing F, yields an age of  $9.9\pm1.0$  Ma. Geothermal gradients and uplift rates derived from the Ar-Ar age data and the geothermometry are in agreement with existing data for this region, and indicate that the hydrothermal activity at the Mont Chemin gold occurrence records one of the last Alpine metamorphic events in the northeastern Mont Blanc massif.

T estimates from F-muscovite-quartz-feldspar equilibrium and oxygen isotope thermometry of coexisting adularia and quartz are combined with the FI isochores to derive depositional P. These data yield geothermal gradients on the order of 50°C/km and uplift rates of 0.44 mm/a for the NE portion of the Mont Blanc massif.

(Authors' abstract)

MARSHALL, Daniel, PFEIFER, H.-R., HUNZIKER, J.C. and KIRSCHNER, David, 1998, A pressure-temperature-time path for the NE Mont-Blanc massif: Fluid inclusion, isotopic and thermobarometric evidence: Eur. J. Mineral., 1998, no. 10, p. 1227-1240. First author at Inst. of Mineral, and Petrog., Univ. of Lausanne, Switzerland; email (marshall@sfu.ca).

The Mont-Chemin region at the NE extreme of the Mont-Blanc massif. Canton Valais, Switzerland, is predominantly comprised of the granitic rocks of the Mont-Blanc intrusive rock suite and the Mont-Blanc basement gneisses. FI, F-mineral equilibria, stable-isotope and radiogenic-isotope studies have been used to derive P. T. age (PTt) and F-composition constraints for a number of Alpine events. The earliest of these events is recorded in a paragonite-katophorite schist hosted within the basement gneissses. The paragonites yield a <sup>40</sup>Arl<sup>39</sup>Ar age of 47 Ma. Mineral thermobarometry is consistent with formation T in excess of 300°C, with minimum P of 1500 bars. A well-defined P-T uplift path is recorded in minerals hosted by veins of different generations. The overall PTt path defines a geothermal gradient of 25°C/km, but the younger portions of this PTt path are consistent with geothermal gradients slightly in excess of 50°C/km, similar to those observed to the East along the Rhône-Simplon line. (Authors' abstract)

See also FIR 30, p. 126 (E.R.).1-63

MARTEL, C., PICHAVANT, M., BOURDIER, J.-L., TRAINEAU, H., HOLTZ, F. and SCAILLET, B., 1998, Magma storage conditions and control of eruption regime in silicic volcanoes: Experimental evidence from Mt. Pelée: Earth and Planet. Sci. Letters, v. 156, no. 1-2, p. 89-99. First author at CRSCM-CNRS, 1A rue de la Férollerie, 45071, Orléans

#### Cedex 2, France.

Differences of eruption regimes in silicic volcanoes, e.g., effusive versus explosive, have commonly been ascribed either to stratification of volatiles in the magma storage region or to G loss through permeable conduit walls. Recent Plinian and Pelean eruptions of silicic andesite magmas from Mt. Pelée (P1: 650 yr B.P., 1902, 1929) show no systematic variations in bulk rock and phenocryst and glass compositions. Rare coexisting Fe-Ti oxide pairs in Pelean products yield T between 840 and 902°C, and NNO between 0.4 and 0.8. Pre-eruptive M H2O contents, calculated from plagioclase-M equilibria, span values from 1.9 to 5.5 wt.%. Glass I from the P1 Plinian fallout have H2O contents between 4.2 and 7.1 wt.%. In contrast, the Pelean I have H2O contents commonly <3 wt.%, due to postentrapment modifications upon eruption. Phase equilibrium studies allow pre-eruptive conditions to be precisely determined and demonstrate that recent eruptions, either Plinian or Pelean, tapped magmas with M H2O contents of 5.3-6.3 wt.%, stored at 2\_0.5 [sic] kbar, 875-900°C and NNO=0.4-0.8. Differences in eruptive style at Mt. Pelee are unrelated to systematic variations in pre-eruptive magmatic H2O concentrations, but may be caused by contrasting modes of degassing in the conduit. (Authors' abstract)

### MARTIN-IZARD, A., CEPEDAL, M.A., FUERTES-FUENTE, M., REGUILON, R., RODRIGUEZ-PEVIDA, L., SPIERING, E., GON-ZALEZ, S., VARELA, A., MALDONADO, C., and BOIXET, LL., 1998, Gold-copper deposits in the belt from Rio Narcea, Asturias, Spain: Boletin Geológico y Minero, v. 109-5, no. 6, p. 479-496 (in Spanish; English abst.).

Intrusion of several igneous rock types in limestones and dolostones of Cambrian and Siluro-Devonian age within the Cantabrian Zone of the Iberian Massif resulted in the formation of calcic and magnesic copper-gold exoskam systems and late epithermal mineralization as an overprint to skams. Along with geological and geochemical data, preliminary K/Ar ages suggest that the ore deposits was formed by overprinting of several hydrothermal events. Copper-gold mineralization is associated to retrograde alteration of the magnesic and calcic skam (306±5 Ma), which is characterized by a metallic paragenesis consisting of magnetite, loellingite, arsenopyrite, chalcopyrite, bornite, pyrrhotite, with electrum, bismuthinite and wittichenite I, and minor mackinstryite, cobaltite and gersdorfite. The retrograde alteration also affects the monzogranite and appears along quartz veins with carbonate and arsenopyrite. After extensive erosion, reactivation of a northeast-trending fracture zone provided conduits for the subsequent emplacement of porphynitic (285±4 Ma) and diabasic (255±5 Ma) dikes and low T hydrothermal alteration that crosscut both the igneous rocks and the skarns. The later events are characterized by the development of quartz/calcite/adularia veins and breccia veins, oxidized jasperoid and jasperoid breccias with epithermal gold mineralization.

The FI study shows a highly-saline magmatic F with Th between 580 and 620°C. This F evolved into two immiscible F: one CO<sub>2</sub> and/or CH<sub>4</sub> rich and the other a high sal aq F. Evidence of immiscibility processes has been found at T between 360 and 420°C and around 1 kbar of P. These processes could be related to the main sulfide mineralization stage. This F evolved into a very low sal aq F with Th ranging from 270 to 360°C. Related to the intrusion of porphyritic to diabasic dikes at least two hydrothermal events took place. The FI study shows a very low sal aq F with lower Th (180-195°C and 120-165°C) suggesting late epithermal events overprinting on the mesothermal skams. Lastly, meteoric alteration produced a new generation of oxidation along fractures and breccias.

Preliminary data from carbon and oxygen isotopic composition from Boinas area point out two types of hydrothermal F. The first one shows an evolution from prograde skarn to retroskarn to Lancara limestone. The other one is a different late hydrothermal F, not related directly with skarn formation. Sulfur isotopic composition also shows an evolution from slightly negative values for the first stages to slightly positive and positive during late hydrothermal process. (Authors' abstract)

MARTY, B., 1998. Volatiles (He, C. N, Ar) in the mantle: Assessment of shallow-level assimilation and fractionation, and evaluation of source composition (abst.): Mineralogical Magazine, v. 62A. V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 959. Author at Centre de Recherches Pétrographiques et Géochimiques. Centre. National de la Recherche Scientifique, BP 20, 54501 Vandœuvre, Cedex, France.

The abundances and the isotopic ratios of carbon, nitrogen, helium and argon have been analysed in 45 mid-ocean ridge basalts. Gases were extracted by crushing and split for purification and analysis, by static mass spectrometry for N. He and Ar, and by conventional dynamic mass spectrometry for C. The data confirm the occurrence of near-constant He and C isotope ratios, and of a light nitrogen component in the convective mantle. (From author's abstract by E.R.)

MARTY, Bernard, TOLSTIKHIN, Igor, KAMENSKY, I.L., NIVIN, Valentin, BALAGANSKAYA, Elena and ZIMMERMANN, J.-L., 1998, Plume-derived rare gases in 380 Ma carbonatites from the Kola region (Russia) and the argon isotopic composition in the deep mantle: Earth and Planet. Sci. Letters, v. 164, p. 179-192. First author at Centre de Recherches Pétrographiques et Géochimiques, Rue Notre-Dame des Pauvres, B.P. 20, 54501 Vandœuvre Cedex; France.

In an effort to document the source of the parental M to carbonatites, we have measured rare G in 380 Ma carbonatites and associated mineral assemblages from the Kola Peninsula, eastern part of the Baltic shield in Russia. These series were emplaced during widespread Devonian magmatism when several large ultrabasic-alkaline-carbonatite massifs were formed. 4Her3He ratios vary from 1 × 106 to 1 × 107 in the bulk He extracted by melting of samples from three localities, including the large Kovdor massif. A comparison of measured abundances of <sup>3</sup>He and <sup>4</sup>He with those expected from in-situ production revealed a large (up to 105 times) excess of <sup>3</sup>He, implying a significant contribution from a mantlederived <sup>3</sup>He-bearing F. Crushing of these samples allowed extraction of F with "He/3He ratios down to 38,000, lower than those of mid-ocean ridge basalts and in the range of "He/"He observed in "He-rich ocean island basalts (OIBs) related to mantle plumes. 20Ne/22Ne up to 12.1±0.2 are higher than the atmospheric value of 9.80, implying the occurrence of primordial (solar-type) neon in the carbonatite source. <sup>20</sup>Ne/<sup>22</sup>Ne and <sup>21</sup>Ne/<sup>22</sup>Ne ratios display a good correlation, with the regression line close to (slightly to the right of) the Loihi Seamount correlation. Extrapolation of the regression to solar 20Ne/22Ne of 13.8 gives a 21Ne/22Ne of 0.045 for the plume endmember, well below the mid-ocean ridge basalt (MORB) source (upper mantle) end-member of 0 07. The measured 40 Ar/36 Ar ratios up to 2790 correlate very well with the Ne isotopic ratios, and the best estimate of the Ar/<sup>26</sup>Ar ratio of the plume source is within 5000±1000. Although the <sup>3</sup>He/<sup>22</sup>Ne ratio in the plume source appears to be comparable to the solar value within a factor of 2, the <sup>22</sup>Ne/<sup>36</sup>Ar ratio, computed from Ne-Ar isotope correlation, is two orders of magnitude lower than the solar value Such difference is unlikely to be due to magmatic fractionation since the observed 4He/40Ar\* ratios are close to values expected for radiogenic production and accumulation in the mantle source. It may rather represent a characteristic of the plume source. The isotope composition of light noble G in samples from ultrabasic-alkaline rocks of the Kola Peninsula, and associated carbonatites, indicate a contribution of material with lower timeintegrated (U+Th)/3He, 22Ne) and (40K/26Ar) ratios than those in the asthenospheric upper mantle, the subcontinental lithosphere, and the continental crust. The location of such material is likely to be below the convective mantle supplying MORB magmas, and reflects the contribution of a plume source material to Kola carbonatitic magmatism. These data support models which advocate a structure of the Earth heterogeneous in its refractory/volatile content. (Authors' abstract)

MAS, G. and PERAL, H., 1998a. Genthelvite from the El Criollo Quarry, Cerro Blanco. Córdoba, Argentine: IV Meeting of Mineralogy and Metallogeny, ["MINMET"] Sept. 23-25, 1998. Bahia Blanca, Argentina, p. 185-190 (in Spanish, Engl. abst.). First author email (Gmas@criba.edu.ar)

Genthelvite occurs in hematite veins in the granite pegmatite of Cerro Blanco, in the Pampa de Achala batholith, Córdoba. The characteristics of this mineral indicate that it is nearly an extreme member of the helvite group. Primary two-phase Fl contain a low to medium sal aq solution and homogenize around 325°C. (Authors' abstract)

MAS, G.R. and PERAL, H.R., 1998b. Fluid inclusions from the miarolites of Cerro Blanco pegmatites, Córdoba Prov., Argentine: Boletin de la Sociedad Española de Mineralogia. v. 21-A, p. 144-145 (abst.). First author email (Gmas@criba.edu.ar)

Differences in crystallization conditions between two types of quartz and genthelvite crystals from the miarolites of the Cerro Blanco pegmatite have been determined by means of Fl data. (Authors' abstract)

MASTER, Sharad, 1998, New developments in understanding the origin of the Central African copperbelt (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). Author at Dept. of Earth and Planetary Sci., Harvard Univ., Cambridge, Mass 02138, USA.

An extensive review (28 references), using published FI studies (E.R.).

MATHEZ, E.A., and MOGK, D.M., 1998, Characterization of carbon compounds on a pyroxene surface from a gabbro xenolith in basalt by timeof-flight secondary ion mass spectrometry: American Mineralogist, v. 83, p. 918-924. First author at Dept. of Earth and Planetary Sci., American Museum of Natural History, New York, NY 10024, USA; email

(mathez@amnh organization) Time-of-flight secondary ion mass spectrometry (TOF-SIMS) yields mass spectra of the upper several monolayers of an analytical surface. The applicability of TOF-SIMS to the characterization of C compounds on crack surfaces in rocks is demonstrated. A pyroxene grain recovered from the interior of a gabbro xenolith from the 1801 flow of Haulalai volcano, Hawaii, was chosen for this initial study because well-developed carbonaceous films are known to exist on many of the crack surfaces in these rocks. In addition to the anticipated major elements (Si, Al. Fe, Mg, Ca), several minor and trace elements (B, Li, Na, Ti, Mn, Co, Ni, Cu) were identified in the positive ion mass spectra. The unsputtered surface is covered with a hydrocarbon-rich layer, as indicated by the presence of numerous light C.H. fragments as well as several masses of several hundred atomic mass units (amu). This layer is much better developed than the ubiquitous atmosphere-derived hydrocarbon layer observed on nominally clean.unsputtered surfaces and therefore must be indigenous. High concentrations of Ni and Cu are associated with the C-rich layer and may exist as organo-metallic compounds. Several C-N fragments, possibly indicative of biogenic compounds, were also identified in negative ion spectra. Imaging reveals the presence of localized islands enriched in oxides of Si, Al, Na, and Ca beneath the carbonaceous layer. This study demonstrates that TOF-SIMS can be used to provide unique and geochemically useful information on crack surfaces in rocks. (Authors' abstract)

MATSUMOTO, Takuya, HONDA, Masahiko, McDOUGALL, Ian and O'REILLY, S.Y., 1998, Noble gases in anhydrous lherzolites from the Newer Volcanics, southeastern Australia: A MORB-like reservoir in the subcontinental mantle: Geochim. et Cosmo. Acta, v. 62, no. 14. p. 2521-2533. First author at Research School of Earth Sci., The Australian Nat'l. Univ., Canberra 0200, Australia.

In order to understand the nature of noble G reservoirs beneath continents, elemental and isotopic compositions of noble G were analyzed from spinel-lherzolites with anhydrous mineral assemblages (i.e., olivine>clinopyroxene-orthopyroxene>spinel); these are considered to be typical of the upper lithospheric mantle. The observed noble G elemental and isotopic compositions are very similar to those found in MORBs. Characteristic features include (1)  ${}^{3}$ He ${}^{4}$ He ratio of about 1 × 10 ${}^{3}$ . (2) linearly correlated  ${}^{20}$ Ne ${}^{21}$ Ne and  ${}^{21}$ Ne ${}^{22}$ Ne ratios plotting on the wellestablished MORB-line, (3) relatively high <sup>40</sup>Ar/<sup>36</sup>Ar ratios, and (4) corre-lated excesses in <sup>129</sup>Xe and <sup>136</sup>Xe with respect to atmospheric xenon. In addition, <sup>3</sup>He to <sup>22</sup>Ne ratios are close to those of a solar component, reinforcing the view that the Earth contains primordial helium and neon of solar composition. The MORB-like noble G are trapped predominantly in CO2-rich FI, which are inferred to be of S origin. These G probably are of metasomatic origin, having been introduced into the lithospheric mantle from the convective upper mantle by CO2-bearing M. The results indicate that a MORB-like noble G reservoir may characterize the upper part of the mantle on a global scale. This reservoir may be underlain by a relatively less degassed mantle reservoir, as plume-like mantle noble G also have been identified beneath southeastern Australia (Matsumoto et al., 1997). Thus, some form of chemical layering appears to be required to explain the noble G signatures both in the subcontinental and suboceanic mantle. (Authors' abstract)

MAZUREK, M., WABER, H.N. and GAUTSCHI, A., 1998, Hydrocarbon gases and fluid evolution in very low-grade metamorphic terranes: A case study from the Central Swiss Alps: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90-5410-942-4, p. 417-420. First author at GGWW, Inst. of Geol. and of Mineral. and Petrol., Univ. of Bern, Switzerland.

In a marl formation that was subjected to low-T metamorphism, free gases and groundwaters were sampled and compared with the bulk and isotopic compositions of FI. Results indicate different sources for G (derived thermally from kerogen) and water (which represents a mixture of connate and metamorphic water). No indications exist for later interactions of the rocks with meteoric waters. (Authors' abstract)

McCANDLESS, T.E., LAJACK, D.J., RUIZ, Joaquin, and GHAZI, A.M., 1998. Trace element determination of single fluid inclusions in quartz by laser ablation ICP-MS: Geostandards Newsletter. the J. of Geostandards and Geoanalysis, v. 21, no. 2, p. 279-287. First author at Centre for Mineral Resources, Dept. of Geosci., Univ. of Arizona, Tucson, AZ 85721, USA.

Single FI in quartz from a Pb-Zn-Ag carbonate replacement deposit were selected for trace element determination by laser ablation ICP-MS. Spikes in element intensities were noted between first breached F versus subsequent analyses, suggesting that accurate element concentrations may not be determined in smaller FI when only one analysis is obtained before the F is exhausted. Elemental concentrations in the FI were determined by external standardisation using solutions sealed in microcapillary tubes Standards and single natural I analyses give repeatabilities (%RSD) of ~20% for Rb and Sr. Rubidium and strontium concentrations range from 0.56-5.07  $\mu$ g ml<sup>-1</sup> and 1.12-27.4  $\mu$ g ml<sup>-1</sup>, respectively, whereas Zn and Ag are below detection limits (<10  $\mu$ g ml<sup>-1</sup>). The results suggest that nearly all Zn and Ag are removed by the time hydrothermal F precipitate gangue minerals. (Authors' abstract)

McCORMICK, K.A. and McDONALD, A.M., 1998, The crystal chemistry of amphiboles in the footwall breccia, at the Fraser mine, Sudbury, Ontario (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A141. Authors at Mineral Exploration Research Center and Dept. of Earth Sci, Laurentian Univ.; email (kmccormick@nickel.laurentian.ca)

Amphiboles from two cores drilled through the footwall breccia between the Sudbury Igneous Complex and the footwall Levack Gneiss at Fraser mine in the North range of the Sudbury Basin were analyzed. Both halogen-poor and halogen-bearing phases are present. The rims on actinolite to magnesiohomblende are an Fe-rich amphibole that is frequently enriched in Cl (0.7-4.0 wt%). The Cl-poor, Fe-rich rims range in compositions from ferroactinolite to ferrohomblende, whereas the Cl-bearing, Ferich rims are always hastingsite. Cl-bearing amphiboles are associated with sulfides, but are erratically distributed through the ore zone. The presence of these Cl-bearing phases suggest that they crystallized from a Cl-Fe-rich F that, at least spatially, is related to mineralization. (From authors' abstract by E.R.)

McCUAIG, T.C. and KERRICH, Robert, 1998, P-T-t deformation-fluid characteristics of lode gold deposits. Evidence from alteration systematics: Ore Geol. Reviews, v. 12, p. 381-453. Authors at Dept. of Geological Sci., Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 5E2.

Alteration during both interseismic and coseismic episodes typically involves the hydrolysis of metamorphic feldspars and Fe. Mg. Ca-silicates to a muscovite/paragonite-chlorite±albite/K-feldspars assemblage; carbonization of the metamorphic minerals to Ca. Fe, Mg-carbonates; and sulphidation of Fe-silicates and oxides to sulphides. Geochemically this is expressed as additions of K, Rb, Ba, Cs, and the volatiles H<sub>2</sub>O, CO<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>S in envelopes of meter to kilometer scale. K/Rb and K/Ba ratios are close to average crustal values, potentially ruling out late stage magmatic F where K/Rb and K/Ba are respectively lower and higher than crustal values.

The hydrothermal ore-forming F were dilute, aq, carbonic F, with sal generally ≤3 wt.% NaCl eq., and X(CO2±CH4) 10-24 wt.%. They possess low CI but relatively high S, possibly reflecting the fact that metamorphic F are generated in crust with ~200 ppm Cl, but ~1 wt.% S. Primary Fl are: (1) H2O-CO2. (2) CO2-rich with variable CH4 and small amounts of H2O, and (3) 2-phase H2O (L-V) I. Inclusions types 2 and 3 represent immiscibility of the type 1 original ore F. Immiscibility was triggered by F P drop during the coseismic events and possibly by shock nucleation, leading to highly variable Th in an isothermal system. A thermodynamic evaluation of alteration assemblages constrains the ore F pH to 5-6; redox controlled by the HSO<sub>3</sub>/H<sub>2</sub>S and CO<sub>2</sub>/CH<sub>4</sub> buffers; and X<sub>CO2</sub> that varies. The higher T deposits formed under marginally more oxidizing conditions. Stable isotope systematics of the ore and gangue minerals yields T of 200-420°C, consistent with the crustal spectrum of the deposits, very high F rock ratios, and disequilibrium of the externally derived ore F with wall rocks. The ore F  $\delta D$  and  $\delta^{18}O$  overlap the metamorphic and magmatic ranges, but the total dataset for all deposits is consistent only with dominantly metamorphic F. Carbon isotope compositions of carbonates span -11 to +2% and show provinciality: this is consistent with variable proportions of reduced C (low  $\delta^{13}$ C) and oxidized C (higher  $\delta^{13}$ C) in the source regions contributing CO<sub>2</sub> and CH4 to the ore F. In some instances, C appears to have been derived dominantly from proximal to the deposits, as in the Meguma terrane (61°C--22%). Sulphur isotope compositions range from 0 to 9‰, and are consistent with magmatic S, dissolution or desulphidation of magmatic sulphides, or average crustal sulphides. <sup>34</sup>S-depleted sulphides occur in ore

bodies such as Hemto where F immiscibility led to loss of H<sub>2</sub>S and consequent F oxidation. Gold is probably transported as an Au(HS)<sub>2</sub><sup>-</sup> complex. Relatively high S but low Cl in the hydrothermal F may explain the high Au slow base metal characteristic of the deposits. Gold precipitated in ore bodies due to loss of S from the ore F by sulphidation of wall rock, or immiscibility of H<sub>2</sub>S; and by oxidation or reduction of the F, or by chemisorption, or some combination of these processes. Most lode gold deposits have been britty reactivated during uplift of host terranes, with S brines or meteoric water advecting through the structures. These S F may remobilize gold, generate retrograde stable isotope shifts, reset mineral geochronometers, and leave trails of S FI. Data on disturbed minerals has led to invalid models for lode gold deposits. The sum of alteration data leads to a model for lode gold deposits involving a clockwise *P-T-t* evolution and synkinematic and synmetamorphic mineralization of the "deep later" type. (From authors" abstract by E.R.)

McDONALD, Iain and TREDOUX, Marian, 1998, No platinum in active hot-springs near Naboomspruit, Northern Province. South Africa: A great idea bites the dust (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). First author at School of Earth and Environmental Sci., Univ. of Greenwich, Chatham Maritime, ME4 4AW, U.K.

Earlier data point to an oxidized, S-poor epithermal F as the source of the Pt. Samples were analyzed by ICP-MS. Rb, Pd and Au were detected in ppt range, but no Pt. (E.R.)

McINNES, B.I.A., EVANS, N.J., GRÉGOIRE, Michel, RYAN, Chris and McCARRON, Joanne, 1998, Characteristics of the mantle source region of the Ladolam gold deposit, Lihir Island, Papua New Guinea (abst.): Geological Soc. of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 303. First author at CSIRO, Exploration and Mining, P.O. Box 136, North Ryde, NSW 2113.

Xenoliths from dredge and TV-grab sampling of a 1 km submarine cinder cone located 14 km SW of the giant Ladolam gold mine returned 130 ultramafic, mafic and sedimentary xenoliths. Petrological studies of these samples has provided an unprecedented view of the source region of an arc magmatic system with a clear propensity to produce giant ore deposits.

Some of the peridotite xenoliths have distinctive vein structures and mineral compositions generated by water-rock interactions within the mantle wedge. The veins are planar, interconnected networks (1 to 6 cm in width) which crosscut earlier ductile deformation. The veins contain fibrous, radiating orthopyroxene with fine-grained Fe-Ni sulfides and minor olivine, clinopyroxene, phlogopite and magnetite. The presence of H<sub>2</sub>O-rich FI in the orthopyroxene and the lack of shear structures in these veins indicates that metasomatism of peridotite occurred via hydraulic fracturing, probably as a result of the influx of slab-derived hydrous F into the mantle. (From authors' abstract by E.R.)

McKEAGNEY, C.J., 1998, Structural and alteration characteristics of the Indarama lode gold deposit, Zimbabwe; implications for craton-wide tectonism and mineralization. PhD thesis, Univ. Southampton.

The Indarama lode gold deposit is part of the Kwekwe gold camp in the Midlands greenstone belt, central Zimbabwe. Gold mineralization is hosted by vertically dipping, Bulawayan (c. 2.9-2.7 Ga) metabasalts of low (greenschist facies) metamorphic grade.

Host rock alteration involved carbonatization, sericitization, chloritization and sulphidation. Variable alteration and microvening intensity is described in terms of four alteration domains. The outermost two domains have undergone chloritization and sericitization, and weak carbonatization and sulphidation, whereas alteration domains closer to the shear veins are characterised by more intensive sericitization, carbonatization and sulphidation, and consequently are strongly bleached. Multiple repetitions of the same alteration assemblages characterise all lodes. Localised increases in F flow, created by lode intersections and mine-scale dilational jogs, greatly increased the extent of host rock alteration, thereby weakening the host rock and promoting brittle-ductile rather than brittle deformation in these localised zones.

Geochemical modelling indicates that gold was deposited from a reduced H<sub>2</sub>O-CO<sub>2</sub> F, with a pH between 5 and 5.6 under P-T conditions of 200-325°C and 0.25-1 kbar. Gold transport was dominantly as AuHS<sup>0</sup>, but Au(HS)<sub>2</sub><sup>°</sup> was also important. Gold deposition occurred in response to destabilisation of the transporting complexes, mainly by F-rock interaction, but also by decreasing F.P. F-rock interaction controlled gold precipitation by decreasing the activities of reduced sulphur species (by sulphide mineral precipitation), increasing pH (by feldspar hydrolysis), and by host rock sulphidation. Phase separation, caused by abrupt F P drops during vein reactivation, contributed to gold precipitation by the escape of volatile components from the F.

The extent of F-rock interaction was tightly controlled by geological structure and provided the dominant control on gold precipitation. The key to mineralization was F access to the host rocks, which was greatly enhanced by development of the microvein networks (damage zones), and by wallrock alteration which led to subsequent local development of a spaced cleavage. (From author's abstract by E.R.)

Uses only earlier FI data of Buchholz (E.R.).

McLEMORE, V.T., GLINES, Joe and LUETH, Virgil, 1998, Quartz epimorphs from the Hermosa District, Sierra County, New Mexico: New Mexico Geol., v. 20, no. 2, p. 63-64.

Indexed under Fl.

McNEIL, B., SHAW, H.F. and RANKIN, A.H. 1998. The timing of cementation in the Rotliegend sandstones of the southern North Sea: A petrological and fluid inclusion study of cements: J. of Petroleum Geol. v. 21, no. 3, p. 311-328. First author at Japan Nat'l. Oil Corp., 1-2-2 Hamada, Mihama-ku, Chiba-shi, Chiba 261, Japan.

When plotted on burial-thermal history diagrams, the FI and petrographic results show that quartz cement precipitated over a range of burial depths. Dolomite precipitation occurred during deep burial diagenesis and ceased largely with the onset of fracturing. Sulphates (anhydrite and barite) were mainly precipitated during the inversion phase in the Sole Pit area. As both the anhydrite FI, and possibly also the quartz FI within some of these cements contain hydrocarbon G, the migration of G took place during the inversion period, using the fractures as migration pathways. (From authors' abstract by E.R.)

MÉNEZ, B., PHILIPPOT, P., CHEVALLIER, P., POPULUS, P. and LEGRAND, F., 1997, Quantitative elemental analysis of individual fluid inclusions using synchrotron X-ray microfluorescence (SXRF): Terra Nova abstract, v. 9, p. 446. First author at CNRS, URA 736. Laboratoire de Pétrologie, Université Paris 7.

The main limiting factor associated with individual FI analysis using SXRF technique is to quantify absorption of the incident and fluorescent radiations by the F and the host material. Mineral host thickness and FI sizes determined by optical means have proved to be highly inaccurate with regards to the degree of precision required. Theoretically,  $(K\alpha/K\beta)i$  ratio of element i in solution is directly proportional to the thickness of material traversed and therefore could be used as a reliable term for absorption correction.

In order to constrain experimentally the relationship between  $(K\alpha/K\beta)i$ , host material thickness and FI geometry and composition, three experiments have been developed on line D15 and BL10 of LURE (Orsay) and ESRF (Grenoble) synchrotron radiation facilities. These are:

1-Interception of the X-ray beam emerging from pure metal targets (Cr, Mn, Fe, Ni, Cu, Zn) by quartz and aluminum plates of different thicknesses (i.e. absorption by the host).

2-Analysis of aq solutions of known metal concentrations (Mn, Ni, Zn) and of different sal (0 and 15 wt.% NaCl eq.) placed in silica glass capillaries of various wall thickness and inner diameter (i.e. absorption by the host and the F).

3-Analysis of synthetic Fl of known metal contents (Ni, Zn) trapped in NaCl crystals (i.e. absorption by the host and effect of I geometry).

Results of experiment 1 indicate that the evolution of  $(K\alpha/K\beta)$  i ratios as a function of host material thickness is in perfect agreement with theoretical prediction, independently of the local analytical environment (reproducibility of the measurements). For experiment 2 and 3,  $(K\alpha/K\beta)$  ratio of a reference element in solution, let say Zn, was used to estimate the thickness of host material traversed. Establishing that the X-ray peak intensity of Zn corresponds to a given concentration, we were able to determine the concentration of the other trace metals present in solution (Mn,Ni) with an accuracy of ±6%. This indicate that reliable quantitative estimation of elemental concentration in individual Fl can be obtained using SXRF technique without precise knowledge of I depth and geometry. (Authors' abstract)

MÉNEZ, B., PHILIPPOT, P., MOSBAH, M., DRAKOPOULOS, M. and SNIGIREV, A., 1998a. Fluid inclusion depth and thickness estimates using resonance of Na nuclear reaction and Si elastic scattering: Int. Conf. Nuclear Microprobe Tech. & Applications 98, Spier. p. xx [NOTE: the MÉNEZ, Bénédicte, PHILIPPOT, Pascal, MOSBAH, Michelle, DRA-KOPOULOS, Michael and SNIGIREV, Anatoly, 1998b, Individual fluid inclusions analysis combining PIXE, PIGE and synchrotron X-ray fluorescence (SXRF): Int'l. Conf. Nuclear Microprobe Tech. and Applications 98, Spier, S. Africa, No. 13. First author at Laboratoire de Pétrologie, CNRS-Université Paris 7, Paris, France.

Proton-induced X-ray  $\gamma$ -emission and synchrotron radiation X-ray fluorescence techniques have shown to be well-adapted for trace element analysis in individual FI. The computational procedures used to estimate elemental concentrations require corrections for X-ray self-absorption by the IF and the host mineral. Because the geometry used for the calculations is approximated as a plane-parallel layer of homogeneous material, the careful determination of the I depth and 3D-geometry is essential for reliable analyses. The choice of target I is best achieved using a spindle stage. Inclusion depth is the most critical parameter for quantitative analyses. This factor is poorly determined with optical techniques.

Two independent means of evaluating I depth have been developed. For X-ray spectra,  $(K\alpha/K\beta)z$  ratio from a given element Z in solution is directly proportional to the thickness of material traversed and has provided I depth estimates commonly better than  $\pm 1 \mu m$ . With regards to  $\gamma$ -ray spectra, the potential performance of the resonant nuclear reaction Na (p, p' $\gamma$ ) Na in estimating I depth has been evaluated (we choose Na because of its common occurrence in natural F). By progressively increasing the energy of the incident proton beam until appearance of the resonance of lowest energy (1.283 Mev) gives, after correction for absorption of the beam by the host quartz, the thickness of quartz traversed and hence the I depth. Similarly, we show how the use of the nuclear reaction Si (p, p) Si can provide information on the FI thickness.

Owing to different ionization cross-sections, PIXE yields more intense X-rays from lighter elements (Z<22) whereas SXRF yields more intense heavy-element peaks. The two techniques are thus complementary and were used in combination to obtain elemental concentration of a wide range of elements. In order to calibrate the X-ray peaks, a standard is required. Approaches that we have tested include choosing one element from previous independent work (e.g., crush-leach), or assuming CI or total salt concentration is known from microthermometry. The PIXE microprobe, under vacuum, is free of the Ar peak that is ubiquitous in SXRF spectra, so PIXE spectra are more suitable for quantifying CI and associated low- to medium-Z elements. Medium-Z elements such as Fe can in turn be used as an internal standard for quantifying heavy trace-metals (Zn. As, Sr) from SRXF spectra. Application to samples from the Brusson gold district and from a Columbian emerald deposit which contain a single generation of I analyzed previously by crush-leach, gave single-I analyses by PIXE and SXRF that are generally very similar to the crush-leach analyses. (Authors' abstract)

### MÉNEZ, B., PHILIPPOT, P., VANKO, D.A., MOSBAH, M., CHEVALIER, P., DRAKOPOULOS, M., POPULUS, P. and SNIGA-REV, A., 1998, Individual fluid inclusion microanalysis combining protoninduced and photon-induced x-ray emission (PIXE and SXRF): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 44. First author at CNRS, Université Paris 7, Paris.

A review, including a discussion of calibration procedures: Approaches that we have tested include choosing one element from previous independent work (e.g., crush-leach), or assuming Cl or total salt concentration is known from microthermometry. The PIXE microprobe, under vacuum, is free of the Ar peak that is ubiquitous in SXRF spectra, so PIXE spectra are more suitable for quantifying Cl. For example, an application to samples from the Brusson gold district (provided by Larryn Diamond) and from a Columbian emerald deposit (provided by Gaston Giuliani) which contain a single generation of I analyzed previously by crush-leach, gave single-1 analyses by PIXE and SXRF that are generally very similar to the crush-leach analyses. In another case, freezing runs modeled on the NaCl-CaCl<sub>2</sub>-H<sub>2</sub>O system for some oceanic Fl showed that a typical 1 contained 40 wt% salts. PIXE analyses of 1 from the same sample were computed by calculating a Na value by charge balance and adjusting the total salts to 40 wt%. The results are consistent with previous SXRF experiments.

See also Philippot, et. al. (this volume) (E.R.). (From authors' abstract by E.R.)

MERNAGH, T.P., 1998a, A fluid inclusion study of the Fosterville mine,

Australia: A turbidite-hosted gold field (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 45. Author at Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601, Australia.

The Fosterville Au mine is located in the world-class, turbidite-hosted Au province in the western Lachlan Fold Belt, Victoria, Australia. The gold is intimately associated with disseminated arsenopyrite and pyrite within pervasively kaolinized and ferruginized lithic breccias in the oxidized zone of the deposit. Mineralized quartz porphyry dikes contain abundant disseminated sulfides and are cut by later quartz/carbonate veins.

Three FI types occur in the quartz/carbonate veins. Type Ia are twophase L-rich FI with no detectable CO<sub>2</sub>. Type Ib FI are also L-rich but contain CO<sub>2</sub>. Type II are V-rich (>20 vol% V), CO<sub>2</sub>-bearing FI and are most abundant. Type III (also common) are three-phase FI containing L and V CO<sub>2</sub>.

Raman microprobe analysis of the V phase of Type Ib. II and III FI confirms the presence of CO<sub>2</sub>, and indicates that N<sub>2</sub> ( $\leq$ 18 mol%) and CH<sub>4</sub> occur in some FI. CH<sub>4</sub> varies from 0 to 25 mol% with the highest concentrations occurring proximal to black shales.

Clathrate melting in CO<sub>2</sub>-bearing Fl occurred around 8.5°C giving sal of 0.5 to 5.8 eq. wt% NaCl with a mode at 3.5 wt% NaCl. Most CO<sub>2</sub>-rich Fl decrepitated before Th but the remaining homogenize between 234 and 384°C. Similar Th are observed for homogenization into both the L and V, with some Fl exhibiting near critical behaviour. However, a small number of Type II Fl homogenize between 146 and 198°C.

Gold deposition is interpreted to be due to desulfidation reactions caused by phase separation and subsequent F mixing. Mineralization within the host rocks occurred as the F flowed from the overpressured veins into the host rocks and reacted with more reduced F or carbonaceous material to precipitate gold and associated sulfide minerals. (From author's abstract by E.R.)

MERNAGH, T.P., 1998b, A fluid inclusion study of shear-zone hosted gold at Fosterville, Victoria (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 311. Author at Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601, Australia.

Shear-zone gold mineralisation at Fosterville extends for at least 10 km and is hosted within a system of subparallel faults in marine sandstones and shales. Wallrock alteration is limited to silicification, minor sericitisation and abundant fine-grained disseminated arsenopyrite and pyrite.

Three types of FI occur within the quartz/carbonate veins: Type Ia are two-phase, L-rich I with <10 vol% V and no detectable CO<sub>2</sub>, type Ib inclusions are also L-rich but contain CO<sub>2</sub> in the V phase; type II are V-rich (>30 vol% V), CO<sub>2</sub>-bearing I and are the most abundant. Many Type II inclusions have only a thin meniscus of water or appear to consist of only CO<sub>2</sub>, type III are three-phase I containing L and V CO<sub>2</sub> and these are also very common.

Raman microprobe analysis of the V phase of Types II and III inclusions confirms the presence of  $CO_2$ , but also indicates that  $N_2$  and  $CH_4$  occur in some 1. The  $N_2$  content of the V phase varies from 0 to 18 mol% and is believed to reflect interaction of the F with organic material within the turbidite sequence.  $CH_4$  varies from 0 to 25 mol% with the highest concentrations occurring proximal to black shales. These results are in accord with microthermometric analyses which showed  $CO_2$  final melting T varied between -58.8 and -56.6°C with the overwhelming majority being close to -56.6°C. The majority of  $CO_2$ -bearing I homogenise between 234 and 384°C with a mode at 270°C, and similar T are observed for homogenise between 146 and 198°C. Coexisting aq I homogenise between 133 and 218°C with a mode at 162°C. Other P, aq I in growth zones in bladed carbonate crystals homogenise between 212 and 338°C with a mode at 247°C.

Type lb F containing up to 25 mol% CO<sub>2</sub> represent the least reacted, deeply sourced F that have migrated through the fault zone at Fosterville. These F were initially at near critical conditions and were trapped at about 270°C and at P from 130 to 200 Mpa. The presence of coexisting aq and CO<sub>2</sub>-bearing I which homogenise around 162°C suggest that this F undergoes phase separation and cooling. Other aq I in subhedral to euhedral carbonate indicate the ingress of a lower sal, meteoric(?) F at T around 247°C. Phase separation was enhanced by mixing with CH<sub>4</sub> and N<sub>2</sub> enriched, reduced F in the country rocks and the resulting partitioning of H<sub>2</sub>S into the V phase led to gold and sulphide precipitation. (From author's abstract by E.R.)

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METRICH, Nicole, JORON, J.-L. and BERTHIER, Bernard, 1998, Occurrence of boron-rich potassic melts in the Vulsini Volcanic District, Italy: Evidence from melt inclusions: Geochim. et Cosmo. Acta, v. 62, no. 3, p. 507-514. Authors at Laboratoire Pierre Sue, CEA-CNRS, CE-Saclay, 91191 Gif sur Yvette, France.

Boron was analyzed by nuclear microanalysis technique, using the <sup>11</sup>B(p,  $\alpha$ )<sup>8</sup>Be reaction, in potassic to highly potassic M (Mg#[Mg<sup>2+</sup>/(Mg<sup>2+</sup> + Fe<sup>2+</sup>)]>0.70) trapped as MI in olivine (Fo<sub>91.7-90.5</sub>) phenocrysts from the Vulsini Volcanic District (northwestern Roman Province, Italy). These data evidence unusual B concentrations from 60 to 100 ppm, up to five times higher than any documented values in primitive subduction-related magmas. The MI display variable concentrations in B, K, Sr, and F, with constant ratios between elements, for a single volcanic event, that strongly suggest variations of the extents of batch partial melting of a mantle source enriched in B, K, Sr, and F.

Conversely, B/K and B/Cl ratios in potassic magmas (Mg#>0.70), as exemplified by MI in olivine (Fo>90), are variable on the scale of the whole Roman Province. These variations cannot be explained by either fractional crystallization or differing extents of the mantle source melting alone. This is also supported by the range in Th/Ta ratios (52-10) of the whole rock samples. Variability of the B/K or B/Cl ratios cannot be related to a single-stage metasomatism event. The data indicate the possible occurrence of B-rich contaminant and/or high inputs of subducted-derived components in the mantle wedge beneath the Vulsini area, within the peculiar geodynamic setting of northern part of the Apenninc arc.

In addition, by determining boron concentrations using nuclear microanalysis involving the  ${}^{11}B(p, \alpha)^8Be$  nuclear reaction, we have illustrated the sensitivity of the nuclear reactions in the analysis of the light elements. (Authors' abstract)

#### MÉTRICH, N., SCHIANO, P., CLOCCHIATTI, R. and MAURY,

R.C., 1998, Constraints on sulfur transfer in subduction zones. The example of Batan (Luzon volcanic arc, Philippines) (abst.): Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998, p. 161 (in French, translation by E.A.J. Burke). First author at Laboratoire Pierre Sue, CEA-CNRS, CE/Saclay, 91191 Git/Yvette

Sulfur contents have been studied systematically in glass I trapped in olivine neoblasts of harzburgite mantle nodules and in olivine phenocrysts of a calc-alkaline bsash of Batan Island. The neoblasts of olivine (Fo<sub>90.7</sub>,  $_{80.7}$ , NiO = 0.25-0.5%; CaO < 0.1%) of the nodules contain at the same time P glass I (SiO<sub>2</sub>= 63.5-60%) rich in sulfur (S= 2540-1440 ppm), iso-lated sulfide globules and/or multiphase FI (H<sub>2</sub>O S+sulfide globules). These SiO<sub>2</sub>-rich L represent the products of low-degree fusion of recycled crust, thus enriching the mantle below Batan (Schiano et al., 1995, Nature, no. 377) This permits proposing a model for sulfur transfer from the sub-ducting crust to the mantle by means of a (hyper)supercritical F. The different sulfur-containing phases (glass and FI, sulfide globules) observed in the olivine neoblasts result from the immiscibility of a sulfur-bearing phase coexisting with a hydrated silicate L and an aq phase, both rich in sulfur.

In the silicate L, sulfur decreases very rapidly, with the lowest contents corresponding to the 1 (SiO<sub>2</sub>= 62-56.6%) in the olivine neoblasts richest in iron (Fo<sub>28,7-86</sub>, figure).

SiO<sub>2</sub> has been recalculated on the basis of an anhydrous composition. On the basis of major elements, the glass I (CaO/Al<sub>2</sub>O<sub>3</sub>= 0.8-1.25) in olivine of the basalt define a continuous evolution with the Batan lavas and the mantle-silicate L. Sulfur does not follow the same evolution (figure), in agreement with its possible fractionation by other phases.

In a first approximation we propose that a high proportion of sulfur in mantle-silicate L and basaltic magmas is of crustal origin.

FIGURE CAPTION: The evolution of sulfur contents in olivine neoblasts (dots) is indicated by an arrow. It is seen that the highest sulfur contents in mantle and in basaltic ( $\beta$ ) glasses are similar at about 2500 ppm. (Authors' abstract)

See figure in the Illustrations appendix.

METRICH, Nicole, SCHIANO, Pierre, CLOCCHIATTI, Robert and MAURY, R.C., 1998b Transfer of sulfur in subduction setting. An example from Batan Island (Luzon volcanic arc, Philippines) (abst.): EOS. Trans., 79 (45) Fall Meet. Suppl., p. F970 First author at Laboratoire Pierre Süe CEA-CNRS, CE-Saclay, Gif sur Yvette 91191, France, email (nmetrich@cea.fr)

Sulfur abundance has been determined in both P silicic and basaltic MI of olivines from harzburgitic xenoliths and a basaltic lava sample, respectively, from Batan Island. In the calc-alkaline basalt sample, both the olivine phenocrysts (Fo>85) and their MI have recorded early stages of crystallization. The average sulfur concentration determined for these calcalkaline basaltic M is 2550 ppm. Assuming that the calc-alkaline basalts at Batan have derived from a metasomatized harzburgitic mantle source, by 15-20% extents of melting, 20-40% of sulfur may have been provided by the slab-derived component. (From authors' abstract by E.R.)

MIGDISOV, A.A., SULEIMENOV, O.M. and ALEKHIN, Yu.V., 1998, Experimental study of polysulfane stability in gaseous hydrogen sulfide: Geochim. et Cosmo. Acta, v. 62, no. 15, p. 2627-2635. First author at Dept. of Earth and Planetary Sci., McGill Univ., Montreal, Québec H3A 2A7, Canada.

The solubility of sulfur in gaseous hydrogen sulfide has been studied experimentally in the H<sub>2</sub>S-S system. Experiments were carried out at T between 50 and 290°C and P up to 200 bars. The results of experiments show significant interaction between S and H<sub>2</sub>S. It is theorized that sulfur solubility in gaseous H<sub>2</sub>S is related to two main chemical reactions, dominated in the different T ranges: sulfur solvation by H<sub>2</sub>S (125-170°C) and polysulfane formation (200-290°C). (From authors' abstract by E.R.)

MIKHÁILOVA, Yu.V., PANKRÁT'EV, P.V. and BEZDELIGA, N.Ya., 1998, The isotope-geochemical and physicochemical regime of formation of the volcanogenic-sedimentary polymetallic deposits of Uzbekistan (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan. Abstracts volume, p. 136-139. (in Russian).

MIKUCKI, E.J., 1998. Hydrothermal transport and depositional processes in Archean lode-gold systems: A review: Ore Geol. Reviews, v. 13, p. 307-321. Author at Centre for Teaching and Research in Strategic Mineral Deposits, Dept. of Geol. and Geophys., The Univ. of Western Australia, Nedlands, WA 6907, Australia; email (emikucki@geol.uwa.edu.au)

Compelling evidence now exists for the formation of Archean lodegold deposits over a substantial range in metamorphic conditions and crustal depth. The commonality of ore-F isotopic and geochemical characteristics, the extreme F-rock ratios within actual ore zones and the observed depth continuity within individual orebodies all suggest that these deposits formed within vertically extensive, crustal-scale hydrothermal systems. Calculations based on new thermodynamic data and estimated ore-F conditions suggest that gold would have been transported as Au(HS)2 over most of this range. Gold transport in the ore F that formed some diopsideand diopside-K-feldspar class deposits (T>550°C) would have been as AuCl<sub>2</sub>', whereas the Au(HS)° complex may have been significant in some of the lower T (<270°C), less alkaline ore F. The high solubility of gold in lode-gold ore F at amphibolite facies conditions (10's to 1000's ppb) suggests that F may have been undersaturated in gold within their source regions, promoting the ore fluid's capacity to retain gold in solution over the large transport distances involved. Ore depositional mechanisms were also likely to vary between crustal levels. F-rock interactions, and wallrock sulphidation in particular, appear to be the most important type of precipitation mechanism. However, with decreasing depth of formation, the scope of other depositional mechanisms, notably phase separation and F mixing, becomes greater. (Author's abstract)

MIKULSKI, S.Z. and SPECZIK, Stanislaw, 1998, Scheelite metasomatites in the Ptasznik enclave of the Klodzko-Zloty Stok intrusion in Sudetes (SW Poland): Extended Abstracts, Anatomy and textures of ore-bearing granitoids of Sikhote Alin (Primorye region, Russia) and related mineralization: Intl. Field Conf. in Vladivostok, Russia, 1-12 Sep-1998, Seltmann, R., Gonevchuk, G. and Khanchuk, eds., p. 59-60. GeoForschungsZentrum Polsdam (GFZ).

Three generations of scheelite-bearing quartz veins are recognized. The T<sub>h</sub> of the 1 from quartz in scheelite-bearing veins fall into three groups:  $300-370^{\circ}$ C;  $210-260^{\circ}$ C and  $100-170^{\circ}$ C. Total salt concentrations in I solutions varies from 1-12 wt%. In the second generation of quartz veins native gold mineralization was also found. (From authors' abstract by H.E.B.)

MILLEDGE, H.J., SUTHERLAND, F.L., KENNEWELL, P. and MEYER, H.O.A., 1998, Studies on Copeton diamonds, east Australia (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A18. First author at Dept. of Geological Sci., Univ. College, London.

The main suite contains two roughly equal proportioned varieties viz yellow, high nitrogen and white, low nitrogen diamonds, with nitrogen concentrations ranging from under 20 to over 2500 ppm. One coesite-

bearing Copeton diamond contained scapolite, as a high P, CO<sub>2</sub>, H<sub>2</sub>O and sulphur-bearing phase. (From authors' abstract by E.R.)

MILODOWSKI, A.E., GILLESPIE, M.R., NADEN, J., FORTEY, N.J., SHEPHERD, T.J., PEARCE, J.M. and METCALFE, R., 1998, The petrology and paragenesis of fracture mineralization in the Sellafield area, west Cumbria: Proceedings of the Yorkshire Geological Society, v. 52, part 2, p. 215-241. Authors at British Geological Survey, Keyworth. Nottingham, NG12 5GG, UK; email (a.milodowski@bgs.ac.uk)

The petrology and paragenesis of fracture mineralization hosted in the Ordovician, Dinantian (Carboniferous Limestone) and Permo-Triassic rocks of the Sellafield area were studied as part of the United Kingdom Nirex Limited programme of site investigations around Sellafield in west Cumbria for a deep repository for radioactive waste. This paper summarizes the petrological and mineralogical observations from 23 of the deep (up to 2 km) boreholes drilled by Nirex.

A paragenetic sequence of nine Mineralization Episodes (ME1 to ME9) was recognized, and has been interpreted in the context of the geological and hydrogeological history of the Lake District massif and East Irish Sea Basin margin areas. ME1 to ME3 produced silicate and sulphidedominated Palaeozoic epithermal to mesothermal mineralization associated with pre-Acadian hydrothermal circulation and late-Caledonian (mid-Devonian) intrusions. ME4 to ME7 represent carbonate-sulphate-fluoritehematite-dominated mineralization associated with warm, complex, Na-Cl-Ca-SO4 brines expelled from the East Irish Sea Basin area during progressive burial of the thick Carboniferous and Permo-Triassic sedimentary sequence. Sulphate-carrying brines expelled to the basin margin in the Sellafield area mixed locally with cooler, more dilute, sulphate-poor groundwaters carrying barium, resulting in the precipitation of barite. ME8 and ME9, by contrast, are closely related to the development of the presentday groundwater system. ME8 involved telodiagenetic, supergene alteration and weathering by near surface oxidizing groundwaters. Isotopic evidence indicates that ME8 was probably initiated following Late Tertiary uplift and may still be ongoing in some areas. ME9 may be coeval with ME8, but represents mineralization in the deeper, more-reducing groundwater environment. This mineralization episode is dominated by calcite (sometimes associated with pyrite, marcasite, barite, anhydrite or gypsum) precipitated from groundwaters of similar composition to those found in the Sellafield area at the present day. Observations suggest that ME9 mineralization occurred during the Quaternary and is ongoing in the present groundwaters (Authors' abstract)

Extensive FI data presented (H.E.B.).

MIN, Kyoungwon and CHO, Moonsup, 1998, Metamorphic evolution of the northwestern Ogcheon metamorphic belt, South Korea: Lithos, v. 43, no. 1, p. 31-51.

The Ogcheon metamorphic belt (OMB) comprises late Proterozoic to Paleozoic metasedimentary and metavolcanic sequences which are intruded by Mesozoic granitoid plutons. P-T conditions of the garnet zone, estimated from garnet-biotite, garnet-chlorite and amphibole-plagioclase geothermometers together with garnet-plagioclase-biotite-muscovite/quartz geobarometers, are in the range of 5-8 kbar and 520-590°C. Retrograde P-T path based on FI studies suggests that the exhumation of the OMB has passed through the P-T range of 1-3 kbar and 350-500°C, following the isochore curves of the CO<sub>2</sub> I. In conjunction with structural and geochronologic data, we conclude that the OMB has experienced a polycyclic P-T evolution characterized by (1) crustal thickening during the middle Paleozoic time and (2) regional retrograde metamorphism in the Triassic. Our result further suggests that the Triassic collision belt in east-central China does not pass through the OMB. (From authors' abstract by E.R.)

MIN, Maozhong and WU, Junqi, 1998. Stable isotope studies of paleokarst-hosted uranium deposits in China: Geochemical Journal, v. 32, no. 2, p. 103-115.

The Devonian-Carboniferous carbonate rocks in south China host several important uranium deposits, which are characterized by their occurrence in solution collapse breccias and by the mineral association of pitchblende, coffinite, carbonates and Fe, Pb, Cu, Zn, Ni sulfides. The deposits represent an economically new, important uranium deposit type in China. The results of sulfur, carbon, oxygen and hydrogen isotope studies on FI, carbonate and pyrite from three typical deposits of this type, i.e., Sangilinyi, Sanbaqi and Saqisan, provide information concerning the nature of the F and sources of sulfur and carbon responsible for uranium mineralization. The  $\delta^{34}$ S values of pyrite from the ores and host carbonate range from 1.0 to -39.8 per mil and from 8.2 to -38.1  $\delta^{18}$ O. respectively. Depletion in  $\delta^{34}$ S and a wide range of the  $\delta^{34}$ S values for sulfide indicate that the sulfur in both the ores and host carbonates is biogenic. The  $\delta^{13}$ C values of calcite from the ores range from 2.9 to -1.4 per mil, which are similar to those of the host carbonate, ranging from 3.3 to -1.8. The majority of  $\delta^{13}$ C and  $\delta^{18}$ O values of carbonate from the deposits lie within the range for carbon and oxygen isotope compositions that exist in marine sedimentary carbonate. The similarity between the sulfur and carbon isotope compositions of the ores and host carbonate indicates that the sulfur and carbon as well as metallic elements in the ores may have derived from the host marine sedimentary carbonate. The 818O and 8D values of the mineralizing F range from 12.6 to -2.1 per mil and from -26.8 to -54.8 per mil, respectively. The oxygen and hydrogen isotope data demonstrate that the mineralizing F were derived from metamorphic water and were mixed with shallow groundwater Such F may have been released by faulting and shearing, which also opened the channel ways for circulation of mineralizing F and facilitated their mingling with meteoric water. (Authors' abstract)

Volume 31, 1998

MINARIK, W.G., 1998, Complications to carbonate melt mobility due to the presence of an immiscible silicate melt: J. of Petrol., v. 39, no. 11 & 12, p. 1965-1973. Author at Geophysical Laboratory and Dept. of Terrestrial Magnetism, Carnegie Inst. of Washington, 5251 Broad Branch Road, Washington, D.C. 20015 USA; email (minarik@gl.ciw.edu)

The relative interfacial energies of immiscible carbonate and silicate M were investigated in olivine and chnopyroxene matrices. Carbonate M has a higher M-solid interfacial energy than does the coexisting silicate M. The silicate M therefore selectively wets the grain-edge channels between solid phases, excluding the carbonate M to the center of M pockets, away from grain edges. This prevents the carbonate M from migrating independently of the silicate M and the carbonate M is unable to separate from the silicate M in a solid-dominated assemblage. The carbonate M will migrate effectively only after the silicate M has solidified, or by separating from the silicate M within L-dominated reservoirs (sills, dikes, or chambers), unrestricted by solid interfaces. This relative wetting behavior may help explain the close association of carbonate and silicate magmas in alkali complexes, and their relative timing of emplacement. These results also place constraints on the generation and separation of derivative M in carbonated silicate M systems and on the style and timing of alkali wall-rock metasomatism. (Author's abstract)

MIRANDA-GASCA, M.A., GOMEZ-CABALLERO, J.A. and EAS-TOE, C.J., 1998, Borate deposits of northern Sonora. Mexico: Stratigraphy. tectonics, stable isotopes, and fluid inclusions: Econ. Geol., v. 93, p. 510-523. First author at Univ. of Arizona, Dept. of Geosci., Tucson, AZ 85721 USA.

Mid-Tertiary tectonic extension produced basins with lacustrine sediments bearing borates, zeolites, gypsum, and detrital gold in northern Sonora. Colemanite deposits associated with howlite. gypsum, and celestite are present in the Magdalena and Tubutama basins. In the Magdalena basin, the La Tinaja del Oso deposit contains at least two generations of colemanite, the first replacing stratiform and probably syngenetic ulexite, and the second, more voluminous, of clear epigenetic origin. FI in epigenetic colemanite indicate deposition from very low-sal hydrothermal F at T up to 180°C, mainly 100-140°C. Water of crystallization from epigenetic colemanite has \deltaD values of -35 to -20 per mil, indicating that water in the hydrothermal F was of meteoric origin but was not lacustrine brine because of the low sal. The 834S values of gypsum associated with colemanite, 4.1 to 10.6 per mil, are typical of sulfate in extensional basins of the region. A realgar specimen has a  $\delta^{34}$ S value of -32.9, consistent with formation of sulfide by bacterial reduction of sulfate. Borate was initially deposited as ulexite, then replaced by colemanite after burnal. Epigenetic colemanite formed after lacustrine brine had disappeared, probably by circulating meteoric water heated as a result of high thermal gradients in the upper plates of metamorphic core complexes. (From authors' abstract by E.R.)

MISRA, K.C., GRATZ, J.F. and LU, Changsheng, 1996, Carbonatehosted Mississippi Valley-type mineralization in the Elmwood-Gordonsville deposits. Central Tennessee zinc district: A synthesis: Society of Economic Geologists. Special Pub. no. 4, 1996, p. 58-73. First author at Dept. of Geological Sci., Univ. of Tennessee, Knoxville, TN 37996-1410, USA.

The lower Ordovician breccia-fill deposits of the Central and East Tennessee districts have many similarities in terms of host rocks, nature of mineralization, ore-gangue mineralogy, and T and sal of mineralizing F. However, significant differences in the origin of the F, sulfur isotope ratios and sulfide precipitation mechanism, isotopic composition of ore lead, and

age of mineralization indicate that the two MVT districts developed without any genetic connection. (From authors' abstract by H.E.B.) Extensive Fl data presented to support their conclusion (H.E.B.)

MIZOTA, Chitoshi, FAURE, Kevin, NAKAYAMA, Katsuhiro and ZENG, Nanshi, 1998, Origin of boulder-size euhedral quartz in the Seto porcelain clay formation, central Japan: Geochemical Journal, v. 32, no. 1, p. 59-63.

Large boulder-size euhedral quartz crystals occur in the basal horizons of the Late Miocene Seto Porcelain Clay Formation, central Japan. The quartz crystals consist of smoky basal portion overgrown by translucent to milky white quartz.  $\delta^{18}$ O values (-1.5 to -0.2 per mil SMOW) of the translucent to milky white quartz are considerably lower than the values of smoky quartz (10.3 to 10.5 per mil). The oxygen isotope ratios of quartz and Th of Fl indicate that the translucent to milky white quartz overgrowths precipitated onto the early-stage smoky quartz in druses of the Naegi and/or Toki granites, from meteoric dominant thermal waters that infiltrated into the granites during the latest stage of granitic activity in the late Cretaceous age. (Authors' abstract)

MIZUTA, T., MIURA, T. and ISHIYAMA, D., 1998, The crystal size distribution and geochemical characteristics of barite from the Motoyama Kuroko deposits, Akita Prefecture, Japan (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A86. Authors at Dept. of Applied Earth Sci, Akita Univ., Japan; email (mizutt@ipc.akita-u.ac.jp)

The crystal sizes versus filling T of FI in barite and crystal sizes versus sal both have positive relationships. These observed data reveal that the T decrease of ascending hydrothermal F were not so large with small degree of seawater mixing within siliceous orebodies locating in the main conduit zone of Kuroko mineralization just below the Kuroko massive ores.

Barite in those ores could be precipitated very close to the baritesaturation curve and crystals should be grown slowly and become larger. (From authors' abstract by E.R.)

MOLNÁR, F., 1996, Fluid inclusion characteristics of Variscan and Alpine metallogeny of the Velence Mts., W-Hungary. in V.A. Popov (ed). Plate tectonic aspects of the Alpine metallogeny in the Carpatho-Balkan regioin. Proc. of the Annual Meeting, Sofia, 1996. UNESCO-IGCP Project No. 356, v. 2, p. 29-44. Author at Dept. of Mineral., Eötvös L. Univ., H-1088 Budapest, Muzeum krt 4a, Hungary.

In the area of the Velence Mts. genetically different igneous and hydrothermal activities took place. The Variscan monzogranite intrusion generated pegmatite, quartz-molybdenite stockwork, quartz-tourmaline metasomatic and vein type polymetallic mineralization. These were deposited in a non-boiling, high P (1-2.3 kbars) postmagmatic system. In contrast to this, a boiling, low P (maximum 400 bars) hydrothermal system was developed in relation to the volcanic activity of Eocene age. Cuporphyry and HS type epithermal ores were deposited in this hydrothermal system. F of this hydrothermal activity also invaded the Variscan intrusion causing the appearance of Cu-porphyry and epithermal mineralization in the monzogranite. (Author's abstract)

MOLNÁR, F., 1977a, Modelling of the formation of epithermal gold deposits on the basis of mineralogical-genetical studies: examples from the Tokaj Mts. NE Hungary: Födtani Kutatás XXXIV/I, p. 8-12 (in Hungarian). Author at Dept. of Mineral., Eötvös L. Univ., H-1088 Budapest, Muzeum krt 4a, Hungary.

The paper contains a short review on the HS and LS type epithermal gold deposits and presents mineralogical and Fl data on the LS type systems of the Tokaj Mts. Microthermometric data prove that hydrothermal activity took place between 100 and 290°C in mineralization characterised by adularia-sericite, as well as alunite-kaolinite alteration. Variation of T and mineralogical data as a function of elevation and temporal evolution of hydrothermal activity is used for modelling of gold deposition. Results show that boiling and cooling of F as well as increase of their oxygen fugacity were responsible for the gold enrichment in the studied areas of To-kaj Mts. (Author's abstract)

MOLNÁR, Ferenc, 1997b, Contributions to the genesis of molybdenite in the Velence Mts. Mineralogical and fluid inclusion studies on the mineralization of the Retezi adit: Földtani Közlöny (Bull. of the Hungarian Geol. Soc.), v. 127, no. 1-2, p. 1-17 (in Hungarian: English abst.). Author at ELTE TTK Asvanytani Tanszek, 1088 Budapest, Múzeum krt. 4/a.: email (finolnar@ccs.carleton.ca)

On the basis of reflected light microscopic and electron microprobe studies carried out on museum samples from the Retezi adit, Velence Mts., It was determined that molybdenite is associated with pyrite, pyrrhotite, sphalerite and galena in stockwork-type mineralization hosted by the Variscan granite and metamorphic shales of the Velence Mts. These rocks show siliceous-sericitic alteration and intensive pyrite dissemination at some places. In addition to the molybdenite-bearing paragenesis, grey ore bearing veinlets also occur in the granite. In this mineralization, Zn-rich tetrahedrite occurs in two varieties with different As- and Fe-contents and is associated with pyrite, galena, sphalerite, chalcopyrite and marcasite. The occurrence of an Ag-Te mineral phase was also detected in this paragenesis. According to the FI data from quartz crystals associated with molybdenite, the T of the polystage hydrothermal activity was about 300°C, as well as between 400 and 500°C. CO2-rich F occasionally were trapped during the hydrothermal activity and indicate phase-separation processes or mixing of two different type of F. The entrapment P of these CO2-rich F in the Fl was about 1.0-2.4 kbars. These data suggest that the molybdenitebearing mineralization was formed in the postmagmatic system of the Variscan granite and not related to hydrothermal activity induced by the andesitic intrusions of Eocene age known in the area of study. (Author's abstract)

MOLNÁR, F., WATKINSON, D.H., EVEREST, J. and JONES, P.C., 1998, Multi-stage fluid mobilization in the footwall units of the Sudbury igneous complex and the role of fluids in the formation of vein-type Cu-Ni-PGE deposits (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A33. Authors at Dept. Earth Sci., Carleton Univ.; email (fmolnar@ccs.carleton.ca)

Vein-type and disseminated sulfides occur in Sudbury Breccia hosted by the footwall units as far as several hundred metres from the magmatic segregational sulfide bodies near the base of the Sudbury Igneous Complex. Major minerals in these ores are chalcopyrite, pyrrhotite, pentlandite, millerite, and bornite. Pd-Pt-Bi-Te-As minerals, Ni-Bi sulfides, magnetite, galena, and sphalerite are the most common accessories. Hydrous silicates have elevated Cl-content. Type 1, NaCl-CO2-H2O F in I of rock-forming quartz are related to the late stages of the contact metasomatic recrystallization of the Levack Gneiss Complex. These F underwent immiscibility during P decrease from 3 to 0.5 kbars at 300-350°C. Type 2, NaCI-CaCl2-H2O F in PI of K-feldspar are related to the K-metasomatic alteration of the Murray Granite between 360-410°C. Type 3, NaCl-CaCl2±(KCl-FeCl2-MnCl2-BaCl2-PbCl)-H2O F occur in P and S 1 of quartz associated with sulfides in all deposits. Minimum T for these F are 200-400°C. Type 4, NaCl-CaCl2-H2O F in S I of quartz also occur in all studied deposits. Tt are below 200-240°C. Type 3 and Type 4 F were occasionally immiscible with carbonic F. F of all stages are characterized by 20-50 wt% sal, lower sal also occur in [certain] carbonic-aq I. Type 3 F post-dating Type 1 and Type 2 F can be related to the formation of the Cu-Ni-PGE enriched veintype ores. Type 4 F are post-ore basinal F. (From authors' abstract by ER)

MONTAÑEZ, I.P., 1996. Application of cathodoluminescent cement stratigraphy for delineating regional diagenetic and fluid migration events associated with Mississippi Valley-type mineralization in the southern Appalachians: Society of Economic Geologists. Special Pub. No. 4, p. 432-447. Author at Dept. of Earth Sci., Univ. of California, Riverside, CA 92521, USA.

Integration of the CL dolomite stratigraphy of Upper Knox carbonates from the southern Valley and Ridge region with radiometric dates of associated noncarbonate minerals, and with dolomite FI and stable isotope data, suggests that late-diagenetic zoned dolomites provide the most complete spatial and temporal record of regional diagenetic events, and of F flow systems that developed in the Knox regional aquifer of the southern Appalachian basin. The precipitation T of zoned dolomites estimated from FI T<sub>h</sub> and systematic trends in their  $\delta^{18}$ O values record a regionally developed prograde-to-retrograde thermal history, which is interpreted to initially record F migration in response to the far-removed orogenies. (From authors' abstract by H.E.B.)

MONTOMOLI, Chiara, 1998, Syn- and post-collisional tectonic structures in the northern Apennines (Italy). The internal Tuscan domain; Summary of PhD research published in Plinius, no. 19, p. 166-169. Author at Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria 53, I-56126 Pisa.

FI studies conducted on quartz from syntectonic veins developed dur-

ing D1 and D2 tectonic phases show several different generations. Primary aq two-phase FI with low sal values have been recognized in D1 syntectonic veins. In the D2 syntectonic veins, different generations of FI have been recognized. P two-phase methane-bearing water-rich I made up of Lwater+L or V-phase rich in methane; rare P, apparently one-phase, L methane I, S two-phase (L rich) L+V water I with variable sal values.

The ranges of composition and the bulk density of the P two-phase methane-bearing water rich I indicate a T range for their trapping between 200 and 290°C and P between 250 and 145 MPa. The presence of rare P apparently one-phase L methane I may testify to the existence of methanewater immiscibility phenomena which sometimes occurred in the system probably due to isothermal P drops in agreement with the regional tectonic framework. (From author's abstract by E.R.)

MOORE, Gordon, VENNEMANN, Torsten and CARMICHAEL, I.S.E., 1998, An empirical model for the solubility of H<sub>2</sub>O in magmas to 3 kilobars: American Mineralogist, v. 83, p. 36-42.

MOORE, J.N., ADAMS, M.C. and ANDERSON, A.J., 1998, The mineralogic and fluid-inclusion record of the transition from liquid-to vapordominated conditions at The Geysers, California (abst.). Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 46. First author at Energy and Geosci. Inst., Salt Lake City UT 84108; email (jmoore@egi.utah.edu)

The Geysers is the most extensively explored V-dominated field and the best characterized. Development of the current thermal system was initiated 1-1.5 million years ago. Petrologic and <sup>40</sup>Ar/<sup>39</sup>Ar spectrum dating demonstrate that L-dominated conditions persisted in the central Geysers until 0.28 Ma when seismic activity triggered catastrophic boiling and venting (Moore and Gunderson, 1995; Hulen et al., 1997). The system has been V-dominated for the last 0.25 my.

Quartz crystals from three wells drilled in the central and northwestern portion of the field contain numerous P L and V-rich FI, indicating growth in a boiling environment.

Th of L-rich I indicate that mineralization occurred over a T range of >305-241°C. Although the majority of the P I yielded sal near 0.0 wgt% NaCl eq., sal as high as 3.7 were recorded. T-enthalpy relationships indicate that the low sal waters represent steam condensate whereas the higher sal F are the residual, boiled brine.

P V-rich I are unusually large, up to approximately 800 microns in length, and typically exhibit negative crystal shapes. Heating and freezing measurements have documented several phase changes. Cooling to approximately -100°C results in the formation of solid CO<sub>2</sub>. As the 1 are warmed, the solid CO<sub>2</sub> sublimes at T that range from -93°C in 1 from shallow depths to -57°C in deeper samples. Although ice-melting T in most 1 yielded apparent sal of 0.0 to 0.4 eq. wgt% NaCl, 1 that trapped boiling brine have sal as high as 2.6 wgt% NaCl eq.

The results of this study provide clear evidence of mineralization in a developing V-dominated heat pipe. As the heat pipe evolved, slightly acidic condensate formed at the base of the cap rock and drained downward, dissolving quartz, calcite, and other minerals present along the vein walls. Deposition of coarse-grained quartz and bladed calcite occurred when the condensate or mixtures of condensate and brine encountered regions of the fracture zones that were still superheated and boiled. Growth of the quartz was episodic, with periods of rapid growth resulting in the formation of skeletal crystals that trapped large P V-rich inclusions. The formation of late-stage clays, which is commonly associated with this quartz-calcite assemblage, is the result of continued downward percolation of the acid condensate. (From authors' abstract by E.R.)

MOORE, J.N., NORMAN, D.I. and KENNEDY, B.M., 1998. Tracing fluid sources in an active hydrothermal system: a case study of The Geysers, California: Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 47. First author at Energy and Geosci. Inst., Salt Lake City, UT 84108; email (imoore@egi.utah.edu)

Fl trapped in S minerals indicate that T within the earlier L-dominated regime ranged from 440°C at distances of 282 m from the pluton to 305°C at a distance of about 1700 m. We use Fi G compositions to trace the origins of the geothermal F and evaluate the processes that have affected them.

Gas analyses of FI, when combined with their noble-G compositions, can provide information on the evolution of the hydrothermal F that is not readily obtained using other techniques. Veins deposited by magmatic F are distinguished by the occurrence of I containing high-T halite-saturated brines. These veins are found within 600 m of the intrusive and in the plutonic rocks. I populations dominated by magmatic waters are characterized by N<sub>2</sub>/Ar ratios much greater than air-saturated water (>100) and a He isotopic ratio of approximately 6 Ra. Veins affected by the subsequent incursion of connate or metamorphic waters are also characterized by high N<sub>2</sub>/Ar ratios but have a He isotopic ratio of 0.5 Ra and high CH<sub>4</sub> contents. Thus, high N<sub>2</sub>/Ar ratios do not in themselves indicate a magmatic influence. N<sub>2</sub>/Ar ratios similar to air-saturated water document the still later incursion of meteoric F into the plutonic rocks.

Steam and I gases from the northwest Geysers have N<sub>2</sub>/Ar ratios greater than air-saturated water and high CH<sub>4</sub> contents, implying that the F are dominantly connate or metamorphic in origin. N<sub>2</sub>/Ar ratios and CH<sub>4</sub> contents of I from the southeast and central Geysers record the progressive incursion of meteoric recharge prior to the onset of V-dominated conditions. Although the I in these rocks have generally low sal, and variable N<sub>2</sub>/Ar ratios, He isotopic ratios are near 6 Ra and, thus, document the input of a magmatic G. The presence of a magmatic component raises the possibility that other gases, including H<sub>2</sub>S and H<sub>2</sub> also have a magmatic origin.

In part, variations in the compositions of the I fluids can be related to differences in the solubilities of the volatile species during progressive boiling. Evidence of boiling includes the presence of abundant P and S V-rich I, variable G contents, and G contents that are much higher than could be accounted for by the trapping P. Quartz-calcite veins deposited by boiling F are characterized by nearly constant CH<sub>4</sub>/H<sub>2</sub> ratios on ternary plots of CH<sub>4</sub>-CO<sub>2</sub>-H<sub>2</sub>. (From authors' abstract by E.R.)

MOORE, J.N., POWELL, T.S., BRUTON, C.J., NORMAN, D.I. and HEIZLER, M.T., 1998, Thermal and chemical evolution of the Tiwi Geothermal System, Philippines: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 671-675. First author at Energy and Geosci. Inst., Univ. of Utah, Salt Lake City, Utah, USA.

The Tiwi geothermal field is related to young volcanic activity on the southern coast of Luzon, Philippines. Nine stages of alteration and vein mineralization have been documented in core from the western part of the Matalibong sector where measured T are close to 270°C. The earliest stage is characterized by chalcedony and clays (stage 1). Stage 2 veins are filled with sericite and chlorite. Stage 3, 5 and 7 veins are characterized by quartz±epidote±adularia±wairakite whereas stage 4, 6 and 8 veins consist of anhydrite and/or calcite. Illite±chlorite were deposited during stage 9. The maximum FI T of stage 4, 5 and 6 vein minerals are close to the boiling point and typically exceeded 300°C while the minimum T are more than 75°C below the present measured values. 40Ar/39Ar spectrum dating indicates that stage 5 adularia was deposited at about 0.30 Ma. The results of the spectrum dating combined with FI data and mineral geothermometers indicate that mineralization during stages 2 to 8 reflects repeated cycles of boiling, P drawdown and the incursion of cooler F between 0.20 and >0.30 Ma. Stage 9 mineralization appears to be related to renewed heating. and boiling that occurred in response to intrusive activity during the last 0.05 Ma. FI G compositions and sal indicate that the hydrothermal F were mainly mixtures of fresh and seawater modified by interactions with crustal and possibly magmatic gases. Only stage 9 minerals are in equilibrium with the present-day F. (Authors' abstract)

MORALES-ALVARADO, Mercedes, and PROL-LEDESMA, R.M., 1998. Preliminary fluid inclusion results from the "El Muerto" pegmatite, Oaxaca, Mexico (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 48. First author at Posgrado en Ciencias de la Tierra, UACPyP.

The El Muerto pegmatite is located in the Oaxaca metamorphic complex. Five zones can be identified in the pegmatite. They are:

- 1. Border Zone It contains mainly allanite-plagioclase±muscovite
- Intermediate Zone L- This zone consists of plagioclasemicrocline±muscovite±allanite±magnetite and minor amounts of quartz and biotite.
- 3. Intermediate Zone II.- microcline-biotite-quartz+magnetite.
- 4. Intermediate Zone III .- microcline-quartz.
- Core Zone It consists of highly fractured massive quartz, milky to transparent.

Microthermometric measurements were performed in isolated I located in areas not affected by fractures.

The FI are highly variable in density and composition, ranging from pure  $CO_2$  (G or L or both phases present at room T). to  $CO_2$ +NaCl (dissolved)+H<sub>2</sub>O,  $CO_2$ +NaCl (dissolved+halite)+H<sub>2</sub>O and NaCl+H<sub>2</sub>O (hydrohalite is frequent and some I have dm). FI composition is inferred from

observed phase changes. Th range from 180° to 300°C. Assuming that the P for the Oaxaca complex calculated from geothermobarometers was 7 kb, the maximum Tt would be between 680° and 800°C. Apparent sal values vary between 20-26 eq. wt% NaCl in the aq phase and 8-10 wt% in the CO<sub>2</sub>+NaCl+H<sub>2</sub>O inclusions. Some I decrepitate before reaching homogenization, apparently due to their moderate to high density. There is evidence of immiscible separation of CO<sub>2</sub>-rich and H<sub>2</sub>O-rich F which would occur at a T of approximately 350°C. (From authors' abstract by E.R.)

MOREIRA, Manuel, KUNZ, Joachim and ALLÈGRE, Claude, 1998, Rare gas systematics in popping rock: Isotopic and elemental compositions in the upper mantle: Science, v. 279, p. 1178-1181. Université Denis Diderot-Paris 7, Laboratoire de Géochimie et Cosmochimie, Inst. de Physique du Globe de Paris, CNRS Unité de Recherche Associée Number 1758, 4 Place Jussieu, 75252 Paris Cedex 05, France: email (moreira@igpg.jussieu.fr)

New experimental data on the isotopic variations of neon, argon, and xenon in a popping rock imply that the  ${}^{40}$ Ar/ ${}^{36}$ Ar ratio of the upper mantle is <44,000 and that the  ${}^{129}$ Xe/ ${}^{130}$ Xe ratio is <8.2. The elemental abundance pattern of rare G is chondritic-like and is quite distinct from the solar pattern. These data imply that Earth accreted from planetesimals that probably underwent a transformation of their rare G budget from solar- to chondritic-like, leaving the isotopic composition unchanged from the solar pattern. (Authors' abstract)

MORIIZUMI, Mihoko and NAKASHIMA, Satoru, 1998a. Time scale estimation for an explosive caldera-forming eruption based on the water diffusion profile in melt inclusions (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F975. Authors at Dept. of Earth and Planetary Sci., Hokkaido Univ., Sapporo 060-0810, Japan; email (moriizu@cosmos.sci.hokudai.ac.jp)

The authors measured the water profile in MI in quartz of the ancient deposits from the Kuttara volcanic group, northem Japan, and propose here a methodology to estimate the magma ascending time of the plinian eruption. Using FTIR, and a 10  $\mu$ m aperture, to be formed by a diffusion process of water from the I toward the host quartz crystals. Fitting the data with diffusion profile simulation, the diffusion time can be evaluated. The resulted diffusion time is 10-20 seconds. The time scale of water diffusion in the I is considered to correspond to the magma ascending time in the vent, that is the duration between the M trapping in magma chambers and the rapid cooling of quartz at the crater. Based on the geochemically estimated depth of the magma chamber (about 5 km; 800°C), the above time scale yields the velocity of the ascending magma to be 250 to 500 ms<sup>-1</sup>. This estimation coincides well with the initial velocity of plinian columns observed at many eruptions. (From authors' abstract by E.R.)

MORIIZUMI, M. and NAKASHIMA, S., 1998b, The distributions of water from melt inclusions in pumices of Plinian eruption (abst.): Abstracts of the 105th Annual Meeting of the Geological Society of Japan, p. 350 (in Japanese).

MOROZ, I.I. and ELIEZRI, I.Z., 1998, Phyllosilicates inclusions in emeralds from various deposits (abst.): 17th General Meeting Int'l. Mineralogical Association. Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A16.

MOROZ, I.I. and VAPNIK, Yevgeny, 1998, Fluid inclusions in emeralds from various deposits (abst.): Geological Society of America Annual Meeting 1998, Abstracts. v. 30. no. 7, p. A-382. First author at lnst. of Earth Sci., The Hebrew Univ., Jerusalem 91904, Israel; email (inessa@vms.huji.ac.il)

For the gemmologist, the identification of 1 in gems is of the utmost importance both for their authentification and for the determination of their geological origin (Dele-Dubois et al., 1987).

FI in emeralds from seven deposits were investigated using Fluid INC. cooling-heating stage. The stone occurrences in Australia, Brazil, Mozambique, Tanzania and Zambia belong to 'schist-type' deposits. CO<sub>2</sub>, H<sub>2</sub>O-CO<sub>2</sub> and undersaturated brine I are usually connected with the growth of these emeralds (except emerald from Zambia, where CO<sub>2</sub> and H<sub>2</sub>O-CO<sub>2</sub> I were not found). The following lower limit of FI entrapment conditions was obtained: Australia: T>200°C, P>0.5 kbar; Tanzania (Lake Manyara): T>280°C, P>1.0 kbar; Tanzania (Sumbawanga): T>260-280°C, P>2.5 kbar; Mozambique: T>280°C, P>2.5 kbar; Brazil: T>300°C, P>1.5 kbar; Zambia: T>230°C.

The specific geological setting for Nigerian emerald deposit (greisen

associations of Mesozoic alkali granite ring complexes together with albitisation processes) resulted in a unique suite of FI in this emerald: oversaturated brine I are typical for it. Brines are of Li-Ca-Mg-Na-Cl composition with sal over 40 wt.% NaCl eq. CO<sub>2</sub>-brine I were found on the intermediate stage of crystal growth. The possible conditions of I trapping are T>450°C, P>300 bar.

The results of the study can be of great use in determining gem sources and, more generally, in understanding conditions under which gems are formed. (Authors' abstract)

MORRIS, G.A. and NESBITT, B.E., 1998, Geology and timing of palaeohydrogeological events in the MacKenzie Mountains, Northwest Territories. Canada: in Parnell, J. (ed.) 1998, Dating and Duration of Fluid Flow and Fluid-Rock Interaction, Geological Society, London, Special Publications, v.144, p., 161-172. Authors at Dept. of Earth and Atmospheric Sci., Univ. of Alberta, Edmonton, AB, T6G 2E3, Canada.

Six distinct F events, which span a time frame from syndeposition (Cambrian-Devonian) to the last stages of the Laramide Orogeny (early Tertiary), have been identified in the MacKenzie Mountain range of the northern Canadian Rocky Mountains. This study represents one of the most complete records of the F history of an area that has seen many palaeohydrogeological events. This combination of field and geochemical observations [Fl data] allows us to estimate the age, as well as the origin, of each event described. (From authors' abstract by E.R.)

MORROW, D., 1998. Regional subsurface dolomitization; Models and constraints: Geoscience Canada, v. 25, no. 2, p. 57-70. Indexed under Fl.

MRESAH, M.H., 1998, The massive dolomitization of platformal and basinal sequences; proposed models from the Paleocene, northeast Sirte Basin, Libya: Sedimentary Geol., v. 116, no. 3-4, p. 199-226.

The Paleocene carbonate succession in the northeast Sirte Basin is composed of two shallowing-upward ramp cycles, where each cycle is under- and overlain by deeper-water, pelagic facies. A significant proportion of each of these two cycles is dolomitized. Petrographic study, supported by geochemical data (stoichiometry, stable isotopes, trace elements, and FI), and integrated with broader tectono-sedimentary information, has provided the basis for interpreting these Paleocene dolomites. Four distinct types of dolomite have been recognized, two have a platformal setting and the other two are basinal. The platform varieties consist of dolomicrites and pervasive stratal dolomites. The dolomicrites, interpreted to be of synsedimentary origin, were probably a product of reflux of seawater, with elevated sal. as suggested by palaeoenvironmental analysis and supported by geochemical evidence (the average  $\delta^{18}$ O value is -1 per mil PDB; the average Sr content is 639 ppm). The pervasive dolomites were formed during the progradation of the platform sequences, and probably stabilized and augmented during shallow burial. A meteoric-marine mixing-zone is thought to have been the most likely process for the formation of these dolomites. This interpretation is supported by geochemical evidence (the average 818O is -2.4 per mil PDB; the average Sr content is 72 ppm) combined with a favourable stratigraphic position. The most characteristic feature related to both mixing-zone and reflux dolomitization is the basinward movement of the dolomitizing F, which suggests that the formation of these platform dolomites was related to a lowstand system tract.

The two basinal varieties comprise thick (over 300 m) basinal dolomudstones and fracture-filling, sparry dolomites. The stratigraphic position of the finely crystalline basinal dolomudstones, within very thick shale successions (as a result of being very close to the depocentre of the Sirte Basin) combined with geochemical evidence (the average  $\delta^{18}$ O is -6.4 per mil PDB), suggest that the dolomitzing F were basin-derived, with Mg<sup>2+</sup> released from dewatering through compaction of basinal shales. The occurrence of this type of dolomite provides one of the rare examples of largescale dolomitization of thick, basinal sequences. Late diagenetic fracturefilling dolomites exhibit a structural control on their distribution. Geochemical evidence (including Fi analysis and the lightest oxygen isotopic signature of -7.3 per mil PDB) suggests that highly saline formation brines were the solutions responsible for their formation. (From author's abstract by E.R.)

MUCHEZ, P., NIELSEN, P., SINTUBIN, M. and LAGROU, D., 1998, Conditions of meteoric calcite formation along a Variscan fault and their possible relation to climatic evolution during the Jarassic-Cretaceous: Sedimentology, v. 45, p. 845-854. First author at Fysico-chemische Geologie, K.U. Leuven. Celestijnenlaan 200C, B-3001 Heverlee, Belgium; email

#### Volume 31, 1998

### **Fluid Inclusion Research**

(philippe.muchez@geo.kuleuven.ac.be)

Two calcite cements fill karst cavities and replace Lower Carboniferous limestones. The first calcite (stage A) is nonferroan. Primary, originally one-phase, all-L, aq I have a final melting T between -0.2 and 0.2°C. indicating a meteoric origin of the ambient water. The 813C and 818O values of the calcites are between -7.3 and -6.3%o, -7.8 and -5.5%o. The second calcite (stage B) is ferroan. Primary, single-phase aq FI indicate precipitation from a meteoric F below 50°C. The  $\delta^{13}$ C values vary between – 7.3 and -2.1‰ and the 818O values between -7.9 and -7.2‰. A precipitation T below 50°C for the stage A calcites and the presence of iron oxide/hydroxide I in the crystals indicate near-surface precipitation conditions. The evolution from the [oxidized] stage A to [reduced] stage B calcites and the associated geochemical changes are interpreted to be related to the change from semiarid to humid conditions in western Europe during late Jurassic-Cretaceous times. [The isotopic shifts could have been] caused by a change in the source of the air masses or by an increase in the amount of rainfall during the early mid-Cretaceous. Although the latter interpretation is preferred, it cannot be proven. (From authors' abstract by E.R.)

See also next item (E.R.).

MUCHEZ, Philippe and SINTUBIN, Manuel, 1998, Contrasting origin of palaeofluids in a strike-slip fault system: Chem. Geol., v. 145, p. 105-114. First author at Fysico-chemische Geologie, K.U. Leuven, Celestijnenlaan 200C, B-3001 Heverlee, Belgium; email

(philippe.muchez@geo.kuleuven.ac.be)

Calcite cements in a dextral strike-slip fault system in the Variscan' Front Complex (Belgium) have been investigated to determine the origin of the F migrating along the fault system. Generation of non-ferroan and ferroan calcites occurs along the fault plane. The general geological setting and the microthermometric data (Tt≤50°C) indicate that calcite precipitation along the faults took place at shallow depth. However, the geochemistry and origin of the F from which the calcites along the fault lane and in the breccia precipitated were different. The non-ferroan calcites along the fault plane precipitated from a highly saline F (18.1 to 25.3 eq. wt.% CaCl2) at a T around 50°C. Secondary I in trails in these calcites demonstrate that similar highly saline F reached T of at least 130°C. The latter migrated from a depth of over 4 km, implying the F was tapped from the Lower Palaeozoic siliciclastic basement. The ferroan calcites along the strike-slip fault plane also formed from highly saline F, but which interacted with Upper Palaeozoic strata before migration to shallow depth. In contrast, P FI in the ferroan calcites in the breccia indicate cementation occurred from a low sal F (1.7 to 8.6 eq. wt.% NaCl) at a T of 50°C or less. This F likely originated from shallow depth. The contrasting origin of the F indicate different flow regimes have been intersected by the faults during their strike-slip reactivation. (From authors' abstract by E.R.)

See also previous item (E.R.).

MUCHEZ, P., ZHANG, Y., DEJONGHE, L., VIAENE, W., and KEP-PENS, E., 1998, Evolution of palaeofluids at the Variscan thrust front in eastern Belgium: Geol. Rundsch, v. 87, p. 373-380. First author at Fysicochemische Geologie, K. U. Leuven, Celestijnenlaan 200C, B-3001 Heverlee, Belgium; email (philippe muchez@geo.kuleuven.ac.be)

The geochemical evolution of the F migrating at the Variscan thrust front in eastern Belgium has been investigated by a petrographic, mineralogical and geochemical study of ankerite, quartz and ferroan calcite veins hosted by lower Devonian rocks. Three vein generations have been recognized. The first generation consists of quartz, chlorite and ankerite filling pre- to early Variscan extensional fractures. The oxygen and carbon isotopic composition of the two ankerite phases and of the ferroan calcites are respectively between -16.4 and -11.4% PDB between -17.8 and -1.7% PDB. This range is greater than that of calcite nodules in the lower Devonian siliciclastic sediments ( $\delta^{18}O = -15.6 \text{ to} -11.1\%$  PDB and  $\delta^{13}C = -13.4$ to-10 2‰ PDB). This suggests precipitation of the carbonate veins from a F which was at most only partly isotopically buffered by the calcite nodules in the host rock. The calculated oxygen isotopic composition of the ambient F from which the calcite veins formed is between 7.8 and 10.0% SMOW. Two main F types have been recognized in FI in the quartz and carbonates. The first F type is present as S FI in the first and second vein generations. The F has a sal of 0.5-7.2 eq. wt.% NaCl and a high, but variable, Th of 124-188°C. Two origins can be proposed for this F. It could have been expelled from the lower Devonian or could have been derived from the metamorphic zone to the south of the area studied. Taking into account the microthermometric and stable-isotope data, and the regional geological setting, the F most likely originated from metamorphic rocks

and interacted with the lower Devonian along its migration path. This is in agreement with numerical simulations of the palaeofluid and especially the palaeotemperature field, which is based on chlorite geothermometry and vitrinite reflectance data. The second F type occurs as S I in the shear veins and as FI of unknown origin in post-Variscan ankerite veins. Therefore, it has a post-Variscan age. The I are characterized by a high sal (18.6-22.9 eq. wt.% CaCl<sub>2</sub>). The composition of the F is similar to that which caused the development of Mississippi Valley-type Pb-Zn deposits in Belgium. (Authors' abstract)

MULLANE, M.M. and KINNAIRD, J.A., 1998, Synsedimentary mineralization at Ballynoe barite deposit, near Silvermines, Co. Tipperary, Ireland: Trans. Instn. Min. Metall. (Sect. B: Appl. earth sci.), v. 107, January-April, 1998, p. B48-B61.

Stratiform mineralization at Ballynoe is hosted by limestones and comprises mainly barite with pyrite. The orebody is conformable with sedimentary rocks in its immediate footwall and hanging-wall.

Thermometric studies show that two F were involved in mineralization. One originated within the crust and had a moderate T (180-225°C) and low sal (8-15 eq. wt.% NaCl). Points of exhalation of this F are marked on the footwall surface by pyrite hydrothermal chimneys. The other F originated in the local depositional basin and had a lower T (68-110°C) and higher sal (20-25 eq. wt.% NaCl). Th of these I increase from the base of the barite units upwards.

Barite and pyrite were apparently deposited as sediments on the seafloor. The most probably depositional model is the sedimentary-exhalative convection cell model. This is consistent with available sulphur isotope data, which indicate that Lower Carboniferous sea-water sulphate was the dominant source of sulphide sulphur (by bacteriogenic reduction) and barite-forming sulphate. (From authors' abstract by E.R.)

MÜLLER, A. and BEHR, H.-J., 1998, The multistage crystallization process of the Schellerhau granites - A quartz CL study (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A86.

Of pertinence to studies of FI in granites (E.R.).

MUNZ, I.A., IDEN, K., JOHANSEN, H. and VAGLE, K., 1998, The fluid regime during fracturing of the Embla field, Central Trough, North Sea: Marine and Petroleum Geol., v. 15, p. 751-768. First author at Institutt for energiteknikk, P.O. Box 40, N-2007 Kjeller, Norway; email (ingridm@ife.no)

The deep Embla field, located in the Central Trough. North Sea, represents the first oil reservoir in Paleozoic rocks to be developed on the Norwegian shelf. The reservoir consists of braided fluvial and alluvial fan sandstones interlayered with floodplain/lacustrine mudstones and volcanics and intrusives. Extensive fracturing of the reservoir has led to the formation of numerous mineralised veins. Three main types of mineralised fractures can be identified: (1) early diagenetic veins and veins which occur in and around mafic igneous rocks; (2) carbonate-dominated veins; (3) barite, clay minerals and bitumen veins. This article presents FI evidence from fracture-filling minerals, suggesting that the fractures were important F conduits of both petroleum and brine migration. The petroleum I data are consistent with an undersaturated oil composition. A range in sal between 23 and 12 wt.% NaCl eg, is found for the ag 1. The variation in sal indicates mixing between a high saline F, related to evaporites, and a F with lower sal. Microthermometry data suggest that the fracturing events occurred at deep basinal levels, at T in excess of 100°C. (Authors' abstract)

MURAMATSU, Y., KOMATSU, R., SAWAKI, T. and SASAKI, M., 1998. Hydrothermal activity after intrusion of the Kakkonda Granite in the Kakkonda geothermal reservoir - Geochemical study of fluid inclusions in anhydrite (abst.): 1998 Annual Meeting of the Mineralogical Society of Japan/Japan Association of Mineralogists, Petrologists and Economic Geologists, Kyushu University, Oct 8-10, 1998, p. 207 (abst. in Japanese).

MURAMATSU, Yasuyuki and WEDEPOHL, K.H., 1998, The distribution of iodine in the earth's crust: Chem. Geol., v. 147, p. 201-216. First author at Nat'l. Inst. of Radiological Sci., Isozaki 3609, Hitachinaka-shi, Ibaraki 311-12, Japan.

Analytical data by ICP-MS measurements after pyrohydrolysis on a reasonably large series of samples representing about 300 rocks of major units and subunits of the earth's crust, and a few organic materials, are provided for a genetic discussion. Metasedimentary gneisses, mica schists and granulites have as little as 12 to 25 ppb I and have lost from 75 to
>95% of their iodine at metamorphic T. Granites, granodiorites, tonalites and basalts are even lower in iodine and contain 4 to 9 ppb 1 almost independent of the species of magmatic rock. The continental crust, the oceanic crust (including seawater) and bulk Earth's crust contain 119 ppb, 777 ppb and -300 ppb 1, respectively. The CVI weight ratios of the continental, oceanic and bulk Earth's crust are 3800, 4500 and 4300, respectively, to be compared with 1210 and 403 in the Orgueil and Ivuna CI chondrites. (From authors' abstract by E.R.)

MURAOKA, Hirofumi, UCHIDA, Toshihiro, SASADA, Masakatsu, YAGI, Masahiko, AKAKU, Kohei, SASAKI, Munetake, YASUKAWA, Kasumi, MIYAZAKI, S.-I., DOI, Nobuo, SAITO, Seiji, SATO, Ko and TANAKA, Shoichi, 1998, Deep geothermal resources survey program: Igneous, metamorphic and hydrothermal processes in a well encountering 500°C at 3729 m depth, Kakkonda, Japan: Geothermics, v. 27, no, 5-6, p. 507-534. First author at New Energy and Industrial Tech. Development Organization, Higashi-Ikebukuro, Tokyo 170-6030, Japan.

The exploration well WD-1a was drilled to a depth of 3729 m in the Kakkonda geothermal field, northeast Japan. using efficient borehole cooling techniques. The well penetrated an entire shallow hydrothermal convection zone, an entire contact metamorphic aureole and part of a neogranitic pluton. The recovered T of the well indicates a boiling pointcontrolled profile up to 380°C to a depth of 3100 m, and a conductioncontrolled profile up to 380°C to a depth of 3100 m and a conductioncontrolled profile with a very high gradient from 3100 m to the bottom of the hole, where the T is 500°C. WD-1a may be the first geothermal well that encountered 500°C, which exceeds the conventional hydrostatic boiling-point curve. An inflection point of the T-depth profile at 3100 m and about 380°C reflects the brittle-plastic boundary. The brittle-plastic boundary constrains the maximum depth of fracture formation, and the fracture distribution constrains the maximum depth of hydrothermal convection. (Authors' abstract)

MURPHY, P.J. and LaGRANGE, M.S., 1998a, Raman spectroscopy of gold chloro-hydroxy speciation in fluids at ambient temperature and pressure: A re-evaluation of the effects of pH and chloride concentration: Geochim. et Cosmo. Acta. v. 62, no. 21/22, p. 3515-3526. First author at Raman and Luminescence Laboratory, Dept. of Physics, Univ. of the Witwatersrand, PB 3, WITS 2050, Johannesburg, South Africa.

Previous work on gold chloride and hydroxide speciation in F has show differences in opinion as to the relative importance of gold (1) and gold (111) species, as well as for the Raman peak assignments for the various species. In addition previous experimental work has not been consistent with theoretical predictions either of the number or of the frequences of the peaks in the Raman spectrum. In order to re-evaluate the effect of pH on Raman spectra and speciation, solutions containing gold (111) chloride were analysed by Raman spectroscopy at ambient T and P, over a range of pH from 1 to 11. Total gold concentrations were from 0.001 to 0.02 M, with total chloride concentrations of 0.004-0.5 M. Hydrolysis of the simple chloride species occurs at lower pH values than found previously, and both gold and chloride concentrations were found to affect the pH ranges of stability for the various chloro-hydroxy species. Decreasing gold concentration resulted in hydrolysis occurring at lower pH values. This is especially important in the absence of excess chloride ( $\sum Cl=\sum Au$ ). Substantial hydrolysis occurred below pH=4 for 0.02 M Au/0.08 M Cl, and below pH=2 for 0.001 M Au/0.004 M Cl<sup>+</sup>. Addition of excess chloride (as NaCl) increases the pH of hydrolysis at a given gold concentration. (From authors' abstract by E.R.)

MURPHY, P.J., LaGRANGE, M.S. and STEVENS, G., 1998b, Analysis of gold speciation in hydrothermal fluids by Raman spectroscopy: the example of gold chloride solutions (abst.): Mineralogical Magazine, v 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1046.

MURPHY, P.J., STEVENS, G. and LaGRANGE, M.S., 1998. Geological applications of Raman spectroscopy and the use of Raman spectroscopy in the study of gold speciation in fluids: Information Circular – Univ of the Witwatersrand, Economic Geol. Research Unit, 321, p. 41.

The system studied was the gold-chloride-hydroxide system, at ambient T and P, and varying pH and chloride concentration. Previous work on gold chloride speciation in F has shown differences in opinion as to the relative importance of gold (I) and gold (III) species, as well as for the Raman peak assignments for the various species. Total gold concentrations were from 0.02 to 0.001 M, with total chloride concentrations of 0.004-0 1 M. The spectra obtained are consistent with the hydrolysis sequence of square-planar Au(III) complex ions  $[AuCl_4(OH)_{(4:X)}]^*$ , where X=0 to 4. [Au  $(OH)_{(4)}]^*$  probably occurred, alongside  $[AuCl(OH)_{(3)}]^*$  at pH values above 11. The spectra show the predicted number of peaks for Au-Cl and Au-OH stretches for each species. However, the peak frequences do not fit precisely with the predictions of Tossell (1996), particularly for Au-OH stretches. Significant differences were found between the pH values of hydrolysis and those presented in previous works, and both gold and chloride concentration were found to affect the pH ranges of stability for the various chloro-hydroxy species. A hydrothermal cell has been developed which allows Raman analysis of F at hydrothermal conditions, up to 350°C and 2 kbar, and in future this will be used to extend this study to conditions relevant to the formation of many lode gold deposits. (From authors' abstract by E.R.)

MUTLU, Halim and GÜLEÇ, Nilgün, 1998, Hydrogeochemical outline of thermal waters and geothermometry applications in Anatolia (Turkey): J. of Volcanol, and Geothermal Research. v. 84, no. 1-4, p. 485-504. First author at General Directorate of Turkish Mineral Research and Exploration, MAT Dept., 06520, Ankara, Turkey.

The chemical compositions of a total of 120 thermal water samples from four different tectonically distinct regions (Central, North, East and West Anatolia) of Turkey are presented and assessed in terms of geothermal energy potential of each region through the use of chemical geothermometers. Na-Ca-HCO3 type waters are the dominant water types in all the regions except that Na-Cl type waters are typical for the coastal areas of West Anatolia and for a few inland areas of West and Central Anatolia where deep water circulation exists. The discharge T of the springs ranges up to 100°C, and the bottom-hole T in drilled wells up to 232°C. Geothermometry applications yield reservoir T of about 125°C for Central Anatolia, 110°C for North Anatolia, 136°C for East Anatolia and 251°C for West Anatolia, the latter agreeing with some of the bottom hole T measured in drilled wells. The results reveal that the highest geothermal energy potential in Turkey is associated with the West Anatolian extensional tectonics which provides a regional, deep-seated heat source and a widespread graben system allowing deep circulation of waters. The North Anatolian region, bounded to the south by the dextral North Anatolian Fault along which most of the geothermal sites are located, has the lowest energy potential, probably due to the restriction of the heat source to local magmatic activities confined to pull-apart basins. The East Anatolian region (undergoing contemporary compression) and the Central Anatolian region (where the compressional regime in the east is converted to the extensional regime in the west) have moderate energy potential. Although the recently active volcanoes suggest the presence, at depth, of still cooling magma chambers that are potential heat sources, the lack of well-developed fault systems is probably responsible for the comparatively low energy potential of these regions. Almost all the thermal waters of Turkey are saturated with respect to calcite and, hence, have a significant calcite scaling potential which is particularly high for West Anatolian waters. (Authors' abstract)

MYSEN, B.O., 1998. Interaction between aqueous fluid and silicate melt in the pressure and temperatures regime of the Earth's crust and upper mantle: N. Jb. Miner. Abh., v. 172, no. 2/3, p. 227-244.

The solubility and solubility mechanisms of  $H_2O$  have been determined for M in the system K<sub>2</sub>O-SiO<sub>2</sub>-H<sub>2</sub>O from 0.8 to 2.0 GPa in the 700-1100°C T range. Solubility and solubility mechanisms of the silicate in coexisting aq F were also determined. (From author's abstract by E.R.)

NADEN, J., KILIAS, S., CHELIOTIS, I., LENG, M.J., SHEPHERD, T.J. and SPIRO, B., 1998. The Profitis Ilias deposit, Milos Island, Greece: A case study of boiling in epithermal system recorded by fluid inclusion and stable isotope data (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). First author at British Geological Survey, Keyworth, Notts., UK.

Milos Island is still geothermally active and hosts a high-enthalphy geothermal resource and metalliferous mineralisation. Two main styles are evident: stratiform Mn-Ba, and epithermal Ag-Au-Pb-Zn-Cu.

The Profitis Ilias gold deposit is classified as an adularia-sericite-type epithermal deposit. FI data were obtained on drill-core samples and surface exposures of the veins. Two main I types were identified: aq L- and V- rich. They occur in ore and post-ore quartz sphalerite, and barite. Quartz and sphalerite contain predominantly L-rich P I, whereas barite contains relatively more (20% by number) V-rich I in comparison. Estimates of eutectic melting (-25 to -38°C) indicate the presence of divalent cations in the ore F, probably magnesium or calcium. Sal of L-rich I, based on microthermometric data, range between 0.1 and 11.4 wt% NaCl eq. in ore-

stage quartz and sphalerite, and between 0.93 and 8.5 wt% NaCl eq. in post-ore barite. V-rich I in ore-stage quartz homogenise between 368 and 399°C (n=3), while V-rich I in barite generally decrepitated before anticipated homogenisation.

Evidence for boiling, in the FI microthermometry data, is shown by examining the relationship between sample elevation and Th. Two distinct distributions are evident. Below 450 m FI Th are tightly clustered and vary only by 20 to 50°C. However, above this level Th show extreme variation (sometimes over 150°C). This is attributed to the heterogeneous trapping of a boiling hydrothermal F in the upper levels of the system. The transition between the two distributions at 450 m is interpreted as the base of boiling. Moreover, samples containing high gold values (>12 ppm) or visible gold are exclusively located above this level.

Where both  $\delta D$  and  $\delta^{18}O$  were measured on the I F, they show a clear trend that is sub-linear and parallels the Mediterranean Meteoric Water Line (MMWL), whereas trends in the F-mineral data are much more ambiguous. The data show how important it is to be able to relate process information (e.g., petrography, Fl and stable isotopes) with the distribution of ore determined from diamond drilling and assay. By integrating genetic and empirical information, we are able to demonstrate that the major control on ore deposition is boiling, with the base of boiling located 450 m above present-day sea-level. In addition, we suggest that data derived by analysing both  $\delta D$  and  $\delta^{18}O$  on I F provide a better framework for interpreting F processes in epithermal systems than current methodologies based on calculating  $\delta^{18}O$  from F-quartz equilibria. (From authors' abstract by E.R.)

See figure in the Illustrations appendix.

NAKAMURA, M., 1998, Dissolution origin and synentrapment compositional change of melt inclusion in plagioclase (abst.): EOS Trans. AGU, 79(17), Spring Meet. Suppl., p. S371. Author at Dept. of Earth and Environmental Sci., Rensselaer Polytech. Inst., Troy, NY 12180, USA; email (nakamm@rpi.edu)

Although the significance of MI studies has been increasing rapidly, the mechanism and petrologic environment of I formation are poorly understood. Furthermore, possible M composition change at the time of entrapment (synentrapment change: SEC) has not been experimentally investigated. In this paper, I present the experimental results at 200 MPa that some types of MI in tabular plagioclase were reproducibly formed by partial dissolution, and evaluate SEC.

The Ca/(Ca+Na) molar ratio and the MgO content in synthesized MI are up to 17 and 61% lower than those in the matrix M, respectively. This SEC is caused by a combination of factors. A model for diffusion in a growing M channel was constructed which revealed that the concentration of incompatible elements with low diffusivities in the M can be significantly lower in the MI in plagioclase than that in the matrix M. (From author's abstract by E.R.)

NAKAMURA, M. and SHIMAKITA, S., 1998. Dissolution origin and syn-entrapment compositional change of melt inclusion in plagioclase: Earth and Planet. Sci. Letters, v. 161, p. 119-133. Authors at Dept. of Earth and Planetary Sci., Tokyo Inst. of Tech., 2-12-1 Ookayama, Muguroku, Tokyo 152, Japan.

In the system Di-Ab-An-H2O, MI in plagioclase were reproducibly formed in a series of partial dissolution experiments, and the compositional differences from the surrounding matrix M were evaluated. At 200 MPa and 1050- -1150°C, a seed crystal of Ans9 was partially dissolved into the matrix M, which was in equilibrium with more calcic plagioclase than the seed. The reaction proceeded inward from the crystal surface by a dissolution and recrystallization process to form a reaction zone composed of M channels and recrystallized calcic plagioclase. The M channels were choked (necked) off by the recrystallized plagioclase at the crystal surface to create MI. The experimentally formed I, having square and zigzag shapes up to a few tens of micrometers in size, are similar in texture to some common types of natural MI. Since the partial dissolution of phenocrysts can occur during various magma mixing processes, it should be taken into consideration as one of the I formation mechanisms when trying to interpret information from natural MI, especially for those in hydrous arc magmas. The chemical composition of the reproduced MI deviates from the matrix M basically along the plagioclase liquidus isotherm. The molar ratio of Ca/(Ca+Na) and the MgO concentration in the synthesized MI are up to 17 and 61% (relative) lower than those in the matrix M, respectively. This compositional difference is caused by a combination of factors: (1) supersaturation with dissolved plagioclase component: (2) insufficient diffusive homogenization in the M channels due to rapid dissolution of

plagioclase: and (3) the choking-off effect. On the basis of the experimental results, a model for diffusion in a growing M channel in dissolving plagioclase was constructed which revealed that the concentration of incompatible elements with low diffusivities can be significantly lower in the MI than that in the matrix M. These results demonstrate the importance of petrography for interpretation of I data and of more experimental studies on MI origin. (Authors' abstract)

NARASIMHA, K.N.P. and SRIKANTAPPA, C., 1996, High density carbonic inclusions from migmatitic gneisses around Bandipur, Karnataka. The Indian Mineralogist, v. 30, no. 1, p. 67-77. Authors at Dept. of Geol., Univ. of Mysore, Manasagangotri, Mysore - 570-006, India.

Carbonic I (0.836-1.053 g/cc) as well as low (4-18 wt % NaCl eq.) to high (32 wt % NaCl) sal aq 1 are noticed in paleosome portion of the amphibolite facies migmatitic gneisses around Bandipur. In contrast, pure CO<sub>2</sub> 1 (0.783-0.956 g/cc) were recorded in leucosome portion of the gneiss. High density CO<sub>2</sub> I are synmigmatitic in nature. Based on the textural evidences as internal generation of CO<sub>2</sub> has been envisaged. (Authors' abstract)

NAUMOV, V.B., KOVALENKO, V.I. and DOROFEEVA, V.A., 1998, Fluorine concentration in magmatic melts: Evidence from inclusions in minerals: Geokhimiya, 1998, no. 2, p. 147-157 (translated in Geochm. Internat'I., v. 36, no. 2, p. 117-127). First author at Vernadsky Inst of Geochem. and Analytical Chem., Russian Acad. of Sci., ul. Kosygina 19, Moscow, 117975 Russia.

The paper summarizes data on fluorine concentrations in magmatic silicate M (833 analyses of fluorine and other major components from 69 publications). This data was obtained in studies of glasses from homogenous MI in minerals and chilled glasses from ocean-floor volcanic rocks. Two types of M were distinguished for basic and ultrabasic magmas (SiO2=40-53 wt.%): the first type contains less than 1.3% of K2O and the second type, more than 1.3%. The average concentration of fluorine in M of the first type is 0.029 wt.% (196 analyses) and 0.299 wt.% (29 analyses) in M of the second type. The concentration of fluorine is 0.143 wt.% (62 analyses) in magmas of intermediate composition (third type, SiO2=53-64 wt.%). Several M types were distinguished for silicic magmas (SiO2>64 wt.%): M with ordinary composition (fourth type), M enriched in chlorine and iron (fifth type, or pantellerite, comendite, and alkaliine granite), and M enriched in fluorine (sixth type, or topaz rhyolite, ongonite, Li-F granite, and pegmatite). The average concentration of fluorine in M of the fourth type is 0.196 wt.% (336 analyses). 0.273 wt.% in M of the fifth type (41 analyses), and 2.087 wt.% in M of the sixth type (169 analyses). Considering the various abundances of these rock types on continents and seafloor, the average concentration of fluorine in magmatic M is estimated as 0.094 wt.% for continental blocks and 0.052 wt.% for continents, continental margins, and seafloor. (Authors' abstract)

NAVON, Oded, 1998. The role of fluids in diamond formation: Israel Geological Society, Annual Meeting, 22-24 March, 1998, p. 72. Author at Inst. of Earth Sci., The Hebrew Univ., Jerusalem, 91904.

Diamonds are, most probably, the deepest available samples of Earth's material. Most are coming from the upper mantle and were formed at depth of 150-200 km, but some carry I from the transition zone and even from the lower mantle, deeper than 670 km. The exact mode of diamond formation in the mantle is still unclear. Formation T recorded by diamond I may be as low as 1000°C, indicating subsolidus formation, but the formation of perfect, single crystals requires growth from F.

Most diamonds contain no FL Rather, the most common I are mineral 1 of graphite, sulfides and silicate minerals of two separate paragenesis: the peridotitic suite (olivine, orthopyroxene, Cr-pyrope garnets, chromites and clinopyroxene) and the eclogitic suite (clinopyroxene and pyropealmandine garnet). Some diamonds do contain F and those have been the focus of our studies over the last 10 years. Volatile-rich F were found in microscopic I (<1 µm in size) in three types of diamonds:

1. Fibrous diamonds. These diamonds consist of slightly mis-aligned diamond fibers and appear as diamonds of cubic morphology or as coats around octahedral diamonds. They carry many Fl which give these diamonds a translucent appearance. The l are rich in water, Fe-, Ca- and Mg-carbonates,  $K_2O$ , and many incompatible elements. The internal P within the l is high, ~1.5-1.8 GPa. These high internal pressures ensure that the l are P and that they were trapped at the diamond source region.

 Cloudy diamonds. These octahedral diamonds carry a cloud of F and mineral I in their center. So far, we have characterized diamonds with eclogitic or peridotitic minerals together with silica-rich F (with broad similarity to the F trapped in the fibrous diamonds), carbonate-rich F. and KCI-rich F. 3. CO<sub>2</sub>-bearing diamonds Here, the only impurity is CO<sub>2</sub> that is pre-

sent as solid under P of 5 GPa.

The presence of CO<sub>2</sub> ensures a source of carbon for diamond genesis. Thermodynamical calculations indicate that diamond may be found in equilibrium with water and either CO<sub>2</sub> or CH<sub>4</sub>. The F found so far indicate the association with CO<sub>2</sub> and point to relatively high oxygen fugacities. However, the reported occurrence of highly reduced mineral assemblages in some diamonds suggests that diamonds may also crystallize in a CH<sub>4</sub>dominated environment. (Author's abstract)

NERÓNSKY, G.I., 1998. The compositional features of gas-liquid in native gold from the Upper Amur Province (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 105-107 (in Russian). See Translations.

NESBITT, B.E. and PROCHASKA, Walter, 1998, Solute chemistry of inclusion fluids from sparry dolomites and magnesites in Middle Cambrian carbonate rocks of the southern Canadian Rocky Mountains: Can. J. Earth Sci., v. 35, p. 546-555. First author at Dept. of Earth and Atmospheric Sci., Univ. of Alberta, Edmonton, AG, T6G 2E3, Canada; email (b.nesbitt@ualberta.ca)

Middle Cambrian carbonate rocks of the southern Canadian Rocky Mountains are host to widespread units of white, sparry, hydrothermal, replacement, and open-space filling dolomite. Contained within the dolomites are occurrences of talc and Mississippi Valley type Pb-Zn (the former Kicking Horse and Monarch mines) mineralization and economic concentrations of magnesite (Mount Brussilof mine). Results of studies of solute chemistry of saline (18-25 eq. wt.% NaCl) I F reveal distinctly low Na/Br (55-220) and Cl/Br (95-340) values. These values indicate that the brines which formed the dolomite originated from seawater that had deposited large amounts of halite in an evaporitic environment. Low I/Br ratios for the dolomite-magnesite I F are consistent with their derivation from seawater and contrast sharply with the high I/Br ratios of Laramide-age F. which formed veins throughout the Rocky Mountains. Variations in F/Br ratios between texturally early and late magnesites indicate the involvement of a second F in the formation of the late magnesites. Results of the study of solute chemistry of I F from hydrothermal dolomites, magnesites, and associated mineralization are consistent with a model of the pre-Laramide formation of these materials from seawater that had undergone extensive evaporation and halite deposition. Distinct differences in I/Br. total sal, and δD values between the dolomite-magnesite depositing F and Laramide-age vein-forming F clearly indicate the lack of the involvement of Laramideage F in the genesis of the dolomites, magnesites, and associated mineralization. (Authors' abstract)

NEUMAYR, P., HOINKES, G., PUHL, J., MOGESSIE, A. and KHU-DEIR, A.A., 1998. The Meatiq dome (Eastern Desert, Egypt) a Precambrian metamorphic core complex: Petrological and geological evidence: J. Metamorphic Geol, v. 16, p. 259-279. First author at Inst. of Mineralogy-Crystallography and Petrology. Karl-Franzens Univ. Graz, 8010 Graz, Austria; email (neumayr@bkfug.kfunigraz.ac.at)

The M1 metamorphic event (T>750°C) is restricted to migmatized amphibolite xenoliths within the Um Ba'anib orthogneiss in the structurally lowest parts of the basement. Typical upper amphibolite facies M2 mineral assemblages include Grt-Zn-rich Spl-Qtz±Bt. Grt-Zn-rich Spl-Ms-Kfs-Bt-Sil-Otz and locally kyanite in metasedimentary rocks. M2 P-T conditions ranged from 610 to 690°C at 6-8 kbar for the metamorphic peak and 530-600°C at about 5.8 kbar for the retrograde stage However, relic kyanite indicates P above 8 kbar, preceding the T peak. A clockwise P-T path is indicated by abundant M2 sillimanite after relic kyanite and by andalusite after sillimanite. M2 FI, trapped in quartz within garnet and in the quartz matrix show an array of isochores. Steepest isochores (waterrich H2O-CO2±CH4/N2 I) pass through peak M2 P-T conditions and flatter isochores (CO2-rich H2O-CO2±CH4/N2 I) are interpreted to represent retrograde F which is consistent with a clockwise P-T path for M2. The M3 assemblage Grt-Chl in the uppermost metasedimentary sequence of the basement limits T to 460-550°C. M3 T conditions within the ophiolite cover napes are limited by the assemblage Atg-Trem-Tlc to <540°C and the absence of crysotile to >350°C. The polymetamorphic evolution in the basement contrasts with the monometamorphic ophiolite [cover] nappes (From authors' abstract by E.R.)

NEWTON, R.C., ARANOVICH, L.Ya., HANSEN, E.C. and VAN-DENHEUVEL, B.A., 1998, Hypersaline fluids in Precambrian deepcrustal metamorphism: Precambrian Research. v. 91, p. 41-63. First author at Dept. of the Geophysical Sci., The Univ. of Chicago, Chicago, IL 60637, USA.

An outstanding debate about the evolution of Precambrian granulite facies terranes concerns the role of F in deep-crustal metamorphism. One line of thought ascribes dryness and large-ion element (LILE) depletion to dehydration melting of rocks containing biotite and amphibole, without important participation of a low-density F phase, and removal of the granitic M to the upper crust during metamorphic episodes. An alternative approach emphasizes field evidence for alkali metasomatism and silica mobility on outcrop and thin-section scales, which seemingly demonstrate Fdriven processes. Nearly ubiquitous CO2-rich FI in granulite facies rocks have been cited by many workers as evidence that important granulite facies F were carbonic, in contrast to the H2O-dominated F of lower-grade metamorphism. However, the low solubilities of silicate constituents in CO2-rich F and the low wetting ability (high dihedral angles) of such F relative to silicate mineral grain boundaries, inhibiting infiltration, have been revealed in experimental studies over the last two decades. Recent experimental work in the system NaCl-KCl-H2O at deep crustal T and P demonstrates that concentrated brines have appropriate low H2O activity. high infiltration ability, and high alkali mobility (especially Rb affinity). Recent observations of brine 1 in granulites support the concept that polyionic salt solutions, immiscible with CO2 in the high-grade metamorphic T range (700-850°C) are feasible granulite facies F. Of the several conceptual sources of hypersaline F in the crust, volatile-rich alkaline basalts seem plausible because of their additional ability to deliver heat for metamorphism. The postulated magmatic emanations may split into concentrated brines and immiscible CO2 during ascent. They transport alkalis and LILE upward in the crust. Alkalic basalts in modern continental settings may represent remelting of subcontinental mantle previously enriched in volatiles and alkalis by subduction processes. (From authors' abstract by E.R.)

NIE, F.-J., 1998, Geology and origin of the Dongping alkalic-type gold deposit, northern Hebei province, People's Republic of China: Resource Geol., v. 48, no. 3, p. 139-158. Author at Inst. of Mineral Deposits, Chinese Acad. of Geological Sci., Baiwanzhuang Road 26, Beijing 100037, P.R.C., email (nfj@mx.cci.gov.cn)

The Dongping deposit is one of the largest gold deposits in China. It is spatially, temporally, and genetically associated with the shallowlyemplaced Hercynian Shuiquangou alkaline intrusive complex that intrudes high-grade metamorphic rocks. Hydrothermal activities can be divided into four periods from early to late including: (1) gold-bearing K-feldsparquartz stockworks and veins; (2) disseminated sulfide and gold zones; (3) gold-bearing quartz veins, and (4) barren calcite-quartz veins.

FI in ore-bearing quartz of periods 1, 2 and 3 are CO<sub>2</sub>-rich, variable sal (2.5-21 wt % NaCl eq.), and have variable Th of 195 to 340°C. Quartz in the gold-bearing k-feldspar-quartz stockworks (period 1), disseminated sulfide and gold zones (period 2), and the gold-bearing quartz veins (period 3) has calculated  $\delta^{18}O_{H2O}$  values between -1.7 and 6.9‰, and  $\delta D$  values of FI waters between -101 and -66‰. All these isotope data of the oreforming F plot between the magmatic F field and the meteoric water line.

The combined FI measurements, sulfur, oxygen, hydrogen, and lead isotope data, and petrological observations indicate that the Dongping deposit was formed from the mixing of these magmatic F with meteoric waters. The deposit is, therefore, believed to be a product of Hercynian alkaline igneous processes within the north China craton (From author's abstract by E.R.)

NIELSEN, P., SWENNEN, R., MUCHEZ, Ph. and KEPPENS, E., 1998, Origin of Dinantian zebra dolomites south of the Brabant-Wales Massif, Belgium: Sedimentology, v 45, p. 727-743. First author at Fysicochemische Geologie, Katholieke Universiteit Leuven. Celestijnenlaa 200C. B-3001 Heverlee, Belgium.

Zebra dolomites, characterized by a repetition of dark grey (a) and light (b) coloured dolomite sheets are several tens of metres thick. Locally, cavities exist between two succeeding white dolomite sheets. These cavities make up  $\approx$ 5% of the zebra rocks and are locally filled by saddle shaped ankerite and/or xenomorphic ferroan calcite.

Geochemical and Fl data (Th≈120°C) indicate a burial diagenetic origin for these zebra dolomites. The a and b1 dolomites are characterized by similar geochemical compositions and Fl data pointing toward a related origin. To explain the zebra textures, a model involving dolomitizing F expelled during the Variscan orogeny is proposed. (From authors' abstract by E.R.)

NIELSEN, R.L., MICHAEL, P.J. and SOURS-PAGE, Rachel, 1998, Chemical and physical indicators of compromised melt inclusions: Geochim. et Cosmo. Acta, v. 62, no. 5, p. 831-839. First author at College of Oceanic and Atmospheric Sci., Oregon State Univ., Corvallis, Oregon 97331-5503, USA.

The utility of the geochemistry of basaltic suites as probes of mantle processes is encumbered by the processing those magmas undergo during transport from the field of melting to the ocean floor. MI provide us with an opportunity to obtain information on intermediate stages in the evolution of a magma system. Such data can be an extra constraint for our modeling of petrologic processes. However, MI have generally undergone some degree of post-entrapment crystallization. Therefore, to quantify the details of geochemical trends represented by MI suites, we must construct a set of criteria to evaluate the degree to which any I or set of I represents the original trapped L composition. The problems encountered in evaluating the degree to which I compositions depart from that standard fall into three categories: (1) Errors caused by the selection of the T or time of heating; (2) Loss or gain of volatiles caused by I rupture; (3) Contamination from alteration products such as manganese oxides or salts in the host crystal.

The criteria that may be used to evaluate the veracity of rehomogenized I compositions include examination of the relationship of the I composition to the host lava suite, the morphology of the I, the Fe and S content relative to the host suite, and the MnO content relative to the I suite and the host lavas. (Authors' abstract)

NIELSEN, R.L., SOURS-PAGE, R.É. and JOHNSON, K.T.M., 1998, The nature of melt extraction and transport in the lower crust and upper mantle: Constraints from melt inclusions (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F1003. First author at COAS, 104 Ocean. Admin., Oregon State Univ., Corvallis, OR 97331-5503, US; email (mielsen@oce.orst.edu)

Data was collected from rehomogenized olivine and plagioclasehosted MI from a variety of different environments, and some characteristics were found to be prevalent throughout. First, MI are generally, though not always, more primitive than their host lava. Second, depleted hosts generally contain depleted I, while enriched hosts contain only enriched I. Third, in most cases the host lava composition is similar to the composite composition of all the MI from that host. Fourth, the LREE, and K behavior is somewhat decoupled from the HREE, P and Ti. Fifth, the distribution of Cl is extremely heterogeneous, however, we have some preliminary information that suggests that Cl may be anomalously high in some ultradepleted 1 (Ti/Zr>1000). Finally, the diversity of MI compositions is largely independent of MgO.

Taken together, these observations suggest that magmas travel on independent paths through the upper mantle and lower crust and that significant fractionation precedes mixing and accumulation. Correlation of degree of enrichment of MI with their hosts demonstrates that enrichment is an inherent characteristic of the parent magmas, not generated by low P processes. The heterogeneous distribution of C1, and its presence in ultradepleted I suggests the possibility of a fluxing F circulating in the upper mantle, enabling the production of M from refractory harzburgite. (From authors' abstract by E.R.)

NIIMI, N. and YAMAMOTO, T., 1998. An inclusion in garnet porphyroblast in a granulite facies migmatite (abst.): 1998 Annual Meeting of the Mineralogical Society of Japan/Japan Association of Mineralogists. Petrologists and Economic Geologists. Kyushu University. Oct 8-10, 1998. p. 113 (abst. in Japanese).

NIJLAND, T.G., TOURET, J.L.R. and VISSER, Diederik, 1998. Anomalously low temperature orthopyroxene. spinel. and sapphirine occurrences in metasediments from the Bamble amphibolite-to-granulite facies transition zone (south Norway): Possible evidence for localized action of saline fluids: The J of Geol., v. 106, p. 575-590. Authors at Dept. of Petrol. and Isotope Geol., Vrije Universiteit. De Boelelaan 1085, NL-1081 HV Amsterdam, The Netherlands.

The question has been raised whether isolated granulite facies "islands," which occur throughout the amphibolite facies of the regional amphibolite-to-granulite facies transition zone in the central part of the Bamble sector, southern Norway are the result of prograde or retrograde metamorphism. Quartz contains Fl of highly saline brines. Relatively small I, usually without a salt cube being present at room T, have sal of c. 25 wt.% NaCl eq., but larger I containing a salt cube with little F indicate that actual sal may have been considerably higher. CO<sub>2</sub>-rich Fl are absent. As no feasible heat transport mehcanism is available to cause an intense, local increase in T, we suggest that breakdown of biotite and development of granulite facies assemblages is due to the localized presence of highly concentrated brines at T close to or lower than peak metamorphic T. Recent experimental and theoretical results demonstrate that salts will strongly recude  $aH_2O$  while maintaining alkali transport properties. The later capacity of the F enabled K<sup>+</sup> derived from biotite breakdown to be transferred to quartz-feldspar leucosomes, which, however, are non-anatectic. The occurrence lends support to recent petrogenetic grids that demonstrate that sapphirine is not indicative of extremely high T, even in quartz-rich rocks, and provides a possible illustration of the action of saline F in high-grade metasediments (From authors' abstract by E, R.)

NIKOLÁEVA, E.I. and KAZHÍKHIN, M.A., 1998, The isotope composition of the ore-lead in the Almalyk porphyry-copper system as an indicator of ore-formation (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 89-91 (in Russian).

NINOMIYA, Atusi and ARAI, Shoji, 1998, Polygenetic olivine phenocrysts in Okete basanite, New Zealand: J. Min. Petr. Econ. Geol., v. 93, p. 235-249. Author at Dept. of Earth Sci., Kanazawa Univ., Kanazawa 920-1192, Japan.

Generation of polygenetic olivine phenocrysts is discussed for a basanite from Okete Quarry, New Zealand, based on descriptions of its ohvine and spinel and the reaction product between the basanite and its peridotite xenoliths. The olivine phenocrysts can be divided into two types. I and II. The phenocrysts (I) are relatively small, subhedral to enhedral and has minute spinel I sparsely throughout the grain. They are free of the textures indicating deformation and fracture. The phenocrysts (II) are relatively large and have spinel I only in the rim. Their core has deformation textures and/or FI trails. The olivine phenocrysts (I) are normally zoned-the core ranges from Fo<sub>85</sub> to Fo<sub>76</sub> and the rim has Fo<sub>76</sub>. The phenocrysts (II) frequently have compositionally flat cores, which are relatively Mg-rich (up to Fo<sub>80</sub>), and zoned rims (Fo<sub>85-76</sub>).

The olivine phenocrysts (I) with low-Fe<sup>3+</sup> spinel I were derived from the orthopyroxene/M reaction product, and those with high-Fe<sup>3+</sup> spinels were precipitated from the basanite M. The olivine phenocrysts (II) are of xenocrystal origin and have been modified by the M to various degrees. The olivine phenocrysts in olivine-rich magmas such as picrite basalts and alkali olivine basalts can be polygenetic due to the reaction between the mantle peridotite and more primitive magmas. (From authors' abstract by E.R.)

NISHIO, Yoshiro, SASAKI, Sho, GAMO, Toshitaka, HIYAGON, Hajime and SANO, Yuji, 1998, Carbon and helium isotope systematics of North Fiji basin basalt glasses: Carbon geochemical cycle in the subduction zone: Earth and Planet. Sci. Letters, v. 154, no. 1-4, p. 127-138. First author at Geological Inst., School of Sci., Univ. of Tokyo,, Tokyo, Japan, We have measured 8<sup>13</sup>C values and CO<sub>2</sub>/<sup>3</sup>He ratios of vesicle-gas, and

We have measured  $\delta^{13}$ C values and  $CO_3/^3$ He ratios of vesicle-gas, and chemical compositions of North Fiji Basin basalt glasses, to estimate the contribution of subducted carbon in back-arc basin basalt quantitatively. It has made clear that the  $CO_2/^3$ He ratio increases and the  $\delta^{13}$ C value decreases with K<sub>2</sub>O content. (From authors' abstract by E.R.)

NIVIN, V.A., IKORSKY, S.V. and KAMENSKY, I.L., 1998, Noble gas isotopes and carbon in rocks of the foidite-syenite complexes, the Kola Alkaline Province (KAP). Russia (abst.): The Ninth Int'l Conference on Geochronology. Cosmochronology and Isotope Geology, Abstracts, published in Chinese Sci. Bulletin, v. 43, Supp., p. 95. Authors at Geological Inst., Kola Scientific Centre, Apatity, Murmansk Region, 184200, Russia.

Recently, owing to the original method that allows to extract G preserved in FI, in some Paleozoic (370 Ma) alkaline-ultrabasic complexes of KAP there have been revealed high <sup>3</sup>He<sup>r4</sup>He ratios exceeding those for the upper mantle and implying activity of a Devonian subcontinental mantle plume in the region. However, synchronous foidite-syenite plutons of this province, whose mantle origin is not debated and Rb/Sr and Sm-Nd isotope systems testify against crustal contamination of the initial M are characterized by two magnitude lower «crustal» <sup>3</sup>He<sup>r4</sup>He ratios under comparable concentrations of U and Th as parental elements for <sup>4</sup>He. To understand the reasons of these distinctions, considering that some ratios of carbon to He and Ar isotopes are crucial geochemical indicators of interaction between mantle and crustal processes. we examined coupled distribution of

these components both in the whole rocks and in Fl. taking the Lovozero alkaline massif as an example. The variations of  $Cr^4$ He (100-6 x 10<sup>4</sup>),  $Cr^3$ He (2 x 0<sup>8</sup>-8 x 10<sup>11</sup>) and  $Cr^{36}Ar$  (1 x 10<sup>7</sup>-6 x 10<sup>8</sup>) ratios as well as a positive correlation between  ${}^{36}Arr^{3}$ He and  $Cr^{3}$ He,  ${}^{3}$ He/ ${}^{4}$ He and  $Cr^{4}$ He,  ${}^{40}Arr^{36}Ar$  and  $Cr^{36}Ar$  with regard to earlier well-founded abiogenic magmatic derivation of carbon in the studied complexes suggest the mantle initial relations of the volatile components. These relations changed likely not because of M degassing, but because of some  ${}^{3}$ He loss and the trapping of G with low  ${}^{3}$ He/ ${}^{4}$ He ratios in S Fl at late- and postmagmatic stages of rock formation and as a result of in situ production of {}^{4}He from U and Th fission. (Authors' abstract)

NORMAN, D.I. and CHOMIAK, B.A., 1998, Understanding fluid pathways in ore forming geothermal systems in light of fluid inclusions gas analyses (abst.) Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-77. Authors at Earth & Environmental Sci. Dept., New Mexico Tech, Socorro, NM 87801; email (dnorman@amt.edu us)

A log (CO2/CH4) vs. log (N2/Ar) diagram is used to differentiate four types of F in geothermal systems; shallow meteoric, magmatic, evolved, and a mixed magmatic-evolved F. Shallow meteoric and magmatic volatiles have CO2/CH4>10, magmatic F have N2/Ar>110, and evolved F at T<200°C are methane rich. In general, geothermal systems exhibit mixing between two end member F, and ore mineralogy changes in time and space within mineral deposits is associated with changes in F sources. Common in many deep epithermal and sediment-hosted deposits are I that have CO<sub>2</sub>/CH<sub>2</sub> about 1 or less, and N<sub>2</sub>/Ar>110. On a CO<sub>2</sub>/CH<sub>2</sub>-N<sub>2</sub>/Ar diagram such analyses indicate mixing of the composite F with shallow meteoric F. We interpret this data as an ore F comprised of evolved water charged with a magmatic component mixing at shallower depths with near-surface circulating F. In the same deposit at shallower depths, or later in the paragenesis, FI have CO2/CH4 from 1 to 10 and Ny/Ar near that of air saturated water. We interpret these I F to be mixtures of deep and shallow circulating F devoid of a significant magmatic contribution. Examples of deposits with these characteristics are: Zacatecas and Fresnillo, Mexico; Changkeng, China; and Getchel and Twin Creeks, Nevada. Skams such as San Martin and Zima-pan, Mexico, indicate mixing of a CO2-rich magmatic F with evolved water. Inclusion volatiles in volcanic-hosted epithermal deposits such as Tayoltita and El Oro, Mexico and St. Cloud, New Mexico, indicate they are dominated by shallow meteoric F. No specific FI G chemistry, sal and T are successful in determining the type of minerals deposited. (Authors' abstract)

NORMAN, D.I., CHOMIAK, B.A. and MOORE, J.N., 1998. Approaching equilibrium from the hot and cold sides in the FeS<sub>2</sub>-FeS-Fe<sub>3</sub>O<sub>4</sub>-H<sub>2</sub>S-CO<sub>2</sub>-CH<sub>4</sub> system in light of FI gas analysis: in Water-Rock Interaction, G B Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 565-569. First author at New Mexico Tech., N. Mex., USA

Water-rock reactions in Broadlands. Tiwi, and The Geysers geothermal systems were studied by FI analysis. I are rich in CH<sub>4</sub> which is attributed to F interaction with organic-rich sediments. Broadlands and Tiwi I have less H<sub>3</sub>S than is calculated for F equilibrium with local pyrite-bearing wall rocks. The Geysers FI, and steam, have greater than equilibrium concentrations of H<sub>2</sub>S. We attribute the high H<sub>2</sub>S to slow kinetics in F recharging the systems - cool ground waters (Broadlands and Tiwi) or hot magmatic volatiles (The Geysers). A slope of 0.08 on CO<sub>7</sub>/CH<sub>4</sub> vs. H<sub>2</sub>S plots suggests that the reaction 2Fe<sub>3</sub>O<sub>4</sub>+12H<sub>2</sub>S+CO<sub>2</sub>=6FeS<sub>2</sub>+10H<sub>2</sub>O+CH<sub>4</sub> controls sulfidation and pyrite destruction reactions. (Authors' abstract)

NOVA, Y., WILDE, S.A., MANGGA, S.A. and SUKARNA, D., 1998, A study of fluid inclusions at the Cikotok gold mine, West Java, Indonesia: Ninth Regional Congress on Geol., Mineral and Energy Resources of Southeast Asia—GEOSEA '98 17-19 Aug. Kuala Lumpur, Malaysia, Program and Abstracts. p. 119, Mineral Resources paper 6. First author at Geological Research and Development Centre, Jalan Diponegoro No. 57. Bandung 40122, Indonesia.

The Cikotok Au-Ag ore deposit is typified by a high silver content in large sulphide-bearing quartz veins and in hydrothermal breccias.

Primary I in quartz veins suggest that the Th and sal of the FI (1.18 eq. wt.% NaCl) are in agreement with the T of the deposition of gold and metal-bearing F.

There are two types of FI: 1) H<sub>2</sub>O-rich with V (two phases) and 2) single F phase (H<sub>2</sub>O G and CO<sub>2</sub> G). The freezing point measurements (-0.1 to -3.7 °C) yield sal estimates of 0.1-3.15 eq. wt % NaCl. The FI with a sal <3.2 wt % NaCl should have a meteoric origin. The Th for the for the FI

hie between 184 and 306°C, with a mean 245°C. Trapping P of 40 bars was obtained from the P-T plot of Shepherd et al., (1985) by using the Th of 245°C. This is equivalent to a lithostatic load, and therefore depth of 210 m. These are typical of the low sal epithermal gold deposits common within active hydrothermal systems and within epithermal gold deposits. These results are similar to those of Sillitoe (1977) who concluded that epithermal deposits which often contain precious metals were deposited from low T (200-300°C), low sal (<2 eq. wt.% NaCl) meteoric water. (From authors' abstract by E.R.)

O'REILLY, C.O., SHANNON, P.M. and FEELY, M., 1998, A fluid inclusions study of cement and vein minerals from the Celtic Sea basins, offshore Ireland: Marine and Petroleum Geol., v. 15, p. 519-533. First author at Dept. of Geol., Nat'l. Univ. of Ireland, Galway, Ireland; email (p.shannon@ucd.ie)

FI petrography and microthermometry have been carned out on Jurassic sandstone cements (quartz, calcite and dolomite) and later fracturefilling calcite (±quartz) veins from the North Celtic Sea and the Fastnet Basins. Fl in the sandstone cements are small (1-8 µm) monophase (L only) or L-rich, two-phase (L+V) aq I; all display irregular to elliptical morphologies. The two-phase aq I homogenise to the L phase between ~60-122°C and have sal ranging from ~7.0-16.0 wt.% NaCl eq., indicating precipitation of the cements by moderate sal waters. In contrast the veins host both ag and petroleum I. The ag I are L-rich, two-phase (L+V) I (~2-30 µm long) that are typically P and show irregular and negative crystal shape morphologies. Their Th (to L) range from 50-145°C and sal from 6-20 wt.% NaCl eq., indicating broadly similar sal coupled with a wider range of minimum Tt to those recorded from the cements. Yellow-brown, two-phase (L+V) petroleum I are hosted by vein calcite from several wells in the central North Celtic Sea Basin. Some of these I appear to be P and all are spatially associated with the aq I. The two-phase (L+V) petroleum I homogenise, mostly to the L, between ~50-130°C. Petroleum I in the vein calcites indicate that petroleum was transported via fractures, at a late stage, through the Jurassic and Cretaceous strata of the Celtic Sea Basins, and apparently not through the sandstone matrix. (Authors' abstract)

OAKES, C.S., PITZER, K.S. and STERNER, S.M., 1998, The system NaCl-CaCl<sub>1</sub>-H<sub>2</sub>O: Part 3. Heats of dilution and mixing at 373 to 573 K and 21.5 MPa using a new high-temperature, flow-through calorimeter: Geochim. et Cosmo. Acta, v. 62, no. 7, p. 1133-1146.

OELKERS, E.H., SHERMAN, D.M., RAGNARSDOTTIR, K.V. and COLLINS, Claire, 1998, A EXAFS spectroscopic study of aqueous antimony (III)-chloride complexation at temperatures from 25 to 250°C: Chem. Geol., v. 151, p. 21-27.

OGATA, Takeyuki, ISHIYAMA, Daizo, MIZUTA, Toshio and KI-MURA, J.-I., 1998a, An examination of scheelite mineralization using a LA-ICP-MS method at the Yamaguchi skarn deposit, Iwate, Japan (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-370. First author at Inst. Applied Earth Sci., Akita Univ., Akita 010-8502, Japan.

The Yamaguchi W-Cu skam deposit occurs in homblende-biotite granite of the Miyako granitic body in the Sn-W province of the outer zone of northeast Japan.

REE content of 140 grains of amphibole, titanite, biotite and plagioclase in granitic rocks and skarn zones were analyzed using a LA-ICP-MS. From quartz diorite to granite, the REE content in amphibole decreases from quartz diorite to granite, while REE content in titanite increases. The chondrite-normalized REE pattern of some of hornblende in the granite are U-shaped. La content in hornblende and titanite of granite ranges 16 to 4.8 and 2653 to 772 ppm, respectively. La content in homblende and titanite of aplite and skarn ranges 0.61 to 0.04 and 62.5 to 51.6 ppm, respectively. LREE-content in both titanite of the aplite veins and amphibole of the skarn is drastically decreased. The REE patterns of titanite in the aplite vein are similar to those of titanite altered hydrothermally in Brazil. The FI in quartz from the deposit contain 3.3 wt.% NaCl eq., and 5.8 wt.% CO2 (liquid CO2). Carbonate complexes of LREE are dominant in CO2-bearing F. F containing CO2 component could be responsible for the significant decrease of LREE in titanite from aplite vein. Therefore, CO2-bearing F probably played an important role on the formation of scheelite-bearing aplite vein was formed. [sic] REE content in titanite and amphibole is good indicator to find generation of F phase in magma-hydrothermal transitional system. (From authors' abstract by H.E.B.)

OGATA, T., ISHIYAMA, D., MIZUTA, T. and KIMURA, J., 1998b, Tungsten mineralization at the Yamaguchi skarn deposit, Iwate Prefecture-An examination of the chemical composition of minerals using LA-ICP-MS method (abst.): Abstracts with Programs, 48th Annual Meeting of the Society of Resource Geology, Tokyo, June 17-19, No. P-18 (in Japanese). Indexed under FL. See previous abstract (E.R.).

OHTANI, T., FUJIMOTO, T., TANAKA, H., TOMIDA, N. and ITO, H., 1998, Paleohydrothermal activity within the Nojima fault zone estimated from the analysis of fluid inclusions (abst.): Abstracts of the 105th Annual Meeting of the Geological Society of Japan, p. 134 (in Japanese).

OHTANI, T., FUJIMOTO, K., TANAKA, H., TOMIDA, N and ITO, H., 1998, Fluid inclusions in the Nojima fault zone: Newsletter, Japanese Assoc. Geothermal Fluid Inclusionists, no. 8, Feb., 1998, p. 29-32 (in Japanese). First author at Geological Survey of Japan.

FI data are presented for Th vs depth and sal vs. depth. (E.R.)

OKUBO, Susumu, 1998, Occurrences and microthermometry of the Miocene hydrocarbon inclusions from the MITI-Mishima well, Niigata Prefecture, Japan: J. of the Japanese Association for Petroleum Technology, v. 63, no. 3, p. 205-215 (in Japanese, Engl. abst.). Author at JAPEX Research Center, Japan Petroleum Exploration Co., Ltd.

Occurrences and microthermometric characteristics of hydrocarbon I found in the MITI-Mishima well in Niigata Prefecture, Japan, have been studied and their implications are discussed. They occur locally in the lower part of the well, from the Miocene Lower Teradomari Formation through to the upper part of the Nanatani Formation, which [are] the main source rocks [for] the Niigata oil and G fields.

Occurrences and crystal shapes of quartz with hydrocarbon I suggest that fractures were the main migration pathways of the hydrocarbons. Quartz crystals with hydrocarbon I were found on extensional open fracture surfaces in cores. They also occur as euhedral or subhedral crystals in cuttings. Intergranular pore spaces in sandstone are rarely observed in this horizon. The occurrences and crystal shapes of quartz indicate that they had precipitated in open spaces, and so the pathways of hydrocarbons mainly lie in the open-fractures of the source rock.

The microthermometric characteristics of the I suggest that the migrations of hydrocarbons occurred at least twice. The hydrocarbons in the I from the MITI-Mishima well, commonly composed of V. L and bituminous solid, are classified into the V-homogenized type and the L-homogenized type. This is based on their behaviour when heated on the stage of the microscope. These two types of I do not exist in the same grain, although they occur in the same range of depth in this well.

The experiments on the estimation of the degree of thermal change of the hydrocarbon I in a closed system show that the Th, which is initially 66.9°C, decreases to 45.9°C. This is after the I have been heated to 370°C for 192 hours. Thus, the hydrocarbons in the I are revealed to have cracked at this T (Author's abstract)

OKUI, Toshiharu, MAEDA, Yuriko and HIRAOKA, Ryozo, 1998. Composition and stability of hydrates with double guests: Bulletin of the Geological Survey of Japan, v. 49, no. 10, p. 517-526 (in Japanese; Engl. abst.). First author at Tokyo Gas Co., Frontier Tech. Research Inst., 1-7, Suchiro-cho 1-chome, Tsurumi-ku, Yokohama, 230 Japan.

Stability of hydrates is sensitively influenced by their composition of guests. Sometimes even a very small amount of guest changes its equilibria drastically. In this report, relationship between equilibria of hydrates with multiple guests and their composition is described. There are two kinds of guest mixtures, one is from mixed G and the other from methane and an additive in water phase.

First, equilibria of hydrates from methane and ethane or propane were investigated. It is difficult to measure composition of multiple guests in hydrate phase, because compositions of G and hydrate phases are different at an equilibrium, and then both change during hydrate formation. A new approach to measure equilibrium composition in hydrate phase by stepwise dissociation and G analysis is introduced.

Next, effect of contaminants in water phase was investigated. In this report tetrahydrofuran was selected as a typical guest in water phase, so that it might form stable hydrate with methane.

The results indicated that equilibrium condition was drastically changed by small addition of a guest in larger cage; on the other hand, methane in small cages did not affect so much. These results suggested that occupancy of large cages in both I and II structures affects stability of hydrates more strongly than in case of small cages. (Authors' abstract) OMAR, G.I., TSENG, H.Y., ONSTOTT, T.C. and PERSON, Mark, 1998, Thermal and hydrogeologic constraint on the origin of deep subsurface micro-organisms within the Taylorsville Basin, Va., U.S.A. (abst.): Abstracts with Programs—Geological Society of America, v. 30, no. 1, p. 65.

Indexed under FI.

ONASCH, C.M., SHEN-TU, Bingming and COUZENS-SCHULTZ, B.A., 1998, Strain partitioning and factorization in a quartz arenite: J. Structural Geol., v. 20, no. 8, p. 1065-1074. First author at Dept. of Geol., Bowling Green State Univ., Bowling Green, OH 43403, USA; email (conasch@bgnet.gbsu.ed)

Most rocks deform by multiple grain-scale deformation mechanisms In order to assess completely the contributions of each mechanism, the strain associated with that mechanism must be known and compared to the finite strain. This study describes the partitioning of strain between three mechanisms, P solution, dislocation creep, and microfracturing, in a quartz arenite deformed at low T. P solution, which occurred primarily during compaction, dominates the finite strain with an average of 24% shortening normal to bedding. Dislocation creep, which occurred during layer-parallel shortening, accounts for about 2% shortening parallel to bedding dip. Microfractures, which occur in three orthogonal sets, resulted in 2-4% extension normal to bedding, parallel to bedding strike, and parallel to bedding dip. The validity of the mechanism strains was tested using strain factorization. Models were constructed using the mechanism strains in an order determined by their relative ages. Because porous, well-sorted quartz arenites, such as the one studied, are likely to undergo some mechanical compaction in the early stages of diagenesis, variable amounts of mechanical compaction were included in factorization models. Models using the measured deformation mechanism strains with an initial 5-10% mechanical compaction yield finite strains in close agreement with the measured finite strains. This suggests that the mechanisms identified, the strain associated with each mechanism, and the deformation sequence are plausible. (Authors' abstract)

O'REILLY, C., SHANNON, P.M. and FEELY, M., 1998, A fluid inclusion study of cement and vein minerals from the Celtic Sea basins, offshore Ireland: Marine and Petroleum Geol., v. 15, no. 6, p. 519-533.

ORSOEV, D.A., KISLOV, E.V. and GLOTOV, A.I., 1998. Fluid regime of the low sulphide PGE mineralization formation at the loko-Dovyren massif, north Baikal region (abst.): IAGOD Newsletter, 1998, p. 42. First author at Geological Inst., Sakhyanovoy str. 6, 670047 Ulan-Ude, Russia. The concentration and composition of volatile components (H2O, CO2, CO, CH4, H2) in plagioclase samples were studied by G chromatography. The plagioclase samples were selected from anorthosites of PGE-bearing. horizon and taxitic rocks (olivine leucogabbro and gabbronorites, gabbro pegmatites) from Layered zone of loko-Dovyren massif. The investigated samples are characterized by the higher contents of H2O (1.84-10.32 ml/g) [sic] CO2 (0 0635-1 234), H2 (0.08-0.27), CO (0.0199-0.1687), CH4 (0.0087-0.0472) in comparison with plagioclase from normal rocks of the massif Layered zone (Balykin et al., 1983). The H2 and CO2 are leading components at the G phase of all plagioclase samples. The CO and CH4 have the subordinated role. At the same time, the plagioclases from rocks of PGE-bearing horizon differ by a higher proportion of H2 and CO2.

This composition of volatile components could not be in equilibrium with M under magmatic T (Neruchev, 1991). Presumably it is result of influx of F from intermediate magmatic chamber. On the other hand, the increased role of CO<sub>2</sub> can be caused by not only P solubility of G in equilibrium with M, but also by partial oxidation of F during massif cooling and the crustal waters circulation. The heavy isotope composition of sulphur at the Ni-Cu and PGE mineralization (Glotov et al., 1998) and that of hydrogen and oxygen in lower margin rocks (Kislov et al., 1991) are evidences of this phenomenon. This process was displayed more heavily in rocks of PGE-bearing horizon than in Mafit zone rocks by a ratio of the CO<sub>2</sub> and CO contents in a cross-section of the massif.

Thus, the evolution of volatile components during formation of PGEbearing horizon take place from carbonaceous composition mainly, that is connected directly with initial M, through hydrogen-methane composition playing an important role in PGE industrial concentrations formation, to water mainly composition as a result of hydrothermal system occurrence on the late magmatic and postmagmatic stages. (Authors' abstract)

ORSOEV, D.A., KONNIKOV, E.G., GLOTOV, A.I. and KISLOV, E.V., 1997, Lower layered horizon of the Fedorovo-Pana gabbroid massif, Kola

Peninsula; features of structure, composition, and fluid phase distribution: Russian Geol. And Geophys., v. 38, no. 11, p. 1811-1820 (in Russian; Engl. abst.).

The inner structure of the lower layered horizon (LLH) of the Fedorovo-Pana Massif was studied in detail on the western slope of Mt. Zapadnyi Kievey. The LLH cross section is characterized by rhythmic layering mainly of gabbronorites and gabbros with different grain size, percentage of mafic minerals, and fabric. Microrhythms have typically two- and three-member structure. Up the section, the microrhythms become thicker and relative volume of leucogabbros and anorthosites increases. The lower part of the LLH, where the low-sulfide PGE mineralization is localized at the plagiopyroxenites and taxitic norites, is distinguished by the finest, most complicated, and contrasting interlayering. Signs of viscous flow of a magmatic M are strikingly displayed in the middle and upper parts of the cross section. The composition and distribution of the F components (H2O, CO2, CH4) in plagooclase monofractions were studied by G chromatography. It has been shown that the G phase evolution proceeded from hydrocarbon-hydrogenous to mainly CO2 on the background of a general decrease in H2O concentration and its share during the differentiation of a magmatic M. This led to the conclusion that the low oxidizing potential (or more reducing conditions) and relative high H<sub>2</sub>O P in the F phase were most favorable for concentrating PGE minerals. (Authors' abstract)

OSENBRÜCK, Karsten, LIPPMANN, Johanna and SONNTAG, Christian, 1998, Dating very old pore waters in impermeable rocks by noble gas isotopes: Geochim et Cosmo. Acta, v. 62, no. 18, p. 3041-3045. First author at Institut für Umweltphysik, Universität Heidelberg, Heidelberg, Germany; email (ka.os@t-online.de) The <sup>4</sup>He, <sup>40</sup>Ar, and <sup>136</sup>Xe content dissolved in the pore water of sedi-

The <sup>4</sup>He, <sup>40</sup>Ar, and <sup>136</sup>Xe content dissolved in the pore water of sedimentary rock samples was measured on samples from borehole cores near the repository for nuclear waste in Morsleben, Germany. Due to the very low permeabilities of the rock formations, conventional groundwater sampling was almost impossible. Hence, we developed a new sampling method for noble G in the pore water of freshly drilled rock cores. This method pro-vides vertical noble G profiles in high depth resolution, even in impermeable rocks. By application of the new technique quantitative age informations of groundwater and pore water have been derived. We find palaeowaters from the last glaciation depleted in  $\delta D$  and  $\delta^{18}O$  with a <sup>4</sup>He age of about 55 kyr. The high saline pore solutions below are at least 6 Mio years [sic] old. This has been concluded from the profiles of radiogenic <sup>4</sup>He and <sup>40</sup>Ar close to dif-fusion in steady-state and from xenon isotopes produced by spontaneous fission of <sup>218</sup>U in the rocks. A <sup>4</sup>He flux of  $2 \times 10^{-7}$  cc STP cm<sup>-2</sup> yr<sup>-1</sup> is derived from the profile, which is due to local <sup>4</sup>He production within the investigated sediments. (Authors' abstract)

PAK, T.M. and BAUMGARTNER, L.P., 1998. Solubility of simple pelitic and granitic mineral assemblages in chloride rich aq solutions at 2 kbar, and 400-650°C (abst.): Mineralogical Magazine, v. 62A. V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1124. First author at Dept. of Geol. and Geophys., Univ. of Wisconsin-Madison, Madison, WI 53706, USA.

We measured the solubility of various assemblages at 650-550°C and 2 kbar over a total chloride range of 0.01 to 4 m Cl<sup>ba</sup>. The results are summarized in Table 1. Accurate predictions of important variables, such as pH, still limit the applicability of quantitative mass transport calculations for metamorphic conditions. (From authors' abstract by E.R.)

See figure in the Illustrations appendix

PAL, D.C., PANIGRAHI, M.K. and MISHRA, B., 1998. Fluid inclusions characteristics of tin-bearing pegmatites of Malkangiri District. Orissa: J. Geological Society of India, v 51, p. 685-696. Authors at Dept of Geol, and Geophys. Indian Inst. of Tech., Kharagpur 721-302.

Stanniferous pegmatites of Malkangiri occur both in metabasics and metasediments showing signatures of deformation but very little wall rock alteration. Fl microthermometric studies in pegmatitic quartz and quartz from quartz veins reveal the following three types of 1: aq biphase, metastable (?) monophase aq 1 which do not show any thermal response, and rare halite-bearing 1. The CO<sub>2</sub>-free nature of the 1 is noteworthy. Isochores of halte-bearing 1 (where Ts NaCl>Th) intersect at P-T values of 2.65 kb and 337°C, implying preservation of the magmatic F that separated during the late stage of felsic magmatism in the area. Additionally, the above P-T values compare reasonably well with those obtained from the intersection of halite liquidi with the corresponding isochores.

Tin-bearing pegmatites in metabasics are characterized by their low Th

and isothermal variation in sal. This is explained by mixing of a Snbearing, granite affilitated, presumably reduced F with a heated, less evolved oxygenated meteoric water that led to cassiterite precipitation. Interestingly, I in cassiterite-bearing pegmatites within metasediments record a low T comparable with those from within metabasics. In contrast, barren pegmatites within the schistose metasediments preserve high T signature and indicate a simple cooling trend. The study reveals different styles of evolution of stanniferous and barren pegmatites at Malkangiri. (Authors' abstract)

PANG, Z.-H and REED, Mark, 1998, Theoretical chemical thermometry on geothermal waters: Problems and methods: Geochim et Cosmo. Acta. v, 62, no. 6, p. 1083-1091.

PARÍLOV Yu.S., 1998. Tests for determining the sources of ore-forming fluids based on the chemical composition of solutions in inclusions (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 27-30 (in Russian).

See Translations.

PARK, S.K., 1998, The influence of fluids on partial melting beneath Nanga Parbat, Pakistan Himalaya (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A296-A297. Author at IGPP, 1432 Geol., Univ. of California, Riverside, CA 92521; email (magneto@ucrmt.ucr.edu)

Rapid exhumation of the Nanga Parbat-Haramosh Massif (NPHM) in the past 3 Ma has exposed rocks from the middle crust. Thin leucogranite dikes, migmatites and small bodies of granite with ages as young as 1 Ma are common. Clearly, partial melting is occurring beneath Nanga Parbat. An interdisciplinary study of the NPHM yields new constraints on the extent of partial melting and the conditions under which that M forms. Abundant microseismicity ceases abruptly at a depth of 5 km below sea level (9-12 km below the surface) and at depths of 8 km on the flanks. which is inferred to be the brittle-ductile (b-d) transition. Fl and oxygen isotopic studies indicate that meteoric waters circulate to shallow crustal depths (above the b-d transition) and are then heated to a dry steam phase before returning to the surface. Most surprising is the lack of evidence for widespread magma below the b-d transition. Prominent S wave arrivals and electrically resistive crust are arguments against widespread magma. Average F contents from rock resistivity are <0.01% in the crust to depths of at least 40 km. Such resistivities above the b-d transition are consistent with evidence of dry steam from the FI and the harmonic nature of some local seismic events. Below the transition, we infer from the finite resistivity and NaCl content of the brines (5% from FI) that these F are interconnected. F generated from metamorphism and partial melting may instead be concentrated in isolated, rapidly deforming regions. The young igneous bodies observed at the surface are due presumably to dry decompression partial melting caused by the rapid exhumation at Nanga Parbat. Generation of granitic M under dry conditions would lead to electrically resistive magma bodies, which would be consistent with the high resistivity. The passage of S waves through this region precludes the presence of large magma bodies, but small pockets of granitic magma are permitted by the MT data, plausible sources of scattering seen in the seismic data, and consistent with the occurrence of only small and scattered young granitic bodies. (Author's abstract)

PARNELL, J., CAREY, P. and DUNCAN, W., 1998, History of hydrocarbon charge on the Atlantic margin. Evidence from fluid inclusions studies, West of Shetland: Geology, v. 26, no. 9, p. 807-810. First author at School of Geosci., Queen's Univ. of Belfast, Belfast BT7 INN, UK.

FI in Jurassic reservoir sandstones help us to understand the history of hydrocarbon charge in the West of Shetland region. The sandstones contain both hydrocarbon and aq FI. Hydrocarbons are present in trails of SI through detrital grains, and as PI in quartz overgrowths. This is direct evidence for at least two episodes of hydrocarbon charge before the present oil entered the rock, consistent with indirect evidence from burial history modeling and organic geochemistry. Fluorescence colors indicate that the two oils are of distinct composition. The first oil was degraded, reflecting an episode of uplift and exposure to near-surface F before reburial and migration of a second live oil. Oils comparable to these two paleocharges were mixed to produce the oils that are encountered in the current reservoir pores, showing that they were preserved despite repeated tectonic events at the Atlantic margin. (Authors' abstract) PARNELL, John, CAREY, Paul and MONSON, Bryan, 1998. Timing and temperature of decollement on hydrocarbon source rock beds in cyclic lacustrine successions: Palaeogeography. Palaeoclimatology, Palaoecology, v. 140, no. 1-4, p. 121-134.

The generation of hydrocarbons causes lubrication of source rock bedding planes which can enhance deformation during basin subsidence and subsequent tectonic events. Minerals precipitated in tension cavities associated with decollement yield FI Th in the ranges 96-139°C and 85-96°C for the Orcadian and Hartford-Deerfield basins, respectively. These data are consistent with burial into the oil window at depths of between 1.5 and 2.0 km. (From authors' abstract by E.R.)

PARRY, W.T., 1998, Fault-fluid compositions from fluid inclusion observations and solubilities of fracture-sealing minerals: Tectonophysics. v. 290, no. 1-2, p. 1-26.

Host-rock chemical alteration and syntectonic veins in and near fault zones are evidence for episodic fracturing and F transport during faulting. Alteration minerals, vein fillings, and FI may be used to estimate fault-F chemistry, T and P. FI in thrust faults, reverse faults hosting mesothermal gold deposits, and exhumed footwall rocks of normal faults show that F components include NaCl, CO<sub>2</sub>, CH<sub>4</sub>, and CaCl<sub>2</sub> in addition to H<sub>2</sub>O. F composition. T and P are spatially and temporally variable on most faults; a typical fault F does not exist. NaCl concentrations in fault F vary from 0 to 39 wt.%, CaCl<sub>2</sub> concentrations range up to 19 wt.% and CO<sub>2</sub> concentrations range up to 32 mol% in FI, but some I are present that are 100 mol% CO<sub>2</sub>.

Th measurements and P estimates confirm that these F were trapped at elevated P at depth on the faults. In CO2-bearing fault F, P fluctuated, and a range of CO2 contents indicate effervescence. Varying solution densities of NaCI-H2O F have been interpreted to result from entrapment of F in I at constant T and varying P. Diverse F compositions are present on some faults with similar Th and estimated P suggesting similar depths on the faults. Pressure, T and F composition determine the solubilities of fracturefilling minerals calcite and quartz and the formation of alteration minerals that are related to the mechanical behavior of the rock. Quartz may precipitate as a result of cooling or P reduction, but calcite solubility increases with cooling and decreases with decreased PCO2. Higher sal increase solubilities of calcite and quartz and decrease the pH for equilibrium among feldspars, muscovite and solution. Mineral assemblages provide evidence of depressurization of the F as F moves from higher- to lowerpressured reservoirs. Precipitation of quartz, calcite, and K-feldspar or albite in fractures may result from F depressurization. Fault-zone rocks containing stilbite and laumontite reacted with F that contained little CO2 at comparatively low T and P; kaolinite, prehnite, muscovite, epidote, and chlorite formed from F at higher T and P. Variations in mineralogy and FI characteristics on individual faults suggest separate F that differ in chemical composition, T and P. (Author's abstract)

PARSON, L.M., WALKER, C.L. and DIXON, D.R., eds, 1995, Hydrothermal vents and processes: Geol. Society Special Pub. #87. Indexed under FL (E.R.)

PASTERIS, J.D. and CHOU, I.-M., 1998, Fluid-deposited graphitic inclusions in quartz: Comparison between KTB (German Continental Deep-Drilling) core samples and artificially reequilibrated natural inclusions: Geochim. et Cosmo. Acta, v. 62, no. 9, p. 109-122. First author at Dept of Earth and Planetary Sci., Washington Univ., St. Louis, Missouri 63130-4899, USA.

We used Raman microsampling spectroscopy (RMS) to determine the degree of crystallinity of minute (2-15  $\mu$ m) graphite I in quartz in two sets of samples: experimentally reequilibrated FI in a natural quartz grain and biotite-bearing paragneisses from the KTB deep drillhole in SE Germany. Our sequential reequilibration experiments at 725°C on initially pure CO<sub>2</sub> I in a quartz wafer and the J. Krauthem (1993) experiments at 900-1100°C on organic compounts heated in gold or platinum capsules suggest that, at a given T, (1) F'deposited graphite will have a lower crystallinity than metamorphosed organic matter and (2) that the crystallinity of F'deposited graphite is affected by the composition of the F from which it was deposited. We determined that the precipitation of more-crystallinity of graphite is established by two conditions (including G fugacities) that pertain as the F first reaches graphite saturation.

Graphite I within quartz grains in the KTB rocks show a wide range in crystallinity index, reflecting three episodes of carbon entrapment under different metamorphic conditions. Isolated graphite I have the spectral properties of totally ordered, completely crystalline graphite. Such crystallinity suggests that the graphite was incorporated from the surrounding metasedimentary rocks, which underwent metamorphism at upper amphibohte-facies conditions. Much of the F'deposited graphite in Fl, however, shows some spectral disorder. The properties of that graphite resemble those of experimental precipitates at T in excess of 700°C and at elevated P, suggesting that the I represent precipitates from C-L-H F trapped under conditions near those of peak metamorphism at the KTB site. In contrast, graphite that is intimately associated with chlorite and other (presumably low-T) silicates in I is highly disordered and spectrally resembles kerogens. This graphite probably was deposited during later greenschist-facies retrograde metamorphism at about 400-500°C.

The degree of crystallinity of F<sup>-</sup>deposited graphite is shown to be a much more complex function of T than is the crystallinity of metamorphic graphite. To some extent, experiments can provide T-calibration of the crystallinity index. However, the difference in time scales between experimental runs and geologic processes makes it difficult to infer specific T for naturally precipitated graphite. (Authors' abstract)

PENG, Z., WATANABE, M., HOSHINO, K., SUEOKA, S., YANO, T. and NISHIDO, H., 1998, The Machangqing copper-molybdenum deposits, Yunnan, China—An example of Himalayan porphyry-hosted Cu-Mo mineralization: Mineral. and Petrol., v. 63, p. 95-117. First author at Dept. of Earth and Planetary Sci., Hiroshima Univ., Hiroshima, Japan.

The Machangging copper-molybdenum deposits consist of two types: (1) Cu-Mo quartz veinlets in magnetite-series granite porphyry; and (2) Cu-Mo skams occurring at the contact between a sedimentary sequence and the granite porphyry. With decreasing T and ak and ak of the hydrothermal F initially in equilibrium with K-feldspar, the following alteration patterns developed within the porphyry, from the center outwards: silicification, K-silicate, phyllic and argillic alteration. The paragenetic sequence of alteration minerals observed in the Cu-Mo skarns resulted from decreasing T and/or increasing aca2+/a2H+ of the hydrothermal F initially in equilibrium with grandite garnet. FI in quartz suggest boiling during the mineralization. The mineralization T based on filling T and sal of quartz are in the following ranges: about 265-400°C and 5.0-14.6 wt.% NaCl eq. for the Cu-Mo veinlets: and 200-500°C and 10.2-42.0 wt.% NaCl eq. for the Cu-Mo skarns. As is evident from log /O2-pH diagrams, ores of the early stage of mineralization in the Cu-Mo skams, characterized by the assemblage magnetite+pyrite+rare pyrrhotite+K-feldspar+quartz, were deposited from highly alkaline and high T F. With decreasing T and /O2, the pH of the ore F was shifted towards slightly alkaline to neutral, with the resultant formation of the main stage ores, characterized by the assemblage chalcopyrite+pyrite+molybdenite+sphalerite+K-feldspar+sericite (muscovite)+epidote+quartz. Very minor amounts of ore minerals, including matildite, bismuthinite and electrum, are associated with a late stage of ore formation

In the case of the Cu-Mo veinlets, it can be stated roughtly that both /S<sub>2</sub> and /O<sub>2</sub> conditions were in the stability field of pyrite, with pH of the ore F buffered by the assemblage sericite+K-feldspar+quartz±calcite. K-Ar determinations were made on the granite porphyry, biotite phenocrysts and hydrothermal biotite in the Cu-Mo skarns, giving ages of 42.5 to 34.6 Ma. 52.3 Ma, and 39.2 to 26.4 Ma, respectively.

It is concluded that the Cu-Mo mineralization at Machangqing shows a close spatial and temporal association with the Himalayan felsic magmatism of the magnetite-series type (Authors' abstract).

PERELLÓ, José, URZÚA, Felipe, CABELLO, José and ORTIZ, Francisco, 1996, Clustered, gold-bearing Oligocene porphyry copper and asociated epithermal mineralization at La Fortuna, Vallenar Region, northern Chile: in "Andean copper deposits: New discoveries, mineralization, styles and metallogeny". Soc. Econ. Geologists Special Publication No. 5, Camus, F., Sillitoe, R.H., and Petersen, R., eds., 1996, p. 81-90.

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The La Fortuna' porphyry cluster is centered on a series of porphyritic stocks of Tertiary age that intruded a sequence of Paleozoic rhyolites and Jurassic red beds. Much of the area is covered by ignimbrites and gravels of Miocene age. Structure is dominated by regional, north-trending reverse faults crosscut by local, northwest-trending faults which are intimately associated with the porphyry-style mineralization. Two main types of mineralization are present in the area: porphyry copper-gold at La Fortuna itself and El Negro, and high-sulfidation epithermal gold at Cantarito (From authors' abstract by H.E.B.)

Fluid-Inclusions Characteristics

A preliminary FI study was undertaken on four samples from La Fortuna and two samples from Cantarito (Skewes, 1993). At La Fortuna, the quartz-veinlet stockworks in the intermediate argillic alteration zone contain two main FI associations: 1) Type I multiphase I, with a V bubble, L, and up to six dxl (hematite, halite, opaques, and sylvite, among others), that homogenize by dissolution of halite at T>600°C. The sal of these I commonly exceed 70 wt.% NaCl eq.

 Type II (two-phase with V and F) I that coexist with Type I inclusions and do not homogenize at T<600°C</li>

The coexistence of these two I types and their similar Th, along with the elevated sal and T, suggest that they were trapped from undiluted, not, boiling F compatible with a magmatic derivation. This, in turn, suggests that such F were likely to have been accompanied originally by K-silicate alteration assemblages, which were later overprinted by the intermediate argillic, sericite-chlorite alteration present now at La Fortuna

Open spaces in hydrothermal breccias associated with advanced argillic alteration in the upper parts of La Fortuna are filled with quartz that contains coexisting I of Types I, II, and III Type I inclusions contain multiple dx), homogenized by V bubble disappearance at T between 194 and  $302^{\circ}$ C, and have sal between 30 and 33 wt % NaCl eq. Low-sal, Type II inclusions, with Th between 248 and 262°C, are common, and Type III, L-rich I homogenize between 172 and 324°C and have sal of <5.4 wt.% NaCl eq.

The FI from this shallow porphyry environment are interpreted to have been trapped from two apparently different boiling F at epithermal T one diluted with an important meteoric component, and the other moderately to highly saline with an important magmatic component.

FI from Cantarito are generally scarce and small (<6 microns). Workable I were found only in quartz within cavities and quartz-alunite-lined hairline fractures and correspond to L-rich Type III. No V-rich I were observed. The Type III inclusions analyzed homogenize to L at room T between 206 and 261°C, and have sal of <5.2 wt.% NaCl eq. Their T and sal ranges compare with those determined for the high-sulfidation epithermal deposits of the Nansatsu district, Japan (Hedenquist et al., 1994). Interestingly, these I are similar to the Type III inclusions from the upper part of the La Fortuna porphyry system, and were probably trapped from the same F.

Feldspar-stable, quartz-K-feldspar stockworks at El Negro contain abundant P Fl of Types I. II, and III. Coexisting Types I and II inclusions have been observed. Neither T nor sal were determined for these I, although the presence of multiple dxl in Type I inclusions and the coexistence of Types I and II inclusions suggest that they were trapped from highly saline, boiling F from a magmatic source. (From the authors' text by H.E.B.)

See figure in the Illustrations appendix.

PERINELLI, C., ARMIENTI, P., TRIGILA, R. and AURISICCHIO, C., 1998, Intergranular melt inclusions within ultramafic xenoliths from Baker Rocks and Greene Point volcanics (northern Victoria Land, Antarctica). Terra Antarctica, v. 5, no. 2, p. 217-233. First author at Dipartimento di Scienze della Terra, Via S. Maria 53, 56126 Pisa. Italy.

At Greene Point and Baker Rocks (north Victoria Land, Antarctica) ultramafic xenoliths have been found enclosed in Cainozoic volcanics of alkali-basaltic and nephelinitic composition. Greene Point xenoliths comprehend spinel-harzburgites with protogranular to porphyroclastic textures; Baker Rocks xenoliths are spinel-harzburgites with protogranular to porphyroclastic textures, cumulatic wehrlites, and composition xenoliths made by granuloblastic harzburgite and wehrlite or harzburgite and pyroxenite. Intergranular glassy I are generally found within the protogranular harzburgites while in cumulitic wehrlites glassy veins or fracture-fillings are more common. Composition of glasses shows significant differences between the two series and, at Baker Rocks, also within different samples. We consider that the origin of the glass I within harzburgites of both series, the widespread occurrence of pyrometamorphic textures, Na, Ba, Sr, Rb, K and LREE enrichment in the bulk chemistry of these xenoliths, and the occurrence of composite xenoliths are all related to a metasomatic event affecting the mantle of this area. Glass I in wehrlitic xenoliths are instead the consequence of fractionation of the M that carried xenoliths themselves, as shown not only by the composition of the glasses, but also by the textural relations between the xenolith minerals and the glass l.

Geothermometric and geobarometric estimates show that the xenoliths have been initially equilibrated between 950 and 1070°C at P between 1 and 1.7 GPa; with a following thermo-baric reequilibration at about 900°C and 0.7 GPa. The above results are in agreement with geophysical data and with other P and T estimates obtained on xenoliths from the same region (Beccaluva et al., 1991; Horning et al., 1991; Zipfel & Wörner, 1991).

## (Authors' abstract)

PETER, J.M., GOODFELLOW, W.D. and Leg 169 Shipboard Scientific party, 1998, Setting, mineralogy and geochemistry of the Middle Valley sulfide deposits: ODP Leg 169 (abst.): 17th General Meeting Int'l Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A132. Authors at Geol. Survey of Canada, Ottawa, email (ipeter@nrcan.gc.ca)

Middle Valley, northern Juan de Fuca Ridge, is a hydrothermally active rift covered by a thick sequence of turbiditic and hemipelagic sediments. The massive Zn-Cu sulfide mounds have been drilled. Several of the drilled holes are now venting hydrothermal F. These sampled F, and those from anhydrite chimneys, are metal-poor and have lower T (145-275°C) than measured in FI in the massive sulfides and feeder zones (up to 354°C), therefore, they are not likely to be representative of F which formed these deposits. (From authors' abstract by E.R.)

PETERSEN, E.U. and FITZMAYER, J.R., 1998. The alumite-scricite association: A new type of epithermal precious metal deposits? (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-127. Authors at Dept. of Geol, and Geophys., Univ. of Utah, 135 S 1460 E, Room 719, Salt Lake City, UT 84112-0111; email (eupeters@mines.utah.edu)

Three major types of epithermal precious metal deposits are well established (Bonham, 1984): the kaolinite-alunite group (HS), the adulariasericite group (LS) and the alkalic group. A fourth type, the alunite-sericite group, can be recognized. The type deposit for this latter group is the largest gold deposit in Bolivia (150 Mt Au), the Kori Kollo deposit (3rd largest in South America). Hypogene precious metal mineralization is hosted in both wallrock and a sheeted vein system dominated by pyrite. Alteration of the andesitic-dacitic hypabyssal intrusion/dome complex consists of pyritization (up to 14 vol.% pyrite), silicification (44-51 vol.% quartz), sericitization (38 vol.% phengite), (K.Na)-alunite+florencite (1-3 vol.%), and local trace kaolinite. A distinctive positive europium anomaly is characteristic of altered wallrock. Vein mineralization consists of Stage 1 (85-90 vol.%) pyrite, arsenopyrite, high-fineness electrum and minor jamesonite, Stage II (-5 vol.%) pyrite, jamesonite, moderate-fineness electrum, galena, sphalerite, tetrahedrite, bournonite, and chalcopyrite, and Stage II (5-10 vol %) Pb-APS minerals which replace earlier sulfides and late alunite. Fl studies show that magmatic F (700-300°C, 8-45 wt.% NaCl) are trapped in P I in quartz phenocrysts. Secondary I record T between 250 and 350°C (5-13 wt.% NaCl). Primary I in rare, vein quartz vield T=250-350°C, 5-9 wt.% NaCl. Primary I in sphalerite yield T=200-300°C. 7-15 wt.% NaCl with S I yielding T=150-225°C, 7 wt.% NaCl. These data suggest minimum burial depths during mineralization between 0.4 and 0.8 km. Kori Kollo shares several characteristics with HS and LS precious metal deposits but does not fit neatly in either category. It is anticipated that more deposits belonging to this class in the region will be recognized as detailed deposit descriptions become available. (Authors' abstract)

PETRICHENKO, O.Y. and SHAIDETSKA, V.S., 1998. Calcium chloride in brines of the Upper Devonian evaporite basins in the Pripyat-Dnipro-Donets riftogene: Study of fluid inclusions in halite: Przeglad Geologiczny, v. 46. no. 8, p. 689-699 (in Polish, Engl. abst.).

Authors at Instytut Geologii i Geochemii NANU, Naukova 3A, 290053. Lviv, Ukraine

Upper Devonian evaporite deposits of Dnipro-Donets (Ukraine) and Pripyat (Belarus) depressions accumulated due to evaporation of water coming from a vast epicontinental sea of the Moscow Syneclise. Periodical occurrence and development of four independent evaporite basins took place simultaneously with the development of the deep rift structure and intensive volcanism. Analyses of FI in sedimentary halite indicate that brines in the Upper Devonian evaporite basins at the beginning of halite precipitation were characterised by a high content of Ca2\* (from 80.0 to 169.0 g/l). During accumulation of thick series of evaporites (up to 2,000 m), the content of Ca2+ in brines decreased to 5.0 g/l, and in some cases to 6.0 g/l (rarely-to 1.5 g/l). The changes of calcium content show inverse proportion with that of K<sup>+</sup> and Br and sometimes Mg<sup>2+</sup>, that does not fit the concept of the genetic relation between the major part of Ca2+ and seawater, and evidences thus an additional source of supply of the ion. Such a source were marine brines buried within chemical and terrigenous deposits. and discharged into the basin during the sediment compaction, as indicated by similar chemical composition of buried marine brines in sub-evaporitic and intra-evaporitic Devonian deposits of both depressions and of bottom brines in evaporite basins of the riftogene in Late Devonian. The constant

presence of Ca<sup>2\*</sup> in brines at all stages of salt accumulation resulted from the constant supply of seawater of Na-K-Mg-Ca-Cl chemical type. Such chemical type was also recorded in brine I in sedimentary halite from other Devonian evaporites. (Authors' abstract)

PETTKE, T., KRAMERS, J.D. and DIAMOND, L.W., 1998, Radiogenic isotopes in hydrothermal fluids: Clues to understanding ore deposit genesis? (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A30. Authors at Isot. Geol. Group, Min.-Petr. Inst., Univ. of Bern, Switzerland; email (tpettke@umich.edu)

Contradictory genetic models for late-metamorphic gold lodes of various formation ages worldwide emerge from literature, testifying to the need of discriminating analytical tools to reliably constrain the source of the F and the gold, and the timing of gold vein formation relative to orogenic events. We elucidate the power and possible pitfalls of radiogenic isotope systematics as applied to hydrothermal gold veins on the basis of the Alpine Monte Rosa Gold District (MRGD; NW Italy).

Vein emplacement was diachronous over the MRGD between 32 and 11 Ma (40 Ar/39 Ar in mica), always -10 m y. post peak metamorphism of the adjacent country rock. P FI in the gold were revealed by step-wise degassing. Their trapped disequilibrium He-Ar abundance patterns are (a) indicative of retrograde boiling coeval with free gold deposition and (b) devoid of any atmospheric contribution. The FI He-Ar isotope compositions reveal a mixture between a crustal and a very subordinate mantle-type component. The initial Sr isotopic compositions of FI and vein minerals (a) are in disequilibrium with those of the adjacent host rocks and (b) monotonically evolve away from the host rock signatures with progressive vein growth. Combined with the CO2-H2O-NaCI-KCI-H2S fluid chemistry, Sr isotopes demonstrate that (1) F flow in the veins was upward, and (2) the F most likely was derived from devolatilization of calcschists. Thus, the hydrothermal F ascended at least 10 km vertically. Gold and the hydrothermal F, however, have different source rocks. Gold is derived from metaophiolites intercalated with and overlying the calcschists as is indicated by the primitive initial Pb isotope compositions of the gold and cogenetic quartz.

Our detailed study underscores similarities between Tertiary and Archean lode gold deposits, suggesting a common genetic driving force, regional metamorphism. However, the principal sources of the F may have changed through time; Mesozoic veins often appear to be genetically linked to graphitic calcschists whereas such rocks are notably scarce in the late Archean. Radiogenic isotopes carefully applied to Fl and hydrothermal vein minerals have the potential, as no other technique available to date, to confine the selection of possible genetic scenarios for a given hydrothermal deposit. (Authors' abstract)

#### PHILIPPOT, Pascal, AGRINIER, Pierre and SCAMBELLURI, Marco, 1998, Chlorine cycling during subduction of altered oceanic crust: Earth and Planet. Sci. Letters, v. 161, p. 33-44.

Eclogitic rocks that have experienced devolatilization, with little or no interaction with external F sources, can be viewed as analogues of crustal material which may be transferred back into the mantle during subduction. Thus, they can be used to evaluate the extent of the recycling of volatile elements, such as chlorine. We report new oxygen isotope ratios of omphacite, and FI data determined from eclogitic metagabbros, of the Rocciavre massif (Italian Alps). The data are compared with those obtained for the Monviso, Cyclades and the Franciscan Complex high-P rocks. In all localities, relics of early dehydration F are preserved as P FI in the cores of omphacite megacrysts (Rocciavre, Monviso and Franciscan Complex) or garnet (Cyclades). Sal estimates of the IF range from 32 to 45 wt.% NaCl eq. in Rocciavre, 17 to 21 wt.% NaCl eq. in Monviso, and are similar to seawater in other areas. Omphacite and bulk-rock 818O values of Rocciavre (5 1-6.8 per mil) and Monviso (3.0-5.3 per mil) metagabbros are markedly lower than those of Cyclades (6.8+14.3 per mil) and the Franciscan (6.7-13.1 per mil) metabasites. The F sal-818O systematics of eclogitic rocks is similar to that documented along a typical section of the altered oceanic crust and unmetamorphosed ophiolites. This suggests that high-P metamorphism, and associated processes, did not modify significantly the variability in chlorine concentrations and oxygen isotope ratios, inherited from a stage of sea-floor hydrothermal alteration under low- (basaltic layer) and high-T (gabbroic layer) conditions, respectively.

Extrapolating the estimated H<sub>2</sub>O and Cl contents of eclogitic rocks to a representative section of the subducted oceanic crust indicates that a minimum of 100-200 ppm Cl could be recycled into the mantle during subduction. This yields a CVH<sub>2</sub>O ratio of 3.6 to  $7.5 \times 10^{-5}$  for the subducted oce-

anic crust, which is similar to E-MORB. On the basis of available Cl isotopic data, we infer that a large proportion (70%) of the Cl stored in the altered crust should be recycled to the mantle to generate an isotopic composition of the subducted crust equivalent to the source of unaltered midocean ridge basalt (8<sup>37</sup>Cl=4.7 per mil). (Authors' abstract)

PHILIPPOT, P., MÉNEZ, B., CHEVALLIER, P., GIBERT, F., LE-GRAND, F. and POPULUS, P., 1998, Absorption correction procedures for quantitative analysis of fluid inclusions using synchrotron radiation Xray fluorescence: Chem. Geol., v. 144, p. 121-136. First author at CNRS-URA 736, Laboratoire de Pétrologie, T26-E3, Université Paris 6 and 7, 4 place Jussieu, 75005 Paris, France.

Describes a series of steps in a procedure to correct for absorption that permit quantitative results <u>without</u> precise knowledge of I depth and geometry (E.R.).

PHILIPPOT, Pascal, MÉNEZ, Bénédicte, DRAKOPOULOS, Michael, SIMIONOVICI, Alexandre, SNIGIREV, Anatoly and GIBERT, Francois, 1998, Mapping trace-metal distribution in individual fluid inclusions using a 3<sup>rd</sup> generation synchrotron light source: Int'l Conf. Nuclear Microprobe Tech. & Applications 98, Spier, S. Africa. p. 4,14,

We have initiated a study aimed at evaluating the applications of SXRF technique to FI analysis. An important problem associated with FI analysis using SXRF is absorption of the beam by the host material. Absorption has crucial effect on sensitivity. Using the LURE photon probe, we have developed a technique for correcting absorption (Philippot et al., 1998, Chem. Geol., 144, 99-119; Ménez et al., this volume). Analysis of FI containing known concentrations (1000 ppm) of various metals (Mn, Ni, Zn) have showed that elemental concentrations in individual FI can be determined with an accuracy commonly better than 20% relative to the known concentrations. The high brightness of an insertion device was necessary to give highly-intense X-ray fluorescence signal and decrease the limits of detection.

Recently, we performed SXRF analysis of Fl using beamline ID-22 Micro-FID of the ESRF, a 3<sup>rd</sup> generation synchrotron. The experimental set-up consists in different Fresnel zone plates that ensured focusing of monochromatized X-rays at different incident energies (12.5 keV and 15.0 keV), with a spatial resolution of about 10  $\mu$ m<sup>2</sup> and a flux of 10<sup>9</sup> to 10<sup>10</sup> ph/sec. The samples studied were from various gold deposits. The limit of detection we obtained was of the order of 1 ppm for trace metals such as Cu, Zn, As or Sr.

Fluorescence X-ray maps were collected for several FI. An example of the distribution of As in a FI from the Brusson gold deposit (western Alps) is presented. For each X-ray fluorescence spectrum, the ( $K\alpha/K\beta$ )<sub>As</sub> ratio of As was used as a means of estimating the thickness of quartz traversed by the photon beam. This value was used in turn for correcting As count rates. The correction procedure resulted in uniformising the count rates of As in the L portion of the I and allowed visualizing the V bubble which contains only trace amounts of As. The strategy for computing the composition of the IF was to use one element from crush leach analysis (As; Yardley et al., 1993, Min. Mag., 57, 407-422) as an internal standard to calculate the concentrations of the other cations (Cu and Zn) present in the solution. Element concentration estimates calculated using SXRF spectra are in relatively good agreement with those determined by crush-leach analysis. This indicates that the F population trapped in the sample studied was homogeneous with respect to electrolyte composition.

These results indicate that 3<sup>rd</sup> generation synchrotron light source can be considered as a promising technique for tracking trace metals in individual I (down to the tenths of a ppm level) and hence, as an invaluable tool for reconstructing the relative chronology of the paleo-hydrothermal events responsible for the concentration of economic resources. (Authors' abstract)

See figure in the Illustrations appendix.

PHILIPPOT, P., MÉNEZ, B., DRAKOPOULOS, M. and SNIGIREV, A., 1997. High-resolution microprobe analysis of "geofluids": An economic perspective (abst.). Special meeting, European Synchrotron Research Facility (ESRF), Grenoble, Nov. 1997. Unpaginated. See next item (E.R.)

PHILIPPOT, P., MÉNEZ, B., DRAKOPOULOS, M. and SNIGIREV, Anatoly, 1998. Mapping trace-metal (Cu, Zn. As) distribution in individual fluid inclusions using a 3<sup>rd</sup> generation synchrotron light source (ESRF, France) (abst.). Program and Abstracts. PACROF1 VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 49. First author at CNRS, Université Paris 7, Paris.

The concentration and spatial distribution of relatively dilute (10 to 100 ppm) trace metals (Cu, Zn and As) were determined in individual FI from various ore deposits using SXRF. The experimental set-up consists in a Fresnel zone plate that ensured focusing of monochromatized X-rays at about 12.5 keV, with a spatial resolution of  $2x7 \ \mu m^2$  and a flux of  $10^{10}$  ph/sec.

The FI analyzed here are from mesothermal gold-quartz veins at Brusson, Val d'Ayas, Italian Alps (kindly provided by Larryn Diamond and Bruce Yardley). The presence of only a single compositional type of FI that has been the subject of detailed chemical analysis using a variety of bulk (crush-leach) and single-I techniques (microthermometry, Raman spectrometry and secondary ion mass spectrometry) makes these samples ideally suited for testing the potential of the X-ray microprobe to be installed at the ESRF. The I are water-dominated H<sub>2</sub>O-CO<sub>2</sub> I with about 5 wt% eq. NaCl.

Fig. 1a shows a typical X-ray spectum obtained during a 10 min acquisition time on a single I (number in parenthesis is the concentration determined by crush-leach; in ppm). Notice that the fluorescence intensity of As is much higher than that of Ca and Fe although its concentration (147 ppm) is lower or similar to the concentration of Ca (665 ppm) and Fe (120 ppm). These differences in X-ray peak intensity are due to three factors. First, X-rays of light elements are significantly or totally absorbed by the quartz host covering the I and the airpath between the detector and the sample. Second, for a given excitation energy (12.5 keV in the present study), the photoionisation cross section scales with Z4 (Z being the atomic number of the analysed element). Third, since the cross section has a (photon energy)<sup>-3</sup> dependence, the majority of the fluorescence events arise from photons whose energy is just above the considered absorption edge. In the present case, this implies that the sensitivity is optimized for elements displaying X-ray fluorescence lines close to the excitation energy [As and to a lesser extent Cu (25 ppm) and Zn (34 ppm)].

Although the conditions of analysis were not optimized and will be easily improved using Bragg-Fresnel optics (lower background, higher photon flux and smaller foci), these results indicate that third generation synchrotron light sources can be considered as a promising technique for tracking trace metals in individual inclustons (down to the ppm and possibly tenths of ppm level) and hence, as an invaluable tool for reconstructing the relative chronology of the paleo-hydrothermal events responsible for the concentration of economic resources. (From authors' abstract by E.R.)

PHILPOTTS, J.A., TAYLOR, C.D., TATSUMOTO, Mitsunobu and BELKIN, H.E., 1998, Petrogenesis of late-stage granites and Y-REE-Zr-Nb-enriched vein dikes of the Bokan Mountain stock, Prince of Wales Island, southeastern Alaska: U.S. Dept. of the Interior, U.S. Geological Survey Open-file report 98-459, 71 pp.

The petrography of the abundant aq Fl is described. (H.E.B.)

PINEAU, F. and JAVOY, M., 1998. H<sub>2</sub>O and CO<sub>2</sub> content and isotopic features in MORB glass and vesicles. Mantle source and degassing imprint (abst.): The Ninth Int'l Conference on Geochronology, Cosmochronology and Isotope Geology, Abstracts, published in Chinese Sci. Bulletin, v 43, Supp., p 100 Authors at Laboratoire de Géochimie des Isotopes stables, Institut de Physique du Globe de Paris, URA CNRS 17-62. 4 place Jussieu, 75 251 Paris CEDEX 05, France.

A systematic study has been made on MORBS from the MAR and EPR. Both vesicles G and dissolved species have been considered

Water is most of the time still dissolved in the glass (concentrations vary from 1000 to 6700 ppm wt%  $H_2O$ ) and then related to geochemical characters of mantle source lavas.  $\delta D$  (-90 to -45‰) are interpreted in terms of source signature or contamination during magma stagnation at shallow levels in the oceanic crust.

Vesicle-rich glasses are the only available samples to approach the relationship of exsolved species with dissolved water and carbon. Vesicles CO<sub>2</sub>  $\delta^{13}$ C varies from -3.6 to -10‰. It is not always homogeneous inside a single fragment of glass. This depends on the conditions controlling CO<sub>2</sub> degassing like vesicle density, magma rate, the relative bubble-magma velocity.

The main parameters allowing to build outgassing models for MORB are the carbon supersaturation level, related to the rate of ascent, and the isotopic disequilibrium between vesicles and glass, related to the length of the rapid ascent episode ("eruption").

Rayleigh distillation commonly occurs during the last few km of magma run toward the surface. The average starts from 3 km depth. However, some extreme supersaturation states (170 ppm compared to an equilibrium concentration of -40 ppm) correspond to a magma velocity >2 m/s, whereas, in the same sample,  $\delta^{13}$ C down to -17‰ points out to extreme isotopic distillation effects, implying that the fast episode started from an initial depth of ~20 km and corresponded to an initial dissolved carbon content ≥6000 ppm C.

Comparison between MAR and EPR samples shows more variable data along the MAR. EPR being more homogeneous due to higher degree of partial melting in relation with higher spreading rate. On a given site, intermediate characters correspond to magma mixing. (Authors' abstract)

PINEAU, F., SHILOBREEVA, S., KADIK, A. and JAVOY, M., 1998, Water solubility and D/H fractionation in the system basaltic andesite-H<sub>2</sub>O at 1250°C and between 0.5 and 3 kbars; Chem. Geol., v. 147, p. 173-184. First author at Laboratoire de Géochimie des Isotopes stables (ESA CNRS no. 7047), Université de Paris 7 Denis Diderot et Institut de Physique du Globe 4 Place Jussieu, 75 251 Paris Cedex 05, France.

Water solubilities in M of basaltic andesite composition have been measured in the range 500-3000 bars, 1200-1250°C. The saturation curve obeys an empirical relationship very close to the square root of P law of Hamilton et al. (Hamilton, D.L., Burnham, C.W., Osborn, E.F., 1964. The solubility of water and effects of oxygen fugacity and water content on crystallization in mafic magmas, J. Petrol., 5, 21-39). The best fit is obtained by a power law H<sub>2</sub>O wt.% =  $aP^n$  (P in b), where  $a=0.05\pm0.01$  and n=0.63; the departure from n=0.5 is mainly due to the increasing importance of dissolved molecular water at high P. Hydrogen isotopic fractionation between water V and total water dissolved in the melt ( $\Delta D_{n,m}$ ) has been measured at 0.5, 2 and 3 kb.  $\Delta D_{v-m}$  decreases with P from 32 to 20±2‰ This variation is related to the increase in molecular water proportions relative to hydroxyl group when water solubility increases. The variation of the D/H ratios in water dissolved in such M thus appears as a possible indirect measurement of the original OH/H2O ratio of total dissolved water, not subject to variation during quenching as the later is. This correlation shows that the  $\Delta D_{v-m}$  isotopic fractionation at very high water V P tend toward a limit of 16±3‰ for basic magmas. (Authors' abstract)

### PIRONON, Jacques, CANALS, Martin, DUBESSY, Jean, WAL-

GENWITZ, Frédéric and LAPLACE-BUILHE, Corinne, 1998a, Volumetric reconstruction of an oil inclusion using confocal scanning laser spectroscopy (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 49. First author at CNRS-CREGU, EP 578, BP 23, 54501 Vandœuvre-lès-Nancy, France.

Density or molar volume of the oil can be precisely determined by measuring the G vol% of the I at a given T.

Confocal Scanning Laser Microscopy (CSLM) has been applied to a reference I in fluorite from a MVT deposit using a MRC 1024 Bio-Rad equipment using Laser light (488 nm), focused on the sample which is immersed in oil. Depth resolutions near 0.5 µm can be achieved, lateral resolution about 0.2 µm. Rapid scanning of multiple sections in 2D computerized in order to measure the l volume.

Gas vol% determination by CSLM is an important step to use with oil I as reliable indicators of physical and chemical conditions of oil migration. Comparisons between Th an G vol.% data of the I and the thermodynamic properties of reference oils could give us the opportunity to determine [an apparent] composition of the oil in the I. Real Tt and P of the oil will be obtained using contemporaneous CH<sub>4</sub>-H<sub>2</sub>O-NaCl 1 by intersection of the two isochores (oil and aq solution). (From authors' abstract by E.R.)

PIRONON, Jacques, CANALS, Martin, DUBESSY, Jean, WAL-GENWITZ, Frédéric and LAPLACE-BUILHE, Corrine, 1998b, Volumetric reconstruction of individual oil inclusions by confocal scanning laser microscopy: Eur. J. Mineral., 1998, no. 10, p. 1143-1150. First author at CNRS-CREGU, UMR 7566, BP 23, F-54501 Vandœuvre-lès-Nancy Cedex, France: email (pironon@cregu.cnrs-nancy.fr)

The composition of oil trapped in Fl cannot be accurately determined with conventional techniques. Consequently, P and T<sub>1</sub> conditions in petroleum environments will only be established by a combination of volumetric and T<sub>6</sub> data. Therefore, analytical procedures and limitations of Confocal Scanning Laser Microscopy (CSLM) have been determined for the volumetric approximation of oil 1. The volumetric analysis of an oil 1 has been obtained using a confocal BIO-RAD inverted scanning laser microscope. Sixty-eight focus planes spaced at 1 µm have been acquired and computerised. Fluorescence image processing (thresholding) allows the oil volume to be estimated. Contouring of each focus plane and surface modelling by GOCAD software to produce a 3D model of the 1 revealed optical aberra-

tion at the level of the V bubble. Consequently, the V bubble may be approximated as a sphere and a G vol% can be calculated from different estimate procedures (voxel counting, surface modelling). The result has shown that the average n-alkane composition corresponding to the estimated G vol% of the I is close to the average n-alkane composition deduced by FT-IR analysis. This work has demonstrated the ability of CSLM to estimate the volume of the cavity of an oil I to an accuracy better than 95%. (Authors' abstract)

See also FIR 30, p. 156 (E.R.).

PITZER, K.S. and DAS, Bijan, 1998, Thermodynamic properties of Na<sub>2</sub>SO<sub>4</sub> (aq) above 200°C: Geochim. et Cosmo. Acta, v. 62, no. 5, p. 915-916.

PIVEC, Edvin, ULRYCH, Jaromir, SREIN, Vladimir, BENDL, Jiri, DOBES, Petr and ZAK, Karel, 1998, Epithermal Tertiary Pb-Zn-Cu (Ag, Te) mineralization in the Roztoky volcanic centre, Ceske Stredohori Mts., Czech Republic: Geologica Carpathica, v. 49, no. 2, p. 139-146.

The abandoned Roztoky silver-base metal deposit represents a scarce example of Tertiary sulphide vein-type mineralization spatially and genetically associated with intraplate volcanic rocks of the Cenozoic West and Central European Volcanic Province. The deposit is situated in the Tertiary Roztoky volcanic centre (RVC) of the Ceske Stredohori Mts., within the Ohre (Eger) Rift. The main ore vein parallels an older bostonite dyke intersecting the monzodiorite body, however, both are intersected by a younger trachyte dike. This suggests that the origin of the mineralization is related to the development of the RVC. The  $\delta^{13}$ C values of vein carbonates indicate the influence of deep-seated CO2 but the O isotopic composition of hydrothermal F (calculated 818Ofluid values from -3 to -7 per mil SMOW) shows the dominance of water with relatively shallow circulation. Sphalerite-galena sulphur isotopic geothermometry yielded T between 200 and 250°C and the presence of cubic hessite indicates T>155°C. The calculated 834S flud values vary in the range -1.0 to -2.0 per mil. The presence of banded "colloform" sphalerite and chalcedony suggests lower T. High lead isotope ratios of galena 206 Pb/204 Pb about 19.03, 207 Pb/204 Pb about 15.67, <sup>208</sup>Pb/<sup>204</sup>Pb about 39.17 can be a result of mobilization of lead either from Tertiary magmatic rocks, which show similar lead isotope ratios and were probably derived from a sublithospheric HIMU mantle source, or from upper-crustal rocks, e.g. local Upper Cretaceous sediments. The 87Sr/86Sr isotope ratios of the principal hydrothermal carbonates rhodochrosite (0,70524) and calcite-dolomite (0.70510) are higher than both the local primitive magma derivatives and even the developed rocks of the RVC and indicate an admixture of Sr derived from local crustal rocks. The volcanic rocks of the RVC were the dominant heat source during the formation of the ore deposit. The hydrothermal deposit was formed during relatively shallow hydrothermal circulation of low to medium sal, low 818 O F supported by CO2 of influx of deep-seated origin. (Authors' abstract)

PLETSCH-RIVERA, Laura, CAVOSIE, Aaron, SELVERSTONE, Jane and SHARP, Zachary, 1998, Testing of a fracture generation model: Fluid inclusion and geochemical constraints from quartz veins in the 1.4 Ga Sandia pluton contact aureole, central New Mexico (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A379-A380. Authors at Dept. of Earth and Planetary Sci., Univ. of New Mexico, Albuquerque, NM 87131.

A fracture generation model proposed by Dutrow & Norton (1995, J. Metamorphic Geol., v. 16, p. 13) predicts that the heating resulting from pluton intrusion into F-saturated, low permeability host rock will repeatedly increase pore F P and cause multiple fracturing events at individual localities. At conditions of 3 kbar and 800°C, the model predicts the greatest fracture density approximately 100 m from the pluton contact. We used quartz veins and FI planes as proxies for macro- and microscope fracture in a natural contact aureole in order to test the assumptions and predictions made by this model. The contact aureole of the 1.4 Ga Sanda Pluton records peak conditions around 3 kbar and 750°C. Field observations indicate that quartz veins are most abundant 400-1000 m from the pluton contact and are rare elsewhere. Microthermometric analysis of FI from quartz veins at 10, 400, and 600 m from the contact indicates two types of F: H2O-CaCl2 and CO2. Entrapment T at 3 kbar ranges from 200 to 550°C for the H2O-CaCl2 I, and from 350 to 650°C for the CO2 I: entrapment T decreases with distance from the pluton. XRF analyses indicate a 6 wt.% decrease in SiO2 and an increase in other elements in the host schist immediately adjacent to the veins. 818O of quartz are 13.3 per mil in the vein and 13.6 per mil in the host rock.

The spatial distribution of quartz veins. Si depletion in vein selvages.

host-rock buffered  $\delta^{18}$ O values, and large range of FI entrapment T all support the model prediction that sequential heating of the country rock induced multiple fracturing events via *in situ* increase in pore F P. However, the presence of CaCl<sub>2</sub>-rich brines in low-Ca host rocks suggests that some of the F were pluton-derived. We prefer a model in which initial heating increased the *in situ* pore F P, initiated fracturing, and produced quartz

veins and a new aureole plumbing system; subsequently, pluton-derived Ca-rich F migrated outwards through the aureole. F in the aureole were thus both internally and externally produced, and fracturing events likely resulted initially from buildup in *in situ* pore F P followed by an increase in the magmatic F P. (Authors' abstract)

PLOTINSKAYA, O.Yu, KOVALENKER, V.A., PROKÓFEV, V.Yu., and NÓSIK, L.P., 1998. The evolution and the nature of the fluid regime in the Kairagach epithermal gold-telluride deposit (Kuráminsk Mountains) (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 133-135 (in Russian).

See Translations.

POKRÓVSKY, A.V., 1998a, The hydrophysical zonation of the Earth's crust (abst.): Second APIFIS Int'l, Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 19-21 (in Russian).

POKRÓVSKY, A.V., 1998b, Sources of water in the Earth's crust and its role in the processes of metamorphism, magmatism, and ore formation (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 21-24 (in Russian).

See Translations

See figure in the Illustrations appendix.

POKROVSKI, G.S. and SCHOTT, Jacques, 1998, Thermodynamic properties of aqueous Ge(IV) hydroxide complexes from 25 to 350°C: Applications for the behavior of germanium and the Ge/Si ratio in hydrothermal fluids: Geochim. et Cosmo. Acta, v. 62, no. 9, p. 1631-1642.

POLETTI, Elena. and CESARE, Bernardo., 1998a. Alpine veins in the Zentralgneis complex of the SW Tauern Window: A fluid inclusions study: EURESCO Research Conf. on "Geochemistry of Crustal Fluids", Crete, 22-27/5/1998; also in Plinius, v. 20, p. 73-74.

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The granitic to tonalitic gneisses of the Zentralgneis Complex in the SW Tauern Window (Italian Eastern Alps) contain several types of discordant veins and segregations [including] quartz-biotite-plagioclase and biotite at the walls, and quartz in the centre. Quartz contains abundant FI, mostly occurring along S planes, however, a few isolated I of possible P origin can be observed. Both "primary" and S FI have comparable shape (irregular to negative crystal), phase contents and degree of filling (20-30% vol.), but differ in size: "Primary" FI are smaller (20-60  $\mu$ m) than S ones (50-100  $\mu$ m). Three-phase I are aq-carbonic mixtures with Lw+Lc+Vc; the 4- or S-phase FI are very similar, with the addition of one or two birefringent dxl.

FI have been characterized by microthermometry and Laser Raman spectroscopy, which have confirmed their similarity also with respect to composition and density. Three FI types have thus been distinguished: the most representative and important is type A, that includes all "primary" and most SI. In this type the carbonic phase is virtually pure CO<sub>2</sub> with a density close to critical values; the mole fraction of CO<sub>2</sub> is quite low (3-12%), and the sal, deduced from the final melting T of clathrate, is <7 mol% (i.e. <20 wt.% NaCl eq.). The final Th of these I is generally >300°C. Owing to the very small size, the nature of the dxl could not be determined; they are likely to be either carbonate or silicates. Isochores calculated for type A inclusions define possible trapping P of 5-8 kbar at the independently constrained T of 550-600°C. These values are in good agreement with the P-T conditions attained in this sector of the Tauern Window during the late stages of the Alpine evolution.

FI, field and petrologic data on the quartz-biotite-plagioclase veins have been integrated in a genetic model where veining is induced and controlled by devolatilization reactions in the host granitoids during the "Tauern Metamorphism" (From authors' abstract by E.R.) POLETTI, E. and CESARE, B., 1998b, Alpine veins in the Zentralgneis Complex of the SW Tauern window: A fluid inclusion study. 78th Nat'l. Congress of SIMP, Monopoli, 1-3 Oct., 1998, published in Plinius no. 20, p. 181-182. Authors at Dipartimento di Mineralogia e Petrologia, Università di Padova.

FI have been characterized by microthermometry and Laser Raman spectroscopy, which have confirmed their similarity also with respect to composition and density. Three FI types have thus been distinguished; the most representative and important is type A, that includes all "primary" and most S I. In this type the carbonic phase is virtually pure CO2 with a density close to critical values; the mole fraction of CO2 is quite low (3-12%), and the sal, deduced from the final melting T of clathrate, is <7 mol.% (i.e. <20 wt.% NaCl eq.). The final Th of these I is generally >300°C. Owing to the very small size, the nature of the dx could not be determined, they are likely to be either carbonate or silicates. Isochores calculated for type A 1 define possible Tp of 5-8 kbar at the independently constrained T of 550-600°C. These values are in good agreement with the P-T conditions attained in this sector of the Tauern Window during the late stages of the Alpine evolution. Fl, field and petrologic data on the quartz-biotiteplagioclase veins have been integrated in a genetic model where veining is induced and controlled by devolatilization reactions in the host granitoids during the "Tauern Metamorphism" (From authors' abstract by H.E.B.)

POLICKOVSKY, V.S., 1998, Thermobarogeochemistry in geology of Uzbekistan on the eve of XXI Century. Privately printed (?), 44 pp (first 22 pp in English, remainder in Russian).

A brief review of the development of thermobarogeochemistry from the early days of Brewster and Sorby to modern days, with particularly detailed coverage of Soviet scientists from Uzbekistan and elsewhere. Includes photos of the seven main Soviet names. Latter half a partial translation of first 22 pages into Russian. In other papers, the author's name is spelled Polykovsky. (E.R.)

POLIQUIN, M.J. and SIMMONS, S.F., 1998, Mineralogical and fluid inclusions studies of the R-1 zone, Emperor gold mine, Fiji (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-302. First author at Almaden Resources, Suite 2020-1055 West Hastings, Vancouver, B.C., Canada.

The R-I Zone was the focus of exploration up through 1996 and lies in the eastern part of the Emperor gold deposit, inside the Tavua Caldera structure. The zone comprises more than 15 steeply dipping, parallel veins hosted by tuffaceous sedimentary rocks and shoshonite lava flows of the Turtle Pool Formation. Veins appear to have developed parallel to lithologic contacts.

L-rich and V-rich FI are found in quartz and calcite indicating the existence of V-saturated F. Most of their Th (150 data) range 200-250°C, whereas ice melting T (70 data) range from 0.0 to  $-4^{\circ}$ C. The estimated sal of gold mineralizing solutions is about 5 NaCl eq. wt.%, whereas the sal of post-mineralizing solutions is <1.4 NaCl eq. wt.%. Crushing studies indicate I F contain up to about 3 wt.% CO<sub>2</sub>. Estimated formation P range from 60 to >100 bars, corresponding to hydrostatic depths of 0.6 to >1 km. At least 200 m of rock have been eroded from the top of the R-1 zone.

The lack of T increase with depth, despite evidence for boiling conditions over the 500 m plus vertical interval of this study is a puzzling feature of the ore-forming hydrothermal conditions of this deposit. (From authors' abstract by H.E.B.)

POLITO, P.A., KYSER, T.K., BONE, Yvonne and CLARKE, J.D.A., 1998, Methane: Its place in Archean lode gold mineralisation? (abst.): Geological Society of Australia, Abstracts No. 49, 14th Australian Geological Convention. Townsville, July 1998, p. 358. First author at Dept. of Geol and Geophys., Univ. of Adelaide, S.A. 5005.

The Junction gold mine is an Archean mesothermal lode-gold deposit It is hosted in a differentiated dolerite sill. Gold mineralisation formed post-peak metamorphism, and is confined to structures within the Junction Shear Zone (JSZ). Three vein generations are observed. Zoning of carbonate species in the alteration halo of the JSZ, together with the abundance of veining associated with mineralisation is indicative of large F flow through the JSZ.

Pre-gold mineralisation molybdenite-quartz±pyrrhotite veins are present throughout the JSZ. Laser-Raman microanalysis on Fl indicates that molybdenite bearing quartz veins host Fl that contain 25-81% CO<sub>2</sub> (ave. 52% CO<sub>2</sub>) and 19-75% CH<sub>4</sub> (ave. 48% CH<sub>4</sub>). These veins are deformed by shear veins, extension veins and breccias that are spatially associated with the JSZ, hydrothermal alteration and gold mineralisation. Syn-gold mineralisation shear vens are filled with massive quartz and minor albite-chlorite±dolomite/calcite. Extension veins are filled with quartz-albite-chlorite-pyrrhotite±calcite/dolomite. Fl microthermometry and laser-Raman microanalysis (Fl-LR) indicates that syn-mineralisation, pyrrhotite (±Au) bearing quartz veins host Fl containing 88-100% CO<sub>2</sub> (ave. 98% CO<sub>2</sub>), 0-12% CH<sub>4</sub> (ave. 2% CH<sub>4</sub>) and formed at approximately 350°C±50°C.

There are two generations of post-mineralisation. SE dipping, quartz veins. These quartz-calcite-biotite-pyrrhotite veins are observed cutting through all rock units and the JSZ. FI-LR shows that the quartz in the steeper dipping vein-set hosts FI containing 100% CO<sub>2</sub>. In contrast, the shallower-dipping vein-set quartz hosts FI containing 37-87% CO<sub>2</sub> (ave. 65% CO<sub>2</sub>) and 13-63% CH<sub>4</sub> (ave. 35% CH<sub>4</sub>).

Coupled Elemental Analysis and Mass Spectrometry (EA-MS) of synmineralised quartz veins indicates that up to 54% (ave. 30%) of the tota G species trapped in FI at the time of quartz±gold-sulphide mineralisation was CH<sub>4</sub>. This value is calculated using fractionation curves and eq. constraints applied to  $\Delta^{13}$ C values obtained from carbonic F liberated from FI and pore spaces of the host quartz veins. EA-MS on pre-mineralisation Mo-bearing quartz chips indicate that up to 85% of the total G species present at the time of gas-F entrapment was CH<sub>4</sub>. EA-MS on postmineralised Po-Cc-Bt bearing quartz veins indicate that CH<sub>4</sub> accounts for up to 33% of the total G species present at the time of G-F entrapment. (From authors' abstract by E.R.)

POLYA, D., BOYCE, A., STUART, F., FOXFORD, K. and FALLICK, A., 1998, Evolution and paragenetic context of low &D hydrothermal fluids from the Panasqueira W-Sn deposit, Portugal: New evidence from microthermometry, stable and noble gas isotopes and halogen composition of primary fluid inclusions (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). First author at Dept. of Earth Sci., Univ. of Manchester, Manchester, M13 9PL.

Remarkably deuterium-depleted ore forming F from the continental collision-related Panasqueira W-Sn-Cu(Ag) deposit in Portugal have been of contentious origin since their discovery by Kelly and Rye (1979), not least because of the lack of published detailed geochemical data on relevant, paragenetically well-constrained P Fl.

Growth zones from quartz crystal Pa66 span the main sulfide stage (MSS) of ore formation at Panasqueira and are defined by abundant two Fphase P Fl as well as by sulfide, muscovite and tournaline I. The growth zones record essentially constant Fl Th (254±6 to 260±5°C), small sal variations in (7.4±0.1 to 8.7±0.1 wt% NaCl eq.) and relatively constant F  $\delta^{18}O$  (3 8±0.3 to 4.4±0.4‰). In contrast,  $\delta D$  varies dramatically between – 60 and -134‰. The reproducibility of the low  $\delta D$  from specific growth zones suggests that they are not post-entrapment artifacts due to isotopic fractionation induced either by reactions with. or hydrogen diffusion through, the host quartz. The effects of small amounts of CH<sub>4</sub> and heterogeneously trapped hydrous minerals on measured  $\delta D$  are insignificant.

The halogen composition of the Fl define two distinct components. The low  $\delta D$  F are Br-rich (Cl/Br=220-240, l/Br=0.036-0.078) in comparison to the high  $\delta D$  F (Cl/Br 400, l/Br-0.08). The F are enriched in Br and I relative to Cl in seawater (Cl/Br 400, l/Br-0.005). This tends to rule out a significant component of magma-derived F, such as those from Hercynian Sn-W mineralisation in SW England, which are Br-depleted relative to seawater. Bromine enrichments in F are common to oilfield brines and residual brines (after evaporation). The large Br/Cl variation compared to the variation in I/Cl suggests that Br/Cl may be a potentially important tracer of the source of  $\delta D$  variation. The low  $\delta D$  F are represented by the lowest l/Br ratios which argues against interaction with organic material as a method of producing low  $\delta D$  F (if I bound to organic molecules is more readily partitioned into water than Br).

<sup>40</sup>Ar excesses in the 1 F increase systematically from the core ( ${}^{40}\text{Ar}/{}^{36}\text{Ar}$ =340) the edge of the crystal ( ${}^{40}\text{Ar}/{}^{36}\text{Ar}$ =531). This coincides with a similar increase in Cl/ ${}^{36}\text{Ar}$  that can be interpreted, most simply, as variable contamination of a  ${}^{40}\text{Ar}$ -. Cl-rich hydrothermal F by atmospheric Ar. However, both  ${}^{40}\text{Ar}/{}^{36}\text{Ar}$  and Cl/ ${}^{36}\text{Ar}$  display a strong correlation with  $\delta D$ ; the low  $\delta D$  being associated with near atmospheric  ${}^{40}\text{Ar}/{}^{36}\text{Ar}$  and low Cl/ ${}^{36}\text{Ar}$  ratios. This is the first evidence of a sympathetic co-variation of other F-hosted species with low  $\delta D$  in FI. Adsorbed atmosphere is unlikely to represent a significant H reservoir, thus we cannot rule out the possibility that the  ${}^{40}\text{Ar}$ -Cl- $\delta D$  co-variation is due to F mixing between a high 3D [sic:  $\delta D$ ?] hydrothermal F and a low  $\delta D$  isotopically exchanged meteoric water. Without detailed knowledge of the palaeogeography of Panasqueira during the time of ore formation, it is difficult to rule out the possibility that the low  $\delta D$  F are due to meteoric water recharging from nearby cold, moun-

tainous terrain, however the low palacolatitude of Panasqueira throughout the main stages of ore formation and the overwhelming predominance of meteoric F in the main, late and post-ore mineralising F with  $\delta D$  of -40 to 60‰ lends little support for this model. The involvement of highly fractionated deuterium-depleted magmatic waters, (Sheppard, 1994) can be ruled out as low Br/Cl ratios and Fl evidence for boiling during the MSS were not observed and the range of <sup>40</sup>Ar\*/Cl ratios (9-19 x 10<sup>-3</sup>) is limited.

Our data rule out a magmatic F involvement during the MSS. Instead, we favour the involvement of waters that were ultimately meteoric in origin. As yet, we cannot definitively explain the characteristics of the low  $\delta D$  F, and any model that does must satisfactorally account for (i) the relative constancy of T, sal and F  $\delta^{18}O$  during excursions to low  $\delta D$ . (ii) the relative constancy of sal coincident with variation in the F  $CU^{36}Ar$  ratio, (iii) the high I/Cl and Br/Cl ratios, (iv) the coincidence of low  $\delta D$  F with the onset of precipitation of phosphates and polymetallic sulfides under reducing conditions, and (v) that unevolved meteoric water in the region around the time of MSS deposition was between -40 and -60‰. On a positive note, this work has identified a number of F tracers that vary with  $\delta D$  and, when combined with stable isotopes, may prove useful for constraining the source and interaction history of exotic F. (Authors' abstract)

#### POTTER, Joanna, RANKIN, A.H., TRELOAR, P.J., NIVIN, V.A.,

TING, Wupao and NI, Pei, 1998, A preliminary study of methane 1 in alkaline igneous rocks of the Kola igneous province, Russia: Implications for the origin of methane in igneous rocks: Eur. J. Mineral., 1998, no. 10, p. 1167-1180. First author at School of Geological Sci., Kingston Univ., Penrhyn Road, Kingston-Upon-Tyames, Surrey, KT1 2EE, U.K.; email (j.potter@kingston.ac.uk)

FI from the Kovdor, Khibina and Lovozero complexes of the Kola alkaline igneous province have been investigated using microthermometric techniques and P-V-T-X modelling CH41, found in all three complexes, are always S in origin and frequently occur in curvilinear arrays associated with S H2O-dominant I and, in Khibina, CH4-H2O I. The S nature of the CH4-bearing I appears to preclude a direct magmatic origin for the methane, which is supported by preliminary C-isotope data which indicate an abiogenic origin. Isochore projections for P CO2- and H2O-dominant I intersect the volatile-saturated, agpaitic, nepheline syenite solidus (at 700°C), at P between 3.5 and 5.5 kbar, compatible with magmatic exsolution of these F at crustal depths of between 11-18 km. By contrast, F phase equilibria and the shallow slopes of isochores derived rom the P-V-T-X modelling of CH4-dominant and related I are indicative of of trapping conditions at P of 0.5 to 1.8 kbar. The close association of CH<sub>4</sub> I with magnetite and late-stage hydrated phases suggests evolution of CH4 during hydration within a reducing environment. This evolution involved subsolidus Fischer-Tropsch reactions of the type CO<sub>2</sub>+4H<sub>2</sub>→CH<sub>4</sub>+2H<sub>2</sub>O, with the water-produced driving hydration reactions which generated magnetite and more H2. Methane production is thus a function of V-mineral reactions in the C-H-O system operative during late-stage hydrothermal processes and, in particular, is due to two self-reinforcing reaction types linked through a positive feedback mechanism. (Authors' abstract)

See also FIR 30, p. 157 (E.R.).

POTTORF, R.J. and VITYK, M.O., 1998, Applications of fluid inclusions technology to hydrocarbon systems (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 51. Authors at Exxon Production Research Company, Houston, Texas 77252.

This technology has proven effective for the identification of migration pathways, seal quality, and proximity to reservoired hydrocarbons.

Estimates of paleotemperature, paleopressure, and hydrocarbon F properties are required. Aq FI in sedimentary basins accurately record maximum burial T, and place valuable constraints on thermal history. In blind tests for both simple and uplifted basins, the FI paleotemperature is usually within 10°C of the actual maximum T. In rare cases where both aq and hydrocarbon 1 are trapped at the same t ime, paleopressure along with paleotemperature can be determined. Examples of P estimated from FI are within 15% of measured data when compared to standard bottom-hole P measurements. Either cryomicroscopy or the fluorescence characteristics of individual oil I are used to estimate the oil density or API gravity. This information allows the properties of included oils to be compared with those presently in the trap. The timing of hydrocarbon migration is estimated by combining information on FI Th. burial history, and the PVT properties of trapped hydrocarbons. The greatest uncertainty in these estimates is the PVT properties of the hydrocarbon I and is an area for continued research. Biomarker analysis of entrapped hydrocarbons using

GC/MS/MS (gas chromatography/mass spectrometry/mass spectrometry) techniques allows interpretations of thermal maturity and source-oil correlations on extremely small samples. Case studies illustrate concepts, current applications, limitations, and future uses of FI technology. (From authors' abstract by E.R.)

POUTLAINEN, M. and SCHERBAKOVA, T.F., 1998. Fluid and melt inclusion evidence for the origin of idiomorphic quartz crystals in topazbearing granite from the Salmi Batholith, Karelia, Russia: Lithos, v. 44, no. 3-4, p. 141-151.

Idiomorphic quartz crystals in topaz-bearing granite from the Salmi batholith contain Pl of silicate M and abundant mostly S aq Fl. Microthermometric measurements on Ml give estimates for the granite solidus and liquidus of 640-680°C and 770-830°C, respectively. Using published solubility models for H<sub>2</sub>O in granitic M and the obtained solidus/liquidus T from MI, the initial water concentration on the magma is deduced to have been approximately 3 wt.% and the minimum P about 2 kbar. At this initial stage, volatile-undersaturation conditions of magma were assumed. These results indicate that the idiomorphic quartz crystals are magmatic in origin and thus real phenocrysts. During subsolidus cooling and fracturing of the granite, several generations of aq Fl were trapped into the quartz phenocrysts. The H<sub>2</sub>O I have sal and densities of 1-41 wt.% NaCl eq and 0.53-1.18 g/cm<sup>3</sup>, respectively. (Authors' abstract)

PRICHARD, H.M. and MALIOTIS, G., 1997, Gold mineralization associated with low-temperature, off-axis, fluid activity in the Troodos ophiolite Au, Cyprus: J. of the Geological Society, London, v. 155, p. 223-231.

Silicification of umbers in the Troodos ophiolite complex in Cyprus provides evidence for low-T hydrothermal activity occurring late in the process of ocean-crust formation, after the crust had moved away from the oceanic spreading centre. Umbers, which are Mn-Fe-rich sediments, precipitate some distance away from oceanic spreading axes. The movement of the F partially silicifying the umbers must post-date umber formation and therefore also occurs off axis. These F may form part of low-T hydrothermal circulation similar to those identified by off-axis heat anomalies in the modern oceans. In Cyprus, the silicified umbers often are located away from volcanogenic massive sulphide (VMS) deposits and are aligned along sea-floor faults. They are characterized by quartz veins as well as pervasive silicification. Recent analyses have revealed unexpectedly anomalous, 1-5 ppm, concentrations of Au in these silicified umbers. Gold mineralization is known to occur in ophiolite complexes as part of the metal concentrations in VMS deposits. These deposits are thought to be formed by ancient hydrothermal circulation similar to that associated with black smokers observed at modern mid-ocean ridges. The research presented in this paper provides evidence for a second phase of Au mineralization in Cyprus caused by low T silicifying F resulting from oceanic hydrothermal activity which occurred away from the spreading centre. The mineralizing F which silicified the umbers may have been more widespread, impregnating other lithologies, and may have overprinted the first phase of Au mineralization in some VMS deposits after they had become inactive and had been movd away from the spreading centre. The mineralizing F passing through these VMS may have used the same structural pathways as the original base-metal-rich hydrothermal solutions which formed the VMS. (Authors' abstract)

PROHL, Hansjörg and SIEMANN, M.G., 1998. The composition of gases in fluid inclusions of Late Permian (Zechstein) evaporites in northerm Germany (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 52. First author at Fachgebiet Mineralogie, Geochemie, Salzlagerstätten; email (prohl@immr.tu-clausthal.de; siemann@immr.tu-clausthal.de)

More than 300 G bearing I in P and S salts were analyzed by Laser Raman Spectroscopy. The obtained data base was used to classify three major groups: 1. N<sub>2</sub>-CH<sub>4</sub>-C<sub>2</sub>H<sub>6</sub>-H<sub>2</sub>-H<sub>2</sub>S, 2. N<sub>2</sub>-O<sub>2</sub>, and 3. N<sub>2</sub>-O<sub>2</sub>-CH<sub>4</sub>.

Whereas the group one and two represent a reducing milieu and an oxidising milieu, respectively, the origin of the G in group three is not settled yet.

The discovery of H<sub>2</sub> in evaporites is of special interest. Hydrogen in Fl may serve as a natural analogue for hydrogen produced by corrosion due to the possible reaction of brines with the material of the high level waste container in the post-closure phase of a final repository. In contrast to migration experiments on drill cores these investigations on hydrogen bearing Fl in undisturbed samples enable studies of hydrogen behavior under natural conditions. Two possibilities for the production of H<sub>2</sub> are considered: (i) Development within organic matter due to cracking processes and (ii) radi-

olysis of hydrogen bearing molecules like H2O and CH4.

The data do not permit conclusions as to whether the gases (i) were incorporated into evaporite minerals throughout the whole time of evaporation, (ii) represent mobilized components of deeper buried layers (iii) are a mixture of (i) and (ii). (From authors' abstract by E.R.)

PROKOF'EV, V.Yu., 1998, Types of hydrothermal ore-forming systems (from fluid inclusions studies): Geology of Ore Deposits, v. 40, no. 6.

PROKOF'EV, V.Yu., ZAGORSKII, V.E., KUZNETSOVA, G. and BE-LOZEROVA. O.Yu., 1998, A new type of exsolution melt inclusion in topaz from the rare-metal topaz—mica rocks of the Erykin deposit: Doklady Akademii Nauk, v. 359, no. 1, p. 94-97 (in Russian, translated in Doklady Earth Sci., v. 359, no. 2, p. 284-287.) Authors at Joint Inst. of Geol., Geophys., and Mineral., Siberian Div., Russian Acad. of Sci., Universitetskii Precambrian Research, v. 91, p.3, Novosibirsk, 630090 Russia.

Odd MI in topaz that look like glass I with either one or several globules of an aq F phase. During heating, several odd phase changes occur until Th at 600-870°C. The composition by microprobe appears to be topaz plus water. There is considerable ambiguity in the interpretations of the significance. (E.R.)

PROKOFYEV, V.Yu., DISTLER, V.V., SPIRIDONOV, A.M., GRE-BENSCHIKOVA, V.L., YUDOVSKAYA, M.A., MATEL, N.L., MI-TROFANOV, G.L. and NEMEROV, V.K., 1998, Fluid regime and conditions of origin of the Sukhoi Log (Russia) gold-platinum deposit (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 52. First author at Vinogradov Inst. of Geochem., SB RAS, Favorsky str.1a., 664033. irkutsk, Russia

The Sukhoi Log gold (Pt) deposit is the largest one in Russia. The ore bodies are of stratiform character, in black shales, and are associated with quartz-sericitic and carbonate metasomatites, quartz pockets and veinlets, magnesium and magnesium-iron carbonatites, and pyrite impregnation.

Thermal and cryometric investigations of individual FI in quartz show that impregnated sulfide mineralization formed at 385-205°C and 2375-235 bars from magnesium-sodium chloride solutions with a salt concentration up to 8.5-5.8 wt% eq. NaCl. The syngenetic G F is nitrogen of high density (0.53-0.12 g/cm<sup>3</sup>). The ratio of total P to the P of water ( $P_{total}/P_{H2O}$ ) is 57.8-7.8. The cross-cutting veinlets with sulfides and calcite formed at 350-275°C and 2280-185 bars from a magnesium-sodium chloride solution with a salt concentration of 10.7-7.6 wt% eq. NaCl, with 7.6-1.8 mol/kg of solution CO<sub>2</sub> of 1.1-0.4 mol/kg of solution CH<sub>4</sub>. Post-ore veinlets formed at 3351-65°C from a magnesium-sodium chloride solution with a salt concentration of 9.5-5.7 wt% eq. NaCl.

The features of ore mineralization are associated with a complicated interaction of metal-bearing hydrothermal solutions with organic substances in the black shale sequences. Further decomposition of the organic substance resulted in the carbonic acid-methane component of the G phase. The changing redox conditions, pH and Eh led to the decomposition of complexes of dissolved noble metals, and their deposition together with sulfides, which resulted in the formation of the Sukhoi Log deposit. (From authors' abstract by E R.)

PROKOFYEV, V.Yu., PEREPELOV, A.B. and BELOZEROVA, O.Yu., 1998, The origin of the shoshonite-latute rock series of Uksichan Volcano (Kamchatka, Russia), from data on melt inclusions(abst.): Program and Abstracts, PACROFI VII, Pan-American Conf on Research on Fluid Inclusions, June 1-4, Univ of Nevada, p. 54 Authors at Vinogradov Inst. of Geochem., RAS, Irkutsk, Russia; email (vpr@igc irkutsk.su)

The origin of the shoshonite-latite series in island-arc systems has been so far open to discussion. The mineralogy and geochemistry of rocks of Uksichan volcano and compositions of their MI, show that the high-K and subalkalic shoshonite-latite series of the volcanic center is derived from high-K aluminous basaltic magmas and its basement rocks from low-K and high-Mg basaltic melts. MI in plagioclases of high-K basalts of the initial, stratovolcanic stage are compositionally proximal to shield volcano shoshonites and latites, but are higher in phosphorus and titanium which accumulate in shoshonitic and latitic magmas until they are involved in later apatite and titanomagnetite crystallization. In other words, glass composition is proximal to that of the residual remaining after fractional crystallization of plagioclase, which attests to the origin of Uksichan rocks from aluminous high-K basaltic melts.

Therefore, the Uksichan shoshonite-latitic rocks derived not from shoshonite basaltic magmas but rather from high-K ones, that are more broadly distributed throughout the island-arc system. The rocks of the volcano were produced by fractional crystallization under gradually decreasing crystallization T and growing F concentration in the latest differentiates. (From authors' abstract by E.R.)

PROL-LEDESMA, R.M., 1998, Pre- and post-exploitation variations in hydrothermal activity in Los Humeros geothermal field, Mexico: J. of Volcanol. and Geothermal Research, v 83, p. 313-333. Author at Instituto de Geofisica, UNAM, Cd. Universitaria, Coyoacán, 04510, Mexico.

Los Humeros geothermal field is a remarkable example of the lack of water-rock equilibrium. Significant variations of hydrothermal activity have occurred before and after exploitation started. Presently, discharged water is not in equilibrium with the alteration suite observed in the reservdir rocks. Hydrothermal minerals identified in core and cuttings define the occurrence of several stages of hydrothermal activity. Cooling at depth is inferred from FI and alteration mineralogy data from the wells located nearby Los Humeros fault. Most wells produce a two-phase F with excess enthalpy, this accounts for the high CO2 content observed in the discharged F. Sulfur and carbon isotopic data indicate that volatile species in the geothermal F have magmatic as well as sedimentary components, while strontium isotopic composition shows that calcium is provided by the andesitic rocks that form the reservoir. As exploitation of the field started, concentration of HCI increased in the discharged F. This shows that recharge of the reservoir is not enough to balance the output for production, and drying out of the field may be taking palce at depth. The lack of chemical equilibrium and the presence of G of magmatic origin suggest that Los Humeros is a relatively young geothermal field related to a recent magmatic intrusion. (Author's abstract)

PROL-LEDESMA, R.M., JUÁREZ-SÁNCHEZ, F., LOZANO, R., Sta. CRUZ, R., ALCALÁ-MONTIEL, E., CRUZ-CASAS, V.A., HERNÁNDEZ-LOMBARDINI, S., CANALS, A. and CARDEL-LACH, E., 1998, Precious and base metal deposition in an active hydrothermal system, La Primavera, Mexico: <u>in</u> Water-Rock Interaction, G.B. Archart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p 649-652. First author at Institut de Geofisica, UNAM Cd. Universitaria, Mexico D.F., Mexico.

High gold concentrations were observed in water and rock: 59 and 263 ppb respectively. Anomalies of Zn and Ba were frequently observed within the geothermal reservoir samples. (From authors' abstract by E.R.)

QI-HAO, Fan, 1998, A notion regarding the same direction prediction in the mineralization of hydrothermal deposits and the migration direction of ore fluids in Australia: Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 25-27 (in English). Author at The Geological Society of Australia and the Australasian Inst. of Mining and Metallurgy, email (qi\_hao\_f@hotmail.com)

The author uses data on Td from various hydrothermal deposits, plus major structural data, to provide prospecting guides, and claims that some blind ore bodies have been discovered in this manner. (E.R.)

QING, Hairuo, 1998, Geochemical constraints on the origin and timing of palaeofluid flow in the Presqu'ile barrier reef. Western Canada sedimentary basin: in Parnell, J (ed.) 1998, Dating and Duration of Fluid Flow and Fluid-Rock Interaction, Geological Society, London, Special Publications, v.144, p. 173-187. Author at Dept. of Geol., Royal Holloway Univ. of London, Egham Surrey, TW20 0EX, UK.

From northeastern British Columbia to Pine Point, over a lateral distance of 400 km, saddle dolomites display remarkable trends of decreasing  $^{87}$ Sr/ $^{86}$ Sr ratios (0.7106-0.7081) and Th of FI (178-92°C) with a corresponding increase in  $\delta^{18}$ O values (-16 to -7‰ PDB). These regional trends suggest that hot, radiogenic basinal F moved eastward up-dip along the Presqu'ile barrier reef.

The  $\delta D$  values of aq FI from Pine Point dolomite are very low (-80 to - 100‰ SMOW) compared with that of Devonian seawater (-10‰ SMOW) suggesting an input of some Columbia-Laramide meteoric waters. If the low  $\delta D$  values are caused by a mixture of F from Pl containing Devonian seawater with Sl that formed later during the Columbia-Laramide Orogenies, the F migration and associated dolomitization and mineralization could be interpreted as late-Devonian events. However, if the mesured F were mostly from the Pl, the low  $\delta D$  values indicate an entrapment of some Columbia-Laramide meteoric waters with Devonian formation waters at the time of dolomitization. This would suggest a Jurassic to early Tertiary age for dolomitization, which is supported by similar low  $\delta D$  values of

present-day Devonian formation waters that consist of mixture of Laramide meteoric waters and original connate brines. The light  $\delta D$  values of Pine Point dolomite I could also occur as a result of reaction of F with organic mater associated with generation of oil and G, which occurred at the maximum burial during the Laramide Orogeny. (From author's abstract by E.R.)

QIU, H.N., SUN, D.Z., ZHU, B.Q. and CHANG, X.Y., 1998. <sup>40</sup>Ar/<sup>39</sup>Ar dating by crushing technique on a quartz sample from the Dongchuan copper deposits in Yunnan, SW China (abst.): The Ninth Int'l Conference on Geochronology, Cosmochronology and Isotope Geology, Abstracts, published in Chinese Sci. Bulletin, v. 43, Supp., p. 106. Authors at Guangzhou Inst. of Geochem., Chinese Acad. of Sci., P.O. Box 1131, Guangzhou 510640, China; email (hnqiu@ms.gzb.ac.cn)

The ore-forming ages of deposits are the basic evidences to study the ore formation regularities in a region. In recent twenty years, geochronologists made many attempts to date the FI by Rb-Sr or <sup>40</sup>Ar/<sup>39</sup>Ar methods and showed a new highlight way to access the ore-forming ages.

In this paper we make further attempt to determine the Dongchuan copper deposits using  ${}^{40}Ar/{}^{39}Ar$  technique on quartz samples by crushing in vacuo. The quartz sample DC-51-1Q was selected from an ore hand-specimen from the Luoxue Formation of the Kunyang Group in Tangdan, Dongchuan, Yunnan Province, SW China. The analysis data form a falling-down age spectrum from as old as 1949 MA at the first stage to as young as ~710 Ma at the last three stages. It yields a plateau with age of 788±63 Ma (39Ar occupying ~86%) from stage 13 to stage 24. The data yield an isochron line on the  ${}^{40}Ar/{}^{36}Ar - {}^{39}Ar/{}^{36}Ar$  diagram corresponding to an isochron age of 712±33 Ma with initial  ${}^{40}Ar/{}^{36}Ar$  ratio of 935±62 (Fig 2) [Fig. 1?]. In consideration of the scatter, the isochron age may range from 640 Ma to 780 Ma (as shown by the two dotted lines in Fig. 1). The isochron age is concordant with its plateau age. They indicate that the mineralization took place just at the end of the Jinning orogeny or the beginning of the Chengjiang orogeny.

The falling-down age spectrum and the high initial <sup>40</sup>Ar/<sup>36</sup>Ar ratio suggest that the FI contain high concentration of excess <sup>40</sup>Ar within the FI especially within the larger ones. (Authors' abstract)

See figure in the Illustrations appendix.

QU, Xiaoming, WANG, Henian and RAO, Bing, 1998, Laboratory study of KD of gold between ore-forming fluid and granitic melt: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 997-1002 (in Chinese).

RAFAILOVICH, M.S., 1998. Geological-genetic models of the major gold deposits of Kazakhstan (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998. Tashkent, Uzbekistan, Abstracts volume, p. 98-100 (in Russian).

RÁFIKOV, Ya.M. and YUSÚPOV, R.G., 1998, The fluid composition, classification, and conditions of formation of accessory minerals (Middle Tien-Shan) (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 55-58 (in Russian).

See Translations.

RAGAN, V.M., COVENEY, Jr., R.M. and BRANNON, J.C., 1996. Migration paths for fluids and northern limits of the Tri-State district from fluid inclusions and radiogenic isotopes: Society of Economic Geologists, Special Pub. No. 4, p. 419-431. First author at Dept. of Geosci., Univ. of Missouri, Kansas City, MO 64110-2499, USA.

Ore deposits are hosted chiefly by silicified Mississippian carbonate beds but even 200 km northward from major mines overlying Pennsylvanian beds contain sphalerite-hosted aq Fl with T<sub>h</sub> ranging from -60 to 130°C and equivalent sal between 22-26 wt.% NaCl eq --similar to those contained by the ores. High T<sub>h</sub> values correlate with proximity to major crosscutting structures and permeable stratigraphic horizons and together with variations in ratios of lead and strontium isotopes may help to locate pathways for hydrothermal F in the region. (From authors' abstract by E.R.)

RAGNARSDOTTIR, K.V. and OELKERS, E.H., 1998, Geochemistry of crustal fluids: A Tyrolean perspective: Chem. Geol., v. 151, p. 1-9. First author at Dept. of Earth Sci., Univ. of Bristol, Bristol, BS8 1RJ, UK; email (vala.ragnarsdottir@bris.ac.uk) An introduction to a series of papers stemming from a 1996 conference (E.R.).

RAGNARSDOTTIR, K.V., OELKERS, E.H., SHERMAN, D.M. and COLLINS, C.R., 1998, Aqueous speciation of yttrium at temperatures from 25 to 340°C at P<sub>int</sub>: An in situ EXAFS study: Chem. Geol., v. 151, p. 29-39.

RAMAMBAZAFY, Andrianasolo, MOINE, Bernard, RAKOTON-DRAZAFY, Michel and CUNEY, Michel, 1998. Significance of carbonic fluids in the granulites and skarns of southeast Madagascar: Sciences de la terre et des planétes (Earth and Planet. Sci.). v. 327, p. 743-748 (in French, Engl. abst. and abridged version). First author at Laboratoire de minéralogie, UMR 5563, CNRS/université Paul Sabatier, 39 allées Jules Guesde, 31000 Toulouse, France.

In the granulites of southeast Madagascar, extensive skarns are the signature of intense F circulation coeval with regional metamorphism. Fl in different minerals from gneisses and skarns are  $CO_2$ -rich ( $X_{CO_2} \ge 0.8$ ) Corresponding isochores are in good agreement with mineral thermobarometry. Such F, with high  $P_{CO_2}$  and  $P_{O_2}$  and  $low P_{H2O}$  are in equilibrium with the observed mineral assemblages. Contrary to some assumptions that granulite facies were produced through F'absent metamorphism, these results demonstrate equilibrium between granulite mineral paragenesis and a  $CO_2$ -rich F phase. (Authors' abstract)

RAMSAY, W.R.H., BIERLEIN, F.P., ARNE, D.C. and VANDEN-BERG, A.H.M., 1998, Turbidite-hosted gold deposits of Central Victoria, Australia: Their regional setting, mineralising styles, and some genetic constraints: Ore Geol. Reviews, v. 13, p. 131-151. First author at Minerals Industry Research Inst., Univ. of Ballarat, P.O. Box 663, Victoria 3353, Australia.

Within the Ballarat metallogenic province, mesothermal mineralisation is hosted by dilational-site's style, in Ordovician sediments which were subjected to upper prehnite-pumpellyite facies conditions to the west and zeolite facies conditions to the east adjacent to the Melbourne metallogenic province. Ore F were of the low sal C-O-H type with 1-10 wt.% NaCl eq. CO2 and CH4 contents of FI tend to be low with variable CO2/CH4 ratios. Depth of deposition (based on evidence from Wattle Gully mine) was in order of 7 km and isotopic data suggest that ore F were derived either from an evolved igneous or from a devolatilised metamorphic source. Toward the eastern margin of the Ballarat metallogenic province and within the adjoining Siluro-Devonian Melbourne metallogenic province, epithermal style Au mineralisation is commonly emplaced in structurally and stratigraphically higher rocks. Tt are lower than in deposits to the west and ore F are of low sal C-O-H-N type with N2>15 vol%. Gangue pyrite has elevated Sb contents and ore F were dominated by evolved meteoric water δ13C values from vein carbonates suggest their derivation from oxidised organic carbon from within the Siluro-Devonian marine sediments.

Alteration styles in gold deposits across central Victoria include sericitisation, carbonatisation, sulphidation, chloritisation, and (de-) silicification. Owing to the P mineral assemblages and the physico-chemical characteristics of the ore-bearing F, visible evidence for wall rock alteration is commonly limited to 5-10 m wide zones of discolouration containing disseminated arsenopyrite and pyrite porphyroblasts and carbonate spotting. However, current petrographical and geochemical studies have demonstrated that the effects of pervasive wall rock alteration are more pronounced and extensive than previously recognised. (From authors' abstract by E.R.)

RAMSAY, W.R.H. and GROVER, M., 1998, Central Victorian gold deposits and the crustal continuum concept (abst.): Geological Society of Australia. Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 368. First author at Earth Sci., School of Ecology and Environment.

In contrast to most other hydrothermal mineral deposits, mesothermal gold deposits are characterised by a wide depositional depth range from near surface to subcrustal depths of 20 km, well below the 400°C britleductile thermal transition zone. To account for such a range in depositional depths in the crust various workers have invoked the crustal continuum concept. Evidence is emerging from younger terranes that mesothermal deposits may likewise exhibit gold emplacement over a considerable vertical extent in the crust.

Within the Ballarat province host rocks were broadly subjected to upper prehnite-pumpellyite facies conditions and mineralisation sites were dominated by brittle-ductile features including crack seal, spurs, breccias,

and fault-dominated locations. Ore F were of low sal of the C-O-H type, with Tt in the west of 300±50°C and in the east 250±50°C.

In the eastern portions of the Ballarat province, where the Ordovician sediments are characterised by diagenic zeolite facies, and in the Melbourne province the Au-Sb-As deposits were deposited from C-O-H-N fluid system with N<sub>2</sub>>15% and Th and sal for aq and CO<sub>2</sub>-bearing Fl in Sbbearing veins range from 145-215°C and 2.9-5.9 wt% NaCl eq. and, 180-260°C and 1.9-5.5 wt% NaCl eq. respectively. (From authors' abstract by E.R.)

RANDELL, R.N., HÉROUX, Y., CHAGNON, A. and ANDERSON, G.M., 1996, Organic matter and clay minerals at the Polaris Zn-Pb deposit, Canadian Arctic Archipelago: Society of Economic Geologists, Special Pub. no. 4, 1996, p. 320-329. First author at 126 Gough Avenue, Toronto, Ontario, Canada M4K 3N8.

Reflectances of 1.3%  $R_o$  in rocks exceed values expected from maximum estimated burial T of 60°C, and are consistent with observed oil generation and FI T of 105°C measured on ore sphalerite and gangue dolomite.

Illitization of pre-existing sedimentary diagenetic clays above the ore may be related to the influx of potassium in the highly saline evaporative brines identified in Fl in Polaris ore sphalerites.

It is proposed that methane co-generated with hydrogen during hydrothermally-induced maturation of organic matter reduced brine sulfates to H<sub>2</sub>S, allowing precipitation of metal sulfide ores. Reactions inferred from observed clay mineral distributions can be accomplished at the T prevalent during ore precipitation. Brines were probably driven by the late Devonian Ellesmerian orogeny, but ore precipitation occurred while the host rocks were horizontal.

Clay mineral analyses and organic matter alteration studies are both potentially useful exploration tools when integrated with available geological data. (From authors' abstract by H.E.B.)

RANKIN, A.H., BÜHN, B., HALLER, M. and RADTKE, M., 1998, Quantitative analysis of Sr-REE-Ba-daughter minerals in fluid inclusions by combined synchrotron micro-XRF and SEM-EDX techniques (abst.). 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A130. First author at Kingston Univ., UK; email (a.rankin@kingston.ac.uk)

This study focuses on the identification and comprehensive geochemical characterization of Sr, REE, Ba-daughter minerals in natural FI in quartz related to carbonatite metasomatism. Namibia. Burbankite (Na,Ca)3(Sr,REE,Ba)3(CO<sub>3</sub>)5 is a rare mineral mostly confined to highly alkaline igneous rocks. The broad spectrum of elements (from Na over LIL elements to the heavy REE) present in the burbankites can be analysed by combining Synchrotron-XRF microprobe and SEM/EDX techniques

Quantitative and semi-quantitative SEM/EDX analyses yield SrO between 5 and 26 wt%, ∑LREE between 8 and 17 wt% and BaO between 2 and 5 5 wt% for burbankite dxl. For Synchrotron-XRF analysis longtime measurements were taken on the spots with the highest count rates for Sr, REE and Ba The quantification via fundamental parameter analysis uses Ba as an internal standard, since it displays a narrow compositional range as indicated by EDX analyses, and because it is a close neighbour to the REE group of elements with respect to atomic weight. The very similar results for the REE quantification by Synchrotron-XRF and EDX analyses. respectively, indicate that the quantification procedures for both techniques yield reliable results The Synchrotron-XRF-derived chondrite-normalized REE patterns display a negative slope of 2-3 orders of magnitude from La to Yb, reflecting a LREE enrichment typical of solid rock carbonatites. The Th/U ratios of burbankites are between 4 and 6 and Y/Ho ratios are very low (<5). The mere presence of REE-carbonates as large dm in these F shows the capability of such H2O-CO2-F-CI fluids in dissolving and transporting high field strength elements in large quantities. (Authors' abstract)

RANKIN, A.H., CHRISTOULA, M. and HALLS, C., 1998. Fluid inclusion evidence for the involvement of basinal brines and granitic fluids in the development of composite Cornish Sn-lodes. SW England (abst.) Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 55. First author at School of Geological Sci., Kingston Univ., Kingston Upon Thames KT1 2EE, UK

The South Crofty tin mine was the last remaining metal producer in the classic mining district of SW England until its closure in late 1997 Recent studies by Farmer et al. (1991, Mineral. Mag., 55:447-458) have identified two main paragenetic stages associated with cassiterite mineralization in the mine; a tourmaline stage and a later chlorite stage in which fluonte is a common gangue mineral.

In this paper we report on the microthermometric and geochemical analysis of Fl in fluorite from the chlorite stage of mineralisation. We distinguish two separate F regimes with similar sal but quite different origins, a high temperature (HT) and a low temperature (LT) F with variable sal. ICP-AES analysis of leachates shows that the HT F are characterized by Na/K atomic ratios of between 3.1 and 9.4 and Na/Li atomic ratios of between 10.6 and 18. These values are significantly lower than the corresponding ratios for LT F (Na/K 11.6 to 12.3; Na/Li 52.5 to 77). A similar trend is noted in the Ca/Na ratios inferred from microthermometric measurements. However, the Cl/Br ratios (determined by INAA methods) for the HT F (860 to 1333) are much higher than for the LT F (303 to 586).

The Cl/Br ratios for the HT F are closely comparable with the "magmatic" ratio of between 1124 and 1234 reported by Bohlke and Irwin (1992, GCActa, 56:203-225) for F responsible for quartz-tourmaline-topaz (greisen) assemblages in SW England. The alkali ratios are also characteristic of high-T granite-associated F from the region. By contrast, the alkali and halogen ratios and microthermometric characteristics of the LT F are very similar to those for the MVT fluorite deposits elsewhere in the UK where basinal brines are known to have been involved (Christoula, 1992, PhD Thesis, University of London, 262 pp.).

The present result confirms the involvement of basinal brines and "magmatic" F in the development of Sn-lodes in SW England, both of which have been modified by F-rock interactions and mixing with meteoric F. The study also shows the importance of careful paragenetic control when reporting on the geochemical characteristics of composite vein samples, especially from bulk FI analysis. (From authors' abstract by E.R.)

RANSOM, B., KASTNER, M. and SPIVACK, A.J., 1998, Chlorine/fluid cycling in subduction zones: Evidence from chloride concentrations and chlorine stable isotopes (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1233.

RAO, D.R., SHARMA, Rajesh and GURURAJAN, N.S., 1998. Geothermobarometry and fluid inclusion studies of leucogneisses from Schirmacher region, east Antarctica: J. Geological Society of India. v. 51, p. 595-607. Authors at Wadia Inst. of Himalayan Geol., 33, General Mahadeo Singh Road. Dehradun - 248 001. India

Fl in the leucocratic rocks show three stages of F entrapment. The monophase CO<sub>2</sub> I, with densities in the range of 0.996 to 0.811 g/cm<sup>3</sup>, show P of about 5.1±0.6 kbars indicate peak metamorphism after crystallization. Early stage deformed aq I, however, represent initial crystallization Entrapment of these I was followed by carbonic aq I, whose CO<sub>2</sub> densities range from 0.816 to 0.624 g/cm<sup>3</sup> with increasing H<sub>2</sub>O F entrapment occurring during the retrogressive stages. Their density and T<sub>h</sub> indicate a P of 2±0.5 kbars.

These P-T conditions of the leucogneisses suggest around 18 kb of crust to have been removed, indicating >50 km thick crust during the amphibolite facies metamorphism corresponding to geothermal gradients of around 37°C/km. A successive decrease in estimated P-T conditions along with density and compositional information suggests retrogression and compressional cooling path for these rocks. (From authors' abstract by E.R.)

RASMUSSEN, M.G., EVANS, B.W. and KUEHNER, S.M., 1998, Lowtemperature favalite, greenalite, and minnesotaite from the Overlook gold deposit, Washington: Phase relations in the system FeO-SiO<sub>2</sub>-H<sub>2</sub>O: The Canadian Mineralogist, v. 36, p. 147-162. First author at Echo Bay Minerals Co., 921 Fish Hatchery Road, Republic, Washington 99166, USA.

At the Overlook gold mine in northeastern Washington, a fayalitebearing assemblge of iron silicates, magnetite, and pyrrhotite, plus quartz and calcite. formed during alteration of a Permian volcanogenic, carbonaterich, massive magnetite-sulfide seafloor deposit. The T of Fl homogenization, oxygen isotope ratios, and phase equilibrium calculations constrain the T of the fayalite-forming environment to approximately 300°C. (From authors' abstract by E.R.)

RAWAT, R.S. and KUMARI, Prabha, 1998. Homogenization experiments: An aid in melt temperature determination. A study from Amritpur Granite series, Kumaun Lesser Himalaya, India: N. Jb. Miner. Mh., 1998, no. 9, p. 417-425. Authors at Dehra Dun, India.

Significance of homogenization (quenching) experiments on the alkali feldspars and perthites is demonstrated. Homogenization experiments include high T studies at normal P. These studies have significance in determining the M T. Pure mineral separates of alkali feldspars from Amrit-

pur Granite Series (AGS) were obtained using conventional techniques. These separated alkali feldspars were homogenized at 1050°C for 48 hours, then quenched and powdered. XRD studies were carried out on these samples. T of 700+50°C is concluded for the granitic M of the AGS. (Authors' abstract)

RAY, J.S., 1998, Trace element and isotope evolution during concurrent assimilation, fractional crystallization, and liquid immiscibility of a carbonate magma: Geochim. et Cosmo. Acta, v 62, no. 19/20, p. 3301-3306. Author at Physical Research Laboratory, Navrangpura, Ahmedabad 380-009, India.

Liquid immiscibility is an important magmatic process that causes unmixing of magmas into L of contrasting compositions. Such magmas may get modified by simultaneous wall rock assimilation and fractional crystallization during the L immiscibility in a crustal magma chamber. The element and isotope effects of such a process are likely to be reflected in the final products. To treat these effects and to understand the evolution of the immiscible L, a model has been developed modifying the assimilationfractional crystallization (AFC) model of DePaolo (1981). I demonstrate the applicability of this model by an example using Sr isotope systematics of silicate-carbonate M immiscibility. The initial <sup>87</sup>Sr/<sup>86</sup>Sr ratio and Sr concentration variation in the silicate rocks of some alkaline-carbonatite complexes of Deccan Province are found to be a result of lower crustal contamination (up to 5%) of the parent carbonated silicate magma, while the 87Sr/86Sr of the carbonate M separated out of the parent remained unaffected. Though the data on silicate rocks could also be explained by the conventional AFC model, the processes treated by the model do not include L immiscibility, needed for explaining the evolution of the cogenetic carbonatites. It appears from this study that the slightly higher initial 87Sr/80 Sr (than that of the coexisting carbonatites) shown by the alkaline silicate rocks could be due to crustal contamination of the carbonated silicate parent magma during concurrent fractional crystallization of silicates and exsolution of carbonate M. Though the model has been applied to a very specific case-that of carbonate-silicate M immiscibility-it can be applied to any case in which both assimilation and immiscibility occur together. (Author's abstract)

REN, Binchen, 1998, Evolution model of mantle F in Baiyinchang copper-polymetallic deposit: 6th National Meeting on Mineral Deposits. Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 993-996 (in Chinese).

REYNOLDS, T.J., 1998, Ancient fluids at the Sweet Home mine: Mineralogical Record, v. 29, no. 4, p. 127-132. Author at FLUID. Inc., P.O. Box 6873, Denver, CO 80206 USA.

The Fl attest to the fact that mineralization at the Sweet Home mine formed from a hydrothermal system that achieved T at least as high as 370°C, which then gradually dropped to as low as about 110°C. No phase separations (boiling, etc.) occurred and no high-sal F were present. The sequence of mineral precipitation probably occurred with cooling of the system and significant dilution began at T below about 250°C. These conclusions are unequivocal from the Fl data alone.

Contrasting these data with that from other types of deposits provides clues about the general environment of formation at the Sweet Home mine. The high T (>300°C) and lack of evidence of boiling eliminates shallow (<1.5 km below the ground water table) epithermal environments. The lack of V-rich and high-sal F common in and above porphyry-copper and porphyry-molybdenum deposits eliminates these two depositional environments for the Sweet Home mine. The absence of visible L CO2 within the I (common in mesothermal, greenstone-hosted, lode-gold deposits worldwide) argues against the high T being solely a result of great depths. Furthermore, in 17 years of studying FI in many types of ore deposits worldwide. I have never studied a locality with the same characteristics found at the Sweet Home mine: (1) only 1 type of F1, (2) T as high as 370°C, and (3) high enough CO2 contents for it to be detectable, but not so high for L CO2 to be visible. Thus, not only do the fantastic mineral specimens which come from the Sweet Home mine dictate that the environment of mineral deposition and the ancient ore-forming processes were unique, but so do the FI data. (From the author's text by H.E.B.)

RICHARD, Laurent and HELGESON, H.C., 1998, Calculation of the thermodynamic properties at elevated T and P of saturated and aromatic high molecular weight solid and liquid hydrocarbons in kerogen, bitumen, petroleum, and other organic matter of biogeochemical interest: Geochim. et Cosmo. Acta, v. 62, no. 23/24, p. 3591-3636. Authors at Dept, of Geol. To supplement the relatively sparse set of calorimetric data available for the multitude of high molecular weight organic compounds of biogeochemical interest, group additivity algorithms have been developed to estimate heat capacity power function coefficients and the standard molal thermodynamic properties at 25°C and 1 bar of high molecular weight compounds in hydrocarbon source rocks and reservoirs, including crystalline and L isoprenoids, steroids, tricyclic diterpenoids, hopanoids, and polynuclear aromatic hydrocarbons. Calculations of this kind permit comprehensive thermodynamic description of the chemical evolution of organic matter with increasing depth in sedimentary basins. (From authors' abstract by E.R.)

RICHARDS, D.A., BOTTRELL, S.H., CLIFF, R.A., STRÖHLE, Klaus and ROWE, P.J., 1998, U-Pb dating of a speleothem of Quaternary age: Geochim. et Cosmo. Acta, v. 62. no. 23/24, p. 3683-3688. First author at School of Earth Sci., Univ. of Leeds, Leeds LS2 9JT, UK; email (David.Richards@bristol.ac.uk)

We demonstrate that U-Pb dating is a promising method for S carbonate materials of Quaternary age and older by obtaining a <sup>206</sup>Pb<sup>+</sup>/<sup>238</sup>U age for a speleothem with high U(>10 µg g<sup>-1</sup>) and very low Pb (<10 ng g<sup>-1</sup>) that is supported by an independent <sup>230</sup>Th age. Thermal ionisation massspectrometry was used to determine the U and Pb isotopic ratios and concentrations for subsamples of a stalactite from Winnats Head Cave. Peak District, UK. We obtained <sup>206</sup>Pb<sup>/234</sup>DP ratios up to 50, and determined a <sup>206</sup>Pb<sup>+/234</sup>U age of 248±10 ka, which is within error of the <sup>207</sup>Pb<sup>+/235</sup>U age of 333±79 ka and a-spectrometric U-Th age of ~255 ka. For samples of Tertiary and Quaternary age, the initial state of U-series disequilibrium is an important consideration and, as with most radiometric dating techniques, the mineral must have remained closed to U. Th, Pb, and all intermediate daughters. We show that dense calcite speleothems are ideal in this respect and that no loss of Rn has occurred. Unlike U-series disequilibrium methods, U-Pb dating has no upper limit and, hence, materials of Quaternary age older than 0.6 Ma can be analysed to investigate landscape development, paleoclimate, horninid evolution or hydrogeochemistry in carbonate terrains. (Authors' abstract)

Pertinent to interpretation of speleothem FI (E.R.).

RICHARDS, J.P. and LAUDRUM, D., 1998, The Mt. Kare alkalic epithermal gold deposit, Papua New Guinea (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-302. First author at Dept. Earth & Atmospheric Sci., Univ. Alberta, Edmonton, AB T6G 2E3, Canada; email (Jeremy,Richards@ualberta.ca)

The Mt. Kare Au deposit is located 18 km SW of the giant Porgera gold mine. It is spatially and temporally associated with geochemically similar 6 Ma-old mafic, alkalic, intrusive rocks to those found at Porgera, and also displays similar styles of mineralization (early carbonate basemetal-sulfide 'A'-veins with microscopic gold, and later quartzadularia/roscoelite-Au° 'D'-veins; adularia has also recently been observed in some D-veins at Porgera). New stable isotope and Fl data show that these similarities extend to isotopic and F compositions at the two deposits.

Sulfur isotopic compositions of sulfide minerals are as follows, with the range observed at Porgera in square brackets: A-veins (pyrite and Ferich sphalerite): 2.0-6.0. n=11 [2.4-5.4, n=34]; D-veins (Fe-poor sphalerite): 1.2-2.4, n=4 [Fe-poor sphalerite: 8.6-2.7, n=3; pyrite, 14.0-0.3, n=8].

Carbon and oxygen isotopic compositions of Ca-Mg-Mn-Fecarbonates from A-veins range from 4.7 to 3.6, n=5 [6.7-4.5, n=17, at Porgera], and 16.9-19.4 [14.8-18.3].

Oxygen isotopic compositions of two samples of quartz from D-veins are 16.3 and 16.5, compared with 16.6-18.9 (n=24) at Porgera.

FI microthermometric data also bear close comparison A-vein quartz and sphalerite:  $250-343^{\circ}$ C (Th), 6.1-11.2 eq. wt.% NaCl [211-365°C, 7.2-15.2 eq. wt.% NaCl]; D-vein quartz with roscoelite:  $163-203^{\circ}$ C, 7.0-8.4 eq. wt.% NaCl [97-158°C, 3.7-9.9 eq. wt.% NaCl, average 7.8±0.7 eq. wt.% NaCl]. The noticeable difference in Th range for D-type veins at the two localities may be due to the requirement for a larger P correction at Porgera, which is believed to be exposed at a deeper paleo-depth than Mt Kare. Ore deposition in A-veins may have been controlled primarily by cooling and neutralization, whereas the presence of CO<sub>2</sub>-bearing V-rich I in D-veins at Mt. Kare provides strong support for phase-separation as the controlling mechanism in these later veins.

These data show remarkable similarities between the two deposits, with observable differences serving merely to distinguish their separate identities rather than indicating fundamentally different processes or component sources. Thus, it is clear that the ore-forming process at Porgera is not unique, but is repeatable with high fidelity at other localities. At Mt. Kare, exploration now seeks to find the equivalent of the fabutously rich Zone VII orebody at Porgera. (Authors' abstract)

RICHET, P. and POLIAN, A., 1998, Water as a dense icelike component in silicate glasses: Science, v. 281, p. 396-398. First author at Laboratoire de Physique des Géomatériaux, Unité de Recherche Associée CNRS 734, Institut de Physique du Globe, 4, Place Jussieu, 75252 Paris Cedex 05, France.

Density and Brillouin-scattering measurements of hydrous andesite glasses at ambient conditions showed that dissolved water has a concentration-independent partial molar volume of  $12\pm0.5$  cubic centimeters per mole and a bulk modulus of  $18\pm3$  gigapascals. Dissolved as hydroxyl ions or as molecular water, water has volume properties similar to those of ice VII, the densest form of ice. These properties point to hydrogen bonding as an important factor in water dissolution, and they indicate that changes of water speciation are driven by the entropy and not by the volume of the system. Water in a concentration greater than 1% by weight also causes a marked decrease of the shear modulus of the glass. (Authors' abstract)

RIDLEY, M.K., PALMER, D.A., WESOLOWSKI, D.J. and KET-TLER, R.M., 1998, Potentiometric and solubility studies of association quotients of aluminum malonate complexation in NaCl media to 75°C: Geochim. et Cosmo. Acta, v. 62, no. 13, p. 2279-2291.

RIGHTER, Kevin, HERVIG, R.L. and KRING, D.A., 1998, Accretion and core formation on Mars: Molybdenum contents of melt inclusion glasses in three SNC meteorites: Geochim. et Cosmo. Acta, v. 62, no. 12, p. 2167-2177. First author at Lunar and Planetary Laboratory, Univ. of Arizona, Tucson, AZ 85721, USA.

Molybdenum, cerium, barium, yttrium, and rubidium contents of glasses in MI in three SNC meteorites (LEW 88516. Governador Valadares, and Chassigny) have been measured by ion microprobe. Ratios of Mo/Ba and Mo/Ce have been used to estimate the Mo content of the primitive Martian mantle, 120±60 ppb. Abundances of five moderately siderophile elements (Ni, Co, Mo, W and P) and Re in the Martian mantle are consistent with metal-silicate equilibrium between S-bearing metallic L (in a core 22 wt% of the planet) and peridotite M at 75 kb. 1620°C, and oxygen fugacity 1.4 log/O<sub>2</sub> units below the IW buffer. This homogeneous accretion scenario is different than many heterogeneous accretion models for the Earth, but similar to recent studies suggesting homogeneous accretion in the presence of a deep terrestrial magma ocean. (Authors' abstract)

RILLER, Ulrich, SCHWERDTNER, W.M. and ROBIN, P.Y.F., 1998, Low-temperature deformation mechanisms at a lithotectonic interface near the Sudbury Basin, eastern Penokean Orogen, Canada: Tectonophysics, v. 287, no. 1-4, p. 59-75.

Southwest of the Sudbury Basin, variations in macroscopic strain, microstructure and deformation mechanisms within Archaean granitoid basement and overlying Proterozoic rocks suggest that rock strength was strongly influenced by large amounts of F. Ductilely deformed granitoids with strong shape fabrics are concentrated in a 150-200-m wide zone parallel to the subvertical basement-cover interface. High F activity in this zone is indicated by: (1) thickness and close spacing of foliation-parallel quartz veins. (2) abundant FI trails in quartz. (3) quartz c-axis fabrics: and (4) transformation of feldspar into phyllosilicates under middle greenschistfacies metamorphic conditions. Away from this zone, brittle-ductile deformation in Archaean granitoids caused grain size reduction of feldspar by fracturing and crystal-plastic deformation of quartz indicating largety "dry" conditions. (From authors' abstract by E.R.)

RIOS, F., VIEIRA ALVES, J. FUZIKAWA, K., and SCHALAMUK, I., 1998, Fluid inclusions study in the epithermal auriferous district of Manantial Espejo: IV Meeting of Mineralogy and Metallogeny, Sept. 23-25, 1998, Bahia Blanca, Argentina, p. 219-226 (in Spanish, Engl. abst.).

A comparison between the fluids detected and the low sulfidization model is presented. Fl studies in the Manantial Espejo area (Macizo del Deseado, Patagonia) showed low sal (0.35/6.54 wt.% NaCl eq.) and Th between 200 and 300°C epithermal aq F. They have precipitated banded and massive quartz which make the body of Veta Maria quartz vein. In this stage Au>>Ag mineralization is related to sulfides. An inversion in this mineralization style, with Ag prevailing over Au occurred toward the final stage of sulfide precipitation (sphalerite), where an increase in sal (12.28 wt.% NaCl eq.) coupled with decreasing Th (<200°C) is shown. (Authors'

# abstract)

RIPLEY, E.M., SEVERSON, M.J. and HAUCK, S.A., 1998, Evidence for sulfide and Fe-Ti-P-rich liquid immiscibility in the Duluth complex, Minnesota: Econ. Geol., v. 93, no. 7, p. 1052-1062. First author at Dept. of Geological Sci., Indiana Univ., Bloomington, Indiana 47405; email (biogeo@indiana.edu)

Apatite- and oxide (ilmenite+magnetite)-rich dunite, pyroxenite, peridotite, melatroctolite, and gabbro occur as transgressive bodies in the Boulder Lake area of the southern Dututh complex. Nelsonite (apatite+ilmenite) is locally found as vein or dikelike bodies whose geometric form resembles veinlike massive Cu-Ni sulfide mineralization in the Babbitt deposit. Massive sulfide mineralization at Babbitt has been attributed to the separation of an immiscible sulfide magma from a tholeiitic parent. These data are thought to reflect the evolution of a Cl<sup>-</sup> and REE-bearing F from the magma that gave rise to the nelsonite and a later separation of an immiscible sulfide-rich L from a basaltic magma in the Babbitt area.

Although an origin involving immiscibility of an Fe-Ti-P-rich L is strongly indicated for the nelsonites, the origin of spatially associated apatite-oxide-rich rock types is problematic. The oxide-apatite-rich rocks may themselves be products of L immiscibility, reflecting a continuum in compositions with nelsonite as an end member. (From authors' abstract by E.R.)

**RIPMEESTER, J.A.** and **RATCLIFFE, C.I.**, 1998, The diverse nature of dodecahedral cages in clathrate hydrates as revealed by <sup>129</sup>Xe and <sup>13</sup>C NMR spectroscopy: CO<sub>2</sub> as a small-cage guest: Energy & Fuels, v. 12, p. 197-200.

ROBERTS, S.J., 1998, Prediction of pH in natural hydrothermal fluids at elevated P-T conditions: Chem. Geol., v. 146, p. 171-185. Author at Dept of Geol., Bowling Green State Univ., Bowling Green, OH 43403, USA; email (sirober@bgnet.bgsu.edu)

The pH of F at elevated T-P conditions are routinely calculated from F compositions measured in the laboratory. Numerical errors, uncertainties in thermodynamic data, and analytical errors can affect these computed values. An analysis of pH values computed at elevated T and P conditions for natural F reveals that the amount of error in computed pH values can be, but is not always, dependent on F composition. Not all reactions occurring in a F affect computed pH values. Therefore, inadequacies in the thermodynamic properties of a species may affect computed pH values in some F compositions but not others. When a single reaction controls the production/consumption of H+, the amount by which the pH changes as a function of T and P is independent of the measured pH. However, when two or more reactions produce/consume sufficient H<sup>+</sup> to change the pH, the amount by which the pH changes as a function of T and P is dependent on the measured pH. Uncertainties in the measured pH are magnified as T and P increase for some F compositions, while the uncertainty decreases in others. When small uncertainties in the measured pH are magnified, the activities of aq species calculated at elevated T and P conditions cannot be used to predict F mineral equilibria. (Author's abstract)

ROCK, Luc, 1998. Differences between limestone and dolomite reservoir properties of Swan Hills Ante Creek pools and Leduc Simonette Pool, west central Alberta, 1998: AAPG Bulletin, v. 82, no. 11, p. 2167. Indexed under FL.

ROEDDER, E. and WHELAN, J.F., 1998a, Ascending or descending water flow through Yucca Mountain tuffs?-Fluid inclusion evidence (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A31. First author at Dept. Earth and Planetary Sci., Harvard Univ., email (roedder@shore.net)

The potential site for a high-level nuclear waste repository at Yucca Mountain. Nevada, lies within a thick series of volcanic tuffs, more than 300 m above the present water table. Recent reports (e.g. Hill et al., 1995, Dublyansky et al., 1996) claim that (1) *ascending* ground water, possibly at elevated T, has in the past risen through the thick unsaturated zone and discharged at the surface, and (2) should this recur in the future, it could flood the repository, with serious consequences.

We have studied the FI in vein and vug calcite from the tuffs and find that all unsaturated zone calcite contains abundant I that are full of L. and lesser numbers of I that are full of G mixtures of atmosphere-like composition at about one atm. P. These latter probably formed by the trapping of exsolved G bubbles sticking to the crystals as they grew from a film of cool water (probably ≤40°C), infiltrating from the surface and *descending* through the unsaturated zone. Calcite also occurs well below the watertable, deep in the saturated zone; textural, stable isotope, and FI evidence indicates that this calcite formed predominantly during a moderate-T hydrothermal event at about 10.4 Ma.

Our FI studies of numerous samples from the underground workings of the Exploratory Studies Facility and from Yucca Mountain boreholes have revealed no evidence of either hydrothermal activity or ascending F during formation of unsaturated-zone S minerals, but have confirmed our earher conclusions that these minerals formed from descending cool waters, above the level of the water table. (Authors' abstract)

ROEDDER, Edwin and WHELAN, J.F., 1998b, Ascending or descending water flow through Yucca Mountain tuffs? – Fluid inclusion evidence (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 56. First author at Dept. Earth and Planetary Sci., Harvard Univ., Cambridge, MA, 02138.

See previous abstract (E.R.).

ROHRLACH, B.D., FU, M. and CLARKE, J.D.A., 1998. Geological setting, paragenesis and fluid history of the Walford Creek Zn-Pb-Cu-Ag. prospect, Mt Isa Basin, Australia: Australian J. of Earth Sci., v. 45, p. 63-81. Authors at WMC Resources Ltd., P.O. Box 860K, Melbourne, Victoria 3001, Australia.

The low-grade Walford Creek Zn-Pb-Cu-Ag deposit is located on the faulted northern margin of the Mt. Isa Basin. Four sulfide generations are recognised. Stage I consists of synsedimentary pyrite and marcasite. Early diagenetic stratiform and stratabound sphalerite, galena with or without pyrite and quartz mineralisation (Stage II) has overprinted Stage I sulfides. FI data are consistent with metal transport by >180°C NaCl-rich F (6-7 wt.% NaCl eq.), and with precipitation by mixing with cool, low-sal (1 wt%), dilute F (<50°C). Mineralisation formed shortly after sediment deposition. Stage III sulfides consist of cavity-filling and vein sphalerite. galena and chalcopyrite, deposited by cooling and mixing of hypersaline (150-170°C) MgCl, brines (-25 wt% eq.) with ambient (<70°C) CaCl2+ MgCl<sub>2</sub> brines. Sal range between 18 to 25 wt.%. Mineralisation post-dates stylolitisation and probably formed at a depth of 1-2 km. Stage IV mineralisation comprises vein chalcopyrite, sphalerite and galena, which were deposited by conductive cooling in association with reduction of hypersaline (125°C) CaCl, brines (~30 wt% eq.). The Walford Creek mineralisation shows affinities with both early sediment-hosted stratiform and late Mississippi Valley-type styles of mineralisation. (From authors' abstract by E.R.)

ROMER, R.L. and HEINRICH, W., 1998, Transport of Pb. U, and Sr in leaky aquifers in a contact metamorphic aureole (abst.): The Ninth Int'l Conference on Geochronology, Cosmochronology and Isotope Geology. Abstracts, published in Chinese Sci. Bulletin, v. 43, Supp., p. 109. Authors at GeoForschungsZentrum Potsdam, Telegrafenberg, D-14473 Potsdam, Germany.

Marbles with thin subhorizontal chert layers have been intruded and contact-metamorphically overprinted by the Buffa del Diente alkah-syenite (NE Mexico). The chert has been infiltrated by high-sal aq F, whereas the marbles were aquitards. FI and stable isotope studies demonstrate that CO<sub>2</sub> generated from the F-driven reaction SiO<sub>2</sub>+CaCO<sub>3</sub>=CaSiO<sub>3</sub>+CO<sub>2</sub> unmixed from the high-sal aq F and infiltrated into the marbles.

Shifts in the isotopic composition of Sr and Pb can be traced along aquifers for >90 m from the intrusive contact, but <5 cm from the aquifermarble boundary. As isotope shifts in Sr and Pb are traceable to similar distances as C and O isotope shifts, it is inferred that Sr and Pb were transported by F rather than diffusion. Anomalously radiogenic Pb and enhanced concentrations of Rb, Sr and U in the residual meta-argillite at the outer border of the reaction rim demonstrate: (1) Pb and Sr infiltration profiles show coherent shifts from the aquifer to the marble with exception of the residual meta-argillite layers. (2) Elements derived from the F that are now enriched in the meta-argillite rim and Pb and Sr that show isotope shifts in the marbles must have fractionated between the unmixed F H<sub>2</sub>O and H2O-CO2 as only the H2O-CO2 F permeated the meta-argillite rim and the marble. (3) Sr in the meta-argillite rim is dominantly residual from the carbonate dissolution, as is Rb in the outer part of the meta-argillite rim. In contrast. Rb in the inner part of this rim is derived from the aq F. Mass balance indicates that about three times more ag F had flowed at the upper aquifer-marble contact than at the lower one. (4) U transported with the highly saline aq F partitioned into the H2O-CO2 F and was scavenged by

the meta-argillite band from that F. (5) There is about 20-40 times more uranium accumulated at the upper border of the aquifer than at the lower one, which implies that considerably the  $CO_2$ -rich F had leaked preferably through the upper margin of the aquifer.

The dispersion of elements transported by aq F from the aquifer into the surrounding marbles is controlled by the degree to which an element can be held by the H<sub>2</sub>O-CO<sub>2</sub> F and the presence of scavenging layers. This is most directly illustrated by radioautographs for uranium and alpha-track maps for boron ( ${}^{10}\text{B}+\text{n}{}^{-2}\text{Li}{}^{+4}\text{He}$ ). (Authors' abstract)

RONGFU, Pei, ed., 1997, Proceedings of the 30th Int'l Geological Congress, v. 9: Energy and mineral resources for the 21<sup>st</sup> century. Geology of mineral deposits mineral economic: at VSP Utrecht, The Netherlands. This volume contains many of the papers from the 30th IGC whose

abstracts were first presented in FIR v. 29 (E.R.).

ROSE, S.R.A. and SPENCER, R.J., 1998. Fluid inclusion and stable isotope analyses applied to Mississippi Valley-Type (Pb-Zn) mineralization on Bathurst Island, N.W.T., Canada (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 57. Authors at Dept. of Geol. and Geophys.. The Univ. of Calgary.

The new discovery in 1995 of a Pb-Zn showing occurs in younger rocks than any other eastern Arctic carbonate-hosted Pb-Zn occurrences.

The lower Blue Fiord Formation (BF<sub>1</sub>) is the locus for metal sulfides deposited by fluids traveling upwards through a north-south trending fault system. This study addresses the microthermometric and isotopic characteristics of BF<sub>1</sub> within the Pb-Zn showing. Fl in replacement dolomite, euhedral dolospar, sphalerite, and late calcispar place constraints on the Tf and relative sal of F.

The  $\delta^{18}$ O values of replacement dolomite show that regional dolomitization of BF<sub>1</sub> occurred during early burial, either at low T, or from hydrothermal F with the same chemistry as the F that formed dolospar. Sphalerite and galena have  $\delta^{34}$ S values averaging -10%, similar to values from Polaris deposit sulfides.

Late calcispar fills vugs and fractures after mineralization and has a wide range of  $\delta^{18}$ O and  $\delta^{13}$ C values (-20 to -9‰ and -23 to -1‰, respectively). The calcispar formed from hot (130-160°C) meteoric water and/or seawater. The variation in the chemical and thermal data for the calcite indicates multiple emplacement. The highly negative carbon isotope values point to the influence of organic matter as a source of carbon for the calcispar,

Fl. stable isotopes, and petrography indicate the mineralizing F of the showing and Polaris were derived from the same source traveling upwards through the N-S trending regional faults. (From authors' abstract by E.R.)

ROSELL, L., ORTI, F., KASPRZYK, A., PLAYA, E. and PERYT, T.M., 1998, Strontium geochemistry of Miocene primary gypsum; Messinian of southeastern Spain and Sicily and Badenian of Poland: J. of Sedimentary Research, Section A: Sedimentary Petrol. And Processes, v. 68, no. 1, p. 63-79.

The strontium contents of P marine gypsum facies were studied in Messinian (Upper Miocene) basins of SE Spain and Sicily, and in the Badenian (Middle Miocene) Carpathian foreland basin of Poland. The results obtained were interpreted on the basis of the findings reported for the gypsum facies of recent salinas in the western Mediterranean Coast. The strontium contents in both the Messinian and Badenian selenitic samples are lower than those in the selenitic crusts of the recent salinas. These lower contents may be a result of a lower sal of the mother brines at the steady state achieved during the precipitation of the thick selenitic sequences, with respect to the highly concentrated (with no reflux) brines of the recent salinas. Our findings highlight the relevance of studying strontium contents in P gypsum facies of marine formations as a tool for interpreting the paleogeography and paleosalinity of the evaporitic environments and for correlating cyclic selenite formations. This method could be especially helpful when combined with other geochemical indicators (i.e., isotopic and/or FI composition). (From authors' abstract by E.R.)

ROSIN, S.M. and JOHNSON, E.L., 1998. A new method of measuring the A-axis in deformed quartz using FI morphology: Michigan Academician. v. 30, no. 3, p. 254, Indexed under FI.

ROTHERHAM, J.F., BLAKE, K.L., CARTWRIGHT, Ian and WIL-LIAMS, P.J., 1998, Stable isotope evidence for the origin of the Meso-

proterozoic Starra Au-Cu deposit, Cloncurry District, northwest Queensland: Econ Geol., v. 93, p. 1435-1449. First author at National Key Centre in Economic Geol., School of Earth Sci., James Cook Univ., Townsville, Queensland 4811, Australia.

New stable isotope data are consistent with a metasomatic origin for the controversial Mesoproterozoic ironstone-hosted Au-Cu deposit at Starra in the Cloncurry district of northwest Queensland. This supports textural and mineralogical evidence that the ore-bearing ironstones formed after the peak of metamorphism and were strongly controlled by britle-ductile deformation. Three dominant paragenetic stages are recognized. These are: (1) early, widespread Na-Ca metasomatism (quartz-albite-scapoliteactinolite), (2) localized K-Fe metasomatism (biotite-magnetite-hematitequartz-pyrite), and (3) mineralization (quartz-anhydrite-barite-hematitecalcite-gold-pyrite-chalcopyrite-bornite-chalcocite-chlorite-muscovite). Crosscutting anhydrite veins associated with carbonate±hematite are rare in the upper parts of the system but more common at depths >700m. Stage 3 minerals demonstrate that the ore F was highly oxidized.

A restricted range of Fe oxide 818O implies isotopically similar F were responsible for the magnetite ironstones and later hematite alteration associated with gold and sulfides (between -0.2 to 3.3% except for one magnetite at 5.4‰). Sulfur isotope compositions suggest that pyrite (-0.2 to 3.9‰), chalcopyrite (-5.8 to -0.7 and -14.6‰), bornite (-4.7‰), chalcocite (-0.1%), and anhydrite (1.1-2.4%) all formed from the same sulfur source. Anhydrite 834S falls within the sulfide range, suggesting that the sulfate inherited its 834S through hydrolytic processes similar to those of some porphyry environments. S13C of ore-stage carbonates range from -7.3 to -2.2 per mil. Temperatures based on stage 2 quartz-magnetite pairs imply 400-500°C for ironstone formation and stage 3 calcite-hematite pairs indicate 180-330°C for mineralization. Stage 2 FI have Th between 345 and 615°C and sal of 34 to 52 wt.% NaCl eq. Stage 3 Fl homogenized between 225 and 360°C and have sal of 30 to 42 wt.% NaCl eq. Calculated 8180 F compositions for magnetite-quartz and hematite-calcite average 7.8 per mil and 9.5 per mil, respectively. F compositions (for stages 2 and 3) fall within the range for a magmatic or metamorphic F However, combined stable isotope and FI data and thermodynamic considerations suggest a magmatic-metasomatic origin for both the magnetite ironstones and the highly oxidized mineral assemblage associated with high-grade gold deposition (Authors' abstract)

Stage 2 shows dm halite, magnetite, calcite and ferropyrosmalite\*, and stage 3 contains halite, ferropyrosmalite, barite, anhydrite and MnCl<sub>2</sub> (See fig. 4.).

\*((Fe,Mn)<sub>8</sub>SiO<sub>15</sub>(OH,Cl)<sub>10</sub>) See figure in the Illustrations appendix.

ROWAN, E.L., THIBIÉROZ, Jacques, BETHKE, C.M. and de MAR-SILY, Ghislain, 1996. Geochemical and hydrologic conditions for fluorite mineralization in regions of continental extension: An example from the Albigeois District, France: Society of Economic Geologists, Special Pub. No. 4, p. 448-464. First author at U.S. Geological Survey, 345 Middlefield Rd., MS 969, Menlo Park, CA 94025, USA.

Many of the world's largest fluorite deposits occur in the footwalls of major normal faults. The absence of associated igneous rocks and the high sal of the FI suggests that the mineralizing F originated in a sedimentary basin. The Permian St. Affrique basin adjacent to the deposits is proposed as a F source.

Our data suggest that aluminum-fluoride complexes (mainly  $AlF_3^{0}$ ) were predominantly responsible for fluorine transport, and that fluorite precipitated as a result of cooling. FI T place constraints on the thermal and F flow regimes during mineralization. Using simple thermal/hydrologic modeling, we examined the processes of advective heat transport by F ascending in a vertical fracture system, and conductive cooling of the F to the surrounding rocks. The results suggest that high initial T in the vicinity of 300°C are required in order to account for measured FI T as high as 200°C. In addition, F fluxes of at least 1.0 X 10<sup>6</sup> m/s (>>30 m/yr) are required to bring isothems between 100 and 200°C sufficiently close to the surface and close together: 1) to account for the FI T<sub>h</sub>, and 2) to create the thermal gradient necessary to precipitate significant quantities of fluorine within a relatively small vertical interval (From authors' abstract by H.E.B.)

ROWE, John, TURNER, Peter and BURLEY, Stuart, 1998. Palaeo magnetic dating of the west Cumbrian hematite deposits and implications for their mode of formation. Proceedings of the Yorkshire Geological Society. v. 52, part 1, p. 59-71.

Indexed under FL

ROWLAND, M.G. and WILKINSON, J.J., 1998a, A fundamental role for mafic melt derived volatiles in porphyry-copper mineralisation. Evidence from Quebrada Blanca, northern Chile (abst.): Mineral Deposits Study Group. Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). Authors at Imperial College, London.

Orthomagmatic models for hypogene mineralisation in porphyry systems in which a volatile phase exsolved from a crystallising felsic M scavenges ore elements fits well porphyry-associated tin-tungsten and molybdenum deposits. Both are associated with highly differentiated portions of M and display unidirectional solidification textures (USTS) consistent with second boiling. USTS are rare and the intrusives with which mineralisation is most closely associated exhibit low degrees of fractionation. These relatively undifferentiated intrusives are highly oxidised, contrasting with the reduced nature of those associated with tin-tungsten deposits.

The porphyry copper deposit of Quebrada Blanca is typical of Chilean porphyry copper deposits. Mineralisation is located within an equigranular to seriate stock of quartz monzonite composition and is spatially associated with cross-cutting porphyritic dykes. Field and petrographic evidence suggests that the quartz monzonite chamber was variably crystallised at the time of mineralisation and that the porphyritic magma was the product of interaction between M at the base of the chamber and an invasive mafic magma.

This magma is seen as andesitic dykes associated with veins and diffuse potassium-copper-iron enrichments thought to have precipitated from a volatile phase introduced with the dykes. Mafic dykes rarely reach the upper levels of the system where the earliest evidence of hypogene mineralisation are diffuse margined A-type quartz veins with cores of anhydrite. perthitic feldspar and biotite. The F responsible for the precipitation of these veins was most probably introduced with the porphyry dykes.

[Our studies] suggest that both the porphyritic and the mafic dykes underwent oxidation in the magmatic state, consistent with the interaction of the  $Fe^{2^*}$ - $Fe^{3^*}$  rock buffer and the SO<sub>2</sub>-H<sub>2</sub>S gas buffer, evidence in support of the coexistence of a volatile phase with the mafic magma. Analysis of Fl in these veins provides permissive evidence for this theory. A genetic model for the hypogene mineralisation at Quebrada Blanca is proposed, involving: 1. Addition of metals and potassium to a small volume of M at the base of the partially crystallised felsic magma chamber from an invasive mafic magma by means of a volatile phase which initially coexisted with the mafic magma.

Production of a volatile-rich, oxidised hybrid which ascended to the upper, fully-crystallised portion of the chamber, where it delivered its metal and potassium-rich volatile phase.

 Separation of this oxidised volatile phase into an oxidised V, and a reduced brine capable of depositing the sulfides which constitute the hypogene mineralisation

Such a model explains why the intrusives associated with mineralisation are relatively unfractionated and oxidised, and lack USTS Significant fractionation within the felsic M is not required to concentrate copper into a residual M and second boiling, the process deemed responsible for USTS, does not occur since volatile saturation is not induced by crystallization within the felsic M. (From authors' abstract by E.R.)

ROWLAND, M.G. and WILKINSON, J.J., 1998b, A hybrid origin for porphyritic magmas sourcing mineralising fluids: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p 569-573. Authors at Dept. of Geol., Imperial College, London, UK.

This contribution presents results of a study of the hypogene evolution of the porphyry copper deposit of Quebrada Blanca, Chile. The hydrothermal evolution of the deposit and the characteristics of the porphyritic lithology associated with mineralisation are used to show that Quebrada Blanca can be considered representative of Chilean porphyry copper deposits. Evidence is presented suggesting that the porphyritic lithology is the product of interaction between a felsic M and a volatile-saturated mafic M. The presence of a source of volatiles and metals other than the felsic magmas traditionally associated with porphyry deposits has important implications for the genetic models for this deposit type. (Authors' abstract)

Th values of <550°C and Tmice range from 0 to -45°C (E.R.)

RUZICKA, A.M., SNYDER, G.A. and TAYLOR, L.A., 1998, Equilibration temperatures of large, sodium-poor melt inclusions in ordinary chondrites (abst.): 61st Meteoritical Society Meeting July 27-31, 1998, Trinity College, Dublin, Ireland, published in Meteoritics & Planetary Sci., v. 33, no. 4 Supple., p. A132-A133. Authors at Planetary Geosci. Inst., Dept. of Geological Sci., Univ. of Tennessee, Knoxville, TN 37996, USA

Ordinary chondrites contain large (up to or >1 cm across), igneoustextured I that have chondrulelike mineralogies, with the notable exception that many contain bytownitic plagioclase or glass [1,2]. Such Na-poor I often appear to have solidified as freely floating M droplets, and they may have formed by processes similar to that which formed normal-sized, ferromagnesian chondrules [1-3]. However, the large sizes of the I make them less susceptible to diffusion-dependent alteration effects, such as Nametasomatism, that appear to have affected normal-sized chondrules [4-6]. Sodium-poor I show major-element chemical trends consistent with Vdependent fractionation processes [2,3], but have relatively uniform Na/AI and Mg# (+Mg/[+ Fe<sub>2</sub> +]) ratios (Fig.1) The latter can be used to infer the conditions under which the I last equilibrated. Here, we model the equilibration of these objects as having occurred in a system containing a low-P (10<sup>-5</sup> bar) G, representative of what could have existed in the solar nebula [7.8].

In the models, we used the PHEQ program of Wood and Hashimoto [8] to determine the composition of stable residues/condensates at various T in a system of specified composition. As the appropriate system composition for anhydrous components in chondrites is uncertain [9], we varied the system composition in a manner similar to that followed by Wood and Hashimoto [8]. We used the presumed "cosmic" composition [10] as a baseline, but also took into account the possibility of higher O/H brought on by the vaporization of "dust" (which contains the rock-forming elements in Cl-chondrite-like abundances). There is some evidence that O/H may have been elevated in the formation of chondrites [9], although to what extent is uncertain. Dust-enriched zones could correspond to the nebular midplane or to zones between turbulent eddies [8,11,12].

Figure 1 compares the compositions of Na-poor MI to the stable condensed phases at various T and in systems with different O/H ratios, in terms of Na/Al and Mg#. The first parameter is especially sensitive to T, the second to O/H ratio. Lower Na/AI ratios correspond to higher T, although the precise T depends also on O/H, and consequently varies with Mg# (Fig. 1). All but two I have compositions that cluster between the 1375 and 1450 K isotherms (Fig. 1). The apparent O/H ratios (not shown) are ~0.4-6.6. a factor of ~470-7800 enhancement compared to the cosmic case. Metasomatic influxes of Na and "FeO," which affected the peripheries of some of the I [2], would tend to move the compositions of the I from the lower right to the upper left, roughly along isotherms, but across contours of constant O/H. Thus, such metasomatic fluxes would not appreciably change the inferred equilibration T, although they could lead to an overestimate in the O/H ratio. Consequently, the compositions of large, Na-poor I in ordinary chondrites are consistent with a final equilibration T of ~1375-1450°K, in a possibly oxidizing "nebular" system containing G with a P of 10" bar. Higher P would increase (and lower P would decrease) these inferred T. The inferred equilibration T are probably similar to the solidi of the I, suggesting that the objects ceased to effectively equilibrate with their surroundings once they solidified. (Authors' abstract)

See figure in the Illustrations appendix.

RYABCHIKOV, I., BROOKS, C.K., KOGARKO, L.N., NIELSEN, T., SOLOVOVA, I.P. and TURKOV, V., 1998, Tertiary picrites from Greenland: Modelling sources and petrogenesis from melt inclusion compositions (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1306. First author at Inst. Geol. of Ore Deposits, Staromonetny, 35, Moscow, Russian Federation,

Picrites rocks from Greenland are suggested to be related to the mantle plume responsible for the opening of Atlantic Ocean (Brooks, 1973; Nielsen, 1975). We attempt to estimate compositions of P magmas, mantle T and source compositions through thermodynamic modelling of MI composition.

Compositions of homogenised 1 in phenocrysts from picrites from west and east Greenland (Table 1) scatter along the common olivine control line. The trapped M, therefore, do not represent parental magmas, but evolved M (From authors' abstract by E.R.)

See figure in the Illustrations appendix.

RYZHENKO, B.N., KOVALENKO, N.I. and BARSUKOV, V.L., 1998, The model of fluid-forming tin-bearing greisens: Geologiya Rudnykh Mestorozhdenii, v. 40, no. 2, p. 114-123, in Russian, translated in Geology of Ore Deposits, v. 40, no. 2, p. 100-108.

SAAL, A.E., HART, S.R., SHIMIZU, N., HAURI, E.H. and LAYNE, G.D., 1998, Pb isotopic variability in melt inclusions from oceanic island basalts. Polynesia: Science, v. 282, p. 1481-1484. First author at Dept. of Geol. And Geophys., Woods Hole Oceanographic Inst., Woods Hole, MA

## 02543, USA.

Previous studies have suggested that melting processes are responsible for the trace element variability observed in olivine-hosted basaltic MI. MI from three individual lava samples (two from Mangaia, Cook Islands, and one from Tahaa, Society Islands) have heterogeneous Pb isotopic compositions, even though the erupted lavas are isotopically homogeneous. The range of Pb isotopic compositions from individual MI spans 50% of the worldwide range observed for ocean island basalts. The MI data can be explained by two-component mixing for each island. Our data imply that magmas with different isotopic compositions existed in the volcanic plumbing system before or during M aggregation. (Authors' abstract)

SAAL, A.E., HART, S.R., SHIMIZU, N., LAYNE, G. and HAURI, E.H., 1998, *In situ* Pb isotope ratios in melt inclusions from oceanic island basalts: Mangaia, a case study (abst.): Mineralogical Magazine, v. 62A, V M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1310. First author at Dept. of Geol., Woods Hole Oceanographic Inst., Woods Hole, MA 02543 USA.

MI, in olivine and clinopyroxene phenocrysts from two primitive lavas from Mangaia, are partially crystallized and ellipsoidal in shape (30 to 300 μm), indicative of their P nature. Partially resorbed clinopyroxene I in the olivine also occur. Some of the MI contain FeCuNi sulphide and MgFeCa carbonate globules. The (La/Yb)<sub>CN</sub> ratios in the I range from ~5 to ~40. The MI from one sample in <sup>207</sup>Pb/<sup>206</sup>Pb - <sup>208</sup>Pb/<sup>206</sup>Pb space reproduce

The MI from one sample in <sup>407</sup>Pb/<sup>406</sup>Pb - <sup>408</sup>Pb/<sup>406</sup>Pb space reproduce the trend defined by the HIMU islands, indicating that lavas from Mangaia do not derive from a single homogeneous mantle source and geochemical models should consider at least two mantle sources. The Pb isotopic composition of the carbonate globules in conjunction with their textures and composition provide direct evidence for a carbonated mantle source for the Austral Islands. (From authors' abstract by E.R.)

SAIDYGÁNIEV, S., AKHUNDZHÁNOV, R., VORÓNICH, T.M., USMÁNOV, A.I., ÁSKAROV, F.A. and MAMARAZYKOV, U.D., 1998, The isotope-geochemical association of magmatic and ore formations in the Shavaz lithium deposit (abst.): Second APIFIS Int'L Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 72-75 (in Russian).

SAKAGUCHI, A., 1998, Fluid distribution and thermal history in the Cretaceous Shimanto accretionary complex, Shikoku, southwest Japan (abst.): Abstracts of the 105th Annual Meeting of the Geological Society of Japan, p. 252 (in Japanese).

SAMSON, I.M., CHEN, Z., FRYER, B.J. and WALKER, R.T., 1998. High sensitivity in-situ analysis of cation/anion compositions of individual fluid inclusions by LAP-ICP-MS using a cold plasma ionization source (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-81. Authors at Earth Sci., Univ. of Windsor, Windsor, Ontario, N9B 3P4; email (ims@uwindsor.ca)

In order to evaluate a new laser ablation microprobe (LAM-ICP-MS) facility at the Univ. of Windsor for the determination of the composition of FL a suite of I from the Oregon 3 pegmatite. South Platte district, Colorado, was selected for analysis. The South Platte district is located in the northern part of the Proterozoic Pikes Peak granite batholith and comprises numerous rare-element pegmatites. The quartz core of the Oregon 3 pegmatite contains several types of aq Fl: two phase L-V I, L-V-anhydrite (LVS) in which the anhydrite is a trapped phase, and L-V-halite (LVH) I. Microthermometry indicates I sal ranging from 0 to 30 wt.% and EDS-decrepitate and Raman analysis indicate that the major solutes are Na>Ca>K, with CI as the only important anion. These data also indicated variable Na/Ca ratios in the I.

In this study, we utilize a cold plasma ionization source (the V.G. PlasmaScreen) with our LAM-ICP-MS, which largely eliminates interferences between many of the major cation/anion components of Fl and the molecular ions present under standard plasma conditions (e.g., Ar40016 on Fe56, Ar38H1 on K39, and Ar40Cl35 on As75, etc.). The LAM system consists of a Surelite I-10 Q-switch Nd YAG laser operating at the fundamental wavelength of 1064 nm, frequency quadrupled to 266 nm using second and fourth harmonic generators with a repetition rate of 20 Hz, allowing controlled energy absorption with the quartz host. A V.G. PlasmaQuad PQ3 ICP-MS with S-Option provides the ultra-high sensitivity analyser.

Analyses of LV I from different S planes, which otherwise have similar MT characteristics, separate into two chemically distinct groups. Both groups are dominated by Na, K and CI, with less Mg, however only one group contains measurable Ca. The LVH I contain more Ca than the LV I and significant Fe. The chemistry of the LVS I is very similar to that of the LVH I. (Authors' abstract)

SANGSTER, D.F. and SAVARD, M.M., 1998. A special issue devoted to zinc-lead mineralization and basinal brine movement, Lower Windsor group (Viséan), Nova Scotia, Canada. Introduction Econ. Geol., v. 93, no. 6, p. 699-702.

SANGSTER, D.F., SAVARD, M.M. and KONTAK, D.J., 1998, A genetic model for mineralization of Lower Windsor (Viséan) carbonate rocks of Nova Scotia, Canada. Econ. Geol., v. 93, p. 932-952. First author at Geological Survey of Canada, 601 Booth Street, Ottawa, Canada K1A 0E8, email (dsangster@easyintemet.net)

This paper summarizes and integrates some of the results of a threeyear research project on the source, path, and timing of F movement within and between sub-basins in Nova Scotia, lower Carboniferous (Viséan) carbonates, and the relationship of these F to base metal mineralization Preore burial T reached 70°C at Walton, 135°C at Gays River, and 65°C at Jubilee Timing of mineralization has been determined by a variety of methods indicating that ore F entered the Gays River area at about 320-300 Ma, the Walton area at 333 to 307 Ma, and the Jubilee area at 330 to 310 Ma. Given the uncertainty in the dating methods used, these data are interpreted to indicate overlapping mineralization among the three areas. Evaporated seawater was the most likely original source of ore F, but these were modified during burial by halite dissolution and by reaction with underlying siliciclastic aquifers.

Temperatures of ore-stage deposition decrease from Walton (median -200°C, range 100-300°C) to Gays River (median -140°C, range 80-220°C), and to Jubilee (median -80°C, range 80-220°C). The high-T, high-sal, ore-forming F is interpreted to have entered the host rocks and mixed with, and was cooled by an ambient low-T, high-sal F. Several possible sources of the extraordinary heat in the P F are proposed and include an underlying basalt plate, high heat-production granites, an increase in geothermal gradient caused by coeval extension, or a combination of these.

Ore F appear to have been primarily complex NaCI-CaCl<sub>2</sub>-KCI-MgCl<sub>2</sub>-FeCl<sub>2</sub> aq solutions with lesser amounts of light G such as CO<sub>2</sub> and CH<sub>4</sub>. Hydrocarbons were present in ore-stage F at both Walton and Jubilee and more than 99.9% of the hydrocarbon occurs as L petroleum. Given the high T of these deposits, the presence of L petroleum indicates a short-lived mineralizing system probably on the order of a few hundred thousand vears.

A clear relationship with underlying basement lithologies is indicated by the sub-basin-specific character of Pb and Sr isotopes in ore-stage minerals, suggesting that ore F leached metals directly from basement rocks, or more likely, from sediments derived from it.

Isotopic data indicate that sulfur at Walton, Gays River, and Jubilee was derived from the same source, probably deeply circulating sulfate-rich brines. The data also suggest that sulfate reduction at Gays River must have taken place away from the deposit area whereas data from the Walton and Jubilee deposits suggest in situ thermochemical reduction of sulfate by hydrocarbons. (From authors' abstract by E.R.)

See also Chi et al., Kontak, Kontak & Sangster, and Savard & Chi, this volume (E.R.).

SANO, Yuji, NISHIO, Yoshiro, GAMO, Toshitaka, JAMBON, Albert and MARTY, Bernard, 1998, Noble gas and carbon isotopes: Applied Geochemistry, v. 13, no. 4, p. 441-449. First author at Dept. of Earth and Planetary Sci., Hiroshima Univ., Kagamiyama, Higasht Hiroshima 739. Japan.

Noble G elemental and isotopic compositions have been measured as well as the abundance of C and its isotopic ratios in 11 glasses from submarine pillow basalts collected from the Mariana Trough. The <sup>3</sup>He/<sup>4</sup>He ratios of 8.22 and 8.51 R<sub>atm</sub> of samples dredged from the central Mariana Trough (~18°N) agree well with that of the Mid-Ocean Ridge Basalt (MORB) glasses (8.4±0.3 R<sub>atm</sub>), where a mean ratio of 8.06±0.35 R<sub>atm</sub> in samples from the northern Mariana Trough (~20°N) is slightly lower than those of MORB. One sample shows apparent excess of <sup>20</sup>Ne and <sup>21</sup>Ne relative to atmospheric Ne, suggesting incorporation of solar-type Ne in the magma source. There is a positive correlation between <sup>3</sup>He<sup>4</sup>He and <sup>40</sup> a. db

 $^{40}$ At/ $^{36}$ Ar ratios which may be explained by mixing between MORB-type and atmospheric noble G. Excess  $^{129}$ Xe is observed in the sample which also shows  $^{30}$ Ne and  $^{21}$ Ne excesses. Observed  $\delta^{13}$ C values of  $\sim 20^{\circ}$ N samples vary from 3.76 to 2.80‰, and appear higher than those of MORB, and the corresponding CO<sub>2</sub>. <sup>4</sup>He ratios are higher than those of MARA samples

at ~18°N, suggesting C contribution from the subducted slab. (Authors' abstract)

SANSONE, F.J., MOTTL, M.J., OLSON, E.J., WHEAT, C.G. and LILLEY, M.D., 1998, CO<sub>2</sub>-depleted fluids from mid-ocean ridge-flank hydrothermal springs: Geochim. et Cosmo Acta, v. 62, no. 13, p. 2247-2252. First author at Dept. of Oceanography, Univ of Hawaii, Honolulu, Hawaii 96822, USA.

The calculated carbon flux is only 2-5% of current estimates of subaerial and submarine volcanic  $CO_2$  emissions ( $-50 \times 10^{11}$  mol yr<sup>-1</sup>), indicating that hydrothermal alteration of oceanic crust on young midocean rdge flanks at T of a few tens of °C is only a relatively minor sink for carbon on a global basis. It is still possible, however, that ridge-flank alteration at lower T (<25°C) is an important component of the global carbon bodget. (From authors' abstract by E.R.)

SARDI, G.F., MAS, G. and BENGOCHEA, L., 1998, Fluid inclusions from the "Faltriquera" veins, La Rioja, Argentina: IV Meeting of Mineralogy and Metallogeny, Sept. 23-25, 1998, Bahia Blanca, Argentina, p. 251-257 (in Spanish, Engl. abst.)

The petrographic and thermometric characteristics of the FI of tungsten-bearing quartz veins of the Faltriquera region, La Rioja, are studied. The vein mineralogy consists of wolframite and scheelite, and chloritization, sericitization and limonization are the most important alteration phenomenon. Silicification is not very usual. Low rank metamorphic rocks of Upper Precambrian-Lower Cambrian age surround the ore deposits.

F1 in quartz veins have variable size (max.  $30 \ \mu$ m). Four main types were recognized three-phase (essentially H<sub>2</sub>O hquid-CO<sub>2</sub> L and V), two-phase (H<sub>2</sub>O L and V), single phase CO<sub>2</sub> and multiphase (with a solid-phase). The first two are very abundant in the ore deposits. The ductile and brittle deformation would have caused H<sub>2</sub>O loss of the 1. (Authors' abstract)

SASAKI, K., KANISAWA, S. and NAKAJIMA, K., 1998. Behaviors of CH<sub>4</sub> and CO<sub>2</sub> in contact metamorphic aureole around the Cretaceous Kurihashi pluton, Kitakami Mountains (abst.): Abstracts of 1998 Japan Earth and Planetary Sci. Joint Meeting, Tokyo, May 26-29, No. Mc-p011, p. 249 (in Japanese).

SASAKI, M., FUJIMOTO, K. and SAWAKI, T., 1998. Characteristics of a magma-related hydrothermal system in the Kakkonda granitic rocks (abst.): Abstracts of the 105th Annual Meeting of the Geological Society of Japan, p. 14 (in Japanese).

Indexed under FI (E.R.).

SASAKI, M., FUJIMOTO, K., SAWAKI, T., SASADA, M., KATO, O., DOI, N. and MURAMATSU, Y., 1998, Study on evolution of thermally metamorphic aureole and late-stage hydrothermal system in the Kakkonda geothermal field, northeast Japan (abst.): Abstracts with Programs, 48th Annual Meeting of the Society of Resource Geology, Tokyo, June 17-19, No. O-27 (in Japanese)

Indexed under FI (E.R.).

SASAKI, M., FUJIMOTO, K., SAWAKI, T., TSUKAMOTO, T., KU-ROSAWA, M., YAGI, M., MURAMATSU, Y., KATO, O. and DOI, N., 1998, Geochemical features of anhydrite from the Kakkonda geothermal field. northeast Japan (abst.): Abstracts with Programs, 48th Annual Meeting of the Society of Resource Geology, Tokyo, June 17-19, No.P-34 (in Japanese). Indexed under FI (E.R.)

SASAKI, M., FUJIMOTO, K., SAWAKI, T., TSUKAMOTO, H., MURAOKA, H., SASADA, M., OHTANI, T., YAGI, M., KURO-SAWA, M., DOI, N., KATO, O., KASAI, K., KOMATSU, R. and MU-RAMATSU, Y., 1998, Characterization of a magmatic/meteoric transition zone at the Kakkonda geothermal system, northeast Japan (abst.) in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 483-486.

Petrological and geochemical features of a transition zone between magmatic and meteoric environments have been investigated at the Kakkonda geothermal system. FI from hydrothermal veins suggest mixing of saline brine (magmatic) with low sal F (meteoric). The CL study reveals that deformation/fracturing mechanism might be different under low and high T conditions. Comparing the Pb-Zn-Cu ratios in the rocks. Pb and Zn are enriched in the shallow reservoir and Cu gradually increases with depth toward the granitic rocks. I F from a quartz vein in a grantic rock contain

metal elements (Pb. Zn and Cu) as well as major elements (Na, K, Ca, Fe, Mn and Cl). (Authors' abstract)

Th values 300-400°C, and sal of 0-35 wt% (E.R.).

SASSANI, D.C. and SHOCK, E.L., 1998, Solubility and transport of platinum-group elements in supercritical fluids. Summary and estimates of thermodynamic properties for ruthenium, rhodium, palladium, and platinum solids, aqueous ions, and complexes to 1000°C and 5 kbar. Geochim. et Cosmo. Acta, v. 62, no. 15, p. 2643-2671.

SATISH-KUMAR, M. and SANTOSH, M., 1998, A petrological and fluid inclusion study of cale-silicate-charnockite associations from southern Kerala, India Implications for CO<sub>2</sub> influx: Geological Mag, v 135, no. 1, p. 27-45. First author at Dept. of Geosci., Fac. of Sci., Osaka City Univ., Osaka 558, Japan.

FI studies indicate that the earliest generation of F preserved in the calc-silicate assemblages are aq (with sal ~8 wt.% NaCl eq.), consistent with mineral phase equilibria defining low aCO2. The estimation of NaCl content in brines coexisting with scapolite, based on the CI content of the scapolite, indicates the presence of up to 20 wt% NaCl during the formation of scapolite consistent with the saline P FI. Primary carbonic I occur within the retrogressed calcite+quartz assemblage after wollastonite, and are considered to represent the post-peak metamorphic carbonic F infiltration event, synchronous with the development of charnockites in the adjacent gneisses. These I have identical characteristics to those in the charnockites. We envisage that the Kerala Khondalite belt F regime was largely internally buffered during the prograde path, and that CO2 infiltration postdated peak metamorphism. Influx of CO2 was mostly structurally controlled, and occurred along a near-isothermal uplift path. Graphite-bearing pegmatitic dykes with abundant CO2-rich 1 in these localities attest to the transfer of carbonic F through magmatic conduits. (From authors' abstract by E.R.)

SATISH-KUMAR, M., YOSHIDA, M., WADA, H., NIITSUMA, N. and SANTOSH, M., 1998, Fluid flow along microfractures in calcite from a marble from east Antarctica: Evidence from gigantic (21‰) oxygen isotopic zonation: Geology, v. 26, no. 3, p. 251-254. First author at Dept. of Geosci., Osaka City Univ., Sumiyoshi, Osaka-558, Japan

Across a 1.2 mm-wide domain, a calcite crystal from a granulite-facies marble from east Antarctica exhibits microscale oxygen isotope heterogeneity that has been enhanced by channelized F flow. The oxygen isotope compositions range over 21%-a gigantic zonation. Calcite along a boundary with phlogopite has an average 518O value of -5%; along a profile that extends about 700 µm into the grain, the oxygen isotope composition remains constant, indicating equilibrium with source F of meteoric origin. Analyses of a transect away from the phlogopite show the  $\delta^{18}$ O values rising to 16‰. The corresponding carbon isotope variation is only about 0.6‰. Isotope heterogeneity is observed mainly in a phlogopite-rich zone where the 818O values are lower (1316 5%) than those away from the zone (17%o±1%o). We inferred that preferential microfracturing and hydrothermal F flow were the causes of the 18O distribution. The constant values of both  $\delta^{18}$ O and  $\delta^{13}$ C for the distance of 700 µm from the grain boundary suggest a solution-reprecipitated calcite and the original grain (core). Our results provide important evidence for the mechanism of isotope exchange between F and minerals and have major implications for microfracture-controlled F-flow processes in the Earth's crust. (Authors' abstract)

SAUSSE, Judith, GENTER, Albert, LEROY, J.L. and LESPINASSE, Marc, 1998, Description and quantification of vein alterations: palaeopermeabilities in the Soultz-sous-Forets granite (Bas-Rhin, France): Bull. Soc. géol. France. v. 169, no. 5, p. 655-664 (in French; Engl. abst. and summary). First author at UMR G2R (7566), UHP Nancy 1, BP 239, F<sup>-</sup> 54506, Vandœuvre cedex.

Discusses the origin and distribution of healed fractures in granite (H.E.B.)

SAVARD, M.M. and CHI, Guoxiang, 1998, Cation study of fluid inclusions decrepitates in the Jubilee and Gays River (Canada) Zn-Pb deposits—Characterization of ore-forming brines: Econ. Geol., v. 93, p. 920-931, Authors at Geological Survey of Canada-Quebec, Centre Geoscientifique de Quebec, 2535 Laurier, P.O. Box 7500, Sainte-Foy, Quebec, Canada G1V 4C7; email (msavard@nrcan.gc.ca)

A SEM-EDS instrument sensitive to C and O is used to measure cation ratios in individual FI decrepitates of main paragenetic phases from two Nova Scotian Mississippi Valley-type deposits. The technique confirms that the analyses obtained for the carbonate hosts are not contaminated by substrate and permits measurements of small amounts of decrepitates. The technique has been used to investigate F compositions in I of presulfide-stage dolomite and calcite, sulfide-stage sphalerite and calcites, and postsulfide calcite at the Gays River and Jubilee Zn-Pb deposits in Nova Scotia. The results indicate that Na and Ca are the two major cations. Minor amounts of K and Mg are also detected. NaCl and CaCl2 ranges for decrepitates from the two deposits are as broad as for modern mixed brines and thereby suggest that solution mixing partly controlled the paleobrine compositions. When compared to other Mississippi Valley-type deposits, the Gays River and Jubilee deposits are similar in NaCl-CaCl2-KCl composition to a group of Mississippi Valley-type districts including deposits from the Ozark region that are associated with large volume clastic sequences or paleoaquifers. Higher proportions of KCI at Gays River and higher proportions of CaCl2 at Jubilee indicate that the mineralizing brines interacted with Horton Group clastic aquifers of different mineral compositions. The brines in the two areas might have originated from evaporation of seawater, but they were later modified by interaction with clastic rocks of different compositions. (Authors' abstract)

See also Chi et al., Kontak, and Kontak & Sangster, this volume (E.R.).

SAVCHUK, Yu.S., MIRKAMALOV, R.Kh. and VANESYAN, G.A., 1998, The magma- and ore-generating role of subduction zones (as exemplified by the Southern Tien-Shan, Uzbekistan) (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 64-69 (in Russian).

SAVOYE, Sebastien, ARANYOSSY, J.-F., BEAUCAIRE, Catherine, CATHELINEAU, Michel, LOUVAT, Didier and MICHELOT, J.-L., 1998, Fluid inclusions in granites and their relationships with present-day groundwater chemistry: Eur. J. Mineral., 1998, no. 10, p. 1215-1226. First author at CEA-SACLAY, DCC/DESD/SESD, F'91191, Gif-sur-Yvette Cedex, France; email (savoye@cea.fr)

Some granitic deep groundwaters have high chloride contents of which the origin is still unclear. Among the different possibilities, leakage of Fl trapped in P minerals was proposed. This hypothesis is examined by studying four granitic sites with various hydrogeological features: drillcores from Äspö (Sweden); Boettstein and Leuggern (northern Switzerland); outcropping granites and drill-core samples from Cauterets and Luchon in the Pyrenees (France); In Tounine granitic massif (Central Ahaggar, Algeria). With the exception of In Tounine, a part of the granite samples selected in each study site displays salt-rich Fl with sal ranging from 22 to 26 wt.% NaCl eq., calcium contents and minimal T, typical of deep sedimentary brines. Most salt-rich Fl occur in S Fl planes in magmatic quartz, but were also found within fissure-in-filling calcite at Boettestein and Äspö.

The wide ranges of Cl/Br ratios in single same rock samples, due to heterogeneities in Fl distribution in rock-forming minerals, and the variability of Cl/Br ratios in F reservoirs, render the use of Cl/Br ratios for F<sup>-</sup> source tracing inaccurate. Only salt-rich l in the Pyrenees samples show a relatively narrow range of Cl/Br ratios, similar to those of associated groundwaters.

Mass-balance calculations based on sal estimates from microthermometry, crush-leach analyses and I counting, coupled with the study of possible mechanisms for leakage, demonstrate that the relatively high sal of deep groundwaters (Boettstein and Äspö) cannot only be accounted for by the leakage of FI trapped in quartz. It cannot be totally excluded that FI may be responsible for the major part of chloride in groundwaters with relatively low sal (Leuggern 1647 m, Cauterets, Luchon, Ahaggar).

The leakage of S FI trapped in P minerals cannot be considered as the main process responsible for the high sal of present-day deep groundwaters in the studied sites. However, the presence of S salt-rich I indicates that sedimentary brines have already percolated the granites, a datum which is important for the evaluation of the hydrogeological history and for the understanding of the modalities of chlorine introduction in the crystalline basement. (Authors' abstract)

SAWAKI, T., 1998, Occurrence and geochemistry of fluid inclusions in granitic rocks in Japan. Newsletter, Japanese Assoc. Geothermal Fluid Inclusionists, no. 8, Feb. 1998, p. 1-28 (in Japanese). Author at Geological Survey of Japan.

An extensive review of the occurrence and phase composition of F1 from 109 plutons, plus microthermometric data for many of these, differentiated into magnetite- and ilmenite-series. and G contents. (E.R.)

SAWAKI, T., SASADA, M. and SASAKI, M., 1998a, Geochemical features of fluid inclusions of granitic rocks in Japan (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A33. Authors at Geothermal Research Dept, Geological Survey of Japan; email (sawaki@gsj.go.jp)

We have studied FI in quartz mainly from granitic rocks (pegmatites) in Japan, additionally from metamorphic rocks, in order to elucidate geochemical features of volatiles released from granitic magma during crystallization. Gases of the I were analyzed by a quadrupole mass spectrometer and a capacitance manometer. In granitic rocks in Japan, (1) aq two-phase L-rich, (2) aq two-phase V-rich, (3) monophase L, (4) L CO<sub>2</sub>-bearing aq, and (5) dm (e.g. halite)-bearing multiphase I occur. Aq two-phase L-rich I occur in Cretaceous ones. Coexistence of dm-bearing and V-rich I are frequent in Tertiary granitic rocks, and indicates that these I trapped twophase F. Granitic rocks whose FI trapped two-phase F were probably emplaced at shallower than 5 km in depth in the crust, based on a phase diagram of NaCl solution and solidus of granitic rocks.

Gas analyses show that H2O is the main component of all FI (88 mol%<), and that CO2 is the main G for almost the samples (12 mol%>) with subordinate amounts of N2 (1.9 mol%>), CH4 (2.8 mol%>) and Ar (0.0004 mol%>), except for I in pegmatitic quartz from the Hidaka belt where granitic magma was probably produced by anatexis of metamorphic rocks. FI from the Hidaka belt are characterized by relatively high CH4 (0 16-9.6 mol%) and N2 (0.03-1.8 mol%) contents, compared to CO2 (0.09-0.94 mol%) FI from S-type granitic rocks in the Outer Zone of southwestern Japan also have slightly high contents of CH4. The high CH4 and N2 contents possibly related to the partial M of sediments. The variation of CO2/CH4 ratios may reflect the difference of /O2 around the granitic rocks where the F flew. CO2/CH4 ratios of I from magnetite-series granitic rocks are slightly higher than those from ilmenite-series ones. Magnetiteseries granites are thought to be formed under higher fO2 condition than ilmenite series. The G ratios are consistent with it, and the analytical results suggest that G compositions of FI are probably controlled by source of granitic magma. (Authors' abstract)

SAWAKI, T., SASADA, M. and SASAKI, M., 1998b, Geochemistry of fluid inclusions in granites and pegmatites from Japan (III) (abst.) Abstracts of the 105th Annual Meeting of the Geological Society of Japan, p. 182 (in Japanese).

See previous abstract (E.R.).

SAWAKI, T., SASAKI, M., FUJIMOTO, K., TAKENO, N., SANADA, K. and MAEDA, S., 1998, Corundum and zincian spinel from the Kakkonda geothermal system, Iwate Prefecture (abst.): 1998 Annual Meeting of the Mineralogical Society of Japan/Japan Association of Mineralogists, Petrologists and Economic Geologists, Kyushu University, Oct 8-10, 1998, p. 173 (in Japanese, Engl. abst. courtesy of T. Sawaki).

Corundum and zincian spinel were found in a drill core of thermally metamorphosed rock at 2843 m in depth of the deep research well, WD-1, which had been drilled in the Kakkonda geothermal area. G-rich Fl occur in corundum, and CO<sub>2</sub>, H<sub>2</sub>S and N<sub>2</sub> were detected in the I by a laser Raman microprobe. The analyses of Fl may indicate F compositions produced at the thermal metamorphism or the earliest stage of geothermal activity. (Authors' abstract)

SAWAKI, Takayuki, SASAKI, Munetake and SASADA, Masakatsu, 1998, Geochemical features of fluid inclusions from the Onikobe geothermal system, northeast Japan: J. Geol. Soc. Japan, v. 104, no. 12, p. 813-824 (in Japanese, Engl. abst.)

First author at Geothermal Research Dept., Geological Survey of Japan, 1-1-3 Higashi, Tsukuba, Ibaraki 305-8567, Japan.

Gases of FI in quartz and anhydrite from the Onikobe geothermal system, northeast Japan, were analyzed with a quadrupole mass spectrometer and a capacitance manometer. The geothermal wells of KR-series are located in the Onikobe caldera where Tertiary-Quaternary volcanic rocks are underlain by Cretaceous granitic and metamorphic rocks. The quartz and anhydrite occur in hydrothermal veins in volcanic, granitic and metamorphic rocks recovered from the geothermal well.s

Results of individual FI analyses show that the FI comprise mainly H<sub>2</sub>O and a variable but small amount of CO<sub>2</sub>. Nitrogen and CH<sub>4</sub> were not detected, but H<sub>2</sub>S was detected in samples at the bottom of well KR-1 Results of bulk analyses show that the I are mainly composed of H<sub>2</sub>O (98-99 mol%) with small amounts of non-condensable G, mainly CO<sub>2</sub> with

small amounts of N2 and CH4. The proportion of N2 is about one order of magnitude lower than CO2, CH4 is generally two orders of magnitude lower than CO2, and Ar is quite small and just above the detection limit of the mass spectrometer. The CO2 content of Fl in guartz from 1350.5 m in well KR-1 is relatively high, compared with other 1 in this area and other geothermal systems. The high Th and G content suggest that high-T and Grich geothermal F was trapped at the deep levels of well KR-1. The CO2/N2 and CO2/CH4 ratios of the FI in quartz from well KR-5, which were formed at the early and high-T stage of the geothermal activity, are higher than those in anhydrite formed at the late stage. This shows that the chemical composition of the geothermal F has changed with time. The CO2 contents of FI in quartz from wells KR-1 and KR-5 are inconsistent with G buffered by alteration minerals. These FI probably trapped F which were not in equilibrium with the alteration mineral assemblages. On the other hand, the CO<sub>2</sub> contents of FI in anhydrite from well KR-5, which were formed at the late stage, are consistent with the kaolinite-bearing mineral buffer system. This suggests that the I may represent the geothermal F at the formation of kaolinite at well KR-5. (Authors' abstract)

#### SCAMBELLURI, M., PENNACCHIONI, G. and PHILIPPOT, P., 1998, Salt-rich aqueous fluids formed during eclogitization of metabasites in the Alpine continental crust (Austroalpine Mt. Emilius unit, Italian western Alps): Lithos, v. 43, p. 151-167. First author at Dipartimento dì Scienze della Terra. Università di Genova, Corso Europa 26, 16132 Genova, Italy; email (msca@dister.unige.it)

The metabasite bodies of the western Italian Alps underwent eclogiticfacies metamorphism (1.1-1.3 GPa and 450-550°C). The metabasites consist of two main rock types' eclogites and eclogitized granulites. In both eclogites and eclogitized granulites hydrated high-P foliations are cut by eclogitic metamorphic veins. The bulk rock chemistry of the metabasites influenced the compositions of both the vein- and rock-forming clinopyroxenes and the compositional correlation between the vein- and rockforming clinopyroxenes indicates that the syn-eclogitic F have reequilibrated with the metabasite hosts. The predominant vein minerals (omphacite, epidote and garnet) contain P high-sal FI. The F consist of two-phase (L+V) and of multiphase (L+V+salt+additional quartz) salty aq 1 containing NaCl, CaCl2 and MgCl2 as the main chloride species. The vein I show a sal range from 17 to 45 wt.% NaCl eq.% salts in eclogites and from 20 to 50 wt.% salts in eclogitized granulites. In contrast, FI in matrix minerals of the eclogitized granulites contain P two-phase I displaying a sal range between 10 and 25 wt.% salts. The marked difference in F sal recorded by the 1 in the eclogitic veins and those in the partially re-equilibrated eclogitized granulites is interpreted in terms of progressive hydration during eclogitication of granulite-facies rocks, which caused an increase in the salt content of the residual I F. (From authors' abstract by E.R.)

SCHEDL, Andrew, 1998, Log ratio methods for establishing a reference frame for chemical change: J. of Geol., v. 106, no. 2, p. 211-228.

A long-standing but often ignored problem in geology is the fact that compositional data are closed, i.e., data sum to a constant and, thus, are not amenable to standard statistical techniques. The undesirable properties of closure can be overcome by converting compositional data to log ratios; the transformed data can usually be analyzed with parametric statistics. Woronow and Love proposed tests for establishing immobile element reference frames for measuring chemical change. These tests are independent of the usual assumption that AI, Ti, Zr and the rare earth elements are immobile, an assumption contradicted by field studies and laboratory experiments suggesting that these elements are sometimes mobile. In this paper, Woronow and Love's tests are examined using an intuitive-geometric approach. Although their tests are generally sound, modifications are proposed to make them more powerful. An additional test for immobility is proposed using variance ratios. These tests were applied to the alteration of the Bingham porphyry deposit. Results suggest that SiO2 is a better reference frame for examining chemical changes than the presumably immobile oxide. Al2O3 Immobility of SiO2 is consistent with low water/rock ratios. acid leaching, and multidirectional F flow inferred from stable isotope and FI data for the Bingham porphyry; thus SiO2 provides a geologically reasonable reference frame at Bingham. Identification of SiO2 as an immobile component shows that this method can lead to unexpected results, which transcend conventional assumptions about fixed components or constant rock values (Author's abstract)

SCHIANO, Pierre, BOURDON, Bernard, CLOCCHIATTI, Robert, MASSARE, Dominique, VARELA, M.E. and BOTTINGA, Yan, 1998, Low-degree partial melting trends recorded in upper mantle minerals:

The study of glass I inside mantle minerals provides direct information about the chemistry of naturally occurring mantle-derived M and the finescale complexity of the melting process responsible for their genesis. Minerals in a spinel lherzolite nodule from Grande Comore island contain glass I which, after homogenization by heating, exhibit a continuous suite of chemical compositions clearly distinct from that of the host basanitic lava. The compositions range from silicic, with nepheline-olivine normative, 64 wt% SiO2 and 11 wt% alkali oxides, to almost basaltic, with quartz normative, 50 wt% SiO<sub>7</sub> and 1-2 wt% alkali oxides. Within a single mineral phase, olivine, the inferred P M composition varies from 54 to 64 wt% SiO2 for MgO content ranging from 8 to 0.8 wt%. An experimental study of the glass and FI indicates that trapped M represent L that are in equilibrium with their host phases at moderate T and P (T nearly=1230°C and P nearly +1.0 GPa for M trapped in olivine). Quantitative modeling of the compositional trends defined in the suite shows that all of the glasses are part of a cogenetic set of M formed by fractional melting of spinel lherzolite, with F varying between 0.2 and 5%. The initial highly silicic, alkalirich M preserved in Mg-rich olivine become richer in FeO, MgO, CaO and Cr2O3 and poorer in SiO2, K2O, Na2O, Al2O3 and CI with increasing M fractions, evolving toward the basaltic M found in clinopyroxene. These results confirm the connection between glass I inside mantle minerals and partial mantle M, and indicate that P M with SiO2>60 wt%, alkali oxides>11%, FeO<1 wt% and MgO<1 wt% are generated during incipient melting of spinel peridotite. The composition of the P M is inferred to be dependent on P, and to reflect both the speciation of dissolved CO2 and the effect of alkali oxides on the silica activity coefficient in the M. At P around I GPa, low-degree M are characterized by alkali and silica-rich compositions, with a limited effected of dissolved CO2 and a decreased silica activity coefficient caused by the presence of alkali oxides, whereas at higher P alkali oxides form complexes with carbonates and, consequently, alkali-rich silica-poor M will be generated. (Authors' abstract)

SCHMIDT, B.C., BEHRENS, H., TAMIC, N., HOLTZ, F. and PI-CHAVANT, M., 1998, Water solubility in haplogranitic melts coexisting with H<sub>2</sub>O-H<sub>2</sub> and H<sub>2</sub>O-CO<sub>2</sub> fluids (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1343.

SCHMIDT, Christian and BODNAR, R.J., 1998, The system H<sub>2</sub>O-NaCl-CO<sub>2</sub> at elevated temperatures, pressures, and salinities: Solvi, lines of equal homogenization temperature, and critical points (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 58. First author at GeoForschungsZentrum Potsdam, Albert-Einstein-Strasse (Telegrafenberg), 14473 Potsdam, Germany; email (hokie@gfz-potsdam.de; bubbles@vt.edu)

The interpretation of naturally occurring H<sub>2</sub>O-NaCl-CO<sub>2</sub> Fl usually requires the availability of volumetric and phase equilibrium data over a large range of PTX conditions. However, little is known about isochore locations at sal above about 10 wt% NaCl and the critical points in this ternary system. In this study, solvi and lines of equal Th in the system H<sub>2</sub>O-NaCl-CO<sub>2</sub> were determined experimentally for P between about 1 to 6 kbar, T of 300° to 800°C, and F compositions up to 40 wt% NaCl and 20 mol% CO<sub>2</sub>, both relative to water. Critical T were determined for ternary compositions up to 20 wt% NaCl and up to 20 mol% CO<sub>2</sub> relative to water. The dataset was obtained by using the synthetic Fl technique in conjunction with conventional microthermometry and a hydrothermal diamond-anvil cell.

At constant sal, the high-P portion of the solvus shows a very significant shift to higher P and T with increasing CO<sub>2</sub> concentration. For a constant Th, the dP/dT slopes of the lines of equal Th become steeper (higher) along pseudobinaries with addition of carbon dioxide and particularly with the addition of NaCl. Up to concentrations of 20 wt% NaCl and 20 mol% CO<sub>2</sub>, a sharp rise in the critical T was observed with increasing sal at a fixed H<sub>2</sub>O/CO<sub>2</sub> ratio. Addition of carbon dioxide causes rapid migration of the critical point towards higher P. With increasing  $X(CO_2)$ , experimentally determined P-T locations of solvi, lines of constant Th/isochores, and critical points (Gehrig, 1980; this study) can deviate significantly from those calculated using the equation of Duan et al. (1995)

See figure in the Illustrations appendix.

SCHMIDT, Christian, CHOU, I.-M., BODNAR, R.J. and BASSETT, W.A., 1998. Microthermometric analysis of synthetic fluid inclusions in the hydrothermal diamond-anvil cell: American Mineralogist. v. 83, p. 995-1007. First author at GeoForschungsZentrum Potsdam. Telegrafenberg D329. Potsdam 14473, Germany. The hydrothermal diamond-anvil cell (HDAC) was employed as a pressurized FI heating stage to determine T of phase transitions in synthetic FI in quartz. Using this technique, the common problem of decrepitation or stretching of I having high internal P was eliminated.

Th of pure H<sub>2</sub>O synthetic I determined in the HDAC are inversely related to the confining P exerted on the sample, suggesting a decrease in I volume with increasing confining P. The very good reproducibility and reversibility of these experiments indicate that volume changes during heating under confining P in the HDAC are elastic in nature. However, results of microthermometric experiments in the HDAC indicate that the change in Th is significantly larger than would be predicted by the EOS for quartz and water. This difference reflects an additional component of volume change related to stress within the quartz host, causing displacement of the I walls into the I cavity, as predicted by theoretical models describing the behavior of I in minerals.

L-V Th and halite dissolution T (Tm halite) were determined for synthetic FI in the ternary H2O-NaCI-CO2. The measured Th were regressed as a function of confining P at Th(L-V) The intersection of the Th(L-V)confining P curve with an independently obtained P-T curve for the solvus of the same temary composition provides the "correct" Th, that is, the Th corresponding to a confining P equal to the P on the solvus at that same T. This method for determining corrected Th(L-V) is based on the assumption that the effect of elastic stress on Th(L-V) approaches zero as the confining P approaches the internal P in the I at homogenization. The Th(L-V) values at these intersection points were used to calculate lines of constant Th (iso-Th lines) For a composition of H2O+40 wt% NaCl+10 mol% CO2. the iso-Th slopes decrease from about 53 bar/°C at Th(L-V)=500°C to 8 5 bar/°C for Th(L-V)=650°C. The halite dissolution T (in the presence of L and V) averages 342°C (range±6°C) without recognizable P dependence. The slopes of iso-Th lines for a composition of H2O+20 wt% NaC1+20 mol% CO2 decrease from approximately 23 bar/°C at Th(L-V)=475°C to 6 bar/ºC for Th(L-V)=600°C.

Using the HDAC technique, the high-P portion of the halite liquidus was redetermined for an H<sub>2</sub>O-NaCl solution containing 40 wt% NaCl. These new measurements confirm the data of Bodnar (1994), which were obtained using a G-flow heating stage at 1 atm confining P. This indicates that Bodnar's (1994) observation of an essentially P independent liquidus at P>-2bar is real and not a result of I stretching. (Authors' abstract)

SCHMIDT MUMM, A., OBERTHÜR, T., VETTER, U. and BLEN-KINSOP, T.G., 1998. High CO<sub>2</sub> content of fluid inclusions in gold mineralisations in the Ashanti Belt, Ghana: A new category of ore forming fluids? A reply: Mineralium Deposita, v. 33, p. 320-322. First author at Institute für Geologische Wissenschaften und Geiseltalmuseum, Universität Halle, Donstr. 5, D-06108 Halle/Saale, Germany; email (Schmidt-Mumm@geologie.uni-halle.de)

A reply to a comment by Klemd (1998, this volume) of the 1997 paper (E.R.).

SCHIMMRICH, S.H. and MARSHAK, Stephen, 1998. Veins in the Siluro-Devonian strata of the Hudson Valley. New York: Investigating the plumbing system of a foreland fold-thrust belt (abst.): The Geological Society of America 33<sup>rd</sup> Annual Meeting, Northeastern Section, March 19-21, 1998, Portland, Maine, v. 30, no. 1, p. 73, ISSN 0016-7592. First author at Dept. of Physical Sci., Kutztown Univ., Kutztown, PA 19530; email (schimmri@kutztown.edu)

The Hudson Valley Fold-Thrust Belt (HVB) consists of deformed Siluro-Devonian strata exposed in a narrow (2-3 km wide) belt west of the Hudson River in eastern New York. Excellent exposures permit determination of the relationship among regional and mesoscopic folds and faults. cleavage, and veins. Calcite veining intensity is stratigraphically controlled, with most veins occurring in clay-poor lithologic units. While calcite veins occur in several distinct structural settings within the HVB, most of the veins clearly formed synchronously with the development of folds and faults. Petrographic, luminescent, and trace-element examinations of the veins indicate that individual vein sets are chemically homogeneous even where they appear to have grown during several increments. Stableisotope, trace-element, and FI results indicate vein forming F reached T of at least 180 to 250°C, with very large water/rock ratios during vein formation, and that the F interacted with the crystalline basement. These data also show that veins from different segments of the HVB, along strike, formed from F with different initial T and geochemical signatures. Specifically, F in the northern portion of the HVB, near Albany, were significantly hotter and geochemically distinct from F in the southern portion of the HVB near Kingston.

In sum, our data indicate that calcite veins in the HVB formed when large volumes of relatively hot vein-forming F passed through the HVB during deformation, and that these F had interacted and equilibrated with the underlying Grenville basement rocks prior to entering the Paleozoic sequence, perhaps through pre-existing faults. Once in the fold-thrust belt, ions in the F precipitated to form veins along faults and within thrust sheets during deformation. In other words, the plumbing that carries vein-forming F into a fold-thrust connects to underlying crystalline basement. Heat advected into the thrust belt by rising F during deformation also may have affected the style of deformation in the belt. (Authors' abstract)

SCHOFIELD, P.F., 1998, Gold complexation by chloride-bearing fluids (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A131

SCOTT, A.-M. and WATANABE, Y., 1998, "Extreme boiling" model for variable salinity of the Hokko low-sulfidation epithermal Au prospect, southwestern Hokkaido, Japan: Mineralium Deposita, v. 33, p. 568-578. Authors at Geological Survey of Japan, Mineral and Fuel Resources Dept., 1-1-3 Higashi, Tsukuba, 305-8567, Japan; email (watanabe@gsj.go.jp.)

The Hokko prospect shows gold-bearing quartz veins of Pliocene age exposed at the surface. The alteration mineral assemblage is typical of lowsulfidation epithermal systems, with the quartz veins associated with adularia alteration overprinted on Late Miocene propylitic alteration. Fl studies of the vein quartz reveal mean Th of approximately 220°C, and the coexistence of low-sal (<2 wt.% NaCl eq.) and moderate sal (2 to 12 wt.% NaCl eq.) FI within the same veins. The moderate sal FI (2-12 wt.% NaCl eq.) typically have relatively low Th between 150 to 200°C. S18O in quartz. showed a gradual decrease with increasing depth. We interpret that low-sal I within the Hokko system represent the composition of the L phase of the F, before boiling, and that the moderate-sal I are representative of the residual L phase, after extensive non-adiabatic boiling and V loss in an open system. Deposition of ore minerals within the Hokko vein system also occurred at this time as a result of boiling and G loss. (From authors' abstract by E.R.)

SECCOMBE, P.K., OFFLER, Robin, AYSHFORD, Shaun and DOWNES, P.M., 1998, Skarn formation and metamorphism: The Palaeozoic magnetite skarn at Tallawang, NSW, Australia (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A168-A169 First author at Dept. of Geol., The Univ. of Newcastle, Callaghan, NSW 2308 Australia; email (psecia geology.newcastle.edu.au)

Located near Gulgong, NSW and a source of high-grade magnetite for coal beneficiation, the Tallawang magnetite orebodies represent an economic Fe-skam developed in the Palaeozoic Lachlan Fold Belt of eastern Australia. The deposit lies within units of the Hill End Trough, adjacent to the post-orogenic, Early Carboniferous Gulgong Granite. Mineralisation has developed within the Dungaree Volcanics, in a sequence of felsic and basic metavolcanics and pelitic and calcareous metasediments of Silurian age, at the margin of a deformed, sill-like microgranodiorite intrusion (Tallawang Granite). Structurally disrupted and deformed, pod-like bodies of semi-massive magnetite and calc-silicates dip steeply W at the contact of the deformed granodiorite.

Skarn formation developed in two major stages. An anhydrous skarn assemblage comprising magnetite, garnet (grossularite-andradite) and hedenbergite formed by contact metamorphism at shallow levels in a continental arc environment (P~1 kb; T-600-650°C) Brecciation of the magnetite preceded a hydrous stage of skarn formation involving deposition of further magnetite, accompanied by Cl-rich hastingsite, hastingsitehornblende, allanite, epidote, quartz, apatite and pyrite.

Veins containing a retrograde metamorphic assemblage of chlonte+epidote+calcite+quartz+(actinolite) were established under greenschist facies conditions, consistent with FI Th data in the range 350-365°C for carbonic and aq FI from vein quartz and epidote Emplacement of the Early Carboniferous Gulgong Granite has had little effect on the skam deposit and represents the onset of late brittle deformation and minor sulfide mineralisation. (From authors' abstract by H.E.B.)

SEE, Jeannette, 1994. The analysis of fluid inclusions and magmatism of gold deposits in the Lake Shortt region, Abitibi, Quebec: Thermodynamic interpretation and metallogeny of the role of mineralizing F in the Archean: PhD dissertation. Univ. du Québec at Chicoutimi. 240 pp (in French. Engl. abst.)

Microthermometric analyses of FI indicate four principal types of FI based on the relative proportions of phases observed either at room T or at sub-zero T: Type 1: Aq I (H2O-NaCl-low sal), L-rich, one- or two-phase (2-5% vol. of vapour), S origin Type 2 Aq I, two-phase (10-20% vol of vapour), representing the most abundant type in different generations of quartz and consisting of brine assemblages (H2O-NaCI-MgCl2?, -KCl?, CaCl2?). Type 3 Carbonic I (H2O-CO2-NaCl) with variable phase ratios. occurring either in planar clusters or isolated (P characteristics); Type 4 Carbonic I (CO2-H2O-CH4+N2?, +H2S?) with variable phase ratios: G-rich (one-phase) or L-rich with CO2-CH4 L+V

The present FI study indicates that the principal mechanism for the transport and the precipitation of gold is by exsolution of carbonic-vapor phases and aq saline phases that are responsible for the disseminated-style mineralization during the emplacement of the intrusions. P drops and density and fugacity variations induce the onset of intermittent unmixing of F phases rich in CO2-H2O-NaCl predominant in mineralized quartz veins. This study shows that plutons of alkaline and non-alkaline compositions which are emplaced synchronously with the mineralization can play an important role in determining the localization and the different styles of gold mineralization in the Archean (From authors' abstract by H E B )

SEIMBILLE, François, ZUDDAS, Pierpaolo and MICHARD, Gil, 1998, Granite-hydrothermal interaction: A simultaneous estimation of the mineral dissolution rate based on the isotopic doping technique: Earth and Planet. Sci. Letters, v. 157, no. 3-4, p. 183-191. Indexed under FI.

SEKINE, K., BANDO, M. and TSUCHIYA, N., 1998. Hydrothermal activity and fluid inclusions in Takidani Granodiorite in the Japan Alps, Central Japan (abst.): Abstracts of the 105th Annual Meeting of the Geological Society of Japan, p. 353 (in Japanese).

SELBY, David, 1998, Geochemistry of porphyry Cu-Au-Mo potassic ore fluids: A case study from the Yukon, Canada: SEG Newsletter, No. 35, p. 6, 1998: Author at Dept. of Earth and Atmospheric Sci., Univ. of Alberta, Edmonton, Alberta, Canada

Stable and radiogenic isotopes are used to determine the geochemistry and origins of potassic ore F at the Casino. Mount Nansen, and Cash. Late Cretaceous (70 Ma) porphyry Cu-Au-Mo deposits. The plutons intrude country rocks of Devono-Mississippian metamorphic rocks and the mid-Cretaceous Dawson Range Batholith. Potassic quartz veins contain a dominant assemblage of coexisting saline and V-rich FI. The I F possess δD values of -140 to -180%, which deviate significantly from values typically reported for P porphyry F (-40 to -100%). The \$7/86Sr = 70 (t=70 means isotope ratios are calculated for 70 Ma) values of the Late Cretaceous plutons are 0.7055 (Casino), 0.7048 (Mount Nansen), and 0.7055 (Cash). The 87/86Sr,=10 compositions of hydrothermal K feldspar are 0.70551 to 0.70834 (n=8; Casino), 0.7063 to 0.7070 (n=4: Mount Nansen), and 0.7058 (n=1; Cash). Analysis of F derived from crushed I F from quartz veins shows  $^{87}$ / $^{86}$ Sr<sub>r=70</sub> compositions that are virtually identical to K feldspar compositions. The  $^{87}$ / $^{86}$ Sr<sub>r=70</sub> values of K feldspar samples describe an increasing radiogenic Sr composition, which is also observed for identical samples for common Pb. The <sup>87/86</sup>Sr<sub>17-70</sub> compositions of hydrothermal K feldspar and I F from quartz veins range from values similar to the genetically related plutons toward more radiogenic composition. Hydrogen. Sr. and Pb isotope results indicate the presence of a low \deltaD, radiogenic Sr, and Pb component in the potassic ore F. Ndr-70 isotope values of plutons are -0.1 (Casino), 1.6 (Mount Nansen), and -0.4 (Cash), which are distinctly more juvenile than those of neighboring country rocks: -4.8 to -6.1 (Dawson Range Batholith), and -6.1 to -14.5 (Devono-Mississippian metamorphic rocks). These data suggest that assimilation of crustal material by the magma was not a major mechanism in generating the hydrogen, Sr. and common Pb isotope values seen in the ore F. The isotope data indicate that the origin of these potassic ore F is not purely magmatic. To generate the H, Sr, and Pb isotope composition, regional crustal F must be a component in the potassic ore F in porphyry mineralization. (Author's abstract)

SELBY, D., NESBITT, B.E., CREASER, R.A. and MUEHLEN-BACHS, K., 1998, The geochemistry of porphyry Cu potassic hydrothermal fluids: Implications for replenishment of the magma chamber or involvement of crustal fluids (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-76. Authors at Earth and Atmospheric Sci., Univ of Alberta, Edmonton, Alberta, T6G 2E3; email (dselby@gpu.srv.ualberta.ca)

The Sr, Pb, and H isotope compositions have been determined for porphyty Cu potassic stage F from hydrothermal K-feldspar and vem

quartz &D values of hypersaline (30-55 NaCl wt.%) | F from guartz veins are -140 to -180‰. The Sr compositions of K-feldspar and quartz vein 1 F are similar, with values trending away from magmatic values toward more radiogenic compositions. The Pb isotopic compositions of the K-feldspars also describe a trend toward more radiogenic values. The H, Sr and Pb isotopic data indicate the presence of D-depleted and radiogenic Sr and Pb compositions in potassic stage hydrothermal F. Evaluation of Sr and Pb diffusion in K-feldspar indicate that the isotopic compositions are not a product of interaction with late stage hydrothermal F and we propose that the values reflect those of the potassic stage hydrothermal F. The possible processes to produce the H, Sr and Pb isotopic compositions are: (1) replenishment of the magma chamber by more radiogenic magma, (2) involvement of crustal F The Sr and Pb isotopic data can be interpreted to be generated from both processes 1 and 2. However, the depleted H isotope ratios suggest the involvement of crustal F of meteoric origin. Though the radiogenic isotopic data correlated with the replenishment of a magma chamber of involvement of crustal F. the decrease in sal (55 to 33 wt.% NaCl) and depleted H isotope ratio suggest that crustal F of meteoric origin are an important component in potassic hydrothermal F. (Authors' abstract)

SEWARD, T.M., 1998, Spectroscopic studies of hydrothermal solutions (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A135.

SEWARD, T.M., HENDERSON, C.M.B. and CHARNOCK, J.M., 1998, X-ray absorption spectroscopic (EXAFS) measurements on aqueous solutions to 350°C (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1369.

SHAIL, R.K., STUART, F.M. and WILKINSON, J.J., 1998, Mantle contributions to Permian granite magmatism and mineralization in SW England-a preliminary noble gas study (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated). First author at Camborne School of Mines, Univ. of Exeter, Redruth, Cornwall TR15 3SE.

A mantle component within the Permian granites of SW England has been inferred on [various bases]. Recognition of such a mantle component has significant implications for models of both granite generation and associated magmatic-hydrothermal W-Sn-Cu mineralization.

The purpose of this study was to test the mantle component hypothesis by analysing the <sup>3</sup>He/<sup>4</sup>He ratios of FI volatiles within mineral specimens sampled from early magmatic-hydrothermal veins across the region. Where FI are trapped by U- and Th-poor, dense minerals, the outward diffusion rate of He is low and the isotope ratios are essentially unmodified from the time of trapping.

The FI in wolframite/arsenopyrite sampled from early magmatichydrothermal veins across the region have an unambiguous mantle He component. (From authors' abstract by E.R.)

SHAMAÉV, O.T., 1998, Peculiarities of formation and the kinds of ores in the deposits of the Altyntopkan orefield (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998. Tashkent. Uzbekistan. Abstracts volume, p. 86-88 (in Russian).

SHANINA, S.N., 1998, Pyrochromatography inclusions in salts (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A33. Author at Inst. of Geol., RAS, Ural Div., Russia; email (common@geo.komi.ru)

Pyrochromatography [i.e., G chromatography] includes sample destruction and extraction of I content by heating.

It is known that organic I up to oil are widespread in natural salts. Of special interest is study of organic I in minerals from the Komi Republic salt deposits (Seregovo, Kechmes) where such kind of investigations have never been carried out.

Chromatographic analyses of organic I were carried out on halite crystals from several salt deposits: Kechmes (Komi), Klodava (Poland), Karvakh (Yemen). The analyses were used to determine the presence and specify the nature, quantities and location of organic substance. (From author's abstract by E.R.)

SHARAPOV, V.N., PAVLOV, A.L. and AKIMTSEV, V.A., 1998. Physicochemical parameters of formation of ore melts and fluid phase in magma chambers under the mid-oceanic ridges. Geologiya Rudnykh Mestorozhdenii, v. 40, no. 3, p. 278-291, in Russian, translated in Geology of Ore Deposits, v. 40, no. 3, p. 250-262. Authors at Joint Inst. of Geol., Geophys., and Mineral., Siberian Div., Russian Acad. of Sci., Universitetskii pr. 3, Novosibirsk, 630090 Russia.

Provides chemical data on "ore melts" and the volatile content of basaltic glasses (H.E.B.).

SHARMA, A., LENG, J. and BODNAR, R.J., 1998, Is the assumption of isochoric fluid inclusion behavior valid? A Raman spectroscopic study of P-T paths of H<sub>2</sub>O fluid inclusions (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 59. Authors at Fluids Research Laboratory, Virginia Tech, Blacksburg VA 24061.

One of the basic assumptions of FI research is that I represent an isochoric system. Following this assumption, it is possible to approximate the formation T and P of a FI by extrapolating the isochore from the P-T conditions at homogenization to some known P or T to determine the P-T trapping conditions. It is also well known that FI are not truly isochoric systems, because the volume of the I changes as a result of thermal expansion and compressibility during heating from homogenization to higher T. The magnitude of this elastic volume change is small, and the error that results from ignoring this change is small compared to errors associated with incompletely known F compositions and slopes of isochores. However, the assumption that the only elastic volume changes experienced by FI during heating are those predicted by the EOS for the host phase, has not been tested. This is because previously there was no procedure for directly measuring pressures inside FI as they are heated through the one-phase field.

In this study the internal P of pure H2O FI were determined along their P-T paths based on the shift in the Raman peak for water as a function of P. For these experiments, synthetic pure H2O FI in quartz formed at 500°C and 1 kbar were used. Heating experiments were conducted using a Chaixmeca heating stage mounted on the Raman spectrometer. The I homogenized at 353°-355°C and were slowly heated to (Tf = 500°C). This resulted in the decrepitation of some larger FI; however, numerous smaller I were preserved Th of those I that did not decrepitate were again determined and only the I showing unchanged Th were used in this study. Those FI which showed no change in Th after being heated to 500°C were then heated again and the position of the water peak in the vicinity of 3500 cm<sup>-1</sup> was recorded using a DILOR XY Raman microprobe. The frequency of the maximum intensity for the water peak was used to determine the internal P in the I at that T using the previously determined calibration of Frantz et al. (1993). The P-T path predicted by the Raman spectra was compared with the isochoric and with the non-isochoric path calculated assuming the only volume changes are those associated with thermal expansion and compressibility of quartz (Figure). Surprisingly, the P-T path determined by this procedure indicates that the deviation of the P-T path from an isochoric path is significantly more than that predicted by the EOS for the host quartz. Implications of these results for determining the P-T formation conditions of natural FI will be discussed. (Authors' abstract)

See figure in the Illustrations appendix.

SHARYGIN, V.V., PANINA, L.I. and VLADYKIN, N.V., 1998, Melt inclusions in minerals from lamproites of Smoky Butte, (Montana, USA): Russian Geol. And Geophys., v. 39, p. 38-54 (in Russian; Engl. abst.).

Two main petrographic varieties of the Smoky Butte rocks (olivinearmalcolite-phlogopite hyalolamproite and phlogopite-sanidine lamproite) have been studied by thermobarogeochemical methods. Thermometric investigations have showed that P MI in olivine are homogenized at T>1250°C, apatite-hosted I-at 1220-1230°C, diopside-hosted I-at 1160-1205°C, and phlogopite-hosted ones-at 1085-1210°C. Trapping P of 1 during crystallization of olivine-2 does not exceed 2 kb. The phase composition of I in these minerals is glass+G bubble+dxl. In some I, G bubble is partially or fully filled by salt phases (Ca-carbonate and others). According to microprobe data, high contents of SiO2 (60-70 wt%), Al2O3 (10-13 wt%), alkalis (9-12 wt%), BaO (0 7-1.9 wt%), ZrO2 and F (up to 0.5 wt%), and moderate contents of TiO2 (2.5-4.5 wt%) and other femic components (<6 wt%) are common of the residual glasses of silicate-M I in minerals. They compositionally differ in the major element contents from the rocks. In general, during crystallization of the Smoky Butte lamproites, primitive mantle-derived magma gradually evolved toward strong agpaitic compositions rich in SiO2, alkalis, FeO, BaO, TiO2, ZrO2 and poor in Al2O3, CaO, MgO, PrOc. F (or salt M) was gradually enriched in CO2 and, possibly, in SO3. Such M evolution peculiarities favored the appearance of K-Tirichterite, K-magnesiorfvedsonite, davanite, carbonates, and barite at the latest stages. In addition to silicate-M I, Al-spinel, fresh leucite and sul-

SHEN, Baofeng, MAO, Debao and LI, Junjian, 1997, Type and geological character of Chinese greenstone belts gold deposits: Progress in Precambrian Research (Qianhanwuji Yanjiu Jinzhan), v. 20, no. 4 (tot. 80), p. 1-12 (in Chinese; Engl. abst.). Authors at Tianjin Inst. of Geol, and Mineral Resources CAGS, Tianjin 300170, China.

Reviews and presents summary FI data for the deposits discussed. (HEB.)

SHEPHERD, T.J., AYORA, Carlos, CENDÓN, D.I., CHENERY, S.R. and MOISSETTE, Alain, 1998. Quantitative solute analysis of single fluid inclusions in halite by LA-ICP-MS and cryo-SEM-EDS Complementary microbeam techniques: Eur. J. Mineral., 1998, no. 10, p. 1097-1108. First author at British Geological Survey, Keyworth, Nottingham, NG12 5GG, U.K.

An interlaboratory study was carried out to assess the complementanness of LA-ICP-MS and cryo-SEM-EDS for the quantitative solute analysis of single 1 in halite. The halite samples were selected from diverse ancient and recent evaporite environments to give a wide range of solute compositions, and were characterized by abundant, homogeneous populations of large (1-100 µm diameter) P brine I. Homogeneity of the I was important because both techniques are destructive and had to be carried out on different individual I. Cryogenic SEM-EDS was chosen because it is one of the few well-established FI techniques to provide absolute concentrations for the major solutes (Na, K, Mg, Ca, Cl, SO4), and could be used to convert the relative element concentration ratios determined by LA-ICP-MS (K, Mg, Ca, Cl, Br, Sr, Li, B) into true concentration units. Normalization was achieved by referring to chlorine.

The results confirm that LA-ICP-MS and cryo-SEM-EDS are perfectly complementary and yield values for Mg and K that agree within 10 SD. Calcium concentrations were generally too low to be measured by cryo-SEM-EDS, but values determined by LA-ICP-MS are consistent with the hypothesis that the brines are saturated with respect to anhydrite. Overall analytical precision (relative SD) for the major solutes is 2-3 times better for cryo-SEM EDS than for LA-ICP-MS (5-15% vs. 10-35% respectively). Internal consistency of results was checked by charge mass balance estimates and halite saturation indices. Though the study utilized halitesaturated I, cryo-SEM-EDS and LA-ICP-MS can be applied equally to lower sal F and, with care, to I that contain dm. (Authors' abstract) See also FIR 30, p. 179 (E.R.).

SHEPHERD, T.J. and RANKIN, A.H., 1998. Fluid inclusion techniques of analysis: Chapt 6 in Techniques in hydrothermal ore deposits geology Reviews in Economic Geol. (Society of Economic Geologists, Inc.) Richards, J.P. and Larson, P.B., eds., v. 10, p. 125-149. First author at British Geological Survey, Keyworth, Nottingham, U.K. NG12 SGG.

In this chapter we describe and critically evaluate, for the nonspecialist user or novice, the principal techniques currently employed for the quantitative and semi-quantitative analysis of Fl. Our aim is to provide clear guidelines for choosing the most appropriate technique based upon the type of I and analytical data required, together with advice on sample preparation, advantages and disadvantages of the methodology, and the time and cost of analysis. (From authors' abstract by H.E.B.)

SHEPPARD, S.M.F., CHAREF, A. and BOUHLEL, S., 1996. Diapirs and Zn-Pb mineralization: A general model based on Tunisian (N. Africa) and Gulf Coast (USA) deposits: Society of Economic Geologists. Special Pub. no. 4, 1996, p.230-243. First author at UMR 5570 ENRS, ENS Lyon and UCB Lyon I, Ecole Normale Superieure de Lyon, 69364 Lyon 07. France

From combined field, petrological and geochemical (FI, H-, C-, O-, S-, Sr-, Pb-isotopes) studies, mineralization is related to a complex combination of processes related to basin evolution, salt diapirism, cap rock formation, migration of hot saline brines and hydrocarbons, seafloor venting (exhalative deposits) and sulfate reduction processes. (From authors abstract by H.E.B.)

Extensive FI data are presented (H.E.B.)

SHI, Lida and LI, Cunyou, 1998: The gold searching test of mineralization solution electrical conductible degree (abst.): Second APIFIS Int'l

Symp Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 98 (in English). Authors at Shenyang Inst. of Geol. and Mineral Resources, CASS

This paper proposes a new deposit or ore body searching method by study of the the changes of mineralization solution electrical conductible degree. Depending on the fact that the areas of high concentration are always the rich gold ore bodies, the method takes the following steps opening I by thermal explosion, extracting the mineralization solution, representing indirectly the concentration of mineralization solution by electrical conductible degree and establishing an electrical conductible degree quantitative model for ore body searching. This value has many applications in ore deposit prospecting and development. [sic] (From authors' abstract by E.R.)

SHI, Zhunli and XIE, Guangdong, 1998, Study on fluid inclusions and genesis of Donghuofang gold deposit, Inner Mongolia: Geoscience-J of Graduate School, China Univ. of Geoscience, v. 12, no. 4, p. 477-484. Authors at China Univ. of Geosci., Beijing, 100083.

Boiling I are first discovered in Donghuofang gold deposit. The distributions of boiling I and orebodies in vertical project indicate that abrupt decrease of ore-forming P is the most important factor, causing boiling of ascending ore F along the opening fault. Boiling of ore-forming F and decrease of the T made Au precipitate in the gold veins. The study on the compositions of FI shows that the transport forms of gold in I and II mineralizing stages were complex Au-S, but in III mineralizing stage complex Au-Cl is major form of transportation. Space-time relationship between orebodies and syenite stock, and the mineralizing thermal field of gold veins around this stock show them having similar sources. Alkali-magma which formed the syenite stock was from mantle Bimodal magmatic association in Donghuofang gold deposit shows the extensional metallogenic geodynamic related to the mantle plume, so the Donghuofang gold deposit is hypo-mesothermal deposit. It is connected with alkali-magma, and formed at period of India-China (239.98 Ma). (Authors' abstract)

SHIGEHIRO, Michiko, 1998, Genetic model of a Carlin-type gold system: Mineral paragenesis and P-T constraints during mineralization at the Turquoise Ridge gold deposit, Nevada: SEG Newsletter, No. 35, 1998, p. 8. Author at Univ. of Nevada, Las Vegas, Nevada,

Gold ore at the Turquoise Ridge gold deposit. Nevada, is hosted by two types of variably metamorphosed sedimentary rocks. Mineralization occurs in brown hornfels at shallow levels and in black hornfels at deeper levels. Ore-bearing brown hornfels is clay-rich with alternating bands of clay minerals and protolith. These clay bands are absent in black hornfels. a more competent graphitic rock. Gold is present in both types as submicron I in ore-stage pyrite. Twenty-two samples from drill hole 94-172 were selected for detailed paragenetic and FI studies. Three types of pyrite are identified: (1) coarse subhedral to euhedral pyrite; (2) banded pyrite; and (3) fine-grained pyrite. Type I pyrite is present in non-ore quartz veins and believed to be associated with a granodiorite stock. Bands of type 2 pyrite imply a sense of bedding, suggesting the pyrite is of diagenetic ongin. Preliminary electron microprobe studies of type 3 pyrite confirm that these grains contain gold, arsenic, and elevated trace-metal values. Goldbearing pyrite is consistently present both within jasperoid quartz, and concentrated along jasperoid quartz grain boundaries, which suggests gold mineralization was introduced during jasperoid quartz deposition. Petrographic studies suggest a successive depositional sequence of (1) pyrite with gold, (2) jasperoid quartz, (3) orpiment, (4) realgar, and (5) calcite. Fl in pre-gold quartz are abundant and approximately 5 µm in diameter. Most are two-phase and contain L and V, but V-rich and V-only I also are present. Daughter crystals, possibly calcite, also are present in rare L-rich 1. Some I occur along fracture planes, indicating a S origin. I in jasperoid are small, usually <2.5 µm in diameter, and are L-rich with a V bubble. Sparse L-V I along ore-pyrite-bearing jasperoid quartz growth zones indicate a P origin. Fl are sparse in orpiment and realgar, and are generally <2.5 µm. Other than the few I in growth zones, or healed fractures in pre-ore quartz, origins of most I are unknown. (Author's abstract)

SHIGEHIRO, Michiko and CLINE, J.S., 1998. Mineral paragenesis and pressure and temperature constraints during gold mineralization at the Turquoise Ridge Carlin-type gold deposit. Nevada (abst.): Program and Abstracts. PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 60. Authors at Univ of Nevada, Las Vegas, 4505 Maryland Parkway, Box 454010, Las Vegas, Nevada, 89154-4010.

We are investigating ore-stage mineral assemblages and related Fl at

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the deep, high-grade Turquoise Ridge deposit, a Carlin-type gold deposit located in northern Nevada. Our research addresses three questions: (1) What is the ore mineral paragenesis? (2) At what P and T did the deposit form? (3) What are the sources of the ore F?

Gold is present in both brown and black hornfels host rocks as submicron I in ore-stage pyrite. Three populations of pyrite have been identified. Type 3 pyrite is present in high-grade samples, and occurs as finegrained and framboidal pyrite. Preliminary electron microprobe studies of type 3 pyrite show that these grains are rich in trace metals, particularly arsenic, and contain gold. This gold-bearing pyrite is consistently present both within jasperoid quartz grains, and concentrated along jasperoid quartz grain boundaries. These observations suggest that gold micralization precipitated prior to, and continued during, jasperoid quartz deposition. Petrographic studies suggest a successive depositional sequence of (1) pyrite with gold, (2) jasperoid quartz, (3) orpiment, (4) realgar, and (5) calcite.

FI in pre gold-ore quartz are approximately 5 micrometers in diameter. Most I are two-phase and contain L and V. However, V-rich and V only I are also present. Daughter crystals, possibly calcite, are also present in rare L-rich I. Sparse L-V I were trapped along quartz growth zones, indicating that they have a P origin; some I occur along planes indicating that they have a S origin. I in jasperoid are small, usually <2.5 micrometers in diameter, and are L-rich and contain L and V. FI are sparse in orpiment and realgar, and are generally <2.5 micrometers. Other than the few I in growth zones or healed fractures in pre-ore quartz, I origins are unknown. Microthermometric data will be collected from samples from shallow and deep non-mineralized and mineralized samples to determine F composition and minimum T and P of the system. The results of this research will be incorporated into a genetic model for the Carlin-type gold systems. (From authors' abstract by E.R.)

SHIMIZU, Nobumichi, 1998, The geochemistry of olivine-hosted melt inclusions in a FAMOUS basalt ALV519-4-1: Physics of the Earth and Planetary Interiors, v. 107, no. 1-3, p. 183-201.

Some 22 MI hosted by high-Mg olivines (Foss.91) from a single basalt lava from the FAMOUS area of the Mid-Atlantic Ridge were analyzed for major and trace elements. The results demonstrate that large chemical variabilities are present in M that existed in close temporal and spatial proximity at the site of host olivine growth. Major element compositions after corrections for growth of host olivine after entrapment show that they are very primitive (MgO ranging from 9 to 14 wt%; Mground 0.73), and that variations of CaO, FeO and SiO; as a function of MgO are much greater than expected from fractionation of olivine from the most magnesian M. Exactly 14 of the MI are consistent with equilibration with mantle minerals at 8.7±2 kbar and 1272±18°C. Abundance patterns of rare earth elements (REE) show that light REE (LREE)-enriched transitional midocean ridge basalts (MORB) and LREE-depleted N-type MORB existed in close temporal and spatial proximity. It is argued that co-variations of trace element ratios, especially La/SmN and Ti/Zr can be modeled by critical melting of a depleted MORB source at depths where garnet is stable to form LREE-enriched M, and at depths of spinel lherzolite residue to form LREE-depleted M. Abundance patterns of middle to heavy REE (M differs from HREE) indicate. however, that important chemical modification has occurred by reactions between deep M and shallow mantle in an AFCtype mechanism during upward migration of M. This mechanism also appears to explain some of the major element characteristics, and suggests general importance of M/mantle reaction during migration of MORB. (Author's abstract)

SHIMIZU, Nobumichi and GROVE, T.L., 1998. Geochemical studies of olivine-hosted melt inclusions from ridges and arcs (abst.): EOS. Trans.. 79 (45) Fall Meet. Suppl., p. F1002-F1003. First author at Woods Hole Oceanographic Inst., Woods Hole, MA 02543, US: email (nshimizu@whoi.edu)

A review of the many advances in geochemistry and petrology based on studies of MI in olivine. (E.R.)

SHIMIZU, Nobumichi, SOBOLEV, A.V. and LAYNE, G.D., 1998. In situ Pb isotope analyses of olivine-hosted melt inclusions from Mid-Ocean ridges (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F950. First author at Woods Hole Oceanographic Inst., Woods Hole, MA 02543, US: email (nshimizu@whoi.edu)

In-situ analysis of Pb isotopes in olivine-hosted MI in mid-ocean ridge basalts show large variations, demonstrating that MORB source mantle is highly heterogeneous on small spatial scales. (From authors' abst. by E.R.) SHIMIZU, Toru, MATSUEDA, Hiroharu, ISHIYAMA, Daizo and MATSUBAYA, Osamu, 1998, Genesis of epithermal Au-Ag mineralization of the Koryu Mine, Hokkaido, Japan. Econ. Geol., v. 93, no. 7, p. 303-325. First author at Dept.of Earth and Planetary Sci., Fac. Of Sci., Hokkaido Univ., Sapporo 060, Japan; email (shimizu@gsj.go.jp)

Koryu is an epithermal gold-silver quartz vein deposit in southwestern Hokkaido, Japan. Based on crosscutting relationships and mineral parageneses, the veins appear to have formed during two mineralization epochs. The earlier event is further divided into three stages (E-1, -II, -III) whereas seven stages can be distinguished in the later event (L-I, -II, -III), IV, -V, -VI, -VII). The wide veins consist of multiple mineralization stages. Most gold-silver mineralization is associated with the L-III stage.

The presence of V-dominated FI in several stages suggests that boiling occurred intermittently throughout ore deposition. The Tf of the earlier mineralization epoch (263-283°C) were slightly higher than those of the later mineralization epoch (246-260°C) except for stages E-III-b (223°C) and L-VII (206°C). Sal range from 0.5 to 6.0 wt.% NaCl eq., although CO<sub>2</sub> concentrations up to 1.4 wt% in some later stages account for a portion of the apparent sal. These data indicate that maximum P<sub>total</sub> of the ore F was 31 to 68 bars, equivalent to 430 to 850 m below the paleowater table.

Quartz morphology combined with Fl studies suggests that boiling of the F occurred repeatedly, leading to silica-supersaturated conditions with respect to quartz and resulting in the formation of the various silica textures. Recrystallization of silica to quartz occurred throughout vein formation.

The stable isotope data combined with parageneses, quartz textures, and Fl studies suggest the following model for the Koryu gold-silver deposits. The venns show two distinct mineralization epochs, an earlier and a later one, which were responsible for type 1 and 2 hydrothermal F, respectively. Both types are dominantly meteoric water in origin. The early F is characterized by relatively heavy  $\delta^{18}$ O values (-5.3 to -4.7‰) and a T of ≥260°C. The later F is characterized by relatively low  $\delta^{18}$ O values (-9.3 to -6.0‰) and a T of ≥250°C. Type 1 F may have circulated deeply and leached Ca and Mn, which were precipitated as manganocalcite and johannsenite during the earlier mineralization epoch. Type 2 F mixed with shallower water, ascended through new conduits, and aparently carried large amounts of gold and silver, although the source of the metals cannot be determined at present. When the hydrothermal F ascended at discrete time intervals to the boiling zone (<850 m) during the later epoch, gold and silver were precipitated at 250°C. (From authors' abstract by E.R.)

The analytical procedures used to measure the CO<sub>2</sub> concentration, hydrogen and carbon isotope ratios of FI, carbon isotope ratios of manganocalcite, oxygen isotope ratios of quartz, and sulfur isotope ratios of pyrite are given in an appendix. (E.R.)

SHMULOVICH, K.I. and CHURAKOV, S.V., 1998, Natural fluid phases at high temperatures and low pressures: J. of Geochemical Exploration, v. 62, p. 183-191. Author at GeoForschungsZentrum, Potsdam, Germany: email (kirill@glg.ed.ac.uk)

Gas phases at low P and high (magmatic) T have certain peculiar properties. The F is mainly water V, which is usually observed during discharging of crystal magmatic M [sic]. At  $>700^{\circ}$ C and <100 bar these peculiar properties include: formation of near 'dry' salt M as second F phase, very strong fractionation of hydrolysis products between V and M, subvalence state of metals during transport processes, and high sensitivity of the G to conditions of sublimate precipitation. Phase diagram analysis as well as results of field and laboratory experiments are presented in this article. The processes could be a model for industrial technologies to clean wastes from toxic, rare and heavy metals. Transport forms of some elements in volcanic G are very similar to the species which were formed first in the protosolar nebula. (Authors' abstract)

SHUMLYANSKIY, V.O. and IVANTYSHYNA, O.M., 1998, Geological features, zonality and ore forming solutions of the Nickitovka mercury ore field (Ukraine) (abst.): GAC/MAC Meeting Quebec 1998, Abstract Volume 23, p. A-172. Authors at Inst. of Fundamental Studies, P.O. Box 291, Kyiv-01, 252001 Ukraine; email (hod@metaldp.kiev.ua)

The Nickitovka mercury ore field discovered in 1879 is among the largest field of quartz-dickite-cinnabar type. High-grade cinnabar ore was widespread in sandstones near the surface, and stibnite-cinnabar ore with a mercury content of about 1% was within disjunctive zones. To a depth of 400-450 m Hg-average content decreases to 0.1% and Sb-content grows, moreover veinlet-disseminated mineralization is relieved by a system of small veins.

Ore-forming T was changed from 320 to 105°C, moreover the main

cinnabar mass was precipitated at a T of 150-105°C and P of 16-12 MPa. Value  $\delta^{34}$ S in cinnabar, stibute and pyrite is changed in limits from

+3 5 to -1.4‰. Ore-forming solution composition is hydrocarbonate and chloridehydrocarbonate (sometimes with SO<sub>4</sub><sup>2</sup>, F) Na-K-Mg (sometimes with Li). Solution concentration in hydrothermal process was decreased from 9.3 to 4.0 wt%. G phase composition (in vol%) is CO<sub>2</sub> (85), N<sub>2</sub> (6-12). CH<sub>4</sub> (up to 5) and H<sup>2</sup> (1-3). In water from a Fl within quartz of the ore stage δD is from -80 to -82‰, and δ<sup>18</sup>O from 2.7 to 0.1‰ SMOW (Panov, 1990).

By isotopic composition the ore-forming solution resembles Salton Sea geothermal brines (Craig, 1966). (From authors' abstract by H.E.B.)

SIBSON, R.H. and SCOTT, J., 1998, Stress/fault controls on the containment and release of overpressured fluids: Examples from gold-quartz vein systems in Juneau, Alaska; Victoria, Australia and Otago, New Zealand Ore Geol. Reviews, v. 13, p. 293-306. Authors at Dept. of Geol., Univ. of Otago, P.O. Box 56, Dunedin, New Zealand, email (rick.sibson@stonebow otago.ac.nz)

The brittle carapace overlying a prograding metamorphic bell embraces the transition between a hydrostatically pressured near-surface F regime and the near-lithostatic F P characterising prograde metamorphism at depth, with the lower portion of the carapace acting as a low permeability barrier. During exhumation, the base of the carapace migrates downwards into the core of a cooling orogen Mesozonal gold-quartz vein systems hosted in fault-fracture meshes (comprising low-displacement shears interlinked with hydraulic extension fractures) may develop towards the base of, or within, the brittle carapace. Such mesh structures, "selfgenerated" by the infiltration of overpressured F at P locally exceeding the least principal compressive stress (i.e. Pr>o3), form high-permeability conduits for episodic large-volume F discharge by fault-valve action. These concepts are explored principally through comparison of gold-quartz vein systems hosted in fault-fracture meshes within the Bendigo-Ballarat zone of the Paleozoic Lachlan Fold Belt in Victoria, Australia, with those developed within the Mesozoic Otago Schists of southern New Zealand. (From authors' abstract by E.R.)

#### SIEMANN, M.G., KLINGENBERG, Imke and PROHL, Hansjörg,

1998, Investigations on fluid inclusions from late Permian (Zechstein) evaporites in northern Germany (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 61. Authors at Fachgebiet Mineralogie, Geochemie, Salzlagerstätten, Technische Universität Clausthal, Adolph-Roemer-Str. 2A, 38678 Clausthal-Zellerfeld, Germany, email (siemann@immr.tu-clausthal.de)

Several FI in mostly S salts in late Permian evaporites from a salt dome were investigated. The gaseous components were measured by Laser Raman Spectroscopy. The brines were then extracted using a micro drilling system, diluted and analysed by lon Chromatography. Due to the existence of dxl in the majority of the I different methods were tested to discover the T1. Th obtained by heating-cooling stage are compared with T calculated from distribution coefficients between dxl and brine.

For the interpretation of brine in FI, their chemical compositions have to be compared with known solid-solution equilibrium data. This comparison yields information on the quality of extraction and dilution. Due to the existence of different data bases the interpretation of brines in I may sometimes be equivocal. The differences of some of these data bases are shown graphically with special consideration of the stability field of canallite. because most of the extracted brines are saturated with carnallite. Whereas some brines are free of MgSO4 and are thus only saturated with halite, carnallite and±anhydrite, other brines are also saturated with kieserite and/or kainite. (From authors' abstract by E.R.)

SIEMANN, M.G. and SCHRAMM, M., 1998. Thermodynamic modelling of Br partitioning in brines and marine evaporites (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998. Extended Abstracts, p. 1400.

SIEWERT, T., BÜTTNER, H. and ROSENHAUER, M., 1998. Experimental investigation of thermodynamic melting properties in the system NaCI-KCI at pressures of up to 7000 bar: N. Jb. Miner. Abh., v. 172, no. 2/3, p. 259-278.

SILLITOE, R.H. and THOMPSON, J.F.H., 1998, Intrusion-related vein gold deposits: Types, tectono-magmatic settings and difficulties of distinction from orogenic gold deposits. Resource Geol., v. 48, no. 4, p. 237-250. First author at 27 West Hill Park, Highgate Village, London N6 6ND.

#### England.

Several features of vein gold deposits, including imprecise relationships to individual intrusive phases, poorly developed mineral and metal zoning, apparent time gaps between intrusion and mineralization and presence of low-sal, CO<sub>2</sub>-rich Fl, are commonly taken to indicate a non-igneous origin and to be more typical of orogenic (mesothermal) gold deposits generated during accretionary tectonic events. However, several or all of these features apply equally to some intrusion-related vein gold deposits and, therefore, do not constitute distinguishing criteria. The currently popular assignment of most gold-rich veins to the orogenic category requires caution, because of the geological convergence that they show with some intrusion-related deposits. A proper distinction between intrusion-related and orogenic gold deposits is crucial for exploration planning. (From authors' abstract by H.E.B.)

SILVA, W.L., XAVIER, R.P. and LEGRAND, J.M., 1998. Fluid regime in lode-gold deposits of the Proterozoic Seridó Belt, Borborema Province. NE Brazil (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 62. First author at Instituto de Geociências e Ciências Exatas/UNESP, Rio Claro – SP, Brazil.

Metamorphism to mid-upper amphibolite factes, and the emplacement of numerous granites and pegmatites, mobilized and/or generated F which altered the regional metamorphic assemblage in this belt and formed high grade, low tonnage lode-gold deposits along NE-striking, regional-scale transcurrent shear zones. The São Francisco and the São Fernando-Caicó are among the most important of such deposits.

FI studies by microthermometry and Laser Raman microspectroscopy LRM) in aunferous vein quartz in both deposits identified three FI types: (type 1) low-sal (3-5 wt% eq. NaCl) H1O-CO2: (type 2) CO1-rich; (type 3) H<sub>2</sub>O with varying sal and solutes. The types 1, 2 and 3 coexist in isolated groups and texturally appear to be P in these groups, the TmCO2 for types 1 and 2 I are -56.6°C to -59.0°C, and LRM reveals the presence of N2 (up to 8.6 mol%) and CH4 (up to 2.4 mol%). These FI also show a large variation in the density of the carbonic phase, as indicated by ThCO2 (1) ranging from -38°C to 31°C. The type 3 Fl in these groups are typically low sal (Tfice up to -8°C) and dominated by NaCl. Types 2 and 3 Fl also commonly delineate intra- and intergranular microfractures, probably representing later F phases than those preserved in the isolated groups. Minor H2O-CO2 FI (type 1) also occur along microfractures. Microfractures rarely host more than one FI type. The composition of type 2 FI along microfractures are similar to those in the isolated groups, although ThCO2 (1) tends to be higher (10°C to 31°C), particularly for those along intergranular microfractures Type 3 Fl along microfractures in auriferous quartz veins hosted by muscovite schists in both deposits show: (i) São Francisco - Te of -75°C and Tfice between -57°C and -20°C; and (ii) São Fernando-Caicó Te of -69°C to -36°C and Tfice between -31°C and -8°C. These aq F have variable sal and a complex mixture of chlorides of Na, K, Ca, Mg, and Li In contrast, FI in gold-bearing veins hosted by sheared metatonalites are low sal (<4 wt% eq. NaCl) and contain NaCl as the major solute.

The study shows that H<sub>2</sub>O±CO<sub>2</sub> F occurred coevally during at least part of the peak metamorphism and lode-gold deposition. Although we highlight the low-sal H<sub>2</sub>O-CO<sub>2</sub> F, it is also likely that multicomponent aq brines also played a role in the transport/deposition of the gold and base metals. Although further studies are necessary, loss of H<sub>2</sub>S during immiscibility, mixing, or cooling may have occurred (From authors' abstract by E.R.)

SIMAKOV, S.K., 1998, Redox state of Earth's upper mantle peridotites under the ancient cratons and its connection with diamond genesis: Geochim, et Cosmo. Acta, v. 62, no. 10, p. 1811-1820. Author at Geological Faculty, St. Petersburg Univ., Universitetskaya emb. 7/9, St. Petersburg, 199034, Russia; email (simakov@vap.usr.pu.ru)

P-T-/O<sub>2</sub> conditions and F compositions were estimated from mineral paragenesis from I in diamonds, diamond-bearing, and diamond-free xenoliths using gamet-orthopyroxene barometers and olivine-orthopyroxenegamet oxygen barometer. The data indicate that upper mantle is zoned, with relatively oxidized lithosphere and reduced astenosphere. The upper mantle becomes increasingly reduced with increasing depth. I within diamonds could have formed in equilibrium with the methane-nitrogen-rich F which corresponded to the existence of metal-silicate M. Diamond-bearing and diamond-free peridotite xenoliths equilibrated with  $CO_2$ -H<sub>2</sub>O and  $CO_2$ -rich F correspondingly. (Author's abstract)

SIMEONE, Rossana, 1998. Precious metal mineralization at Osilo

(Northern Sardinia): Summary of PhD research published in Plinius, no. 19, p. 229-232. Author at Dipartimento di Geoingegneria e Tecnologie Ambientali, Università di Cagliari, Piazza d'Armi 1, 1-09123 Cagliari.

FI studied were hosted by crystalline quartz from several stages. Two types of FI were observed: two phase L-rich I and two phase V-rich I. where the first type is dominant. T<sub>h</sub>=198-270°C, with a general increase of T with depth. Ice melting (T<sub>m</sub>) range between 0.0 and -2.3°C indicating that F contain <4.1 wt.% NaCl eq. Melting point depression down -1.5°C could be caused by presence of small amount of CO<sub>2</sub><0.9 m CO<sub>2</sub> in absence of CO<sub>2</sub> clathrate formation. Coexisting L-rich and V-rich groups of FI indicate that boiling took place during their formation. T<sub>h</sub> measured for stages 1, II, and III were fitted to boiling point for depth curves characteristic of dilute F composition assuming that ascending hydrothermal solutions were governed by hydrostatic gradient. The position of the paleo-water table was estimated assuming that piezometric level coincides with the water table. The minimum paleo-water table was between 200 and 300 m above the present day erosion surface. (From author's abstract by E.R.)

SIMON, Grigore, KESLER, S.E., HALL, C.M. and RUSSELL, Norman, 1998, Jacinto, Cuba: An epithermal gold deposit in an Old Island arc (abst.). Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-372. First author at Dept. of Geological Sci., Univ. of Michigan, Ann Arbor, MI 48109.

The Jacinto deposit in the Camagüey district of central Cuba is a typical, low-sulfidation adularia-sericite epithermal gold deposit. It includes at least five veins that are up to 1 km in length, up to 2 m wide, and at least 300 m deep. The veins consist almost entirely of quartz, with minor amounts of adularia, calcite (commonly bladed), pyrite and gold. Gold ore shoots are restricted vertically (about 50 m) but continuous horizontally and indicate that the system was tilted about 5° NE. FI in vein quartz yield Th of 200-320°C and sal of <1 eq. wt.% NaCl, and confirm that the hydrothermal F boiled. Stable isotope analyses of quartz, calcite, and I waters indicate that mineralizing solutions evolved from isotopic compositions near those of magmatic water toward values typical of meteoric water. (From authors' abstract by H  $\pm$  B.)

SIMONOV, V.A., LAPUKHOV, A.S., MILOSNOV, A.A., KOVYAZIN, S.V. and MEL'NIKOVA, R.D., 1998, Ore-forming processes in the south Atlantic magmatic and hydrothermal systems (Bouvet Triple Junction): Russian Geol. and Geophys., v. 38, no. 12, p. 1963-1970. Authors at United Inst. of Geol., Geophys. and Mineral., Siberian Branch of the Russian Acad. of Sci., Universitetskii pr. 3, Novosibirsk, 630090, Russia.

Investigation of a collection of rocks with ore and hydrothermal minerals gathered during the 18th cruise of the research vessel Akademik Nikolai Strakhov (1994) at the Bouvet Triple Junction provided new data on composition of sulfides and characteristic distribution of gold in magmatic associations. Liquid CO<sub>2</sub> I have first been found for the lithosphere of modern oceans: they indicate a considerable role of CO<sub>2</sub> in hydrothermal systems near the Bouvet hotspot. According to data of analysis of CO<sub>2</sub> and aq solution I, parameters of H<sub>2</sub>O-CO<sub>2</sub> F that formed quartz from sulfide ore have been determined (NaCl+CaCl<sub>2</sub>+H<sub>2</sub>O+CO<sub>2</sub>: T=200-310°C, P=900-1700 bars). It has been established that aq solutions compositionally close to sea water (NaCl+MgCl<sub>2</sub>+H<sub>2</sub>O) with T of 170-200°C are predominant in hydrotherms with insignificant contents of ore components. (Authors' abstract)

SINGH, Jagmohan, BLENCOE, J.G. and SEITZ, J.C., 1998, Experimentally determined excess molar volumes for H<sub>2</sub>O-N<sub>2</sub> fluids at 300°C, 75-1000 bars (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-319. First author at Oak Ridge National Laboratory, P.O. Box 2008, Bldg. 4500-S, Oak Ridge, TN 37831-6110; email (singh)@oml.gov)

Compared to H<sub>2</sub>O-CO<sub>2</sub> F at 300°C. 75-1000 bars. H<sub>2</sub>O-N<sub>2</sub> mixtures have systematically larger excess molar volumes and a wider compositional range of immiscibility. This indicates that, at these P-T conditions. H<sub>2</sub>O-N<sub>2</sub> F are significantly more nonideal than H<sub>2</sub>O-CO<sub>2</sub> mixtures. (From authors' abstract by H.E.B.)

SINGOVI, Blackwell and KHIN Zaw, 1998. Formation of magnetitescheelite skarn mineralization at Kara, northwestern Tasmania: Constraints from mineral paragenesis, fluid inclusion and oxygen isotope studies (abst.): Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada, p. 63. Authors at CODES SRC, University of Tasmania, GPO Box 252-79. Hobart, Tasmania 7001.

## See FIR, v. 29, p. 195 (E.R.)

SIRBESCU, Mona-Liza, and NABELEK. Peter. 1998. Inclusions in the Harney Peak granite and its associated pegmatites (Black Hills, South Dakota): implications on geochemical evolution of magmatic fluids in a leucogranitic system (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 64. Authors at Dept.of Geological Sci., Univ. of Missouri, Columbia, MO 65211.

We performed a comparative petrographic and microthermometric study of I within the texturally variable Proterozoic Harney Peak leucogranite (HPG) and in several simple and zoned pegmatites from its associated pegmatite field. Mixed saline CO2-H2O (type I) F dominate P and PS I in quartz, tourmaline, and garnet of homogeneous, layered granites and pegmatitic segregations within the HPG. Distinct saline aq (type II) and carbonic (type III) S F, which are present throughout all investigated samples, are considered to have formed as a result of unmixing of the type I fluid. The type I primary I from a large, zoned, rare element Bob Ingersoll pegmatite are similar in composition (sal of aq phase around 52 wt% NaCl) and ThL-V=300±75°C to the type I fluids trapped in the HPG. In a narrow simple pegmatite dike, the "Carol Creek" pegmatite, the presence [i.e. validity?] of PFI in large quartz and apatite crystals is questionable as they were largely obliterated by intense circulation of type II and III secondary F. Nonetheless, P F are evident in garnet, as well as in small quartz grains within the graphic feldspar quartz intergrowths.

EDS-SEM analyses were performed on solid-bearing FI and fully crystalline polymineralic I within quartz, tourmaline and gamet. Some of the observed solids are dm crystallized out of a cooling F or M rather than accidentally trapped crystals during host crystal growth or particles mechanically transported by S F. Mixed H2O-CO2 I within Harney Peak Granite and its pegmatites contain various aluminosilicates and simple or complex compounds of P, S, Cl, etc., some bearing rare elements such as Cs. Pb and Sn. In contrast, mixed I in quartz filling necks of boudinaged granite sills, with identical thermometric properties, contain relatively simple Ca, Mg, Na and/or K chlorides. EDS-SEM analysis of dxl proves to be a relatively rapid and simple tool, giving a useful indication of F chemistry in situations in which co-existence of distinct populations of FI and/or insoluble daughters make bulk chemical analyses of extracted F inappropriate. Additional WDS-SEM microanalysis will provide information on elements lighter than Na. This investigation provides a necessary base for more sophisticated in situ microanalyses of F and/or solid I chemistry by LA ICP-MS or Raman spectroscopy. (From authors' abstract by E.R.)

SISSON, T.W., 1998, Evidence for melting processes in the sub-arc mantle from melt inclusions in phenocrysts (abst.): EOS, Trans., 79 (45) Fall Meet. Suppl., p. F1002. Author at USGS, 345 Middlefield Rd., Menlo Park, CA 94025, USA; email (tsisson@usgs.gov)

Melting beneath arcs is generally thought to involve water released from the subducting slab that enters the mantle wedge and allows peridotite to melt. Because MI in phenocrysts can trap magmatic volatiles that would otherwise exsolve, they can provide decisive information on melting processes. High H2O contents (to 6 wt%) analyzed in matic M1 from arcs and somewhat lower values (to 2 wt%) measured in glassy pillow rinds from back-arc basins verify that H2O is directly involved in generating many arcrelated basaltic magmas. MI from some primitive (to 11 wt% MgO) arc basalts have surprisingly low H2O contents (0.2-0.4 wt%), similar to values in MORB. These dry magmas allow firm estimates of T and flow paths in parts of the sub-arc mantle wedge. Dry M and high T at shallow levels are explained most simply if hot peridotite upwells into the mantle wedge and undergoes P-release melting The relative contributions of H2O-fluxing versus upwelling-induced melting probably vary between arcs and over time in single arcs, but the relative significance of these melting processes has yet to be estimated anywhere. (From author's abstract by E.R.)

SLOAN, E.D., Jr., 1998, Gas hydrates: Review of physical/chemical properties: Energy & Fuels, v 12, p. 191-196. Author at Center for Hydrate Research. Colorado School of Mines, Golden, CI 80401, USA.

An overview is provided of time-independent physical/chemical properties as related to crystal structures. The following two points are illustrated in this review: (1) Physical and chemical properties of structure I (sl) and structure II (sl1) hydrates are well-defined; measurements have begun on sH. Properties of sl and sll are determined by the molecular structures, described by three heuristics: (i) Mechanical properties approximate those of ice, perhaps because hydrates are 85 mol% water. Yet each volume of hydrate may contain as much as 180 volumes (STP) of the hydrate-forming

species. (ii) Phase equilibrium is set by the size ratio of guest molecules within host cages, and three-phase  $(L_x-H-V)$  equilibrium P depends exponentially upon T. (iii) Heats of formation are set by the hydrogen-bonded crystals and are reasonably constant within a range of guest sizes. (2) Fundamental research challenges are (a) to routinely measure the hydrate phase (via diffraction, NMR, Raman, etc.), and (b) to formulate an acceptable model for hydrate formation kinetics. The reader may wish to investigate details of this review further, via references contained in several recent monographs. (Author's abstract)

SLOBODNÍK, M., MUCHEZ, Ph., SINTUBIN, M. and MELICHAR, R., 1997, Geometrical analysis of synkinematic calcite veins in the Variscan front complex: Examples from the Statte-Flémalle Anticline (Belgium): In: Belgian Symposium on Structural Geology and Tectonics, Aardk Mededel., 1997, v. 8, p. 169-172. Includes discussion of use of Fl (E.R.)

SLODKEVICH, V.V. and SHAFRANOVSKY, G.I., 1998. The diamondiferous mineral association of gas-fluid origin in the Bel'tau stratified pluton (Uzbekistan) (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan. Abstracts volume, p. 45-46 (in Russian).

See Translations.

SMIRNOV, S.K. and KOZLOV, V.V., 1998b, Second APIFIS Int'l Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent. Uzbekistan. Abstracts Volume, 165 pp., in Russian and English. Individual abstracts are in this volume of FIR (E.R.). See Translations.

SMIRNOV, S.Z., BAKUMENKO, I.T., TOMILENKO, A.A. and BU-KIN, G.V., 1998, Inclusions of a mineral-forming medium as indicators of the origin of synthetic gernstones: Russian Geol. And Geophys., v. 38, no 10, p. 1669-1678 (in Russian; Engl. trans. 1998 Allerton Press, Inc.) Authors at United Inst. of Geol., Geophys. and Mineral., Siberian Branch of the Russian Acad. of Sci., Universitetskii pr. 3, Novosibirsk, 630090, Russia.

Inclusions of a mineral-forming medium give important information on mineral origin. Applying methods commonly used in the study of natural mineral formation conditions, the authors attempted to show the special features of MI in synthetic ruby, sapphire, emerald, alexandrite, and spinel. Crystals grown from M and flux solutions have been studied. Morphological features of the I as well as their phase composition and phase transformation conditions are under discussion. I in synthetic crystals have a number of typomorphic features, e.g., crystalline aggregate as vacuole infill, high T of phase transformation, and specific composition. These features are not typical of I in natural gemstones, thus permitting one to distinguish between natural and synthetic gemstones on the one hand, and to choose an appropriate method for gemstone synthesis, on the other. (Authors' abstract)

SMIRNÓVA, S.K. and KOZLÓV, V.V., 1998a, Mineral associations and the origin of the ore-shows at Akcha-Talbulak. Uzbekistan (abst.): Second APIFIS Int'L Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 120-123 (in Russian).

SMITH, Martin and HENDERSON, Paul, 1998a. Fluid evolution during formation of the Bayan Obo Fe-REE-Nb deposit. China (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec. 1998. St. Andrews, Scotland (unpaginated). Authors at Dept. of Mineral., The Natural History Museum, London, SW7 5BD: email (mars@nhm.ac.uk)

The Bayan Obo Fe-REE-Nb deposit, Inner Mongolia, China, is the world's largest REE deposit. The deposit has been interpreted to be of hydrothermal origin, related to either carbonatite magmatism, or to F generated during subduction. However, very little is known about the P-T conditions of the deposit's formation, and the nature of the mineralising F Here we report the results of a study of Fl in a range of minerals carried out in order to provide new constraints on F evolution in the deposit.

FI in the earliest stages of mineralisation (disseminated monazite) are aqueous-carbonic I (Lw+Lc+V), with bulk sal in the range 1.0 to 2.2 wt% NaCl eq., and estimated CO<sub>2</sub> contents of 47 to 66 wt%. FI from apatite and bastnäsite from the main stage banded ore mineralisation are both aq (Lw+V) and Lw+Lc+V. Sal of Lw+V I range from 6 to 10 wt% NaCl eq. Lw+Lc+V I show bulk sal from 1 to 3 wt% NaCl eq. and estimated CO<sub>2</sub> contents of 18 to 40 wt%. Th in these I range from 290 to 340°C for Lw+Lc+V1, and from 240-290°C for Lw+V1 No independent P-T information is available, but minimum P for banded ore formation calculated from the Th data suggest mineralisation at P>2 kbar, accompanied by cooling from minimum T of 450-300°C and by evolution of the F to more CO<sub>2</sub>-rich compositions.

Fl in aggirine from the banded ores and from aggirine veins all contain an aq L plus V, with no detectable CO<sub>2</sub>. Th ranges from 280 to 350°C, and sal from 5 to 15 wt% NaCl eq. Lw+Lc+V l occur in apatite and bastnäsite from aggirine veins, and show Th ranging from 230 to 300°C, bulk sal from 0.3 to 3 wt% NaCl eq., and CO<sub>2</sub> contents of 30 to 80 wt%. The final stage in vein and vug fill is fluorite, which shows both halite bearing aq l, and low sal Lw+Lc+V l in the same populations. Th in the Lw+Lc+V is typically around 240 to 270°C. This population is indicative of immiscibility between aq and carbonic F at P=1-1.5 kbars. If this is assumed to be a representative P for the vein formation, through apatite and bastnäsite deposition at around 340-280°C, to fluorite deposition at around 240-270°C

Fluorite in banded ores and veins hosts a wide range of secondary Lw+V I with Th ranging from 240 to 150°C. The general trend of sal in these I suggests dilution from around 10-15 wt% NaCl eq. to 5 wt% NaCl eq. Halite-bearing I in these populations may indicate episodes of boiling, under P dropping to as low as a few tens of bars. Aq I in barite have very low sal (<I wt% NaCl eq.) and homogenise from 130-200°C.

All the FI generations can be correlated with the different paragenetic stages of REE mineralisation at Bayan Obo, and indicate changes in F composition during a long history of F circulation, ore deposition and remobilisation. Many of the features of the evolution in F composition at Bayan Obo are comparable to what is known about post-magmatic F evolution in carbonatites. A re-evaluation of current models based on isotopic data is necessary to confirm this comparison, or to demonstrate that the similarities are purely a function of REE mineralisation in a carbonate host rock. (Authors' abstract)

SMITH, Martin and HENDERSON, Paul, 1998b, The textural and chemical characteristics of rare-earth minerals from Bayan Obo, China: Constraints on the evolution of the world's largest REE resource and implications for the hydrothermal transport of the REE (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). Authors at Dept. of Mineral., The Natural History Museum. London, SW7 SBD.

A review, including discussion of FI evidence (E.R.).

SMITH, M.E.H., LOVETT, D.R., PRING, P.I. and SANDO, B.G., 1998, Dead Bullock Soak gold deposits Australasian Inst. of Mining and Metallurgy, v 22, p. 449-459. Indexed under FL

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SO, C.-S., ZHANG, D.-Q., YUN, S.-T. and LI, D.-X., 1998, Alterationmineralization zoning and fluid inclusions of the high sulfidation epithermal Cu-Au mineralization at Zijinshan, Fujian Province, China: Econ. Geol., v. 93, no. 7, p. 961-980. First author at Dept. of Earth and Environmental Sci., Korea Univ., Seoul 136-701, Republic of Korea.

The Zijinshan mine in Fujian Province in the southeast of China is the first recognized example of high sulfidation epithermal Cu-Au mineralization of Cretaceous age in mainland China. The Cu-Au mineralization occurs around a dacitic volcanic pipe which changes downward into a potassic-altered granodiorite porphyry associated with porphyry copper-style mineralization. indicating a close spatial and temporal association between high sulfication Cu-Au and porphyry copper mineralization

Zoning of hydrothermal alteration and ore mineralization assemblages at Zijinshan is typically recognized from the deep and central zones toward shallower and outer portions within the epithermal system.

Geochemical, mineralogical, and Fl data are consistent with progressive acid leaching toward shallower portions of the hydrothermal system, accompanying the general decrease of T from 300 to 380°C for the deeper phyllic assemblage and associated subeconomic chalcopyrite+tennantite+bornite mineralization, through 250 to 320°C for the alunite alteration and high sulfidation copper mineralization, to 100 to 180°C for the shallow silicic alteration and gold deposition. Hypogene hydrothermal F at Zijinshan were derived initially from a deep-level granodiorite porphyry in the southeastern area of the mine. Following the formation of phylic and dickite alteration assemblages at 180 to 380°C through simple cooling and dilution of hydrothermal F. the V-rich magmatic F containing HCI and SO<sub>2</sub> was probably formed by phase separation of a deep magmatic F and subsequently ascended northwestward. The upwelling

magmatic V condensed into meteoric water at shallow levels (higher than 1,700 m below the paleosurface), forming the high sulfidation epithermal F (<320°C) responsible for the formation of the funnel-shaped, alunite and silicic alteration zones. The Cu and Zu mineralization occurred after the acid leaching of rocks by the V condensates and the subsequent hydrothermal brecciation. Progressive mixing with meteoric water and the subsequent changes of the physicochemical environment (e.g., decreases of T and chloride ion activity and increase of pH) could result in the successive precipitation of copper (within the alunite alteration zone) and gold (in the shallow silicic alteration zone) at T<250°C. (From authors' abstract by E.R.)

SOBOLEV, A., HOFMANN, A.W. and NIKOGOSIAN, I., 1998, Anomalous Sr in melt inclusions from Mauna Loa, Hawaii: Fingerprint of recycled gabbro? (abst.): EOS Trans. AGU, 79(17), Spring Meet Suppl., p. S345. First author at Vernadsky Inst. of Geochem., Russian Acad. of Sci., Kosigin 19, Moscow, 117979, Moscow; email (asobolev@glas.apc.organization)

The composition of Hawaiian magmas contains several enigmatic features which rule out derivation of these magmas from ordinary depleted or primitive mantle reservoirs. Among these are anomatously low Th/Ba and Th/La ratios, anomalously high Sr abundances (relative to REE), and low <sup>18</sup>O abundances, features which are found in many gabbros from ophiolites and are caused by the presence of cumulus feldspar and seawater circulation through the lower oceanic crust (e.g. Hofman et al., 1996 a.b. Eiler et al. 1996). However, it has not been clear whether the magmas acquire this signature by recycling such crust through the plume source, or by interaction of the plume magmas with the present-day lower oceanic crust.

We have studied (by EPMA and SIMS) 88 MI trapped in olivine phenocrysts (Fo84 to Fo90) from 3 picritic Mauna Loa basalts. Most show moderate Sr excess (up to 100%) relative to Sm (or Nd), which is correlated with La/Sm. Five I have extreme Sr excesses between 150 and 300% and strong positive correlations between Sr and Ba/(Th, Nb). The results are consistent with a model in which recycled (originally) feldsparcumulus-bearing material is present in the Hawaiian plume source in the eclogitic facies. We therefore envision the plume source as a mixture of normal peridotite and peridotite enriched in recycled oceanic gabbro. (From authors' abstract by E.R.)

See also Jochum, this volume (E.R.)

SOBOLEV, N.V., SNYDER, G.A., TAYLOR, L.A., KELLER, R.A., YEFIMOVA, E.S., SOBOLEV, V.N. and SHIMIZU, Nobumichi, 1998, Extreme chemical diversity in the mantle during eclogitic diamond formation: Evidence from 35 garnet and 5 pyroxene inclusions in a single diamond: Internat'I. Geol Review, v. 40, p. 567-578. First author at United Inst. of Geol., Geophys. and Mineral., Siberian Branch, Russian Acad. of Sci., Universitetskiy Prospekt 3. Novosibirsk 90, 630090 Russia.

We report major- and trace-element variations in 35 garnet l extracted from a single eclogitic diamond from the Mir kimberlite pipe, Yakutia. The variability in garnet composition is attributed to changing F chemistry in successive metasomatic fronts moving through a subducted oceanic slab in the mantle. These metasomatic F also could have been the carbon source for the diamond. (From authors' abstract by E.R.)

### SOBOLEV, N.V., YEFIMOVA, E.S., CHANNER, D.M.DeR., AN-DERSON, P.F.N. and BARRON, K.M., 1998, Unusual upper mantle beneath Guaniamo, Guyana shield, Venezuela: Evidence from diamond inclusions: Geology, v 26, no. 11, p. 971-974. First author at Inst. of Mineral. and Petrog., Siberian Div. of the Russian Acad. of Sci., Novosibirsk 630090, Russia.

The geochemistry of mineral I in diamond is an important source of information about the composition of the continental lithospheric mantle at depths exceeding 120-150 km. At these depths, two main types of geochemical environment support diamond formation: they are ultramafic (or peridotitic) (U-type) and eclogitic (E-type) environments as shown by minerals that occur as I in diamonds. In P diamond-bearing kimberlite or lamproite rock the ratio of diamonds from these two geochemical environments varies widely between localities. The U-type environment dominates for a very limited number of localities in South Africa, North America, and Australia. The present study shows that an uncommonly high percentage (99.4%) of E-type diamonds with extremely variable I assemblages is found in kimberlites in the northwestern part of the Guyana shield at Guaniamo, Venezuela. These variations range from previously unknown silica-undersaturated corundum eclogite to abundant silica-rich coesite eclogite assemblages representing 22% of all E-type diamonds, some of which

contain syngenetic ilmenite and magnetite. The compositional variations of garnet and omphacite 1 are extremely broad. The wide variability of the eclogitic source in which diamonds formed beneath the Guyana shield indicates a broadly basaltic chemistry in this environment, which may represent ancient subducted oceanic crust. Such specific features have not been reported for any other diamond occurrence and reflect an unusual composition of the deep lithospheric mantle in this area (Authors' abstract).

SOCKI, R.A., ROMANEK, C.S. and GIBSON, E.K., Jr., 1998. An online technique for the measurement of oxygen and hydrogen isotopes from microliter quantities of water (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-80. First author at C-23 Lockheed Martin, 2400 NASA Road, Houston, TX 77058; email (rsock/@ems.jsc.nasa.gov)

We report here a technique for the extraction of oxygen and hydrogen isotopes from small (10 microliter) water samples. The need exists for a routine oxygen isotope extraction method of micro-quantities of water from Fl, structural water within hydrous minerals, and for use in doubly-labeled water studies in the medical and the veterinary sciences. Furthermore, our technique eliminates the need for potentially dangerous, expensive and messy reagents (e.g. bromine pentafluoride and guanadine-HCI) associated with other micro-analytical extraction techniques. Our method is a modification of the traditional Epstein and Mayeda, 1953 CO2-H2O equilibration technique. The method described here involves a reaction carried out exclusively in 6 mm pyrex tubes which, after CO2-H2O exchange is complete (-28 hours), are attached via a stainless steel tube cracker directly to the inlet portion of an isotope ratio mass spectrometer for analysis. Carbon dioxide is cryogenically separated from the water and frozen into a cold trap connected to the microfinger inlet of a Finnigan Delta S mass spectrometer. Because the water sample is not destroyed it can be frozen into a separate zinc-filled 6 mm pyrex tube attached to the tube cracker. After the water is transferred, the tube is flame-sealed and stored for later reduction of water to hydrogen for D/H isotope analysis. Because the molar ratio of oxygen in water to that in CO2 is lower than with conventional analyses. application of the Craig, 1957 correction factor becomes critical. Provided this correction is applied, the accuracy and precision of this method are comparable to other techniques using much larger samples. On the basis of the number of analyses, oxygen isotope reproducibility of three international standards (V-SMOW, GISP, and SLAP), and one laboratory standard is better than ±0.09 permil. Furthermore, hydrogen isotope reproducibility is comparable to that using the standard zinc reduction technique. (Authors' abstract)

SOKERINA, N.V. and SHÁNINA, S.N. 1998, Peculiarities of the formation quartz veins in the area of the Sinil'ga prospect (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 111-112 (in Russian). See Translations.

SOLOMON, Mike and KHIN Zaw, 1998. "In praise of understanding ore-forming processes"—A reply: SEG Newsletter No. 34, p. 40.

SOLOVOVA, I.P., RYABCHIKOV, I.D., KOGARKO, L.N. and KO-NONKOVA, N.N., 1998, Inclusions in minerals of the Palaborwa carbonatite complex. South Africa: Geokhimiya, 1998, no. 5, p. 435-447 (in Russian, translated in Geochm. Internat'l., v. 36, no. 5, p. 377-388.) First author at Inst. of Geol. of Ore Deposits. Petrog., Mineral. and Geochem. (IGEM), Russian Acad. of Sci., Staromonetnyi per. 35, Moscow, 109017, Russia.

I were studied in apatite from phoscorite and pyroxene from the pyroxenite of the southern core of the Palaborwa Complex, South Africa. It was determined that the rocks formed in the presence of salt M at T of 850-870°C and P of 4-4.5 kbar. The calcic carbonatite M contained up to 7 wt% StO<sub>2</sub> and 11.5 wt% P<sub>2</sub>O<sub>3</sub>. The crystalline and M (salt) I bear portlandite, sulfates, and fluorite, whose action as fluxing components explains the origin of the low-T carbonatite magmas, even at moderate contents of alkalis. The important role of water in this process is highlighted by the occurrence of zeolites in the crystalline I. (Authors' abstract)

An analysis is given of a carbonate MI (from during apatite crystallization), based on volume percentages of dm calcite, pyroxene, phlogopite, apatite, and fluorite (Table 6). In addition to Ca and CO<sub>3</sub>, it shows in % SiO<sub>2</sub>-7, MgO-3, F<sup>-3</sup>.4, and P<sub>2</sub>O<sub>3</sub>-11.5 (E.R.).

SOMARIN, A.K. and ASHLEY, P.M., 1998, The Glen Eden Mo-Sn-W

deposit, New England orogen. NSW (abst.): Geological Soc. of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 232. Authors at Div. of Earth Sci., Univ. of New England. Armidale, NSW.

The Glen Eden Mo-Sn-W deposit in NE NSW is an example of a leucogranite-related, low-grade, large tonnage hydrothermal system. The deposit is hosted within a pipe-like quartz-rich greisen breccia body over 200 m in diamter, surrounded by a greisen zone several hundred metres across. The dominant ore minerals, largely hosted as open space fillings and disseminations in quartz and quartz-rich greisen, are molybdenite, wolframite and cassiterite.

Breccia formation and associated hydrothermal alteration are interpreted to be related to devolatilisation of the crystallising, highly fractionated Glen Eden Granite. The breccia pipe could have formed in part by rock dissolution and collapse, as well as be explosve degassing of boiling F. Fl evidence is consistent with boiling, with breccia pipe formation and mineralisation having largely occurred at 300-350°C from F with sal of 0.4 to 7 wt.% NaCl eq. in the dilute type and 30-47 wt.% NaCl eq. in the hypersaline F and metals. The  $\delta S^{34}$  values of various ore minerals vary in the narrow range from 0.6 to 4.4‰ indicating a homogeneous sulfur source The  $\delta C^{13}$  values of siderite lie in the narrow range of -1.56 to -5.25‰ suggesting a mantle or deep-seated source for carbon. The calculated  $\delta D_{H2O}$  and  $\delta^{18}O_{H2O}$  values of water in equilibrium with muscovite show magmatic character. The 818O values of quartz decrease outward the breccia pipe indicating that there has been mixing with isotopically light (high latitude) meteoric F, mainly after brecciation and formation of breccia pipe. The main mechanism of mineral precipitation were boiling of the F, interaction with wall rock, mixing with meteoric water and cooling. The Glen Eden hydrothermal system has analogies with Climax-type porphyry Mo deposits. (From authors' abstract by E.R.)

SOUISSI, P.F., FORTUNE, J.-P and SASSI, Radhia, 1998, The Mississippi Valley-type fluospar deposit of Jebel Stah CaF<sub>2</sub> (nonheastern Tunisia): Bull. Soc. Géol. France, v. 169, no. 2, p. 163-175 (in French; Engl. abst. and abridged version). First author at Laboratoire de Géochimie, URNE-INRST, BP 95, 2050 Hammam-Lif-Tunisie.

The mineralization of Jebel Stah consists almost exclusively of fluorite. It is associated to the unconformity surface which separates the palaeorelief of the Lower Liassic limestones (Oust Formation) from the condensed layers of the Carixian phosphatic limestones and the Middle-Upper Domerian marls-limestones alternance. Evidences of emergence are visible at the top of the infra-Liassic and the Carixian carbonates. These two formations have, furthermore, undergone a strong epigenetic dolomitization.

The mineralization is hosted in the Carixian layers essentially. We observed that the mineralization has been deposited during an epigenetic stage both replacing the dolomitic rocks and within vens and geodes.

The microthermometric study of FI in fluorite and quartz (two-phase aq I. aq I enclosing a fine L hydrocarbon drop, and gaseous CO<sub>2</sub>-rich I) shows that the mineralizing F are hydrothermal brines. Two stages of crystallization of the fluorite are identified. The ore s.s. (fluorite I) has deposited from a highly saline (20±1 wt.% NaCl eq.) under 135±20°C T conditions. Fluorite II and silica crystallized in later stages owing to the circulation of less saline (10±1 and 5.5±1 wt.% NaCl eq., respectively), but warmer F (185±20°C and 225±20°C, respectively), occurring within geodes and fractures. This late heating is generated by the opening of fractures within an extensional context characterized by a high geothermal gradient. This gradient prevailed over a long period as evidence by the multitude of the crystallization phases.

The association of the mineralization with the unconformity surface within carbonate host rocks that underwent a strong epigenetic dolomitization, the T and sal of the F which deposited the fluorite ore, and the presence of L hydrocarbons in the late mineral phases allow to compare the Jebel Stah fluorite deposit to those of the Mississippi Valley-type group where fluorite dominates. (Authors' abstract)

SOURS-PAGE, R. and NIELSEN, R.L., 1998. Constraints on the diversity of mantle melts using rehomogenized melt inclusions (abst.): Mineralogical Magazine, v 62A, V. M. Goldschmidt Conf., Toulouse 1998. Extended Abstracts, p. 1430-1431. Authors at College of Oceanography and Atmospheric Sci., 104 Ocean Administration Bldg., Oregon St. Univ., Corvallis, OR 97331-5503, USA.

Our work has focused on plagioclase-hosted MI from the Gorda Ridge, the Galapagos Platform and the Endeavour Segment of the Juan de Fuca Ridge. In all areas we found that there was a correlation between the mean MI composition and the host. The major element composition of the I are more primitive than the host lava suite, but can be linked to that suite by fractional crystallization. In contrast, the minor and trace element characteristics of populations of MI exhibit extreme diversity even within a single sample. (From authors' abstract by E.R.)

SPANDLER, Carl, MAVROGENES, John, EGGINS, Steve and AR-CULUS, Richard, 1998, The petrology and PGE mineralisation of the Greenhills Complex, Southland, New Zealand (abst.): Geological Soc. of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 421. First author at GEMOC, Dept. of Geol., Australian Nat<sup>1</sup>, Univ. Canberra ACT 0200.

The Greenhills Complex is a relatively small (14 km<sup>2</sup>) ultramafic- to mafic-layered intrusion. On the basis of whole-rock and mineral chemistry, together with calculated high oxygen fugacities (FMQ 0 to FMQ +3), we suggest the layered series was formed by fractional crystallization of a wet, primitive magma in an island-arc setting. MI trapped within cumulus chrome spinel grains were analysed for trace elements by LA ICP-MS. Multi-element trends constructed from both the dyke and MI data closely compare to the trend of typical low-K island arc tholeites and it is suggested that the parent magmas to the Greenhills Complex were also low-K island arc tholeites, derived from an incompatible element-depleted mantle source. (From authors' abstract by E.R.)

SPRY, P.G. and THIEBEN, S.E., 1998. The origin of gold-silver telluride deposits of the Central Montana alkalic belt (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-301. Authors at Dept of Geological and Atmospheric Sci., Iowa State Univ., Ames, IA 50011-3212; email (pgspry@iastate.edu)

The ore mineralogy is complex and consists of Au-Ag tellurides, and in some deposits, molybdenite, Bi-tellurides, and/or various Bi-, Au-, and Ag- sulfosalts. Alteration related to ore-stage F is localized primarily adjacent to veins and is characterized by

quartz±fluorite±adularia±sericite/roscoelite±illite+kaolinite. Fl studies suggest that gold mineralization was deposited from low-T (130-270°C), moderately saline (1-12 eq. wt.% NaCl), non-boiling, CO<sub>2</sub>-poor, near neutral pH, relatively oxidizing F. Oxygen and hydrogen isotopes indicate that gold-silver telluride mineralization was deposited from meteoric water (Zortman/Landusky) or by mixing of magmatic and meteoric waters (Gies, Golden Sunlight, Spotted Horse-Kentucky Favorite). Lead isotope compositions of galena from Golden Sunlight (<sup>206</sup>Pb/<sup>204</sup>Pb=18.020-19.105, <sup>207</sup>Pb/<sup>204</sup>Pb=15.574-15.759, <sup>208</sup>Pb/<sup>204</sup>Pb=38.002-39.151) and nine deposits in the Judith Mountains (<sup>206</sup>Pb/<sup>204</sup>Pb=17.990-19.946, <sup>307</sup>Pb/<sup>204</sup>Pb=15.587-

in the Judith Mountains (<sup>206</sup>Pb/<sup>20</sup>4Pb=17.990-19.946, <sup>107</sup>Pb/<sup>204</sup>Pb=15.587-15.823, <sup>208</sup>Pb/<sup>204</sup>Pb=38.764-41.007), as well as sulfur isotope compositions from sixteen deposits for a variety of sulfides (pyrite, sphalerite, galena, chalcopyrite, marcasite), suggest a genetic relationship between alkaline magmatism and gold mineralization as well as contributions of ore-forming components from Paleozoic and Proterozoic sedimentary sources. These alkaline igneous-related gold-silver telluride deposits occur at the magmatic-epithermal transition and are affiliated with porphyry molybdenum mineralization. (From authors' abstract by H.E.B.)

St.-AMAND, Katie, STIX, J., DELMELLE, P., GAONAC'H, H., LOV'EJOY, S. and WILLIAMS-JONES, G., 1998, COSPEC measurements at Masaya Volcano, Nicaragua: Part I- SO<sub>2</sub> fluxes, petrology of melt inclusions, and multifractal analysis of COSPEC signals (abst.): EOS. Trans., 79 (45) Fall Meet. Suppl., p. F977. First author at Dept. de Géologie. Université de Montreal, Montreal, Québec, H3C 3J7, Canada; email (stamandk@ere.umontreal.ca)

COSPEC measurements were conducted along three roads at distances of 5.5. 15 and 30 km from Masaya Volcano, Nicaragua, and petrologic analyses were also performed on glass samples. The sulfur contents in glass I do not exceed 400 ppm and are generally lower than 300 ppm. S/CI ratios in glass I average 0.32 with a range from 0.17 to 0.71. This suggests that the magma at a shallow level may be degassed or partially degassed with the majority of SO<sub>2</sub> coming from another level in the conduit or the magma chamber. (From authors' abstract by E.R.)

STACHOWIAK, Anja and SCHREYER, Werner, 1998, Synthesis, stability and breakdown products of the hydroxyl end member of jeremejevite in the system Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-H<sub>2</sub>O. Eur. J. Mineral., v 10, no. 5, p. 875-888.

Indexed under FI.

STALDER, R., FOLEY, S.F., BREY, G.P. and HORN, L. 1998. Mineral-aqueous fluid partitioning of trace elements at 900-1200°C and 3.0-5.7

GPa: New experimental data for garnet, clinopyroxene, and rutile, and implications for mantle metasomatism: Geochim. et Cosmo. Acta. v. 62, no. 20, p. 1781-1801. First author at Institut für Mineralogie, Universität Frankfurt, Senckenberganlage 28, 60054 Frankfurt/Main, Germany.

In order to constrain the role of F phases during metasomatic processes in the upper mantle, trace element partition coefficients for Ba, Sr, Pb, Nb, Ta, Zr, Hf, Ti, La, Ce, Sm, Tb, and Yb between aq F and eclogite assemblage minerals (garnet, clinopyroxene, and rutile) have been determined experimentally at 900-1200°C and 3.0-5.7 GPa. Using a new experimental technique in which diamond aggregates are added to the experimental capsule set-up, the F was separated from the solid residue so that both quenched solute and residual minerals could be analysed directly. Trace element concentrations were determined in situ by laser ablation microprobe (LAM).

The partitioning behaviour is controlled by T. P. and crystal chemistry, whereas F composition is not as crucial. Neither addition of hydrochloric acid nor high silica concentrations in the F have strong effects on trace element partitioning. Results indicate that in the presence of garnet or clinopyroxene. Nb and Ta are highly soluble in aq F, whereas Zr and Hf show variable solubilities. Low field strength elements (LFSE) and light rare earth elements (LREE) are always enriched in the F (D<sup>thud/Man>1).</sup> Generally, D(flud\*Cpx) is positively correlated with T only for high field strength elements (HFSE), but positively correlated with P for all other elements. Therefore, the lowest Nb/La is achieved at ihgh P and low T. However, even the highest P and lowest T examined did not exhibit strong negative HFSE anomalies in the F. Garnet retains compatible trace elements at 3 GPa and 1000°C much more effectively ( $D^{(flud/gt)}Yb=0.002$ ) than at 5.7 GPa at the same T ( $D^{(flud/gt)}Yb=0.04$ ). Decreasing T results in a lowered D<sup>(flud/gt)</sup> particularly for Zr, Hf and heavy REE. At 5 GPa and 900°C a strong intra-REE fractionation is observed (D<sup>(flud/gt)</sup>Sm/Yb around 100) and significantly negative anomalies for Hf and Zr, but not for Nb and Ta, are developed. Only residual rutile fractionates all HFSE from all other trace elements. Tantalum and niobium are retained most effectively by rutile, as is the case for rutile/M partitioning,

F/mineral trace element partitioning has important implications for mantle metasomatism in subarc regions. A model is proposed in which HFSE depletions, as observed in island arc volcanic rocks, could originate from a selective enrichment of the mantle wedge in LFSE and LREE by aq F derived from a rutile-bearing subducted slab. It is shown that melting of the enriched mantle wedge, which had previously been depleted by M extraction (depleted MORB mantle) can produce magmas with trace element patterns similar to those of subduction-related volcanic rocks. (Authors' abstract)

STALDER, R., ULMER, P., THOMPSON, A.B. and GÜNTHER, D., 1998, Experimental determination of second critical endpoints in fluid/melt systems (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1441-1442.

STEINMANN, Marc and STILLE, Peter, 1998. Strongly fractionated REE patterns in salts and their implications for REE migration in chloriderich brines at elevated temperatures and pressures: Sciences de la terre et des planètes/Earth and Planet. Sci., v. 327, p. 173-180. Authors at ULP-EOST-CNRS, Centre de géochimie de la surface, UMR 7517. 1, rue Blessig, 67084 Strasbourg cedex. France; email (ms@illite.u-strasbg.fr)

Rare earth element (REE) distribution patterns have been determined in a salt profile adjacent to a basaltic intrusion. The REE concentrations in the salts are in the ppb range, which required an enrichment prior to ICP-MS analysis. The results document a strong REE fractionation with increasing distance from the basalt contact which could be due to REEchloride solution complexation. The observed fractionation occurred at elevated temperatures and pressures and indicates a higher mobility of Ce, Pr. Nd, Sm and Eu. This finding is of interest for basic research and for the disposal of nuclear waste in salt formations. (Authors' abstract)

The analyses are of bulk salt samples, but the REE might be in FI in the salt? (E.R.)

STERN, L.A., KIRBY, S.H. and DURHAM, W.B., 1998. Polycrystalline methane hydrate Synthesis from superheated ice, and low-temperature mechanical properties. Energy & Fuels, v. 12, p. 201-211.

STIPP, S.L.S., 1998, Spontaneous movement of ions in calcite at room temperature and pressure: Are there implications for fluid inclusion composition, isotope ratios and relative trace metal distribution" (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A90 Author at Interface Geochem., Geological Inst., Copenhagen Univ., Denmark, email (stipp@geo.geol.ku.dk)

Atomic Force Microscopy (AFM) proves that freshly-cleaved, single crystals of Iceland spar calcite are atomically flat over hundreds of nanometers; chemical maps from Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) demonstrate that initially, the topmost atomic layers are homogeneous, composed only of CaCO<sub>3</sub>.

However, during exposure only to air, surface morphology and composition change. Over several months, crystallites form on some of the surfaces, they are composed mostly of Na<sup>\*</sup>, K<sup>\*</sup> and Cl<sup>\*</sup> and range in size from a few to hundreds of nanometers wide and tall.

Stringent precautions preclude the possibility of external contamination. The shape and distribution of the crystallites are reminiscent of FI. and indeed, samples containing abundant I of a size visible by optical microscopy yield aged surfaces with abundant submicrometer scale crystallites, whereas samples without visible I result in aged surfaces where crystallites are absent, in spite of identical preparation and storage. These observations, together with evidence showing movement of divalent ions, Cd2\* and Zn2\* into the bulk, leads us to question what other ions might also move in calcite or in other ionic solids such as the halides or phosphates. lonic mobility may help to explain some data from FI, isotope ratios and trace element distribution for calcite samples that is apparently incongruent with general geological relationships. If calcite does not behave as a closed system, caution must be used in selecting samples for studies of petrogenesis, geochronology, paleoclimate or paleogeographic conditions. In environmental systems, movement of ions from or toward calcite surfaces may increase uptake and release capacity for contaminants. (From author's abstract by E.R.)

See also next two abstracts (E.R.).

STIPP, S.L.S. and KONNERUP-MADSEN, J., 1998, Movement of monovalent ions through calcite at room temperature and pressure (abst.): 23<sup>rd</sup> Nordic Geological Winter Meeting, 13-16 January, 1998, Abstract Volume, p. 283. Authors at Interface Geochem. Laboratory, Geological Inst., Copenhagen Univ., Øster Voldgade 10, DK-1350 Copenhagen K., Denmark.

Fl, isotope ratios and relative trace element composition from minerals give valuable information about the formation conditions and evolution of rocks, but the use of these data is valid only if bulk composition has remained unchanged throughout geologic time. Until now, submicrometerscale movement at Earth's surface T and P has escaped observation, partly because of detection limitations of our traditional methods. In this study, high resolution observations from a combination of two relatively new surface-sensitive techniques complement classical geochemical data. Scanning force microscopy (SFM), which provides images of topography with resolution laterally of about 2 Å and vertically of about 0 1 Å, is excellent at providing information about the physical nature of the surface, insitu, without carbon-coating or high vacuum. Time-of-flight S ion mass spectrometry (TOF-SIMS) gives chemical maps of the topmost atomic layer of a solid, with lateral resolution of less than a micrometer. Both of these techniques were used in this work, to complement data collected using classical geochemical methods.

Cleavage surfaces of single crystals of Iceland spar, that contained submillimeter scale FI, were examined immediately following cleavage and then again after storage for several months. Wet chemical analysis showed the crystals to be essentially pure CaCO3, with <1% substitution of other cations. SFM showed that fresh surfaces were atomically flat over a range of hundreds of nanometers and TOF-SIMS chemical maps proved that after cleavage the surface was composed only of the expected components of calcite. After storage of several months in air, discrete cubic crystallites were observed with both techniques. They were a few to several hundred nanometers in height and were composed of Na', K+, Cl' and F-. Stringent storage and handling conditions precluded the possibility of contamination. The pattern and distribution of these crystallites, aithough at a much smaller scale, was reminiscent of the pattern and distribution of the FI Heating stage experiments showed that the F were composed of Na', K+ Ca2", and CIT [sic]. The development of salt crystallites on these single calcite crystals suggests movement of monovalent ions from internal positions in the bulk to the surface.

The similar pattern of linear defects in the bulk and the absence of micro- or nanoscale holes or fractures imply diffusion along lines of crystal defects. These results prove that in some samples of calcite, composition changes with time, even at ambient conditions. They suggest that coarselycrystalline calcite may not necessarily provide samples that represent origi-
nal formation conditions. Combined with other indications for solid-state diffusion of cations in calcite (Stipp et al. 1992, 1994), these results have serious implications for our trust in the integrity of FI composition, and also in the isotope ratios and trace element distribution in some calcite samples. (Authors' abstract)

See also previous and next abstracts (E.R.).

STIPP, S.L.S., KONNERUP-MADSEN, J., FRANZREB, K., KULIK, A. and MATHIEU, H.J., 1998, Spontaneous movement of ions through calcite at standard temperature and pressure: Nature, v. 396, p. 356-359. First author at Geologisk Institut, Københavns Universitet, Øster Voldgade 10, DK-1350 København K., Denmark.

At the resolution limits of traditional geochemical techniques, there is little evidence to challenge the common assumptions that, under the Earth's ambient surface conditions, dry calcite is static and that the bulk mineral behaves as a closed system. Solid-state diffusion has been recognized at elevated temperatures, but it has always been assumed that diffusion in carbonate minerals is negligible under standard conditions. There is, however, some evidence to the contrary. More than 30 years ago, the 45Ca diffusion coefficient was estimated to be -8x10'20cm2 and, more recently, we have demonstrated movement of adsorbed Cd2+ and Zn2+ into bulk calcite at rates of tens of nanometres over weeks to months. Here we present evidence that monovalent ions, Na\*, K+ and CI\*, originating from FI, accumulate in crystallites on the surface of calcite. This process is spontaneous at the Earth standard surface conditions, in air. The results show that calcite under standard conditions does not always behave as a closed system, which is a critical assumption in the use of isotope ratios, trace-element distribution and FI composition for interpretations of palaeoclimate geochronology or petrogenesis. Moreover, calcite's uptake capacity for contaminants in environmental systems is probably higher than current models predict, because surface sites are constantly renewed by ionic mobility. (Authors' abstract)

See also previous abstracts (E.R.).

STUART, F.M., HARROP, P.J., KNOTT, R., FALLICK, A.E., TURNER, G., FOUQUET, Y. and RICKARD, D., 1995. Noble gas isotopes in 25.000 years of hydrothermal fluids from 13°N on the East Pacific Rise: in Parson, L.M., Walker, C.L. and Dixon, D.R. (eds.), 1995, Hydrothermal Vents and Processes: Geological Soc. Special Pub. #87, p. 133-143. First author at Dept. of Geol., Univ. of Manchester, Manchester, M13 9PL, UK.

Noble G isotopes have been measured in FI in sulphides spanning 25,000 years of hydrothermal activity at 13°N on the East Pacific Rise. The 3He/4He ratios are typical of mid-ocean ridge hydrothermal F, albeit slightly higher than contemporary vent waters, and reveal no temporal variation or correlation with the 84S of the host sulphide. The absence of radiogenic He in F from the 25,000 year-old mineralization on the SE Seamount suggests that the hydrothermal circulation occurred within an active magmatic system and not within the underlying 130 ka oceanic crust. This implies that seamount volcanism and hydrothermal activity occurred simultaneously off-ridge, and that magmatic activity shifted approximately 5 km off-ridge at this time. Helium concentrations in FI from three samples are significantly greater than the end-member hydrothermal F at mid-ocean ridges. Small excesses of <sup>40</sup>Ar in the included F demonstrate that mantle-derived <sup>40</sup>Ar has been degassed along with primordial helium. Both are consistent with the direct addition of magmatic volatiles into the hydrothermal system at times during the history of hydrothermal activity at the site (Authors' abstract)

STUART, F.M. and TURNER, Grenville, 1998. Mantle-derived <sup>40</sup>Ar in mid-ocean ridge hydrothermal fluids: Implications for the source of volatiles and mantle degassing rates: Chem. Geol., v. 147, p. 77-88. Authors at Dept. of Geol., Univ. of Manchester, Manchester M13 9PL, UK; email (stuart@surrc.gla.ac.uk)

<sup>40</sup>Ar excesses of up to 2.6% relative to atmospheric Ar are present in F in hydrothermal sulfides from 13°N. East Pacific Rise. FI <sup>3</sup>He /<sup>4</sup>He are typical of mid-ocean ridge vent F implying a mantle origin for the <sup>40</sup>Ar. Helium concentrations calculated from <sup>4</sup>He/<sup>36</sup>Ar, are similar to high T vent F and cannot be derived by leaching the oceanic crust during hydrothermal seawater convection. It is proposed that volatiles are acquired during F flow through a narrow, highly permeable zone close to the crystallising magma chamber. The ratio of mantle-derived <sup>4</sup>He to <sup>40</sup>Ar in the F, denoted (<sup>4</sup>He/<sup>40</sup>Ar)<sub>mande</sub>, range from 3.4 to 36.4. The data displays a bimodality similar to mid-ocean ridge basalt ratios. The low (<sup>4</sup>He/<sup>40</sup>Ar)<sub>mande</sub> volatiles are similar to bulk mantle M and probably represent volatiles exsolved during an early stage of degassing. The high ( ${}^{4}\text{He}/{}^{40}\text{Ar}$ )<sub>mattle</sub> volatiles are derived from an already degassed magma. The mantle  ${}^{46}\text{Ar}$  flux calculated from  ${}^{46}\text{Ar}_{martle}$  in the hydrothermal F ranges from 1 to 2.4 x 10<sup>7</sup> mol a<sup>-1</sup>. This is at least twice the previous estimates and overlaps the flux calculated from highly vesiculated mid-ocean ridge basalt (1.6-4.2 x 10<sup>7</sup> mol a<sup>-1</sup>). This cannot be derived from the decay of  ${}^{40}\text{K}$  in an upper mantle above 670 km which produces <1 x 107 mol a<sup>-1</sup>). If the measured  ${}^{40}\text{Ar}$  flux reflects steady-state degassing of the upper mantle, then a significant proportion of the rare G must be transferred from a deeper reservoir. (Authors' abstract)

STUCKLESS, J.S., MARSHALL, B.D., VANIMAN, D.T., DUDLEY, W.W., PETERMAN, Z.E., PACES, J.B., WHELAN, J.F., TAYLOR, E.M., FORESTER, R.M. and O'LEARY, D.W., 1998, Hill, C.A., Dublyansky, Y.V., Harmon, R.S., Schluter, C.M., Comments on "Overview of calcite/opal deposits at or near the proposed high-level nuclear waste site, Yucca Mountain, Nevada, USA: Pedogenic, hypogene, or both": Environmental Geol., v. 34, no. 1, p. 70-78. Authors at U.S. Geological Survey, Box 25046, MS 425, Denver Federal Center, Denver, CO 80225, USA.

A critical review of the FI evidence provided by the proponents of rising hydrothermal waters at Yucca Mountain, NV (E.R.).

STURKELL, E.F.F., BROMAN, Curt, FORSBERG, Per and TORS-SANDER, Peter, 1998. Impact-related hydrothermal activity in the Lockne impact structure, Jämtland, Sweden: Eur. J. Mineral., v. 10, p. 589-606. Authors at Dept. of Geol. and Geochem., Stockholm Univ., S-106 91 Stockholm Sweden: email (Erik.Sturkell@geo.su.se)

F trapped as F1 in minerals from cavities in the impact breccia are mainly composed of hydrocarbons and/or a brine. The earliest F, that consists of methane, ethane and possibly aromatic hydrocarbons, was probably derived from an organic-rich dark Cambrian clay flowing into the crater during the resurge phase, and thermally altered by the residual heat of the impact. The heat also generated a hydrothermal convection system.  $\delta^{34}$ S values of 1 to 5.5‰ (CDT) for chalcopyrite and pyrite suggest that sulfur was leached from the shattered basement rocks below the impact breccia. Calcite and sulfides were deposited in cavities between the breccia clasts from a brine with a sal around 20 wt% eq. CaCl<sub>2</sub> at a T that reached 210°C.  $\delta^{13}$ C for calcite is between -2 and -14‰ (PDB), which indicates mixing with carbon from a marine and an organic source.  $\delta^{18}$ O for calcite is homogeneous, varying from 10 to 14‰ (SMOW). The oxygen composition may indicate a meteoric or seawater source. (From authors' abstract by E.R.)

SU, Wenchao, QI, Liang, HU, Ruizhong and ZHANG, Guoping, 1998, Analysis of rare-earth elements in fluid inclusions by inductively coupled plasma-mass spectrometry (ICP-MS): Chinese Sci. Bulletin (Kexue tongbao), v. 43, no. 22, p. 1922-1927 (in English). Authors at Open Laboratory of Ore Deposit, Inst. of Geochem., Chinese Acad of Sci., Guiyang 550002, China.

Inductively coupled plasma-mass spectrometry (ICP-MS) is used to determine rare-earth elements abundances in FI. Quartz separates from the Lannigoug and Yata Carlin-type gold deposits, southwestern China, were prepared by the decrepitation-leach method. Leachates were analyzed by ICP-MS, using conventional sample introduction. The results demonstrate that the decrepitation-leach method, in combination with ICP-MS analysis of leachates. is effective for REE determination. The chondrite-normalized REE patterns of IF for the Lannigou and Yata samples associated with gold mineralization are characterized by light REE enrichment, with a weak negative Ce anomaly and a positive or negative Eu anomaly, whereas the pattern for the Lannigou sample associated with late gold mineralization (quartz-calcite stage) is characterized by LREE enrichment relative to HREE, with negative Ce and Eu anomalies. (Authors' abstract)

SU, Wenchao, YANG, Keyou, HU, Ruizhong and CHEN, Feng, 1998, Fluid inclusion chronological study of the Carlin-type gold deposits in southwestern China: As exemplified by the Lannigou gold deposit, Guizhou Province: Acta Mineralogica Sinica, v. 18, no. 3, p. 359-362 (in Chinese; Engl. abst.) Authors at Inst. of Geochem., Chinese Acad. of Sci., Guiyang, 550002.

Rb and Sr isotopes were analyzed in Fl extracted from quartz and calcite gangue minerals of the Lannigou Carlin-type gold deposit, Guizhou Province. The results demonstrate that Rb and Sr isotopes in Fl are useful tools for dating mineralization events when applied to the Carlin-type gold deposits.

Rb-Sr isotope data of FI indicate that the mineralization age of the Lannigou Carlin-type gold deposit may be at 82~105.6 Ma, and is in consistence with the geological events of these areas. (Authors' abstract)

SULEIMENOV, O.M. and SEWARD, T.M., 1998, UV-visible spectrophotometric measurements of metal complex formation at high temperatures. The stability of Mn (II) chloride species (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p 1477-1478.

SUM, Yumei and GUO, Naiyan, 1998. The application and implication of fluid inclusion to oil/gas exploration in Yinggehai Basin, South China Sea (abst.) Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998. Tashkent, Uzbekistan. Abstracts volume, p. 149-150 (in English). Authors at China Offshore Exploration & Development Research Center (EDRC), 22 East Street, Gaobeidian, Hebei.

FI microscopy Th, sal and Laser Raman Microprobe (LRM) analysis of [inclusions in] quartz in siltstone, mudstone and fine sandstone of Miocene-Pliocene in Yinggehai Basin, South China Sea, indicate that hydrocarbon FI exist mainly in fractures in quartz, and are mainly gaseous. Three major stages of 1 Th were recognized in the center diapir structure zone. The first stage is mainly of gaseous-L phase I, and the Th ranges between 130-150°C. The second stage is mainly of gaseous phase I, and the Th [sic] is about 170-190°C. The third stage is mainly of gaseous phase and gaseous-L mixture I, and the Th is above 200°C Comparison of light hydrocarbon characteristic of oil-gas in FI with G in current reservoirs suggests the drying factor of G trapped in I is less than that in the current reservoirs, and the alkene content in I is higher than that in the current reservoirs. The result also suggests that oil-G in I is less mature than that in the current reservoir. I fluorescence microscopy indicates a range in maturity of trapped oil/G. Microscopy examination have shown that some G "bubble" or gaseous-L two phase mixture drops charge between the grains, which suggests that the reservoir was still charged with larger volumes of more mature oil/G in late stage. (From authors' abstract by E.R.)

SUN, Qing, WENG, Shifu and ZHANG, Xu, 1998, µFTIR microanalysis limits of hydrocarbon fluid inclusions: Matrix minerals absorption: Earth Science-J. of China University of Geosci (Diqiu Kexue, Zhongguo Dizhi Daxue Xuebao), v. 23, no. 3, p 248-252 (in Chinese; Engl. abst.). Authors at Dept. of Geology, Peking Univ., Beijing 100871.

It's an interesting and troublesome problem that mineral matrices will strongly absorb mid-IR radiation over wide spectral ranges, even for very thin rock wafers. Even in those regions of the IR spectrum where no foundational [fundamental?] vibration absorption appears, overtone and combination tone vibrations of the matrix may still be present. These vibrations may cause misidentification of the bands. If the matrix mineral is carbonate, the problem becomes important. The cause of matrix absorption, the absorption ranges of quartz and calcite, and the ways of reducing matrix absorption are presented. It is also pointed out that the absorption band near 1750 cm<sup>-1</sup> can be used for identifying carbonyl, and emphasized that the matrix absorption should be given more attention in the analysis of IR spectrum. (Authors' abstract)

SUN, Qing and ZENG, Vishan, 1998. Carboxylate composition of fluid inclusion leachate in the Linlong gold deposit. Shandong Province: Geochimica, v. 2, no. 6, p. 579-584 (in Chinese with Engl. abst.)

Carboxylate composition of FI leachates from quartz and other minerals in the Linlong gold deposit were detected by ion chromatography. The results show that the content of shortchain carboxylates (the dominant species (oxalate) is low. The carboxylate concentration is higher in the leachates from pyrite and chalcopyrite than that from quartz. The monofunctional carboxylate concentration is higher in early ore-forming F than that in middle to late ones. (Authors' abstract)

SUN, Xiaoming, NORMAN, D.I., SUN, Kai and CHEN, Binghui, 1998, The Changkeng Au-Ag 'Carlin-type' deposit, central Guangdong, China (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A126-A127. First author at Dept. of Earth Sci., Zhongshan Univ., Guangzhou, 510275, P.R. China; email (eessxm@zsu.edu.cn)

The Changkeng deposit is sediment hosted, hence is called a Carlintype deposit. It is comprised of two types of ore that occupy a gently dipping fault separating Triassic terrigenous sediments and Carbonaceous limestones. The gold deposit with >40 tons Au is comprised of black crystalline quartz with finely disseminated pyrite and minor realgar. Gold occurs in quartz, pyrite, and mixed with clay alteration minerals. The silver ore containing >3000 tons Ag are associated with white crystalline quartz. and calcite, with a few percent sphalerite. I in both types of ore have Th

values mostly between 200 and 250°C and sal are about 5-10 eq. wt % NaCl; oil is common in auriferous quartz. Calculated isotopic composition of ore F is 8D -30 to -59 per mil, and 818O -7.8 to 9.8 per mil: 3Her4He are 0.0054 to 0.84 Ra (n=5). FI G analyses indicate N2/Ar 30-2000, most values are >air saturated water. Inclusion H2S correlates with N2/Ar FIG analyses indicates Au ores were deposited by a F with an order of magnitude more H2S and lower CO2/CH4 than silver depositing solutions. Calculated metal solubility in ore solutions based on I analyses indicates the Au ore solutions could transport Au but little Ag and Zn, and vice versa for Ag ore F.

The data are consistent with ore F mixtures of meteoric, evolved, and magmatic F. Different F pathways for Au and Ag mineralization are suggested by the differences in FI chemistry. (Authors' abstract)

SUNAGAWA, L, 1998, Growth, morphology and perfection of diamonds (abst.) 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A11 Author at Yamanashi Inst. Gemmology and Jewellery Arts.

Natural diamond crystals grew in a silicate solution phase (magma). Eclogitic and ultramafic suites are assumed to be two different chemical environments. (From author's abstract by E.R.)

SUTHERLAND, F.L., 1998, Gem corundum origins from eruptive sources (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A13. Author at Australian Museum; email (lins@amsg.austmus.gov.au)

Sapphires and rubies of many colours come from alkali basaltic eruptives in various localities (Australia, SE Asia, China, Africa, Madagascar, Europe). FI of CO2 and CO2 with saline aq F and dm indicate corundum crystallization above 680°C. Secondary exsolutions of Fe and Ti oxides in corundum-bearing xenoliths indicate original crystallization around 900°C. (From author's abstract by E.R.)

SVARA, P., De POLI, A., LEISCHNER, K., MOSCA, F. and TUR-RINI, C., 1998, Modelling in thrusted areas; sensitivity analysis and application: First Break, v. 16, no. 1, p. 9-20. Indexed under FL

SVENSEN, H., JAMTVEIT, B., YARDLEY, B. and AUSTRHEIM, H., 1998, Eclogite facies fluids from the Caledonides of western Norway; compositions and implications for fluid-rock interactions (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1481-1482. First author at Dept. of Geol., Univ. of Oslo, P.O. Box 1047 Blindern, N-0316, Oslo, Norway.

Both matrix omphacites and omphacites from eclogite facies veins have a wide range of dms (or, in part possibly "step-daughters." from retrograde F-mineral reactions). Phases identified include calcite, halite, gypsum, K-feldspar, amphibole, quartz, albite, Fe-oxide, rutile, various sulfides with CuFe-NiZnAsPb, and halides with NaKCaPb plus Cl or Br. Pb concentrations of 10.000 to 200,000 Pb are found. Cl/Br ranged from -50 to 850, and ppm Br from -100 to 3500. (E.R.)

SZABÓ, Cs. and BODNAR, R.J., 1998, Fluid inclusion evidence for an upper-mantle origin for green clinopyroxenes in Late Cenozoic basanites from the Nógrad-Gömör volcanic field, northern Hungary/southern Slovakia: Int'l. Geol. Review, v. 40, p. 765-773. Authors at Fluids Research Laboratory, Dept. of Geological Sci., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061-0420.

Green clinopyroxenes with elevated Fe and Na contents coexist with "normal" clinopyroxene phenocrysts in alkali basalts from the Nograd-Gömör volcanic field (NGVF) of northern Hungary and southern Slovakia The coexistence of these clinopyroxenes with incompatible compositions in the same sample is often used as evidence for mixing between a mafic and a more evolved M. However, results of FI, textural, and geochemical studies of samples from Tertiary basanites from the NGVF suggest that the majority of the green clinopyroxenes could not have formed from magma mixing but rather, are products of lithospheric processes such as metasomatism or dynamic M flow,

Two distinct types of green clinopyroxenes have been identified. Group I green clinopyroxenes are AI rich and contain CO2 I: Group 2 green clinopyroxenes are Al poor and lack CO21. On the basis of analysis of CO2 I, the Group 1 clinopyroxenes, observed as xenocrysts and major constituents of clinopyroxenite xenoliths, were entrained into the host basanitic magmas in the uppermost mantle. These clinopyroxenes originally formed during a metasomatic event or as a result of dynamic M flow in the mantle.

Group 2 clinopyroxenes likely represent xenocrysts from disaggregated dioritic cumulates produced from M related to the host basanitic magmas. (Authors' abstract)

TAGIROV, B.R. and KORZHINSKIY, M.A., 1998, Solubility of ironbearing minerals in supercritical NaCl (KCI)-rich acid solutions (abst.): Mineralogical Magazine, v 62A, V M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1488-1489.

TAGUCHI, S., TAKAGI, H., MAEDA, H., SANADA, K., HAYASHI, M., SASADA, M., SAWAKI, T., UCHIDA, T. and FUJINO, T., 1998. Gas behavior at some geothermal fields in Japan, revealed by Laser Raman Microprobe analysis of fluid inclusions. <u>in</u> Water-Rock Interaction. G.B. Archart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p 695-696. First author at Fukuoka Univ., Japan.

Laser Raman microprobe (LRM) was applied to FI analysis during a development of prospective technology to explore fractured-type geothermal reservoirs, which was promoted by NEDO. LRM is a powerful tool to get useful information on dynamic F behavior and geothermal structures even in a geothermal system with very dilute G contents such as Japanese one. (Authors' abstract)

TAKAHASHI, Miwa, MIZUTA, Toshio, ISHIYAMA, Daizo, MA-TSUBAYA, Osamu and KIMURA, J.-I., 1998, LA-ICP-Mass spectrometry of rare earth elements in quartz of various mineralization stages from the Hishikari epithermal gold-quartz vein deposit, Japan (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30. no. 7, p. A-369 First author at Inst. of Applied Earth Sci., Akita Univ., Akita 010-8502, Japan; email (miwat@galena.mine.akita-u.ac.jp)

The Hishikari deposit is one of the most representative of epithermal gold-silver vein deposits in Japan. Main focus of this study is to clarify the time-spatial relationships of Au-quartz mineralization from the analytical data of rare earth elements using a LA-ICP-MS and oxygen isotopic ratios of quartz. REE concentration in quartz crystals in very early mineralization stage with high Au grade, and successive later stage quartz at shallower levels and quartz bands of various stages are examined grain by grain. XRD data show that the contamination of clay minerals such as kaolinite and montmorillonite are negligible.

The studied veins are the highly Au-rich Ryosen No. 1 vein (2.130 g/t Au) and the Ryosen No. 5 vein (3,700 g/t Au), especially in earlier stages, and the Hosen No. 5 vein with average Au grade (200 g/t) and continuing their mineralization stages at 100 m deeper level in the Hishikari deposit. The fluctuation of filling T measured for P FI in quartz are not detected and are around 200°C with very low sal of 0.0-0.5 wt.% NaCl eq. REEs in quartz with various types of textures such as mosaic, comb and microcrystalline are analyzed. REEs in the earlier mineralization stage of high Au grade vein are considerably high, however, REEs in quartz of inner and later stage quartz bands with average Au grade (200 g/t) are clearly low even in the same vein. Calculated  $\delta^{18}$ O values of ore F in the Ryosen No. I vein, Ryosen No. 5 vein and Hosen No. 5 vein are from -2.6 to -1.7, -3.3 and from -4.7 to -3.2 per mil. respectively. Those isotopic and REE data with Au grades show that ore-forming F in earlier stage of mineralization could be formed by a sufficient reaction with underlying host rocks. There are some possibilities such as mixing between magmatic hydrothermal solutions and meteoric water sufficiently equilibrated with wall rocks and contaminated with various kinds of cations such as Au, REEs and <sup>18</sup>O. On the contrary, F of later stages with common or lower Au grade bands within the same veins have low REE contents and slightly lighter 180. Isotopic values plotted on 8O vs 8D diagram along the line between isotope data of earlier stage F and local meteoric water.

New fracturing system could be responsible to be a new F path of the high REE, heavier <sup>18</sup>O and high Au mineralization with low water/rock ratio, and later F should be mixed with large amounts of meteoric water during the successive mineralization stages and filled the inner parts of old fissures. (Authors' abstract)

TANER, H., WILLIAMS-JONES, A.E. and WOOD, S.A., 1998. The nature, origin and physicochemical controls of hydrothermal Mo-Bi mineralization in the Cadillac deposit, Québec, Canada: Mineralium Deposita, v. 33, p. 579-590. First author at 1107 Gablefields Private, Gloucester, Ontano, Canada, K1J 1E3.

Mo-Bi mineralization occurs in subvertical and subhorizontal quartzmuscovite±K-feldspar veins surrounded by early albitic and later Kfeldspathic alteration halos in monzogranite of the Archean Preissac pluton. Abitibi region, Québec, Canada. Mineralized veins contain five main types

of FI: ag L and L-V I, ag carbonic L-L-V I, carbonic L and VI. halitebearing aq L and L-V I. trapped mineral-bearing aq L and L-V I. The carbonic solid in frozen carbonic and aq-carbonic I melts in most cases at -56.7±0.1°C, indicating that the carbonic F consists largely of CO2. All aq I types and the aq phase in carbonic I have low initial melting T (≥70°C). requiring the presence of salts other than NaCl. Leachate analyses show that the bulk F contains variable proportions of Na, K, Ca, Cl and traces of Mg and Li. The following solids were identifed in the FI by SEM-EDS analysis halite, calcite, muscovite, millerite (NiS), barite and antarcticite (CaCl2 • 6H2O). All are interpreted to be trapped phases except halite which is a dm, and antarcticite which formed during sample preparation (freezing). Aq I homogenize to L at T between 75 and 400°C; the mode is 375°C Aq-carbonic I homogenize to L or V between 210 and 400°C. Halite-bearing aq I homogenize by halite dissolution at approximately 170°C. Aq I containing trapped solids exhibit L-V homogenization at T similar to those of halite-bearing aq l. T of vein formation, based on oxygen isotopic fractionation between quartz and muscovite, range from 342 and 584°C. The corresponding oxygen isotope composition of the aq F suggests that the L had a significant meteoric component. Isochores for aq FI intersect the modal isotopic isotherm of 425°C at P between 590 and 1900 bar. A model is proposed in which molybdenite was deposited owing to decreasing T and/or P from CO2-bearing, moderate to high sal F of mixed magmatic-meteoric origin that were in equilibrium with K-feldspar and muscovite. (From authors' abstract by E.R.)

TARNAI, T., 1998, Mineralogical-petrological study on ore vein penetrated by the key-borehole Baksa No. 2 SE Transdanubia, Hungary: Acta Mineralogica-Petrographica, v. 39, p. 21-34. Author at Dept. of Mineral., Geochem. and Petrol., Attila József Univ., Szeged, Hungary.

In 1995/96 a complex study on ore minerals occurring in a 7 cm thick massive sulfide vein traversed in the drilling Baksa 2 at 186.4 m depth was made.

Possibly, the vein was formed in closed system at low P in a T interval ranging from 250 to 310°C. A two-phase formation can be supposed. It is most likely that F forming the ore vein are differentiates of a real magmatic M. Identification of the regional connection is quite difficult, however, it can be brought into connection with either the Permian volcanism in the Villary Mountains or an unknown independent volcanic activity. (From authors' abstract by H.E.B.)

TAYLOR, L.A., MILLEDGE, H.J., BULANOVA, G.P., SNYDER, G.A. and KELLER, R.A., 1998, Metasomatic eclogitic diamond growth: Evidence from multiple diamond inclusions: Internat'I. Geol. Review, v 40, p. 663-676. First author at Planetary Geosci. Inst., Univ. of Tennessee, Knoxville, Tennessee 37996.

Diamond formation from metasomatic F, rather than from igneous M. remains controversial but is paramount to our understanding of diamonds' mantle origins. Physical and chemical properties of diamonds, their I, and host eclogites from the Mir kimberlite, Yakutia, Russia, form the basis for our evaluation of diamond origin. Mir eclogitic diamonds and their multiple I show a definite break in time and T between the formation of the core zones and the rims of the diamonds. Extreme changes in chemistry for multiple diamond I (DIs) between the cores and the rims cannot be accounted for by magmatic fractional crystallization. Evidence also exists for large T decreases (40-140°C) from the cores to the rims of some diamonds. The distinct changes in nitrogen contents and aggregation states from cores to rims of diamonds would appear to reflect different residence times for these portions of the diamonds in the mantle-i.e., formation of cores and rims at vastly different times (e.g., 2 Gy). Many of the mineral-chemical characteristics, including C and N isotopes and N aggregation states of the diamond, can best be explained by crystallization of the diamonds after formation of the eclogite host. This suggests that the formation of the eclogite and the nucleation and growth of some diamonds are not coeval and possibly not cogenetic.

Most diamondiferous eclogite xenoliths probably have never experienced analysis major magmatic episode (i.e., complete M stage) after subduction of their crustal protoliths into the mantle. Carbon isotopes in diamond, sulfur isotopes from sulfide DIs, and oxygen isotopes from eclogite minerals all point to crustal protoliths for many eclogites.

All of the factors above, taken as a whole, indicate that many eclogitic diamonds are the result of petrogenesis by metasomatism over a prolonged period of time. Introduction of metasomatic F facilitates the precipitation of the diamonds, either *in toto* or as rims on previously formed diamonds. Inasmuch as some eclogites are considered to be igneous in origin—e.g., Group-A eclogites of Taylor and Neat (1989)—it is entirely possible that

these eclogites may contain truly igneous diamonds. However, even some of these diamonds may have later metasomatic overgrowths. (Authors' abstract)

TAYLOR, L.G. and BORNHORST, T.J., 1998, A boiling model for the formation of enargite-bearing veins in the Central City district. Colorado: The Mountain Geologist, v. 35, no. 1, p. 15-22. First author at Dept. of Geological Engineering and Sci., Michigan Technological Univ., Houghton, MI 49931.

The Togo Mine is within the Central City mining district in the Colorado Front Range, a district which has produced over \$100 million in Au, Ag, Cu, Pb, Zn and U since 1859. The mine is one of several enargitebearing deposits along a northeast-southwest trend in the eastern part of the district. Veins and fractures hosted by Precambrian gneiss contain an early pyrite-quartz stage of minerals followed by a base-metal sulfide stage. FI studies and mineral assemblages suggest that hydrothermal F were at about 250°C with about 10 wt.% NaCl eq., pH of 4.5 to 5.8, log/O<sub>2</sub> of -34, and log/S<sub>2</sub> of -10. Highly variable L-V ratios in FI, abundant sericite alteration, brecciated minerals, and repetitively banded veins indicate boiling of the hydrothermal F at the Togo Mine. Mineral deposition at the Togo Mine is attributed to the decline in mineral solubilities resulting from a rise in pH during boiling. We suggest that boiling played an important role in the formation of other enargite-bearing deposits within the Central City mining district. (Authors' abstract)

TEDESCO, Dario, NAGAO, Keisuke and SCARSI, Paolo, 1998, Noble gas isotopic ratios from historical lavas and fumaroles at Mount Vesuvius (southern Italy): Constraints for current and future volcanic activity: Earth and Planet. Sci. Letters, v. 164, p. 61-78. First author at Inst. for Studies of Earth's Interior, Okayama Univ., Misasa, 682-01 Tottori-ken, Japan; email (darioejing@aol.com)

Helium, neon and argon isotope ratios have been analysed from phenocrysts of eleven lava samples belonging to the last eruptive cycle of Mount Vesuvius (1631 until 1944). The phenocrysts separates include pyroxene (N=10) and olivine (N=1). All phenocrysts samples show simi-larly low G contents (He, Ne and Ar-10<sup>-10</sup> cm<sup>3</sup>/g). <sup>3</sup>He<sup>A</sup>He ratios, 5.3-2.11 Ra, are generally low if compared to those typical of the MORB and those of the European Subcontinental Mantle (ESCM), respectively R/R, 8.5±1 and 6.0-6.5. A decreasing trend is found from 1631 to 1796, while a more homogeneous set of data is obtained for mor recent eruptions, as evidenced by an average R/Ra value of 2.85. Neon ratios 21 Ne/22 Ne and 20 Ne/22 Ne strongly differ from those typically found on volcanoes and suggest that a crustal component has been added in the source region to Mt. Vesuvius magmas. Argon ratios (41 Ar/36 Ar and 38 Ar/36 Ar) have values similar to the atmosphere and are well correlated. The low 40 Ar/26 Ar ratio (max. 302) is. however, in the range of the <sup>40</sup>Ar/36Ar ratios obtained from several lava samples at other Italian volcanoes and might be considered to have a deep origin. Two hypotheses have been discussed: (1) a deep argon-like-air source, due to subduction of air-rich sediments and/or (2) a preferential loss of Ar. in comparison to lighter noble G. from silicic M. Helium isotopic analysis of G samples recently collected from crater and submarine fumaroles are similar to those of lavas belonging to the final part of this eruptive cycle. This result supports the idea that no new juvenile F from the source origin have been injected into the magmatic reservoir during the 1631-1944 eruptive cycle and, more importantly, until 1993. Both sets of data help to understand the genesis of these F and to constrain the current activity of the volcano. (Authors' abstract)

THIEBEN, S.E., 1998, Geology and geochemistry of epithermal goldsilver telluride deposits of Montana. USA: SEG Newsletter, No. 35, p. 8. Author at Dept. of Geological and Atmospheric Sci., Iowa State, Univ., Ames, Iowa.

Epithermal Au-Ag telluride deposits in central Montana are spatially and genetically related to alkaline igneous intrusions of Cretaceous-Teritary age and to the Great Falls Tectonic Zone. Mineralization styles include bonanza veins, carbonate replacement at igneous/carbonate contacts, breccia pipe-hosted, fault-controlled and sediment-hosted. More than one mineralization style may be present in a given deposit; however, all exhibit some structural control. Ore mineralogy is complex and consists of Au-Ag tellurides, native Au, and in some instances. Bi-tellurides and Bi, Au-, and Ag-sulfosalts. Alteration related to ore-stage F adjacent to veins characterized by silica±fluorite±adularia±sericite±illite±kaolinite. A regional alteration halo is present in at least one locality and roscoelite is associated with tellurides at several deposits. Several hundred FI measurements suggest the gold telluride mineralization was deposited from low-T (130270°C), moderately saline (1-12 wt.% NaCl eq.), non-boiling, CO<sub>2</sub>-poor, oxidizing F with near-neutral pH. Oxygen and hydrogen isotope measurements indicate Au-Ag telluride mineralization was deposited by F with a meteoric or a mixed meteoric-magmatic source. Sulfur isotope data suggest a variety of magmatic and/or sedimentary sulfur sources. Some of these Au-Ag telluride deposits either contain molybdenite or have elevated Mo contents and may represent one end member of a continuum with porphyry molybdenum deposits. (Author's abstract)

THIÉRY, Régis and DUBESSY, Jean, 1998, Description of vapour-liquid phase equilibria of the H<sub>2</sub>O-NaCl system between 100 and 900°C with a thermodynamic model based on the Mean Spherical Approximation. Eur. J. Mineral., 1998, no. 10, p. 1151-1165. Authors at CREGU, Centre de Recherche sur la Géologie des Matières. Minérales et Energétiques, BP 23, F\*54501 Vandœuvre-lès-Nancy Cedex, France.

The Mean Spherical Approximation (MSA) of the ion-dipole mixture is used to describe the V-L equilibria of the H<sub>2</sub>O-NaCl system. Companson with experimental data reveals that the H<sub>2</sub>O-NaCl mixture cannot be solely modelled by the MSA ion-dipole model. Discrepancies have been significantly reduced by taking into account NaCl ion pair formation in V at all T and in high-T L (T>387°C). A van der Waals interaction term must be included at lower T (T<387°C) and is believed to describe effects of the solvation of ions by water molecules or short-range interactions between anions and cations. The model has been fitted in the 100-850°C T range, and represents experimental data with a good accuracy from dilute aq solutions to fused salts. This model provides insights on the effects of electrostatic interactions (ion-ion, ion-dipole, dipole-dipole) and stresses the importance of NaCl ion pair formation and other effects on the V-L equilibria of the H<sub>2</sub>O-NaCl system. (Authors' abstract)

See also FIR 30, p. 192-193 (E.R.).

THOMAS, R, 1998, What can we learn from melt inclusions in granite pegmatites? (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A146. Author at GeoForschungsZentrum Potsdam, Germany D-14473; email (thomas@gfz-potsdam.de)

A review of FI studies of MI from pegmatites. (E.R.)

THOMAS, Rainer, WEBSTER, J.D. and RHEDE, Dieter, 1998, Strong phosphorus enrichment in a pegmatite-forming melt. Acta Universitatis Carolinae-Geologica, v. 42, no. 1, p. 150-164. First author at GeoForschungsZentrum Potsdam, Albert-Einstein-Straße-Telegrafenberg, D-14473 Potsdam, Germany.

MI trapped in pristine igneous minerals are potentially the best source of data on the real element contents of silicic M, particularly the volatiles and semi-volatiles in the magma. We report here some bulk and traceelement data for MI trapped within quartz from peraluminous pegmatites associated with the famous tin deposit of Ehrenfriedersdorf. The remarkable feature of these MI is the extremely high abundance of some volatiles and semi-volatiles as well as some ore-forming elements (Sn, Zn, Cu, W) when compared to the granitic host rock.

The MI composition implies that the pegmatite L achieved extreme levels of chemical differentiation. Fractions of the pegmatite-forming L were extremely enriched in P<sub>2</sub>O<sub>3</sub>+F+Al<sub>2</sub>O<sub>3</sub>, and they contained a high abundance of Sn, Zn, Li, Rb, Cs, Nb, Ta, and Be.

We have also found textural evidence for L immiscibility in the reheated and quenched silicate MI—two coexisting and differently coloured glasses separated by a sharp meniscus or phase boundary in the I. According to microprobe and RAMAN studies the second M consists of Prich. Si-poor M droplets in a F-rich silicate M. The proof of berlinite and berlinite-like molecules in the studied MI demonstrates the strong complexing of P and Al in F-rich pegmatite M. (Authors' abstract)

Includes three complete analyses, plus trace elements, of MI, as well as as major Raman modes for possible dms: berlinite, variscite, angelite, trolleite, lazulite, triplite, isokite, apatite, amblygonite, burangaite, and an unknown (E.R.)

THOMPSON, T.B., Cripple Creek—A world-class gold-bearing, diatreme-Alkalic intrusive complex, Colorado, USA (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-301. Author at Center for Research in Economic Geol., Mackay School of Mines/169, Univ. of Nevada-Reno, Reno, NV 89557; email (tommyt/a/mines.unr.edu)

The Cripple Creek district is localized within a mid-Tertiary diatremealkaline intrusive complex, focused on a Proterozoic fabric trending north-

westerly and crosscut by northeasterly-trending structures. Igneous rocks range from phonolite to youngest lamprophyric dikes and diatremes.

Orebodies in the district are two general types: (1) high-grade, sheeted veins (0.2-2.5 m) having great vertical extent (>1,000 m) and adulariasencite characteristics; and (2) bulk-tonnage, low-grade deposits in diatreme and hydrothermal breccias. Wallrock alteration is restricted to narrow widths adjacent to veins but is more extensive in the bulk-tonnage deposits. The bulk-tonnage deposits have alteration assemblages consisting of adularia±biotite, sericite-smectite, Fe-Mn oxides, sulfates (Ca, Ba, Sr), and carbonates, attesting to oxidation as hydrothermal F approached the paleosurface. Hydrothermal products include sulfides (<3 vol.%), tellurides (Au, Ag, Pb, and Hg), quartz, adularia, roscoelite, sulfates, and carbonates.

Five vein stages are recognized; stage I boiling, alkaline, low-total sulfide F (T=320-200°C, 47.8 to 28.1 eq. wt.% NaCI) became progressively cooler and more dilute through stage IV (T<200°C; 9 to 7 eq. wt.% NaCI). The bulk-tonnage deposits have 3 recognizable stages; stage I fluids (T=262-152°C;~9 eq. wt.% NaCI) were boiling and exhibit dilution and cooling to stage III (T<200°C; 8-4 eq. wt.% NaCI). All F contained significant CO<sub>2</sub>.

FI, stable isotope, and trace element data along with the spatial relationships between ores and igneous rocks indicate that the ore F were magmatically-derived. Sulfur isotope data reflect the effects of oxidation on the ore F and the proportions of H<sub>2</sub>S:SO<sub>4</sub>. The Au-Ag ratios of doré produced over the 100+ year history of the district indicate that subtle zoning of precious metals is present with deeper level Au:Ag>10 and shallow level ores having ratios <5. The high-level deposits exhibit strong correlation of gold with K<sub>2</sub>O, As, Te, and F but no correlation with Ag and S. (Author's abstract)

THORDARSON, T., WOOD, C.P. and HOUGHTON, B.F., 1998. Magmatic sulfur content of the 1995-1997 Ruapehu eruptions, New Zealand in Water-Rock Interaction, G.B. Archart & J.R. Huiston (eds), Balkema. Rotterdam ISBN 90 5410 942 4, p 499-502. First author at Inst. of Geological and Nuclear Sci., Wairakei Research Centre, New Zealand & CSIRO, Magmatic Ore Deposit Group, Div. of Exploration and Mining, Australia.

Two significant eruption episodes occurred at the Ruapehu volcano in New Zealand between September 1995 and July 1996 during a period characterised by intermittent small explosive eruptions. Juvenile ejecta are porphyritic (25-42 vol %) medium-K calc-alkaline andesite with ~58 wt% SiO<sub>2</sub>. Dacitic glass compositions, represented by microlite-free groundmass phase and 1 in phenocrysts, indicate a complex M evolution, where processes of crystal fractionation and magma mixing were important. The degassed groundmass contains ~65 to ~225 ppm S, whereas the S-content of the I ranges from ~250 ppm to ~865 ppm. The total atmospheric SO<sub>2</sub>venting by the activity at Ruapehu is estimated as 266,000 tons. (Authors' abstract)

THROWER, C.D., BURNARD, P.G., TURNER, G. and PATTRICK, R.A.D., 1998a, Mantle input into the mineralizing fluids of the Colorado mineral belt: The noble gas story (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 65. Authors at Earth Sci. Dept. Univ. of Manchester. Manchester, England, M13 9PL.

Note—At the time of the meeting when this paper was presented, the first author indicated that some revisions were needed in the abstract as printed. The following is the revised abstract (E.R.).

Samples from a selection of mineral deposits of the Colorado Mineral Belt have been crushed under vacuum in order to analyse the noble G isotopic compositions of their I-trapped F. The noble G budget of Fl can come from three P reservoirs namely: a) the atmosphere, by way of air saturated ground waters (ASW), b) the crust, and c) the mantle.

The noble G analyses carried out on these samples clearly show a very large input of mantle derived <sup>3</sup>He into the mineralizing F of the Colorado Mineral Belt. These data fit mixing curves, indicating that the ore forming F in the deposits studied are the result of mixing between a crustal F and modified magmatic end members.

Distinguishable isotopes are created by the production of radiogenic noble G in the crust, the retention of primordial <sup>4</sup>He by the mantle and the loss of He from the atmosphere. The isotopic ratios of interest for the atmospheric (ASW) noble G reservoir include; a <sup>40</sup>Ar/<sup>34</sup>Ar value of 295.5 and a <sup>3</sup>He<sup>A</sup>He value of 1.39 x 10<sup>45</sup> = the atmospheric <sup>3</sup>He<sup>A</sup>He value or 1R<sub>a</sub> (all other helium ratios are quoted relative to this value). In comparison, the isotopic ratios of crustal F reflect the production of radiogenic elements: <sup>40</sup>Ar/<sup>36</sup>Ar value of >295.5 (up to 30,000) and a <sup>3</sup>He<sup>4</sup>He value of between 0.01 and 0.05 R/R<sub>a</sub>, while mantle F exhibit a <sup>40</sup>Ar/<sup>36</sup>Ar value of up to 40,000 and a <sup>3</sup>He<sup>4</sup>He value of between 6 R/R<sub>a</sub> for depleted mantle and 30R/R<sub>a</sub> for undepleted mantle. For the Colorado Mineral Belt area the range will be around 6 to 8 R/R<sub>a</sub>.

The study has highlighted the distinct input of mantle derived <sup>3</sup>He (and therefore mantle heat) into the ore forming F of the London deposit, as well as the 'Leadville' and 'Sherman'-type mineralisation styles, which have been the focus of ongoing debate. As the mantle has an R/R<sub>4</sub> value of 8 however, all deposits show evidence of mantle F mixing with crustal F with a low R/R<sub>4</sub> value.

The noble G data from the Sherman ('Sherman-type') deposit shows no similarity to typical MVT deposits, ruling out such a genetic model. In contrast, Sherman and Black Cloud ('Leadville-type') data fit a distinct plane on a 4-isotope plot, indicating that they share the same noble G endmember components and are therefore genetically related.

<sup>3</sup>Sherman-type' F appear to differ from 'Leadville-type' F due to the addition of a deep crustal F component, decreasing the <sup>8</sup>He<sup>4</sup>He value whilst increasing the <sup>40</sup>Ar/<sup>36</sup>Ar value. This may have occurred with the Sherman-type deposits forming as part of the periphery to the Leadville mineralising system, or having formed slightly later, once some crustal F had become entrained into the magmatic system at depth.

Not all of the London deposit data plots on the Sherman- and Leadville-type plane. This could either preclude a genetic link to these deposit types, or be the result of a process during ore formation, which caused a degree of noble G isotopic fractionation. (Authors' abstract)

See also next two items (E.R.)

See figure in the Illustrations appendix.

THROWER, C.D., BURNARD, P.G., TURNER, G. and PATTRICK, R.A.D., 1998b, Mantle input into the mineralising fluids of the Colorado Mineral belt: The noble gas story (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998. St. Andrews, Scotland (unpaginated). Authors at Earth Sci. Dept., Univ. of Manchester, Manchester, England M13 9PL.

Samples from a selection of mineral deposits of the Colorado Mineral Belt have been crushed under vacuum in order to analyse the noble G isotopic compositions of their inclusion-trapped F. The noble G budget of FI can come from three P reservoirs namely: 1) the atmosphere, by way of air saturated ground waters (ASW), b) the crust, and c) the mantle.

The noble G analyses carried out on these samples clearly shows a very large input of mantle-derived <sup>3</sup>He into the mineralising F of the Colorado Mineral Belt. These data fit mixing curves, which indicate that the ore forming F in the deposits studied are the result of mixing between a crustal F and modified magmatic end members.

The study has highlighted the distinct input of mantle-derived <sup>3</sup>He (and therefore mantle heat) into the ore-forming F of the 'Leadville' and 'Sherman'-type mineralisation styles, which have been the focus of ongoing debate. As the mantle has an R/Ra value of 8 however, all data show evidence of mantle F mixing with crustal F with a low R/Ra value.

The noble G data from the Sherman ('Sherman-type') deposit shows no similarity to typical MVT deposits (a suggested genetic scenario for these deposits), ruling out such a genetic model. In contrast, Sherman and Black Cloud ('Leadville-type') data fit a distinct plane on a 4-isotope plot, indicating that they share the same noble G end-member components and are therefore genetically related. (From authors' abstract by E.R.)

THROWER, C.D., BURNARD, P.G., TURNER, G. and PATTRICK, R.A.D., 1998c, Mantle input into the mineralising fluids of the Colorado mineral belt: The noble gas story (abst.): Mineralogical Magazine, v 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1515-1516 Authors at Earth Sci. Dept., Univ. of Manchester, Manchester, England, M13 9PL, UK.

This work reports a study for selected ore deposits of the Colorado Mineral Belt. The noble G budget of I trapped F can come from three primary sources: the atmosphere, by way of air saturated ground waters (ASW), the crust and the mantle. These sources contain very distinct noble G isotopic compositions, especially with respect to He and Ar. (From authors' abstract by E.R.)

See also previous two abtracts and Turner et al., this volume (E.R.)

TIAN, Yunhua, 1997, Geology-geochemistry and ore genesis of Liudou gold deposits in Yunxi County, Hubei province: Progress in Precambrian Research (Qianhanwuji Yanjiu Jinzhan), v. 20, no. 3 (tot. 79), pp. 11-20 (in Chinese; Engl. abst.). Author at Northwestern Hubei Survey of Geol. and

Mineral Resources Hubei Province.

In recent years a new type of gold-bearing quartz vein and altered rock has been discovered in Liudou district Yunxi county.

Based on geological environment, controlling ore deposits developments, rock alteration, ore mineral, physical-chemical features, F1, and F isotopic chemistry, the author suggests that these gold deposits belong to hydrothermal gold bearing solutions of middle-lower T which occurred along ductile-sear deformation zones. (From author's abstract by E.R.)

TIMOFEEFF, M.N., LOWENSTEIN, T.K. and BLACKBURN, W.H., 1998a, Secular variations in seawater chemistry. Results from fluid inclusions in Permian and Cretaceous halites (abst): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-221. Authors at Dept. of Geol. Sci., State Univ. of New York, Binghamton, NY 13902; email (BF21297@binghamton.edu)

ESEM X-ray EDS is a new technique developed for chemical analysis of individual FI using an environmental scanning electon microscope (ESEM) with an attached EDS. The ESEM X-ray EDS technique is being used to analyze FI in Phanerozoic halites to address the unresolved question of whether seawater has changed chemical composition over time. Deposits of similar age from geographically separated areas are analyzed to obtain a 'global' seawater signal. Halites with P FI bands, formed in perennial subaqueous environments, provide samples of parent surface brines. To backtrack from the brine analysis obtained via the ESEM to the required parent seawater composition, the water evaporation computer program of Harvie and Weare (1980) is used as a forward modeling tool. ESEM X-ray EDS involves analysis for major cations and anions in frozen FI from cleaved halite crystals compared to frozen aq standard solutions of similar chemical composition. Accuracies (mean-expected/expected) of 6-12% are obtained for Ca, Mg, K and sulfate from ESEM X-ray EDS analysis of Fl. Permian halites (Salado Formation, New Mexico) formed from parent waters close to modern seawater in major element composition but with somewhat higher calcium and lower sulfate, as reported by Horita et al. (1991). Cretaceous (Aptian) halites from the Congo Basin, west Africa and from the Ibura Member of the Muribeca Formation. Brazil, contain sylvite (KCl), the unusual Ca-Mg chloride mineral tachyhydrite, and no Mgsulfate salts. Fl in halite contain high calcium molalities (2.9 to 3.2 m). mMg=2.8-3.5, mK-0.15-0.18, and no detectable sulfate, all of which indicate a parent water quite different in composition from modern seawater. FI in halites from the late Cretaceous Maha Sarakham Formation, Khorat Plateau, Thailand, also contain similar Ca-rich, sulfate-poor brines, which suggests that Cretaceous seawater differed significantly from modern seawater (Authors' abstract)

TIMOFEEFF, M.N., LOWENSTEIN, T.K. and BLACKBURN, W.H., 1998b, ESEM X-ray EDS: A new technique for major element chemical analysis of frozen fluid inclusions using an environmental scanning electron microscope with attached energy dispersive system (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ of Nevada, p. 66. Authors at Dept. of Geological Sci. and Environmental Studies, Binghamton Univ.-State Univ. of New York, Binghamton, NY, 13902-6000.

The ESEM-EDS has advantages over other methods including: 1) direct measurement of major elements in FI. 2) FI in opaque minerals can be analyzed, 3) a conductive coating is not necessary, allowing direct observation of the FI surface to be analyzed, 4) dozens of FI and hundreds of spectra can be analyzed in one session on the ESEM.

Method – Water is removed from the ESEM to eliminate frost buildup on the sample. The chamber is set to hold a dry ambient atmosphere of nitrogen; the ESEM and attached Oxford cryostage are cooled with L nitrogen to -150°C. Operating conditions are 1.2 Torr, 20 kV beam energy. 1.71 A filament current, and a 50% condenser setting. The "skirt effect", whereby electrons from the beam are scattered by collisions with G molecules between the emitter/detector and the sample, is minimized by keeping the distance between the last aperture in the electron path and the sample as short as possible, and the environmental chamber P low.

Analyses of aq standards (brines in the Na-Mg-K-Ca-Cl and Na-Mg-K-SO<sub>4</sub>-Cl systems) yield an accuracy (analyzed mean minus expected value over expected value) of 3 percent with the ESEM-EDS technique. Preliminary results from Fl in laboratory grown halite crystals give accuracies of 6% for elements with atomic numbers greater than magnesium (Ca,K,SO<sub>4</sub>,Cl). Analyses for magnesium and sodium in Fl in laboratory grown halite crystals are accurate to 18%.

[The detailed steps in sample preparation and calibration are described ] (From authors' abstract by E.R.) See also adjacent entry (E.R.).

TIMOFEEFF, M.N., LOWENSTEIN, T.K., BLACKBURN, W.H. and HARDIE, L.A., 1998, Environmental SEM (ESEM) X-ray EDS chemical analysis of frozen fluid inclusions: Preliminary results from aqueous standards, fluid inclusions in laboratory-grown halite crystals, and Phanerozoic halites (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 67. First author at Dept. Geol. Sci. & Envir, Stud., Binghamton-SUNY, Binghamton, NY, 13902-6000

The ESEM-X-Ray-EDS technique is being used to analyze Fl in Phanerozoic halites to address the unresolved question of whether seawater has changed chemical composition over geologic time. Recently, Hardie (1996) suggested that secular changes in the P mineralogy of potash evaporites, which occur in phase with mineralogical cycles in manne limestones ("aragonite seas" versus "calcite seas"), could be explained by secular changes in the major ion chemistry of seawater.

FI in crystals of P halite from geographically separated deposits of the same age are being analyzed in order to obtain a "global" seawater signal To backtrack from the brine analysis obtained via ESEM X-Ray EDS to the required parent seawater compositions, the water evaporation computer program of Harvie and Weare (1980) is used as a forward modelling tool.

Preliminary results show that Permian evaporites (Salado Formation. New Mexico and Hutchinson salts. Kansas). formed from parent waters close to modern seawater in major element composition, but with somewhat higher Ca and lower SO<sub>4</sub> as reported by Horta et al (1991). Cretaceous evaportes from the Congo Basin, west Africa, contain sylvite (KCl), the unusual Ca-Mg chloride mineral tachyhydrite, and no MgSO<sub>4</sub> salts. FI in crystals of P halite contain high calcium (m<sub>Ca</sub>=2.9 to 3.2). m<sub>Mg</sub>=2.8 to 3.5, and m<sub>K</sub>=0.15 to 0.18, all of which indicate a parent water quite different in composition from modern seawater. If FI in halite from other geographically separated deposits of Cretaceous age show similar chemical compositions, then the case may be made that Cretaceous seawater differed from modern seawater. (From authors' abstract by E.R.)

See also adjacent entry (E.R.).

TITOV, A.V., KRUK, N.N., POSPELOVA, L.N., ZHURAVLEV, D.Z. and PALESSKII, S.V., 1998, Crystallization conditions and origin of magmas of the Rybalka gabbrodiorite-tonalite intrusion (Gorny Altai): Russian Geol. and Geophys., v. 38, no. 12, p. 1950-1962. Authors at United Inst. of Geol., Geophys. and Mineral., Siberian Branch of the Russian Acad. of Sci., Universitetskii pr. 3, Novosibirsk, 630090, Russia

This paper presents results of complex geological, mineralogical, isotopic, and MI studies of granitoid rocks from the Rybalka Massif (Gorny Altai). The geological study of the massif has revealed numerous signs of viscoplastic interaction of magmas, with abundant schlieren and I. The detailed mineralogical studies of the rocks have shown a complex structure of plagioclase phenocrysts, often with resorbed cores of labradoritebytownite. High T of crystallization (1030-1180°C) for basic rocks and rather low T for tonalites and granodiorites (680-720°C for middle and late stages) have been distinguished in MI studies. According to Rb-Sr isotopic data, the massif is of Late Devonian age; the values of parameters  $E_{Nd}$  (-0.6...-1.2) and Esr (+17...+23) and the pattern of REE distribution spectra testify to the magma generation by melting of the lower- and middle-crust material. Analysis of the data obtained suggests that the melting events and magma-magma "mixing" and "mingling" interaction are the main petrogenetic mechanisms; crystal fractionation processes were suppressed. (Authors' abstract)

TOJO, S., MIZUNO, K., HISADA, K. and MIYANO, T., 1998, Timing and significance of the homblende dehydration reaction in quartzofeldspathic gneisses from the Limpopo Northern Marginal Zone, Zimbabwe (abst.): Abstracts of the 105th Annual Meeting of the Geological Society of Japan, p. 354 (in Japanese).

Indexed under FI (E.R.)

TOMILENKO, A.A., CHEPUROV, A.I., PAL'YANOV, Y.N., SHE-BANIN, A.P. and SOBOLEV, N.V., 1998. Hydrocarbon inclusions in synthetic diamonds: Eur. J. Mineral., 1998, no. 10, p. 1135-1141. Authors at United Inst. of Geol., Geophys. and Mineral., SB Russian Acad. of Sci., Novosibirsk, 630090, Russia, email (tomilen@uggm.nsc.ru)

Primary (syn-growth) FI in synthetic diamonds, produced within the field of their thermodynamic stability in a high-P split-sphere apparatus using the T gradient method, have been studied by optical microscopy and Raman spectroscopy. 1 in tabular diamond crystals contain CH<sub>4</sub> and other

of carbon from F on cooling. The obtained results emphasize the possible role of hydrocarbons in the process of diamond crystallization. (Authors' abstract)

See also FIR 30, p. 196 (E.R.).

TONARINI, Sonia, DINI, Andrea, PEZZOTTA, Federico and LEEMAN, W.P., 1998. Boron isotopic composition of zoned (schorlelbaite) tourmalines, Mt. Capanne Li-Cs pegmatites, Elba (Italy) Eur. J. Mineral., v. 10, no. 5, p. 941-951.

Indexed under FI

TORNOS, F., RIBERA, F., ARIAS, D., LOREDO, J. and GALINDO, C., 1996, The carbonate-hosted Zn-Pb deposits of NW Spain: Stratabound and discordant deposits related to the Variscan deformation: Society of Economic Geologists, Special Pub no 4, 1996, p. 195-203. First author at Instituto Tecnológico Geominerao de España c/Rios Rosas 23, 28003 Madrid. Spain

The mineralization seems to be formed by reaction of the hosting carbonates with low-saline (<7 wt.% NaCl eq.) water-rich F [Fl data presented] that circulated along major lithologic contacts or extensional faults. Isotopic composition of the hydrothermal F falls within the field of low-grade metamorphic or basinal waters ( $\delta^{18}O = -10$  to +6.3%;  $\delta D = -43$  to -31‰). The ore-forming process occurred at T between 150 and 250°C and at low F P (<500 b) (From authors' abstract by E.R.)

TÖRÖK, Kálmán, 1998, Fe-rich hypersaline aqueous and CO2 inclusions, associated with retrograde metamorphism of the chlorite-muscovitequartz schist from the Sopron-area (eastern Alps, W-Hungary) (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions. June 1-4, Univ. of Nevada, p. 68. Author at Dept of Geophys., Eötvös L. Univ. H-1082 Budapest Ludovika ter 2., Hungary; email (torokklm@ludens.elte.hu)

S aq FI with soluble dm and  $CO_2$  I were studied from quartz veins of garnet-bearing chlorite-muscovite-quartz schist of the Sopron area. All of the FI are S and were found in quartz veins, which may contain tourmaline and nutile as well. Most of the I contain a supersaturated aq F with one or more dm and variable amounts of  $CO_2$ .

Several low T phase transitions can be observed in the I. During freezing, three new solid phases appear. The first phase appears during cooling between -9 and -30°C and dissolves between 23 and 92°C. The second phase appears during warming at about -85°C and disappears between -58.2 and -47.3°C (CaCl<sub>2</sub>-hydrate or FeCl<sub>2</sub>-hydrate?). The third phase forms by reaction of the soluble dm with water and disappears metastably between 7.8 and 12.5°C (NaCl-hydrate?). First melting of the ice occurs between -56 and -59.4°C and ice melts between -38.1 and -18°C. During heating, the solid phase dissolves between 193.5 and 250.3°C. All of the 1 decrepitated prior to homogenization, between 265 and 370°C.

Melting of the solid CO<sub>2</sub> phase in the CO<sub>2</sub>-bearing I occurred between -56.6 and -58.2°C, which indicates minor N<sub>2</sub> or CH<sub>4</sub>. The CO<sub>2</sub>-hydrate disappeared between -17.8 and -19.3°C. Homogenization of CO<sub>2</sub> phases occurred between -8.0 and +24.1°C. EDS analyses of precipitated salts showed Fe, Ca, Na with minor Zn, K, and Mn as cations and Cl and SO<sub>4</sub> as anions.

Isochores of  $CO_2$  I show that infiltration of the  $CO_2$ -bearing, hypersaline F infiltrated the rocks during retrograde metamorphism. (From author's abstract by E.R.)

TOURET, J.L.R., 1998, Melt/fluid inclusions in granulites: Carbonic metamorphism and "vapor-absent" melting (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto. Canada. Abstracts and Programs, p. A30. Author at Dept. of Petrology and Isotope Geol., Free Univ. Amsterdam. The Netherlands; email (touj@geo.vu.nl)

A review, showing that "vapor-absent" melting in the lower crust can in fact happen in the presence of free, low H<sub>2</sub>O-activity F, either locally derived or introduced from an external source. F-assisted and "vaporabsent" metamorphism are two complementary facets of the various processes occurring in the lower crust, involving complicated interaction between rocks, F and M. (From author's abstract by E.R.)

TRAXEL, K., ARNDT, P., FRIEDEL, C., MAETZ, M., POVH, B., SCHELOSKE, S., SCHNEIDER, T., SCHWALM, D., WALLIANOS, A. and WIES, C., 1998, Trace-element analyses of melt inclusions as probes for the evolution of Bolivian tin porphyry deposits. Max Planck Inst. fur Kemphysik Heidelberg, Tatigkeitsbericht 1997/1998, p. 280-282 (in Engl.)

Micron-sized M I were analyzed by PIXE and µNRA [i.e., PIGE]. The necessary technical requirements for high-precision PIXE measurements including a precise determination of the beam current, an analysis of dead-time losses due to electronic pulse processing and the calibration of the whole PIXE setup were built up to reach an overall accuracy for absolute quantification of 5%. For multi-element spectra, the modeling of the detector response is of great important. In this context a new fitting program for determining the detector response was written and employed. The boron and lithium NRA analysis was done at the Saclay nuclear microprobe and checked by SIMS using the Cameca IMS 4f ion microprobe at Woods Hole. Major elements were also analyzed by a Cameca SX100 electron microprobe at TU Clausthal.

Immobile-element data (Ti, Zr, Ta) of bulk rock samples display a rhyodactic to dacitic composition with only a moderate degree of fractionation. Contrary to this, the PIXE analyses of MIs revealed their highly fractionated character similar to tin granites. From 12 measured quartzhosted MI a geometric mean of 225 ppm boron can be derived.

The highly evolved nature of the MI with respect to bulk rock composition cannot be explained by equilibrium crystal-L fractionation alone.

We suggest hydrothermal F to be supplied by unexposed, highly evolved granitic portions, represented by MI. The high B, As, Cs, and Li contents in MI point to an involvement of pelitic source lithologies not depleted in these F-mobile elements, i.e., first-cycle metamorphic rocks. Magmatic fractionation enriched (depleted) the trace-element abundances within one log-unit range. (From authors' abstract by E.R.)

TSÓI, V.D., 1998, The nature of the quartz-carbonate veins in the goldsilver deposits of the Kuraminsk subzone (abst.): Second APIFIS Int<sup>\*1</sup>. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 123-125 (in Russian). See Translations.

TSÓI, L.A., DÚNIN-BARKÓVSKAYA, E.A. and LÉBEDEVA, S.E., 1998, Conditions of formation of the fluorite mineralization in the Chilten Depression (eastern Uzbekistan) based on a study of fluid inclusions (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 139-143 (in Russian).

See Translations

TUNKS, A.J. and COOKE, D.R., 1998, Structural and geochemical controls on gold deposition at the Tanami gold mine, Northern Territory (abst.). Geological Soc. of Australia, Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 444. First author at Centre for Ore Deposit Research (CODES), Univ. of Tasmania, GPO Box 252-79, Hobart, 7001.

The Tanami Gold Mine (TGM) is one of several significant Au deposits in the Palaeoproterozoic Granites-Tanami Inlier of the Northern Territory. Gold mineralisation at the TGM is hosted in brittle shear zones and veins. Auriferous quariz±sericite+chlorite±pyrite±ankerite+chalcopyrite veins and breccias were deposited from high-T (300°C), low-sal (5 wt.% NaCl eq.), low-CO<sub>2</sub> F (0.5 m) with 8<sup>34</sup>S values around 12‰ and calculated 818Owater values between 9 0 and 11 4‰. Mineralogical, isotopic and FI data are consistent with a weakly acidic (pH-5), reduced (mH75>mso32), HiS-rich (=0.006 m) hybrid magmatic/metamorphic F generated during granite emplacement and associated contact metamorphic devolatilisation. Cyclic rupturing and sealing of the fault zones due to variations in the F P and shear stress coupled with subsequent hydrothermal self-sealing created conditions favourable for F-wall rock interaction and the formation of sericite-pyrite-carbonate alteration halos. Pyritisation of magnetite and chlorite in the basalts, and hematite in the sedimentary rocks destabilised AuHS and Au(HS), causing gold deposition in the veins and country rocks. (From authors' abstract by E.R.)

TURESEBEKOV, A.Kh., 1998. A geological-genetic model for the fundamental porphyry-copper association and its relationship with other ore deposits of the Kuraminsk subzone (abst.). Second APIFIS Int'l Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 82-85 (in Russian).

TURKOV, V.A., KOGARKO, L.N., BROOKS, C.K. and NIELSEN,

T.F.D., 1998, Comparison of the picrite evolution from East and West Greenland (melt inclusion data) (abst.): Mineralogical Magazine, v 62A, V. M Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1549-1550. First author at Vernadsky Inst. of Geochem. and Analytical Chem., Moscow, Russia.

MI in phenocrysts (olivine, spinel and clinopyroxene) from 13 picrite samples are mostly partly crystallized. They contain glass, spinel, orthopyroxene, plagioclase, albite, titanomagnetite, amphibole, ilmenite, potassium feldspar, apatite and sometimes F

The comparison of compositions of homogenised I has shown that the picrites of West Greenland were generated under much higher T compared with picrites from East Greenland. The East Greenland M are much more Ti, Ca and K-rich and have lower contents of Al and Fe. (From authors' abstract by E.R.)

TURNER, G., BURNARD, P., PATTRICK, R., CALIGARI, A. and HU, Ruizhong., 1998. Helium and argon in ore fluids: so what? (abst.): Mineralogical Magazine, v. 62A, V.M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts. p. 1551-1552. Authors at Dept. of Earth Sci., Univ. of Manchester, M13 9PL, UK.

The isotopic composition of He and Ar trapped in crustal F and FI carries a signature of the source of the F and the processes which have affected them. There are three distinct sources of the noble G: atmosphere, crust and mantle. Atmosphere G carried in groundwaters are characterised by the presence of  ${}^{36}Ar$  and  ${}^{40}Ar$  and minor amounts of helium. The crust is a source of radiogenic  ${}^{40}Ar$  and  ${}^{41}He$ , very low levels of  ${}^{31}He$ , and no  ${}^{36}Ar$ . The prime signature of the mantle is helium with a high  ${}^{3}He$  content, together with  ${}^{40}Ar$  and, in most situations, negligible  ${}^{36}Ar$ . F trapped in ore minerals frequently carry all three components.

We have investigated He and Ar isotopes, sometimes in combination with halogens, trapped in ore F from sulfides from the Machangqing porphyry Cu (West Yunnan province, PRC), and the Sungun porphyry Cu (NW Iran), and from fluorite from the North Pennine Pb-Zn Mississippi Valley-type (UK). (From authors' abstract by E.R.)

See also Thrower et al., this volume (E.R.)

TURSUNOV, K.T., 1998, The origin and facies nature of the gabbrodiabase dyke-complex of Western Uzbekistan (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 52-55 (in Russian).

UCHIDA, E., 1993, Estimation of relative concentrations of cations in the skam-forming solutions based on experimental data of ion exchange equilibria: Resource Geol., v. 43, p. 301-310 (in Japanese with Engl. abst.).

Relative concentrations of CaCl<sub>2aq</sub>, MgCl<sub>2aq</sub>, FeCl<sub>2aq</sub>, MnCl<sub>2aq</sub>, ZnCl<sub>2aq</sub> and CdCl<sub>2aq</sub> in the skarn-forming solutions were estimated from experimental data of ion exchange equilibria between aq chloride solution and garnet, clinopyroxene, carbonates (calcite, dolomite and magnesite), tungstates (scheelite and wolframite) and sphalerite. The equilibrium T is assumed to be 400 to 600°C, and the P I kbar. The chemical compositions of clinopyroxene and garnet in exoskarns indicate that the concentration of CaCl<sub>2aq</sub> is extremely high and that of MgCl<sub>2aq</sub> is very low in the skarnforming solution. The FeCl<sub>2aq</sub>/MnCl<sub>2aq</sub> ratio is nearly equal to the Fe/Mn ratio in garnet. Scheelite is more stable in the solution than wolframite. The average sphalerite composition of skarn deposits in Japan suggests that relative concentrations are in the order of

FeCl2ag+MnCl2ag>ZnCl2ag>>CdCl2ag (Author's abstract)

UCHIDA, Etsuo, INOUE, Ryo and OGISO, Koichi, 1998, Aqueous speciation of cadmium chloride in supercritical hydrothermal solutions at 500 and 600°C under 0.5 and 1 kbar. Geochemical Journal, v. 32, p. 339-344.

UCHIDA, Etsuo, NAITO, Masahiro and UEDA, Shunnosuke, 1998, Aqueous speciation of zinc chloride in supercritical hydrothermal solutions from 500 to 700°C and 0.5 to 1.0 kb. Geochemical Journal, v. 32, p. 1-9.

ULLRICH, T.D. and CLARK, A.H., 1998. Evolution of the Candelaria Cu-Au deposit. Ill region, Chile (abst.): Geological Society of America Annual Meeting 1998. Abstracts. v. 30, no. 7, p. A-75. First author at Dept. of Geological Sci., Queen's Univ., Kingston ON Canada K7L 3N6; email (3tdu@qlink.queensu ca)

Cu-Au mineralization was associated with Ca-Na metasomatism superimposed on the barren K- and Fe-metasomatised andesitic and tuff. Calcic amphibole (<1.9% Cl), chalcopyrite, magnetite, hematite (pseudomorphed by magnetite), pyrite, albite and quartz±pyroxene, pyrrhotite, sphalerite, electrum and molybdenite, were deposited in veins and as massive-to-disseminated replacements with local haloes of K-feldspar. Barren scapolite-pyroxene-amphibole- and calcic garnet skarns in the upper andesite are probably cogenetic with this event. Hydrothermal amphibole gave a plateau age of 111.7±0.8 Ma ( $2\sigma$ , 61% of G released). FI in quartz are hypersaline and CO<sub>2</sub>-rich, defining a retrograde thermal evolution from >396°C (Th) to ≥202°C. Amphibole was replaced by epidote±allanite prior to the formation of dilatonal veins of, successively, hematite-calcitechalcopyrite-quartz-chlorite±pyrite±tourmaline, anhydrite, and calcite-clay.

Although resembling both porphyry and skarn deposits, the Candelaria orebody proper differs from the former in the association of Cu mineralization with late-stage amphibole, epidote and calcite, and from the latter in the vein style and associated Ca enrichment. (From authors' abstract by H E.B.)

URBANO, R., 1998, Intragranitic gold deposits in the NW Iberian massif Boletin Geológico y Minero, v. 109-5, no. 6, p. 469-478 (in Spanish, Engl. abst.). Author at ITGE, Dirección de Recursos Minerales, Rios rosas, 23, 28003 Madrid.

This article describes the intragranitic gold deposits of Corcoesto (Coruña), Tomiño, (Pontevedra). Penedono (north of Portugal) and Pino (Zamora). All of them show similar characteristics regarding lithological and structural control of the mineralizations and the gold enrichment process. (From authors abstract by H E.B.)

FI data presented (H.E.B.).

USDOWSKI, E. and DIETZEL, M., 1998. Atlas and data of solidsolution equilibria of marine evaportes, published by Springer.316 pp.

The present volume on the phase equilibria of marine evaporites is a new and revised edition of the solubility data of the quinary seawater system Na<sub>2</sub>Cl<sub>2</sub>-K<sub>2</sub>Cl<sub>2</sub>-MgCl<sub>2</sub>-Na<sub>2</sub>SO<sub>4</sub>-K<sub>3</sub>SO<sub>4</sub>-MgSO<sub>4</sub>-H<sub>2</sub>O (also denoted NaCl-KCl-MgCl<sub>2</sub>-Na<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>O) and its pertinent five quaternary, nine ternary, and six binary systems. The purpose of the volume is to provide an easy and fast access to reliable data and an understanding of the interrelation of the various systems. It has been organized into the sections

Derivation of Phase Diagrams from Solubility Data, Data and Diagrams for Solid-Solution Equilibria, and The Computer Program SALSYS. (From authors' text by H.E.B.)

USMANOV, F.A., ed, 1998, Second APIFIS Int'l Symp., Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts Vol., 165 pp (Russian and/or English).

Abstracts or titles are given in this volume of FIR, for further details, see "Meetings" section.

The contents are listed under four section headings, translated by Dr. D.A. Brown:

I General problems in the study of mineral-forming fluids and the origin of rocks and ores.

II Origin and facies-nature of magmatic and metamorphic rocks.

III Origin of hydrothermal ore-forming systems and prospecting criteria for endogenetic ore deposits.

IV Study of fluid inclusions in petroliferous areas, and the origin of endogenetic rocks and ores. (E.R.)

See Translations.

VANCON, S., DUBOIS, M., POTDEVIN, J.-L. and LEDÉSERT, B., 1998, Mass-balance and fluid-inclusion studies of the alteration of the hydrothermalized granite of Soultz-sous-Forêts (Alsace, France) (abst.): Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998, p. 205 (in French, translation by E.A.J. Burke). First author at Université de Lille 1, URA 719, 59655 Villeneuve d'Ascq.

The granitic basement of the Soultz-sous-Forêts horst (Rhine graben) underwent a hydrothermal phase connected with the circulation of F descended from the sedimentary cover along its network of faults. The resulting alterations in the granite body show local intensity variations. The granitic basement of the Rhine graben has been partially hydrothermalized by F along its network of faults. The granite alteration is heterogeneous, as well in intensity as in kind.

The mobilities of the chemical elements connected with this hydrothermalism have been estimated with mass-balance calculations (method of Gresens), which compare the composition of unaltered granite with that of several types of altered granite. The study in thin section of destabilization reactions of minerals in unaltered granite and the mass balances on the scale of the rock indicate that the mobility of elements varies with the scale of observation and with the type of alteration. The mobility of elements is very important on the scale of the grains, but seems to be limited on the scale of the specimen, from the alteration zone or from the granitic massif. Only two elements, potassium and sodium, appear to be mobile on the scale of the massif. The sometimes total leaching of sodium could explain the high sal of some F. The observed supplies of potassium might find their origin in the evaporites in the sedimentary cover. Calcium is also mobile, but its leaching in certain zones has been compensated for by the precipitation of calcite veins in other parts of the granite.

Mass-transfer balances have been calculated with regard to the unaltered rock in order to determine the displacement of chemical elements associated with the different types of alteration. These show that the mobility of elements varies with the scale of observation. The weakest alterations seem to be isochemically on the scale of the specimen, whereas stronger alterations show real changes in their chemistry. For the massif in question, however, mass displacements seem to be equilibrated between the different alteration facies and the fillings of veins.

As a matter of fact, only sodium seems to have been the subject of transport out of the granite, because it does not enter in any of the newly formed phases. A supply of potassium from the evaporites in the sedimentary cover seems also to be possible.

The study of Fl in crystals of quartz and ankerite in several veins indicates fluctuations in T and composition of the F which circulated in the granite. The T<sub>t</sub> (150°C) are similar, between 150 and 190°C, are higher than the T measured at the same depth (142°C, 2200 m, drilling EPS1), but there is evidence for the entry of hotter fluids (190°C) [sic]. The calculated sal are very variable, as they range between those of meteoric water and brines (about 30 wt.% eq. NaCl). The study of Fl present in different phases precipitated in the veins (quartz and ankerite) indicates that the F at the moment of their formation fluctuated between 150 and 190°C, higher than the T actually measured at this depth (142°C). The observed sal are also very variable, from that of meteoric water to that of brines (almost 30 wt.% eq. NaCl), which could be explained by the loss of sodium.

These results indicate that the hydrothermal alteration of this granite is complex, as well in the T levels as in the nature of the implied F. Moreover, the chemical transfers seem to happen at different scales, depending on the element and on the degree of transformation, and whether the system was closed or open. (Authors' abstract)

van KEKEN, P.E. and BALLENTINE, C.J., 1998, Whole-mantle versus layered mantle convection and the role of a high-viscosity lower mantle in terrestrial volatile evolution: Earth and Planet, Sci. Letters, v. 156, no. 1-2, p. 19-32.

Indexed under FI.

van SOEST, M.C., HILTON, D.R. and KREULEN, R., 1998, Tracing crustal and slab contributions to arc magmatism in the Lesser Antilles island arc using helium and carbon relationships in geothermal fluids: Geochim. et Cosmo. Acta, v. 62, no. 19/20, p. 3323-3335. First author at Dept. of Earth Sci., Vrije Universiteit, De Boelelaan, 1081 HV Amsterdam, The Netherlands.

We report helium and carbon isotope and COy3He ratios from a regional survey of geothermal F from the Lesser Antilles island arc. an arc system where there is compelling geochemical evidence for the superimposition of a crustal component onto mantle-derived magmas. A predominant mantle helium isotope signature is observed throughout the arc. The highest ratios coincide with MORB helium (~8 Ra where Ramair He/He) and occur toward the centre of the arc (the islands of Martinique, Dominica, Guadeloupe, and Montserrat). In the south and north of the arc (Grenada, St. Vincent, St. Lucia in the south and Nevis and Saba in the north) <sup>3</sup>He/<sup>4</sup>He ratios are lower and lie between 4.9 and 6.8 Ra. This regional variation is also apparent in the carbon isotope systematics: the central portion of the arc (Martinique to Montserrat) have 813C(CO1) values between -2 and -4‰ (vs. PDB), heavier than the range observed in MORB (-4 to -9‰). The south of the arc (Grenada to St Lucia) is characterized by MORB-like carbon isotope ratios (centred on -6%). CO2/ He ratios are significantly higher than the MORB value ( $\sim 2x10^{9}$ ) for the entire arc. The values in the central islands fall close to  $10^{10}$  whereas the southern volcanoes have higher ratios between 1010-1013

Assuming the Lesser Antilles mantle wedge has a MORB-like helium and carbon composition, our data can be explained by mixing of mantle wedge carbon with at least two other carbon components; an isotopicallyheavy marine limestone endmember of slab-derivation and an isotopicallylighter component representing either slab-derived organic carbon and/or

an upper crustal component with a large fraction of organic carbon. The helium-carbon systematics of the central portion of the arc are consistent with a large slab-derived marine limestone input to the carbon inventory. and we calculate a non-mantle mantle carbon flux of 5.7.1. MORB-like helium isotope ratios, which are sensitive to perturbation by crustal additions to degassed magmas, imply a relatively minor role for upper crustal contributions in this part of the arc although it could reach a maximum of 20% of the total carbon flux if the light-C component is solely of crustal origin. Higher CO2/3He ratios in the southern islands coupled with lighter <sup>3</sup>C imply (1) an increase in the flux in the non-mantle contribution relative to the central arc, and (2) an enhanced role for an isotopically-light carbon component in this part of the arc. Compared to the central islands, the increase in the non-mantle carbon flux in the southern islands is by a factor of 4.2. Assuming that the isotopically-light carbon has a 813C of -10%, then its southern arc flux is a factor of 9.1 times that of the central arc. Lower <sup>3</sup>He/<sup>4</sup>He ratios in the southern arc indicate that the origin of this carbon component is likely to be the uppermost crust: in this case, ~50% of the total carbon lost via the southern Lesser Antilles would be of crustalderivation. This conclusion is compatible with the increased availability of carbon both in the southernmost forearc sediments and arc crust. Our approach of combining helium and carbon systematics serves to emphasize the importance of volatile provenance on mass balance considerations of the terrestrial carbon inventory at convergent margins. (Authors' abstract)

VANKO, D.A. and LAVERNE, Christine, 1998, Hydrothermal anorthitization of plagioclase within the magmatic/hydrothermal transition at midocean ridges: Examples from deep sheeted dikes (Hole 504B, Costa Rica rift) and a sheeted dike root zone (Oman ophiolite): Earth and Planet. Sci. Letters, v. 162, p. 27-43. First author at Dept. of Geol., Georgia State Univ., Atlanta, GA 30303 USA; email (dvanko@gsu.edu)

The unique petrological record from the deep sheeted dikes of ODP Hole 504B gives insight into the magmatic/hydrothermal transition and the hydrothermal reaction zone at mid-ocean ridges. A high-T peak hydrothermal event at Hole 504B, defined as Stage 1, corresponds to an early stage in the evolution of an axial reaction zone, and perhaps to an initial high-T phase of black smoker activity. The T and/or the aca/a2 Na ratios of hydrothermal F overlapped and even exceeded those inferred for the reaction zones of many modern black smoker systems. The volume of hydrothermally altered rock at this stage of evolution of the reaction zone was much less than 10%. Stage 1 is manifest in hand specimen by reaction halos adjacent to hornblende veins and by irregular alteration patches. There is no epidote associated with Stage 1. Wallrock reactions involved the replacement of magmatic clinopyroxene by magnesiohornblende and of magmatic plagioclase by hydrothermal plagioclase. These secondary minerals were not in equilibrium. Hydrothermal plagioclase varies in composition from Ansy to Anss, and has low MgO and FeOTot. It has distinctive bright DL and a porous appearance. Stage 1 at Hole 504B occurred at P between 38 and 85 MPa (0.38 and 0.85 kbar) and T in excess of about 425°C, these P-T conditions closely approach the two-phase field for seawater Stage I is overprinted by retrograde alteration that caused further replacement within halos and patches as well as 10-40% alteration, mostly to chlorite and albite, of all the fresh sheeted dikes that were unaffected during Stage 1. Stage 1 alteration at Hole 504B is unique among oceanic and ophiolitic samples. However, we report one area from the Oman ophiolite that exhibits features similar to Stage 1 at Hole 504B. Early halos around homblende veins contain secondary homblende and porous hydrothermal calcic plagioclase (Ansi-Anas) with low MgO and FeOTor F in quartz show that some early hydrothermal F had 5.6±2.3 wt.% NaCl eq. at T constrained to be above 320°C and below 510°C, as well as a saline brine with 31 to 40 wt.% NaCl eq. and similar T constraints. Although evidence for Stage 1 alteration of sheeted dikes is far from ubiquitous, it is now identified in an oceanic setting (Hole 504B) and in an ophiolitic example from Oman. (Authors' abstract)

VANKO, D.A. and MAVROGENES, J.A., 1998, Synchrotron-source Xray fluorescence microprobe: Analysis of fluid inclusions: in McKibben, M.A., and Shanks, W.C., eds., Applications of Microanalytical Techniques to Understanding Mineralizing Processes: Reviews in Economic Geol., v. 7, (Society of Economic Geologists), p. 251-263.

A thorough review of the instrumentation, sample procedures, calibration, limitations and data reduction, and some recent applications (East Pacific Rise, Mid-Atlantic Ridge, and Questa Mo), plus their interpretation. (E.R.)

VAPNIK, Ye, 1998a, Fluid inclusions in calcite veins and detrital quartz

grains in the Kokhav Dolomite (the Heletz-Kokhav Oil Field): Israel Geological Society Annual Meeting, Mitzpe R., Weinberger, R., Gavrieli, I., Yechieli, Y., Porat, N. and Ayalon, A., eds., 1998, 22-24 March, p. 106. Author at Dept. of Geological and Environmental Sci., Ben Gurion Univ. of the Negev, P.O.B, 653, 84105 Beer Sheva.

Temperature is one of the controlling factors in petroleum generation. FI provide a useful and important way of direct measurements of paleotemperatures (Barker, 1996). Six samples (Reny Calvo's collection) of coarse grained calcite veins hosted in the Kokhav Dolomite were investigated. FI in calcite are mainly two phase I (L+G) of PS origin. Inclusions are of Na-Ca-Cl composition with sal of about 8 wt.% NaCl eq. The Th is in the range of 130-220°C.

Hydrocarbon I were found in one sample. These are two phase I (L+G) of P and PS origin. The Th is in the range of 50-170°C.

The data on FI indicate a high effective T of oil generation. The high T are in a good agreement with  $C_{29}$  20S/20R sterane ratios equivalent and recalculated vitrinite reflectance values obtained for the Barnea Formation (Bein & Sofer, 1987).

Amit (1976) taking into account low-T data on vitrinite reflectance in the Gevaram formation proposed the Toronian-Senonian time of oil generation. The obtained high effective T makes oil generation possible before the Toronian, already in the Albian time (Cohen, 1971).

The high Tt of FI in calcite veins can indicate the hydrothermal origin of calcite veins and questions the isotopic model of calcite vein formation from water originated in the "Mavqi'im Sea" (Calvo, 1993).

Other interesting findings are the PS CO<sub>2</sub> and H<sub>2</sub>O-CO<sub>2</sub> I in small detrital quartz grains. Rounded quartz grains with Fi hosted in near-byvein dolomite were found in one of the samples. The H<sub>2</sub>O-CO<sub>2</sub> I were trapped at T>300°C and P>2.5 kbar and provide evidence for a mediumto-high grade metamorphic provenance for the quartz grains (Bodnar, 1994), which suggests an interesting insight into the nature of crystalline basement of Israel. (Author's abstract)

VAPNIK, Ye., 1998b. Melt inclusions in granitoids of the Timna Igneous complex, southern Israel: Mineralogical Magazine, v 62, no. 1, p 29-40. Author at Dept. of Geol., Ben-Gurion Univ. of the Negev, P.O. Box 653, Beer-Sheva 84105, Israel.

High T microthermometry and Scanning Electron Microprobe (SEM) analyses were used to study natural magmatic remnants in quartz crystals in granitoids from the Timna Igneous Complex, southern Israel, and to constrain physicochemical parameters during their crystallization. For the porphyritic granite, alkali granite and quartz monzodiorite, liquidus T are 710-770, 770-830 and 770-840°C, respectively; solidus T are 690-770, 710-890 and 770°C, respectively. P during crystallization and water content in the magmas were determined using the phase diagram of the modal granite system. The determined P-T conditions are typical for watersaturated granitoid magmas (>4-8 wt%) generated and crystallized at a shallow crustal level.

SEM data on MI support conclusions of previous investigations on two types of granitoid magmas exposed in the Timna Igneous Complex: the porphyritic and alkali granites. Different trends of crystallization are proposed for these granites. Crystallization of the porphyritic granite started with cotectic crystallization of plagioclase and terminated in residual K-feldspar-rich crystallization; crystallization of the alkali granite took place at higher T, starting with K-rich alkali-feldspar crystallization and terminating in residual Na-rich eutectic crystallization.

Parameters not available from other sources—T and P of the liquidus and solidus stages, water content, trends of crystallization—were obtained for the porphyritic and alkali granites. (Author's abstract)

VARELA, M.E., CLOCCHIATTI, R., DURAUD, J.P., KURAT, G., MASSARE, D., MÉTRICH, N.I., MOSBAH, M. and THELLIER, B., 1998, Contributions of the study of glass inclusions to the understanding of the formation processes of meteorites (chondrites and achondrites) (abst.): Réunion des Sciences de la Terre, Brest, 31 March-3 April, 1998, p. 205 (in French, translation by E.A.J. Burke). First author at Laboratoire Pierre Süe, CEA-CNRS 91191 Gif-sur-Yvette, France.

The aim of studies carried out at the Pierre Süe Laboratory is to give an explanation for the mode of formation of glass I in meteorite minerals.

The glass I of chondrites (Allende, Kaba, Murchison, Renazzo and Murray) consist essentially of the refractory elements Al. Si, and Ca (with contents of 27, 45, 27 wt.% oxides). The contents and the repartition of carbon and sulfur, analysed with a nuclear microprobe, show that the two elements have a heterogeneous distribution, probably due to the heterogeneity of the setting during the formation of the 1.

The trace-element distribution curves, measured with SIMS, of two I in Renazzo have a chondritic signature, which means that they were formed by a condensation process (Kurat et al., Meteoritics, v. 32, 1997).

Glass I of the achondrites Aubres, Norton County, Shallowater have a chemical composition rich in SiO<sub>2</sub> (70-80 wt.%), Al<sub>2</sub>O<sub>3</sub> (3-16 wt.%), alkaline elements (10 wt.%), and volatiles (Cl 0.02-0.15 and S 0.2-0.3 wt.%). They have been formed in a not yet completely degassed setting. A detailed study of the I in Chassigny, an achondrite from Mars, sheds strong doubts on the generally accepted hypothesis of its magmatic cumulative origin. The nature of the I, heating experiments, and certain trace-element ratios (measured with the nuclear microprobe) indicate that these I were formed by a non-magmatic process. (Authors' abstract)

VARELA, M.E., CLOCCHIATTI, R., KURAT, G. and MASSARE, D., 1998, Glass-bearing inclusions in Chassigny olivine: Heating experiments suggest nonigneous origin (abst.): 61st Meteoritical Society Meeting July 27-31, 1998, Trinity College, Dublin, Ireland, published in Meteoritics & Planetary Sci., v. 33, no. 4 Supple., p. A158. First author at UNS-CONICET, Dipartimento de Geologia, San Juan 670, 8000 B. Blanca, Argentina.

Multiphase (minerals plus glass) I in olivine of the Chassigny achondrite have been extensively studied [1-3]. These I are widely believed to be residuals of the parental M that was trapped during growth of the olivine from the M. Under the assumption that Chassigny is a cumulate rock and the glass-bearing I represent the parent magma, the calculated chemical composition of the initial trapped M resembles that of terrestrial bonnite lavas [2]. Subsequent closed-system cooling of these trapped M will produce an assemblage of dxl and a quenched glass. However, based on petrographic features and on the chemical composition of glasses of all types of I in Chassigny olivine, [4] proposed that the multiphase I could have been formed by heterogeneous trapping of its constituents rather then by trapping of a parental M.

Three types of glass I are present in the Chassigny olivine: pure glass, monocrystal, and multiphase I (glass, glass plus one mineral, or glass plus several minerals respectively). Glass/mineral ratios are highly variable. The P petrographic nature of the I suggests that they are very likely samples of the ambient phases that exist during the growth of the Chassigny olivine. If the parental M would be trapped contemporaneously into two I in a given host phase and some phases grow in one I but not in the other, the chemical composition of the glasses in these I must differ from each other. However, this is not the case with the glasses in the three types of I in the Chassigny olivine, which all have very similar compositions.

Heating experiments allow for the reversal of the processes that occurred inside the I during cooling. The phases that formed after the closed system evolved will dissolve in the M during heating. Thus, after quenching, the chemical composition of the glass in a heated residual MI will be different from that of an unheated one. Heating experiments were performed in a Pt-Ptw \*\*\*\*Rh<sub>10</sub> heating stage in a hot He atmosphere as O getter [5] with quenching times (from 1200°C to 500°C) of <1 s. The optimum condition runs lasted for ~8 hr. each with final T of 900. 1000, and 1200°C, respectively, which were held for 30 min. The final T of 1200°C exceeds the "accumulation" T of 1140°C estimated for Shergotty and Zagarni shergottites (other members of the SNC group) [6]. Thus, at 1200°C some reactions between glass (M) and the host can be expected. However, there was no reaction in glass-bearing I in the Chassigny olivine.

The composition of glasses inside the heated 1 and close to the 1 walls remains rich in  $SiO_2$ ,  $Al_2O_3$ , and  $K_2O$  and poor in FeO and MgO (Table 1). The compositional similarity between heated and unheated glassy and multiphase I indicates that the latter are not the product of a M evolution after closed-system cooling. Therefore, the glass of glass-bearing I in olivine is not a residual M but rather is an independent phase that was trapped either with or without mineral phases, giving rise to the three I types present. (Authors' abstract)

See figure in the Illustrations appendix.

VARELA, M.E., CLOCCHIATTI, R., MASSARE, D. and SCHIANO, P., 1998, Metasomatism in subcontinental mantle beneath northern Patagonia (Rio Negro province), Argentina: Evidence from silica-rich melt inclusions: Mineral and Petrol., v. 62, p. 103-121. First author at Universidad Nacional del Sur-CONICET, Bahia Blanca, Argentina.

Melt and FI trapped in spinel lherzolite and harzburgite xenoliths contain three types of genetically related I hosted by olivine, orthopyroxene, clinopyroxene and spinel: silicate glass I, multiphase silicate MI and CO<sub>2</sub> FI. CO<sub>2</sub> densities of early FI (0.93-1.02 g/cm<sup>3</sup>) and Th of MI (1220°C) indicate that they were trapped at upper-mantle depths.

Silicate MI occur as isolated I as trails along fractures and decorating lamellae deformation. They are composed of glass, or of glass with "daughter" crystals of clinopyroxene, amphibole, apatite and ilmenite. Glass I are characterized by high contents of silica, alumina and alkali elements. The nature and chemistry of the dm indicate that MI can be considered as trapped metasomatic M. Moreover, glass I show chemical variations from high silica (68 wt%) Microthermometry trapped as Isolated I in olivine Fo<sub>91</sub> towards less siliceous (60 wt%) M trapped as SI in olivine Fo<sub>89-90</sub>, onhopyroxene and spinel. This chemical evolution cannot be reconciled with magmatic processes, like fractional crystallization or different degrees of partial melting. The existence of two stages in their evolution could reflect the heterogenous nature of the mantle source of the M and the presence of a deep-seated F phase during melting. (From authors' abstract by E.R.)

VAUGHN, B.H., WHITE, J.W.C., DELMOTTE, M., TROLIER, M., CATTANI, O. and STIEVENARD, M., 1998, An automated system for hydrogen isotope analysis of water: Chem. Geol., v. 152, p. 309-319. First author at INSTAAR, University of Colorado, Campus Box 450, Boulder. CO 80309-0450, USA.

An automated inlet system has been developed for deute-

rium/hydrogen isotope analysis of water using on-line reduction hydrogen. A modified HPLC autosampler introduces precise aliquots of water (0.5 to 5  $\mu$ ) into a heated expansion chamber which is connected via a capillary to hot uranium where the water is reduced to uranium oxde, and hydrogen for analysis. The 600°C uranium reduction furnace is kept at analyzer P in the mass spectrometer, which maximizes the lifetime of the reductant to handle more than 4000 injections per 0.5 g of depleted uranium. This is a flowthrough system, and unlike zinc or catalyst methods, some "memory" effects are encountered, requiring two injections to obtain a  $\delta$ D precision of < $\pm 1\%$ , and four injections for a precision of < $\pm 0.5\%$ . Sample preparation is limited to getting water into an autosampler vial. The computercontrolled system provides extended unattended operation allowing, for instance, large runs of samples that can occupy the instrument over entire weekends.

(Authors' abstract)

VAVELLDIS, M. and MELFOS, V., 1998, Fluid inclusion evidence for the origin of the barite silver-gold-bearing Pb-Zn mineralization of the Triades area, Milos Island, Greece. 8th Int'l Congress of the Geological Soc. of Greece, Geol, Soc. Greece, v 32, no. 3, p. 137-144.

Indexed under FI.

VÁZQUEZ, Rodrigo, VENNEMANN, T.W., KESLER, S.E. and RUS-SELL, Norman, 1998, Carbon and oxygen isotope halos in the host limestone, El Mochito Zn-Pb-(Ag) skam massive sulfide-oxide deposit, Honduras: Econ. Geol., v. 93, p. 15-31. First author at Dept. of Geological Sci., Univ. of Michigan, Ann Arbor, MI 48109.

El Mochito, the largest operating mine in Central America, is a typical skam sulfide-oxide, limestone-replacement lead-zinc-silver deposit. Fl and stable isotope geochemistry of the skarn and sulfide mineralization at El Mochito are compatible with a high T (350-500°C) origin from hydrothermal F with  $\delta D$  values of -40 to -90 per mil and  $\delta^{1x}O$  values between 10 and -1 per mil which were probably of mixed magmatic-meteoric origin. A detailed study of stable isotope compositions of the host limestone around the El Mochito deposit indicate a gradual depletion in "C and "O with approach to the ore body, indicating that the changes in isotopic composition were imposed on the limestone during the hydrothermal activity related to the mineralization. Oxygen isotope exchange between the hydrothermal F and limestone produced a strong depletion in <sup>18</sup>O of up to 18 per mil relative to background limestone compositions. 18O depletion is easily detected for distances of up to 4 km from the orebody The depletion of <sup>13</sup>C is much more restricted, with changes of up to 4 per mil in 8<sup>13</sup>C values relative to the inferred original limestone, extending only 30 m of the ore deposit. The original stable isotope composition of the limestone, as inferred from distal, unaltered samples (δ13CPDB≈5.0‰. δ<sup>18</sup>O<sub>SMOW</sub>≈23.5‰), is similar to that of other Cretaceous limestones. Small-scale stable isotope analyses of the matrix, relict fossils, and latestage veins within the limestones, and comparison to the isotopic composition of the bulk-rock samples suggests that the extent of stable isotope alteration was a function of the initial grain size, the permeability of the rocks, the F/rock ratio, and the T of the hydrothermal system, as well as the isotopic composition and dominant C-bearing species within the hydrothermal F Both extensive recrystallization of lime-mud matrices and the presence of faults and fractures may have enhanced the S porosity and

permeability of the limestones, allowing for effective F infiltration and increasingly pervasive F flow with approach to the ore deposit. The mechanisms responsible for C and O isotope alteration of the limestone were calcite recrystallization and late calcite veining. Large stable isotope alteration halos within limestones surrounding ore deposits of this type provide useful guides to exploration. (Authors' abstract)

Eight analyses are presented for 9 G, including H<sub>2</sub>S and HCl, and 16 analyses of garnet, sphalerite, and galena for H<sub>2</sub>O,  $\delta D$  and  $\delta^{18}$ O, and for CO<sub>2</sub>,  $\delta^{13}$ C and  $\delta^{18}$ O. (E.R.)

VEKSLER, I.V., NIELSEN, T.F.D. and SOKOLOV, S.V., 1998, Mineralogy of crystallized melt inclusions from Gardiner and Kovdor ultramafic alkaline complexes: Implications for carbonatite genesis: J. of Petrol., v. 39, no. 11 & 12, p. 2015-2031. First author at Earth and Planetary Sci., American Museum of Natural History, New York, NY 10024. USA.

Cumulus olivine, clinopyroxene, melilite and perovskite from silicate rocks and carbonatites of the Gardiner (East Greenland) and Kovdor (Kola Peninsula) ultramafic alkaline complexes contain P MI crystallized into aggregates of dm. The petrography and Th of the I constrain the fractionation paths and the formation of carbonatites in the complexes. Carbonated melanephelinite was parental to both complexes and early cumulates (dunite, olivinite, peridotite and melteigite) are comparable. The common occurrence of phlogopite and amphibole in the I and in the host rocks indicates that these were important liquidus phases. In both complexes the fractionation of phlogopite and amphibole drove the M towards Ca-rich (lamite-normative) compositions. At the ijolite stage, the evolutionary trends are believed to separate and the evolved lamite-normative M produced calcite-bearing ijolite in Kovdor and melilitolite in Gardiner. The two assemblages are related by decarbonation reactions. A fractional crystallization origin is suggested for the Kovdor carbonatite, whereas the Gardiner carbonatite formed by L immiscibility in the course of melilite fractionation Na-K-Ca and Na-Mg carbonates are common daughter phases and especially abundant in late-stage 1. Thus, all carbonatite M in the two complexes are alkaline. Calcite carbonatites appear to be cumulates. (Authors' abstract)

VENGOSH, Avner, DeLANGE, G.J. and STARINSKY, Abraham, 1998, Boron isotope and geochemical evidence for the origin of Urania and Bannock brines at the eastern Mediterranean: Effect of water-rock interactions: Geochim. et Cosmo. Acta. v. 62, no. 19/20, p. 3221-3228. First author at Research Dept., Hydrological Svc., PO. Box 6381, Jerusalem 91063, Israel: email (avnerv@vms.huji.ac.il)

The origin of hypersaline brines from Urania and Bannock deep anoxic basins in the eastern Mediterranean Sea has been investigated by integrating geochemical data and boron isotopic ratios. Bottom brines from Urania basin have chloride contents up to 4200 mmole/kg H2O and a marine Na/CI ratio (0 87). All the other ionic rates are different from the marine ratios and show a relative enrichment in Ca, K, Br, and B and depletion in Mg and SO<sub>4</sub>, as normalized to the chloride ion. The  $\delta^{11}B$  values of the Urania brines (811B=29.8±2.9‰; n=7) are lower than that of Mediterranean seawater (39%). The concentrations of Cl and Na. which make up 95% of the total dissolved ions (in molal units), suggest that the Urania brines were derived from eightfold evaporated seawater. The relative enrichment of Ca and depletion of Mg and SO4 reflect dolomitization, gypsum precipitation, and sulfate reduction processes which modified the original evaporated seawater while the brines were entrapped as interstitial waters in the sedimentary section of the Mediterranean. The relative enrichments of Br, B, and K, and the low 811B value of the Urania brines suggest high-T interactions of the evaporated sea water with sediments. Mass-balance calculations suggest that desorption of exchangeable B from the sediments (8"B-20%) modified the marine B isotopic composition of the original eightfold evaporated seawater. Potassium was also leached from clay minerals whereas Br was contributed from degradation of organic matter in the sediments. This is consistent with a thermal anomaly (up to 45°C) recorded at depth in the region of Urania basin. In contrast, bottom brines and shallow interstitial F from Bannock basin with low T (15°C) show marine o<sup>11</sup>B (o<sup>11</sup>B=39.6±2.8‰; n=5; 38.5±2.2‰; n=5, respectively) and B/CI ratios (7 x 10<sup>-4</sup>). The B isotope data confirm that the Bannock brines were derived from rwelvefold evaporated seawater. We argue that the brines from both basins are relics of fossil evaporated seawater that was entrapped in Late-Miocene sediments and accumulated in the deep basins of the Mediterranean seafloor. (Authors' abstract)

VERHEYDEN, S., KEPPENS, E., FAIRCHILD, I.J., McDERMOTT, F. and WEIS, D., 1998, Palaeoclimate reconstructions from geochemistry and isotopegeochemistry study of speleothems (abst.): Mineralogical Magazine, v. 62A, V.M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1593-1594. First author at Departement Géologie, Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussel, Belgium.

Our study was performed in the Ardenne massif, Belgium. The stalagmite provided a  $\delta^{18}O$ ,  $\delta^{13}C$ , Mg/Ca and Sr/Ca record throughout the Holocene, and oxygen isotopic analyses were carried out on meteoric waters, present-day seepage waters and present-day calcite.

Covariation of the oxygen and carbon isotopic signature along single layers suggests that many parts of the stalagmite were not deposited in isotopic equilibrium with the dripwater.

In addition, covariation of  $\delta^{1a}$ O and  $\delta^{13}$ C, Mg/Ca and Sr/Ca ratios along the longitudinal axis of the stalagmite (i.e. timeseries) suggests that the isotopic composition as well as the chemical composition of the stalagmite depend on the amount of available water.

These results confirm the idea that the variation in isotopic composition of the stalagmite is acquired during deposition of the calcite and further support the hypothesis of evaporation and degassing control of the calcite deposition.

As a conclusion, this stalagmite rather seems to be a proxy-tool for studying fluctuations in the precipitation amount during the Holocene than it would be for estimating T evolution. It also suggests that stalagmites which are not deposited in isotopic equilibrium with the dripwater can still be used for palaeoclimatic studies. (From authors' abstract by E.R.)

VIETS, J.G., HOFSTRA, A.H. and EMSBO. Poul, 1996, Solute compositions of fluid inclusions in sphalerite from North American and European Mississippi Valley-type ore deposits: Ore fluids derived from evaporated seawater: Society of Economic Geologists, Special Pub. no. 4, 1996, p. 465-482. First author at U.S. Geological Survey, P.O. Box 25046, MS 973, Denver, CO 80225, USA.

The purpose of this study is to characterize the chemical composition of I F in sphalerite from major MVT districts in North America and Europe. This data is used to determine the origin of the brines, map brine provinces, and identify subsequent compositional modifications resulting from mineral precipitation, F-rock reactions, and F mixing. This information places important constraints on genetic models for MVT deposits.

Sphalerite samples (43) were analyzed for Na<sup>+1</sup>, NH<sub>4</sub><sup>+1</sup>, K<sup>-1</sup>, Ca<sup>+2</sup>, Mg<sup>+2</sup>, Sr<sup>+2</sup>, Cl<sup>+1</sup>, Br<sup>+1</sup>, F<sup>+1</sup>, CO<sub>3</sub><sup>-2</sup>, S<sub>2</sub>O<sub>3</sub><sup>-2</sup>, SO<sub>4</sub><sup>+1</sup>, and acetate by a new ion chromatographic method with a detection limit for most ionic species of 1 nanogram or less. Analytical results are reported in nanograms and molar ratios (e.g. Cl/Br). Absolute concentrations are not reported because the method cannot measure the amount of 1 water released from samples.

The Cl/Br'Na/Cl systematics show that the solutes in the ore F are derived from evaporated seawater and water that has dissolved halite. All of the samples have low Na/Cl and high Ca/Cl ratios when compared to seawater, which is typical of most basinal brines. The Cl/Br'Na/Cl systematics indicate that the primary reason for the low Na/Cl ratios is precipitation of halite from evaporated seawater, although albitization of plagioclase may have played a minor role.

Other reactions affecting the composition include dolomitization, precipitation of anhydrite or gypsum, sulfate reductioin, and organic matter. The FI solute data shows that MVT districts in the United States were deposited from four compositionally distinct brines derived from different sources. (From authors' abstract by E.R.)

#### VIGGIANO, G.J.C., GONZÁLEZ, P.E. and IZQUIERDO, M.G.,

1998, Fluid inclusion study in the Las Tres Virgenes, B.C.S. (Mexico): Evidences of a magmatic uprising fluid (abst.): 17th General Meeting Int'l Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A34. First author at C.F.E. Exploración, UMSNH, Facultad de Ingenieria Civil.

The study of F1 in minerals from the Tres Virgenes geothermal field, Baja California, Mexico, shows that the parental (i.e., unboiled or better non-boiled) F is typical of orthomagmatic deposits in its pneumatolithichydrothermal state with ranging T between 250-300°C and with even 30.000 ppm TDS. This F has given place to a forced up-flow, due to its low permeability, which is greisenizing (presence of tournaline and mica among other minerals) the nearest rock to the skam, that is, the granodtorite. The meteoric water, also identified in the F1 according to the sal, could have infiltrated during the forced convective flow and its presence can be verified in the diluted F1 of relatively high T which frequency is subordinated respect to those of high sal. (From authors' abstract by E.R.

VIKRE, P.G., 1998a, Intrusion-related polymetallic carbonate replacement

deposits in the Eureka district, Eureka County, Nevada: Nevada Bureau of Mines and Geol., Bulletin 110, 52 pp.

Skam mineral assemblages and FI compositions (XCO2\*0.075) indicate that pyroxene+gamet skam formed above 470°C, and hydrous skam at lower T, minimally 420°C. Minimum entrapment T (P-corrected) and sal ranges for FI in hydrous skarn (~340-385°C, NaClog=6 to 13 wt%) and sulfide replacement deposit minerals in the vicinity of Ruby Hill (~360-395°C, NaClos<3.5-10.4 wt%), determined by microthermometry, are broadly similar to T derived from arsenopyrite+sphalerite+pyrite (+pyrrhotite) equilibria (averaging ~320 and 315°C for hydrous skam and sulfide replacement deposits, respectively; maximum for hydrous skarn is -385°C), and, in part, to sulfur isotope fractionation T modes (350 and 270°C for sulfide replacement deposits). The differences between skarn mineral equilibria T and Fl entrapment T, -25-80°C, are perhaps a result of insufficient P corrections. P of -1 to 1.6 kbars, determined from H2O+CO2+NaCl fluid systematics and hornblende AlT geobarometry, indicate that granodiorite emplacement and formation of skarns and sulfide replacement deposits occurred at minimum depths of 3 8-6.1 km (2.3-3.7 miles). Hydrogen and oxygen isotope compositions of FI waters extracted from skarn and sulfide replacement deposit minerals are compatible with Cretaceous meteoric water, mixed with increments of magmatic water, that has exchanged varying amounts of oxygen with carbonate wall rocks. (From authors' abstract by H.E.B.)

VIKRE, P.G., 1998b, Quartz-alunite alteration in the western part of the Virginia range, Washoe and Storey Counties, Nevada Econ. Geol., v. 93, p. 338-346. Author at ASARCO, Inc., 510 East Plumb Lane, Reno. NV 89502 USA.

Large areas of Miocene volcanic rocks in the area were altered to quartz, alunite, and clays, and all significant precious metal and mercury deposits throughout the range, including the Comstock Lode, Ramsey, and Talapoosa districts, occur in or adjacent to extensively altered andesites and dacites. Oxygen, deuterium, and sulfur isotope analyses of alunite, quartz, and water extracted from FI in quartz-alunite altered rocks in the western part of the Virginia Range, and FI microthermometry, show that the altering F were composed of magmatic water and mixtures of meteoric and magmatic water, and that the alteration took place in the T range -205 to 265°C. FI water isotopic analyses indicate that Comstock Lode district veins were also deposited by a mixed magmatic-meteoric water F, and that subsurface altered intrusions, such as the molybdenite-bearing diorite in the Washington Hill alteration zone, can be identified by isotopic analyses of water in surface samples. Sources and thermal characteristics of F involved in quartz-alunite alteration and gold mineralization in the Ramsey district, similar to that at Goldfield, Nevada, and for other deposits in the Virginia Range, have not been determined, but mixing of magmatic and meteoric water at moderate hydrothermal T may have been important in localizing ore. (From author's abstract by E.R.)

VILA, Tomás, LINDSAY, Nicholas and ZAMORA, Richard, 1996, Geology of the Manto Verde copper deposit, northern Chile: A speculariterich, hydrothermal-tectonic breccia related to the Atacama fault zone: in Ändean copper deposits: new discoveries, mineralization, styles and metallogeny", Soc Econ. Geologists Special Publication No. 5, Carnus, F., Sillitoe, R.H. and Petersen, R., eds., 1996, p. 157-170.

The Manto Verde copper deposit is associated with specularite-rich breccias emplaced during extensional tectonism along brittle faults of the Atacama fault zone (AFX). The AFZ is a complex simistral strike-slip/dipslip system that originated during oblique subduction in a Jurassic to Early Cretaceous magmatic arc. Activity of the AFZ is documented from the Middle Jurassic, with intermittent movements occurring at least into the late Miocene. South of Manto Verde, the AFZ is a major control on the emplacement of apatite-bearing magnetite deposits in the Cretaceous Iron Belt (CIB). Preliminary studies indicate a predominance of three-phase FI as well as the coexistence of V-rich and L-rich, two-phase I evidencing boiling. The Th for two- and three-phase | in translucent quartz veinlets and fragments accompanying early iron-copper-(gold) mineralization range between 180 and 320°C, although they are mainly between 180 and 250°C Sal for the three-phase I vary from 30 to 47 wt % NaCl eq., although a decrease in F sal (14-21 wt.% NaCl eq.) is detected in two-phase I from late mineralization, chalcopyrite-bearing calcite veins.

The geologic features of the Manto Verde deposit suggest a common magmatic-hydrothermal origin with the apatite-bearing magnetite deposits of the CIB. Manto Verde probably represents the copper-rich, specularitedominated, and possibly younger end member of a continuum of deposits that extends to copper-poor, magnetite-dominated deposits at the other VITYK, M.O. and BODNAR, R.J., 1998, Statistical microthermometry of synthetic FI in quartz during decompression reequilibration. Contrib. Mineral. Petrol., v. 139, p. 149-162. Authors at Fluids Research Laboratory, Dept. of Geological Sci., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061 USA

FI microthermometric data are often reported as Th frequency histograms Interpretation of such histograms for a single FI assemblage (FLA) of non-reequilibrated FI is usually straightforward and provides an accurate determination of the original density (Th) of that FIA. However, interpretation of such histograms for reequilibrated 1 is more problematic. Decompression experiments using synthetic 1 in natural guartz, conducted at 2-5 kbar and 600-700°C with a maximum internal overpressure of 2 kbar indicate that histogram shape reflects the sample's P-T history. Our results further indicate that the mean, mode, range, standard deviation, extreme values, etc., all have a significance with respect to the P-T history of the sample. Thus, a mound-shaped, unimodal histogram with low range indicates a nearly isochoric cooling P-T path. A unimodal histogram that is slightly skewed to the right, and with a low standard deviation but high range, results from I deformation in the plastic regime (high T/low strain rates). FI deformed plastically show no correlation between size and density. Histogram outliers should not be ignored and may be used to determine an isochore that passes close to the conditions of entrapment (minimum Th) or close to the final reequilibration conditions (maximum Th). The histogram mean Th value corresponds to an isochore that represents the internal overpressure (about 1 kbar) that can be maintained over geologic time by a majority of reequilibrated FI. A multimodal histogram with high range and high standard deviation indicates I brittle deformation (low T/high strain enviroments). FI deformed in a brittle manner show strong positive correlation between size and density. Histograms produced in the laboratory show many similarities to histograms for natural samples, offering the hope that laboratory results may be used to interpret P-T histories of natural samples. (Authors' abstract)

VITYK, M.O., BODNAR, R.J., and DOUKHAN, J-C., 1998, Plastic flow associated with fluid inclusions in quartz (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 69. First author at Department of Geological Sci., Virginia Tech. Blacksburg, VA U.S.A. 24061, email (max.o.vityk@exxon.sprint.com)

Aq synthetic F1 in quartz were experimentally reequilibrated for 30 and 180 days at conditions of internal overpressure. Microstructures associated with reequilibrated (stretched) FI were examined with the TEM. Quartz in healed fractures in samples that were not subjected to overpressures shows low dislocation activity. Quartz adjacent to reequilibrated Fl, however, showed a marked increase in dislocation activity compared to unreequilibrated samples. Stretching of the I walls occurred anisotropically by expansion of mobile dislocations in their slip systems. Dislocation expansion was controlled by glide in the rhombohedral planes {1011} restricted to narrow zones (<3 µm) in the immediate vicinity of the FI walls outside of the healed fracture plane. These plastic zones were observed after both short term (30 days) and long term (180 days) experiments and can be attributed to hydrolytic weakening of quartz matrix around FI due to water diffusion during the experiment. Association of water bubbles with dislocations shows clearly that water was lost from I during both the 30 and 180 day experiments. Our results indicate that even relatively fast experimental loading rates allow synthetic FI in natural Brazilian quartz to recover (chemically and volumetrically) such that internal stresses probably never reach the point where the I fail by brittle fracture. The driving force for FI recovery arises from two complementary, competing mechanisms: plastic deformation of the I walls weakened by water, and water leakage induced by pre-existing and strain-induced dislocations. (Authors' abstract)

# VOZNYAK, D.K., LITOVCHENKO, A.S. and KULCHITSKAYA, A.A., 1998, The γ-radiation impact on hydrocarbon inclusions: Mineral Zhurnal, 1998, no. 3, p. 22-26 (in Russian, Engl. abst.)

Results of cryometric investigation of the hydrocarbon I in quartz (the Carpathians, the Donetsk Basin) before and after  $\gamma$ -radiation (the dose  $1 \times 10^8$  Gy, the source  $^{60}$ Co) are presented in the paper. During  $\gamma$ -radiation the P methane solution of the I is enriched with hydrocarbons which are heavier than methane, and the quantity of methane diminishes. CO<sub>2</sub> of the I also takes part in the radiolysis as the material for the synthesis of hydrocarbons. During  $\gamma$ -radiation water solution of phenols (?) and methane solution in the I from L (as oil) and solid hydrocarbons, almost pure water

forms a separate phase. The ability of the hydrocarbon solutions to react sensitively to ionizing radiation permits using them for estimation of dosages. (Authors' abstract)

WACHOWLAK, N.M., GUMMER, P.K., GROTZINGER, J.P. and SPOONER, E.T.C., 1998, -1.89 Ga, MVT/SSC mineralization, Esker deposit, Rocknest carbonate platform, Wopmay orogen, N.W.T., Canada (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-369. First author at Dept. of Geol., Univ. of Toronto, 22 Russell St., Ontario, Canada M5S 3B1, email (nawojka@zircon.geology.utoronto.ca)

The Esker Zn-Pb deposit (80.6 Mt MVT deposit grading 4.5% combined Zn+Pb) is part of the Epworth property, owned jointly by Rhonda Mining Corp. and Noranda Mining and Exploration, Inc., Mineralization is hosted in a ~1.89 Ga carbonate shelf (Rocknest formation) which formed at the passive margin of the Wopmay Orogen, and is older than 1.88-1.84 Ga.

MVT mineralization at Esker is preferentially hosted and stratabound in a conophyton stromatolite biohermal reef 3-5 m thick. The conophytons are cone-shaped, columnar stromatolites that have enveloped thrombolitic to fenestral domes to form massive reefs. Within the reef, P textures have been largely replaced by a buff white chert. Mineralization consists of laterally zoned sphalerite and galena with minor amounts of chalcopyrite and pyrite. High grade areas occur in dissolution breccias located in the cores of conophyton bioherms. Currently, mineralization in the Esker horizon is interpreted to have been the result of basinal F movement upwards and outwards through Rocknest stratigraphy. The saline (20.81±2.8 wt.% NaCl eq.) and low T (100-150°C) brines moved laterally through the conophyton horizon, utilizing both P permeability and S porosity. Precipitation of the sulfides is currently interpreted to have been the result of reaction of the brines with organic matter in the conophyton horizon. The occurrence and association of stratiform Cu (SSC) in the underlying siliciclastic Odjick Formation with the substantial MVT mineralization in the Rocknest will continue to be researched and explored for its future economic potential. (Authors' abstract)

WADA, Naoko and MATSUDA, J.-J., 1998, A noble gas study of cubic diamonds from Zaire: Constraints on their mantle source: Geochim. et Cosmo. Acta, v. 62, no. 13, p. 2335-2345. Authors at Dept. of Earth and Space Sci., Grad. School of Sci., Osaka Univ., Toyonaka, Osaka 560-0043, Japan.

Cubic diamonds are known to contain F in submicrometer I which are thought to originate from the mantle beneath the continental crust. Noble G elemental and isotopic compositions of sixteen cubic diamonds from Zaire are noticeably different from those in MORB. From the <sup>3</sup>He<sup>4</sup>He and <sup>40</sup>Ar/<sup>36</sup>Ar ratios, some constraints can be made on the origin of cubic diamonds. The observed ratios can be explained if the cubic diamonds crystallized in a F which separated from a mantle source previously suggested model for the origin of F<sup>-</sup>bearing diamonds. The <sup>38</sup>Ar/<sup>36</sup>Ar ratios in the cubic diamonds are slightly but significantly higher than the atmospheric ratio. This high <sup>38</sup>Ar/<sup>36</sup>Ar ratio may represent the primordial isotopic ratio preserved in the mantle. Alternatively, the observed excess <sup>38</sup>Ar may be attributed to the nuclear reaction <sup>35</sup>Cl((\alpha,p))<sup>38</sup>Ar in the F phase if the production rate of nucleogenic <sup>38</sup>Ar is about ten times higher than the previously encycled using reported value and the age of the Fl is quite old (>10<sup>9</sup> yr). (From authors' abstract by E.R.)

WALGENWITZ, F.R., EICHENSEER, H. and BIONDI, P., 1998, Do stable isotopes and Fl allow to constrain the origin and timing of dolomitization in deeply buried carbonate reservoirs? Example of the Pinda Formation, Angola: <u>in</u> Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p 369-372. Authors at Elf Exploration Production, CSTJF, L1/37, Pau, France.

Oxygen isotope compositions and Th of Fl measured in massively dolomitized Albian carbonate reservoirs of the Angola margin, vary according to the present-day burial depths and reservoir T. It is argued that Fl and stable isotopes are reset during Tertiary burial, and reflect the conditions of recrystallization of pre-existing dolostones, early diagenetic in origin. (Authors' abstract)

WALKER, R.T. and SAMSON, I.M., 1998, Cryogenic Raman spectroscopic investigations of fluid inclusions in the NaCl-CaCl<sub>2</sub>-H<sub>2</sub>O system (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A33. Authors at Dept. of Earth Sci., Univ. of Windsor, email (ims@uwindsor.ca)

We have characterized the solid assemblages present in frozen, natural Fl and synthetic F using Raman spectroscopy in order to test whether this method can yield useful information about the composition and phase behaviour of aq FI. Specifically, we were interested in characterizing the presence and abundance of a CaCl2 component, which is commonly hypothesized as being responsible for low Te, and as a justification for modeling phase equilibria in the system NaCl-CaCl2-H2O. In order to obtain spectra which represent the bulk F composition, analyses were carried out on fine-grained aggregates of ice and hydrate, rather than large hydrate crystals. After initial. rapid freezing, most I and synthetic solutions yield spectra that indicate the presence of hexagonal ice, but not salt-hydrates. On warming, the F commonly exhibit a phase transition between about -70 and -50°C, that is manifested as a wave of crystallization or coarsening and darkening of the I. Raman spectra acquired after immediate cooling, indicate that this transition represents hydrate crystallization. As this phase transition could be mistaken for eutectic melting in natural I, some low Te reported in the literature may be erroneous, and in such cases, additional components may not be required to explain the observed phase behaviour. Frozen 1 from a rare-element granite pegmatite and the Mt. Pleasant W-Mo deposit contain detectable ice+hydrohalite±antarcticite. Mathematical modeling and comparison with the synthetic F indicate that other hydrates were absent or below detection and that NaCl>CaCl2. These results are supported by EDS-decrepitate analysis which also indicate small amounts of K in some I. Modeling of phase equilibria in these I using the NaCl-CaCl2-H2O system therefore seems justified. (Authors' abstract)

WALLACE, P.J., 1998, Water and partial melting in mantle plumes: Inferences from the dissolved H<sub>2</sub>O concentrations of Hawaiian basaltic magmas: Geophysical Research Letters, v. 25, no. 19, p. 3639-3642. Author at Ocean Drilling Program and Dept. of Geol. and Geophys., Texas A&M Univ., College Station.

Knowledge of dissolved H<sub>2</sub>O in P Kilauean magmas provides a constraint on H<sub>2</sub>O abundance in the deep mantle region that feeds the upwelling plume beneath Hawaii. Given an H<sub>2</sub>O/K<sub>2</sub>O mass ratio of ~1.3 for basaltic glasses and MI from Kilauea, the mantle source is estimated to contain 450±190 ppm H<sub>2</sub>O. This value is ~3 times greater than that estimated for the mantle source for mid-ocean ridge basalts. Consideration of OH solubility in olivine suggests that water undersaturated melting of the upwelling Hawaiian plume probably begins at a depth of ~250km. Thus during plume ascent through most of the upper mantle, water is partitioned between nominally anhydrous silicates and a small mass fraction of entrained hydrous silicate M. Because water strongly influences the viscosity of olivine aggregates, partial melting and M extraction will have important effects on the rheology of the upwelling plume beneath Hawaii. (Author's abstract)

WALSHAW, R.D. and MENUGE, J.F., 1998, Dating of crustal fluid flow by the Rb-Sr isotopic analysis of sphalerite: A review in Parnell, J. (ed.) 1998, Dating and Duration of Fluid Flow and Fluid-Rock Interaction, Geological Society, London, Special Publications, v.144, p. 137-143. Authors at Geology Dept., Univ. College Dublin, Belfield, Dublin 4, Ireland.

The sphalerite Rb-Sr isochron technique is a relatively new and powerful geochronological tool allowing the direct dating of zinc sulphide mineralization. Recently, insights have been gained into the Rb-Sr isotope systematics of sphalerite, in particular the crystallographic residence sites of Rb and Sr and the mechanisms by which the Rb/Sr ratio of sphalerite is fractionated over that of its parent hydrothermal F. This, along with independent testing against three other dating techniques, has resulted in the vindication of the sphalerite Rb-Sr isochron technique. The resultant isochron ages have allowed very precise chronological constraints to be placed on the genesis of American and Australian Mississippi Valley-type deposits, greatly reducing the controversy which has surrounded this class of base metal deposit. (Authors' abstract)

Discusses Rb-Sr techniques applied to FI (H.E.B.)

WANG, Denghong, CHEN, Yuchuan, and MAO, Jingwen, 1998. The Ashele Deposit: A recently discovered volcanogenic massive sulfide Cu-Zn deposit in Xinjiang, China. Resource Geol., v. 48. no. 1, p. 31-42. First author at Inst. of Mineral Deposits, Chinese Acad. of Geological Sci., 26 Baiwanzhuang Road, Beijing 100037, P.R.C.

The Ashele Cu-Zn deposit is a recently discovered volcanogenic massive sulfide deposit in Xinjiang, Northwestern China. It is the largest Cu-Zn deposit of this type in China. Zonation of metal elements in the Ashele mine is typical of volcanic-related exhalative Cu-Zn sulfide deposits in the world. Black ores enriched in Pb, Zn and Ag occurs on the top of the No. I orebody, yellow ores enriched in Cu in the middle part, and the chalcopyritization stringer [is] below the massive sulfide ores. Studies of ore petrology suggest that the massive ores were volcanogenic and deposited by exhalative process. The different atomic weights of Fe, Cu, Pb and Zn may be responsible for both the vertical and horizontal zoning pattern of elements. Based on this fact, a new model for the exhalative deposits such as the Ashele deposit is suggested in this paper (From authors' abstract by E.R.)

Th ranged from 211 to 313°C. Eight analyses of FI from sphalerite and barite are listed, in unstated units of "10<sup>4</sup>,"as follows (rounded): Na 1-13; K 0.3-15; Ca 0.18-5; Mg 0.03-5; Cl 1-20, SO<sub>4</sub> 2-47, H<sub>2</sub>O 300-960; CO<sub>2</sub> 10-100; H<sub>2</sub> 0.04-0.6; N<sub>2</sub> 5-50; CH<sub>4</sub> 0-24 (E.R.).

WANG, Lijuan, 1998a, Fluid inclusion studies of copper, lead, zinc and tin deposits in northern margin of north China platform and its northern adjacent areas: Mineral Deposits, v. 17, no. 3, p. 256-263 (in Chinese; Engl. abst.) Author at Beijing Inst. of Geol. for nonferrous mineral resources, CNNC, Beijing 100012.

Based on Fl studies of quartz from 52 deposits, the authors have divided these deposits into three subtypes, namely, intrusion-bound, stratabound and complex-bound.

The intrusion-bound deposits are genetically related to magmatism. In deposits within or near intrusions, dm are abundant in the FI, and gaseous I account for a considerable percentage. With the increasing distance from the intrusion, the Th and sal decrease, and the T, sal, density, pH. Eh and  $JO_2$  values show regular variation. The metallogenic F are derived from mixed magmatic water and meteoric water. The F<sup>-</sup> and Cl<sup>-</sup> contents are relatively high. The strata-bound deposits are mainly controlled by strata. With the intensification of reformation, lenticular orebodies or vein orebodies were formed. The complex-bound deposits are controlled not only by strata but also by intrusions. Different reformation intensities result in differences in size, concentration, type and chemical composition of FI. (From author's abstract by E.R.)

WANG, Lijuan, 1998b, Analysis and study of the composition of fluid inclusions: Geological Review (Dizhi Lunping), v. 44, no. 5, p. 496-501 (in Chinese; Engl. abst.). Author at Research Center of Mineral Resources Exploration, Chinese Acad. of Sci., Beijing, 100101.

This paper introduces a set of analytic methods of Fl composition, including mainly the ICP-MS and PIXE methods for analyzing the L-phase composition of bulk Ff, the LA-ICP-MS methods for analyzing L-phase the composition of separate [i.e., individual] I and the LRM and FT-IR methods for analyzing the gaseous-phase composition of separate 1. These methods greatly raise the level of analyzing the FI composition. But there are still some problems. (Author's abstract)

WANG, Lijuan, 1998c, Fluid inclusion research of quartz from Huogeqi copper-polymetallic deposit, Langshan district, Inner Mongolia, China. 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28,1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 965-968 (in Chinese).

WANG, Ping'an, DONG, Faxian, LIU, Jianmin, CHEN, Bailin, ZHU, Yongyu and SHEN, Tingyuan, 1998, Geology and geochemistry of the Dabeiwu gold deposit, Jiangxi province: Mineral Deposits, v. 17, no. 1, p. 57-69. First author at Inst. of Geomechanics, Chinese Acad. of Geological Sci., Beijing 100081.

The Dabeiwu gold deposit is hosted by metasedimentary rocks adjacent to a late Mesozoic granitic intrusive. Orebodies occur as veins, lenses or beads within or outside the quartz veins, controlled by a ductile sheer zone and the compressional fracture zones in this ductile sheer zone. Au abundances are -7 to  $43 \times 10^{-9}$ . FI studies of quartz yield Th of 180-386°C, T1 233-423°C, and F P of  $(224-826) \times 10^5$  Pa. Sal of P FI range from 2.7 to 5.1 wt % NaCl eq. and densities are 0.618 to 0.917 g/cm<sup>3</sup>. Sulfur, lead, carbon, silicon, oxygen hydrogen and strontium isotopic data indicate that the ore-forming substances of this deposit were derived mainly from the crust, and the ore-forming F were mainly magmatic F and subordinately metamorphic residual intercrystalline F. It is concluded that the Dabeiwu gold deposit is a mesothermal to hypothermal type gold deposit related to the Yanshanian granitic magmatism and controlled by magmatite and shattered zones. This conclusion is rather different from the previous genetic view that the deposit was of the shear zone type formed in Neoproterozoic. (From authors' abstract by E.R.)

WANG, Yigang, YU, Xiaofeng, YANG, Yu and ZHANG, Jing, 1998. Applications of fluid inclusions in the study of paleo-geotemperature in Sichuan basin: Earth Science-J. of China University of Geosci. (Diqiu Kexue, Zhongguo Dizhi Daxue Xuebao), v. 23, no. 3, p. 285-288 (in Chinese, Engl. abst.). Authors at Geol. Exploration and Development Inst. of Sichuan Petrol. Administration, Chengdu 610051.

With the Th of FI, the paleo-geotemperature gradient of the strata in different geologic times in the middle part of Sichuan Basin can be calculated on the basis of an integrated analysis of the depositional-burial history of the Basin, the main geothermal events, the data of logging T and vitrinite reflectance (Ro) from the cores of wells. Furthermore, the paleogeotemperature gradient chart can also be established. The chart can be used to calculate the paleo-geotemperature of individual stratum in different geologic time in Sichuan Basin. The results show that the paleogeotemperature gradient decreases with the strata changing new. The present-geotemperature is the inheritance of the ancestor Dongwu movement period with the large scale basalt eruption is the maximum geotemperature gradient period of Sichuan Basin, measuring 6.5°C/100 m. The geotemperature gradient of the basin is related to the tectonic setting. The maximum value of paleo-geotemperature gradient of Southwest Sichuan is nearing the Kangtian rift, and the paleo- and present-geotemperature gradient are gradually decreasing as far away from the Kangtian rift. (Authors' abstract)

WANG, Yongjin, CHEN, Qi, LIU, Zechun, CHEN, Ye, ZHOU, Chunling and LU, Conglus, 1998, A continuous 200 ka palaeoclimatic record from stalagmite in Tangshan Cave, Nanjing: Chinese Sci. Bulletin (Kexue tongbao), v. 43, no. 3, p. 233-237.

An oxygen isotope T record from 381 to 166 ka B.P. (<sup>230</sup>Th/<sup>234</sup>U dating and tuned ages) has been obtained by combining data on the isotopic composition of calcites with that of Fl trapped in a stalagmite from a limestone cave in which a fossil cranium [was] deposited. Several laminae in microsequence of the stalagmite represent climatic events or shifts. The Nanjing man fossil was older than 381 ka B.P. (Authors' abstract)

WANG, Yuxiang, ZHANG, Wenqi and TANG, Cheng, 1998. A preliminary study on the origin of the Houdidong gold deposit in Longjing City. Jilin province: Jilin Geology (Jilin Dizhi), v. 17, no. 2, p. 49-53 (in Chinese, Engl. abst.). First author at Team 605, Jilin Bureau of Nonferrous Metal Geological Exploration. Longjing City 133401.

The Houdidong gold deposit is a typical one related to basic rocks in an eugeosynchine area of Yanbian, Jilin province. The geological features and S, H and O isotope components of the deposit and ores are studied in the study area. It is considered that the material source and the ore-forming solution source of the deposit are deep basic magma, and the deposit belongs to mesothermal gold deposit. (Authors' abstract)

FI data are presented and discussed (H E.B.).

WARNER, S., ABDEL-RAHMAN, A.M. and DOIG, R., 1998. Apatite as a monitor of fractionation, degassing, and metamorphism in the Sudbury igneous complex. Ontario: The Canadian Mineralogist. v. 36. Indexed under Fl.

WARREN, Ed, O'LEARY, John, HERBERT, Richard, PULHAM, Andy, GRAHAM, Rod, and BONNELL, Linda, 1998. Porosity prediction for deeply-buried quartz arenites in the Llanos Foothills, eastern Cordillera, Colombia: AAPG Bull., v. 82, no. 10, p. 1980-1981.

Sandstones of the Eocene Mirador formation are the major reservoir target in the Llanos Foothills of Colombia. They are quartz arenites heavily cemented by quartz. Despite low porosity (typically <10 p.u.) they retain high permeability (up to 5000 md) where coarse grained. Porosity is a critical exploration risk because the structures are deep, in excess of 12,000 feet and structural restoration indicates that the sandstones may have been buried over 3000' deeper prior to thrusting and uplift. FI data from quartz cements indicate that quartz cementation occurred over a broad T range between 80 and 150°C. Significant differences were found in the onset T of quartz cementation in different thrust sheets. Very low abundances of P petroleum I in general indicates that most quartz cementation pre-dated petroleum emplacement. The porosity evolution of the Mirador Fm in the different thrust sheets was unraveled using the petrographic and FI data referenced to a compaction curve for rigid-grained sands. The FI data establish the depth of quartz cementation using the geothermal gradient of the region. The present porosity of all thrust sheets is much less than that predicted from a compaction curve at this depth, indicating that significant porosity loss has occurred subsequent to compaction.

WAWRZYNIEC, T.F., SELVERSTONE, J. and AXEN, G., 1998. Relationships among fluid compositions and structural styles during footwall uplift below the Simplon low-angle normal fault, Central Alps, Switzerland (abst.): Geological Society of America Annual Meeting 1998. Abstracts, v. 30, no. 7. p. A-64. First author at Dept. of Earth & Plan. Sci., UNM, Albuquerque, NM 87131; email (timwaw@unm.edu)

The Simpton Line is a W-down, low-angle normal fault that defines the W margin of the Lepontine Dome of the Central Alps. The NWstriking detachment surface formed in a releasing bend between the seismically active Rhone fault system, and the tectonically quiescent Periadriatic lineament. Our results suggest that F distribution and composition may influence the structures developed at mid- to upper-crustal levels in the footwalls of major low-angle normal faults.

Previous work along the Brenner Line established that footwall uplift was accommondated by post-mylonitic, sub-vertical, synthetic and antithetic brittle faults. Similar structures are present in the Simplon region. However, in the Simplon footwall, these subvertical faults are replaced Nward by tensile crack arrays, kink bands, tensile veins, and moderate-angle. brittle-ductile shear zones. These latter structures are consistent with footwall uplift controlled by flexural failure rather than subvertical simple shear. Microthermometric analysis of kinematically referenced Fl arrays (FIAs) reveals a systematic variation in F composition associated with the two end-member structural styles. FIAs associated with strike-slip and subvertical, synthetic, (W-down) brittle normal faults contain a mixed carbonic-ag F. Density data indicate that W-down brittle faulting occurred at 15-25 km depth and 500-550°C. FIAs associated with antithetic (E-down) brittle normal faults contain a similar mixed F. However, sparse, preliminary density data indicate that E-down faults were active at shallower depths of 5-15 km depth and T<400°C. In contrast, FIAs in the mylonitic foliation, brittle/ductile shear zones, and extensional veins are aq brines that record a comparable range of P-T conditions. All of these observations are independent of rock type. We speculate that different wetting characteristics of carbonic vs. aq F influenced the mechanical behavior of the rocks. Specifically, nonwetting carbonic F may have locally increased F P and induced brittle failure at high T; rocks lacking a carbonic F deformed by ductile mechanisms at the same time. Alternatively, the different structural styles may be an expression of contrasting F P/transmissivity regimes where local plumbing systems tapped F reservoirs of differing composition. Tests of these competing hypotheses are in progress, but our preliminary observations suggest that F composition may play a significant role in controlling deformational style at mid-crustal depths (Authors' abstract)

WAYNE, D.M. and McCAIG, A.M., 1998, Dating fluid flow in shear zones: Rb-Sr and U-Pb studies of syntectonic veins in the Néouvielle Massif, Pyrenees: in Parnell, J. (ed.) 1998, *Dating and Duration of Fluid Flow* and Fluid-Rock Interaction, Geological Society, London, Special Publications, v. 144, p. 129-135. First author at Chemical Sci. and Tech. Div., CST-1, MS-G740, Los Alamos Nat'l Laboratory, Los Alamos, New Mexico 87545, USA.

Rb-Sr and Pb-Pb data are reported from separated minerals (amphibole, albite, calcite, epidote), altered wall rocks, and FI trapped in quartz, from veins associated with retrogressive shear zones cutting the Néouvielle granodiorite massif in the central French Pyrenees. Alteration in the shear zones was caused by movement of hypersaline brines during deformation. Shear zones with similar kinematics occur in granodiorites and high grade gneisses throughout the northern Axial zone of the Pyrenees, and have been attributed variously to both the Variscan and Alpine orogenies. Rb-Sr data on a syntectonic, polymineralic vein and its altered wall rock support an Alpine age for deformation and F flow, giving an isochron of 47±8 Ma, or 48±2 Ma if albite is excluded Another vein gives a similar age for altered wall rock and albite, but chlorite and guartz-hosted Fl are out of equilibrium. Pb data plot as quasi-linear arrays on ratio plots, with no age significance. The usefulness of this latter technique is restricted by the slow rate of uranium decay in these young rocks, but in any case Pb isotopic ratios do not appear to have homogenized during vein formation. (Authors' abstract)

WEARE, J.H., DUAN, Z. and MØLLER, N., 1998, Supercritical thermodynamics and fluid/fluid phase coexistence in thermodynamic systems: A corresponding states model and results of simulation (abst.): Mineralogical Magazine, v. 62A, V. M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 637-1638.

WEBSTER, J.D., RAIA, F. and de VIVO, B., 1998, Relationships involving magmatic volatiles and eruptive behavior at Mt. Vesuvius during interplinian volcanic activity (472A.D.-1944A.D.) (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A31. First author at Dept. Earth and Planetary Sci., AMNH; email (jdw@amnh.org)

As part of a systematic study of pre-eruptive magma geochemistry, we have analyzed silicate MI in clinopyroxene phenocrysts from 9 rock samples (lava and scoria) from Mt. Vesuvius. Most MI require reheating and quenching to a glass prior to analysis because they contain dm. 1 were analyzed for major, minor, and trace elements by electron and ion microprobes and FTIR. The rock samples are products of two intervals of interplinian volcanic activity: the 472A.D.-1139A.D. medieval period and the 1631A.D. to 1944A.D. modern period. These two eruptive periods were interrupted by the 1631 plinian eruption of Vesuvius, and each interval exhibits dramatically different eruptive behavior.

The MI data provide important constraints on magma geochemistry. The major element compositions of the magmas ranged from phonotephrite to tephri-phonolite. Although the magmas of the medieval and modern periods were roughly similar in major-element composition, the trace and volatile elements show distinctly different behavior. The compositions of MI from samples of the modern period are consistent with simple silicate M evolution (via fractional crystallization) characterized by increasing Cl, S, Rb, Cs, Si, Al, and K and decreasing Ca and Sr. Conversely, MI from samples of the medieval period show evidence of M evolution via fractional crystallization, multiple inputs of more primitive magma, and strong evidence of a volatile phase or phases. Exsolution of at least one volatile phase, before entrapment of the I and before cruption, is indicated by fixed Cl contents, a small range in S contents, and relationships involving other elements soluble in aq volatile phases (e.g., H<sub>2</sub>O, B, Li).

The presence of a volatile phase in medieval magmas, which displayed comparatively greater violence during eruptions, contrasts with the apparent lack of a volatile phase prior to eruption of the modern magmas which erupted much more frequently and in a relatively passive manner. (Authors' abstract)

WEBSTER, J.D. and REBBERT, C.R., 1998, Experimental investigation of H<sub>2</sub>O and Cl' solubilities in F-enriched silicate liquids; implications for volatile saturation of topaz rhyolite magmas: Contrib. Mineral. Petrol., v. 132, p. 1998-207. Authors at Dept. of Earth and Planetary Sci., American Museum of Natural History, Central Park West at 79<sup>th</sup> St., New York, NY 10024-5192, USA.

To interpret the degassing of F bearing felsic magmas, the solubilities of H2O, NaCl, and KCl in topaz rhyolite L have been investigated experimentally at 2000, 500, and =1bar and 700-975°C. Chloride solubility in these L increases with decreasing H2O activity, increasing P, increasing F content of the L from 0.2 to 1.2 wt% F, and increasing the molar ratio of ((Al+Na+Ca+Mg)/Si). Small quantities of CI' exert a strong influence on the exsolution of magmatic volatile phases (MVPs) from F-bearing topaz rhyolite M at shallow crustal P. Water- and chloride-bearing volatile phases, such as V, brine, or F, exsolve from F-enriched silicate L containing as little as 1 wt% H2O and 0.2 to 0.6 wt% Cl at 2000 bar compared with 5-6 wt% H2O required for volatile phase exsolution in chloride-free L. The maximum solubility of Cl' in H2O-poor silicate L at 500 and 2000 bar is not related to the maximum solubility of H2O in chloride-poor L by simple linear and negative relationships: there are strong positive deviations from ideality in the activities of each volatile in both the silicate L and the MVPs. Plots of H2O versus Cl' in rhyolite L, for experiments conducted at 500 bar and 910-930°C, show a distinct 90° break-in-slope pattern that is indicative of coexisting V and brine under closed-system conditions. The presence of two MVPs buffers the H<sub>2</sub>O and Cl<sup>+</sup> concentrations of the silicate L. Comparison of these experimentally-determined volatile solubilities with the pre-eruptive H2O and CI' concentrations of five North American topaz and tin rhyolite M, determined from MI compositions, provides evidence for the exsolution of MVPs from felsic magmas. One of these, the Cerro el Lobo magma, appears to have exsolved alkali chloride-bearing V plus brine or a single supercritical F phase prior to entrapment of the MI and prior to eruption. (Authors' abstract)

WEBSTER, J.D., THOMAS, R., VEKSLER, I., RHEDE, D., SELT-MANN, R., and FÖRSTER, H.-J., 1998. Late-stage processes in P- or Frich granitic magmas: Acta Universitatis Carolinae-Geologica. v. 42. no. 1, p. 181-188. First author at Dept. of Earth and Planetary Sci., American Museum of Natural History, Central Park West at 79<sup>th</sup> St., New York, NY 10024-5192, USA: email (jdw?@amnh.org)

To understand magmatic degassing of P, F, and Al. experiments were

conducted to determine the solubility of P-, F-, and Al-rich silicate L in aq F at 2 kbar and 800°C and the solubility of Ca-, Mg-, and F-rich L in Kand Al-rich silicate L at >>1 bar and 1100 to 1400°C. The former experiments show significant solubility of P-, F-, and Al-rich L in F, and the latter experiments demonstrate that immiscible F-rich L exsolve from silicic L containing  $\geq$ 4 wt% F at these conditions. Integration of these new results with observations on two-phase (P-rich L and Si-rich L) bearing MI from P-rich granites suggests that under certain conditions immiscible P-=F-rich L as well as late-stage aq F may be important iin the release of P. F. and Al from granitic L which may explain the transport and deposition of these components to form fluorite, topaz, apatite, and triplite in greisens, hydrothermal miaroles, and hydrothermal veins associated with some granites. (Authors' abstract)

WEI, Jiaxiu and MAO, Jingwen, 1998, Fluid inclusions of Dashuigou Te deposit and their mantle source origin: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1091-1094 (in Chinese).

WEI, Jiaxiu and TAO, Gongyi, 1998, Ore-forming fluids and mineralization model of Zijinshan Cu-Au deposit: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1095-1098 (in Chinese).

WEI, L. and ZHANG, D., 1998. Fluid inclusion study on the Shibangou gold ore deposit, Xixia, Henan, P.R. China (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A34. Authors at Faculty. of Earth Resources, China Univ. of Geosci., Wuhan, P.R. China 430074; email (ZYb@cug.edu.cn)

The Shibangon lode-type gold ore deposit Xixia, Henan Province, P.R. China, is hosted in ductile-brittle shear zones. Microthermometry of Fl in quartz indicates five types of 1: Type 1, two-phase G-rich, Th 330-350°C, Type 2, two-phase liquid-rich, Th 170-310°C and sal 4.4-13.6 NaCl eq. wt%; Type 3, polyphase with dxl, Th 278-371°C and sal 36.2-43.0 NaCl eq. wt%; Type IV, secondary two-phase L-rich, Th 130-230°C and sal 4.6-1.3 NaCl eq. wt%; Type V, S one-phase L, Th sal 2.3-6.5 NaCl eq. wt%;

K and Na are the most abundant cations, F is slightly greater than Cl. In G phase, H<sub>2</sub>O is dominant, followed by CO<sub>2</sub>.  $\delta$ DH<sub>2</sub>O values of l in the range of -24.0 to -37.3‰, and  $\delta$ OH<sub>2</sub>O in range of -2.49 to 1.99‰, and  $\delta$ <sup>11</sup>CCO<sub>2</sub>- values of CO<sub>2</sub> G in l are -11.12 to -14.59‰. This suggests that ore-forming F was a mixed F. (From authors' abstract by E.R.)

WEI. Liu and ZHANG, Dehui, 1998a, Fluid inclusions in quartz and the inference to mineralization at depth, Yinshan polymetallic deposit, Jiangxi Province, P.R. China (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada (abstract distributed at meeting but not published in the volume). First author at China Univ., Geosci., Beijing, 100083, P.R. China; email (Zyb@cug.edu.cn)

The Yinshan deposit, a large-scale Cu-Pb-Zn-Au-Ag polymetallic deposit, is located 2 km north of Dexing, Jiangxi Province, China. In this paper, new advances of Fl in quartz from the Yinshan deposit are presented. The study shows 1. In polymetallic ore veins, Fl with halite dm have been discovered. 2. The Fl data may be divided into high sal and low sal groups. The sal of saline Fl varies 30-45 wt% NaCl eq. and low sal Fl vary 2.86-14.4 wt% NaCl eq. 3. There are Fl containing L CO<sub>2</sub> in polymetallic ore veins. 4 Th of Fl range 95-520°C displayiing a very wide range. 5. The plot of Th versus sal indicates there are two groups of data and a curvilinear correlation between Th and sal. 6. A trend of decreasing sal and Th is indicated.

From these data, the conclusions can be drawn as follows. The high sal of FI indicate that the hotter hydrothermal F is most consistent with having a magmatic origin. The two groups of data of T and sal have been attributed to mixing of a hot, saline F with a cool, dilute F. It is inferred that there may be a concealed igneous body and porphyry copper deposit at depth. (Authors' abstract)

WEI, Liu and ZHANG, Dehui, 1998b. Fluid inclusions in quartz, Shibangou gold ore deposit. Xixia. Henan, P.R. China (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4. Univ. of Nevada (abstract distributed at meeting but not published in the volume). First author at China Univ., Geosci., Beijing, 100083, P.R. China; email (Zyb@cug.edu.cn)

The Shibangou lode-type gold ore deposit Xixia, Henan Province, P.R.

China, is hosted in ductile-brittle shear zones. FI characteristics in quartz and the nature of ore-forming F were deduced from 53 samples from this area. Microthermometry of FI in quartz indicates five types of I: 1. twophase G-rich I (Type A), 2. two-phase L-rich I (Type B), 3. polyphase I that contain dxl (Type C), 4. S, two-phase L-rich I (Type D) and 5. S, one-phase L I (Type E). Type A I have Th of 330 to 350°C. Type B I have Th 170-310°C. Type C I have Th 278-371°C. Type D I have Th 130-230°C. Type B I have a sal range 4.4-13.6 NaCl eq. wt%. Type C I have a sal range 36.2-43.0 NaCl eq. wt%. Type D I have a sal range 4.6-11.3 NaCl eq. wt%. Type E I have a sal range 2.3-6.5 NaCl eq. wt%. Ore-forming F are basically of the NaCl-KCl-H<sub>2</sub>O system.

The most striking characteristic of the F composition is that in cations, K<sup>\*</sup> and Na<sup>\*</sup> are most numerous and in anions, F<sup>\*</sup> is slightly greater than CF. In the G phase, H<sub>2</sub>O is dominant, followed by CO<sub>2</sub>  $\delta$ D values of H<sub>2</sub>O in I F range from -24.00 to -37.30‰ and  $\delta^{18}$ O of H<sub>2</sub>O in the I ranges from -2.49 to 1.99‰  $\delta^{13}$ C values for CO<sub>2</sub> G in the I are -11.12 to -14.59‰. These data suggest that the ore-forming F was a mixed F. (Authors' abstract)

WEN, C.Q., XU, X.H. and YANG, F.Q., 1998a: Characteristics of oreforming fluid in the Xiaorequanzi copper deposit, Xinjing, China (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 145-146 (in English). Authors at Chengdu Univ. of Tech., Chengdu, P.R. China.

Xiaorequanzi copper deposit is mainly in volcano-clastic-sedimentary rocks. The mineralization processes may be divided into 4 epochs and 6 stages in the deposit, but it mainly formed at sedex (sedimentationexhalation) mineralization epoch and the hydrothermal mineralization epoch (two stages of the hydrothermal epoch, i.e. quartz-sulfide stage and chlorite-sulfide stage are the most important).

The Th of quartz, fluorite and sphalerite from the sedex, quartz-sulfide, and chlorite-sulfide stages ranged as follows: 87-126°C, 120-225°C, and 114-180°C, respectively. The corresponding Tf were estimated as 210, 270 and 240°C, respectively. At the same time, the sal, density, fugacity, acidity-alkalinity and oxidation-reduction potential have been estimated based on the composition, T and sal of ore-forming F.

We conclude that the Xiaorequanzi copper deposit is a strata-bound volcanic-associated Cu(-Zn) deposit, which was formed at sedex (diagenetic) epoch and by superposition-information of mixture F at the hydrothermal epoch [sic] (From authors' abstract by E.R.)

WEN, Chunqi, XU, Xinhuang and YANG, Faqiang, 1998b, Fluid inclusion study of Xiaorequanzi copper deposit, Xinjiang province; 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1079-1082 (in Chinese).

WENDTE, Jack, QING, Hairuo, DRAVIS, J.J., MOORE, S.L.O., STASIUK, L.D. and WARD, Grant, 1998. High-temperature saline (thermoflux) dolomitization of Devonian Swan Hills platform and bank carbonates, Wild River area, west-central Alberta: Bulletin of Canadian Petroleum Geology, v. 46, no. 2, p. 210-265.

The origin of replacive dolostones in the deeply buried (3000-5000 m) Swan Hills Formation has been studied by fluorescence petrography, identifying two major phases of dolomite formation. This epifluorescencedefined stratigraphy provided a framework in which geochemical data could be analyzed in an unambiguous manner. Th measured from both phases overlap, but are generally higher for second-phase saddle dolomite cements. These second-phase dolomite exhibit a wide range of elevated Th and isotopic signatures which match T and F chemistries forecasted for burial from depths of approximately 1.2 to 7 km. These relationship imply that these dolomites correspond to a phase of heating, followed by cooling, prior to Cordilleran burial, and formed at burial depths shallower than approximately 1.7 km, the estimated maximum depth of burial before Cordilleran loading. Other petrographic relationships and FI measurements further constrain dolomitization to burial depths of at least a few hundred metres and from residual evaporitic brines with elevated T up to 140°C. These conditions are also substantiated by FI measurements from burial calcite cements, which are partly replaced by dolomite in the zone of transition from limestone to dolostone. These same calcue cements, and associated saddle dolomite cements, also occur in Swan Hills and Leduc limestones away from the dolostones. These cements also have elevated Th, indicating heating by thermal conduction away from the dolostones, prior to Cordilleran burial Our dolomitization model has been built by constraining both the age and burial depth of dolomitization, as well as the

T and composition of the dolomitizing F. (From authors' abstract by E.R.)

WESOLOWSKI, D.J., BÉNÉZETH, Pascale and PALMER, D.A., 1998, ZnO solubility and Zn<sup>2\*</sup> complexation by chloride and sulfate in acidic solutions to 290°C with in-situ pH measurement: Geochim. et Cosmo. Acta, v. 62, no. 6, p. 971-984.

WETTEN, A.F., 1998, Hydrothermal veins from "Tocota", San Juan Province: Thermometric and isotopic data: IV Meeting of Mineralogy and Metallogeny, Sept. 23-25, 1998, Bahia Blanca, Argentina, p. 279-283 (in Spanish, Engl. abst.).

The Tocota Mining District is placed on the east slope of Cordillera Frontal, at the southern border of Iglesia Department, San Juan province. A great number of arsenic veins were exploited in the 40s and 50s. It is possible to identify the presence of anomalous copper, gold and other metals not only in the Tocota zone but also in the south region. Mineralized veins from various mining sectors in this zone were sampled to obtain thermometric and isotopic data. The frequency distribution of Th defines ranges between 258-308°C and 312-385°C for mines at Tocota drainage and Quebrada Larga respectively. Sulphur isotope ratios showed a magmatic origin related to granitic composition. (Author's abstract)

WIESHEU, Robert and HEIN, U.F., 1998. The history of fluid inclusion studies: p. 309-325 in Toward a History of Mineralogy. Petrology, and Geochemistry, Proceedings of the International Symposium on the History of Mineralogy, Petrology, and Geochemistry, Munich, March 8-9, 1996, Bernhard Fritscher and Fergus Henderson, eds., Institut für Geschichte der Naturwissenschaften München 1998.

The study of FI has become a routine method for solving a wide range of geoscientific problems of different disciplines like petrology, structural analysis, or the genesis and exploration of ore or hydrocarbon deposits. It took, however, a long time to establish FI as a reliable tool for answering geological questions. This paper refers to the historical development of FI research from early observations to first experiments and introduces the work of the most important scientists in its historical context. Finally, some statistical data about the latest developments and a short outlook on the near future are given. (Authors' abstract)

WILKINSON, J.J. and EVERETT, C.E., 1998. Fracture-controlled flow of mineralizing fluids in basement rocks beneath carbonate-hosted base metal deposits, Ireland (abst.): Program and Abstracts. PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 70. First author at T.H. Huxley School of Environment, Earth Sci and Engineering, Imperial College, London SW7 2BP, U.K.; email (i.wilkinson/@ic.ac.uk)

Ordovician-Silurian rocks, which form the metasedimentary basement to the Zn-Pb-Ag mineralized Carboniferous basins of Ireland, are host to several different cross-cutting vein types: (1) early hematitic calcitequartz±pyrite; (2) quartz-calcite±sphalerite, galena. chalcopyrite, pyrite, barite; (3) ankerite-ferroan dolomite-quartz±sphalerite, pyrite. P Fl data from vein types 2 and 3 show Th-sal characteristics (Th range: 123-238°C, sample means: 144-216°C: 9.7-20.6 wt% NaCl eq.) comparable with the high T F end-member reported from the overlying base metal deposits Significantly, P I hosted by quartz and sphalerite commonly contain CO2 as has been recently reported in sphalerite-hosted I from the Navan deposit Bulk FI analyses on quartz vein samples show that the F composition is comparable with experimental data on seawater equilibrated with greywackes at T of 200-300°C and with contemporary submarine hydrothermal vent F. In particular, the very low Mg content and elevated CO2 are typical of seawater that has interacted extensively with crustal rocks. Alkali geothermometry gives T (158-219°C) not significantly different to mean Th suggesting that the veins at the present level of exposure formed under low F P. at quite shallow depths. These data provide convincing evidence for the regional flow of high T F, similar to the ore-forming F, within the Lower Paleozoic metasedimentary basement. Furthermore, F compositions are consistent with the F having equilibrated with basement rocks and are permissive of a seawater origin. In combination with existing isotopic data and thermal constraints, this strongly suggests that deep circulation of surface-derived F through fault and fracture zones was a fundamental process in the genesis of the Irish deposits. (From authors' abstract by E.R.)

WILKINSON, J.J., EVERETT, C.E., EYRE, S.L. and BOYCE, A.J., 1998. Fluid flow and mineralization in the Irish orefield (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated). First author at Royal School of Mines,

#### Imperial College, London, U.K.

A single model limited to a relatively short time period cannot account for the range of mineralization characteristics observed in the Irish deposits. Seven key processes involving F and geochemical data are consistent with a hydrothermal system evolving over probably >10 Ma in which early synsedimentary mineralization with underlying epigenetic feeder zones was synchronous with, and succeeded by, syn-diagenetic and deeper replacive mineralization. The features apparently common to all deposits are the presence of a remarkably homogeneous basement-circulated F as the main metal-transporting agent and the interaction of this F with shallow formation brines at the site of mineralization (From authors' abstract by E.R.)

WILKINSON, J.J., LONERGAN, L., FAIRS, T. and HERRINGTON, R.J., 1998, Fluid inclusion constraints on conditions and timing of hydrocarbon migration and quartz cementation in Brent Group reservoir sandstones, Columba Terrace, northern North Sea: <u>in Parnell, J. (ed.)</u> 1998, Dating and Duration of Fluid Flow and Fluid-Rock Interaction. Geological Society, London, Special Publications, v.144, p. 69-89. First author at T.H. Huxley School of Environment, Earth Sci, and Engineering, Imperial College, Prince Consort Road, London SW7 2BP, UK.

FI data have been obtained from Brent Group sandstones from the Columba Field on the margin of the East Shetland Basin, northern North Sea. Cogenetic P aq and hydrocarbon I trapped during the initial stages of late diagenetic quartz overgrowth are common, indicating that the pore F present during the onset of a major phase of quartz-kaolinite(-illite) diagenesis consisted of immiscible saline aq and petroleum phases. Similar I are also observed in abundant planar arrays cross-cutting detrital and authigenic quartz. Th and sal data from the two types of aq I are statistically indistinguishable, as are the properties of the two types of hydrocarbon I. suggesting that the same two-phase F was present probably throughout the main phase of quartz cementation. FI thermobarometry shows that the majority of the F were trapped in the range 104±6°C and 300±33 bars. These data are consistent with either (1) trapping of a warm, over-pressured hydrocarbon+aq F, probably in thermal and chemical disequilibrium with the host reservoir rocks, derived from a Kimmeridgian source in the deep Viking Graben basin to the east of the reservoir within the period 85-55 Ma, or (2) trapping of a hydrostatically pressured F, in thermal equilibrium with the host reservoir rocks, with hydrocarbon±aq F derived by lateral updip migration from a local Kimmeridgian hydrocarbon source in the East Shetland Basin within the period 65-40 Ma. A maximum duration of 10 Ma for the F flow event can be estimated based on a typical burial history model for the area. (Authors' abstract)

WILLAN, R.C.R., ARMSTRONG, D.C., BOYCE, A.J. and FAL-LICK, A.E., 1998, Silica-alunite deposits in the south Shetland Island volcanic arc: Formation in magnatic-hydrothermal and magnatic-steam environments (abst.): Mineral Deposits Study Group Annual Winter Meeting 14-16 Dec, 1998, St. Andrews, Scotland (unpaginated) First author at British Antarctic Survey. Madingley Road, Cambridge CB3 0ET, U.K., email (r.willan@bas.ac.uk)

The alteration type is due to moderate T (250-280°C), very low pH (<3), high- $fO_2$ , sulphate-bearing waters at high W/R ratios. Sericitic, argillic and propylitic alteration indicate more pervasive circulation of neutral pH, low- $fO_2$  waters some 1-2 m, y, after the advanced-argillic alteration.

Preliminary O and D data indicate that the advanced-argillic alteration has  $\delta^{18}$ O values near the magmatic-water 'box' but isotopically heavy  $\delta$ D values (>-60) suggest release of D-enriched water from an undegassed magma at depth. Further isotopic work is in progress to constrain F endmember compositions, in particular the composition of palaeo-meteoric waters in this high-latitude setting. (From authors' abstract by E.R.)

WILLARD, D.T. and CLINE, J.S., 1998, Paragenetic and fluid inclusion data from the Vizcachitas porphyry copper project, central Chile (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 71. Authors at Univ. of Nevada, Las Vegas, NV, 89154

The Vizcachitas porphyry system, located in the central Andes mountains of Chile, contains P chalcopyrite (vein and disseminated) and bornite (disseminated) copper mineralization. The system also contains P vein and disseminated molybdenite mineralization that appears to be related to emplacement of a granodiorite intrusive body. Cross-cutting relationships indicate the presence of at least six distinct vein types.

The following populations of FI were identified, in decreasing order of abundance. Type 1 inclusions are L-rich and contain liquid (L)+vapor (V)±small opaque daughter crystals (SO). Type 1 inclusions are subdivided into type 1a inclusions that contain L+V+SO±small translucent daughter crystals (ST) and type 1b in which only L+V are visible. V bubbles occupy ~30 to 55 vol% of the I. Type 2 inclusions contain L+V+halite (H)±SO±ST Some I are simple L+V+ H inclusions; however several SO and ST daughters are common. Type 3 inclusions contain only L+V with V bubbles occupying <20 vol% of the I. Type 3 inclusions are L-rich and commonly are irregular in form. Type 4 inclusions contain only L+V with V bubbles occupying >68.5 vol% of the I, these homogenize to V upon heating.

Preliminary microthermometric data have been obtained for type 1 and 4 inclusions. Type 1a inclusions (most abundant) display two modes of Th, 340°C to 380 °C and 480°C to 500°C. Most type 1a inclusion sal range from 4 to 5 wt% NaCl eq. Type 1b Fl homogenize from 330°C to 410°C. Sal for these I range from 4-8 wt% NaCl eq. Type 4 Fl homogenize from 420°C to 540°C. (From authors' abstract by E.R.)

WILLIAMS, P.J., 1998, Metallogeny of the McArthur River-Mount Isa-Cloncurry Minerals Province: Economic Geology and the Bulletin of the Society of Economic Geologist, v. 93, no. 8, p. 1119. Author at Economic Geology Research Unit, School of Earth Sci., James Cook Univ., Townsville, Queensland 4811, Australia; email (patrick.williams@jcu.edu.au)

A preface to a special issue of Econ. Geology of 379 pp. including many papers that make use of published Fl data (E.R.).

WILLIAMS, P.J., DONG, Guoyi, POLLARD, P.J., RYAN, C.G., CHAPMAN, L.H. and PRENDERGAST, Kylie, 1998, Two-stage, dual source origin of Broken Hill-type Pb-Zn-Ag deposits (abst.): Geological Society of Australia. Abstracts No. 49, 14th Australian Geological Convention, Townsville, July 1998, p. 470. First author at School of Earth Sci., James Cook Univ., Townsville, Queensland 4811.

FI data from medium to high T (300-500°C) postmetamorphic veins in large Proterozoic Pb-Zn-Ag ore systems at Cannington and Broken Hill show that high concentrations of distinctive ore and gangue components (Ca, Mn, Fe, Zn, Pb) were present in a mobile aq F phase. Very similar multiphase I are present in both deposits and are hosted by quartz, garnet and hedenbergite. The characteristic drn assemblage consists of halite, sylvite, pyrosmalite and a Pb-K chloride. The veins commonly lack Zn and Pb minerals, and any sulphides that are present are paragenetically younger than the minerals that host the I. Coupled with the presence of Pb-K chloride daughter salt (as opposed to galena) this all implies that the F were strongly undersaturated with metals at the time of entrapment despite the fact that proton microprobe analyses commonly show extremely high Pb concentrations in the range of 5-10 wt%.

Abundant postmetamorphic S-poor, Fe-rich Cu-Au deposits occur in the Cloncurry district near the Cannington deposit. These formed from Ca-Mn-Fe-rich saline F of likely magmatic derivation that had variable low to high concentrations of Zn and Pb. This demonstrates that such high sal F were widespread and also suggests that highly soluble metals such as Pb and Zn were abstracted from the host sequences. The distinctive chemistry (high metal grades, low S-content, Ca-Mn-Fe-P-halogens), zoning similar to that in skarn deposits, down T paragenetic evolution, homogeneous S isotope geochemistry. Pb-isotope geochemistry related to the host sequences, and structural controls of Broken Hill-type deposits can all be explained by a two-stage process involving interaction of pre-existing base metal concentrations with hot, S-poor, high sal F. (From authors' abstract by E.R.)

WILLIAMS, P.J., PENDERGAST, W.J. and DONG, Guoyi, 1998, Late orogenic alteration in the Wall Rocks of the Pegmont Pb-Zn deposit, Cloncurry District, Queensland, Australia. Econ. Geol., v. 93, p. 1180-1189. First author at Nat'l. Key Centre in Economic Geol., School of Earth Sci., James Cook Univ. of North Queensland, Townsville, Queensland 4811, Australia: email (patrick.williams@jcu.edu.au)

Pegmont is one of several significant Pb-Zn±Ag deposits in metamorphosed late Paleoproterozoic rocks of the Mout Isa Eastern fold belt of northwest Queensland. The fracture-controlled hydrothermal alteration involved infiltration of hot (>500°C), very saline, Na-K-Fe-Ca-Mn-Cl'rich fluids. Proton microprobe (PIXE) analyses of FI reveal that these F, at least locally, had high concentrations of Pb (as great as 1.45 wt%) and Zn (to 0.8 wt%), and therefore, that metals were mobile beyond the boundaries of the mineralized ironstone. Later F produced illite/phengite-chlorite-carbonate alteration and minor Fe-Cu-dominated sulfide mineralization. (From authors' abstract by E.R.)

WILSON, S.D.R., 1998, A mechanism for the lateral transport of gas bub-

bles in silicic lava rising in a vertical conduit: Earth and Planet. Sci Letters, v. 156, p. 13-18

WILTSCHKO, D.V. and MORSE, J.W., 1998, Force of crystallization origin for veins. Crystallization pressure versus fluid pressure as the driving force for vein opening (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-197. First author at Dept. of Geol. and Geophys. & Center for Tectonophysics, Texas A&M Univ., College Station, TX 77843-3115; email (d.wiltschko@tamu.edu)

Crack-seal veins are often pointed to as evidence for episodic crack opening driven by oscillations in F P or bulk strain. Advances in understanding the geochemistry of precipitation, data on veins, and recent experiments by Li and Means suggest that force of crystallization may be a better explanation for many observations on veins. We propose that some veins originate at sites of precipitation and then propagate by the force of crystallization. As materials precipitate, the vein walls are pushed apart creating an opening identical to that for hydraulic fracture the difference being that the force of crystallization takes on the role of internal F P. A non-zero remote differential stress serves to align veins. If no remote differential stress exists then concretions or vug filling will result instead. Mechanical and geochemical considerations suggest that this process will be most important in producing veins in weak, relatively low permeability rocks such as greenschist-grade pelites where diffusion, probably from sites of dissolution, rather than advection is the dominant mass transport process. Thus, in tectonic regions veins may owe their orientation to tectonism but their mitiation and [to?] growth processes that supersaturate the pore F. Crack-seal veins involve cracking to the extent that precipitation forces an original flaw to extend during precipitation. Cyclic quartz-mica bands result from either oscillations in the chemistry of the F or simply the composition of the F and the relative solubilities of the components. Numerous observations on veins are consistent with the force of crystallization hypothesis 1) lack of competitive crystal growth and therefore lack of open space, 2) hydrostatic F P results from FI in veins yet, 3) veins shapes reflecting growth as Mode 1 fractures. (Authors' abstract)

WIRYANA, S., SLUTSKY, L.J. and BROWN, J.M., 1998, The equation of state of water to 200°C and 3.5 GPa: Model potentials and the experimental pressure scale Earth and Planet. Sci. Letters, v 163, p. 123-130.

WITT, W.K. and VANDERHOR, F., 1998. Diversity within a unified model for Archaean gold mineralization in the Yilgam Craton of western Australia: An overview of the late-orogenic, structurally-controlled gold deposits: Ore Geol. Reviews, v. 13, p. 29-64. First author at Geological Survey of Western Australia, 100 Plain St., East Perth, WA 6004, Australia.

The Archaean Yilgam Craton has produced >3000 T of gold, and encompass a wide range of host rocks, structural settings and structural styles and alteration types. However, several consistent features justify grouping the deposits into a single class of mineralization. These features include timing relative to orogenesis, high gold to base metal ratios, an association with potassium metasomatism and carbonation of host rocks, low sulfide contents, and a low-sal H<sub>2</sub>O-CO<sub>2</sub>(-CH<sub>4</sub>) ore F. The term 'mesothermal' is an inappropriate description for this class of mineralization. The term lateorogenic, structurally-controlled gold deposits is proposed. (From authors' abstract by E.R.)

FI data, from the literature, are discussed briefly (p.50) (E R )

WOOD, S.A. and FINUCANE, K.G. and SAMSON, I.M., 1998. Fluid inclusion microthermometry of minerals of the Snowbird deposit, Mineral County, Montana (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v. 30, no. 7, p. A-20, First author at Dept. of Geol. and Geological Engineering, Univ. of Idaho, Moscow. ID 83843; email (swood@uidaho.edu)

The quartz-carbonate-fluorite-hosted hydrothermal Rare Earth Element (REE) Snowbird deposit formed during two stages of mineralization. The former stage is characterized by coarse-grained (up to several meters) subhedral to euhedral quartz+calcite+ankerite+fluorite, and the latter is characterized by the presence of massive quartz+fluorite+ankerite+parsite (2CeFCO<sub>3</sub> × CaCO<sub>3</sub>) and the absence of calcite — Although Stage I quartz is nearly barren, the Rare Earth Element-bearing Stage II Quartz. Fluorite, and Parisite yield numerous, measurable FI. This is convenient in light of the purpose of the study, which is to glean further understanding of the F responsible for REE-mineralization. For simplicity, all T in this report are given as arithmetic mean followed by the average deviation. Microthermometric measurements of Stage II quartz. fluorite and parisite suggest the influence of at least three chemically distinct F during and after its formation.

Primary I in parisite and P and PS I in quartz and fluorite contain at least three phases at room T: aq L, a V bubble, and a halite daughter. Melting of solidified V occurs at  $-57.0\pm0.33^{\circ}$ , indicating the presence of CO<sub>2</sub>. First melting occurs at  $-47.7\pm1.8^{\circ}$ , indicating the presence of dissolved CaCl<sub>2</sub>. These I homogenize nearly always to the V phase, at  $401\pm74^{\circ}$ . Many I of this type decrepitated prior to homogenization at  $309\pm50^{\circ}$ . A minimum Tf, therefore, is suggested to be around  $400^{\circ}$ .

Secondary I in fluorite and quartz occur as two other types. The first contain aq F, a V bubble, and a halite daughter at room T. Dissolution of halite upon heating occurs at 200 $\pm$ 30°, indicating a minimum sal of 30 wt.% NaCl. Homogenization to the V phase occurs upon further heating at 267s±80° [sic], given here as a minimum T of fracture healing, uncorrected for P. The second type of SI contains aq L and a V bubble at room T. After freezing, ice finally melts at  $-0.75\pm0.5^\circ$ , indicating a solution of nearly pure water. These I homogenize at 146±27°.

It is evident that the parisite of the Snowbird deposit formed from relatively high T  $CO_2$ -NaCl-CaCl<sub>2</sub>-bearing F, and the deposit was somewhat affected further by moderate T, NaCl-bearing, and low T, NaCl-poor waters. (Authors' abstract)

WORDEN, R.H., OXTOBY, N.H. and SMALLEY, P.C., 1998, Can oil emplacement prevent quartz cementation in sandstones? Petroleum Geosci., v. 4, no. 2, p. 129-137.

In the current debate on the ability of oil emplacement to halt quartz cementation in sandstone oil reservoirs, this paper supports a "yes, it can" answer. Although we find some of the empirical data (petroleum Fl abundances, quartz-depth trends) to be inconclusive, we have made progress in this debate by examining theoretical controls for three end-member quartz cementation scenarios. (1) Silica externally sourced via advection. Oil emplacement must halt quartz cementation because of the associated massive reduction in relative permeability to water. (2) Silica supplied internally, water-wet reservoir. Quartz cementation will be inhibited because the rate of diffusion will be reduced by orders of magnitude, making diffusion the rate controlling step. The degree of inhibition will depend on rock fabric and oil saturation; at very high oil saturations quartz cementation could effectively cease. (3) Silica supplied internally, oil-wet reservoir. Quartz cementation will be halted as water cannot access to grain surfaces. (Authors' abstract)

WU, Ruihua and LIU, Qionglin, 1998. Mineralogy of corundums from Yingshan County, Hubei province: Geological Review, v. 44, no. 6, p. 627-633. Authors at Gemological College, China Univ. of Geosci., Beijing, 100083.

The corundum deposit in Yingshan County, Hubei province, was found 1950-1960. The corundum has coarse grain size, good morphology and light color. It can be blue-yellow- and flesh red-colored by means of heat treatment. But gem-quality stones are rare owing to well-developed fractures, I concentrated I [sic] and poor transparency. More should be done on the technique of healing the fractures in order to raise the production of gem-quality stones from these corundums. (From authors' abstract by E.R.)

WU, Xiangyao and LUO, Yaonan, 1998. A study on metallogenic model for gold-bearing silver deposits of shear belt type in the Tiarnwan area of Shimtan Country. Stchuan: Acta Geologica Sinica (Diqtu Xuebao), v. 19, sup. sum 52, p. 19-28 (in Chinese; Engl. abst.) First author at Chengdu Inst. of Tech.

Morshi shear zone, a brittle-ductile shear zone of sinistral strike-slip, is favourable for the migration, concentration and ore-forming of gold-silvercopper and related element (As, Sb, Pb, Zn). The Tiarnwan gold-bearing silver tetrahedrite deposit occurs in Morshi shear zone.

From the study of the fissure Fl, it is indicated that gold-bearing silver deposits of the Tengwong ductile shear belt type are low sal ( $w(NaCl)_{eq}$ ) = 6.5%, moderate T (>240°C), high sulphur rich CO<sub>2</sub>, Cl and base cations, weak alkalinity, reducing environment (Eh = -0.54V,  $fO_2$  = 10<sup>-29</sup> Pa). There are three types: CO<sub>2</sub>, CO<sub>2</sub>-H<sub>2</sub>O and H<sub>2</sub>O. They occur together in minerals and have different sal and density. It showed that boiling occurred when the I were trapped. It is considered that the key factor of gold-silver mineralization is boiling.

The metallogenic physicochemical condition stable isotope geochemical characteristics and the sources of ore-forming materials for typical goldbearing silver deposits in Tiamwan ore field are discussed, the metallogenic mechanism of this deposit is analysed. Based upon the discussion, we suggest a metallogenic model of tectono-geochemistry for the deposit. (From authors' abstract by E.R.)

WYDER, R.F. and MULLIS, Joseph, 1998. Fluid impregnation and development of fault breccias in the Tavetsch basement rocks (Sedrun, Central Swiss Alps). Tectonophysics, v. 294, no. 1-2, p. 89-107.

Microstructural, mineralogical and microthermometric studies provide an insight into the brittle deformation mechanisms and the P-T-t-x evolution of fault breccias from the Tavetsch massif. The fault breccias are overprinted by several pre- to early Alpine deformation events (summarized as deformation stage I), and at least five Alpine to late Alpine deformation stages (II to VI). Stages III to VI were responsible for the generation of cohesionless fault breccias. The predominant loss of cohesion occurred at a depth of 9-6 km, 280-190°C and F P of 2.3-0.6 kbar. These conditions prevailed between deformation stages IV and V. The loss of cohesion is interpreted to be the result of pore space interconnection induced by brittle deformation. This process was accompanied by a decrease in F P towards hydrostatic conditions. Finally stage VI generated fault gouge and further fault breccias due to small displacements (millimetre to centimetre range) along discrete faults and fractures The F evolution shows a retrograde trend to lower sal, indicating a meteoric influence during hydrostatic conditions (Authors' abstract)

WYLLIE, P.J. and LEE, W.-J., 1998, Model system controls on conditions for formation of magnesiocarbonatite and calciocarbonatite magmas from the mantle J. of Petrol., v. 39, no. 11 & 12, p. 1885-1893. Authors at Div. of Geological and Planetary Sci., California Inst. of Tech., Pasadena, CA 91125, USA; email (wjl@gps.caltech.edu)

Experimental data indicate that carbonate-rich magmas may be generated at depths >-70 km by partial melting of carbonated peridotite. At conditions of mantle melting, there is a large separation between the silicate-carbonate L immiscible volume, the silicate-carbonate liquidus field boundary, and probable L paths. The formation of carbonate-rich L immiscible with silicate magmas in the mantle is therefore unlikely, which denies the generation of immiscible CaCO<sub>3</sub> ocelli and P natrocarbonatite magmas. Our new data at 1 GPa confirm an earlier proposal that P calciocarbonatite magmas can be generated at some depth between 70 km and 40 km, but indicate considerably higher silicate components. The shallowest magmas contain a maximum of 73 wt% CaCO<sub>3</sub> (equivalent to 89% CaCO<sub>3</sub> in the carbonate components of the L), with 18% silicate components at 1 GPa. Phase relations in the system CaO-MgO-CO<sub>2</sub>-H<sub>2</sub>O shows that magnesiocarbonatite magmas can precipitate sövites (calciocarbonatite rocks). (From authors' abstract by E.R.)

WYLLIE, P.J., and RYABCHIKOV, I.D., 1998. Fluid inclusions in diamonds suggest critical end-point for solidus of peridotite-H<sub>2</sub>O-CO<sub>2</sub> in upper mantle (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998, Toronto, Canada, Abstracts and Programs, p. A12. First author a Div. Geol. Planet. Sci., Cal. Inst. Technology.

A review (E.R.)

XIA, Zuehui, 1998: Pyrite deposits in Zhangjiagou. Liaoning: Studies of fluid inclusions and stable isotopes (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 147 (in English). Author at MCI Geological Inst. for Chemical Minerals.

There are two different types of pyrite deposits in Zhangjiagou district with various geological characters. Geochemical studies of Fl and stable isotopes suggest that the deposits are distinguished by mineralizing T between 140 and 300°C,  $lg/S_2$  between -10.39 and -15.70,  $lg/O_2$  between -34.14 and -45.16, and pH between 4.64 and 6.15. Mineralizing solutions evolved from a low-sal, high-density, hot F at the early stage to a slight acidity, reduced one at the late stage, consisting mainly of sulphur-bearing hot waters by seafloor volcanic exhalation along with those by late metamorphism. Stratiform and vein ore bodies represent two different hot events. (Author's abstract)

XIAO, Zhifeng, GAMMONS, C.H. and WILLIAMS-JONES, A.E., 1998, Experimental study of copper(1) chloride complexing in hydrothermal solutions at 40 to 300°C and saturated water vapor pressure: Geochim. et Cosmo. Acta, v. 62, no. 17, p. 2949-2964. First author at Dept. of Earth and Planetary Sci., McGill Univ., Montreal, Québec H3A 2A7, Canada.

The solubility of Cu phases was measured in V-saturated aq HCl/NaCl solutions at T ranging from 40 to 300°C, total chloride concentration from 0.01 to 1 m, and pH from 0 to 3.5. Data collected from the experiments were regressed to determine equilibrium constants as functions of T (K).

These equations can be used to calculate equilibrium constants at T up to  $350^{\circ}$ C and V-saturated P. Our results at T<150°C agree well with those published by other researchers, but the agreement is variable for results at T>150°C.

The solubility of chalcopyrite was calculated for a variety of conditions. Chalcopyrite will deposit in response to an increase in pH, or decreases in  $a_{CL_n}$ , T, and oxygen fugacity. Calculations of the solubility of chalcopyrite in seafloor hydrothermal systems show that the Cu-nch zones in volcanogenic massive sulfide deposits form at T>250°C and that cooling and/or pH increase are the most likely depositional controls. Below 250°C, chloride brines are incapable of transporting significant quantities of Cu unless conditions are unusually oxidized. (From authors' abstract by E.R.)

XIAO, Y.-L., HOEFS, J., van den KERKHOF, A.M. and ZHENG, Y.-F., 1998, Fluid inclusions in ultra high-pressure eclogites from the Dabie Shan, eastern China (abst.): Mineralogical Magazine, v. 62A, V.M. Goldschmidt Conf., Toulouse 1998, Extended Abstracts, p. 1667-1668. First author at Inst. of Geochem., Univ. of Goettingen, Goldschmidstrasse 1, 37077 Goettingen, Germany.

To obtain information on the physical-chemical conditions of the F phase during UHP metamorphism, we studied Fl in coesite-bearing eclogites from the Bixiling complex in the southern Dabie Shan. The boundary between the eclogites and country rock shows tectonic contact relations. The complex mainly consists of eclogites and elongated (1-40 m) lenses of garnet peridotite. The field observations suggest that both eclogites and garnet peridotite underwent coesite-eclogite-facies metamorphism.

They typically contain garnet, omphacite, phengite, rutile, quartz, kyanite, with minor zoizite, amphibole, plagioclase, epidote, biotite, zircon and coesite. Four types of FI were distinguished:

(1) High-sal brines in quartz blebs in kyanite, and also in the kyanite itself, represent the oldest generation of FI. These FI do not show any phase transition during cooling; on subsequent warming, they show a granular texture between -65 and -75°C, interpreted as a devitrification phenomenon.

(2) High-sal aq I ( $\pm$  halite) in omphacite and kyanite occur as tubes that are oriented parallel to the growth zones of the host mineral, suggesting P origin. They probably contain relic metamorphic F of the eclogite-facies. They show clear freezing between -60 and -70°C [i.e., Tn ice on cooling?] and display T<sub>m</sub> ice between -24 and -16°C. They have T<sub>e</sub> between -30 and -21°C, indicating a dominantly NaCl-bearing F.

(3) Carbonic I were found both in omphacite and in matrix quartz. They are monophase at room T, and have  $T_{mCO2}$  around -58.5°C and  $T_h$  (to liquid) between -31 and -25°C.

(4) The majority of the Fl are low-sal aq l trapped in matrix quartz. The Fl show that the F evolved from highly concentrated Cadominated brines ± CO<sub>2</sub> (prograde metamorphism), towards Na-dominated solutions (peak metamorphism) and low sal aq F during retrograde uplift. (From authors' abstract by E.R.)

XIE, Yihan, FAN, Hongrui and WANG, Yinglan, 1998. CO<sub>2</sub>-H<sub>2</sub>O inclusions and their prospecting significance from granites in Xiaoqinling area, Henan province: Acta Petrologica Sinica, v. 14, no. 4, p. 542-548. Authors at Inst. of Geol., Chinese Acad. of Sci., Beijing, 100029.

There are abundant  $CO_2$ -H<sub>2</sub>O FI in Yanshanian Wenyu granite which [are?] known to be related with gold mineralization, showing that F are enriched in CO<sub>2</sub> with lower density (<10 wt.% NaCl) and similar to FI types and F nature in gold-bearing quartz veins. FI in Huashan granite, which is not related with gold mineralization, are aq type with poor CO<sub>2</sub> and low sal. Less CO<sub>2</sub>-H<sub>2</sub>O I are developed in Liangliangshan granite, which has relations with gold mineralization but poor gold veins occurring in nearby metamorphic rocks. CO<sub>2</sub>-H<sub>2</sub>O I can be used as symbol to identify relationship degree between granite and gold mineralization, and CO<sub>2</sub>-H<sub>2</sub>O I abundance can be practiced to evaluate gold grade, mineralizing scale and exploration potentials. (Authors' abstract)

XU, Guojian, 1998, A fluid inclusion study of syntectonic Zn-Pb-Ag mineralization at Dugald River, northwest Queensland, Australia: Econ. Geol., v, 93, p. 1165-1179. Author at Nat'l. Key Centre in Economic Geol., Dept. of Earth Sci., James Cook Univ., Townsville, Queensland 4811, Australia; email (g.xu@qub.ac.uk)

Petrographic, microthermometric, and laser Raman microprobe analyses of FI from the Zn-Pb-Ag sulfide deposit at Dugald River, northwest Queensland, indicate that F with a wide range of compositions in the CO<sub>2</sub>-CH<sub>4</sub>-H<sub>2</sub>O-NaCl system were involved in the formation of the deposit.

Early P I are characterized by higher Th centered on 360°C, an average sal of 13 wt.% NaCl eq., and they tend to be relatively CO<sub>2</sub>-rich. Such F migrating through the thick sequence of the middle Proterozoic metasediments of the Corella Formation would acquire metals and reduced sulfur as well as CH<sub>4</sub> due to its interaction with the country rocks at deep levels. Ore deposition is interpreted to have resulted from syntectonic boiling of CH<sub>4</sub>rich volatile and aq chloride solutions, and consequent filling and replacement of brecciated and foliated black slate by metal-bearing hydrothermal F. The P and T conditions of mineralization show a narrow P range of 1.1 to 1.5 kbar and a wide T range of 315 to <450°C, but mainly operated at about 315°C and 1.1 kbar [See fig. 11].

The close resemblance of Fl data between three different ore types favors the view that they were all subjected to a similar evolutionary history and probably have the same origin. The Fl data provide further evidence supporting an epigenetic formation model for the Dugald River deposit and this matches well with previous microstructural investigations. (Author's abstract)

See figure in the Illustrations appendix.

XU, Hong, 1998. Genesis and geological and geochemical characteristics of Qixia gold deposit, Shandong, China: Chinese J. of Geochemistry, v. 17, no. 4, p. 338-345 (in English). Author at Nanjing College of Communications. Nanjing, 210018.

The Qixia gold deposit is one of the important quartz vein-type deposits hosted in metamorphic rocks in the east of Shangdong, China. Compositionally, the wolframite which is associated with gold mineralization in the deposit is rich in iron, but poor in manganese, showing that this mineral crystallized from hydrothermal solution at low T. The T at the main metallogenic stage of the Qixia gold deposit are within the range of 160-280°C. The gaseous phases in FI are dominated by H2O and CO2, while Na\*, Ca2\* and CI' are the major species in the F phase with K+ and F- present in relatively small amounts. The sal of F are 4.2 wt%-8.0 wt % NaCl eq. Meanwhile, the F is characterized by either Ca2 >Na2 K+ (in five samples) or Na\*> Ca1+>K+ (in two samples), quite similar to the composition of ore-forming F derived from meteoric water. Primary data on the hydrogen and oxygen isotopic compositions of the ore-forming F fall within a wide range:  $\delta D_{H20}$ =-56-95‰ and  $\delta^{18}O_{H20}$ =-3.6-4.5‰ relative to SMOW. These isotopic values fully reflect the distribution features of meteoric water which has exchanged with the metamorphic rocks of the Jiaodong Group at different T and W/R ratios, and the metallogenic process is characterized by low W/R ratios. The Rb-Sr isochron age of the Qixia gold deposit is 125.8±1.7 Ma, with (<sup>\$7</sup>Sr/<sup>86</sup>Sr), being 0 7168, and the time interval between the gold deposit and its country rocks (granite or metamorphic rocks) is very large. The formation of the Qixia gold deposit is directly related to the evolution of geological history in eastern Shandong, and a genetic model in which the deep convective circulating meteoric water reacts with the country rocks can be used to explain the metallogenic mechanism of the deposit (Author's abstract)

XU, J. and CHU, X., 1998, Sulfide- melt inclusions in mantle xenoliths of Hannuoba, China (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A38. First author at Univ. of Sci. and Tech., Beijing 100083.

The samples of this study were collected from Damaping, Qingyanggou, and Jieshaba of Hannuoba in Zhangjakou area. China, where alkalibasalt and tholeiite occur horizontally as alternating beds. Mantle xenoliths were captured within some alkali-basalt strata, dominantly comprised by spinel lherzolite and accompanied with pyroxenite, dunite and pyroxene megacryst. Five types of F (and M) I occur. 1) pure CO2, 2) CO2 M, 3) CO2 M [sic], 4) sulfide-M, and 5) CO2 sulfide-M. LRM analysis of G composition shows a CO2 content range of 50-60 mol% H2S, SO2 and CH4 are detected, too. Sulfur (H2S+SO2) occupies larger proportion in G composition, generally more than 20 mol%. Sulfide-M I (type 4 and type 5) of Hannuoba are usually seen in spinel-lherzolite and olivine pyroxenite, and usually contain two phases, sulfide and glass phases, or only one sulfide phase. EPMA analyses have been made for sulfides in the MI. The sulfide I in Iherzolite are mainly pentlandite, with small amount of chalcopyrite. while those in olivine pyroxenite are pentlandite, and pyrrhotine, too. The sulfide phases are rich in As, both sulfide I and sulfide minerals in mantle xenoliths of Hannuoba are rich in Cu. Zn. Au and Ag in some degree (From authors' abstract by E.R.)

XU, J.H., XIE, Y.L. and QIAN, D.Y., 1998, Mineralization and isotope study of gold deposits in Daqinshan District, Innermongolia, China (abst.): The Ninth Int'l Conference on Geochronology, Cosmochronology and Isotope Geology, Abstracts, published in Chinese Sci. Bulletin, v. 43, Supp., p. 149. Authors at Dept. of Geol., Univ. of Sci. and Tech., Beijing 100083, P.R. China.

Located in the mid-west of Innermongolia, the Daqinshan Mt. district has many gold deposits occurring along a east-west striking ductile shear zone within a greenstone belt, which is mainly composed of the Archean Wulashan group. Hydrothermal mineralization can be divided into four stages: I. pyrite-quartz; II. quartz-pyrite; III. polymetallic sulfides; and IV. carbonates-quartz. The major metallic minerals in the ore of gold-bearing, veins are native gold, electrum, pyrite, chalcopyrite and galena, and gangue minerals mainly quartz, secondarily sericite, ankerite and calcite. Principal alteration patterns in gold deposits are sericitization, silicification, pyritization, carbonitization, and chloritization. FI study shows that ore-forming F were low in sal and rich in CO2. Measured SD values of FI in quartz from the ore veins range from -65 to -104 per mil. And the values of 818 Oquanz from ore veins vary from 10.0 to 12.8 per mil. These data show that the water in hydrothermal F precipitating the ore bodies could have been mainly magmatic water and metamorphic water, but local meteoric water might take part in the late mineralization. The values of  $\delta^{13}$ C from FI in the ore vary from -3.3 to -6.2 per mil, indicating that carbon was derived from magmatic or anatectic source. The values of 834S from sulfide samples in gold deposits range from -4.1 to +4.0 per mil, which are identical with those from Shi Zhunli et al. (1993). It is concluded that gold deposits in Daginshan district are similar to those in Xiaoqinling Mt area, in aspects of geological characteristics, mineral association and stable isotope composition. (Authors' abstract)

XU, Jiuhua, XIE, Yuling and SHEN, Shiliang, 1998, Tectonic environment of hydrothermal gold deposits and physico-chemistry of ore-forming fluid: Acta Geologica Sinica (Diqiu Xuebao), v. 19, no. 2, p. 204-209. Authors at Dept. of Geol., Univ. of Sci. and Tech., Beijing.

Metallogenic physico-chemical conditions of hydrothermal gold deposits are greatly associated with ore-controlling fault environment. A comparison of physico-chemical parameters of Fl from different tectonic environments (including Xiaoqinling, Jiaojia, Linglong and Taibei gold deposits) has been studied. The result shows that the P of ore-forming F of gold deposits in ductile shear zones are higher, so the values of CO<sub>2</sub>/H<sub>2</sub>O of Fl are high. K<sup>+</sup>/Na<sup>\*</sup> and F<sup>-</sup>/Cl<sup>\*</sup> of Fl varies in different tectonic environments, which is not only related to chemistry of host rocks, but also related to tectonic stress. Because ore-forming F P vary, other parameters of physico-chemistry change systematically, very useful for gold prospecting. (Authors' abstract)

XU, Xinwang, CAI, Xinping and ZHANG, Baolin, 1998, Ore-forming fluids in tectonic process and metallogeny: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998; Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1067-1070 (in Chinese).

XU, Xuechun, 1998a, A study on fluid inclusions in granulite facies metamorphic rocks from the northern margin of the north China platform (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v 30, no. 7, p. A-229. Author at Geol. Dept., Changchun Univ. of Sci and Tech., 6 Ximinzhu st., Changchun, Jilin, 130026, P.R. China.

The Precambrian granulite facies metamorphic rocks are distributed widely in the northern margin of the North China platform. They are mainly composed of granulite-gneiss group and sillimanite-gamet gneiss group. The T and P of granulite facies metamorphism is 750-850°C and  $5\sim10$  kb. There are a lot of Fl in minerals of the rocks. CO<sub>2</sub> is dominant and often contains detectable amounts of H<sub>2</sub>O, CH<sub>4</sub>, N<sub>2</sub>, CO and H<sub>2</sub>S in Fl. The CO<sub>2</sub> content is over 50 mol% in most Fl.

The study of physicochemical nature indicates that FI have high density  $CO_2$ ,  $D_{CO2} = 0.724 - 1.03$  g/cm<sup>3</sup>. The molecular volume of  $CO_2$  is 44.81 ~60.77 cm<sup>3</sup>/mol. The Th of the FI is -8-23.5°C. According to the relation between  $lg/O_2$  and T in F system, the oxygen fugacity obtained is  $10^{-15.5}$ - $10^{-24}$ Pa at 0.3 GPa. On the basis of relation between T and Eh, the value of oxidation-reduction potential calculated is -0.75~1.90. The water activity calculated is 0.04-0.24 in  $CO_2$ -H<sub>1</sub>O system. The lower water activity represents a desiccant metamorphic condition. (Author's abstract)

XU, Xuechun, 1998b, Fluid and fluid-rock interaction of granulite facies metamorphism: Earth Sci. Frontiers (Dixue Qianyuan), v. 5, no. 4, p. 284-290 (in Chinese; Engl. abst.). Author at Changchun Univ. of Sci. and Tech., Changchun 130026.

Discusses the FI evidence for fluids and fluid-rock interaction in granulites (H.E.B.). XU, Y., SCHOONEN, M.A.A., NORDSTROM, D.K., CUNNING-HAM, K.M. and BALL, J.W., 1998, Sulfur geochemistry of hydrothermal waters in Yellowstone National Park: 1. The origin of thiosulfate in hot spring waters: Geochim. et Cosmo. Acta, v. 62, no. 23/24, p. 3729-3743. First author at Dept. of Geosci., SUNY at Stony Brook, New York, NY 11794-2100, USA; email (mschoonen@notes.cc.sunysb.edu)

Thiosulfate  $(S_2O_3^{2-})$ , polythionate  $(S_xO_6^{2-})$ , dissolved sulfide  $(H_2S)$ , and sulfate  $(SO_4^{3-})$  concentrations in 39 alkaline and acidic springs in Yellowstone National Park (YNP) were determined. The analyses were conducted on site, using ion chromatography for thiosulfate, polythionate, and sulfate, and using colorimetry for dissolved sulfide. Thiosulfate was detected at concentrations typically <2 µmol/L in neutral and alkaline chloride springs with low sulfate concentrations (Cl/SO<sub>4</sub><sup>2-</sup><10), thiosulfate concentrations were also typically lower than 2 µmol/L. However, in some chloride springs enriched with sulfate (Cl/SO<sub>4</sub><sup>2-</sup> between 10 to 25), thiosulfate was found at concentrations ranging from 9 to 95 µmol/L, higher than the concentrations of dissolved sulfide in these waters. Polythionate was detected only in Cinder Pool, Norris Geyser basin, at concentrations up to 8 µmol/L, with an average S-chain-length from 4.1 to 4.9 sulfur atoms.

The results indicate that no thiosulfate occurs in the deeper parts of the hydrothermal system. Thiosulfate may form, however, from (1) hydrolysis of native sulfur by hydrothermal solutions in the shallower parts (<50 m) of the system. (2) oxidation of dissolved sulfide upon mixing of a deep hydrothermal water with aerated shallow groundwater, and (3) the oxidation of dissolved sulfide by dissolved oxygen upon discharge of the hot spring. Upon discharge of a sulfide-containing hydrothermal water, oxidation proceeds rapidly as atmospheric oxygen enters the water. The transfer of oxygen is particularly effective if the hydrothermal discharge is turbulent and has a large surface area. (Authors' abstract)

YAMASHITA, Hiroyuki and KOIDE, Yoshiyuki, 1998, Stability of carbon phase in the mantle: Bulletin of the Kanagawa Prefectural Museum, Natural Sci., v. 27, p. 31-48 (in Japanese, Engl. abst.).

Carbon phase in the mantle should be as constituents of minerals or F studied by the petrology, mineralogy and high P and high T experiment. The information of carbon phase in the mantle derived from igneous rocks (kimberlite, carbonatite and lamproite), minerals of diamond and carbonate minerals and F in diamond 1. The high P and high T experimental results of the simple-component systems such as C, CaO-CO<sub>2</sub> and CaO-MgO-SiO<sub>2</sub>-CO<sub>2</sub>, show that diamond, aragonite, dolomite and magnesite are stable in the mantle conditions. On the other hand, diamond and magnesite are stable in the complex system. The stable field of magnesite might expand to the lower mantle condition. Kimberlite and carbonatie petrogenesis are closely related with carbon phase in the mantle. The magmas are considered to be derived from partial melting of carbonate bearing peridotite. The geochemical character of this partial M is similar to the diamond 1 F. (Authors' abstract)

YANG, Fuquan, 1997, Physical chemistry of ore-forming fluid of Hogeqi copper-polymetallic deposit, Inner Mongolia: Bulletin of the 562 Comprehensive Geological Brigade, Chinese Acad. of Geological Sci., 1997, no. 13, p. 85-93 (in Chinese; Engl. abst.).

Hogeqi copper-polymetallic deposit is a stratabound deposit formed mainly by submarine volcanic eruption-sedimentation followed by regional metamorphism and magmahydrothermal reform. The author discusses the sources of F during various stages as well as other physical chemistry parameters (pH,  $E_h$ ,  $FS_2$ ,  $FO_2$ , etc.) of ore-forming F. The large number of data [some F1] provided in this paper are useful for the research on ore genesis. (From author's abstract by E.R.)

YANG, Jianmin, MAO, Jingwen, ZHANG, Zhaochong et al., 1998, Genesis and mechanism of Huashugou copper deposit, north Qilian Mt., China: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1019-1012 (in Chinese).

YANG, Kaihui, 1998, Magmatic fluids and mineralization: Observations of subaerial volcanic-hydrothermal processes, black smokers on modern sea floor and melt inclusion studies: Earth Sci. Frontiers. v. 5, no. 3, p. 7-38 (in Engl.). Author at Marine Geol. Research Laboratory, Dept. of Geol., Univ. of Toronto, Toronto, Canada M5S 3B1.

Large amounts of volatiles and metals are observed to be degassed from magmas into subaerial and submarine volcanic-hydrothermal systems at divergent and convergent plate margins. CO2-dominated F are associated with the volatile-poor MORB magmas that result from partial melting

at mantle beneath mid-oceanic ridges. In contrast, abundant H2Odominated F are degassed from the volatile-rich arc magmas that are originated from dehydration of the subducted oceanic slabs. Magmatic F consist typically of many different volatile components plus variable amounts of metals. Governed by the solubilities of volatiles in M, the first F phase that is degassed from a magma is predominantly CO2, and the later F phase is more enriched in H2O. As T decreases, a magmatic F of mixed CO2 and H2O, usually associated with felsic magmas, may separate into a low sal (low density) gaseous phase and a saline (high-density) L due to immiscibility. In a F-M system, many ore metals are extremely partitioned into the F phase, and are scavenged by the F when it is separated from the M. The metals are transported, mostly as chloride and sulfide complexes, in both the gaseous phase-volatile transport dominated by their volatility, and the saline solution-hydrothermal transport subjected to their solubility. Magmatic F may contribute large quantities of volatiles and ore metals to the subaerial and submarine hydrothermal systems that are responsible for the mineralization associated with igneous intrusions and volcanic rocks. (From author's abstract by E.R.)

YANG, Kyounghee and LEE, Jaeyeong, 1998, Fluid inclusions of the Ilkwang Cu-W-bearing breccia-pipe deposit, Kyongsang Basin, Geosci, Journal, v. 2, no. 1, p. 15-25. First author at Dept. of Geol., Pusan Nat'l, Univ., Pusan 609-735. Korea; email (yangkyhe@hyowon.cc.pusan.ac.kr)

The copper-tungsten mineralization of llkwang mine, Jyongsang Basin was associated with crystallization of a small stock of granodiorite and quartz monzonite, explosive brecciation, and exsolution of magmatic hydrothermal F. FI in quartz phenocrysts of granitic rocks and hydrothermal quartz in breccia matrix trapped aq F that had caused brecciation and precipitation of copper-tungsten ore minerals. Four groups of FI are identified Type I (V-rich and low sal), Type II (L-rich and low to moderate sal), Types Illa and IIIb (L-rich and high sal) and Type IV (CO2-bearing, V-rich and low sal). The earliest high-saline F (Type Illa) and the following CO2bearing F (Type IV) were exsolved from crystallizing M and trapped at relatively high P (>1 kbar). As water was partitioned from M to ag F, the volume expansion caused overpressuring of the magmatic hydrothermal system and led to an explosive hydrothermal brecciation. The P quenching related to the brecciation was followed by crystallization of the matrix producing early-hydrothermal quartz and tourmaline. Additionally, a subsequent decrease in P produced boiling of aq F, generating Types I and IIIb inclusions. They were associated with sulfide-mineral precipitation at 493-343°C and 450-120 bars. The separation of V phase including acid volatile species CO2 from the L phase might have raised pH of the hydrothermal F, which was favorable for the formation of sulfides. The latemagmatic, high-sal F (Type IIIb) were mixed with circulating meteoric F and then were cooled and diluted to form lower-T and lower-sal hydrothermal F that were trapped as I during the final stage of hydrothermal activity. The FI data are comparable with those from breccia-pipe deposits of porphyry-copper systems. It is suggested that hydrothermal activities and favorable structure factors in the Ilkwang mining district played a role for the generation of favorable P-T conditions and helped provide sufficient energy to form a breccia zone. (Authors' abstract)

See figure in the Illustrations appendix.

YANG, K. and SCOTT, S.D., 1998. Volatiles in pre-erupted magmas and their possible contribution to a seafloor hydrothermal system in the Manus back-arc basin, western Pacific (abst.): 17th General Meeting Int'l. Mineralogical Association, Aug 9-14, 1998. Toronto, Canada, Abstracts and Programs, p. A34. Authors at Dept. of Geol., Univ. of Toronto; email (kaihui@quartz.geology.utoronto.ca)

Degassing of magma may have contributed significant amounts of volatiles to formation of the PACMANUS massive sulfide deposits in the eastern Manus back-arc basin, western Pacific. Microanalysis has been carried out on MI in phenocrysts and the matrix glass of volcanic rocks ranging in composition from basalt, basaltic andesite, dacite to rhyolite. The glass of the MI has relatively high and homogenous concentrations of H<sub>2</sub>O (7.41±2 33 wt%) and Cl (0.23±0.04 wt%). In contrast, the matrix glass is extremely inhomogenous in the concentrations of H<sub>2</sub>O (4.47±2.33 wt%) and Cl (0.15±0.15 wt%). Relatively high concentrations of Cl are noted in the dacite and rhyolitic glass. Unlike H<sub>2</sub>O and Cl, F is highly variable with no significant concentration difference between the glass of MI (0.05±0.06 wt%) and that of the matrix (0.06±0.07 wt%). The major element composition of the glass in the MI and of the glass in the matrix are similar.

The high concentrations of H<sub>2</sub>O and Cl in the MI are compatible with those of subduction-related volcanic rocks elsewhere and are typical of pre-

in the volatile contents between the glass of the MI and the matrix glass of the PACMANUS volcanic rocks suggest that significant amounts of magmatic volatiles were released during the degassing process. This is further supported by the presence of an ore metal-rich volatile phase in bubbles in the MI and in vesicles in the matrix glass. Such a magmatic F may have been contributed to the hydrothermal systems that are presently forming massive sulfide deposits in the Manus back-arc basin. (Authors' abstract)

YANG, Minzhi, 1998, Replacement, formation and evolution of oreforming fluids in silver deposits, North Hebai: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1027-1028 (in Chinese).

YANG, Rongyong, LI, Zhaoling, MAO, Yanhua, et al., 1998. Oreforming fluids of Qiaogashan gold deposit, Xinjiang: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998. Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1023-1026 (in Chinese).

YANG, X.-Z., ISHIHARA, Shunso and MATSUEDA, Hiroharu, 1998, Multiphase melt inclusions in the Jinchuan complex, China: Implications for petrogenic and metallogenic physico-chemical conditions: Internat'l. Geol. Review, v. 40, p. 335-349 First author at Ueyama-Sisui Co., Ltd., N-2 E-13, Chuou-Ku, Sapporo 060, Japan

Three types of MI were identified in pyroxenes, olivine, and chromite from the Jinchuan intrusion—sulfide I (I), crystallized polyphase I (II), and FI (III). Sulfide I in chromite are spherical and occur parallel to chromite growth planes. Polyphase I are found in olivine and consist of olivine, orthopyroxene, chrome-spinel, amphibole, and sulfide dm. Primary FI are usually found in olivine and pyroxene with spherical to tubular shapes.

Lasar Raman analysis was used to identify dm and F phases in the I. The result shows that F consist mainly of CO<sub>2</sub>, with minor amounts of SO<sub>2</sub>, H<sub>2</sub>S, and CH<sub>4</sub>. This indicates that the parental magma of the Jinchuan intrusion contains abundant volatiles.

Microthermometry shows that Type II inclusions in dunite and sulfiderich lherzolite have higher Tt (1000-1050°C), whereas Tt in sulfide-poor lherzolite are lower (900-950°C). The result of low-T microthermometry indicates that the CO<sub>2</sub> Th of 10 to 15°C correspond to depths of 12.9 to 15 km (deep-level magma chamber) and the Th of 26 to 29°C correspond to depths of 6.9 to 9.3 km (upper magma chamber). The immiscible sulfide in the I demonstrates that segregation of the sulfide M occurs at an early stage during magmatic differentiation. (Authors' abstract)

YANG, Zhaozhu, XIE, Qinglin and MA, Dongsheng, 1998, The genesis and ore-forming fluid of the super-large antimony deposit of Xikuangshan, China: Contribution to Geol. and Miner. Resour. Research, v. 13, no. 3, p. 49-60 (in Chinese with Engl. abst.). First author at Dept. of Earth Sci., Nanjing Univ., 210093, Nanjing.

Studies on FI, stable isotopes, trace elements and experiments indicate that the ore-forming F originated mainly from meteoric water with lower sal (0.63-8.65 wt%) and medium to low T (100-300°C). It was weak alkalic and reductive solution. The ore materials were derived from pre-Devonian strata (mainly from the Sinian and Cambrian strata). The regional strata has been leached by large-scale movement of the F. Circulating underground water leached ore-bearing strata and extracted metallogenic element to form ore-bearing F. The F went up along major fault and was focused on ore-forming space. The precipitation of ore minerals was caused by the changes of F physicochemical conditions and components of the F. (Authors' abstract)

YARDLEY, B.W.D., GLEESON, S.A. and MUNZ, I.-A., 1998, Dry deep stable crust and its rheology: Evidence from deep-penetrating fluid (abst.): Geological Society of America Annual Meeting 1998, Abstracts, v 30, no 7, p. A-393. First author at School of Earth Sci., Univ. Leeds. Leeds LS2 9JT, UK, email (bruce@earth leeds.ac.uk)

The lower crust has been interpreted both as containing lithostaticallypressured F, and as essentially dry; alternatives which have very different implications for crustal rheology. A clear test between the wet and dry models is to determine whether F is leaking out from the deep crust to the surface or is penetrating the crust from above.

Munz et al. (1995) described coarse quartz veins in high grade basement rocks to the west of the Oslo graben. Norway, that were formed at 250-300°C and c. 5 km depth. The presence of diverse hydrocarbons along with brines as FI in the quartz indicates that F originated in overlying sediments. New work reported here concentrates on the brine I in this vein suite, and aims to address the extent of F infiltration and the role of hydration reactions in enhancing the deep F sal.

P and S two-phase, L-V, aq Fl occur in the vein quartz, together with halite-bearing SI in some samples. Overall, aq I show a range in sal from 0 10 c. 40 wt.% NaCl eq Liquid-vapor I exhibit a wide range of densities. homogenising between 120 and 340°C. Halite bearing I from some samples show halite dissolution before homogenisation to the L phase, and finally homogenise near 230°C, while in others homogenisation is by halite dissolution and occurs at c. 190°C. The wide spread in sal at relatively constant homogenisation T within individual samples is not consistent with an increase in sal due to progressive hydration of the wall-rocks but suggests that the variation in sal reflects heterogeneous F sources. The variable homogenisation characteristics of the halite-bearing I suggests that the brines were halite-saturated basinal F that in some cases were heated significantly in the basement before trapping. This is consistent with brief, large fluxes of F along fractures through otherwise dry crust. We conclude that the rheology of cooled crystalline crust is likely dominated by dry rock properties, but water-infiltration along fractures can cause transient and permanent weakening effects at mid-crustal depths during specific tectonic events. (Authors' abstract)

YARDLEY, B.W.D., KONMINOU, A., BARNICOAT, A.C. and HENDERSON, I.H.C., 1998, Is gold transported in oxidised hydrothermal fluids? (abst.): Mineral Deposits Study Group, Annual Meeting, 5-6 January, 1998, Univ. Greenwich, UK (unpaginated). Authors at School of Earth Sci., Univ. of Leeds, Leeds, LS2 9JT.

Like gold, uranium solubility decreases progressively with  $fO_2$  from high oxygen fugacity, but it shows no spike of higher solubility due to sulfides. We have input data on a full range of aq complexes to the EQ3/6 database, and can show that H<sub>2</sub>S-rich, reduced F have potential to precipitate gold, but do not transport uranium, whereas oxidised F may coprecipitate gold and uranium when they are reduced.

Detailed textural studies (Barnicoat et al., 1997) indicate that gold in the Witwatersrand Basin has grown from hydrothermal F, and is intimately associated with hydrothermal U-mineralisation. This is possible only if the ore F were oxidised, and establishing the origin of suitable F will provide the final piece for the new hydrothermal model of Witwatersrand mineralisation. The Au-U association is also known from a number of other deposits, and can likewise be confidently ascribed to the infiltration and reduction of oxidised F. (From authors' abstract by E.R.)

**YAZDI, Mohammad, PERTOLD, Z.** and **ZACHARIAS**, J., 1998, Gold mineralization in the granitoid rocks of the Voltus area and its comparison to the Petráchkova hora porphyry gold deposit (abst.): Proc. of the Int'l. Conf. "Palaeozoic Orogenesis and Crustal Evolution of European Lithosphere". published in Acta Universitatis Carolinae-Geologica 1998, v. 42, no. 2, p.360. Authors at Dept. of Geochem., Mineral. and Mineral Resources, Charles Univ., Albertov 6, 128 43 Prague 2, Czech Republic.

The [purpose of this] paper is to show evidences: is there gold mineralization in the porphyritic granitoid rocks of the Voltus area, similar to the Petráckova hora porphyry gold deposit?

F1 of the granitoid rocks of the Voltus area are composed mainly of H<sub>2</sub>O-Cl±KCl. Th<sub>tot</sub> in analyzed F1 from granodiorites and dacites of the Voltus area range from 115 to 350°C for L+V +L transition, and from 290 to 490°C for L+H→L homogenisation via halite dissolution. Sal ranges from 3 to 22 wt% NaCl eq., for two-phase L-rich Fl and from 37 to 58% for 1-bearing dm. According to Th and isochore path, the calculated minimum P of trapping of saline (40-50% NaCl) F1 is about 0.5 kbar. This corresponds to lithostatic P at depth of about 2 km (for 2.7 average rock density). The average estimated P of trapping of low saline (<20% NaCl) F1 is about 500 bars. These correspond to hydrostatic P at a depth of 5 km.

The granitoid rocks of the Voltus area reveal geochemical and petrological similarities with granodiorites of the Petráckova hora porphyry gold deposit, but the mineralization processes are not similar in the Voltus area. The limited ore mineralization in the granitoid rocks of the Voltus area seems to be related to alteration and F evolution, like Petráckova hora. The granodiorite body of the Petrackova hora is associated with high T ore minerals (like scheelite). But they have been not observed in the Voltus area. Hydrothermal F of the granitoid rocks of the Voltus area are related to shallow depth (low T). It is suggested that there will be in greater depth similar alteration and mineralization process like Petráckova hora. (From authors' abstract by E.R.)

YEMANE, Keddy, GILL, Susan and GRUJIC, Djordje, 1998. How accurately do thermal alteration indices (TAI) indicate burial temperatures for sedimentary sequences? (abst.). Geological Society of America Annual

Meeting 1998, Abstracts, v. 30, no 7, p. A-175. First author at Dept. of Geol., Univ. of Pennsylvania, Philadelphia, PA 19104-6316; email (ky-emane@sas.upenn.edu)

Because thermal alteration of organic matter that accompany burial is irreversible, thermal alteration indices (TAI) of palynomorphs are commonly used for estimating maximum burial T in sedimentary sequences. Consequently, palynomorph colors are routinely employed as a tool in evaluating the hydrocarbon potential of sedimentary basins. We test the validity of TAI as accurate burial T indicators in the extensively studied Middle Pennsylvanian Llewellyn Formation of the Southern Anthracite field Although a maximum burial T range of 200-300°C across the Anthracite region is generally agreed upon, estimates for the Southern Anthracite field vary significantly from 170-240°C and 205°C (methane-bearing and FI studies), to 200-225°C (vitrinite reflectance data), to 190-300°C (conondont alteration index). Siderite concretions from the bedding plane of the sandstone-shale interface below the fully mined Bottom Split coal bed in the Bear Valley Strip Mine near Shamokin, PA, contain palynoforms attributable to Lycospora, Renisporites, Laevigatosporites and Densosporites. These palynoforms and liptinites are golden yellow in color (TAI=2 to 2+), whereas the host shale is devoid of palynoforms and the kerogen is dark brown to black (TAI=6-7). Based on these TAI values alone, burial T of <100°C and >200°C can be deduced for the concretions and for the shales that host these concretions, respectively.

Obviously, differing T and P conditions cannot be invoked to explain the discordant degree of thermal alteration between these concretions and the shales that intimately host the concretions. Rather, we suggest that cementation during early concretion formation completely sealed off the palynomorphs, excluding further modifications by elements such as chemically potent G and waters circulating within the sediment. The presence within the concretions of pyrite patches and rims. septarian cracks, uncompressed plant stems, randomly oriented clay particles, and enriched <sup>13</sup>C of siderite cement strongly point to complete isolation, despite subsequent high burial T. Thus, it appears that the role of volatiles in the maturation of organic matter may be as important as that of T in determining thermal maturity. This calls into question the wide use of TAI as indicators of burial T. (Authors' abstract)

YISHAN, Zeng and JIAQ1, Liu, 1998, Carboxylates in fluid-inclusions in minerals: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 131-136. First author at Dept. of Geol., Peking Univ., Beijing, P.R.China.

The carboxylate (formate, acetate, propionate and oxalate) compositions for FI leachates from minerals collected from various hydrothermal mineral deposits were determined using ion chromatograph. The minerals studied include quartz, fluorite, barite and a few ore minerals occurred in tungsten, gold and some non-metal mineral deposits. The analysis [29 samples] results showed that short-chain carboxylic acids or carboxylates are common components in hydrothermal ore-forming F. (Authors' abstract)

YOUNG, C.M., CAMPBELL, A.R. and CHÁVEZ, W., Jr., 1998. Oxygen isotope traverses across mineralized and unmineralized fault zones: Lone Tree complex, Humboldt County, Nevada (abst.): Geological Society of America Annual Meeting 1998. Abstracts. v. 30, no. 7, p. A-75. First author at E&ES Dept., New Mexico Tech, Socorro, NM 87801; email (cyoung@nmt.edu)

The Lone Tree, North Peak, and Trenton Canyon gold deposits are approximately 30 miles west of Battle Mountain, Humboldt County, Nevada. The field areas consist of Paleozoic sediments of the Havallah and Antler sequences and the Valmy formation. Ore bodies, with fine grained gold particles, appear to be structurally controlled to fault zones. Alteration suggests that there was F movement along both barren and gold-bearing faults. Petrographic analysis indicates an increase in the abundance of quartz veinlets toward mineralized structures at Lone Tree and North Peak.

Previous work (Kamali, 1996) at Lone Tree and preliminary work at Trenton Canyon indicates average Th of 275°C for quartz found in mineralized fault zones. The  $\delta^{18}$ O values for hydrothermal quartz are 12.0% and 8.0% for Lone Tree and Trenton Canyon, respectively with corresponding calcuated  $\delta^{18}$ O water values of 4.6‰ and 0‰. (From authors' abstract by H.E.B.)

YOUNG, E.D., FOGEL, M.L., RUMBLE III, Douglas and HOERING, T.C., 1998, Isotope-ratio-monitoring of O<sub>2</sub> for microanalysis of <sup>18</sup>O/<sup>16</sup>O and <sup>17</sup>O/<sup>16</sup>O in geological materials; Geochim, et Cosmo. Acta, v. 62, no. 18, p. 3087-3094. First author at Dept. of Earth Sci., Univ. of Oxford. Oxford OX1 3PR, UK

Experiments were performed to test the viability of using isotope-ratiomonitoring G-chromatography mass spectrometry (*irm*-GCMS) as a means for isotopic analysis of nanomole quantities of  $O_2$  released in a vacuum system suitable for laser extraction and fluorination. Several sources of error were identified and eliminated, including false signals from extraneous scattered ions and adsorption of  $O_2$  to metal surfaces. Results show that with appropriate attention to these potential impediments, coupling high-precision *irm*-GCMS to laser sampling of microgram quantities of silicate and oxide minerals is feasible. (Authors' abstract)

YU, Fengchi, MA, Guliang, WEI, Ganfeng, WANG, Yongxiang and MEI, Anjiang, 1998, Geological characteristics and ore-controlling factors of the Tanjianshan gold deposit, Qinghai Province: Mineral Deposits (Kuangchuang Dizhi), v. 17, no. 1, p. 47-56 (in Chinese; Engl. abst.) First author at Xian College of Geol., Xian 710054.

FI studies show that ore-forming F were composed mainly of Na-rich metamorphic water and K-rich magmatic water. REE contents and REE patterns of ores and host rocks suggest that ore-forming materials came from carbonaceous mylonite schist and intrusive rocks.

Related to repeated opening-closing evolution of the regional crust, the Tanjiangshan gold deposit is a polygenetic composite deposit. The ore deposit was predicted to be large in size, and this has been proved to be true in practice. (From authors' abstract by H.E.B.)

YUSUPOV, R.G., POLICKOVSKY, V.S., [spelled Polykovsky elsewhere], SAVARDDINOV, I.A. and UMAROV, B.N., 1998, The gas composition of inclusions in accessory minerals of barofavourite and heavy level [sic] types of magmatic complexes of rocks of Tien Shan (abst.): Program and Abstracts, PACROFI VII, Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 72. Authors at Uzcomgeo, 1, Furcat str., Tashkent, 700027, Uzbekistan.

The G composition of I in accessory barofavourite [sic] and heavy level [metal?] minerals (virgin metals and non-metals on the base of Fe,Si, Cr, etc., siliciums and carbidiums of metal and non-metal etc.) of magmatic complexes of rocks of Tien Shan and nearby territories were studied thermobarogeochemically (TBG) by vacuum decrepitation and G chromatography [sic]. (From authors' abstract by E.R.)

Results of analyses, presumably stated in vol. or mol% (?), with up to three significant numbers, are given in a table for 10 G, in 6 samples (mostly <u>un</u>located) The samples include various aggregates of unlisted mineral names, diamond, and mawsonite (E.R.).

YUSUPOV, R.G., RAFIKOV, Ya.M. and POLYKOVSKY, V.S., 1998, The gas composition of fluid inclusions in accessory minerals of pressuredependent and refractory kinds (the role of fluids in magma-formation (Tien-Shan) (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 59-60 (in Russian).

See Translations.

ZACHARIAS, J., 1998, High-temperature Au-porphyry style deposit "Vacikov-Petrackova hora" near Rozmital pod Tremsinem-complex genetic study: PhD thesis, Charles Univ., Fac. of Sci., Prague, 254 pp.

A new mineralisation of porphyry gold style has been recently described from the Bohemian Massif at the Petrackova hora deposit. The deposit is believed to originate from mixing of two contrasting F types: a magmatic. highly saline (60-70 wt.% NaCl eq.) F partly exsolved directly from granodiorite magma, and from external low-saline (5-10 wt.% NaCl eq.), high-T F (>400°C) External F, however, were also in oxygen isotope and chemical equilibrium with granodionite rocks or magma. This high-T F mixing took place at 2 kbars and 600 to 400°C during quasi-isobaric cooling path. General absence of hydrothermal alterations around quartz veins points to a thermal and chemical equilibrium between F and granodiorite host and low W/R ratio also. Gold was probably introduced into the deposit by magmatic F. The source of gold could be Upper Proterozoic rocks that contaminated the granitoid magma (O, Pb isotopes). Final hydrothermal stages (post-Au, 300-120°C, ca. 1 kbar) denotes increasing influence of upper crustal F (N2 and H2O types). (From author's abstract by P. Dobes)

ZAK, Karel, DURISOVA, Jana, STRNAD, Ladislav, GOLIAS, Viktor, LEACH, David, SNEE, L.W., VIETS, John, and STEIN, H.J., 1998. The evolution of pressure, temperature and composition of hydrothermal fluids in a regional shear zone during retrograde metamorphism, regional

uplift. and cooling: The Kasperske Hory gold deposit case study (Bohemian Massif, Czech Republic) (abst.): Program and Abstracts, PACROFI VII. Pan-American Conf. on Research on Fluid Inclusions, June 1-4, Univ. of Nevada, p. 73. First author at Czech Geological Survey, Klarov 3, 118 21 Prague, Czech Republic.

The Kasperske Hory gold deposit is located in a regional shear zone in the high-grade metamorphic rocks. Hydrothermal mineralization occurred here during several successive stages of F movement during Hercynian retrograde metamorphism, uplift and cooling.

Stage 1 mineralization is represented by several structural types of quartz veins±oligoclase and muscovite. Stage 2 is characterized by the presence of Co+Ni sulfoarsenides.

FI representing stage 1 and stage 2 mineralization are small (<5  $\mu$ m) and affected by subsequent quartz deformation and recrystallization. Optical study and micro-Raman analyses indicate CO<sub>2</sub>-rich F with densities corresponding to a P decrease from 450 to ~200 MPa during the evolution of individual structural types of quartz vens. A small amount of water could have been leaked from the FI during ductile deformation.

Stage 3 mineralization, largely occurring as a relatively younger phase within quartz veins, is the mineralization of economic importance. The mineral assemblage consists of molybdenite, native Au, Te and Bi, hedleyite and maldonite indicate T of 260-380°C. Ore minerals are associated with minor calcite. FI in this calcite and also numerous FI planes crosscutting several older quartz grains, are of the H<sub>2</sub>O type, with sal between 0.5 and 8.0 wt% NaCl eq., and Th between 170 and 300°C.

Stage 4 mineralization is represented by carbonate filling of youngest brittle fractures and steep faults. Carbonate is locally accompanied by minor adularia, fluorite, galena and pyrrhotite. FI data and the presence of open space features indicate P below 25 MPa. This hydrothermal stage was formed during and/or after the final stages of the uplift of the Moldanubian unit at -295 Ma. (From authors' abstract by E.R.)

ZANGRILLI, Paul, 1998, Fluid inclusion and stable isotope constraints on temperature and pressure of late quartz-calcite veins in deformed Devonian rocks near Catskill, New York (abst.): The Geological Society of America 33<sup>rd</sup> Annual Meeting, Northeastern Section, March 19-21, 1998, Portland, Maine, v. 30, no. 1, p. 85, ISSN 0016-7592. Author at Dept. of Geol., Colgate Liniv., Hamilton, NY 13346; email (pzangrilli@center.colgate.edu)

Lower and Middle Devonian carbonate rocks exposed near Catskill New York contain hydrothermal veins formed during Alleghenian(?) folding and thrusting. Veins are developed in fractures associated with bedding-plane thrusts and minor folds. Quartz and calcite crystals in veins are often deformed, but late, macroscopically undeformed crystals are present. In thin section, quartz crystals exhibit growth-zonation marked by P methane-water I. Later S two-phase aq I trains are present, as well as singlephase methane I. These later I mark subtle, post-crystallization deformation that is not obvious in hand sample.

T<sub>h</sub> of texturally P methane-water I in quartz range from 220-260°C (mean~240°C). Single-phase methane I form a V bubble during cooling and subsequently homogenize between -84 and  $-80^{\circ}$ C, indicating nearly pure methane. T<sub>m</sub> of water ice range from -3.1 to  $-1.4^{\circ}$ C. corresponding to average sal of 3.6 wt.% NaCl eq. Methane-water I form clathrate on freezing: clathrate T<sub>m</sub> range from 22.0 to 25.1°C. Oxygen isotope values of co-existing quartz ( $\delta^{18}$ O SMOW 25.0-24.2) and calcite ( $\delta^{18}$ O SMOW 21.9-21.5) allow calculation of equilibrium T of crystallization of 234-279°C, using the constants of Sharp and Kirschner (1994).

Clathrate  $T_m$  and estimation of volume proportions of water and methane permit calculation of methane-water 1 isochores, using the constants of Zhang and Franz (1992). Given that  $T_h$  of methane-water (-240°C) and isotope geothermometers (-250°C) are similar, the T of quartz crystallization is estimated to range from 1600-1900 bars.

Calculation of the  $\delta^{18}$ O of the waters from which quartz and calcite precipitated, using the Fl T<sub>h</sub>, yield values of 14 to 16 SMOW. suggesting that while the waters were of normal marine sal, the F had undergone rockwater equilibration during burial. These data suggest that the veinmineralizing F were derived from connate waters within the immediately adjacent sedimentary rocks during deformation. (Author's abstract)

ZAVEL'SKII, V.O., SALOVA, T.P., EPEL'BAUM, M.B. and BEZ-MEN, N.I., 1998, Inclusions of undissociated molecular water in aluminosilicate glasses: An NMR study: Geokhimiya, 1998, no. 11, p. 1179-1183 (in Russian, translated in Geochm. Internat'l., v. 36, no. 11, p. 1065-1069). First author at Inst. of Physiologically Active Compounds, Russian Acad, of Sci., Chernogolovka, Moscow oblast, 142432 Russia. The extensive study of water dissolved in aluminosilicate glasses has been focused mainly on the influence of water on the characteristics and properties of the glasses, such as viscosity, bonding strength, and so on. Our experiments are a unique facility to study the properties and characteristics of the water itself: the size of water I contained in the amorphous aluminosilicate matrix, interaction of H<sub>2</sub>O molecules with the matrix material, and thereby, the properties of the matrix. It is concluded that a 'HNMR spectral study shows four types of I of undissociated water with different sizes  $[\le 5 \mu m]$  and properties. The properties of incorporated water are controlled mainly by water-glass interfacial interactions. They are also dependent on the sample-preparation procedure and glass chemistry. (From authors'text by E.R.).

ZENG, Xiaodong and LI, Beizeng, 1998, Mineralization of mantle fluids: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998, Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1085-1086 (in Chinese).

ZENG, Yishan, AI Ruiying and AI, Yongfu, 1998, Experimental study on the flow-through interaction between andesine and alkali-chloride hydrothermal solutions: N. Jb. Miner. Mh., 1998, no. 5, p. 193-207.

The interactions between andesine grains (0.25-0.45 mm) and NaCl and KCI+NaCl solutions were experimentally studied under flow-through conditions. It is concluded that alkali-metasomatism of andesine at flowthrough condition involves the dissolution of the mineral, and the formation of alkali-rich feldspar. (From authors' abstract by E.R.)

ZENG, Yishan and LIU, Jiaqi, 1998a, Carboxylates in fluid inclusions in minerals: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p 131-134 First author at Dept. of Geol., Peking Univ., Beijing, P.R.C.

The carboxylate (formate, acetate, propionate and oxalate) compositions for Fl leachates from minerals collected from various hydrothermal mineral deposits were determined using ion chromatograph. The minerals studied include quartz, fluorite, barite and a few ore minerals occurred in tungsten, gold and some non-metal mineral deposits. The analysis results showed that short-chain carboxylic acids or carboxylates are common components in hydrothermal ore-forming F. (Authors' abstract)

ZENG, Yishan and LIU, Jiaqi, 1998b, Organic acid in fluid inclusions of W-Sn-Be deposit in South China. 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1083-1084 (in Chinese).

ZHAI, J.P., LING, H.F. and HU, K., 1998, Hydrogen and oxygen isotopes of water-rock interaction in Dalongshan uranium deposit, Anhui province, China: in Water-Rock Interaction, G.B. Arehart & J.R. Hulston (eds), Balkema, Rotterdam ISBN 90 5410 942 4, p. 595-601. Authors at Dept. of Earth Sci., Nanjing Univ., P.R. China.

The  $\delta D$  and  $\delta^{18}O$  values for ore-forming F of the Dalongshan uranium deposit agree well with the results of water-rock interaction between the melt-derived water, meteoric water and Jurassic sandstone of the Xiangshan Group at various T. The early mineralization of the deposit was related with the melt-derived water and the sandstone, while the major and late mineralization resulted from exchange between the meteoric water and sandstone. The ore-forming uranium was derived from the sandstone of the Xiangshan Group. (Authors' abstract)

Presents 4 analyses of LI for 8 constituents (E.R.).

ZHAI, Jianping, XU, Guangping and HU, Kai, 1998, Mineral, oreforming fluid and isotope characteristics of the Qixia gold deposit and their implications: Mineralium Deposita, v. 17, no. 4, p. 307-313. Authors at Dept. of Earth Sci., State Key Laboratory of Mineral Deposits, Nanjing Univ., Nanjing 210093.

The Qixia gold deposit is one of the important quartz-vein type deposits hosted in metamorphic rocks in eastern Shandong. Wolframite associated with gold mineralization of the deposit is rich in iron but poor in manganese, suggesting that the mineral is crystallized from hydrothermal solution at low T. The main metallogenic stage of Qixia gold deposit has T of 160-270°C, and the gaseous phase in the FI is dominated by H<sub>2</sub>O and CO<sub>2</sub>. Na<sup>-</sup> Ca<sup>2-</sup> and CI are the major components of the L phase while K<sup>+</sup> and F<sup>-</sup> are present in relatively small amounts: the wt. % NaCl eq. values of F are between 4 and 8%. In addition, the F is characterized by either Ca<sup>2-</sup>Na<sup>-</sup>>K<sup>+</sup> (in five samples) or Na<sup>-</sup>>Ca<sup>2+</sup>×K<sup>+</sup> (in two samples), quite similar to the composition of the ore-forming F derived from meteoric wa-

ter. Initial data of the hydrogen and oxygen isotopic compositions of oreforming F fall within a wide range:  $\delta D_{H2O} = -56\% \sim -95\%$  and  $\delta^{18}O_{H2O} = -3.6\% \sim -4.5\%$ , relative to SMOW. These isotopic values fully reflect the distributive features of meteoric water exchanging with metamorphic rocks of Jiaodong Group under the conditions of different T and W/R ratios, and the metallogenic process is charactered by low W/R ratios. The formation of Qiaxia gold deposit is directly related to the evolution of geological history in eastern Shandong, and a genetic model in which the deep convective circulating meteoric water react with country rocks can be used to explain the metallogenic mechanism of the deposit. (From authors' abstract by E.R.)

ZHANG, Baolin, CAI, Xinping, WANG, Jie, QIN, Dajun and GAO, Haozhong, 1998: Mesozoic emplacing epoch of the Archean amphibolitehosted Jinchangyu gold deposit in eastern Hebei, China (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 102-105 (in English). Authors at Inst. of Geol., Beijing 100029; email (caixp@igcas.igcas.ac.cn).

Extensive studies have been made of the giant Jinchangyu gold deposit. The former researchers only studied the rocks in upper part of the deposit and did not establish a complete ore-control structure model of the deposit. We think that gold deposits are different from other metal deposits and have unique peculiarities, especially controlled by geological structures. Therefore, the prerequisite for researchers of ore genesis and metallogenic prognosis based on analytical results of FI, mineral paragenesis and stable isotopes is to clearly understand ore-control structures. Before that, the explanation of analytical results should be limited. If not, it is difficult to properly understand metallogenic process, even wrongly directly ore prospection. (From authors' abstract by E.R.)

ZHANG, D., LIN, X. and ZHANG, C., 1993. A study on the property of ore-forming F of the quartz-vein type wolframite deposits: Resource Geol., v. 43, p. 349-354.

Through the study of geological and geochemical characteristics of several quartz-vein type wolframite deposits in South China, it is proposed that the ore-forming F responsible for the deposits are transitional F of magma M-hydrothermal solution. The FI geochemical features, metallogenic experiments and relevant evidences also support this argument. (Authors' abstract)

ZHANG, Fuxin, ZONG, Jingtin and MA, Jianqing, 1998, A tentative discussion on the Carlin-type gold deposits in Qinling and related probtems: Mineral Deposits (Kuangchuang Dizhi), v. 17, no. 2, p. 172-184 (in Chinese; Engl. abst.). First author at Dept. of Geol., Northwest Univ., Xian 710069.

FI data presented and discussed in light of the origin of the Chinese Carlin-type gold deposits (H.E.B.).

ZHANG, Jibing, 1998. Geological and geochemical features of the gold deposit of Kuoer Zhengkuona. Xingjiang: Mineral Resources and Geology (Kuangchan Yu Dizhi), v. 12, no. 1, p. 7-13 (in Chinese; Engl. abst.). Author at Bureau of Geological prospecting for Non-ferrous Metals of Xinjiang, Urumqi 830000.

The gold deposit of Kuoer Zhengkuona, formed in island-arc environment during Hercynian period, was discovered in the late eighties in Sauer Mountains of Xinjiang. The mineralization is controlled by faults. The studies of petrochemistry, geochemistry of Fl and stable isotopes show that the ore-forming matter came from the deep crust, and the ore-forming F was of mixed origin, and the metallogeny was related with the differentiation and evolution of the middle-basic volcanic magma in late Hercynian period. (Author's abstract)

ZHANG, Libo, CHAN, L.-H. and GIESKES, J.M., 1998, Lithium isotope geochemistry of pore waters from ocean drilling program sites 918 and 919, Irminger Basin: Geochim. et Cosmo. Acta, v. 62, no. 14, p. 2437-2450. First author at Dept. of Geol. and Geophys., Louisiana State Univ., Baton Rouge, LA 70803, USA; email (glchan@lsuvm.sncc.lsu.edu)

The distribution of Li isotopes in pore waters to a depth of 1157 m below seafloor is presented for ODP Sites 918 and 919 in the Imminger Basin, offshore Greenland. Lithium isotope data are accompanied by strontium isotope ratios to decipher diagenetic reactions in the sediments which are characterized by the pervasive presence of volcanic material, as well as by very high accumulation rates in the upper section. The lowering of the <sup>art</sup>Sr/<sup>ab</sup>Sr ratio below contemporaneous seawater values indicates several zones of volcanic material alteration. The Li isotope profiles are complex suggesting a variety of exchange reactions with the solid phases. These include cation exchange with NH4\* and mobilization from sediments at depth. in addition to the alteration of volcanic matter. Lithium isotopes are, therefore, a sensitive indicator of sediment-water interaction.

 $\delta^{0}$ Li values of pore waters at these two sites vary between -42 and -25%. At shallow depths (<100 mbsf), rapid decreases in the Li concentration, accompanied by a shift to heavier isotopic compositions, indicate uptake of Li into alteration products. A positive anomaly of  $\delta^{0}$ Li observed at both sites is coincident with the NH<sub>4</sub>\* maximum produced by organic matter decomposition and may be related to ion exchange of Li from the sediments by NH<sub>4</sub>\*. In the lower sediment column at Site 918, dissolved Li increases with depth and is characterized by enrichment of <sup>6</sup>Li. The Li isotopic compositions of both the waters and the solid phase suggest that the enrichment of Li in deep interstitial waters is a result of release from pelagic sediments.

The significance of sediment diagenesis and adsorption as sinks of oceanic Li is evaluated. The maximum diffusive flux into the sediment due to volcanic matter alteration can be no more than 5% of the combined inputs from rivers and submarine hydrothermal solutions. Adsorption on to sediments can only account for 5-10% of the total inputs from rivers and submarine hot springs. (Authors' abstract)

ZHANG, Mingjie, WANG, Xianbin, LIU, Gang, WEN, Qibin and LI, Liwu, 1998. The fluid compositions and C. O isotopic geochemistry of Cenozoic alkali basalts in eastern China: Geochimica. v. 27, no. 5, p. 452-457 (in Chinese with Engl. abst.). First author at Dept. of Geol., Lanzhou Univ., Lanzhou 730000.

The F compositions in Cenozoic alkali basalts in eastern China have been determined by pyrolysis-MS method, meanwhile the carbon and oxygen isotopic compositions of CO<sub>2</sub> released from these samples at different heating T have been analyzed by stepped vacuum heating method. The volatile contents and carbon, {and} oxygen isotopic compositions of CO<sub>2</sub> in these alkali basalts show the inhomogeneous upper-mantle sources in eastern China, and these alkali basaltic magmas may be generated in the oxidizing millieu, comparing with mantle rock-derived xenoliths in these alkalı basalts, and exotic volatile components were mixed into these magmas in the process of their formation and development. (Authors' abstract)

ZHANG, Ronghua and HU, Shumin, 1998a, Some basic questions of chemical [dynamics] of ore-forming hydrothermal system: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1029-1034 (in Chinese).

ZHANG, Ronhua and HU, Shumin, 1998b, Observation of NaCl-H<sub>2</sub>O ore-forming system and ore genesis: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuang-chuang Dizhi), v. 17 Supplement, p. 1035-1038 (in Chinese).

ZHANG, Shaonan, QING, Hairuo and BJORLYKKE, K., 1998. Quartz overgrowths and their influence on the reservoir quality of tight sandstone in the western Sichuan basin. Geological Review, v. 44, no. 6, p. 649-655. First author at Dept, of Petroleum Geol., Chengdu Univ. of Tech., Chengdu, Sichuan, 610059, China.

The petrographic study of reservoir sandstones in the Xiangxi Formation of the Upper Triassic Western Sichuan basin indicates that S enlargement of quartz is an important diagenetic process reducing porosity during burial diagenesis. Quartz overgrowths as the product of multiple stage diagenesis are well developed in the sandstones which have little or no matrix and less grain coating and ductile rock fragments. The Th for aq and hydrocarbon FI within the quartz overgrowths range from 70 to 127°C. The large volume of quartz overgrowths, however, occurred [when] the T [were] higher than 90°C. Quartz overgrowths are T-dependent during progressing diagenesis of sandstones. In comparison with the Th of calcite precipitated in fractures. FI of quartz overgrowths have not been reset and stretched, and the T of both aq and hydrocarbon FI represent natural variations of T in the conditions of quartz overgrowth precipitation. Microprobe analysis of the geochemical composition indicates that the content of Al<sub>2</sub>O<sub>3</sub> in quartz overgrowths has the trend of increasing with the growth of quartz overgrowths toward the center of the pores, suggesting that the Al2O3 was in situ or came from very short distance because of the very low solubility of Al. The diagenetic illite was precipitated during the burial diagenesis. The amount of authigenic illite slightly increased with burial depth and kaolinite decreased sharply at a depth of 3600 m. The illitization that resulted from K-feldspar and kaolinite dissolution might play an important

role in the development of quartz overgrowths during the deep-burial diagenesis. The silica that formed overgrowths, therefore, might have originated from both P solution and illitization of kaolinite. The porosity reduced in the Xiangxi Formation was mainly influenced by quartz overgrowths in medium- and coarse-grained sandstones. The coincident illitization filled part of the porosity and reduced intensely the permeability of the reservoir although the illite was present in a small amount. (Authors' abstract)

ZHANG, Sheng, LI, Tongjing and WANG, Liankui, 1998a, Geochemistry of ore-forming fluids of Changkeng gold-silver deposit, Guangdong Province, China: Acta Mineralogica Sinica, v. 18, no. 1, p. 46-51. Authors at Guangzhou Inst. of Geochemistry, Chinese Acad. of Sci., Guangzhou, 510640.

There are two main types of Fl, i.e., monophase L type and Ldominated two-phase type, in the Changkeng gold-silver deposit. in addition to minor G-type I coexistiing with L-dominated-type I, which reflects boiling of the ore-forming F. The T and P of mineralizing F which are weakly acid to weakly basic solutions with moderate-low sal and relatively high densities range from 300 to 170°C and from 20 to 45 MPa, respectively. The concentration of total sulfur in the ore-forming solutions is ~10° <sup>5</sup> to 10°2° m, while log/O<sub>1</sub> = -32 ~ -50 and log/S<sub>2</sub> = -10 ~-20. The mineralizing F are of the K-Ca-Cl type in the early stage, followed by the evolution into the Ca-Na-Cl type during the late stage, whose compositions are significantly different from those of the typical hydrothermal solutions in modern seafloor. (Authors' abstract)

ZHANG, Sheng, LI, Tongjing and WANG, Liankui, 1998b, Geochemistry and genesis of the Changkeng large-superlarge gold-silver deposit, Guangdong Province: Mineral Deposits (Kuangchuang Dizhi), v. 17, no. 2, p. 125-134 (in Chinese; Engl. abst.). Authors at Guangzhou Inst. of Geochem., Chinese Acad. of Sci., Guangzhou 510640.

In the Changkeng gold-silver deposit, SiO2 and Al2O3 contents of mineralized silicified rocks, whose compositions are distributed in both hydrothermal and hydrogenous regions of the Al-Fe-Mn ternary diagram, are 73-95% and 1.13-10.44%, respectively. The siliceous gold ores with REE contents of 33 94 x 10<sup>th</sup> to 91.86 x 10<sup>th</sup> are distinctly enriched in LREE, while the LREE enrichment of siliceous silver ores with  $\sum REE$ contents of 1.94 x 10-5 to 45.18 x 10-6 is lower. Both gold and silver siliceous ores are rich in As, Sb, Bi, Hg and Ba. In addition, Zn. Pb, Cu contents of the silver ores are also high. The transitional element patterns of ores are similar to those of country rocks. The  $\delta^{34}$ S values of sulfides in gold ores vary widely from -35.4 to 8.8% with an average of -2.4%, but the 834S values of sulfides in silver ores are comparatively concentrated, varying from -7.2 to 7.3‰, with an average of 2.5‰. The calculated sulfur isotopic composition of the hydrothermal solution is 4 to 7‰, and the  $\delta^{13}C$ values of calcite are -3.23 to 0.25%. The gold ores are enriched in 206Pb with a wide range of <sup>206</sup>Pb/<sup>204</sup>Pb ratio from 18.580 to 19.885, whereas the silver ores are relatively enriched in <sup>207</sup>Pb and <sup>208</sup>Pb, with the <sup>207</sup>Pb/<sup>204</sup>Pb ratios being 15.682 to 15.941. Both kinds of ore lead are anomalous lead. enriched in radiogenic lead. The sulfur, carbon and lead isotopes of the ore deposit are crust materials or of sedimentary origin. The 818O and 8D values of the ore-forming solutions derived from evolved heated meteoric waters of formation waters are -5.5 to 9.0% and -59 to 39%. The oreforming solutions mainly contain K\*, Ca2+, Na+, Cl and SO42+ with sal of 6.0 wt% to 15.8 wt% NaCl. and the mineralizing T are between 170 and 300°C. The metallogenic mechanisms include solution boiling, mixing of F, and water-rock interaction. Both siliceous gold ore and silver ore are formed by hydrothermal percolating metasomatism and filling, and hence are products of a unified hydrothermal event in different metallogenic environments and under different ore-controlling conditions. The gold-silver deposit and the Ag-Pb-Zn deposit in this region belong to the same metallogenic series. (Authors' abstract)

ZHANG, Wenhuai and TAN, Tielong, 1998, Relationship between organic fluids and gold mineralization in the Jinshan gold deposit, Jiangxi Province: Mineral Deposits (Kuangchuang Dizhi), v. 17, no. 1, p. 15-24 (in Chinese; Engl. abst.) First author at China Univ. of Geosci., Wuhan 430074.

Jinshan is a large gold deposit within volcanics-bearing epimetamorphic rocks, with mineralization obviously controlled by a ductile shear zone. FI studies show four types: (1) G-L brine, which make up 80-85% of total; (2) pure hydrocarbon, which account for 10-15% of total; (3) saline dm-bearing polyphase that constitute some 1%; (4) pure CO<sub>2</sub> (as well as L CO<sub>2</sub>-bearing three-phase) that make up <1%. A pre-ore deep-seated fault [is believed] responsible for the upward migration of deep F, which carried deep pure  $CO_2$  F and postmagmatic high sal F; with the late-stage tectonic activity, large quantities of downward circulating meteoric water not only became increasingly hotter, but also extracted organic matter from the strata; the formation of organic F raised the activation and migration capacity of gold in the strata, whereas the mixing between the organic F and the postmagmatic hydrothermal solution caused the precipitation and accumulation of gold ores. The role of organic F seems to have been one of the important mechanisms responsible for the formation of the Jinshan gold deposit. (From authors' abstract by E.R.)

ZHANG, Yongbei, ZHANG, Wenhuai, WEI, Qirong, WANG, Hao and XU, Chengyan, 1997, Discovery and significance of the carbonatic melt on debris and the melt inclusions in Daqing Cu-bearing dolomite: Geological Sci and Tech. Information (Dizhi Keji Qingbao), v 16, no. 4 (tot. no. 69), p. 35-38 (in Chinese; Engl. abst.). Authors at China Univ. of Geosci., Wuhan 430074.

Carbonatic melted debris and MI have been discovered from Daqing Cu-bearing dolomite of Kunyang group, Middle Proterozoic Erathem in the west metallization zone of Ruoci-Wuding area Yunan province. The MI can be divided into carbonatic type and silicatic type. Average compositions of the latter are similar to that of trachytic or trachyandesitic alkali magma. The discovery indicates that the silicate-carbonatite magma actually activated in this area in the Middle Proterozoic, and the genesis of Daqing Cu-bearing dolomite is probably related to the magma eruption. (Authors' abstract)

ZHANG, Youxue, 1998, Mechanical and phase equilibria in inclusionhost systems: Earth and Planet. Sci. Letters, v. 157, no. 3-4, p. 209-222.

Mechanical and phase equilibria in I-host systems are investigated in this paper. An I-host system that is initially under lathostatic P and in mechanical and phase equilibria may undero P-T change. The new elastic and plastic equilibrium, possible viscous relaxation, and phase equilibrium are considered. The new I P typically differs from both the initial P and the P on the outside surface of the host. The I is under isotropic stress ( a single P) but the host is anisotropically stressed. The relative volume change of the I differs from that of the I-free host by 0.75 (Pm-Pout))/Gh where Pm and Pour are the pressures on the inside and outside surfaces of the host, and Gh is the shear modulus of the host. Different I in a single host may be under different P. A simple case of elastic anisotropy is also considered and the result shows that incorporation of elastic anisotropy is necessary for accurate calculations of volume and strain effect. For I with roughly constant bulk modulus, the time scale of viscous relaxation is found to be 4eta/3K, where etah is the viscosity of the host phase and K, is the bulk modulus of the I phase. If the host mineral does not relax viscously and does not fracture into pieces, the host mineral partially protects the I and phase transition in the I-host system is partial and spans a large T-P range even for onecomponent systems, in contrast to sharp phase transitions under isobaric and isothermal conditions. For example, a graphite I in a diamond host does not completely convert to diamond when P on the diamond host increases. Using the chemical potential formulation of Kamb, about 1% of graphite would convert to diamond for every 1 GPa increase in host P. Because the I P may be different from the lithostatic P on the host, P obtained from thermobarometers using 1-host pairs may not have depth significance. Correct "reading" of information stored by I-host pairs requires an understanding of mechanical and phase equilibria involving the I and host (Author's abstract)

ZHANG, Zhengwei, YANG, Xiaoyong, LIN, Qianlong and LIU, Deliang, 1998, Properties of the ore-forming fluid of the gold deposits at eastern foot of Funiu Mountain, Central Henan province: Scientia Geologica Sinica (Dizhi Kexue) v. 33, no. 4, p. 475-482 (in Chinese; Engl. abst.). First author at Inst. of Geological Sci. of Henan Province, Zhengzhou 450053.

There mainly exist two moderate hydrothermal and alteration structural rocks which bear gold deposits at the eastern foot of the Funiu Mountain. The distributions of the gold deposits are controlled by the regional shear zones. By testing the G-L components, sal and isotope compositions of the Lexisting in the rocks and minerals of Penggou and Liugou--the two typical gold deposits in this region, the authors have obtained the fact that the properties of ore-forming belong to the gold deposit from ductile shear zones, and the metallogenetic hydrothermal F mainly came from the metamorphic water mixed with magmatic and rain waters to some extent, which shows the physical-chemical characters of the mineralization from ground F. Combined with the components of rocks

and minerals analysed by EPMA, both the T and P of the ore-forming wall-rocks--their metamorphism and mineralization are calculated. The paper presents the undoubted facts that the metallogenesis of gold deposits mainly belongs to metamorphic hydrothermal F with metasomatic alteration in a depressure environment. The paper also shows that the following marks of I can be used to find these types of gold deposits in this region; the CO<sub>2</sub>-rich boiling I groups, high content of S and HCO<sub>3</sub>' in the L of I and CO<sub>2</sub>-rich and high values of CO<sub>2</sub>/H<sub>2</sub>O in the G phase of the I. (Authors' abst.)

ZHANG, Zheru, LIU, Ronggao and MAO, Huahai, 1998, Fluid-rock process of gold mineralization: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1039-1042 (in Chinese).

ZHANG, Zhijian and ZHANG, Wenhuai, 1998, The study of organic ore-forming fluids in the Lannigou gold (mercury, antimony) deposit, Guizhou province: Mineralium Deposita, v. 17, no. 4, p. 343-354. Authors at China Univ. of Geosci., Wuhan 430074.

The metallogenic process of the Lannigou superlarge Carlin-type gold (mercury, antimony) deposit was related to organic ore-forming F, whose organic matter was derived from marine algae in ore-bearing strata. The MPV-III [sic], FTIR and LRM studies of organic I show that the organic matter in the ore-forming F consisted mainly of fairly matured aromatic hydrocarbon and polyatomic compounds, which migrated in the form of L unmixed with water. The ore-forming F had very low sal and could not form oilfield brine, the formation of the ore deposit was attributed to the mechanism of "migration at low T and precipitation at high T". (Authors' abstract)

ZHAO, Jianong, REN, Fugeng, DING, Shiying and LI, Zenghui, 1998, Dianfang gold deposit in an explosive breccia chimney of Proterozoic, Henan province: Progress in Precambrian Research (Qianhanwuji Yanjiu Jinzhan), v. 21, no. 1 (tot. 81), p. 1-9 (in Chinese; Engl. abst.). Authors at Tianjin Inst. of Geol. and Mineral Resources, MGMR).

Dianfang gold deposit is located at the east part of the Machaoying fault zone, and hosting in the south contact of an explosive breccia chimney. Xionger Group. It is characteristically enriched in Au associating with Pb, and occurs in mineralizing breccia and polymetal-bearing breccia. The ore metal minerals are mainly pyrite, galena, native gold and electrum. The silver/gold ratio is high. The typical alteration minerals are partschinite, [sic] actinolite and calcite. Gold deposition was developed under the conditions of medium to high T (200–438°C), slight alkalinity (pH>7) with log  $fS_2 = -39.85$ –19 37 and  $fO_2 < 33$ . The S and Pb isotope compositions of ore are similar to that of wall rock, reflecting both of them have the same original sources. Gold mineralization linked with residual magmatic F evolved from central-vent volcanic eruption during the Xionger tectonic event. (Authors' abstract)

ZHAO, Lunshan, CHEN, Yuelong and YE, Rong, 1998. Synthetic experiments of gold-bearing pyrite and the ore-formation of gold in hydrothermal process: Earth Sci. Frontiers, v. 5, no. 2, p. 301-310.

There are two important types of gold in hydrothermal deposits: I and "fissure" gold in pyrite; the latter forms rich ores. The formation of these two types of gold in hydrothermal mineralization is controlled by the tectono-dynamic environment and thermodynamic evolution of ore-forming system. A series of synthetic experiments of gold-bearing pyrite have been carried out in order to investigate the mechanism of the formation of rich surface components semi-quantitatively. The extreme near-surface sensitivity and very high lateral resolution (<0.1 I mu m) [sic] make it possible to identify the heterogeneity and discrete domains of mineral surface on a submicrometer scale. AES in scanning mode can be used to identify the newly nucleated alteration minerals and to get the chemical composition of the residue from the decrepitated FI film on a nanometer scale. Depth profiles determined by AES are important to studies of chemical weathering. They provide direct evidence for the depth of reaction, and thus changes in the surface chemistry can be monitored as a function of depth within the minerals. When AES is combined with X-ray photoelectron spectroscopy, it can be used to study the mechanism of transportation and reactions on mineral-F interfaces. (Authors' abstract)

ZHAÚTIKOV, T.M., 1998, Mineral-forming fluids and ore-genesis in the gold-ore deposits of Kazakhstan (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent. Uzbekistan, Abstracts volume. p. 94-95 (in Russian).

See Translations

ZHENG, Jianping and LU, Fengxiang, 1998, The constituents of deep mantle fluids beneath north-China platform—Information from the impurities in diamond: Scientia Geologica Sinica (Dizhi Kexue) v. 33, no. 1, p 51-60 (in Chinese; Engl. abst.) Authors at China Univ. of Geosci., Wuhan 430074.

The constituents of deep mantle F revealed by Fl in diamonds are C, H, O, S and N, 16.87%, 47.47%, 30.90%, 3.02% and 5.38%, respectively, which is richer in H and poorer in O compared with atmosphere and hydrosphere. The deep mantle F are one of the sources of F participating in the shallow geological processes, and are of close relationship with earth evolution. (From authors' abstract by E.R.)

ZHENG, Youye, LI, Xiaoju, MA, Lijuan and LIN, Songhui, 1998, Application status of organic inclusion in the research on oil generating basin: Earth Sci. Frontiers (Dixue Qianyuan), v. 5, no. 2, p. 325-331 (in Chinese: Engl. abst.). First author at Fac. of Earth Resources, China Univ. of Geosci. Wuhan, 430074.

A review of many aspects of FI studies related to petroleum origin and exploration. (E.R.)

ZHENG, Youye, WANG, Siyuan, LI, Xiaoju, HUANG, Gaojian and LIU, Chenghong, 1998, Application of organic inclusion research in petroleum geology: Geology-Geochemistry, v. 26, no. 6, p. 72-76. First author at Fac. of Earth Resources, China Univ. of Geosci., Wuhan, 430074.

New results of application of organic I research in petroleum basin analysis, oil-G migration, accumulation and evolution, as well as oil-G estimation and perspective prediction are systematically introduced in the paper. Some progresses in organic I research in recent years are also briefly introduced. (Authors' abstract)

ZHOU, Wenwen, 1998: Fluid hydrocarbon inclusions on offshore oil-gas exploration (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 151-152 (in English). Author at Offshore Oil Exploration & Development Research Center, Gaobeidian, Hebei Province, China 074010.

Geologic data were gained including stages, T, depth, time and phase state of oil-gas migration and others by way of studying the hydrocarbon I in the offshore oil G fields. The important geologic basis was provided for offshore oil-gas exploration by means of the hydrocarbon I.

Fluid hydrocarbons I in Zhu III Depression, Pearl River Mouth Basin, and in the Taibei Depression, East China Sea Basin are described. The existence of hydrocarbon with dxl I shows there was the hydrothermal activity in the Taibei Depression. The distribution of biomarker in hydrocarbon I indicates that the lower aquatic organism and algae are the main source of hydrocarbon in I, second source of hydrocarbons is the terrigenous plants. It belongs to fairly good source. The result is in agreement with the source rock. It shows that the hydrocarbon of I come from the deep depression. (From authors' abstract by E.R.)

ZHU, Laimin, 1998, Physico-chemical conditions of Au-Sb association micro-disseminated gold field, southwest Guizhou, China: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1005-1010 (in Chinese).

ZHU, Laimin, LIU, Xianfan, JIN, Jingfu and HE, Mingyou, 1998. The study of the time-space distribution and source of ore-forming fluid for the fine-disseminated gold deposits in the Yunnan-Guizhou-Guangxi area: Scientia Geologica Sinica (Dizhi Kexue) v. 33, no. 4, p. 463-473 (in Chinese; Engl. abst.). First author at Inst. of Geochem., Chinese Academy of Sci., Guiyang 550002.

Limited FI data presented (H.E.B.).

ZHU, Laimin, LUAN, Shiwei, YUAN, Haihua and QI, Huawen, 1998, "Double source" sedimentary-transformation metallogenic model of the Disu lead-zinc deposit: Mineral Deposits (Kuangchuang Dizhi), v. 17, no. 1, p. 82-90 (in Chinese: Engl. abst.). First author at Laboratory of Ore Deposit Geochem., Inst. of Geochem., Academia Sinica, Guiyang 550002. F1 compositional data is presented (H.E.B.)

ZHU, Yongfeng, PENG, Qiufa, ZHANG, Qijia, et al., 1998, Temperature and pressure geochemistry of ore-forming fluid in Taihangshan gold deposit: 6th National Meeting on Mineral Deposits, Nanjing, China, Nov. 25-28, 1998: Mineral Deposits (Kuangchuang Dizhi), v. 17 Supplement, p. 1003-1004 (in Chinese).

# TRANSLATIONS

Editor's note: The Second APIFIS Int'I. Symposium Mineral Forming Fluids and Ore Genesis was held Oct 28-30, 1998, in Tashkent, Uzbekistan. The Abstracts Volume (165 pp), edited by F.A. Usmanov and He Zhili was published by the Acad. Sciences of Uzbekistan. Twenty-one of the 69 items were given in English and are listed in this volume by author. The other 48 items were in Russian, 28 of these are listed by author (title only) in this volume of FIR, and 20 were selected for complete translation on the basis of only the translated titles, and are given below. The translations have not been shortened as have most other items in FIR; they are given here in full as they provide a broad view of the history status of Soviet inclusion research in a variety of interesting fields such as the genesis of diamonds, magnatic immiscibility between carbonatite and silicate melts, the transition from silicate melts to salt melts to hydrothermal fluids, the strange mineralogy of metals, carbides, silicides and hydrides in magmatic rocks, and the extensive study of decrepitation in mineral exploration. All translations are courtesy of Dr. David A. Brown.

DIVÁEV, F.K. and POLYKÓVSKY, V.S., 1998. Thermochemical characteristics of fluids and the origin of the diamond-bearing carbonatites of the southern Nuratau (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998. Tashkent, Uzbekistan, Abstracts volume, p. 39-41 (in Russian). First author at Inst. of Mineral Resources, Tashkent; second author at Chilanzar 7-47-40, Tashkent.

The diamondiferous carbonatites of the southern Nuratau were first discovered in 1996 in the sequence of a provisionally Middle-Upper Triassic trachyte-carbonatite complex. The Chagatai trachyte-carbonatite complex consists of a compact swarm of closely-spaced sub-parallel dikes and volcanic explosion pipes, developed in the basin of Chagatai Creek on the northern slopes of the southern Nuratau range, 5-10 km west of Koshrabad village. In the complex there is a predominance of carbonatites which occurs both as dikes (0.5-6.0 m thick and 20-1000 m in extent) striking at 020-030° and dipping mainly vertically (with about 50 dikes in all), and also as two explosion pipes (dimensions 80 x 170 and 150 x 200 m respectively). The trachytes consist of isolated dikes (three in all), 0.5-1.5 m thick and up to 100 m in extent, in spatial association with the carbonatite dikes.

The carbonatites consist of rocks both of essentially calcitic composition, so-called sovites, and also rocks of transitional carbonate-silicate composition, so-called kazenites, ringites, and melilite carbonatites, clearly dominating in the make-up of the complex. Externally, the kazenites and ringites are massive and less commonly breccia-like, fine- and medium-grained rocks consisting of calcite (40-60%), diopside-hedenbergite (5-30%), biotite (3-20%), schorlomite-andradite and hydrogamet (5-30%), apatite (3-10%), and magnetite (3-15%).

Typical accessory minerals are fluorite, zircon, rutile, pyrite, barites, periclase, moissanite, corundum, gold, silver, lead, graphite, and diamond. The diamonds are extremely unevenly distributed, from single to hundreds of grains per 10-20 kg sample. The grains range in size from 0.05 to 0.2 mm.

The grains consist of crystals of octahedral form and their fragments. There are often intergrowths of several octahedra. The crystal boundaries are most commonly smooth, and the edges are sharp. The color of the grains is yellowish-greenish, less commonly with a grayish tint.

The most common texture is poikilitic, and the presence of idiomorphic I of pyroxene, melilite, garnet, and magnetite into large tabular grains of calcite is characteristic.

Both the dikes, and also the diatremes, have distinct intrusive contacts both with the surrounding silty-slate, and also with one another.

We must note the very feeble contact effect of the carbonatite bodies on the surrounding silty-slates, manifested in a zone 0.1-0.3 m thick and expressed in weak hornfelsing and the development of fine-flaky biotite. Metasomatic changes show up only as weak albitization and limonitization over a range of 0.1-0.5 m.

At the same time, the greater part of the carbonatite dikes and especially the explosion pipes, have been subjected to a certain degree to processes of autometasomatic alteration, in particular, albitization, chloritization, amphibolization, montmorillonitization, limonitization, zeolitization, and quartzification. The quantity of newly-formed minerals varies from a few percent up to 50-60%. Incidentally, along with the autometasomatic changes, there is recrystallization of calcite into a fine-grained aggregate.

The chemical composition of the Chagatai carbonatites in respect of petrogenic oxides is extremely similar to that of the corresponding carbonatites of eastern Siberia, and also to the carbonate-silicate lavas of Uganda in east Africa. They are also similar in respect of increased amounts of such elements, typical of carbonatites, as Sr, Ba, P and V. There are differences in the increased amounts of K in the Chagatai carbonatites and in the decreased amounts of rare earths in them and also of such elements as Nb and Zr, typical of the classical carbonatites. Attention is drawn to the increased amounts of Au, and especially of Ag which is a distinguishing feature of the described rocks. The distribution of rare elements, and also of Rb and Sr in the Chatagai carbonatites not clearly corresponds to the alkali-basaltoids of the East African rifts, and also to the camptonites and monchiquites of the southern Tien-Shan alkali-basaltoid complex.

The carbon-isotope composition of the calcites from the unaltered carbonatites varies within the limits of -4.3 to -5.2‰, virtually repeating the values of  $\delta^{13}C$  for carbon of calcites from the standard carbonatite massifs of Scandinavia and Eastern Siberia (-4.0 to -6.3‰). The carbonates from the kimberlite pipes also have a similar  $\delta^{13}C$  composition (-4.0 to -5.4‰), as well as the diamonds from these kimberlite pipes ( $\delta^{13}C^{=-5.7‰}$ ).

A study of the morphology of the GLI in minerals of the carbonatites has been carried out with the aid of Labre Lux and Polam-213 microscopes, at magnifications of 40 x 12 and 60 x 12 in specially prepared near-polished plates, 0.1-0.05 mm thick, and also in mineral fragments from sample-crushings. The largest number of GLI, having dimensions from 0.005 up to 0.030 mm, has been revealed during microscope investigations, mainly of calcites and in individual grains of apatite. Moreover, with the aid of an REM-200 microscope. FI having dimensions of 0.001 mm and smaller have been studied in calcites from the carbonatites. From morphological features, we have identified limited and semi-limited negative crystals among the l, being marked by the presence of boundaries of the prism (1010), pinacoid (0001), dipyramids (1011), (1121), etc. [sic]. Most of the GLI in apatite have tubular, club-shaped, drop-like, and irregular forms.

A study of the T regime of the F which had participated in the formation of the carbonatite minerals examined was achieved with the aid of a VD-5M vacuum decreptograph and a homogenization chamber (VMS model).

On the basis of the investigations carried out by the vacuum decreptograph method, we may recognize three phases of activity of the mineral-forming F, marked by the following T intervals: phase I (late magmatic) 640°C (and above) to 480°C; phase II (autometasomatic) 440 to 380°C, and phase III (hydrothermal) 380 to 90°C.

A study of the chemical composition of the GLI in the calcite crystals from Chagatai carbonatite complex has revealed a marked predominance of carbon compounds (CO<sub>2</sub>, CO and CH<sub>4</sub>) and an extremely small content of water. According to F.A. Letnikov, the region of generation of such a composition lies in the deepest horizons of the upper mantle.

The origin of the carbonatites is a complicated and disputable problem. In the case of the Chagatai carbonatites, and allowing for their mineralogical and petrochemical composition, and also the thermal characteristics of the GLI, the most likely hypothesis is that the carbonatites formed as a result of carbonatization and subsequent liquation of an alkali-basaltoid magma, similar in composition to that of the southern Tien-Shan complex of alkaline basaltoids and their lamprophyres.

In conclusion, we must state that the study of the geological position and material composition of the Chagatai carbonatites and of the FI contained in them points to their magmatic and most likely their mantle origin, and therefore the discoveries of diamonds in these rocks provides good prospects in the search for commercial deposits of diamonds of a new carbonatite kind.

# DIVÁEV, et al. Table 1: Recommended Distances between Sampling Profiles and Spacing in Accordance with the Scale of Work

Phase of work (scale)	Distance between profiles (m)	Sampling spacing (m)
Geological-survey work 1:50000 1:25000	1000 500	250 100
General research 1:10000	200 100	50 25
Research-prospecting work 1:5000 1:2000	50 25	10 5
Geological-exploration work 1:1000 1:500	10 5	1

DIVÁEV, F.K., POLYKÓVSKY, V.S., STREL'TSÓV, S.M., and SMIYÁNOV, V.A., 1998, The Acoustic Decreptometer Luch (Ray)-II and procedure for prospecting a concealed mineralization based on steam halos (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 160-162 (in Russian). First author at Inst. of Mineral Resources, Tashkent; secondary authors at Chilanzar 7-47-40, Tashkent.

The decreptometer method for investigating FI in minerals and rocks proposed by G. Scott and F. Smith (1948-1949), was worked out in detail for application in the search for concealed mineralization by N.P. Ermakov (1950, 1963, 1979).

In geological-research and prospecting work, there is widespread use of results of acoustic decreptometric (thermoacoustic) analysis of I, obtained with the aid of various models of decreptometers (Yu.A. Dolgov, Leningrad State Univ., 1953; E.E. Kostylev, IGEM, 1958; A.I. Zakharchenko and A.A. Moskalyuk, VSEGEI, 1958; L.S. Dmitrik and L.S. Puzanov, VIMS, 1966; N.P. Ermakov and A.D. Nefelov, Moscow State Univ., 1963; V.S. Polykovsky and M.T. Bozhko, SAIGIMS, 1971; etc.).

The proposed LUCH-II decrepitation equipment, developed by the present authors, differs from the earlier well-known decreptometers in its increased capacity, good operating qualities, and reproducibility of D-analytical results.

The LUCH-II decreptometer consists of the following units:

1. A control panel with two microfurnaces, a preliminary booster (?), chromel-alumel thermocouples, signal valves, and a changeover switch (?).

2. A semi-automatic device for even heating of the furnaces.

3. A millivoltmeter with thermocouple.

4. A PP-16 radiation counter.

The normal application of the instrument is achieved at a T of the surrounding atmosphere from 10 up to 35°C in housing protected from electric. magnetic, mechanical, and acoustic noises. The level of the last-named must not exceed 60 db.

The source of supply for the instrument is an AC circuit with 220V output (±0.5V). The power required by the instrument is not in excess of 500 watts.

Sample heating in the instrument from the external atmospheric T up to 700°C takes place in 20 minutes. The even nature of the T increase is ensured by a special semi-automatic device with thermostat

The background of the instrument is radiation through a complete heating cycle [sic]; grounding is mandatory.

The instrument will produce decrepitation recording with a frequency sequence of the order of 10 pulses/sec. (?) In its packaged form, the instrument is readily transportable.

Procedures and Operation Sequences for LUCH-II

The instrument is switched on for 30 minutes prior to the commencement of analytical work. This is necessary to warm up the instrument and to insert the radiation counter and potentiometer into the operations. Moreover, the main switch on the control-panel must be set in the mid-position, that is, at '0' [no diagram or photo is shown].

The mineral- or rock-sample under examination is crushed and sieved, with separation of fractions of -1 +0.5 mm or -0.5 +0.25 mm, which are charged using a 1 cm3 measuring spoon.

The lever of the semiautomatic regulator is moved to the extreme right-hand position and is fixed by the reductor knob (?). The pointer of the main switch is reset in position "1". In addition, the indicator bulb is switched on and the reductor begins to rotate the axis of the autotransformer, providing steadily-increasing heating by the microfurnace.

The heating T of the sample is read on a millivoltmeter and the results are recorded every 20 minutes [sic] in the log in the prescribed form. Concurrent with making the main switch, the radiation counter switches on,

Following the analysis, all units of the instrument revert to their original position, that is, the main switch is reeturned to '0', the radiation counter provides a breakdown of the readings.

Any new analysis is accompanied by a repetition of all the operations in the above-described sequence.

The low-T-steaming haloes (LTSHs) consist of country rocks permeated in varying degree by F that participated in the formation of the ore bodies. Depending on the proximity of the ore body to the contact, the degree of saturation of the country rocks in GLI increases, which also ensures an increase in D-activity of the rocks displaying LTSHs, this activity appearing during the process of decreptophonic investigations. The width of the LTSHs depends on the genetic type, structural-tectonic position of the location, the mineral composition, and the thickness of the ore bodies which usually exceed the last-named by 2-15 times. Most of the LTSHs are marked by a zoned construction, reflecting the presence of a zone of high D-activity, an intermediate zone of anomalously low D-activity, and an outer zone of moderately increased D-activity, gradually diminishing to the background value, depending on the distance from the contact with the productive body.

During the work on the search for the concealed mineralization, we began to use the decreptometer for carrying out determinations of the background indicators of D-activity of all the varieties of rocks in the region under examination.

Subsequently, work has been conducted to compare standard sections, marking the most typical relationships between the D-activity of earlierdiscovered ore bodies and the LTSHs. In addition, special attention has been focused on the dependence between the thickness of the LTSHs and the level of the erosion surface, the thickness of the ore bodies, the lithological-petrographical composition of the country rocks, and the peculiarities of the LTSHs that formed in the hanging- and foot-walls of the ore bearing formations. From these characteristics, intervals between the decreptometic-sampling sites (sampling spacing), have been chosen. For example, in prospecting for gold ore bodies of the vein kind with a thickness of 1-1.5 m, the following distances between the sampling sites (in the direction from the contact with the vein), are recommended: 0.25, 0.50, 0.75, 1.00, 1.50, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 12.5, 15.0, 17.5, 20.0, 30.0, 40.0, 50.0, 75.0 and 100.0 m).

After mathematical treatment of the analytical results obtained and compilation of standard decreptophonic sections, work is carried out on a systematic selection compilation of decrepitation sections in the most promising sections of the area under examination. These are chosen in accordance with the actual geological environment, the set objective, and the scale of work being planned for completion. See Table 1

Each individual decreptometric sample is a bulk specimen of rock weighing 100 gm which needs to be crushed down to 1 mm in size, quartered and sieved and separated into fractions - 1: +0.5 mm and - 0.5: +0.25 mm. The minimum volume of the sample of the sieved fraction for a single analysis is 10 [units?].

On completion of the work, it is necessary to switch off equipment

The information obtained from decreptometer analyses is one of the T-P-methods of investigation used to determine relative T of mineral-formation and in the search for concealed mineralization based on LTSHs.

The principal application of the decrepitation method during geological-research work is mainly concerned with LTSHs, which are formed in the county rocks during the process of reaction of the ore-generating fluids on them.

More detailed information on the decreptometric method, as a constituent part of thermobarogeochemical investigations, have been set out in V.S. Polykovsky's publication, and also in publications about the results of decreptometric investigations conducted in the Northern Caucasus (A.K. Kuznetsov), Siberia (V.G. Prokhorov), Transbaikaliya (Yu.A. Lyakhov), Kazakhstan (V.A. Kormushin), the Far East (A.A. Shaider), and the USA (E. Roedder), [sic] etc.

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DÚNIN-BARKÓVSKAYA, E.A., LÉBEDEVA, S.E. and TSOI, L.A., 1998, Thermobarogeochemical investigations at IGG Akad. Nauk Uzbekistan (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 30-35 (in Russian). Authors at IGG AN Uzbekistan, Tashkent.

T-P-geochemical methods are widely used at present during scientific investigations for determining the physicochemical parameters of mineral- and ore-formation (T, P, composition, and concentration of mineral-forming solutions) and in the practice of geology for establishing research and assessment tests for mineralization taking account of T zonation. T gradients, typomorphic features of ore-enclosing quartz, and other signs.

We find the first information about FI in minerals in the works of the most famous scientist of the East, the ninth-century encyclopaedist Abu-Raikhona Beruni, in his book entitled, "A Collection of Information about Precious Stones," written more than 1000 years ago and reissued in Moscow in 1963. The scientist drew attention to the presence of bubbles of L in fluorite crystals from Kafirnigan and pointed to its affiliation to that medium in which this mineral had been formed.

In 1854, the English scientist Sorby worked out a method of homogenization. However, this method only found wide application after N.P. Ermakov had constructed a convenient heating chamber in 1941. The method of homogenization enables us to determine the minimum T of mineral formation, which has been tested on artificial minerals, manufactured under specific prescribed parameters (V.B. Naumov, V.S. Balitsky, L.N. Khetchikov et al.). In order to determine the true T, it is necessary to introduce corrections, dependent on overall P. Records of mineral-formation, density, concentration of solutions have been retained in the L.

In 1948, the British scientist Scott suggested a decrepitation method for studying Fl, and in 1953, Yu.A. Dolgov and L.D. Raikher created a decreptometer, detecting by microphone the decrepitation-effect from the explosion of Fl during heating. Since then, numerous developments of thermo-acoustic decreptometers have followed, and subsequently vacuum types also (L'vov. Rostov-on-Don, Moscow, etc.).

In the middle of the 20th century, the science of FI in minerals was transformed into an independent scientific specialization—thermobaro[T-P-]geochemistry [now rendered as "thermobarogeochemistry"]. Its founder, N.P. Ermakov, began his work in the 1950s using piezo-optical material from the Pamirs. In 1944, for the first time in Uzbekistan, Ermakov, with the aid of a self-constructed thermal chamber, studied the Th of fluorite, obtained at that time from the Aurakhmat fluorspar deposit in the Chatkal Mountains. G.G. Grushkin, the first investigator of FI in the Inst. of Geol. of the Uzbekistan Acad. of Sci., continued this work.

Since 1960, scientists from all countries have begun a widespread study of FI. All-Union (in the former USSR) and international meetings and conferences have taken place based on methods, apparatus, and scientific investigations into mineral-forming solutions. Various constructions of thermo-, and then cryo-chambers have been developed in the USSR (IGEM, VIMS, GEOKhl in Moscow, IGG in Novosibirsk, IG and KazIMS in Alma-Ata, IGG in L'vov, etc.), in France, the USA, Great Britain, etc.). The study of G-L I in applied fields has for many years occupied a group of workers under the direction of V.S. Polykovsky in the geological-survey system (SAIGIMS, 'Khimgeolnerud' Expedition). In individual gold-ore deposits (Kochbulak, Muruntau, etc.), thermobarogeochemistry has also been used by scientists from Moscow and L'vov (VA. Kovalenker, VB. Naumov, N.M. Ziri et al.). There are [also] O.T. Razykov's data on the Koitash skam-scheelite deposit. Investigations by the staff of IGG AN Uzbekistan are considered below.

At present, global practice in the study of the physicochemical parameters of the mineral- and ore-forming solutions, employs the following methods: homogenization, decrepitation, cryometry, chemical analysis of aq extracts, electron microscopy, electron microprobe, emission microelectrical analysis [spectrometry?]. Raman spectroscopy, etc.

Development of thermobarogeochemistry investigations in IGG AN Uzbekistan

The 50-year period of rapid and fruitful development of T-P-geochemistry in the former USSR and throughout the world has its history also in this institute. We may recognize three periods in the conduct of thermobarogeochemical studies, which in general features reflect their state in the Republic: first—early thermometric investigations, second—thermoacoustic decrepitation studies, and third—the most active comprehensive studies with the creation of a true laboratory base.

First period—early thermometric investigations (1950-1960): For the first time, scientific staff member G.G. Grushkin introduced thermometric investigations in the Ermakov thermo-chamber. He measured Th and determined the water-salt composition of 1 in fluorite from the Aurakhmat deposit in the Chatkal Mountains, having continued the studies begun by Ermakov (Grushkin, 1950, 1961; Grushkin & Prixod'ko, 1952). After his departure from Uzbekistan, FI were not studied at the institute for a long time.

Second period—thermoacoustic decrepitation (TAD) studies (1970-1980): During this interval, the thermoacoustic decreptometer appeared, enabling us to determine the T the entire content of the GLIs during sample heating to 700°C with definition of the content of the exploded I in terms of sound. During this period, some of the institute staff, not having their own equipment for thermometry, sporadically made analyses in SAIGIMS in V.S. Polykov-sky's group, by the TAD method on an 'SAIGIMS-2' machine. They examined quartzes from veins with Bi, Cu-Bi, Mo, Cu, and fluorite mineralization from the Chatkal-Kuraminsk Mountains (Dunin-Barkovskaya, Golovanov & Polykovsky, 1970). As a result, the T intervals of quartz decrepitation from various mineral associations in the Brichmullinskoe, Suyuksuiskoe, Sansalakskoe, Verkhnekandaganskoe, Shavazsaiskoe, Karabashskoe, and Kyzylgut-skoe orefields were identified. It was demonstrated that quartzes from monotypical mineral associations in the various orefields had similar decrepitation peculiarities. The decrepitation activity of the quartzes is inversely proportional to their Tf and increases in the veins with depth.

In IGG AN Uzbekistan in 1970, construction began on a thermoacoustic decreptometer (A.V. Tsoi, G.M. Stashkov), although with the departure of these authors from the institute, the work was not completed. In 1971, staff member L.E. Morgenshtein in company with V.S. Polykovsky derived a formula for calculating the Th of I in fluorite based on specimens from the Abshir and other deposits in southern Fergana.

The TAD method has been used to study quartzes and metasomatites from some auriferous prospects in eastern Uzbekistan (Smirnov & Polykovsly, 1978; Smirnova, Moiseeva et al., 1980). They have demonstrated the typomorphic features of quartzes mainly through decreptograms, and the possibility of using this method for research on blind gold mineralization, based on supra-ore metasomatites from the Chadak and other deposits.

Third period—active comprehensive investigations (1980 onwards): Under the direction of E.A. Dunin-Barkovskaya, a T-P-geochemistry group was set up in 1980 and acquired the necessary equipment: a thermochamber for homogenization (VIMS), a cryochamber (IGG, Novosibirsk), and a vacuum decreptometer in a set with a G chromatograph (RGU, Rostov-on Don, 1982), etc. The staff visited Moscow and L'vov, and participated in All-Union meetings on T-P-geochemistry. In 1980-1984, the first project on the geochemistry of ore-forming solutions in some deposits in the Chatkal-Kuraminsk Mountains was completed (E.A. Dunin-Barkovskaya, S.E. Lebedeva, N.S. Evtushenko, and L.A. Tsoi).

Methods of thermobarogeochemical studies in IGG AN Uzbekistan

At present, the following methods are being employed in scientific studies in the institute optical microscopy, vacuum decrepitation, G chromatography, homogenization, cryometry, electron microscopy, provision of aq extracts and their chemical analysis, and microprobe analysis.

These methods are used mainly to study vein minerals (quartz, fluorite, barites, and carbonates) from hydrothermal deposits of Au, fluorite, W, Bi, and Mo (Dunin-Barkovskaya, Smirnova, Ismailov & Tsoi, 1996, etc.). Recently we have begun to study 1 in the rock-forming minerals of granitoids, for exam-

# ple, from the Muruntau super-deep well (Dunin-Barkovskaya, Tsoi & Zuev, 1996).

Optical methods of studying Fl

Visually FI are being studied on both sides of polished sections [sic] of transparent and semitransparent minerals. Determination of the morphology, phase composition, and genetic type of the I is carried out under a MIN-8 optical microscope (Polam, USSR), and since 1996, a Nikon Optiphot 2 Pol (Japan), by V.V. Kozlov and L.A. Tsoi. The advantage of the Nikon instrument lies in higher-resolution optics, and in the fact that mapping of I phases may be carried out on a [TV] monitor in order to create a graphic file. The photography of I is carried out on a special MFN-11 camera with a MIN-8 microscope and a camera included in the set with the Nikon microscope.

The electron-microscope method for studying FI

The morphology of vacuoles of opened small and very small FI, and the presence in them of solid phases (mineral-captives) [i.e., daughter minerals] have been examined under the electron microscope at magnifications of 1200-24,000. This method enables us to calculate the number of small and very small I per mm<sup>4</sup>. In the institute, the method was adopted in 1982 in T.I. Yaskolko's electron microscope section, and was later used by other specialists in electron microscope. As long ago as 1985, an electron microscope study was carried out on the morphology and quantity of small FI in quartz from many deposits in eastern Uzbekistan. Ustarasai. Sargardon, Agata-Chibargata, Naugisken, Revashte, etc. (E.A. Dunin-Barkovskaya); and Chadak and Kochbulak (S.K. Smirnova).

#### Vacuum decrepitation - thermal method of opening FI

Vacuum decrepitation is performed on a BD-4 instrument produced by RGU in 1982 (Rostov-on-Don). It is based on the P change in a closed system during heating to 550°C of the G released from burst FI (analyst S E. Lebedeva). The advantage of this method over thermoacoustic procedure lies in the fact that in the former the cleavage of the minerals and their cracking have no effect on their decrepitation, whereas in the latter, an additional noise effect is created and they distort the decreptogram [sic]. The layout of the decreptograms permits grouping of the sample (quart\_ etc.) on the basis of T intervals of gas- and water-release and the overall saturation of the mineral in fluids, and also [provides samples] for [stepwise] G chromatography. During I 7 years of work in the institute on vacuum decreptometry, a large number of analyses have been conducted for scientific-investigatory investigations based on depositis of Bi, W. Au, fluorite, polymetals, etc. In the research field, a study has been conducted on aureoles of hydrothermal low-T steaming in the oreenclosing granites by the vacuum-decrepitation method (Sargardon, etc.).

Determination of the gas phase in FI by the gas-chromatography (GC) method

Gas chromatography is performed on an LKhM\_8DM G chromatograph combined with a vacuum decreptometer, and enables us to determine the amount of water (percent) in a sample, and that of the G CO<sub>2</sub>, CO, and CH<sub>4</sub> in mols/litre of water. GC has been conducted for those samples subjected to vacuum decrepitation. Since 1986, [stepwise] GC has also been carried out. Its particular feature is that the determination of water and G may be carried out for each T group of I (Q.F. Mironova's procedure, GEOKhI, analyses by S.E. Lebedeva).

An example of results of [stepwise] GC in conjunction with decrepitation may be given. In a quartz from wolframite-sulphide veins in the Sargardon deposit, there are two principal groups of GLI. The first is medium-T, bursting at 120-130°C, and the second is high-T (320-350°C). In the medium-T l, only half of the H<sub>2</sub>O and about 35% of total CO<sub>2</sub> is present. The CO<sub>2</sub> content of the high-T l in quartz is greater than in the medium-T forms. [Stepwise] GC has also revealed the differences in three kinds of fluorite: 1-from K-feldspar metasomatites; 2-from a vug in a quartz-mica greisen among granites; and 3-from a quartz-fluorite body in limestones. The overall amount of CO<sub>2</sub> is greater in the first kind. Fluorite, like quartz, contains various kinds of Fl, the CO<sub>2</sub> enrichment of which increases from low- to high-T forms.

Determination of chemical (water-salt) composition of the L phase of F1 by the method of water extracts

Two different procedures are employed for obtaining triple water extracts and their chemical analysis from bulk samples of clean selected material, complete and abridged. For a complete chemical analysis, the extract is obtained from 60 g of monomineratic sample with a grainsize of 0.1-1 mm, and is analysed for K, Na, Ca, Mg, SO<sub>4</sub>, F, H, NH<sub>4</sub>, Cl and SiO<sub>2</sub>, but in the case of quartz, SiO<sub>2</sub> is not determined (procedure of D.N. Khitarov; N.I. Myaz', Zh. Simkiv). For an abridged analysis, the extract is prepared from samples, previously subjected to vacuum decrepitation and G analysis, because the FI in them have already been opened. The samples are combined, pulverized, and 500 mg are selected, processed and centrifuged. The solution is analysed for K, Na, Ca, Mg and Cl (the procedure of L.G. Pal'mova and K. Bitsoev). S.E. Lebedeva carried out the analyses.

Determination of homogenization temperature of FI

These studies are conducted after an optical visual examination of the L and determination of their genetic affiliation and phase composition. Determination of Th is carried out in a UMTK-1 microthermochamber of VIMS construction under a MIN-8 microscope. Since 1997, homogenization studies have been conducted using a Nikon Optphot 2 Pol microscope (Japan) with high-resolution optics and a Linkam THMSG-500 thermocryochamber (UK). This chamber enables us to determine the Th in a single L and to carry out cryometry, that is, to determine the concentration. The set includes a videocamera and a computer with printer. V.V. Kozlov and L.A. Tsoi made the investigations. More details about the new technique and its use in T-P-geochemical investigations are given in V.V. Kozlov's report.

# Determination of the phase composition of individual FI by cryometry

Since 1995 and up to and including 1997, investigations have been carried out in a cryochamber (constructed by IGG, Siberian Branch of Acad. Nauk USSR. Novosibirsk, 1982). The phases of Fl are being examined by L.A. Tsoi in a duplex [sic] of polished sections under a MIN-8 microscope by freezing with liquid nitrogen, injected into the cryochamber from a Dewar flask. Since 1996, cryometry has been carried out with new equipment. In a general way, we may also note the great possibilities of new instruments for homogenization and cryometry.

The use of thermobarogeochemistry in mineral-geochemical investigations in IGG AN Uzbekistan

Thermobarogeochemistry methods are widely used in the mineralogical-geochemical work being carried out by the staff of IGG AN Uzbekistan. A definite landmark in 20th century investigations has been presented in the publication, "A Study of the Physicochemical Parameters in the Formation of the Productive Parageneses of Minerals of Gold-ore, Rare-metal, and Fluorite Deposits of Uzbekistan" (Dunin-Barkovskaya, Ismailov, Smirnova, Kozlov, Tsoi et al., 1996; Bunin-Barkovskaya, Smirnova, Ismailov and Tsoi, 1996). This work illustrates the usage of thermobarogeochemistry methods in studying the paragenetic associations of minerals and the conditions of their formation in deposits of W (Sargardon, Daikovoe, and Koitash), Mo and W (Chavata), Bi (Ustarasai, Kyzylgut, etc.). Au (Chadak, Akcha-Talbulak, Revashte, etc. and partly at Muruntau and SG-10), and fluorite (Agata-Chibargata, Naugisken, Supatash, Kichik-Arsagan, etc.).

In the 21st century, the institute will take on the latest analytical equipment, including that for thermobarogeochemistry, which will open up new possibilities for scientific investigation.

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DUNIN-BARKOVSKAYA, E.A., SMIRNOVA, S.K., KOZLOV, V.V., TSOI, L.A. and LEBEDEVA, S.E., 1998, The fluid regime of the formation of the major productive mineral associations and parageneses of gold-ore, rare-metal, and fluorite deposits of Uzbekistan (abst.): Second APIFIS Int'l. Symp Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 69-72 (in Russian). Authors at IGG AN Uzbekistan, Tashkent.

We discuss the conditions of formation of productive mineral parageneses among earlier separated mineral associations (Dunin-Barkovskaya et al., 1992, 1996) on the basis of a study of the mineralogy; T-P-geochemistry, and isotopes for deposits of Au, W, Bi and fluorite in sedimentary-terrigenous and magmatic rocks.

During this work on selected mineral associations, we examined the composition of the mineral-forming solutions on the basis of an examination of GLI in gangue minerals: 1) Morphology and phase composition of the GLI in doubly-polished sections under the microscope and in grains at high magnifications and under the electron microscope; 2) Vacuum decrepitation and the intensity of G-water saturation on a VD4 vacuum decreptometer; 3) Bulk composition of the G phase (CO<sub>2</sub>, CO, N<sub>2</sub>, CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub>) and the composition of the G phase at T intevals up to 550°C on an LKhlM-8D G chromatograph in series with the vacuum decreptometer; 4) Composition of the L phase of bulk samples by the method of triple water extractions, determining Ca, Mg, Na, and K by the atomic-absorption method, and Cl on an ion-selective electrode; 5) Th of individual GLI in a thermochamber under the microscope; and 6) Phase composition of individual GLI by the cryometric method.

1. Productive parageneses of minerals and their formation temperatures (based on vein quartz)/

Such productive parageneses have been found in gold-ore deposits in Ordovician-Silurian black slates with an Au-Ag mineralization in quartz veins and stockworks (Mardzhanbulak), and in quartz veins and stockworks among metasomatites with Au-sulphide and low-sulphide rare-metal - Au-ore mineralization (Muruntau), as follows: sulphide-native (Au), and sulphide-sulphosalt-native (Au, Ag) parageneses, sometimes with scheelite (360-160°C). New results on the post-magmatic alteration of granites, concealed at depth, have been obtained from the Muruntau orefield. Their transformation involved pneumatolytic solutions with a varying CO<sub>2</sub>-gas-water composition (the amount of G in the Fl in the rock-forming quartz makes up 25-75%, and Th=320-340°C), and hydrothermal solutions (15% and 220-253°C, respectively). From an analysis of the bulk composition of the G phase, carried out on a G chromatograph, it has been shown that the phase consists mainly of CO<sub>2</sub> (1 kg of water from the I contains 3.52 mol CO<sub>2</sub>, 0.01 mol N<sub>2</sub>, and 0.005 mol CH<sub>4</sub>). A comparative rating of the thermobarogeochemical features of the granite and the quartz veins has been carried out for the Muruntau orefield. The G phase of the solutions extracted from the Fl of the granite and the quartz veins has a similar composition. It consists of 90% co<sub>2</sub> (3.52 mol per kg of water extracted from the granite, and 3.17-1.15 mol per kg of water extracted from the quartz veins and veinlets). CH<sub>4</sub> and CO are also present in the composition of the G phase. The G from I in the granitoids differ from those in the vein quartz veins and veinlets). CH<sub>4</sub> and CO are also present in the composition of the G phase. The G from I in the granitoids differ from those in the vein quartz in having a trace of nitrogen. Mineralization of the Muruntau Au-ore deposit has been assigned to the polygenic metamorphogenic-hydrothermal category.

In the gold deposits in the quartz-sulphide veins and explosion pipes among the Middle Carboniferous volcanics (Kochbulak), the following parageneses (320-200°C) are productive: sulphide-native Au, and sulphide-sulphosalt-telluride-native Au, and for the Au-Ag deposits in the quartz veins among the Permian volcanics (Chadak, Revashte, and Kyzylalma) and an intrusion (Kyzylalma): sulphide-native electrum and sulphide-sulphosalt (electrum, custerite, and Au). At Revashte, the T of the ore-forming solutions was 365°C and at Kyzylalma, 316°C.

V.V. Kozlov and S.K. Smirnova have studied the conditions of deposition and high-T metamorphism of the ores in the Chadak deposit: the ores of the early productive gold (electrum)-adularia-quartz mineral association were precipitated in the T range of 370-260°C (Au-pyrite mineral paragenesis) and 290-190°C (paragenesis of electrum with argentite and sulphosalts of Ag) from chloride-bicarbonate Ca>Na>K>Mg, periodically-boiled solutions with a salt concentration of <5% eq. NaCl and a CO<sub>2</sub> content of up to 5 mol%. The P in the ore-forming system varied within the range of 75 to 200 bars. The ores were formed under conditions of a lithostatic P at a depth of about 1 km below the volcanic cover of Permian age (Shurabsai and Ravash Groups) in the zone of mixing of rising solutions of magmatic origin and meteoric waters. The subsequent high-T of the ores with the formation of wollastonite, garnets, and other Ca silicates was caused by the ingress into the system of high-T brines (>60% eq. NaCl) of magmatic origin with a T above 500°C. Deposition of minerals of this phase took place mainly from heterogeneous solutions made up of a mixture of highly-concentrated aq solution (containing chloride slis of Ca, Na, Mn, and Fe) and a CO<sub>2</sub> F with a density in the P range of 250-450 bars. The ores of the late mineral associations were deposited in the T range of 300-120°C from heterogeneous solutions with a sal of up to 10-35% eq. NaCl.

For the wolframite mineralization in quartz veins with microcline-topaz-zinnwaldite greisens in Permian granites (Sargardon), the productive parageneses are quartz-cassiterite-wolframite (380°C, P 500-1600 atm., and boiling F), and cassiterite-sulphide (285-240°C).

For the As-Bi mineralization in quartz veins and sulphide deposits in Upper Devonian carbonate-terrigenous rocks (Ustarasai), these parageneses are pyrite-scheelite-bismuth (352-273°C) and pyprite-lead-Bi-sulphosalt (316-320°C). formed during the phase of deposition of Bi-sulphides in quartz veins and pyrrhotite metasomatic layers, and a later paragenesis (essentially arsenopyrite) in the form of almost monomineralic layers was formed at 210-140°C.

For the fluorite deposits in volcanics, granitoids, and limestones, these parageneses are quartz-fluorite (Supatash and Shabrez) and quartz-baritesfluorite (Agata-Chibargata, Naugesken, and Kenkol). The Th of the Fl are 100-235°C (Agata-Chibargata) and 100-165°C (Supatash). In the central part of the orebodies, these T are greater than on the flanks.

2. Composition of FI in vein quartz.

The composition of the FI has been determined for quartz on the basis of analyses of aq extracts and of the G phase on an LKhIM-8DM G chromatograph and by the cryometric method.

The ore-forming solutions of vein Au-ore and Au-Ag deposits are marked by an alkali-chloride (Kochbulak and Revashte) and an alkali- $CO_2$ -chloride composition (Kyzylalma and Chadak) with a sodic alkalinity (Na>Ca>K and Cl>CO<sub>2</sub>). In the G phase from the Kochbulak quartz, CO<sub>2</sub> is present (0.13 mol per kg of H<sub>2</sub>O), and from the quartz at Revashte and Kyzykalma, CO<sub>2</sub> substantially predominates (0.7-1.07) over CH<sub>4</sub> (0.03-0.05) and C<sub>2</sub>H<sub>4</sub> (0.02-0.06 mol per kg of H<sub>2</sub>O).

The ore-forming solutions from the Ustarasai As-Bi deposit and the Daikovoe tungsten (scheelite) deposit in the Brichmullinskoe orefield, located in carbonate-terrigenous and homsfelsed rocks, are marked by an alkali-CO2-chloride composition of the F with essentially sodic (Na>Ca>K) alkalinity (Us-tarasai) and with essentially calcic (Ca>Na>K) alkalinity (Daikovoe).

The Cu-Bi mineralization in quartz veins among granites (Kyzylgut) is marked by a sodic-chloride composition of the F

The quartz-wolframite veins, occurring in Permian granites (Sargardon) and the quartz-molybdenite veins in Lower Carboniferous granites (Chavata) have an alkali-chloride-CO<sub>2</sub> composition for the I with a K-Na alkalinity (at Sargardon Ca>Na, and at Chavata Na>Ca).

In fluorite deposits in magmatic rocks, fluorite from the quartz-fluorite productive paragenesis contains Ca-F fluids in the vacuoles (Supatash),

whereas those from the quartz-barites-fluorite paragenesis contain Ca-ammonium-F fluids (Agata-Chibargata), and those from quartz-fluorite bodies occurring in limestones contain Ca-CO2-F fluids.

In the hydrothermal and greisen deposits, the G phase in the vacuole F consists of CO<sub>2</sub> (>90%) with a trace of N<sub>2</sub>, CH<sub>4</sub> and C<sub>2</sub>H<sub>4</sub>, and it played an important role in the processes of ore-deposition.

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I. The geological model of the gold-productive system has been based on data from a geological-geophysical model of the Kaul'dy orefield and a geological-geochemical model of the Kaul'dy deposit. In accordance with the recommendations for systemic analysis, the model of the ore-genetic system is represented on the basis of its elements:

1. The framework of the ore-genetic system consists of intrusive complexes of the Caledonian structural stage, and the terrigenous-carbonate deposits and the intrusive complexes of the lower Hercynian structural stage (the root portions of the ore-genetic system), overlain by a volcanogenic cover of the Chashli and Akchinsk volcanogenic complexes (the ore-enclosing sequence). The important feature of the framework of the ore-genetic system is its multistage construction which determined the evolution of the flat-lying ore-distributing and ore-localizing structures during repeated tectonic dislocations.

 As a source for the ore-bearing solutions, we have suggested the deep-seated magma chambers of the Akchinsk volcanogenic complex, producing during the concluding phase of its evolution, residual acid M, injected into the ore-enclosing sequence with the formation of clastic varieties of andesites and andesite-dacites, and ore-bearing solutions, favorable for ore-deposition.

 Ore-conduits have been recognized in the nodal zones at the intersections of deep-seated faults. The principal ore-conduits are confined to the branches of the meridional Chaidar deep-seated fault.

It is suggested that the ore-conduits were long-lived structural-tectonic elements of the orefield which appeared during Bashkirian time. They were magma-outlets for the porphyry intrusions of the Kuraminsk Complex, transecting the facies of the Chashli and Akchinsk volcanogenic complexes, and also ore-outlets for the metamorphogenic and gold-productive ore-genetic systems.

4. The ore-distributing surfaces comprised the inter-associational contact level between the lower-and upper-Hercynian structural stages with volcanotectonic, gently-dipping structures. In the nodal zones of conjunction between the volcanotectonic structures and the steeply-dipping faults, we have recognized ore-distributing conduits of various orders.

5. The ore-localizing sectors are local portions of ore-distributing surfaces, favorable in geological-structural respects for the discharge of ore-bearing solutions and the concentration of mineralization. The dominant influence of structural and lithological factors for controlling the localization of gold mineralization is typical. The effect of the latter has also been reflected in the evolution of peri-ore metasomatites of the argillisite association.

The sectors of mutual junction between volcanotectonic structures and the interassociational surface are extraordinarily effective in localizing gold mineralization. Thus, the authors have identified a wedge-like ore-localizing structure at the side on the junction between the structure of the 6th orebearing zone and the Kaul'dy structure. In this unique 'pocket', the main ore reserves of the deposit have been concentrated.

II. The model of the evolution of the gold-ore process in the Kaul dy deposit has been based on physicochemical (T°, CO<sub>2</sub>/CH<sub>4</sub>, CO<sub>2</sub>/H<sub>2</sub>O) and isotope-geochemical sub-models.

1. The T model of the deposit demonstrates the uniqueness of the nature of the distribution of the T parameters in the plane of the reference section. The epicentre of the T maxima (T>300°C) shows up on the +850 m horizon. The uniqueness of the model of T-zonation is expressed in the regular drop in the parameters along the ore-controlling structures upwards and downwards through the section. With a predominance of T fields, limited by the 230-270°C isograds, we may recognize two fields, marking the lowest-T fragments of the process of evolution of the F system (T<220°C).</p>

The deposition of the gold-productive mineral complexes was limited to T=220-250°C. The mineral complexes, formed in the T range of <200°C, is poorly productive of gold.

2. The general model of the redox regime of development of a F system is marked by the synchronized nature of changes in T and the CO<sub>2</sub>/CH<sub>4</sub> ratio of the parameters, with a maximum value of the latter parameter (>200) in the zone of high-T, low-productive ore-deposition, and a minimum (<50) in the fields of development of the low-T mineral complexes. A similar but more complicated distribution has also been observed for the parameter CO<sub>2</sub>/H<sub>2</sub>O.

The patterns of change in the parameters CO<sub>2</sub>/CH<sub>4</sub> and CO<sub>2</sub>/H<sub>2</sub>O unequivocally point to growth in the reducing properties of the F system from highto low-T areas of the ore-genetic system.

3. The sulphur-isotope model of evolution of the ore process clearly displays a correlative dependence of the nature of dispersion of  $\delta^{34}$ S in relation to the variability of T<sup>o</sup> and the CO<sub>2</sub>/CH<sub>4</sub> ratio of the parameters of the F system.

The isotope-geochemical zonation is determined by the growth of  $\delta^{34}$ S in the sulphides of the region of high-T ore-deposition with respect to the low-T category. In this case, the zonation has a mirror reflexion upwards and downwards from the +860 m horizon.

III. The physicochemical and isotope-geochemical sub-models of the Kaul'dy deposit emphasize and represent in detail the geological premises on the evolution of the gold-productive ore-genetic system. The unusual zonation of the physicochemical and isotope-geochemical parameters are dependent on the geological-structural conditions of the evolution of F during the existence of the ore-conduit in the zone of junction between the northwestern steeply-dipping faults and the structure of the 6th ore-bearing zone, and also the ore-distributing surfaces in association with the volcanotectonic structures

Consideration of the geological-genetic features of the gold-productive ore-genetic system under this situation has enabled us to create a geologicalgenetic model of ore-formation and to work out the forecast-research complexes for revealing the gold mineralization in the Kaul'dy orefield. GOLOVKO, A.V., TOLMACHEVA, E.V. and ORLOVA, M.P., 1998, T-P-geochemical investigations into the shonkinites of the various facies in the Karashakho pipe (westem Uzbekistan) (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 43-44 (in Russian). First and second author at State Committee on the Geol. and Mineral Resources of Uzbekistan, Tashkent; third author at VSEGEI, St. Petersburg.

The Karashakho Pipe consists of two bodies (north and south) made up of olivine shonkinites of various facies: porphyroid shonkinites (PS) in the north, and shonkinite-porphyries (SP) in the south. PS contains large xenocrysts of chrome-diopside with phenocrysts of chrome-spinel and magnetite and segregations of olivine, titanaugite, and K-feldspar, comprising 40-45%. The groundmass is made up of crystals of clinopyroxene, biotite, and K-feldspar laths. SP also contains xenocrysts of chrome-diopside, but besides the chrome-spinels and magnetite in them, we have noted moissanite. The phenocrysts (30-50%) consist of titanaugite and olivine. The groundmass consists of microcrysts of clinopyroxene, magnetite, laths of biotite, and isometric, and less commonly, elongated grains of K-feldspar.

The I of mineral-forming media have been examined in the chrome-diopside xenocrysts and in the titanaugite phenocrysts in both PS and SP. In the former, the chrome-diopside contains an exceptionally large quantity of P I of M of irregular shape: its crystallization had been rapid. The I have dimensions of 0.002-0.02 mm and consist of devitrified glass (20%), a fine-grained aggregate of acicular, dark, opaque crystals (50%), and a brownish-red pleochroic mineral (30%), diagnosed as biotite. The Th of the I of this kind into M is 1260-1270°C. Secondary I of M have also been observed, confined to cracks, transecting the chrome-diopside grains, and consisting of glass (40%), an aggregate of an acicular dark mineral (10%), and an idiomorphic prismatic crystal of clinopyroxene. Such I occasionally contain a crystal of magnetite and a visible F phase. The distribution of these I in the chrome-diopside and M.

The titanaugite phenocrysts in PS contain a few short chains of P I of M and later F, highly-concentrated water-salt I. Within the chains of MI, there are isolated FI, which indicates degassing of the M during the process of crystallization of the titanaugite. The MI consist of glass (80%), grains of a dark-colored xenomorphic mineral, and an aggregate of an acicular brown mineral. Xenogenic magnetite is often present. Their Th into M is 1120-1135°C. The water-salt I consist of two varieties. The earliest contain two salts (one of which is NaCI), comprising up to 20% of the volume of the I, a xenomorphic carbonate, and sometimes magnetite. The later I have a water-carbonate composition. The Th of the water-salt I varies within a wide range (520-610°C), while the highest-T I contain more NaCI, and the lower-T forms have been enriched in carbonate.

The chrome-diopside xenocrysts in SP have revealed numerous MI and I of chrome-spinel and moissanite crystals. In the central portion of grains of MI, they have an oval shape, and their dimensions are 0.02-0.01 mm. They consist of glass (10%), several laths of a translucent mineral and an aggregate of an acicular mineral. In these I there is sometimes an anomalously large (up to 20%) F phase, but the greater part of such I has been exploded and is surrounded by a halo of submicroscopic FI, which points to the high F-saturation of the M during crystallization of the chrome-diopside. The Th of these I (without a visible F phase) into M is 1250-1260°C. The quantity of I increases toward the grain periphery, and their shape and composition change: they acquire an irregular, vermiform shape, often 'unlaced', and consist of glass (30%), a reddish-brown mica (biotite), a large pyroxene crystal (15%), and often a xenogenic magnetite. Homogenization of such I takes place in the 1170-1240°C interval. These data indicate that the I under consideration in the chrome-diopside are S and their formation is a consequence of reactive interaction between chrome-diopside and the M.

The titanaugite phenocrysts in SP contain MI, the degree of crystallization of which varies within wide limits and regularly diminishes from the center toward the periphery of the grains, which is typical of crystallization during the ascent of a magma. The I in the center of the grain have dimensions of 0.001-0.015 mm, an isometric but often irregular shape, and consist of glass, a prismatic anisotropic crystal of pyroxene, and a F phase, and in the peripheral area, they consist of glass and a finely-crystalline aggregate. In the chains of MI, distributed in the peripheral portion of the titanaugite grains, we often observe F, G, and less commonly GLI, often with xenogenic magnetite. The P, determined from a G-L water-salt 1, amounts to 1.5 kbars. Th of the MI varies within the 1200-1210°C interval. Moreover, the titanaugite contains chains of later primary-secondary I of melt-brines, consisting of a variable quantity (from 5 up to 90%) of carbonate, an acicular dark-colored mineral, and a finely-crystalline aggregate. Within these chains, there are I of exclusively carbonate composition and those of carbonate with a thin selvedge of a water L phase, which is probably the consequence of demixing of the original M into silicate and carbonate forms.

3. [sic] thermobarogeochemical studies have shown that:

1) the chrome-diopside xenocrysts in PS and SP crystallized at similar T and have P1 of similar composition, which suggests a common magmatic focus for them.

2) the evolution of the portions of M (original for SP and PS), which separated from the magma, was varied; the differing F-saturation of the M I in the xenocrysts of PS and SP indicates that the portion of the overall magmatic focus most enriched in F were the original magmas of SP, whereas those of PS were depleted.

 the crystallization of SP was probably accompanied by demixing of the magma into carbonate and silicate components, which could have led to the formation of complementary carbonatites.

4) during the process of crystallization of SP, a hydrothermal system could have been formed, which led to the formation of the carbonate rocks of hydrothermal-metasomatic origin.

ISMAILOV, M.I., BABAZHANOV, A.A. and LEBEDEVA, S.E., 1998. The rare-metal deposits of western Uzbekistan based on thermobarogeochemical data from ore quartz (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 85-86 (in Russian). Authors at IGG AN Uzbekistan, Tashkent.

In order to clarify the physicochemical parameters of the process of W-Mo ore-formation in skamoid - rare-metal deposits (Ingichka, Yakhton, Koitash, Lyangar, etc.) of western Uzbekistan, the authors have employed the results of personal observations on ore quartz of various generations, and also similar data of Kh.N. Baimukhamedov and A.T. Razykov (1986).

It has been established that the W-Mo kind of mineralization has been formed as a result of the appearance of quartz 1 - amphibole II - scheelite III, and quartz II - molybdenite - scheelite IV of the typomorphic paragenetic associations of the acid phase, introduced into skarns, skarnoids, calcareous and magnesian formations, hornfelses, granitoids, and into other rocks.

Thermobarogeochemical investigations into quartz l and ll of the Koitash deposit demonstrate that in quartz l there are P, two-phase (G and L), rounded I, measuring 3-5  $\mu$ m. PS I, single- (L) and two-phase (G<<L), elongate or oval-elongate in shape, and measuring 3-5  $\mu$ m, are homogenized into the L phase at 410-380°C (average of 3 analyses) with decrepitation at 440-380°C, which is 30°C higher than the homogenization interval, and pH=5.4.

In quartz II, there are two kinds of P I: (G<<L) and multi-phase (G<<L+S), where the solid phase has the form of a cube, a prism measuring 1-2  $\mu$ m, and even an I of oval-elongate, weakly-rounded shape, measuring 6-10  $\mu$ m. The solid phase consists of ore minerals. The L phase in quartz II has a Th of 260-280°C (average of 7 analyses), and according to the decreptiation data, 280-420°C, which is 20°C greater than the homogenization figures, and pH=6.9 (Baimukhamedov & Pazikov, 1986). As the Tf of the ore quartz falls (ore formation), the acidity of the hydrothermal solutions diminishes.

The chemical composition of GL1 of quartz I. determined by the suspension [sic] method is different from those of quartz II. The former is marked by a sulphate-fluoride-chloride-chloride-bicarbonate composition, and latter by a sulphate-chloride-bicarbonate composition (anion portion). In the cation portion, we have discovered Ca. Mg, K and Na in amounts ranging from 0.197 mg per 100 g/r [sic] up to 1.930 mg. They are the principal precipitators of tungsten in the form of scheelite and wolframite. The concentration of these elements, especially Ca, is dependent on the medium of ore formation. Therefore, it follows that in a limestone-skarn medium, the Ca concentration is significantly greater than in a magnesian-skarn medium. Consequently, for the deposition
of scheelite, the most favorable is the limestone-skam medium, which also explains the increased ore-capacity of this association of rare-metal deposits of western Uzbekistan as compared with the magnesian-skam category.

Moreover, the chemical composition of the GLI of ore quartz of varying generation in the deposits at Lyangar, Koitash, Ingichka, and Sarytau has been examined on a VD-4 vacuum decreptometer (IGG AN) Uzbekistan, analyst S.E. Lebedeva) by the G-chromatography method. The results have shown that the chemical composition of the aq extracts is marked by the presence of water, CO, CO<sub>2</sub>, and CH<sub>4</sub>.

During a comparison of the averaged total amounts of individual components in the deposit, a pattern has emerged which indicates that the average content of H<sub>2</sub>O, CO<sub>2</sub>, CO and CH<sub>4</sub> (in mol/kg in H<sub>2</sub>O) in the make-up of the GLI in quartz increases from the Ingichka deposit, which had formed under deeper (3-4 km) mesoabyssal conditions to one side of the Koitash and Lyangar deposits, generated in shallower (2.5-1.5 km) hypabyssal parts of the crust, determined by the facies nature of the individual intrusive massifs and the above-noted deposits associated with them.

The comparative data, based on T-P-geochemical investigations into ore quartzes I and II of the W deposits of western Uzbekistan and foreign countries, demonstrate that the ore process, that is, the formation of scheelite and molybdenite, took place within the T range of 420-240°C with a pH value=3-7.4. This indicates that the W deposits of western Uzbekistan belong to the high-T category. The medium-T W deposits of Dae-Hva (South Korea), Pasto-Buena (Peru), and Panasquera (Portugal), according to the homogenization data for the GLI of ore quartz, were formed at 200-235°C.

KHALMUKHAMEDOV, T.R., ISLÁMOV, F.I., ZAÍRI, N.M., KONÉEV, R.I., MEKHMANKHODZHÁEV, A.D., ZHURÁEV, A.Zh. and GÉRT-MAN, Yu.L., 1998, The formation of gold-ore mineralization in the Kairagach deposit (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 131-133 (in Russian). Authors at Geological and Geophysical Party 'Tashkentgeologiya', Tashkent.

In recent times, the methods of thermobarogeochemistry and isotope geochemistry have attracted special attention for resolving problems of reconstruction of the physicochemical conditions of ore-deposition, prospecting, and forecasting concealed gold-ore.

As exemplified by the study of sectors of the Central and Chukurkotan (generalizing the section along II-II) deposits at Kairagach, we have obtained several physicochemical parameters (Td of quartzes and other mineral associations; sulphur isotopes of sulphide and sulphate minerals, carbon isotopes of the carbonates and oxygen isotopes of the quartzes; IR-spectroscopy of quartzes, etc.). The analysis and correlation of these investigations have enabled the authors to formulate an isotope-geochemical model for the formation of gold-ore mineralization in the Kairagach deposit, individual events in which are expressed as follows:

1. The T interval for the formation of mineralization is 200-400°C, and for the richest gold-associations, 210-300°C. The principal mineralization in the Central sector has been formed at 230-300°C. In this case, the high-T zones (Tav=300°C) form series of linearly-extended zones of differing thickness, of which the thickest has been traced along the level of the present erosion surface. Three others seemingly trace out linear zones of influx of generating systems and have no surface outcrop. The mineralization formed at T=300°C has been regularly altered by a lower-T mineralization with Tav=230°C, and the section ends along the Central sector with an ore-formation Tav=200°C.

A characteristic feature of the section in the Central sector is the presence in it of deep horizons of mineralization, formed at T≤200°C, which is normal for the near-frontal portions of the deposit. Similar characteristics have been identified in the Chukurkotan sector, within which a near-frontal portion of a concealed orebody has been discovered.

In general, in the Chukurkotan sector, we may note a series of high-T portions of the zones of mineralization (Tav= $350^{\circ}$ C), which crops out on the surface at the present erosion level. An analysis of the erosion surfaces of the sectors of the deposit examined, based on the nature of the distribution of the T-gradient, indicates the extensive eroded nature of the zones of mineralization in the Chukurkotan sector as compared with the Central sector.

2. An analysis on  $T^* - \delta^{34}S$  coordinates demonstrates the presence of a definite correlation between them, with a clearly-defined tendency toward isotope 'lightening' of the sulphides along the gradient of the T field, varying from 270 down to 170°C, which indicates a mutual dependence of change in the variation of  $\delta^{34}S$  on T° of the regime.

During consideration of the trend in the evolution of the ore-forming system in the deposit, we have constructed diagrams on various coordinates, which enable us to determine the relationship between the various parameters of the system — T°, the amount of water, the  $CO_2/CH_4$  and  $CO_2/H_2O$  ratios, the isotope composition (estimated) of oxygen in the water from hydrothermal solutions that participated in the mineral-formation. The overall trend in the change in the  $CO_2/CH_4$  ratio of the mineralization in the deposit is a regular increase in that ratio from the high-T area of ore deposition ( $\geq 220 - \geq 270^{\circ}C$ ) towards the low-T area ( $\leq 210^{\circ}C$ ). The  $CO_2/CH_4$  ratios in the initial phase of ore-deposition are marked by relatively stable values, but a marked change in this parameter (from 50 to 200), is synchronized with a drop in T° of the regime. It is interesting to note that precisely in this area there is a symbiotic increase in the  $CO_2/CH_4$  ratio, whereas in the interval of  $CO_2/CH_4$  = 100-150, there is a progressive increase in the water content.

The changes in the redox reactions in the F systems (except for the T<sup>o</sup> - Eh parameters) are a determining factor in the precipitation of gold from solutions. The results demonstrate that the bulk of the gold is precipitated in a threshold change with the  $CO_2/CH_4$  ratio  $\geq$ 50. A similar result is also obtained by a threshold change of  $CO_2/CH_4$  at the value of >0.25, when the bulk of the metal is precipitated.

3. The sulphur-isotope model of the evolution of the ore process is based on the appearance of a vector of the trend of concealed sulphur-isotope zonation and the nature of sulphur fractionation during the formation of sulphide complexes. The overall tendency, determining the trend of evolution of the sulphur-isotope zonation is a regular accumulation of  $\delta^{32}S$  in the low-T area of sulphide-formation, with a vector of zonation of  $\delta^{34}S$  Tav=300°C = +4.5±0.05‰ (T≥270°C)  $\rightarrow \delta^{34}S$  Tav=300°C = +2.5±1.0‰ (T=220°C)  $\rightarrow \delta^{34}S$  Tav=300°C = +0.7±1.5‰ (T≤190°C).

The zonation obtained indicates that the evolution of the F systems is accompanied by an increase in its oxidation properties in the low-T area of oredeposition. An indicator of this process is the steady increase in the CO<sub>2</sub>/CH<sub>4</sub> ratio.

A certain dependence has been established between the nature of the distribution of the variations in  $\delta^{34}$ S of the sulphides. More than 80% of the gold content from 0.001 up to 0.1 ppm occurs in sulphides with  $\delta^{34}$ S from 6.0 to 3.0, whereas with Au concentrations from 0.001 up to 15 ppm (>70%), it varies from 0.8 up to 15 ppm in sulphides with  $\delta^{34}$ S = 3.0-1.0‰. The sulphur-isotope model in two adjacent sectors of the deposit is somewhat different, but with an overall pattern in the evolution of  $\delta^{34}$ S from the near-root portions of the zones toward the near-frontal portions.

4. In comparing individual elements of the physicochemical and isotope-geochemical zonation, it is seen that the revealed patterns are identical both for T<sup>o</sup> - CO<sub>2</sub>/CH<sub>4</sub> and also for  $\delta^{34}$ S, which is an additional criterion for affirming their interdependence. Differences in the two adjacent parts of the deposit are expressed in the clear manifestation of fragments of the near-root portions of the zones ( $\delta^{34}$ S>6.0‰) on the level of the present surface of the Chukurkotan sector, and in the Central/near-frontal zone. The picture obtained may be explained by differences in the levels of the erosion surface, and in the investigated fragments from the deposit.

Similar investigations, conducted within the Kyzylalmasai, Kyzyldinsk, and Kochbulak orefields have enabled us to substantiate the possibility of using a set of isotope-geochemical methods in the interests of research and diagnosis of concealed and buried gold-ore prospects.

KHAMRABAEV, I.Kh., AKHUNDZHANOV, R., USMANOV, A.I. and KOZLOV, V.V., 1998, Ideas about the genetic association between magmatism and mineralization based on a study of solid micro-inclusions in rock-forming minerals (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 62-64 (in Russian). Authors at Kh.M. Abdullaev Inst. of Geol. and Geophys., Tashkent.

The development of new methods of mineralogical-geochemical and petrographical investigation and the construction of high-resolution and precision apparatus will enable us to study the material composition and structure of minerals more closely and to formulate more up-to-date ideas about their origin.

One such method is the study of solid micro-inclusions in rock-forming minerals. Solid micro-inclusions are the object of the science of micromineralogy (L.V. Tauson, 1988; G.M. Chebotarev, I.Kh. Khamrabaev and R.I. Koneev, 1986; R.I. Koneev, O.K. Kushmuradov and A.Kh. Turesebekov, 1994, etc.) Along with FI, they contain information about the material composition and the history of formation of the rocks and ores. Using the ore microscope and the new JEOL JXA 8800R electron microprobe, we have been able to examine solid micro-inclusions in rock-forming minerals of magmatic rocks from the Muruntau gold-ore deposit (Navoiiskaya Oblast'), the Kal'makyr Cu-Mo deposit (Almalyk), and the Shavazsai Li deposit (Tashkent Oblast'). Investigations along these lines are being carried out in IGG AN Uzbekistan for the first time. Along with solid micro-inclusions in rock-forming minerals, to consideration of which the present report is devoted, we have made a series of investigations based on a study of the composition of volcanic glasses, and glass (M) I in thin sections. A.A. Kustarnikova and A.I. Usmanov have produced a report about these results. We are in the initial stage of such work. Therefore, along with undoubtedly important results in theoretical and practical respects, a mass of unresolved problems have arisen.

In quartz and partly in plagioclases from leucocratic granites from the concealed Muruntau granitoid intrusion of Permian age, intersected at a depth of 4005-4300 m by DH SG-10 (1.Kh. Khamrabaev, Yu.N. Zuev, P.T. Azimov, and I.P. Sidorova, 1994; G.I. Nasyrova and I.Kh. Khamrabaev, 1996) along with translucent radioactive accessory minerals (thorite, monazite and uraninite), we have discovered and studied opaque ore minerals (arsenopyrite, sphalerite and magnetite) with the aid of the microprobe. Under the microscope, along with the minerals listed, we have diagnosed native gold and a carbonaceous substance (graphite?) (Z.I. Khamrabaeva). Thus, in almost unaltered granites, nearly all of those ore and gangue minerals characteristic of the Muruntau ores have been found in the grains of quartz and plagioclase. These minerals occur in the form of minute micro-inclusions ranging in size from 3-4 up to 5-10 microns. They form streaks and micro-intercalations of two ages: the earlier have the shape of a necklace, whereas the later ones are like crack fillings in which the ore minerals are associated with carbonaceous matter.

As is well-known, there is no unique view as to the origin of the Muruntau deposit. One group of specialists (V.G. Gar'kovets, S.T. Badalov, et al.) regard it as a sedimentary-epigenetic deposit. The role of magmatism (especially granitoid intrusions) has either been ignored or is confined to thermal activity (L. Drew et al., 1998). Another group (S.D. Sher, V.I. Smirnov, I.Kh. Khamrabaev, et al.) believe it to be postmagmatic, associated with granitoid (Late Carboniferous-Permian) magmatism. This indicates that the effect of the granitoid intrusion has not been limited to thermal activity, but was also geochemical (material) in nature. At the same time, the presence of later micro-inclusions, their distinct association with crushing in the rock-forming minerals, and also the presence in them of carbonaceous matter, points to a more complicated rather than a direct genetic character of the link between gold mineralization and this magmatism.

In the Almalyk ore region, in the quartz and feldspars from the weakly-altered syenite-diorites of Kal'makyr (Almalyk), we have discovered microinclusions of pyrite, hematite, chalcopyrite, and sphalerite, forming a fine segregation and micro-veinlets. We have studied the highly-concentrated S Fl in the rock-forming quartzes and K-Na feldspars from altered diorites (C<sub>2</sub>) and quartz-porphyries (P<sub>2</sub>-Tr) of the Kal'makyr and Sary-Checku deposits. In a number of I, these minerals are accompanied by small grains of hematite and chalcopyrite (Fig. 1) [not suitable for reprinting here].

It is evident that the relicts of chloride-enriched alkalies and ore components of the ore-forming F have been responsible for the formation of the Kal'makyr and Sarycheku deposits. FI, similar in composition and salt concentration with a Th up to 850°C, are typical of other porphyry-copper deposits of the globe (E. Roedder, 1984).

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KOZLÓV, V.V., SMIRNÓVA, S.K. and USMÁNOV, A.J., 1998. The use of modern equipment in the thermometry and analysis of the composition of fluid inclusions (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998. Tashkent, Uzbekistan, Abstracts volume, p. 163-165. (in Russian). Authors at IGG AN Uzbekistan, Tashkent.

Fl are relicts of mineral-forming media, and they allow us the unique possibility of studying earlier-extinguished hydrothermal ore-forming systems. A vast number of publications have been devoted to their study, and without the aid of the quantitative information obtained from them, it would not have been possible to make a serious investigation into the origin of the deposits. The methods of studying Fl are being constantly perfected and rapid progress may be readily traced in the data emanating from the annually-alternating conferences of ECROFI in Europe and PACROFI in North America. This also applies both to the traditional methods of optical microthermometry, and also particularly to the methods of quantitative analysis of their composition. The main difficulty in such investigations is the size of the l, only in rare cases exceeding 15-20 µm and the extremely insignificant quantities of the material enclosed within them. This dictates the necessity to use the highest-resolving and most sensitive methods for their analysis. The most pressing requirement is a local analysis of actual Fl. In order to study their composition, we must use the most modem methods of local analysis, namely, laser Raman spectros-copy, ISP-mass-spectrometry with laser ablation, sources of synchrotron radiation, etc. The use of high-resolution mass spectrometers and laser ablation make it possible to determine the Rb-Sr absolute age from the Fl. The more traditional 'bulk' methods of analysing Fl (the analysis of the salt composition based on aq extracts and the analysis of the G composition), still continue to be employed and brought up-to-date.

Recently, a collection of modern equipment has been set up in the Inst. of Geol. and Geophys., permitting reasonable opportunities to investigate FI. In order to determine the Th and freezing T of the FI, we have employed a microthermometry system, including:

1. A Nikon Opiphot Pol 2 optical microscope, equipped with Nikon SLWD objectives with a large focal distance (2 cm [for the] 20X objective) and a videocamera connected to a computer;

 A computer-controlled Linkam THMSG-600 cryothermocamera for conducting high-precision (±0.1°C) measurements in the range from -196 up to 600°C. In the cryothermocamera set, there is a program provision for obtaining and treating images with the microscope videocamera, and also for documentation and analysis of the thermometer data of the FI.

3. A Linkam TS-1500 high-T camera designed for studies at T up to 1500°C and applicable to the study of MI.

The study of the composition of the FI is achieved by two methods:

A JEOL JXA-8800R sonde microprobe, capable of operating as a scanning microscope and equipped with a Link ISIS-300 energy-dispersive spectrometer for analysing the dm of the FI, and also saline sediments after evaporation of the FI (Table 1). With its aid, we have obtained valuable information about the composition of the earliest, presumably magmatogenic solutions, which took part in the formation of the gold-ore deposits at Muruntau, Chadak, and Kochbulak, and the porphyry-copper deposits in the Almałyk region (Kal makyr and Sarycheku). The principal role in the composition of the solutions in the porphyry-copper deposits was played by Na and K, and high concentrations of S, Fe, and Cu (in the make-up of the daughter phases of clacopyrite and hematite, Fig. 1), have been identified. The FI of the highly-concentrated early solutions of the Muntau deposit have been enriched in chlorides, sulphates, and carbonates of Ca. Mg, and Fe. Chlorides of K, Na. Ca, and Mg played the principal role in the composition of the ore-forming solutions of the epithermal deposits at Kochbulak and Chadak. A number of unusual dm in the FI have been

# KÓZLOV, et al.

Table 1. Chemical composition of dry precipitates of salts and daughter minerals in vacuoles of fluid inclusions.

Eleme	ents										Remarks
Na	Mg	S	Cl	K	Ca	Ti	Mn	Fe	Sn	Pb	
Chada	ak, Fls o	of skarne	oid phase	2							
20.7	21.1	3.2	55.0								Dry precipitate in vacuole
18.8	20.5	3.1	18.3						39.3		Dry precipitate in vacuole
43.8	4.3		52.0								Dry precipitate in vacuole
41.6	58.7										Dry precipitate in vacuole
Kochl	oulak, F	ls in qua	artz of A	u-T, prod	luctive ph	ase					
5.2		36.1	56.8	2.0							Dry precipitate in vacuole
4.9		46.6	47.9	0.6							Dry precipitate in vacuole
25.3		19.2	14.8	18.2				22.5			Dry precipitate in vacuole
32.0		29.5	38.6								Dry precipitate in vacuole
3.3		47.2	49.5								Dry precipitate in vacuole
9.2		46.5	44.3								Dry precipitate in vacuole
Muru	ntau, Fl	s of Au-	arsenop	yrite-sche	elite-qua	rtz vein	s				
14.5	10.8	7.9	22.9	24.7	9.0		1.9	8.3			Dry precipitate in vacuole
22.3	11.6	11.2	23.8	10.7	2.1			18.3			Dry precipitate in vacuole
31.0	16.0	3.3	49.7								Dry precipitate in vacuole
2.4	1.4	1.0	28.9	35.8	13.4	9.7		7.5			Dry precipitate in vacuole
7.6	11.5	3.2	11.9	18.2	6.5			41.1			Dry precipitate in vacuole
5.8	3.8	1.2	35.8	44.2	2.4			6.9			Dry precipitate in vacuole
11.5	2.2	2.5	40.9	21.2	12.1			9.6			Dry precipitate in vacuole
Kal'm	akyr, se	condary	Fls of p	orphyrit	ic quartz	segrega	tions				
25.2	1.2		45.0	9.2	1.4		2.5	15.4			Dry precipitate in vacuole
27.1	2.4		33.7	6.5	1.6	3.4	25.4				Dry precipitate in vacuole
7.1			15.5	2.8			5.0	69.7			Dry precipitate in vacuole
	0.1	3.6	45.4	45.6	0.6		1.0	3.8			Dry precipitate in vacuole
		24.6	14.1	4.3	0.7		0.3	56.1			Dry precipitate in vacuole
10.0			50.0	35.7							Sylvite
38.6	61.	4									Halite
36.6			62.8	0.6							Halite
35.3		0.6	61.4	0.7	0.4		0.0	1.5			Halite
		0.2	32.2	9.4						58.2	Pseudocotunnite
		0.4	32.0	9.5						58.2	Pseudocotunnite

identified - Stibarsen [SbAs] (Kochbulak), a Mn chloride (scacchite) (Chadak), and a chloride of K and Pb (pseudocotunite) (Kal'makyr).

An analysis of the triple aq extracts from FI of minerals has been carried out by the mass-spectrometric method with an inductively-coupled plasma (Perkin Elmer ELAN-6000 ISP mass-spectrometer). The advantage of this method is the exceptionally high sensitivity (order of 0.01-0.001 µg) and the possibility of analysing not only the principal components of the 1 (K, Na, Mg, Cl, etc.), but also the minor components. Additional possibilities arising from the increase in sensitivity of the analyses from micro-volumes of the aq extracts is ensured by the system of input of the sample into the plasma with the aid of electrothermic atomization. We are currently developing special methods of analysis of aq extracts from local groups of FI, supposedly collected in the transparent sections or grains of translucent minerals. This enables us to avoid difficulties in interpretation, typical of the bulk analysis of several generations of FI present in the sample.

Figure 1 Daughter minerals (halite, chalcopyrite, and hematite) in a vacuole of a FI in a porphyritic segregation of quartz, Kal'makyr deposit. Photograph in secondary electrons. JEOL JXA-8800R, x 800 [not reproduced here].

See Table 1.

The analyses were carried out with the aid of a JEOL JXA-8800R microprobe and a Link ISIS-300 ED-spectrometer in fresh crushings of quartz, spray-coated with a conducting layer. For comparison, we used samples of NaCl, KCl, CaSO<sub>4</sub>, MgO, CaCO<sub>3</sub>, Ti, Mn, Fe, Sn and Pb. In a number of analyses, we discovered a deficit in anions which is associated with the absence of any possibility of analysing elements lighter than Na (C, O, F, etc.).

NERONSKY, G.I., 1998. The compositional features of gas-liquid inclusions in native gold from the upper Amur Province (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 105-107 (in Russian). Author at Amur Group Research Inst. (KNII) of Far Eastern Div. of Russian Acad. of Sci., Blagoveshchensk.

The Upper Amur Province is situated in the zone of the southeastern environs of the North Asian Craton and includes the Stanovoi, Dzhagdinsk, and Bureya districts, which correspond to the various structures with a specific metallogeny. Gold is the element in common for all of the metallogenic districts. In order to decipher the conditions of formation of the gold-ore deposits, it is important to have evidence about the composition of the F, relicts of which have been encapsulated in the GLI of the minerals. They enable us to judge the associational category of the ores, the mineral kind of mineralization, the depth of the orebodies, to differentiate between the productive and gangue phases, to solve the problems of horizontal and vertical zonation of the deposits, and to recognize the enriched sectors of the orbodies, etc. (Lyakhov, 1988).

Mostly, in order to resolve these problems, we use the composition of the GLI in productive quartz and the results are distributed to the ore minerals. In fact, the gold in the ores is precipitated after the quartz and, naturally, under other physicochemical conditions.

A comparative analysis of the composition of GLI in gold, cassiterite, and productive quartz in some deposits in the Far East has shown that the diversity in composition of the F in the quartz and ore minerals is substantially different. This indicates the invalid nature of tranferring data on the composition of I in productive quartz to the composition of I of ore minerals associated with it (Moiseenko & Mironyuk, 1989).

On the basis of the bulk composition of I in native gold, a regular change in the F regime for the monotypical gold-ore deposits of the Transbaikalian, Amur, Sikhoté-Alin', and Sea of Japan blocks has already been identified (Moiseenko & Sorokin, 1988).

At the same time, within the Upper Amur metallogenic district (Amur Block) for each of the metallogenic zones, both ore and placer gold have been distinguished on the basis of morphology of the grains, grainsize, assay, trace-element composition and quantities, paired correlation of the amounts of additives, internal structure, and T of vacuum decrepitation. These features of gold are dependent on the manifestation of gold mineralization of various mineral and associational types.

Because the ore deposits in the Amur region are isolated, the study of the composition of the GLI in the gold from different metallogenic districts requires us to use gold from placers from nearby drift on the sites of its intense inflow into the alluvial deposit with its ore aspect. In such gold, the GLI are completely preserved. As a result, it has been established that in each metallogenic district, the F regime of formation of the gold-ore deposits has its own peculiarity (Table 1).

During the study of the internal structure of the gold, it has been established that the crystallization of its grains took place in several stages: early-ore, productive, and late-ore. This is emphasized by the difference in structure and composition of the various phases of the gold within a single grain, and the multimodal graph of the vacuum decreptograms indicates a change in Tc.

In order to clarify the evolution of the F composition, the author for the first time used a stage-by-stage opening of the GLI in the gold in accordance with the Td. From single analyses, a clear increased concentration of salts and G during the productive phase of crystallization has been identified, and the coefficient of F oxidation increases during the late-ore phase.

Thus, the determination of the F regime of gold crystallization and the evolution of its composition proceeds expeditiously through the phases of crystallization in accordance with its Td.

PARÍLOV Yu.S., 1998, Tests for determining the sources of ore-forming fluids based on the chemical composition of solutions in inclusions (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 27-30 (in Russian). Author at Inst. of Geological Sci., Alma-Ata, Kazakhstan.

A knowledge of the source of ore-forming F is essential in making metallogenic forecasts and forming a scientific basis for prospecting individual regions and orebodies in any particular form of mineral resources. From the lengthy history of the water bodies, [sic]it is important to obtain an understanding of the time interval that preceded hydrothermal ore-formation. This is related to the formation of the chemical composition of the F, and its enrichment in ore components. And although the subsequent processes of transfer and deposition of the ore material leave their mark, the chemical composition of the solutions in the FI of ore minerals must reflect the characteristic features of those conditions in which that composition was formed. This feature has also been involved in determining the sources of the ore-forming F.

There are usually five such sources: 1-mantle F, formed as a result of degassing and differentiation of mantle magmatic M; 2-metamorphic F, related in their origin to the transformation of deeply-subsiding sediments, accompanied by the formation of rocks of the eclogite, granulite, and other metamorphic facies; 3-fluids, arising during degassing and crystallization of acid magmatic M within the Earth's crust; 4-buried subsurface waters of marine or meteoric origin; and 5-pore solutions of the country rocks, the involvement of which may have brought about metamorphism of already-formed ores and mobilization of disseminated ore material. At the present time, there is a great deal of information available that points to significant differences in the composition of the volatile and saline components in the F of the various magmatic and metamorphic rocks, buried waters, and pore solutions. This information is summarized in Table 1.

We present some typical examples of compositions of solutions in 1 for each of the sources of ore-forming F (Kazakhstan deposits).

1. The pyritic-polymetallic deposits of the Rudnyi Altai are localized in the form of two extensive zones (Northeastern and Irtysh, along which tectonomagmatic activation has involved rocks of the Earth's crust and mantle down to a depth of >250 km. In general, the region is marked by a high saturation in deposits of the ore zones, an essentially polymetallic mineralization, localization of the orebodies in zones of increased permeability over a large vertical range, intense pre-ore metasomatism, a lengthy multiphase manifestation of the ore process, several age levels of mineralization, and connected with a Devonin basalt-andesite-rhyolitic assocation. All these data indicate that the source of the ore F existed for a long time, was spatially stable, occurred at a great depth, and possessed a vast mass and energy. Such a source may have been the upper mantle, which most investigators of the Rudnyi Altai are inclined to accept. This conclusion is not contradicted by the results of a study of the FI (Table 2). The F are marked by a low water content (7-13% of the mass), and extremely high concentrations of salts (64-70%), among which chlorides, fluorides, and sulphates of Na and K predominate; there is

# NERONSKY, G.I.

Table 1. Composition of GLI in gold from the Upper Amur Province

Stanovaya	Metallogenic districts Dzhagdinsk	Bureya
38.7	27.3	28.7
18.1	21.4	15.9
76.2	96.1	150.8
133.0	144.8	195.4
48.8	81.0	21.0
9.0	31.0	9.1
2.0	1.1	1.9
4.3	3.4	2.7
2.3	0.93	2.1
3.6	1.3	6.3
	Stanovaya 38.7 18.1 76.2 133.0 48.8 9.0 2.0 4.3 2.3 3.6	Metallogenic districts Dzhagdinsk           38.7         27.3           18.1         21.4           76.2         96.1           133.0         144.8           48.8         81.0           9.0         31.0           2.0         1.1           4.3         3.4           2.3         0.93           3.6         1.3

# PARÍLOV, Yu.S. Table 1. Compositional features of fluids of varying origin

Varieties of fluids	H <sub>2</sub> O/CO <sub>2</sub> +CO)	Salt concentration	Chemical composition			
Mantle fluids	0.1-5	High, up to salt melts	Chlorides, fluorides and sulphates of Na, K, and ammonia			
Metamorphic fluids of eclogite and granulite facies possible	0.4-5	Low		High concentrations of $N_2$		
Metamorphic fluids of amphibolite facies	7-18, ≤50			High concentrations of $N_2$		
Fluids of granitoid magmas of different origin and composition	15-20, ≤50	From low to high				
Deep subsurface waters	100 and more	Low and medium		Small amounts of H <sub>2</sub> S		
Pore solutions		Medium and high		CO <sub>2</sub> , hydrocarbonates, and sulphates of Ca, Mg, and sometimes Fe predominate		

Note. The following quantitative differences in salt concentration have been accepted, wt%: low - <20, medium - 20-50, high - 50 and above.

PARILOV, Yu.S.

Table 2. Composition of fluids in inclusions of minerals of the ore associations of some deposits of copper, lead, and zinc in Kazakhstan

Mineral associations No	of Analy	ses Chemical composition of fluids		H20/(CO2+CO)
Deposits	of the Ru	dnyi Altai (Ridder-Sokol'noe, Zyryanovskoe, Or	lovskoe, and Nikolaevskoe	2
Fine-grained massive pyrite	6	H <sub>2</sub> O <sup>11</sup> H <sub>2</sub> S <sup>10</sup> CO <sub>2</sub> <sup>5</sup> (CO,NH <sub>3</sub> ,H <sub>2</sub> ,N <sub>2</sub> ,Ar) <sup>4</sup> M <sup>70</sup>	SO4 <sup>80</sup> Cl,F <sup>16</sup> CO3 <sup>4</sup> Na <sup>46</sup> K <sup>20</sup> Ca <sup>14</sup> Mg <sup>13</sup> Fe <sup>7</sup>	0.9-3.8/2.1
Chalcopyritic			SO458C1,F28CO314	0.5-1.2/0.9
	5	H <sub>2</sub> O <sup>7</sup> H <sub>2</sub> S <sup>11</sup> CO <sub>2</sub> <sup>8</sup> (CO,NH <sub>3</sub> ,H <sub>2</sub> ,N <sub>2</sub> ,Ar) <sup>6</sup> M <sup>68-</sup>	Na <sup>33</sup> K <sup>28</sup> Ca <sup>20</sup> Fe <sup>14</sup> Mg <sup>5</sup>	
Chalcopyrite-sphalerite	2	H <sub>2</sub> O <sup>7</sup> H <sub>2</sub> S <sup>12</sup> CO <sub>2</sub> <sup>12</sup> (CO,NH <sub>3</sub> ,H <sub>2</sub> ,N <sub>2</sub> ,Ar) <sup>5</sup> M <sup>64-</sup>	SO4 <sup>66</sup> Cl,F <sup>20</sup> CO3 <sup>14</sup> Na <sup>29</sup> Ca <sup>22</sup> K <sup>18</sup> Fe <sup>17</sup> Mg <sup>14</sup>	0.4-0.6/0.5
Galena-sphalerite- sphalerite-pyrite	13	H <sub>2</sub> O <sup>13</sup> H <sub>2</sub> S <sup>7</sup> CO <sub>2</sub> <sup>4</sup> (CO,NH <sub>3</sub> ,H <sub>2</sub> N <sub>2</sub> ,Ar) <sup>6</sup> M <sup>70</sup>	SO4 <sup>62</sup> C1,F <sup>20</sup> CO3 <sup>18</sup> Na <sup>38</sup> Ca <sup>30</sup> K <sup>16</sup> Mg <sup>10</sup>	1.5-4.5/2.8
		Deposits of the Zhungar Alatau (Tekeli and Yabl	onevoe)	
Quartz-carbonate- galena-sphalerite	2	H <sub>2</sub> O <sup>70</sup> CO <sub>2</sub> <sup>16</sup> (H <sub>2</sub> S,CO,H <sub>2</sub> ,N <sub>2</sub> ,Ar) <sup>2</sup> M <sup>12</sup>	Cl,F <sup>55</sup> SO4 <sup>45</sup> Na <sup>78</sup> Mg <sup>8</sup> Ca <sup>7</sup> K <sup>5</sup>	4.0-4.8/4.4
		Alaigyr Deposit (Central Kazakhstan)		
Galena-quartz- sericite	2	H <sub>2</sub> O <sup>67</sup> H <sub>2</sub> S <sup>5</sup> (CO <sub>2</sub> ,CO,NH <sub>3</sub> ,H <sub>2</sub> ,N <sub>2</sub> ,Ar) <sup>7</sup> M <sup>21</sup>	Cl,F <sup>51</sup> SO4 <sup>46</sup> Na <sup>36</sup> K <sup>24</sup> Ca <sup>20</sup> Mg <sup>9</sup> Fe <sup>8</sup>	20.0
Galena-albite- quartz	ì	H <sub>2</sub> O <sup>66</sup> H <sub>2</sub> S <sup>4</sup> (CO <sub>2</sub> ,CO,NH <sub>3</sub> ,H <sub>2</sub> ,N <sub>2</sub> ,Ar) <sup>6</sup> M <sup>24</sup>	SO4 <sup>78</sup> Cl,F <sup>11</sup> CO3 <sup>11</sup> Na <sup>57</sup> K <sup>21</sup> Ca <sup>17</sup>	21.9
	Depos	its of the Karatau (Mirgalimsai, Achisai, Shalkiy	a, and Talap)	
Sulphide-quartz- carbonate	8	H <sub>2</sub> O <sup>75</sup> (H <sub>2</sub> S,CO <sub>2</sub> ,CO,NH <sub>3</sub> ,H <sub>2</sub> ,N <sub>2</sub> ,Ar) <sup>4</sup> M <sup>20</sup>	Cl.F <sup>58</sup> SO4 <sup>29</sup> CO3 <sup>13</sup> Na <sup>51</sup> Ca <sup>18</sup> K <sup>14</sup> Mg <sup>10</sup>	35-368/134
Sulphide-carbonate- barytes	4	H <sub>2</sub> O <sup>79</sup> (H <sub>2</sub> S,CO <sub>2</sub> ,NH <sub>3</sub> ,H <sub>2</sub> ) <sup>4</sup> M <sup>17</sup>	SO4 <sup>52</sup> Cl,F <sup>43</sup> CO <sub>3</sub> 6 Na <sup>37</sup> Mg <sup>23</sup> K <sup>13</sup> NH4 <sup>11</sup> Fe <sup>7</sup>	149-407/253
Sulphides in veinlets of Alpine type	2	H <sub>2</sub> O <sup>57</sup> CO <sub>2</sub> <sup>7</sup> (H <sub>2</sub> S,CO,N <sub>2</sub> ,Ar) <sup>7</sup> M <sup>29</sup>	CO3 <sup>58</sup> SO4 <sup>23</sup> Cl,F <sup>19</sup> Mg <sup>38</sup> Ca <sup>25</sup> Fe <sup>21</sup> Na <sup>12</sup>	3.5-12.2/7.9

Note. In the chemical-composition formulae, the following amounts (in wt%) of H<sub>2</sub>O, H<sub>2</sub>S, CO<sub>2</sub> and other gases, and the total salt concentration - M; and amounts (in eq.%) of Cl<sup>-</sup>, F<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, and other salt components, are shown. In the rubric 'H<sub>2</sub>O/(CO<sub>2</sub>+CO)', the numerator shows the limits of values, and the denominator, the average values.

little involvement of Ca, Mg and Fe. The quantity of CO<sub>2</sub> and H<sub>2</sub>S is of the same order as water, whereas the H<sub>2</sub>O/(CO<sub>2</sub> +CO) ratio varies from 0.4 to 4.5. As seen in Table 1, all this is typical of mantle F.

2. The pyritic-lead-zinc deposits of the Zhungar Alatau (Tekeli and Yablonevoe), located within the Tekeli fold zone, have been assigned to the Precambrian sequence. During Caledonian and Hercynian time, movements were renewed along the zone. The galena-sphalerite-pyrite ores in the form of layered bodies are conformable with the coaly-chert-carbonate rocks of the Tekeli Group, and had a hydrothermal-sedimentary and hydrothermal-metasomatic origin. The quartz-carbonate-galena-sphalerite aggregates of the hydrothermally-metasomatic ores contain (in the 1), an aq solution with a low salt content (12%), consisting of halogenides and sulphates of Na; the H<sub>2</sub>O/(CO<sub>2</sub>+CO) ratio is 4.4. Such a [fluid] composition is typical of metamorphic rocks of the eclogite and granulite facies. In the deposits, rocks of the amphibolite facies immediately underlie the ore-surrounding sequence. The existence of rocks of higher metamorphic grades at depth has not been excluded.

3. The Alaigyr Deposit (Central Kazakhstan) is located within bodies of rhyolitic porphyries, within the contour of hydrothermally-altered rocks. Lead-isotope studies of the galena and the ore-surrounding porphyries, K-Ar dating of the metasomatites and porphyries, and data based on the extraction of lead from the porphyries, all point to an association between the mineralization and the acid magmatic rocks. Analyses of F in the 1 of the ore-mineral associations have shown that they were formed with the involvement of aq solutions, which contained 21-24% of salts (chlorides and sulphates of Na and K; the values of the H<sub>2</sub>O/(CO<sub>2</sub>+CO) ratio in them is about 20. This composition of the solutions is not at odds with the view that the sources of the ore-bearing F were crustal granitoid magmas.

4. The lead-zinc deposits of the Karatau are located in Famennian and Tournaisian carbonate rocks in the form of layered, and also cross-cutting vein- and lensoid orebodies. Mineralogical and T-P-geochemical investigations have enabled us to separate three kinds of processes of ore formation: 1-hydrothermal-sedimentary, 2-hydrothermal in the lithified rocks, and 3-dynamometamorphic, which led to partial recrystallization and redeposition of the ores. In the minerals of the epigenetic associations, the FI contain aq solutions with 17-22% of salts (halogenides and sulphates of Na, K, and NH<sub>3</sub>), and they have small concentrations of H<sub>2</sub>S, and an extremely high H<sub>2</sub>O/(CO<sub>2</sub>+CO) ratio (on average 134-257), and a maximum of 407. All these features are inherent in deep buried waters which were evidently the source of the F for the lead-zinc deposits of the Karatau.

Some investigators are inclined to consider the sulphides in the late veinlets and post-ore breccias in the Karatau deposits as a manifestation of an additional phase of mineralization. From Table it may be seen that about 30% of salts are present in the make-up of the solutions in the I, consisting of carbonates and sulphates of Ca. Mg, and Fe, and they also have an increased amount of CO<sub>2</sub>. This suggests that these deposits were formed as a consequence of redeposition of material of earlier ores involving pore solutions, in the composition of which components of the country rocks predominate.

Table 2-Note. In the chemical-composition formulae, the following amounts (in wt%) of H<sub>2</sub>O, H<sub>2</sub>S, CO<sub>2</sub>, and other G, and the total salt concentration-M; and amounts (in eq.%) of Cl', F', SO<sub>4</sub><sup> $\star$ </sup>, Na<sup>\*</sup>, K<sup>\*</sup>, Ca<sup>2\*</sup>, and other salt components, are shown. In the rubric 'H<sub>2</sub>O/(CO<sub>2</sub>+CO)', the numerator shows the limits of values, and the denominator, the average values.

PLOTINSKAYA, O.Yu, KOVALENKER, V.A., PROKÓF'EV, V.Yu., and NÓSIK, L.P., 1998, The evolution and the nature of the fluid regime in the Kairagach epithermal gold-telluride deposit (Kuráminsk Mountains) (abst.): Second APIFIS Int'L Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 133-135 (in Russian). Authors Plotinskaya, Kovalenker and Nosik at IGEM RAN, Moscow; author Profok'ev at A.P. Vinogradov Inst. of Geochem. (RAN Sib. Div.), Irkutsk.

Geological construction The Kairagach deposit is located in the Priangrensk region on the northern slope of the Kuraminsk Range within a collapse caldera. The caldera has been filled with volcanogenic-sedimentary and subvolcanic andesites and andesite-dacites of Middle and Late Carboniferous age, which were disrupted by Early Permian diabase dikes. Propylitization and acid-sulphate metasomatism is expressed in the formation of alunitic and kaolinitic quartzites. Mineralization has been localized in the subvertical and gently-dipping zones of quartzification with quartz and quartz barite veins and zones of brecciation.

Phases of mineral-formation Four phases of mineral-formation have been recognized: 1) a phase of pre-ore metasomatites during which time berezites (quartz-pyrite-sencite-carbonate rocks) were formed; 2) a gold-quartz-pyrite or early ore phase consisting of metasomatic quartzites; 3) the principal ore or gold-fahlore-sulphosalt-telluride phase during the early stage of which an auriferous quartz-barite aggregate was formed, and in the late phases, quartz-barite veins with fahlores (goldfieldite and tetrahedrite), chalcopyrite, sulphobismuthites, and tellurides of gold and silver, and native gold. 4) a postore phase consisting of quartz-carbonate, barite and gypsum-anhydrite veinlets with galena, chalcopyrite, sphalerite, and pyrite.

Fluid inclusions Thermo- and cryometric investigations of Fl in quartz have shown that the Tf of the principal ore stage amounted to  $155-333^{\circ}C$  (4 samples, n=133), and the post-ore stage,  $130-390^{\circ}C$  (2 samples, n=53). The F were mainly weakly saline (1.0-6.0 eq. NaCl). Boiling of the F occurred, accompanied by the release of CO<sub>2</sub> (in one of the Gl, CO<sub>2</sub> of low density is present, with a Tm of -56.6°C). The P, determined from 1 from the boiling zones ranged from 12 up to 120 bars. This has enabled us to estimate the depth interval of formation of the deposit as of the order of from 100 m down to 1-1.5 km, if it is accepted that the P was hydrodynamic. According to the Te values (Borisenko, 1977), it has been established that the F of two kinds took part in the formation of the principal ore phase: with predominance of NaCl, and with predominance of Mg- or Fe-chlorides. During the post-ore phase, essentially K and essentially Ca F were added to them.

 $\delta^{18}$ O of quartz and sericite The  $\delta^{18}$ O of quartz of the early ore phase amounts to +9.69 to +10.39‰ (SMOW), the principal ore phase, +3.39 to +11.05‰ and the post-ore phase, +0.47±8.12‰. The  $\delta^{18}$ O of sericites from the berezites amounts to +0.8‰, those of the early ore phase +2.3‰, and of the main ore phase +5.3‰ (Kovalenker et al., 1994). The calculations (Field & Fifarek, 1985) have shown that the  $\delta^{18}$ O of the mineral-forming F has increased from -4.2‰ during the phase of pre-ore metasomatites to -4.9 to -0.86‰ during the early ore phase and to +3.47 to +0.3‰ in the main ore phase, and during the formation of the post-ore phase it fell to -0.83‰ (Fig. 1). The values obtained may be both the result of enrichment of the meteoric waters in  $\delta^{18}$ O (water from the Paleozoic sediments in the region amounts to -8.5 to -9.5‰ (Chernov & Sultankhodzhaev, 1989)), and also of depletion of the F of magmatic origin in  $\delta^{18}$ O, as a result of isotope exchange with the country rocks at a T ranging from 200 to 300°C, and a water/rock ratio=0.1.

 $\delta^{34}$ S in sulphides and sulphates This factor in pyrite from the early ore phase comprises -1.47 to -0.64‰ (CDT), in minerals from the main ore phase in pyrite it is -5.10 to -4.54‰, and in barite it is +9.22 to +21.17‰ for the early mineral associations and +13.96 to +24.0‰ for the late associations; in barite from the post-ore phase, it is +6.98 to +22.03‰, in pyrite, +0.72 to +1.72‰, and in galena it is -5.1 to -0.61‰ (Fig. 2).

The marked increase of  $\delta^{34}$ S in barite and the relatively small increase in pyrite indicate that in the F, during the formation of the ore phases, H<sub>2</sub>S predominated \*\*\*\*over SO<sub>4</sub><sup>2</sup> and that the  $\delta^{34}$ S if the F amounted approximately to +3 to +5‰ (Ohmoto, 1986; Rye, 1993), which matches the isotope composition of sulphur of magmatic origin (Field & Fifarek, 1985).

The lower values of  $\delta^{34}$ S in barite from the post-ore phase are explained by the fact that barite was formed not in an acid medium, as in the ore phases, but in a neutral medium, where the sulphide-sulphate isotope fractionation has been intensely retarded, and possibly, by partial oxidation of H<sub>2</sub>S as a result of mixing with oxygen-bearing meteoric waters.

Increase in 8<sup>34</sup>S barite with depth has been observed, which is explained by differences in the velocities of cooling of the F in depth and close to the surface (Ohmoto & Lasaga, 1982). The T, calculated from the galena-barite V of the post-ore phase from the lower horizons of the deposit amounts to 293°C, which agrees with data from the FI and indicates the existence in depth of conditions close to equilibrium.

The combination of data from the study of stable isotopes and the geochemical profile of ore mineralization suggests that the F of the Kairagach deposit, initially had a mixed meteoric-magmatic nature, and in it there was a predominance of NaCl. During the pre-ore and ore phases, the F was gradually enriched in  $\delta^{18}$ O and chlorides of Mg and Fe as a result of exchange with the country rocks, whereas during the post-ore phase, owing to dilution with meteoric waters, it was depleted in  $\delta^{18}$ O and enriched in KCl and CaCl<sub>2</sub>. The work was carried out with a financial grant from the Russian Foundation for Fundamental Investigations, Grant No. 98-05-64052. The authors express their gratitude to V.R. Geinke and V.V. Pomortsev for assistance in collecting

# PLOTINSKAYA, et al. Figure 1



- ♦ sericite
- calculated values in fluid from sericite

# PLOTINSKAYA, et al. Figure 2



## the factual material.

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The problem of water sources in the crust and the role of water in endogenic geological processes is one of the most difficult in geology. However, in spite of lengthy investigations, it still remains disputable in many aspects and is extremely topical. Current views about this problem may be reduced to the following three concepts.

 Magmatism, metamorphism, and ore-formation take place mainly under the influence of mantle 'trans-magmatic solutions', according to D.S. Korzhinsky, depending on the degree of percolation through the crustal rocks, evolving in composition from originally-reduced to early-alkaline, and then to acid and late-alkaline kinds. Moreover, the heat introduced by these solutions and released during their oxidation serves as the principal source of energy for these processes.

The evolution of metamorphism and granitoid magmatism in the crust is stimulated by the heat and fluids injected into its base by mantle basaltic magma.

3 The main factors in the manifestation of most of the endogenic geological processes are exogenic energy (mainly solar) and water, buried in the crustal rocks and remobilized during their progressive metamorphism.

At the present time, serious objections are being raised against the first two concepts, mainly as follows. The rising mantle F (according to H. Termier) which have served as the prototype of the 'trans-magmatic solutions', in modern parlance are the plumes of 'hot spots' and determine the manifestation, not of a granitoid but of an alkali-basalt magmatism, both in the oceanic and also in the continental crust. Having probably served earlier as the most weighty arguments in favor of the existence of these solutions, the application to the granulite complexes of granitization and a lower-T metamorphism, for example, in the Vakhan Series of the Southwestern Pamir has produced a more logical and well-founded explanation for the influence of the F released during metamorphism and the remelting of the hydrated rocks of the oceanic crust in the subduction zones, which have sunk beneath the continental blocks. Beyond the active continental margins, even in the deepest levels of continental crust exposed by erosion (Greenland, the Canadian Shield, etc.), beneath the zones of high-T metamorphism and granite-formation, closely contemporaneous with them, no manifestations of mantle F and basaltoid magmatism have anywhere been reliably identified. It has also been revealed that the mantle F consist mainly of hydrogen, hydrocarbons, and carbonic acid, and water is virtually absent from them. In this respect, the first two concepts are now only of historical interest. Some historical data on equipment development and the workers involved is also given.

The third concept is more promising for resolving the problem under consideration. According to an assessment by A.B. Ronov and A.A. Yaroshevsky, the rocks of the present crust include  $0.38 \times 10^{24}$  g of chemically-combined water (H<sub>2</sub>O<sup>+</sup>) with an average content of 2.4%. According to the former author's calculations (Fig. 1), and allowing for the average chemical compositions of the principal petrographical types of metamorphic rocks (A.A. Marakushev), these P values in their original substrate (based on minimal estimates) were respectively 0.58 × 10<sup>24</sup> g and 3.7%. During progressive metamorphism from the phyllite to the eclogite facies, as a result of multiphase dehydration of the rocks, the average amount of chemically-combined water in them diminished by 1.3% with a water yield of up to 187.6 kg/m<sup>3</sup>. Finally, this led to the release of about 35% of this water with an overall mass of 0.2 x 10<sup>24</sup> g, which comprises 9% of its total amount in the Earth (2.2 x 10<sup>24</sup> g and 14% of the waters of the World Ocean). Such a gigantic amount of water (200 x 10<sup>12</sup> tonnes by weight and 200 M.km<sup>3</sup> by volume) has been involved in the endogenic geological processes, and currently participates in the surface waterexchange. The seepage of water from mantle sources in this way was evidently not significant, because it was restricted by the later superimposed zones of rifting and magmatism of the 'hot spots', but it plays a major role in the formation of the oceanic crust.

A general scheme for the behavior and role of water in the formation of continental crust may be presented as follows:

The chemically-combined water, buried during sedimentation and [?] hydration in the rocks of the phyllite facies, is released during the higher-T metamorphism and forms metamorphogenic mineralized solutions and supercritical F. Their migration and the redistribution of matter associated with it, including ore components, result in local T-P-gradient fields, with relief of stress mainly in the fault and crush zones and the formation of ore-bearing pegmatilic, quartzose, and other veins and various metasomatiles. These solutions and F comprise a single upwardly-open hydrophysical system in the crust and the adjacent upper mantle, which is emphasized by the regular change in their composition. From a study of the mineral parageneses and FI, it has been ascertained that the proportion of water in them in rocks of the phyllite facies is markedly predominant (0.8-0.95), in those of the granulite facies it gradually diminishes to 0.2, and in the eclogite facies, it is virtually zero, which is compensated mainly by CO<sub>2</sub>. This agrees completely with the lowering of water yield with depth and the progressive decarbonation of the rocks.

In the granulite and eclogite facies, final breakdown of the hydroxyl-bearing micas and amphiboles takes place, with the formation of dissociated highly-mineralized silica-alkaline F, supercritical in a marked degree. Their appearance indicates a fundamental discontinuity in the evolution of the entire hydrophysical system and in the crust as a whole, with its transition to a continental type. Because of the high energy-state, these F migrate into the overlying rocks of the amphibolite facies and determine their metasomatic granitization, up to the stage of formation of various metagranitoids (gneiss-granites, gneiss-tonalites, etc.), and also the inflow of energy, apparently mainly as a result of recombination of the water molecules. When attaining low-melting eutectoid compositions and amounts of water of the order of 2%, they undergo selective melting with the formation of migmatites and akmolith bodies of abyssal leucogranites. After passing through the M phase of optimal volume (26-30%) and the transition T of  $\alpha$ - $\beta$  quartz (575°C), the granitized and migmatized rocks acquire increased plasticity and a capacity toward rheomorphic injection of the entire mass, and form large diapiroid granite-gneiss domes and swells.

They rise to the level of more water-saturated rocks (3.4-6.7%) of the greenschist and phyllite facies (4-6 km from the surface) and actively interact with them. In this instance, transvaporization of the mobilized F in the surrounding medium takes place, along with its osmotic distillation in the migma of the apical portions of the granite-gneiss domes in which the water content increases to 4-5%. The physicochemical and energy aspects of these processes have been substantiated by V.A. Nikolaev and V.A. Zhankov. We may note only that the solution in the M of one gram of water vapor is accompanied by the release of 170 calones, which exceeds by more than twice the average heat of melting of silicates (75 cal/g.). This leads to additional warming-up and remelting of the rocks of the granite-gneiss domes and to the formation of para-autochtonous S foci of a relatively homogenized palingenic granitoid magma, with cooling-off of the forming 'basite' plutons, the compressed laccolith-like shape of which is supported by geological and geophysical data. Its

composition and ore-capacity are mainly determined by the petrochemical and geochemical features of the parent rocks and partly by interaction with the surrounding sequence on the site of emplacement. The introduction of F also ensures an increase in volume, and as a consequence, in the dislocation P of the palingenic magma and its injection into higher crustal levels, as far as the surface, with the formation of allochthonous intrusive bodies of granitoids, and sometimes volcanics. The release of postmagmatic F and solutions from the magma is achieved as a result of its boiling and marked decompression, or the subsequent release, depending on lowering of the T of the intrusive bodies, during three principal phases: its polymerization, and the crystallization and cooling-down of the rocks. This defines the specific nature and the multiphase pulsation character of the ore-formation associated with them. In conclusion, we may note that after the relief of stress and cooling-down of the postmagmatic and more deeply-seated metamorphogenic F and solutions, the water contained in them is returned through near-surface thermal and subsurface springs to the hydrosphere, terminating its complete cycle of circulation in the Earth's crust.

FIG 1: Graph of rock dehydration during progressive metamorphism. Facies of metamorphism: 1) phyllite; 11) greenschist (glaucophane), 111) amphibolite (garnet-glaucophane); 1V) granulite (garnet amphibolites). V) eclogite. Curves of rock dehydration: A) subduction eclogite-glaucophane; B) continental-margin charnockite-andalusite-schist types of metamorphism: C) metamorphic complexes of the Southwestern Hissar Region; D) the Front Range of Karnchatka. Abcissa, metamorphic facies; Ordinate, content of combined water (H<sub>2</sub>O+)

SLODKEVICH. V.V. and SHAFRANOVSKY, G.I., 1998. The diamondiferous mineral association of gas-fluid origin in the Bel'tau stratified pluton (Uzbekistan) (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis. Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 45-46 (in Russian). Authors at VSEGEI, St. Petersburg.

The number of discoveries of diamonds of non-kimberlite origin in various kinds of rocks continues to grow, which predicates the accumulation of data for the precise determination of the processes of formation (sometimes not trivial) and preservation of diamonds. The 'survival' of diamonds under metastable conditions is restricted by the readily achieved possibilities of oxidation, solution, or polymorphism. The last situation seems to be the strongest negative factor in their preservation in intrusive bodies, where conditions of quenching are attainable in complex ways, leading to the formation of a graphite paramorph after diamond.

The accepted procedure for exposing the apo-diamond nature of the polycrystalline aggregates of graphite from the garnet clinopyroxenites of the Beni-Bushera pluton in Morocco, and [shown] in a number of prospects in Kazakhstan, Siberia, and Spain, has also been used as proof of the extradiamond nature of lherzolites (the wehrlite-clinopyroxenite-gabbro Bel'tau Pluton in Uzbekistan (Slodkevic, 1987)). From the residue of thermochemical disintegration of a 552 g sample of a phlogopite-plagioclase lherzolite, we separated 48 polycrystalline aggregates of graphite measuring from 0.05 to 0.7 mm, having rhombdodecahedral, octahedral, and isometric habits, and also their combined forms. The core portion of the paracrysts consists of graphite flakes textured along four directions.

From the core of one of the graphite polyhedra, we discerned under the binocular microscope a diamond relict (0.056 x 0.056 x 0.070 mm) with a weakly defined cubo-octahedral habit and a matte surface. The smoothness of the forms increases toward the cube edges, that is, being complicated by arcuate embayments. The grain, weakly anisotropic under crossed nicols and translucent in transmitted light, is traversed by fine planar cracks, oriented along octahedral directions, and bearing micro-inclusions of graphite. Under UV illumination, there is a yellow [fluorescence].

We were unable to determine the carbon-isotope composition of the diamond, but for the associated paramorphoses,  $\delta^{13}$ C is -18.4‰. Since the isotope shifts for phase transitions in the graphite-diamond system are insignificant, it is suggested that there is also correspondence in the values of  $\delta^{13}$ C in the present instance. A remarkable feature of the paramorphoses is the presence of fullerenes of C70 and traces of C63, C68 and C75.

Diamond has been identified by the method of combination dispersion of light (CD) and laser photoluminescence (PL). The CD spectrum shows an intense peak at 1334 cm<sup>-1</sup> with a high-frequency shift and amplification up to 5 cm<sup>-1</sup> as compared with the parameters of the standard (1332.5 and 1.65 cm<sup>-1</sup>, respectively). In the PL spectrum, against a background of broad bands in the area of 520 and 680 nm, there are lines (without background) at 503 and 638 nm (defects H3 and 638 nm, additional to centre C). Their amplification indicates the high defect nature of the crystal (which is also emphasized by optical heterogeneity), associated with the presence of [impurity] nitrogen, or by stresses caused by internal graphitization.

The textural features of diamond from the graphite paramorphosis demonstrate its significant difference from the high-P naturally-synthesized diamonds, and congruence with diamonds, obtained by the method of vacuum condensation from a methane-hydrogen mixture at 50 mm Hg P and 700-900°C (Miamoto et al., 1993). The characteristics of the CD spectrum (high-frequency shift of Raman lines, anomalous amplification of non-background lines, and the high concentration of vacancies) are regarded as a typomorphic feature of the analysed diamond, emphasizing its natural genetic individuality and its formation from a water-methane G-F phase at moderate T, low P, and high growth-velocities. The discovery of diamonds in polycrystalline graphite aggregates is a unique forecast event and serves as a direct proof of their apo-diamond nature.

A peculiarity of the diamondiferous phlogopite-plagioclase lherzolite is the presence in it of mineral associations of P (olivine, ortho- and clinopyroxene, plagioclase, pargasite, phlogopite, pleonaste, ilmenite, zircon, and sulphides) and introduced (calcite, phlogopite, chlorite, prehnite, amphibole, diaspore, scapolite, apatite, fluorite, moissanite, pyrite, and other sulphides) [origin.] The former category is associated with sporadically-appearing graphite, and the latter with graphite and diamond.

The place and time of appearance of minerals of crystalline carbon is determined by the following factors: 1) the occurrence of paramorphoses in the lower third of the section of the pluton in interstratified units of phlogopite-plagioclase lherzolites, wehrlites, clinopyroxenites and gabbro-norites; 2) the presence of diamond relicts exclusively in the near-sole ultramafic rocks; 3) the absence of any relationship between the dimensions and habits of the forms, and the topographic position; and 4) a paragenetic association with the introduced mineral associations. Of the three recognized G-F flows with chloride-lime sodic, hydrogen-methane phosphate-potash, and water-carbon dioxide alumina geochemical specializations, the most saturated in carbon is the second. The diamondiferous mineral association is clearly situated within the second category, filling the thin veinlets and amygdales.

The restriction of the apo-diamond graphite to the through zones of epigenetic mineralization and their temporal detachment from the enclosing mineral medium indicate formation of diamonds in the low-T-P regime of G-L infiltrating currents during emplacement of the stratified pluton in an open magma chamber. Consequently, the Bel'tau Pluton may be the first petrotype in which hydrothermal-pneumatolytic conditions for the origin of diamond have been achieved

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SOKERINA, N.V. and SHANINA, S.N., 1998, Features of formation of quartz veins in the area of the Sinil'ga Prospect (abst.): Second APIFIS Int'l. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998, Tashkent, Uzbekistan, Abstracts volume, p. 111-112 (in Russian). Authors at Inst. of Geol. of Komi Scientific Centre, Uralian Div. of Russian Acad. of Sci., Syktyvkar.

The vein-type Sinil'ga Prospect was discovered in 1984. In structural respects it is confined to the axial part and western limb of an anticlinal fold, in the core of which slates of the middle sequence of the Puivinsk Group have been exposed. The rocks have been disrupted by three systems of fissures. 1) dip to 310-312° at 80-90°, 2) dip to 000° at 30-33°, 3) dip to 170-190° at 50-60°.

The auriferous veins have a typical structural plan, sharply transecting the stratification of the country rocks, filling the transverse breakaway fissures (Tarbaev & Kuznetsov, 1994). The strike of these veins is sublatitudinal, with a dip to 160-180° at 50-80°. The form of the veins is laminar, with a thick-

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ness of from 3-5 cm up to 40-50 cm.

Occasionally, there are swells up to 1 m thick. The contacts with the country rocks are distinct and disrupted. The peri-vein rocks have been intensely altered by hydrothermal solutions.

Various kinds of quartz veins have been sampled. A visual study of the GLI under the microscope has shown that the vein quartz from the conformable veins typically has a small number of GLI. Among them we commonly find single-phase LI. Less often we find two-phase I with a content of the G phase of up to 15%. The Th of the GLI in such formations does not exceed 220-260°C. An analysis of the aq extracts has shown a relatively large amount of  $Ca^{2*}$ , HCO<sub>3</sub>\*, and SO<sub>4</sub><sup>2\*</sup>. According to the chromatographic data, the amount of G in such I is insignificant. The H<sub>2</sub>O/N<sub>2</sub> ratio varies from 4.7 to 20.29. The G saturation of the rock is 4.82-128.1 mg/kg.

A study of the GLI from vein quartz in the cross-cutting veins has enabled us to reveal some patterns typical of the gold-ore quartz of this territory. Chromatography has revealed a large amount of CO<sub>2</sub> and N<sub>2</sub>. The ratio H<sub>2</sub>O/N<sub>2</sub> varies from 0.97 to 18. The G saturation of the rock is 41.5-120.7 mg/kg. In the ag extracts, relatively large amounts of Ca<sup>2+</sup>, HCO3<sup>+</sup>, and SO<sub>4</sub><sup>2+</sup> have been observed.

As a result of visual observation and the use of homogenization data, it is possible to recognize several stages of hydrothermal development.  $N_2$ ,  $CO_2$  and  $Ca^{2+}$ ,  $HCO_3^-$ , and  $SO_4^{2-}$ .

 High-T stage. This is marked by three-phase I (water-L CO<sub>2</sub>-G) with a Th of 340-375°C, while solution of the G phase in the L CO<sub>2</sub> already takes place under the influence of the microscope lamp, and homogenization progresses according to the second type. The amount of L CO<sub>2</sub> makes up 80%.
 Medium-T stage. This is marked by two-phase I with a G-phase volume of 30-40%. Th is 255-295°C, and homogenization proceeds according to

the first type.

3. Low-T stage. This stage is marked by two-phase I with Th of the order of 190-220°C. The amount of G phase is 15%.

4. Low-T stage, marked by an amount of G phase of the order of 0-5%, with Th up to 165°C.

From the results of the investigations, we may reach the following conclusions:

1. The T interval of formation of the quartz veins in the territory under discussion is very wide, but the formation of this particular gold-ore association took place in the range of 340-375°C.

2. The formation of this prospect has involved hydrothermal solutions containing an increased amount of N2, CO2 and Ca2+, HCO3 and SO47-References

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In this paper, new data are presented on the nature of ore-bearing quartz-carbonate veins in some Au-Ag deposits of Karamazar. In this respect, ideas about the age of the mineralization, the direction of research work, and the prospects for Au-Ag mineralization have been altered. The main objects of study are Nadak and Charbi, located in the southern part of the Lashkerek volcanic structures. In addition for comparison, specimens similar in origin from deposits at Aprelevka and Kyzylcheku, and also the Sallyatash limestones (Lower Carboniferous) with cherty concretions, have been examined. Genetically related objects in the Kuraminsk Range are those at Shkol'noe and Chadak.

Detailed mineralogical investigations, carried out in the deposits at Nadak, Charbi, Shkol'noe. Aprelevka, Kyzylcheku, and Chadak, and the Verkhnekattakashkasai prospects, and also a study of the sections of the Sallyatash limestones, and dolomites with cherty concretions, has enabled us to obtain a new glance at the geological situation in the deposits at the above-mentioned sites. In our opinion, the auriferous quarz-carbonate veins at Nadak. Charbi, and other places, are blocks, packets, and sheets of carbonate sedimentary rocks that have been altered during the process of metamorphism, and under the influence of ore-bearing hydrotherms.

In the stratigraphical columns at the bases of the Akchinsk and Nadak Groups, we have noted carbonate sedimentary rocks in the form of lenses, blocks, xenoliths, and packets. And the 'veins' examined are precisely located in the Akchinsk or Nadak volcanics.

With a series of mineralogical-geochemical methods, we have attempted to demonstrate the apo-carbonate (sedimentary) nature of the auriferous quartz-carbonate 'veins'. The complexity of the demonstration lies in the fact that these carbonate rocks have undergone metamorphism through the injection of younger magmatic rocks, and also hydrothermal solutions. The significant role of metamorphism may be judged from the extensive fields of S quartzites developed through the Akchinsk volcanics close to the Verkhnekattakashkasai prospects and the Nadak deposits. A sketch of the formation of the auriferous quartz-carbonate 'veins' may be presented in the following form. Onto the Akchinsk and Nadak carbonate-bearing volcanics were superimposed auriferous hydrothermal, essentially silicate solutions, as a result of which the carbonate rocks, frequently with cherty concretions (analogs of the Sallatash limestone (Lower Carboniferous)), have been transformed into silicified porcellanous rocks resembling quartz veins. In outcrop, the surface of these 'veins' looks like that of the Sallyatash limestones with an upper carbonate portion and ridges of chert (?). On the fresh surface, they look like quartz veins. The gold mineralization, in our view, is synchronous with that of the diabase porphyntes (Mid-Permian to early Triassic). This is con-firmed by the data of Lisogor & Turtychkin (1975) on the innoculation of the diabase porphyrites with gold.

In interpreting the results of analysis, we must take account of the effect of metamorphism and the superimposition of the auriferous hydrotherms on the carbonate rocks.

The thermoacoustic decrepitation curves for the Nadak chert concretions differ in the lower decrepito-activity and the absence of significant peaks. Allowing for the similar low decrepito-activity of the chert concretions in the standard Sallyatash limestones, we can remark on the initially sedimentary nature of the Nadak chert concretions. The choice of the chert concretions and not calcite for decrepitation studies has been conditioned by the false sound effects produced by calcite, owing to its cleavage.

Thermoluminescence (TL) studies of the calcites from the Nadak, Aprelevka, Kyzylcheku, Chashma-Dinar and the Sallyatash Mountains have established that they have similarities and differences. Thus, the TL curves for the hydrothermal calcites of Chashma-Dinar are marked by the low intensity of thermoluminescence and by the presence of two peaks at T of 250 and 325°C, and also a single peak at 315°C. The TL curves for the Sallyatash calcites differ markedly from the purely hydrothermal calcites of Chashma-Dinar. The former are marked by the high intensity of thermoluminescence with two peaks at 235°C, 315°C (Sample No. 3169) and 250°C, 310°C (Sample No. 3168). An intermediate position in TL intensity is occupied by the calcites from Nadak, Aprelevka, and Kyzylcheku. In the Nadak calcites, three-quarters of the peaks occur at 70°C, 235°C and 370°C. Calcites from Kyzylcheku and Aprelevka, collected from similar formations, are marked by two peaks. The maxima at 235 and 325°C correspond to the radiation bands of the Mn<sup>+2</sup> centre in calcite. The low-T peak (at 70°C) has been associated with luminescence in the lattice defects (anion complexes). The high-T peak has so far no definite interpretation, and is apparently associated with certain additives or additional energy obtained as a result of some processes.

In general, from the intensity of thermoluminescence, the calcites from Nadak, Aprelevka, and Kyzylcheku occupy an intermediate position between the hydrothermal calcites of Chashma-Dinar and the sedimentary calcites of the Sallyatash Mountains. Hence, the quartz-carbonate formations of the Nadak deposit could have an initially sedimentary origin, having subsequently undergone repeated alterations, associated with volcanic and hydrothermal activity.

The carbon- and oxygen-isotope composition of the carbonates is of important and genetic-information value (Yushkin, 1986). For comparison, the results of isotope analysis have been plotted on a Taylor diagram, with additions from Plyusnin and Savel'ev. The CO<sub>2</sub> of the Nadak carbonates is not of

# TSÓI, et al Table 2: Average amounts of water and gases in the fluid inclusions from the fluorite of the Karabash and Chilten Depressions

Deposit gases Ore-prospect	Mineral Association	H <sub>2</sub> O, %	CO <sub>2</sub>	CO	CH4	Total
Kamyshly	Quartz-barytes-fluorite with polymetals	0.0293	1.4275	0.0914	0.0885	1.60
Karabau	Quartz-barytes-fluorite with polymetals	0.0169	0.5355	0.1355	0.055	0.7265
Kuakol'	Quartz-barytes-fluorite with polymetals	0.0155	0.3813	0.2127	0.093	0.693
Kichik-Arsagan	Quartz-barytes-polymetallic with fluorite	0.0260	0.3260	0.1335	0.036	0.4977
Agata-Chibargata	Quartz-barytes-fluorite with polymetals	0.0293	1.2314	0.1088	0.0987	1.4389

Amount of gases in mols/liter of water

Note. The analyses were carried out on an LKhIM-8MD gas chromatograph. Analyst S.E. Lebedeva (IGG AN Uzbekistan).

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Table 3: Results of chemical analysis of aqueous extracts from fluorite taken from the Chilten and Karabash calderas (average amounts, %)

Deposit, ore-prospect	1	CI-	1	K+	1	Na <sup>+</sup>	1	Ca++	Mg++
Agata-Chibargata	1	2.52	1	0.26	1	0.98	1	6.67	0.18
Kichik-Arsagan	4	1.80		0.18	1	0.36	+	5.02	0.11
Kamyshly		2.47		0.26		0.56		4.58	0.13
Karabau		2.10	1	0.26		0.61	1	9.35	0.47
Kuakol'		2.28		0.89	1	0.45	1	7.24	0.46

Analyses carried out in IGG AN Uzbekistan. Analysts S.E. Lebedeva, Y.Yu. Khomenko, and A.D. Kosolapov.

normal sedimentational diagenetic origin, but has undergone an extremely substantial disproportionation both with respect to carbon and also to oxygen. At the same time, the area of distribution of the isotope values for the Nadak carbonates does not coincide with that of the pure hydrothermalites, that is, it appears that the Nadak carbonates have an extremely complicated origin, being initially sedimentary with the subsequent effect of volcanic, hydrothermal (epithermal), and metamorphic processes. The Nadak carbonates, as a consequence of these processes, have undergone repeated redeposition. Evidence of this redeposition is clearly observed in the thin-sections.

The proposed treatment of the nature of the quartz-carbonate veins places in doubt the existence of a pre-Nadak gold mineralization. From our data, gold mineralization in the quartz-carbonate 'veins'is of a later Permian-Triassic age

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Geological construction. The Chilten Depression is a volcanotectonic structure of caldera type with an area of 250 km<sup>2</sup>. It consists mainly of rocks of the Lower Permian rhyolite association (lavas and tuffs of rhyolite-dacites, rhyolites, trachyrhyolites, trachytes, and ignimbrites). In the interior part of the depression, there are subvolcanic and extrusive facies, and along the periphery, explosion facies (Tulyaganov, Yudalevich & Korzhaev, 1984). Two fluorite-bearing areas have been recognized: the Karabau-Alatan ginsk, set in the central part of the depression in the zone where the Chilten and the Kuakol'sk Faults intersect, and the Arsagansk area, in the southeastern part, in the zone of the Arsagansk Fault, which feathers the Kokrel'sk Fault. Fluorite mineralization is distributed among the Lower Permian volcanics. The largest fluorite prospects in the Karabau-Alatan ginsk area are: the Karabau, Kamyshly, and Kuakol' ore-prospects, and in the Arsagansk area, the Kichik-Arsagan deposit. In terms of structure, numerous fluorite prospects congregate around a branch of the Chilten Fault.

Characteristics of the ore zone of fluorite prospects in the Chilten Depression. The ore zones extend for 100-1000 m. The ore bodies consist of a series of steeply-dipping lensoid veins of quartzose, quartz-barite, quartz-barite-fluorite, and calcite-fluorite composition with an impregnation of sulphides. Galena is the predominant sulphide, and there is a subordinate development of sphalerite (cleiophane), pyrite, and chalcopyrite. The amount of fluorite in the ore bodies varies from 15 to 90%. The ore bodies are 1-5 m thick. Those in the central part consist of the quartz-barite and quartz-barite-fluorite mineral associations, and toward the selvedges, there is an increase in the amount of quartz with an impregnation of sulphides. The selvedges consist of quartzified rocks with a breccia-like texture with a grey hornfelsed quartz.

The process of ore-deposition under conditions of active intra-ore tectonics was multiphase. Up to 3-5 fluorite generations and 3-7 quartz generations have been recognized. Similar paragenetic mineral associations have been developed in the Karabau, Kamyshly, and Kuakol' ore-prospects, and the Kichik-Arsagan deposit: 1. Black-quartz - pyrite - sphalerite-molybdenite (Kichik-Arsagan deposit); 2. Quartz-barite-sulphide; 3. Quartz-barite-fluorite; 4. Quartz-carbonate-sulphide, 5. Silicate-carbonate. The quartz-barite-fluorite mineral association is productive in fluorite.

A study of the FI by various methods of thermobarogeochemistry has enabled us to obtain some idea of the composition, and the T interval for the formation of the productive mineral association. Fl occur in all of the mineral associations, but the largest are developed in the fluorite (10-20 µm). In the fluorite, predominantly PS FI with rhomboid (octahedral) and multifaceted three-dimensional morphology have been developed along with S FI of irregular compressed shape, confined to sealed microcracks of different order. Apparently, the intense processes of intra-mineralized tectonics contributed to the elimination of the P FI, and to the preservation of the predominantly PS and S forms. P I have been developed in the form of negative crystals (tetrahedra) and are marked by a random distribution within the fluorite grains and through the zones in the case where zoned aggregates of coarsely-crystalline fluorite has been developed. Such FI have been found in fluorite from a fluorite breccia from the lower zones of the ore body of the Kuakol' ore-prospect (area of the old adit), and in fluorite from a quartz-fluorite veinlet in the Kichik-Arsagan deposit. In the Kuakol' ore-prospect, aggregates of coarsely-crystalline fluorite of 'ocean-wave' color, and columnar-crystalline structure in the form of incrustations, cover altered fragments of the country rocks, creating a cockade texture. In the Kichik-Arsagan deposit, coarsely-crystalline fluorite of greenish color and translucent, fills a cavity in a quartz vein. Fluorites of such kind contain a small number of FI, including P F, and possibly, processes of recrystallization and redistribution of material had occurred. Coarselycrystalline aggregates of fluorite from a mineralized crush zone in the Agata-Chibargata deosit (Karabash Depression, southwestern spurs of the Chatkal Range), formed under such conditions, also contain P FI in the form of tetrahedra. Apparently, preservation of the P FI was associated with the conditions of fluorite formation, deposition in a relatively quiet tectonic environment, in the presence of free cavities with good circulation of the ore-forming solutions

The phase composition of FI in fluorites from the ore-prospects of the Chilten Depression: L, aq one-, two-, and three-phase FI (with a phase of L CO2), and rarely multiphase (1-2 anisotropic solid phases are present), have been developed. The G phase content ranges from 5 to 12% (Table 1). The phase of L CO2 has been visually noted in the form of a rim around a G bubble, and during heating it has been homogenized into the G phase at a T below 31"C (Roedder, 1987). An analysis of the morphogenetic features of the FI leads to the conclusion that in the later portions of the hydrothermal solutions the CO2 content diminishes: the S FI are essentially aq in composition, and G-L. And only in the Kamyshly ore-prospect do the S FI contain a rim of L CO2 (Table 1).

The stage-by-stage G-chromatographic data also show that in the fluorites of the Chilten Depression there are two kinds of FI: 1. Low-T aq; and 2. Relatively higher-T aq FI containing CO2, CO and CH4. CO2 predominates in the G component (Table 2). The largest amounts of CO2 are in the fluorite from the Kamyshly ore-prospect, which is comparable with those in the fluorite from the Agata-Chibargata deposit

Cryometric studies of F1 in fluorite from the Chilten Depression have shown that the ore-forming solutions were weakly concentrated. This is also indicated by the constant presence of 'metastable superheated ice under negative P in the L aq solutions' during the conduct of experiments (Roedder, 1984 [1987?]). According to the results of chemical analyses of an aq extract, the ore-forming solutions contain ions of F. Cl. K. Na. Ca and Mg. The geochemical kind of aq extract is comparable with that from the Agata-Chibargata deposit: fluoride-bicarbonate-Ca Na (Dunin-Barkovskaya, Lebedeva & Evtushenko, 1987). The Na\*/K\*>1, which suggests a deep-seated source of fluorite [sic] for most of the fluorite prospects in the Chilten Depression.

The determination of Th of the Fl from the fluorite in the Chilten Depression shows that the low-medium-T intervals of mineral-formation are 80-190°C (Table 1). Moreover, this interval in the Karabau ore-prospect is 120-180°, at Kuakol'-120-140°, and at Kamyshly-80-160°, and in the Kichik-Arsagan deposit-100-190°. PS FI in fluroite have higher Th as compared with later S FI-110-130°C. As is known, the Th of the FI give extremely minimal values for the T of mineral-formation (Ermakov, 1972).

The set of data, obtained by various methods of T-P-geochemistry during a study of the FI from fluonte in the ore-prospects of the Chilten Depression, suggest that the formation of the productive association of fluorite mineralization took place in the T range of 80-190°C from weakly concentrated (<6%) ore-forming solutions, in which ions of Cl, Na, K. Ca and Mg had been dissolved. There is a predominance of CO2 in the gaseous component of the F. Mineral-formation took place against a background of overall lowering of T of the hydrothermal solutions. A deep-seated source of fluorine is suggested References

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Table 1:	Homogenization temperatures (Th) of FIs of Chilten Depression Fluori	ites

Ore-prospect	Association	Color	FI Kind	*Phase Composition	Amount of Gas Phase in%	Th
Kuakol'	Quartz-fluorite	Gray-blue	Primary- Secondary		7-10 5	135-150 115
Kuakol'	Quartz-fluorite	Gray-blue	Primary- Secondary; Secondary		5	122-135
			Secondary			115
Kuakol'	Quartz-fluroite	Bluish-green	Primary- Secondary; Secondary		5-7	122-142 110-115
Karabau	Quartz-barytes	Grayish-green	Primary-		10	120-180
			Secondary		5	115
Kamyshly	Quartz-fluorite	Violet	Primary- Secondary;		3-10	80-160
			Secondary		5	117
Kichik-Arsagan	Quartz-fluorite	Blue	Primary Secondary		10-15 5-7	160-190 115-135

Determination of Th carried out in a VIMS thermochamber by L.A. Tsoi. Note. II-primary FI, IIB-primary-secondary, B-secondary FI

[the Russian symbols for phases are not defined but probably are as follows:

rn - gas y - liquid CO<sub>2</sub> b - liquid H<sub>2</sub>O

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The accessory minerals of pressure-dependent and refractory kinds (stilicides of metals and non-metals, metal carbides, native metals and non-metals, etc.) have been subjected to determinations of the G composition of the FI, employing a VD-5 vacuum decreptograph, and an LKhM-80 gas chromatograph. The following data have been obtained.

The G composition of the 1 in the accessory minerals of the categories mentioned from rocks of the Tien-Shan magmatic complexes, is clearly correlated with nitrogen-hydride forms during oxidizing participation of CO<sub>2</sub> by mantle components [sic], which was stabilized during the Cenozoic Era.

The saturation of magmatic M in metalliferous volatile components ensures the process of formation of metal-carbonaceous metastable complexes with their fractionation of disunted segregations of drop-like shape, measuring 0.5-0.6 cm and more. Under conditions of great depth and high T, molecular hydrogen acquires the significance of an active reducer of metals and non-metals, and the low oxygen fugacity related to the drop in T, favors the transition of the 'drop-like liquid', metal-carbonaceous segregations into mineral crystalline units, consisting of native Fe, Cr, inter-metals, and various kinds of M of metals, non-metals, etc. Metal and non-metal silicides, metal carbides, diamonds, and other accessory minerals accumulate mainly 'heavy' components of gaseous composition in their make-up.

It is submitted that. 1) during the interval of new magmatic activity in the Tien-Shan, against a backdrop of intensification and development of overall degassing of the mantle substrate, the deep-seated magmatic systems and their accompanying foci were saturated with metalliferous F components, 2) during the transport of metals and non-metals, the carbonaceous component of the G-F systems (CO, CH<sub>4</sub>, CO<sub>2</sub>, etc.) was of great significance; and 3) under crustal conditions, during excessive increase in the oxygen-fugacity, a transformation occurred in the F systems directed toward a growth in their oxide components (H<sub>2</sub>O, CO<sub>2</sub>, etc.). In case of the deep-seated G-F systems, heterogeneities in composition of a lateral aspect are suggested, with changes in the values of K<sub>B</sub> (reducing nature of F) from <1 up to 10 and more; in the case of the rocks of the magmatic complexes and their minerals, K<sub>B</sub> is estimated at 3, whereas in the mantle rocks of the ancient platforms, it is close to 10. According to the compositions of the GI and the K<sub>B</sub> values, the native 'readily-fusible' metals and non-metals (Ag, Te, Bi, Pb, Sn, etc.) are distinguished by a predominance of 'light' over 'heavy' components, and thereby are indicative of their indifference to deep-seated processes and relatively high thermal indices. [sic]

ZHAUTIKOV, T.M., 1998. Mineral-forming fluids and ore-genesis in the gold-ore deposits of Kazakhstan (abst.): Second APIFIS Int'I. Symp. Mineral Forming Fluids and Ore Genesis, Oct. 28-30, 1998. Tashkent, Uzbekistan, Abstracts volume, p. 94-95 (in Russian). Author at K.I. Satpaev IGG Mineralog. Sci. Kazakhstan, Alma-Ata

The results of geological-petrographical and experimental investigations obtained in recent years have shown that the processes of ore-formation in gold-ore deposits are not only complex and polyphase but also require the insertion of significant and fundamental corrections to the procedures for studying them. This primarily concerns thermobarogeochemistry and G chromatography, the results of which mainly reflect the terminal portion of the sequentially manifested ore process. By their nature, the mineral-FI, enclosed in the ore mineral associations, are heterogeneous and have evolved in accordance with the dynamics of the geological processes, which has not been completely taken into account during collection of the samples.

In the list of data that have fundamental significance, we must first note the results of studies of organic matter (OM), which is an important factor in the mobilization, transport, concentration, reduction, and conservation of metals. It has been established that the presence of OM has no [sic] significant effect in changing the Eh and pH of the medium of mineral-formation. There are also data on the use of kinds of OM and the level of its carbonization for classifying the L and gaseous hydrocarbon F that participate in the formation of some ore deposits.

It is likely that there is vast ore-genetic value in the conclusion reached by G.R. Kolonin et al. (1997), on the basis of multistage thermodynamic calculations that, in the presence of CO<sub>2</sub> both in a chloride and also in a sulphide F, the solubility of Au is significantly lowered, that is, carbonic acid during the process of ore-formation may play the role of a precipitator of the metal from auriferous F.

As is well-known, the most important component of the ores of gold deposits is silica, which also has a heterogeneous origin. Along with the distinctive [?] category, deposits contain silica that migrated during processes of diagenesis, catagenesis, and catametamorphism from the country rocks in the form of a silica gel. The wide variations in their varieties, according to the degree of crystallization (opal, chalcedony, quartz) and the levels of textural ordering (the quartz group, coesite, stishovite), determine the significant breakdown of compositions and quantitative values of the components contained in the GLI. Often, the amounts of reducing gases (C<sub>2</sub>H<sub>2</sub>, C<sub>2</sub>H<sub>6</sub>, CH<sub>4</sub>, H<sub>2</sub>, CO, N<sub>2</sub>) and other volatile components vary within a wide range of values, which once again emphasizes the association of various kinds of silica in the single sample.

The principal (in significance) component of the ores (gold), also evolves in accordance with the dynamics of the geological processes from its more metastable form to the more stable native phase. In this case, in the native phase of gold itself, there is a regular replacement of the relatively low categories of morphosigns [sic] by higher and more complicated kinds (V.N. Matvienko, 1988). Just such 'heterogeneity' in native gold determines the compositional variations and spread of values of the G phase, exhibited by the so-called 'monotonous' gold specimens in the deposits.

A detailed study of the various aspects of the petrology and geochemistry (especially barogeochemistry) of the most important commercially-genetic kinds of gold-ore deposits in Kazakhstan with sufficient coverage, demonstrate their lengthy and multistage formation with involvement of sequentially manifested polygenic (sedimentation, vulcanism, diagenesis, intrusive magmatism, and metamorphism) geological-metallogenic processes. This determines the temporal evolution of the composition of the ore-forming F (transformation, migration, etc.), and the regular change in PT conditions depending on the specific nature of each cycle of mineral-formation (also including a regressive stage), and other parameters of the process of formation of gold-ore deposits.

# YUSUPOV, R.G.: Table 1

Gas composition of inclusions, vol,%	Accretion of suessite, kham- rabaevite, graphite	Ferrite, A-224	Accretion of josephinite, chromite, TK-3	Diamond (Koshmansai), K-2	Diamond (Arkansas)	Moissanite, K-3	Porpezite [sic] K-69
02	_	-	5.2		-	2.2	1.3
H <sub>2</sub>		2.1	1.4	20.2	19.4	23.7	16.4
cō	-	0.1	4.1	4.4	3.8	1.8	2.1
CO <sub>2</sub>	21.0	28.8	9.2	10.3	15.5	19.4	15.3
CH4	1.5	0.3	0.1	4.2	3.7	2.0	1.8
C <sub>2</sub> H <sub>4</sub> CH <sub>3</sub> OH +	30.0	-	-	0.5	-	10.5	12.7
CH <sub>3</sub> CH <sub>2</sub> OH	-		-		2.0	-	-
H <sub>2</sub> O		27.9	7.4	9.8	39.6	20.0	8.8
N <sub>2</sub>	47.0	40.9	72.0	50.3	15.9	30.3	41.8
Ar	0.8	-	-	0.3	-	0.1	0.1
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# **APPENDIX OF**

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# **ILLUSTRATIONS**

Fig. 1. (A) Longitudinal section through a quartz crystal from the Yankee Lode Sn deposit, showing numerous trails of pseudosecondary fluid inclusions and three growth zones recording the precipitation of Imenite, cassiterite, and muscovite onto former crystal surfaces. The fluid inclusions shown in the right part of the figure represent four different stages in the evolution from a magmatic fluid toward a meteoric water-dominated, system. Th<sub>tot</sub> corresponds to the final homogenization temperature. (B) Photomicrograph of fluid inclusions formed by healing of a former crack within the crystal. Bnne and vapor inclusions coexisting along the same trail demonstrate that the hydrothermal fluid was boiling at the time of trapping. The inset shows laser ablation craters after analysis of three inclusions.





Figure 2 Raman spectra of standard solution and fluid inclusions. Bottom trace, spectrum of an acidic (pH = 0) NsC1-Na<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>SO<sub>4</sub>-HC1-H<sub>2</sub>O standard solution in a glass capillary. Other traces are spectra of individual 5-30 µm diameter primary fluid inclusions in Permian halite samples (Doeche Shale, Nippevalla Group and Hutchinson Sati) and modern Dearth Valley halite. The optical quality of the Nippevalla and Opeche halites yielded high signal to noise ratios, which allow interpretation of the presence of the ~892 cm<sup>-1</sup> and 1054 cm<sup>-1</sup> peaks for HSO<sub>7</sub>. The presence of the 1,054 cm<sup>-1</sup> peak indicates that Shine inclusions have pH < 1. BENISON

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BODNAR

Fig. 1 Distribution of fluid inclusion types as a function of depth and time in the porphyry copper environment



Fig. 1. Series of photomicrographs captured from a videotape showing a fluid inclusion with a moving vapor bubble in the martian meteorite ALH 84001,146. The inclusion is about 1.8 µm in diameter. Note that the dark, rounded vapor bubble, indicated by the arrow in the third image from the top, is in a different position in each of the five images. When examined under the microscope at room temperature, the bubble is in continuous rapid Brownian motion from the small thermal gradients caused by the microscope light source.



FIG. 11. Homogenization vs. salinity plot for inclusions from the Vergenoeg pipe and surrounding hematite-fluorite sediment. Measurements are coded to represent the different fluid inclusion assemblages described in Table 2. Temperatures and pressures shown for assemblage 1 fluid inclusions are minimum estimates because Fe chloride and an opaque daughter mineral failed to homogenize before decrepitation. Measurements on vaporrich inclusions from assemblages 2 and 8 are not shown because salinities could not be determined. Data from deposits other than Vergenoeg come from Sidder et al. (1992) for Pea Ridge, Baker et al. (1996) for Eloise, and Oreskes and Einaudi (1992) for Olympic Dam.

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# TABLE 3. Classification of Fluid Inclusions Detected in Quartz in this Study

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Type Vapor(%)		Daughter minerals (at 20° C)	Comments		
1	5-20	Absent	Well-defined trails		
2	20–90	Absent	Phase separated, occurs in trails with type 1		
3 a	5-15	ha, rarely sy, an	Rare py/hm		
3 b	5–15	>>2-8, without an; ha dominant	Rare py/cpy/hm ± sy, un		
3 с	5–15	>>2-8, including an.	Rare py/cpy/hm ± ha, sy, un		

Abbreviations: an = anhydrite (CaSO<sub>4</sub>), cpy = chalcopyrite, ha = halite (NaCl), hm = hematite, py = pyrite, sy = sylvite (KCl), un = unknown



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2

Phase	Calcite	Pyroxene	Philographic	Apatite	Fluorite	Total
SiO <sub>2</sub>	0.00	2.82	4.31	0.13	0.02	7.28
TiO <sub>2</sub>	0.00	0.00	0.07	0.00	0.00	0.07
Al <sub>2</sub> O <sub>3</sub>	0.00	0.00	1.11	0.00	0.00	1.11
FeO	0.05	0.17	0.52	0.00	0.00	0.74
MgO	0.15	0.83	2.21	0.00	0.00	3.19
MnO		0.08		0.01		0.09
CaO	29.12	1.35	0.06	15.34	2.90	48.77
Ns <sub>2</sub> O	0.03	0.03	0.00	0.00	0.00	0.06
K20	0.00	0.00	0.77	0.00	0.00	0.77
BaO	0.09	0.00	0.01	0.00	0.00	0.10
SrO	0.31	0.00	0.02	0.00	0.03	0.36
F	0.00	0.00	0.08	0.89	2.44	3.41
P2Os	0.00	0.00	0.00	11.46	0.00	11.46
CO2	22.59	0.00	0.00	0.00	0.00	22.59
Vol % of the phase	55	5	10	25	5	100
Density, g/cm3	2.8	3	2.83	3.24	3.18	2.94

Table 6. Calculation of the composition (wt %) of carbonatite melt during apatite crystallization

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TABLE 1.

	1 10 10 10 10 10 10 10 10 10 10 10 10 10	
Assemblage	T. C	K Na**
ab-kfs-and -otz	650	0.33 (±0.02)
as the sum the	600	$0.3(\pm 0.02)$
ab-mu-and -otz	550	$0.2(\pm 0.01)$
ab-kis-mu -qtz	600	$0.3(\pm 0.01)$
	550	$0.25(\pm 0.02)$
	500	0.23 (±0.03)
	450	0.16 (±0.06)
	400	0.15 (±0.06)

all data at 2kbar and 1mCltot.

\*\*molar ratio



1.4

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600 -1001

2000

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QIU, ET AL.

711 5 ± 33 4Ma R = 0 9802 J = 935 1 ± 62.3

300

250

150 -

100 "Art"Ar



ROTHERHAM, ET AL.



RUZICKA, ET AL.

RYA	BCH	IKOV	ET	AL.

TABLE 1. Compositions of homogenised melt inclusions (EMP)

	1	2	3	4	5	6	7	8	9	10
Host	01	OI	01	OI	01	OI	OI	Срх	Cpx	Sp
SiO-	46.79	51.61	47.24	52.85	45.37	46.00	51.22	52.44	49.30	50.50
TiO:	1.24	0.93	1.31	1.34	1.34	1.21	3.11	2.85	3.58	1.70
Al-O:	12.96	13 64	14.26	15.36	13.30	12.38	9.71	7.90	8.46	13.00
FeO*	10.95	6.52	10.51	8.66	11.60	14.03	10.50	10.94	14.70	10.10
MgO	14.85	10 11	12.46	9.20	11.64	10.44	9.01	10.43	8.48	9.38
MnO	0.09	0.09	0.16	0.13	0	0	0	0	0	0
CaU	11.46	11.85	12.16	10.28	11.34	11.18	12.83	12.84	12.25	11.19
Na:0	1.64	2.40	1.81	2.10	1.60	2, 1.64	1.40	1.97	1.90	2.01
K-0	0.10	0.08	0.09	0.56	013	0.13	1.24	0.81	0.47	0.70

1.2 GGU332771 (WG); 3 GGU400450(WG); 4 GGU176669(WG); 5.6 GGU362148(WG);7+9 GM75-755(EG); 10 GM40644(EG)



SCHMIDT ET AL.



FIG. 1. Noble gas analyses for selected deposits of the Colorado Mineral Belt. (Open square: Columbia: open circle: Sherman, open triangle: Black Cloud; closed triangle: Sunnyside: closed square: London) Three mixing lines are plotted between a crustal fluid and three magmatic end member fluids (A, B and C).

VARELA, ET AL.

 
 TABLE 1. Averaged electron microprobe analyses (wt%) of glasses in heated glass-bearing inclusions.

	and the second sec	No. of Concession, Name		
T(fin)	900°C (7)	1000°C (6)	1200°C (6)	
SiO,	69.9	71.1	70.0	
TiO,	0.15	0.12	0.20	
A1,0,	17.6	16.4	16.8	
FeO	1.18	2.08	3.28	
MnO	0.06	0.04	0.11	
MgO	0.83	0.52	1.16	
CaO	0.81	1.24	1.31	
Na,O	3.67	3.78	3.62	
K,Ô	4.53	4.10	3.19	
Total	99.03	99.38	99.67	

Number in parentheses is the number of glass inclusions heated.

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1.4

## INDICES

The user should keep in mind the following features of these indices. The indexing procedures and entries are continuously evolving and hence are not uniform from one volume of *Fluid Inclusion Research* to the next, and even within a given volume, consistency cannot be claimed. The number of indexing entries has been reduced again this year, and in many entries, only the more significant items are listed. Several changes have been made. Although entries under <u>Analysis data</u> have been split into <u>aqueous</u> and <u>silicate melt</u> categories. For some years, the rising importance of studies of mixed transitional silicate-salt-water inclusions has made it necessary to divide both <u>Daughter minerals</u> and <u>Inclusions</u> into three categories: aqueous (fluid, non-melt), magmatic/hydrothermal transitional, i.e., "salt melts", and melt (nono-aqueous). Caveats: overlapping compositional ranges cause ambiguity in placement within categories, and some items might involve several categories.

To keep the indexing chore manageable. I have deleted the isotopes of C. H. O and S except where they appear to deal with the fluid inclusion composition itself, not the host. Much ambiguity remains in some index entries e.g., items on basins might be under Organics...and/or Inclusions in sediments. Some new entries, e.g., "Mantle metasomatism" were introduced partway through the indexing. Indexed items are cited by first author's last name only. This may cause occasional ambiguity (e.g., with prolific authors or with different authors having same last name), but this inconvenience is believed to be less than that resulting from use of the previous procedure, where a whole page had to be scanned for every citation that was looked up. Feedback from users on indexing procedures and/or indexing entries (and omissions) is welcomed.

## Subject Index

See general notes above. I have tried to make this a user-oriented index rather than a documentalist's type index. Only data in the title and abstract are indexed, and then only if the appear to be of more than incidental mention. Thus, most ore deposit studies could also be listed under "Rock-water interaction" but are not. Misleading or erroneous translations may have resulted in occasional incorrect or omitted entries. Some entries are included under a given appropriate subject heading even though the index word does not occur in the abstract. The aim has been to err on the side of completeness and convenience to the user. Thus, I have attempted to index some related or possibly pertinent items, and even ones involving negative data or evidence, under each category. The deposit-type terms such as porphyry copper and Mississippi Valley are used loosely. The deposit type is indexed only where it is evident without research. Analysis for specific elements are indexed only when they are particularly unusual or significant: thus, semiquantitative spectrographic analyses and statements of analyses as "Na-Ca-Cl fluids" are generally ignored. The mineral host for the inclusions studied is indexed except for quartz and calcite, and for decrepitation studies. Entries that would include too many citations to be useful are listed without citations. Some entries with broad and diffuse applicability have only a few of the most pertinent citation references. Names in parentheses refer to individual articles in a volume entered alphabetically here under the editor's name.

Age determination, dating by inclusions, effect of inclusions on, and relation to mineralization-Luczaj. Qing. Qiu. Sangster. Su. Walshaw. Wayne Analysis data and discussion, liquid (non-melt) inclusions; General (for many constituents). Includes gas inclusions in igneous rocks. See also Analysis methods: Daughter minerals: Complexes: Isotopes (Minor concentrations ignored). <sup>3</sup>He/<sup>4</sup>He-Hu, Moore, Shail, Sun Acetate-Leach. Viets Ag-Gallup, Kasai Al-Rowan Amphibole-Feng Ar-Chomiak, Irwin, Kendrick, Lindaas, Norman, Sawaki As-Gallup, Heinrich, Ménez, Philippot Au-Gallup. Heinrich. Kasai. Zhao Au-As-Ag-Sb Na-Fan B-Ellendorff. Ishiyama. Tonarini. Vengosh B/CI-Vengosh Ba-Buehn, Molnar, Prol-Ledesma, Rankin BaO-Andreeva Bases-Sangster Br-Board, Cathelineau, de Ronde, Eggenkamp, Ellendorff. Graupner, Irwin Leach, Nesbitt, Petrichenko, Polya. Savoye, Siemann, Svensen, Turner, Vengosh Br -Viets Br/Cl-Board, Boiron, Bruce, Campbell, Cathelineau, Kendrick, Nesbitt, Polya, Savoye Br/I-Nesbitt C-H\_Bakker, Johan Ca/Na-Rankin Ca<sup>2</sup>-Viets, Zhai, Zhang Ca-Abidin, Allen, de Ronde, Fabre, Fonarev, Ghazi, Khin Zaw, Kodera, Kontak, Lang, Lodemann, Molnar, Petrichenko. Pletsch-Rivera, Sangster, Sasaki.

Shepherd, Silva, Sirbescu, Timofeeff, Török, Tsöi. Vengosh, Xiao, Xu CaCl-Wood CaMgNaCl-Rohrlach CaO-Andreeva Cd-Uchida Cd2 -Stipp CH4-Aquilina, Bakker, Cepedal, Chen, Darling, de Ronde, Dubessy, Dugdale, Dúnin-Barkovskava, Egle, Field. Fonarev. Giuliani, Graupner, Grishina, Guilhaumou, Herms, Hou, Jarmolowicz-Szulc, Ji, Johan, Kastner, Khalmukhamedov, Khin Zaw, Knoll, Kontak, Lawrie, Leach, Lee, Leng, Li, Lindaas, Lodemann, Lu, Marescotti. Marignac. Markl. Martin-Izard. McCuaig, Mernagh, Montomoli, Moore, Neumayr, Norman, Polito. Prokofyev. Ramsay. Sangster, Sawaki. See, Silva, Sun, Török, Tsöi, Voznyak, Xu, Zangrilli CI-Stipp, Zhai. Zhang Cl/Br-Essarraj. Giuliani. Neronsky. Rankin, Svensen. Viets CI/F-Neronsky CI/I-Muramatsu CI/SO4-Essarraj Cl'-Viets CI-Andreeva. Cathelineau. de Ronde. Eggenkamp, Feng. Heinrich, Irwin, Ishiyama, Linnen, Marescotti, Markl, McCormick, McCuaig, Ménez, Molnár, Petrichenko, Polya, Samson, Sangster, Sasaki, Savoye, Török, Tsói, Turner, Wang, Xu CO-Markl, Tsöi, Xu CO-Tsói CO<sub>3</sub>-Cesaretto CO<sub>3</sub><sup>2</sup>-Viets COS-de Ronde. Graupner Cr-Menez

Cs-Heinrich, Sirbescu Cu-Bodnar, Buehn, Frank, Gallup, Heinrich, Kasai, Kyle, Ménez, Philippot, Sasaki Cu/Cl-Viets Epidote-Feng F-Andreeva, Buehn, Chen, Feng, Lewis, Malinin, Rowan, Wang, Xu F'-Viets F/Br-Nesbitt Fe-Collyer, Halter, Heinrich, Kodera, Kontak, Kyle, McCormick, Ménez, Molnar, Philippot, Samson, Sangster, Sasaki, Török, Uchida Garnet-Feng Gases-Aquilina, Chomiak, Compagnoni, Dragusanu, Dublyansky, Frezzotti, Killawee, Lindaas, Liu, Lokhov, Maglambayan. Moore, Norman, Prohl. Ramsay. Sawaki, Siemann, Vazquez, Wang, Xu General-Benison, Board, Boiron, Buchn, Cendon, Cesaretti, Chen. Dobes, Dúnin-Barkovskava, Ellendorff, Fanlo, Feng, Graupner, Ismailov, Kovalevich, Parilov. Shepherd, Sokerina, Tsói, Wang, Williams, Zhai H-Ballentine H2-Prohl H-O/HCI-Markl H-O/HF-Markl H-S-Chang, Chomiak, Cline, Hutcheon, Kastner, Komatsu, Leach, Li. Lindaas, Liu, McCuaig, Migdisov, Norman, Parilov, Sawaki, See, Sun, Tunks, Vazquez, Xu. Yardley HC-Mazurek. Voznyak HCI-Vazquez HCO3-Buehn, Cesaretti, Chen He-Aquilina, Ballentine, Chomiak Hematite-Feng Higher hydrocarbons-Dublyansky, Grishina, Guilhaumou, Lawrie, Prohl, Voznyak HS-Liu HSO4-Benison HSO<sub>4</sub>—McCuaig Hydrocarbons-Dublyansky, Sangster I-de Ronde, Irwin, Muramatsu, Polya, Turner I/Br-Polva I/CI-Boiron, Kendrick K-Avora, de Ronde, Fabre, Ghazi, Halter, Heinrich, Irwin, Khin Zaw, Kodera, Kontak, Lawrie, Molnar, Petrichenko, Samson, Sangster, Sasaki, Shepherd, Silva, Sirbescu, Timofeeff, Török, Tsöi, Vengosh, Xu K+-Stipp. Zhang K+1-Viets K2O-Andreeva K/Na-Khin Zaw Kr-Invin Li-Dobes, Ellendorff, Fabre, Silva LiNaKCaCIMg-Taner Magnetite-Feng Mg-Ghazi, Khin Zaw, Kontak, Petrichenko, Samson, Sangster, Shepherd, Silva, Sirbescu, Timofeeff, Tsöi, Vengosh Mg<sup>-2</sup>-Viets Mn-Halter, Heinrich, Kontak, Kyle, Marescotti, Ménez. Molnar, Philippot, Sasaki, Suleimenov, Török, Uchida, Williams N-Khin Zaw, Xu

N-Aquilina, Bakker, Chazallon, de Ronde, Dúnin-Barkovskava, Fonarev, Giuliani, Graupner, Grishina, Herms, Knoll, Lindaas, Lodemann, Lokhov, Marignac, Markl, Mernagh, Neumayr, Norman, Ramsay, Sawaki, See, Silva, Sokerina, Török N-/Ar-Magro. Sun Na-de Ronde, Fabre, Fan, Heinrich, Khin Zaw, Kodera, Kontak, Ménez, Petrichenko, Samson, Sangster, Sasaki, Silva, Sirbescu, Török, Tsöi, Xu Na'-Stipp, Zhai, Zhang Na+1-Viets Na-O-Andreeva Na/Br-Board, Nesbitt Na/Ca-Essarraj, Fabre Na/Cl-Vengosh, Viets Na-Fe-K-Mn-Ca-Kasai Na/K-Essarraj, Fabre, Neronsky, Rankin, Tsói Na/Li-Cathelineau. Essarraj. Fabre, Rankin NaK-Parilov Nb-Philpotts NH1-Grishina, Leach NH, 1-Viets NH<sub>4</sub>-de Ronde. Parilov. Zhang Ni-Ménez, Philippot Noble gases-Bach, Ballentine, Magro, Moore, Pettke O-Chazallon Pb-Buchn, Gallup, Heinrich, Kasai, Kyle, Molnár, Sasaki, Sirbescu, Svensen, Williams Pd-Gallup Pt-Gallup Pyroxene-Feng Rb-Ellendorff. Ghazi, Heinrich. Newton. Su, Walshaw, Wayne REE-Buehn, Kolonin, Lewis, Ogata, Philpotts, Rankin, Steinmann, Su, Takahashi S-Li  $S_2O_3^{-2}$ -Thiosulfate—Xu  $S_2O_3^{-2}$ -Viets  $S_xO_6^{-2}$  polythionate—Xu Sn-Sirbescu SO1-Andreeva SO4-Andreeva, Ayora, Benison, Board, Feng, Timofeeff, Vengosh. Xu SO4/CI-Lewis SO4/F-Lewis SO,2 -Viets, Zhang Sr-Buehn, de Ronde, Ellendorff, Ghazi, Hitzman, Lodemann, Ménez, Mresah, Philippot, Rankin, Ray, Rosell, Selby, Su, Walshaw, Wayne Sr -- Viets SrO-Andreeva Th-Buehn TI-Bebie U-Buehn Xe-Irwin Y-Philpotts Zn-Anderson, Buehn, Gallup, Heinrich, Kasai, Kyle, Ménez, Philippot, Prol-Ledesma, Sasaki, Török, Uchida, Williams Zn2 -Stipp Zr-Philpotts Analysis data and discussion, silicate melt inclusions; General (for many constituents). Includes gas inclusions in igneous rocks. See also Analysis methods: Daughter minerals. Only

special items listed under individual elements. Ordinary

multiple-constituent analyses listed only under General analyses. <sup>3</sup>He/<sup>4</sup>He-Matsumoto Ag—Xu Al—Grossman Ar-Boyce, Brooker, Burgess, Cartigny, Yusupov As-Traxel Au-Xu Ba-Clark, Gioncada, Perinelli, Righter, Sharygin B-Belkin, Brenan, Gioncada, Metrich, Tonarini, Traxel, Webster Be-Brenan. Gioncada Br-Burgess C-Agrinier, Bureau, Cartigny, Holloway, Zhang C<sub>2</sub>H<sub>2</sub>—Zhautikov C<sub>2</sub>H<sub>4</sub>—Yusupov C<sub>2</sub>H<sub>6</sub>—Zhautikov Ca-Della-Pasqua, Fabre, Li, Nakamura, Navon Ce-Righter CH4-Blencoe, Charlou, Della-Pasqua, Johan, Later. Navon, Orsoev, Potter, Sasaki, Tomilenko, Xu, Yang, Yusupov. Zhaútikov Cl-Armstrong, Belkin, Bureau, Burgess, Crawford, Dingwell, Frank, Fulignati, Gioncada, Gurenko, Harms, Izraeli, Kravchuk, Naumov, Navon, Nielsen, Pak, Ransom, Ripley, Varela, Webster, Yang, C/N-Cartigny Co-Righter CO-Yusupov. Zhautikov CO-Della-Orsoev, Pasqua, Yusupov CO<sub>1</sub>-Izraeli Cs-Traxel. Webster Cu-Armstrong, Della-Pasqua, Thomas, Xu Eu-Gioncada, Krekeler F-Belkin, Bureau, Dingwell, Gurenko, Harms, Metrich, Naumov, Sharygin, Thomas, Webster Fe-Li. Navon Gases-Divaev. Eschenbacher. Orsoev. Xu. Zheng General-Agrinier. Armstrong. Audétat. Belkin. Bureau. Crawford, Chabiron, Chupin, Clocchiatti. Danyushevsky. Della-Pasqua, Dietrich, Eggins, Gioncada, Grossman, Gurenko, Jochum, Kent, Krekeler, Li, Nakamura, Naumov, Nielsen, Prokof'ev, Ráfikov, Ruzicka, Ryabchikov, Saal, Schiano, Sharygin, Shimizu, Sobolev, Sours-Page, Spandler, Thomas. Varela, Webster H2O/K2O-Wallace H2O-Agrinier, Bureau, Danyushevsky, Harms, Izraeli, Moriizumi, Navon, Orsoev, Sisson, Wallace, Webster, Yang H2-Potter: Yusupov. Zhautikov H<sub>2</sub>S-Xu. Yang HC-Orsoev. Tomilenko He-Burgess Higher hydrocarbons-Laier I-Burgess KCI/HCI-Frank K-Crawford, Fabre, Grossman, Izraeli, Metrich, Navon, Nielsen, Perinelli La/Nb-Gioncada La/Sm-Sobolev Li-Belkin, Brenan, Chou, Fabre, Traxel, Webster LREE-Gioncada, Perinelli Magnetite-Li Mica-Li

Mg-Li. Nakamura, Navon Mo-Righter N-Cartigny N2-Blencoe. De Corte, Della-Pasqua, Yusupov, Zhaútikov N<sub>2</sub>/A-Cartigny Na-Crawford, Fabre, Perinelli Na/K-Gioncada Na-K-Fe-Mn-Pb-Chapman Nb-Brenan, Gioncada, Li Nd-Ducea Ni-Della-Pasqua, Righter Noble gases-Bogard, Burnard O-Zhang O-Yusupov P-Li, Nielsen, Righter, Thomas, Webster P-O-Clark Pb-Layne, Shimizu Quartz-Li Rb-Ducea, Gioncada, Perinelli, Righter, Webster REE-Chabiron, Clark, Krekeler, Nielsen, Ripley, Sobolev, Titov S-Armstrong, Bureau, Crawford, Della-Pasqua, Gioncada, Gurenko, Harms, Mandeville, Metrich, St.-Almand. Thordarson, Varela S/CI-St.-Almand Stor Stor-Gurenko Se-Della-Pasqua Siderite-Li Sn-Dietrich, Thomas SO-Thordarson, Xu. Yang SO1-Belkin Sphalerite-Li Spinel-Li Sr-Belkin, Clark, Della-Pasqua, Ducea, Gioncada, Jochum, Metrich, Perinelli, Webster Ta-Gioncada Th/Ba-Sobolev Th/La-Sobolev Ti-Li. Nielsen, Sharygin Ti/Zr-Nielsen U-Chabiron Water-Behrens, Hauri W-Fulignati, Thomas Y-Della-Pasqua. Righter Yb-Brenan Zinc spinel-Li Zn-Thomas. Xu Zr/Nb-Gioncada Zr-Belkin, Sharygin Analysis, methods Auger electron spectroscopy-Li Atomic force microscopy (AFM) -Stipp Capillary electrophoresis-Pironon Cathodoluminescence-Jarmolowicz-Szulc. Lewis. Motañez, Vanko Confocal scanning laser microscope-Bigge, Pironon Crushing procedures (for opening and for gas pressure)-Bigge, Chomiak, Dublyansky, Giuliani, Hall, Ménez. Philippot, Poliquin, Qiu, Thrower Decrepitate analysis-Khin Zaw. Kontak. Savard. Su. Walker Na/Ca-Samson Diamond anvil cell-Bureau. Chou, Schmidt Electron microprobe-Armstrong. Fulignati EA-MS-Polito

ESEM-Timofeetf

- EXAFS-Collings. Oelkers. Ragnarsdottir. Seward
- Fourier transform infrared spectroscopy (FT-IR)—Agrinier, Amthauer, Bai, Behrens, Chen, Compagnoni, Crawford, De Corte, Eschenbacher, Faure, Guilhaumou, Izraeli, Komov, Li, Moriizumi, Pironon, Sun, Wang, Webster, Zhang
- Frozen inclusions (CRYO-SEM-EDS)—Shepherd, Timofeetf, Walker
- Gas chromatography-ion chromatography-Andresen. Chen, Chi. Dublyansky, Fedorov, Graupner, Johan. Kontak, Orsoev, Shanina, Sokerina, Yusupov
- Gas chromatography-mass spectrometry (GC-MS)—Guo GC-MS-MS—Pottort
- Inductivity coupled plasma-emission spectroscopy (also ICP-AES) for atomic emission spectroscopy—Benison, Rankin
- Inductively coupled plasma spectrometry (ICP-MS)-Ghazi, Su
- Infrared laser mass spectrometry—Khalmukhamedov Infrared microscopy—Guilhaumou, Li
- Ion chromatography (IC)—Benison, Dobes, Ellendortf, Graupner, Siemann, Sun, Viets, Zeng
- Ion microprobe (SIMS (SHRIMP)—Armstrong, Belkin, Grossman, Layne, Lewis, Mandeville, Mathez, Philippot, Righter, Traxel, Webster
- Isotope ratio monitoring-mass spectrometry (IRM-MS)-Young
- LA-HR (high resolution)-ICP-MS-Larsen
- Laser ablation microprobe ICP-MS (L-ICP-MS, LA-ICP-MS, LAM-ICP-MS, LAMP, ICPM, MS)—Audétat, Crawford, Ellendorff, Heinrich, Heinrich, Ishiyama, Jackson, Kendrick, Kurosawa, McCandless, Ogata, Samson, Shepherd, Takahashi, Wang
- Laser ablation stable isotope ratio micro-analysis system (LA-SIR-MAS)—Eggins
- Laser ablation optical emission spectrography (LA-OES)— Fabre
- Laser Raman spectroscopy (LRS) Only special applications—Benison, Bernardo, Chazallon, Chou. Dubessy, Fournier, Frantz, Garland, Graupner, Knoll, Krüger, Leng, Maeda, Murphy, Philippot, Sharma, Slodkevich, Walker
- Leaching—Andresen, Aquilina, Benison, Ducea, Essarraj, Graupner, Kendrick, Ménez, Su, Sun, Taner, Zeng
- Luminescence microspectography—Andresen, Buick, Cesaretti, Graham, Jarmolowicz-Szulc, Kontak, Li, Parnell, Sum, Wendte
- Mass spectrometry—Chomiak. Cline. Compagnoni. Hall. Lindaas, Lokhov, Mallard. Sawaki
- Multiple collector ICP-MS-Halliday
- Neutron activation (INNA), and radionuclide neutron activation analysis (RNNA)—Komov, Rankin, Williams
- Proton induced gamma emission (PIGME)-Ménez, Ménez, Philippot, Traxel
- Proton (and deuteron) induced X-ray emission (PIXE)-Della-Pasqua, Dietrich, Ménez, Khin Zaw, Kurosawa, Philippot, Traxel, Wang, Williams

SEM-EDS-Rankin

- Scanning force microscopy SFM-Stipp
- Synchrotron X-ray absorption fine structure (XAFS)-Anderson, Philippot
- Synchrotron X-ray fluorescence (SXRF)—Guilhaumou, Jochum, Kyle, Ménez, Philippot, Rankin, Vanko

- TOF-SIMS-Li. Stipp
- Transmission electron microscopy (TEM)—Cmiral. Vityk Ultraviolet laser ablation ICP-MS (UV-LA-ICP-MS; UV LAMP)—Brooker
- X-ray fluorescence (XRF, XAFS, and X-ray CT)-Anderson
- Books, journal volumes, symposia. See also Reviews—Arehart, Carroll, Rongfu, Smirnov, Usdowski, Usmanov, Williams
- Boreholes (land) See also Geothermal—Aquilina. Drescher. Lodemann, Pasteris, Vançon
- Brines, sedimentary and igneous rocks—Appold. Benison. Bruce, Cathelineau, Chi, Cooke, Davidson, Egle, Everett, Gleeson, Guo, Hitzman, Kadko, Kasai, Mresah, Nesbitt, Newton, Nijland, Petrichenko, Randell, Rankin, Rosell, Sangster, Sangster, Savoye, Savrd, Sheppard, Siemann, Souissi, Wachowiak, Wayne, Wendte, Zhang
- Complexes, metal-inorganic, metal organic, metal organic, stability, solubility—Anderson. Baker. Baranova. Bebie. Belevantsev. Blamey. Buehn, Cao. Choi. Choi. Collings, Crocket. Cunningham. Fournier. Gibert. Halter, Hanor. Heinrich. Jiyuan. Khalmukhamedov. Khin Zaw. Kolonin, Lawrie. Lewis. Mallard. McCuaig. McKeagney. Migdisov. Mikucki. Murphy. Oelkers. Ogata. Pokrovski, Ragnarsdottir. Ridley. Rowan. Sassani. Schoffield. Seward. Shi. Steinmann. Suleimenov. Sun. Thomas. Tunks. Uchida. Wesolowski, Xiao. Yang. Yardley
- Computer programs, development and use, modeling. See also Modeling—Appold. Barker. Blencoe. Bodnar. Brown. Cathelineau, Clemens, Dutrow, Halter, Iwamori. Kamijo. Komatsu, Larsen, MacGowan, Moore, Pironon, Svara, Thiéry, Timofeeff, Usdowski, Walker, Yardley
- Daughter minerals in <u>aqueous</u> (fluid, non-melt) inclusions and their significance. Includes phases developed below room temperature. May include some trapped solids
  - Albite-Svensen
  - Amphibole—Svensen
  - Anhydrite-Cannell, Rotherham, Sasaki, Siemann
  - Antarcticite—Taner
  - Barite-Rotherham
  - Burbankite-Rankin
  - Calcite-Rotherham, Shigehiro, Svensen
  - Carnallite-Siemann
  - Chalcopyrite-Cannell, Kozlóv
  - CuFo sulfide—Svensen
  - Fe chloride—Borrok
  - Fe-oxide—Svensen
  - Fe-oxide-Svelisen
  - Ferropyrosmalite-Rotherham
  - Graphite-Bernardo, Larsen, Luque, Pasteris
  - Gypsum-Svensen
  - Halite—Borrok, Campbell, Cannell, Kozlóv, Perelló, Rotherham, Siemann, Smith, Svensen, Taner, Wei, Willard, Wood, Yardley
  - Hematite-Borrok, Cannell, Kozlóv, Perelló
  - Kainite-Siemann
  - K-feldspar-Svensen
  - Kieserite-Siemann
  - Magnesian calcite-Larsen
  - Magnetite-Rotherham
  - MnCl-Rotherham
  - Muscovite-Beurlen
  - NaCI-Lawrie, Nijland, Pal
  - Nahcolite-Larsen
  - NaKCaPbCl/Br—Svensen
  - Nakcaroci/bi-svensen
  - NiZnAsPb sulfide—Svensen Opaque—Perello

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Ore minerals-Ismailov Pseudocotunite-Kozlóv Pyrite-Cannell Pyrrhotite-Frank Quartz-Svensen Scacchite-Kozlóv Stibarsen-Kozlóv Sylvite-Borrok, Campbell, Cannell, Perello Unknown-Cunningham. Willard Daughter minerals in magmatic/hydrothermal transitional inclusions, ±salts, i.e., "salt melts. Amphibole-Crawford Apatite-Buehn, Campbell Arsenide sulfide of Cu-Buehn Arsenide sulfide of Fe-Buehn Arsenide sulfide of Pb-Buehn Arsenide sulfide of Zn-Buehn Barite-Andreeva Biotite-Golovko Burbankite-Buehn Calcite-Andreeva, Buehn Carbonate-Golovko Chalcopyrite-Crawford Clinopyroxene-Crawford, Golovko Crvolite-Buehn Fluorite-Andreeva, Buehn, Campbell, Chabiron, Solovova F-rich mica-Chabiron General-Khamrabaev Halite-Andreeva, Buehn Hematite-Crawford Hornblende-Crawford KCI-Buehn, Crawford K-feldspar-Dristas Magnetite-Crawford, Golovko Mica-Crawford NaCl-Buehn, Crawford NaHCO<sub>1</sub>-Buehn Nahcolite-Buehn Nouvilleite Na<sub>3</sub>Ca<sub>2</sub>CO<sub>3</sub>-Buehn Parisite-Chabiron Portlandite-Solovova Pyrosmalite-Chapman Sulfate-Crawford, Solovova Svlvite-Buehn Titaniferous magnetite-Dristas Zeolite-Solovova Daughter minerals in melt (non-aqueous) inclusions, including gas, and their significance. Includes phases developed below room temperature. May include some trapped solids-Dunin-Barkovskava, Ismailov Albite-Johan, Turkov Amblygonite-Thomas Amphibole-Turkov, Varela, Veksler, Yang Angelite-Thomas Anhydrite-Johan Apatite-Johan, Solovova, Thomas, Turkov, Varela Berlinite-Thomas Bervl-Li Biotite-Golovko, Johan Burangaite-Thomas Calcite-Solovova Carbonate-Golovko, Veksler Chlorides-Fulignati Chrome-spinel-Yang Clinopyroxene-Golovko, Izraeli, Varela

Fluorite-Fulignati. Solovova F-Turkov Glass-Turkov Graphite-Tomilenko Hematite-Li Ilmenite-Turkov, Varela Isokite-Thomas K-feldspar-Turkov Lazulite-Thomas Magnetite-Golovko Muscovite-Johan Olivine-Yang Orthopyroxene-Kamenetsky, Turkov, Yang Phlogopite-Izraeli Phlogopite-Solovova, Veksler, Turkov Pyroxene-Solovova Spinel-Turkov Sulfide-Yang Sulfide globules-Métrich Titanite-Johan Titanomagnetite-Turkov Tremolite-Johan Triplite-Thomas Trolleite-Thomas Variscite-Thomas Diffusion-Aquilina, Bakker, Boyce, Burnard, Clocchiatti, Doremus, Drescher, Edwards, Graham, Guilhaumou, Klügel, Laier, Larsen, Moriizumi, Nakamura, Polya, Shail, Stipp, Zhang Equilibrium COH speciation-Chiodini. Fedorov Equipment for extraction, freezing, heating, crushing, etc .-Divaev. Dúnin-Barkovskaya. Crawford. Ellendorff. Levin Experimental systems. See also Fluids, physical and thermodynamic properties: Gases in inclusions: Complexes-Aranovich Aqueous-gas-Anovitz, Blencoe, Chou, Duan, Ho, Javanmardi, Leng, Singh Aqueous-metal-Baldassaro, Gibert, Mikucki, Tagirov Aqueous-salt(s)-Brodholt, Cooper, Darling, Krüger, Malinin. Oakes. Pitzer. Schmidt, Thiery, Zhang Aqueous-silicate (and other volatiles)-Koziol, Lee. Mysen, Schmidt, Stachowiak, Stalder, Uchida Other systems-Bai, Hu. Kooi, Linnen, Quartz, Siemann Rocks-Dingwell. Kravchuk. Pak. Webster. Wyllie. Zeng Exploration, use of inclusions in, ore deposits, petroleum-Akande, Armstrong, Bai, Bodnar, Chen, Diváev, Dunin-Barkovskava, Field, Frank, Gil', He, Hedenguist, Khalmukhamedov, Khin Zaw, Li, Lin, Liao, Mango, Neronsky, Pal. Randell, Richards, Shi, Sillitoe, Taguchi, Warren, Xie, Zheng, Zhou Fluids and gases, equations of state Anovitz, Duan, Dubessy, Mallard, Sharma, Thiery, Wiryana Fluids and gases, physical and thermodynamic properties-Anovitz, Bakker, Blencoe, Bodnar, Brodholt, Driesner, Duan. Fournier, Helgeson, Labotka, Larsen, Mallard, Oakes, Pitzer, Richard, Richet, Roberts, Sassani, Schmidt, Seward, Siemann, Singh. Thiery, Weare, Zavel'skii Fluid Flow. See also Origin. cracking of rocks-Allen. André. Appold. Bayuk. Beaudoin. Bodnar. Boiron. Boullier. Brantley. Bruce, Bukata, Cathelineau, Chen, Chi, Diamond, Dobes, Dombrowski, Dutrow, Evans, Everett, Frezzotti, Gleeson, Goebel, Goldfarb, Graham, Halter, Hedenquist, Iwamori, Jenkin, Labotka, Lewis, Li, Lindaas, Lodemann, Morris,

Muchez, Mutlu, Norman, Park, Pletsch-Rivera, Qi-Hao,

Ramambazafy, Roedder, Romer, Rose, Rowan, Sangster,

Satish-Kumar, Schimmrich, Sibson, Stuckless, Szabö, Vazquez, Walshaw, Wayne, Wilkinson, Yardley, Zhai, Zhang

- Gas hydrates-Bakker, Chazallon, Javanmardi, Kastner, Lu, Okui, Ripmeester, Sloan, Stern
- Gases and fluids, mantle, deep-seated. See also Inclusions in diamonds: Kimberlites: Xenoliths—Albarede, Bakker, Brenan, Brooker, Bureau, Burgess, Carroll, Chazallon, Clemens, D'Alessandro, Danyushevsky, De Corte, Feng, Fischer, Haggerty, Hansteen, Harmer, He, Heath, Holtoway, Hopp, Hu, Hurai, Iwamori, Jambon, Javanmardi, Jochum, Kamijo, Kastner, Kontak, Kunz, Lokhov, Lu, Mandeville, Mao, Marty, Marty, McInnes, Moreira, Navon, Newton, Nivin, Okui, Park, Pettke, Philippot, Pineau, Pokróvsky, Ren, Ripmeester, Sano, Schiano, Shi, Shimizu, Simakov, Sloan, Sobolev, Spandler, Stalder, Stern, Stuart, Szabó, Thrower, van Keken, Wada, Wallace, Wei, Wyllie, Yamashita, Yardley, Yusupov, Zeng, Zheng
- Gases (volatiles) in igneous rocks, magmas, and volcanism. See also Analysis, data. gases—D'Alessandro, Della-Pasqua, Frank, Gurenko, Harms, Martel, Pineau, Ragnarsdottir, St. Almand, Sharapov, Tedesco
- Geothermal fluids and systems, active and fossil. See also Mineral deposits. Epithermal: Dredge samples—Abidin. André, Bargar. Brown. Christenson. Darling. Gallup. Hedenquist. Hopkinson. Hou. Hua, Imai. Ishizuka, Jean-. Baptiste, Ji, Kadko. Kasai. Komatsu. Lüders. Ma. Magro. Moore. Muramatsu. Muraoka. Mutlu. Naden. Norman. Ohtani. Pang. Parson. Peter. Pettke. Prichard. Prol-Ledesma. Sansone. Sasaki. Sekine. Simonov. Stuart. Taguchi. van Soest. Vanko. Viggiano, Xu, Yang

## Geothermometry

- Decrepitation data—Chen, Dúnin-Barkovskaya, Li, Neronsky, Tsói, Yusupov
- Decrepitation theory, methods, and comparison with other methods—Bai, Diváev, He, Ismailov, Levin, Li, Shi
- Freezing data, interpretation (gases or liquids)—Baldassaro, Collyer, Killawee, Török, Walker, Xiao
- Homogenization. aqueous ≥500°C—Allen, Andreeva, Aquino, Audétat. Baker, Bakker, Boiron, Borrok, Brauer, Cassidy, Cepedal. Christenson, Edraki. Feng, Fortuna, Frezzotti, Gil', Giuliani, Golovko, Gunn, Hezarkhani, Ishiyama, Kasai, Khamrabaev, Khin Zaw, Kodera, Kyle, Lang, Lu, Martin-Izard, Mikucki, Muraoka, Pasteris, Peng, Perelló, Poletti, Rao, Rotherham, Rowłand, Schmidt, Sharma, Solovova, Sutherland, Taner, Vanko, Vazquez, Wawrzyniec, Willard, Williams
- Glass, properties, etc.—Kustárnikova, Sharapov Homogenization method, accuracy, comparisons, and factors affecting—Awwiller, Barker, Chi, Muchez, Schmidt, Vityk, Yemane

Immiscibility-Bastnaesite-Liu

Silicate-carbonate—Brooker, Clark, Golovko, Harmer, Lee, Minarik, Ray, Saal, Wyllie Silicate-silicate—Newton Silicate-steam—Bureau Silicate-sulfide—Métrich, Saal, Sharapov

Other types—Chou, Frank, Genge, Hurai, Ripley, Thomas, Yang Inclusions, <u>aqueous</u> (fluid, non-melt, in host minerals, oil and

gases and discussion) includes oil and gases in non-igneous materials. Aegirine—Smith

Allaktite—Jonsson Andradite—Amthauer Anhydrite—Jarmolowicz-Peter, Samson, Sawaki, Szulc Ankerite—Baker, Muchez, Nielsen, Vançon

Apatite-Divaev, Sibescu, Smith, Solovova, Warner

- Barite-Cathelineau. Deneele, Jonnson, Kontak, Lu.
- Lüders. Maglambayan, Mizuta. Naden. Smith. Wang. Zeng
- Barofavourite-Yusupov
- Bastnasite-Smith
- Beryl-Giuliani. Khin Zaw
- Calcite, —Ishiyama, Jarmolowicz-Szulc, Jonnson, Lu, Mach, Maglambayan, Mango, Muchez, Nielsen, O'Reilly, Parry, Poliquin, Richards, Rose, Savard, Stipp, Wendte, Zak
- Cassiterite-Audétat
- Chromite-Johan

Cinnabar-Lu

- Colemanite-Miranda-Gasca
- Corundum-Garland, Sutherland, Sawaki
- Diopside-Edwards, Lu
- Dolomite—Baker, Cathelineau, Chi, Feng, Hitzman, Lu, Luczaj, McNeil, Morrow, Nesbitt, Nielsen, O'Reilly, Qing, Randell, Rose, Savard, Walgenwitz, Wendte
- Dolomite FI-Montañez
- Emerald-Giuliani. Ménez. Moroz

Enargite-Lindaas

- Epidote-Scambelluri
- Fayalite-Rasmussen
- FeCl2-2H2O-Baker
- Fe-Mn-Cl'Si-Baker
- Fluorine-Rowan
- Fluorite—Borrok, Cathelineau, Chen, Cline, Cunningham, Giuliani, Khin Zaw, Kozlowski, Pironon, Rankin, Smith, Souissi, Tsói, Wen, Wood, Zeng
- Forsterite-Gunn
- Galena-Leach. Vazquez
- Garnet—Allen, Herms, Kaindl, Khin Zaw, Linnen, Liu, Lu, Neronsky, Niimi, Philippot, Scambelluri, Sirbescu, Vazquez, Vikre
- Gemstones-Liu
- General-de Ronde
- Genthelvite-Mas
- Glaucophane-Liu
- Graphite-Pasteris
- Gypsum-Rosell
- Halite-Baker, Benison, Cendón, Fanlo, Ghazi, Grishina, Horita, Kovalevich, Petrichenko, Sawaki, Lowenstein, Prohl, Samson, Shepherd, Siemann, Steinmann, Timofeeff, Williams

Helvite-Khin Zaw

Hsianghualite-Liu

- Ice-Golden, Killawee
- K-feldspars-Luczaj
- Kyanite-Kaindl, Xiao
- Magnesite-Nesbitt
- Monazite-Smith
- Omphacite-Philippot, Scambelluri, Svensen, Xiao
- Orpiment-Cline, Shigehiro
- Orthopyroxene-Bodnar, McInnes
- Parisite-Wood
- Pb-K chloride-Williams
- Pyrite-Burnard
- Pyrosmalite-Baker. Williams
- Pyroxene-Allen, Solovova, Vikre
- Quartz-Chen. Etoh
- Realgar-Cline, Shigehiro

Sapphirine-Nijland Sarkinite-Jonsson Scapolite-Dombrowski Scheelite-Baksheev, Dúnin-Barkovskaya, Graupner, Ogata, Singoyi Siderite-Garrido, Hurai Sphalerite-Chi, Garrido, Heimbach, Ishiyama, Leach, Luczaj, Lüders, Maglambayan, Mango, Naden, Ragan, Randell, Richards, Rose, Savard, Vazquez, Viets, Walshaw, Wang, Wen, Wilkinson Sylvite-Baker, Grishina, Williams Tachyhydrite-Timofeeff Topaz-Halter, Khin Zaw, Kozlowski Tourmaline-Kozlowski, Sirbescu, Tonarini Vesuvianite-Compagnoni Wolframite Chen, Gunn, Shail Inclusions, magmatic/hvdrothermal transitional, ±salts, i.e., "salt-melts." Apatite-Sharygin. Solovova Diamond-Izraeli Diopside-Sharygin Fluorite-Andreeva Garnet-Chapman General-Crawford, Lin, Zhang Halite-Chapman Olivine-Sharvgin Pb-K-Cl-Chapman Phlogopite-Sharygin Pvroxene-Chapman, Solovova Quartz-Shmulovich Svlvite-Chapman Topaz Chang Inclusions, melt, gas, silicate and sulfide melt in host minerals, and discussion. See also Silicate melt inclusions. Accessory-Ratikov Alexandrite-Smirnov Alkali feldspar-Rawat Anorthoclase Eschenbacher, Hurai Apatite-Diváev Barite-Kontak Bervl-Li Bytownite-Titoy Calcite-Bargar, Diváev, Kodera, Kontak, Veksler Chrome-diopside-Golovko Chromite-Yang Clinopyroxene-Belkin, Crawford, Dristas, Gurenko, Hansteen, Hurai, Jousselin, Minarik, Saal, Sobolev, Stalder, Szabö, Turkov, Varela, Veksler, Webster Corundum Smirnov, Wu Diamond-Amantov, Burgess, De Corte, Diváev, Fedorov, Garanin, Gassymova, Haggerty, Izraeli, Kaneoka, Kasimova, Larsen, Milledge, Navon, Simakov, Slodkevich. Sobolev. Sunagawa. Taylor. Tomilenko. Wada, Wyllie, Yamashita, Yusupov, Zhang, Zheng Diopside—Dristas Emerald-Smirnov Ferrite-Yusupov Forsterite-Abe Garnet-Gassymova, Kasimova, Kodera, Linnen, Stalder General-Armstrong, Brennan, Dietrich Graphite-Larsen Hornblende-Crawford Josephinite Yusupov Kaersutite-Hurai

Khamrabaerite-Yusupov

Labradorite-Titov Melilite-Veksler Moissanite-Yusupov Na-K-Ca-Veksler Na-Mg-Veksler Olivine-Bureau, Clocchiatti, Cmiral, Danyushevsky, Della-Pasqua, Eschenbacher, Gassymova, Gioncada, Grossman, Gurenko, Hansteen, Hauri, Jousselin, Kamenetsky, Kasimova, Kent, Lee, Métrich, Minarik, Nielsen, Ninomiya, Saal, Shimizu, Sobolev, Tedesco, Turkov, Varela, Veksler, Xu, Yang Orthopyroxene-Varela Perovskite-Veksler Perthite-Rawat Plagioclase-Armstrong. Belkin, Briggs. Eschenbacher. Jousselin, Lee, Mandeville, Nakamura, Nielsen, Orsoev. Prokofyev, Thordarson, Titov Pyroxene-Tedesco, Yang Quartz-Vapnik Rutile-Stalder Sanadine-Fulignati Sphalerite-Kodera, Kontak Spinel-Smirnov, Spandler, Thomas, Turkov, Varela Titanaugite-Golovko Topaz-Chang. Prokofev. Webster Wairakite-Bargar Wollastonite-Hoisch Zircon-Chupin, Gassymova, Kasimova Inclusions in rocks. See also appropriate minerals. Alkaline-Bobrov, Kasimova, Lokhov, Nivin, Orsoev. Potter Andesite-Martel. Pineau. Richet. Thordarson. Ullrich Ankaramite-Della-Pasqua Anorthosite-Orsoev Basalt-Cartigny, Heath, Hurai, Jochum, Kamenetsky, Kent, Letnikov, Metrich, Nishio, Pineau, Pokróvsky, Prokofyev. Ripley, Saal, Sano, Sharapov. Shimizu, Steinmann, Stuart, Wallace, Zhang Basanite-Eschenbacher. Hansteen, Ninomiya. Szabő Blueschist-Manning Boninite-Danyushevsky. Varela Carbonatite-Andreeva, Brooker, Buehn, Campbell, Cartigny, Clark, Diváev, Harmer, Lee, Marty, Ray, Solovova, Veksler, Wyllie, Yamashita, Zhang Charnockite-Satish-Kumar Dacite-Mandeville, Thordarson, Yang Diopside-Sharvgin Dolerite-Cooke Dunite-Hansteen. Johan Eclogite-Ayers, Cartigny, Izraeli, Kooi, Liu, Manning, Philippot. Pokróvsky. Scambelluri. Sobolev. Stalder. Svensen, Taylor, Xiao Enderbite-Fonarev Evaporite-Ayora, Benison, Board, Cendón, Davidson, den Brok. Ellendorff. Fanlo. Ghazi. Grishina, Horita. Hurai. Kovalenker, Kovalevich, . Lowenstein, Markl, Nesbitt, Petrichenko, Prohl, Randell, Rosell, Shepherd, Siemann, Steinmann, Timofeeff, Usdowski, Wendte Gabbro-Orsoev. Philippot. Sobolev Granite-Anderson, Chupin, Crawford, Dingwell, Dobes, Dominy, Hotta, Hurai, Khin Zaw, Komatsu, Koval, Kozlowski, Linnen, Lodemann, Mallard, Mas, Mikulski, Mizota, Molnár, Müller, Muramatsu, Naumov, Park, Peng. Philpotts. Pletsch-Rivera, Pokróvsky, Poutiainen, Qu. Rankin, Rawat, Riller, Samson, Sawaki, Schmidt,

Sekine, Sirbescu, Thomas, Titov, Vançon, Vapnik, Webster, Xie Granodiorite-So, Titov, Vikre, Wayne, Willard, Yazdi. Zacharias Granulite-Anderson, Aranovich, Bobrov, Fonarev, Gibert, Harlov, Herms, Kooi, Larsen, Markl, Newton, Niimi, Nijland, Pokróvsky, Ramambazafy, Rao, Satish-Kumar, Scambelluri, Touret, Xu Greisens-Dominy, Halter, Kozlowski, Linnen, Ryzhenko, Somarin Harzburgite-Burnard, Danyushevsky, Hansteen, Johan, Kamenetsky, Métrich, Nielsen, Varela ljolite-Veksler Kimberlite-Divaev, Kasimova, Slodkevich, Yamashita Lamproite-Lokhov Apatite-Sharygin Lafite-Prokotyev Lamprophyre-Huang Lherzolite-Ayers, Ducea, Matsumoto, Słodkevich, Varela, Xu, Yang Metamorphic, low/medium grade-Brantley, Egle, Frezzotti, Marescotti, Marshall, Mazurek Metamorphic. medium/high-Bargar. Cassidy. Fonarev. Giuliani, Gleeson, Harms, Hoisch, Invernizzi, Kaindl, Larsen, Markl, Marshall, Narasimha, Neumayr, Newton, Nijland, Poletti, Rao, Scambelluri, Tojo, Török, Touret, Xiao, Xu Metamorphic P-T paths-André. Craw. Herms. Invernizzi, Liu, Mandeville. Marshall. Min, Neumayr. Satish-Kumar, Sharma, Xiao Meteorite, teklite, impactite, lunar-Bodnar, Bogard, Genge, Grossman, Koeber, Righter, Ruzicka, Sturkell, Varela Migmatite-Park, Pokróvsky MORB-Agrinier. Cartigny. Darling. Ernst. Holloway. Kamenetsky, Kaneoka, Kent, Lokhov, Marty, Matsumoto, Philippot, Pineau, Sano, Sharapov, Shimizu, Sisson, Stalder, Tedesco, van Soest, Wada, Wallace, Yang Olivine-Schiano, Sharygin Ongonite-Naumov Ophiolite-Invernizzi. Johan. Jousselin. Neumayr. Pettke. Prichard, Sobolev, Vanko Pantellerite-Naumov Pegmatite-Anderson, Beurlen, Chou, Dragusanu, Khin Zaw, Larsen, Li, Linnen, Mas, Morales-Alvarado. Naumov, Pal. Samson, Sawaki, Sirbescu, Thomas Peridotite-Eggins, Harmer, Holloway, Johan, Jousselin, Kamenetsky, Klügel, Ninomiya, Simakov, Sobolev, Wyllie, Yamashita, Xiao Phlogopite-Sharygin Phonolite-Eschenbacher, Harms, Webster Picrite-Jochumk, Kent, Sobolev, Turkov Pvroxenite-Johan Quartz monzonite-Vapnik Rhyolite-Briggs, Chabiron, Lewis, Mandeville, Naumov, Webster, Yang Rodingite-Compagnoni Sedimentary, authigenic, diagenetic, cements, overgrowths, basins-Akande, Aquilina, Awwiller, Avora, Barker, Benison, Blvth, Brennan, Cathelineau, Cesaretti, Chen, Chi, Davidson, De Ros Luiz, Deneele, Dombrowski, Duval, Egle, Essarraj, Evans, Everett, Fanlo, Feng, Fernández-Martínez, Frimmel, Ghazi, Gleeson,

Goodman, Guilhaumou, Guo, Hall, Hao, Helgeson,

Hitzman, Horita, Hutcheon, Imai, Large, Lawrie, Li. Lisk, MacGowan, Milodowski, Miranda-Gasca, Mresah, Muchez, Mullane, Munz, Mutlu, Nielsen, Omar, O'Reilly, Parnell, Petrichenko, Pottorf, Oing, Rankin, Richard, Rock, Rosell, Rowan, Sangster, Savoye, Sheppard, Sum, Tornos, Vapnik, Vengosh, Walgenwitz, Wang, Warren, Wendte, Wilkinson, Yardley, Yemane, Zangrilli, Zhang, Zheng Shonkinite—Golóvko Shoshonite—Prokofyev Skarn-Artykov, Cepedal, Edraki, Feng, Gilg, Ismailov, Kodera, Kozlóv, Kyle, Lang, Li, Ling, Lu, Mango. Martin-Izard, Norman, Ogata, Peng, Ramambazafy, Singovi, Uchida, Vazquez, Vikre Speleothems, vadose zone-Burns, Dennis, Gatter, Goede, Hill, Huang, Richards, Verheyden, Wang Svenite-Shi Tholeiite-Clocchiatti. Lee, Ripley, Spandler Tonalite-Bobrov, Chupin, Hurai, Poletti, Titov Trachyte-Divaev, Dristas, Pivec, Zhang Ultrabasic-Nivin, Perinelli, Veksler Inclusions, inherited, melt or aqueous-Briggs. Chupin. Kent, Krekeler, Traxel Isotopes, data, fractionation, exchange, etc. (on inclusion fluids, but gases might be from glass or rock minerals, not inclusions). See also Analysis data. noble gases. Argon-Boyce, Burgess, Cartigny, Hopp, Hu, Kendrick, Lokhov, Marty, Moore, Nivin, Qiu, Stuart, Turner Bromine-Eggenkamp Boron-Vengosh Carbon-Burgess. Cartigny. Darling. Fischer. He. Lewis. Marty, Xu Chlorine-Eggenkamp, Lodemann, Lokhov, Philippot, Ransom General principles, fractionation, exchange, analytical proc., equlibria Bogard, Burnard, Chi, Dipple, Doremus, Halliday, Hopple, Lewis, Satish-Kumar, Socki, Vaughn, Turner Helium-Bach, Burgess, Charlou, Darling, Fischer, Hu, Jean-Baptiste, Lokhov, Marty, Nishio, Nivin, Stuart, van Soest. Turner Hydrogen-Alderton, Altamura, Choi, Cline, Dennis, Dobes, Egle, Feng, Gleeson, Hauri, Hopple, Imai, Naden. Nie, Pineau, Qing, Selby, Simon, Socki, Vaughn, Vazquez, Vikre, Wei, Xu K-Grossman Lead-Layne. Shimizu Lithium-Zhang Neodymium-Ducea Neon-Cartigny, Marty, Tedesco Nitrogen-Lokhov Noble gases-Albarede, Altamura, Ballentine, Burnard, Drescher, Jambon, Kamijo, Kaneoka, Kendrick, Marty, Matsumoto, Moreira, Nivin, Osenbrück, Polya, Sano, Stuart. Thrower, Wada Oxygen-Alderton, Altamura, Beaudoin, Borrok, Bruce, Choi, Cline, Dennis, Dobes, Edwards, Feng, Giuliani, Gleeson, Graham, Lewis, Naden, Nie, Satish-Kumar, Simon, Socki, Vaughn, Vazquez, Vikre, Walgenwitz, Wei. Xu Strontium-Ducea, Hitzman Sulfur-Hu Xenon-Kaneoka, Kunz,

Magmatic differentiation-Jochum, Kent. Sobolev
Mantle metasomatism-Metrich, Nielsen, Sobolev, Stalder, Szabö, Taylor, Varela Metastability-Darling Mineral Deposits. See also Locality Index: Inclusions in minerals: Analysis, data, for appropriate elements. Antimony-Bailly, Belevantsev, Choi, Gray, Jonsson, Oelkers, Ramsav, Yang, Zhang, Zhu Arsenic-Baker, Cline, Dunin-Barkovskaya, Essarraj, Gray. Jiyuan, Jonsson, Ramsay, Wetten Barite-Bruce, Cathelineau, Dobes, Everett, Hitzman, Kontak, Milodowski, Mizuta, Mullane, Vavelldis, Zhang Bervllium-Beurlen, Chou, Zeng Bismuth-Allen. Baker. Coutinho. Dobes. Dúnin-Barkovskaya. Gao. Khin Zaw. Kozlóv. Taner. Thieben. Zhang Borate -- Miranda-Gasca Cadmium-Coutinho Chromite-Johan. Yang Cobalt-Bortnikov, Cannell, Dobes, Essarraj Copper-Bailly, Baker, Cannell, Cepedal, Choi, Dobes. Essarraj, Feng, Frank, Hedenquist, Heinrich, Hu, Ji, Khamrabaev, Khin Zaw, Kontak, Kozlóv, Lawrie, Li. Lindaas, Lu, Martin-Izard, Master, Molnar, Ogata, Peng, Peter, Pivec, Polya, Qiu, Ren. Rohrlach, Shail, So. Taylor, Ullrich. Vila. Wachowiak. Wang. Wei. Wen. Wetten, Yang, Zhang Epithermal and hotspring-Bailly. Cepedal. Crawford. Dominy, Heinrich, Imai. Kozlóv, Lüders, Martin-Izard. McDonald, Molnar, Norman, Willan, Plotinskaya Fluorite-Bruce, Cathelineau, Cunningham, Dobes, Dúnin-Barkovskava, Rowan, Souissi, Tsói Germanium-Pokrovski Gold (major entries) Carlin-Brake, Cline, Khin Zaw, Liu, Lu, Prokofyev, Shigehiro, Su. Sun, Zhang Epithermal-Agrinier, Aissa, Alderton, Aquino, Bailly, Basuki, Camprubí, Cao, Faure, Gál, Gatter. Hedenquist, Heinrich, Imai, Ishizuka, Jargalan, Kozlóv, Lindaas, Love, Maeda, Maglambayan, Molnár. Naden. Noya. Perellö. Petersen. Plotinskaya, Poliquin, Ramsay, Richards, Rios, Scott, Shimizu, Simon, So, Spry, Takahashi, Thieben, Thompson, Vikre, Wu Mesothermal-Altamura, Bai, Bain, Baker, Baksheev, Boiron, Bortnikov, Boullier, Dobes, Egle, Fricová, González, Jargalan, Khin Zaw, Lawrie, Marshall, McCuaig. Mernagh. Parry. Polito. Ramsay, Ramsay. Shi, Sibson, Sillitoe, Taylor, Wang Metamorphic-Baker, Buccholz, Cassidy, Coutinho. Dugdale. Dunin-Barkovskava, Egle, Fan. Gao. González, Groves, Khalmukhamedov, Kontak, Lawrie, Lee, Li, Mernagh, Nie, Pettke, Shen, Silva, Tian. Tsói, Witt, Xu. Zhai Porphyry-Crawford, Yazdi, Zacharias Skarn-Allen, Baker VHMS-Khin Zaw, Lawrie, Liu, Lu Other, includes unknown type-André, Ball, Blamey, Bobrov, Boiron, Burnard, Cannell, Chang, Chauvet, Chen. Dziggel, Fent, Gil, Goldfarb, Gray, He, Hu. Huang, Jelsma, Ji, Kataoka, Khamrabaev, Klemd. Li, Liao, Liimatainen, Lindley, Liu, Lizorkina, Long, Lu, Mao, Mapani, Ménez, Neronsky, Prichard, Rasmussen, Reynolds, Schmidt Mumm. See, Sillitoe, Simeone, Smith, Sokerina, Sun, Tunks,

Ullrich, Urbano, Vavelldis, Wei, Wetten, Xie, Xu. Yang, Young, Yu, Zhang, Zhautikov, Zhu Gold, lesser deposits, minor mention (geochemistry, etc.)-Altamura, Badálov, Baranova, Choi, Crawford, Diváev, Dobes. Dúnin-Barkóvskaya, Fan. Gibert. Golóvko. Heinrich, Konëev, Murphy, Philippot, Prol-Ledesma, Qu. Schofield. Shi. Simonov. Vila. Williams. Yardlev. Zhang, Zhao, Zhautikov Graphite-Benison, Lodemann, Rowe, Singoyi, Smith, Vila Iron (including siderite and BIF)-Borrok. Fonarev. Kodera Kaolin-Dominy Kuroko-Ishizuka. Maglambayan. Mizuta Lead and lead-zine-Appold. Baker. Beaudoin. Bechtel. Bruce, Chapman. Charef. Chi, Choi, Costagliola. Davidson, Dobes, Everett, Fallara, Feng, Fernández-Martinez, Frimmel, Gao, Garrido, Gaunt, Giles, Gilg, Goebel, Kontak, Kozlóv, Leach, Guan, Gunn, Hanor, Hitzman, Ishizuka, Jiyuan, Jonsson, Khin Zaw, Kontak, Kyle, Mach, Mango, McCandless, Molnár, Muchez, Parilov, Pivec, Ragan, Randell, Rohrlach, Rose, Sangster, Savard, Sheppard, Taylor, Tornos, Vavelldis, Vazquez, Wachowiak, Wang, Wei, Wilkinson, Williams, Xu, Zhang, Zhu Lithium-Beurlen. Khamrabaev. Linnen, Saidygániev Manganese-Jonsson, Mach. Marescotti, Wang, Yang Massive sulfide. VHMS-Foley. Khin Zaw. Lang. Prichard Mercury-Essarraj, Lu. Vikre. Zhang Mississippi Valley-Akande, Appold, Chi, Cooke, Davidson, Goebel, Heimbach, Leach, Luczaj, Misra, Montañez, Muchez, Nesbitt, Pironon, Ragan, Rohrlach. Rose, Savard. Souissi. Thrower. Tornos. Turner. Viets. Wachowiak, Walshaw Molybdenum-Baker, Chabiron, Coutinho, Cunningham, Ismailov, Khamrabaev, Molnár, Molnár, Peng, Somarin, Taner, Walker Nickel-Dobes, McCormick, Molnár Niobium-Smith Platinum and PGE-Crocket. Johan, Mapani. McDonald, Molnár, Orsoev, Prokofyev, Sassani, Spandler, Polymetallic-Camprubi. Cathelineau. Chen. Dobes. Foley. Gál. Khin Zaw. Liu. Lu. Lüders. Mikháilova, Molnár, Ren, Taylor, Vikre, Wang, Wei, Wu, Xu, Yang, Zhao Porphyry Au-Lindaas. Maglambayan. Nikoláeva. Parilov. Perellö. Rowland, Schedl, Selby, So, Turesebekov, Willard, Yang, Yazdi, Zacharias, Porphyry Cu (±Au)-Aquino. Armstrong. Baker. Bodnar. Cepedal, Chen. Fortuna. Heinrich. Hu, Hedenquist, Kaldyshkina, Khamrabaev, Kozlóv, Kyle, Perellö. Tumer Porphyry Cu and Mo (±Au)-Garrido. Hezarkhani. Peng. Selby, Willard Porphyry Mo (Au)-Peng. Somarin. Spry. Thieben Potash-Ayora, Cendón, Grishina Pyrite. See also Massive sulfide-Parilov Quartz-Lokhov, Lueth. Mizota Rare earth elements (REE) -Cannell. Liu. Rankin. Smith. Wood Rare metal deposits (Soviet usage)-Artykov, Dúnin-Barkovskaya, Ismailov Selenium-Coutinho. Hedenquist Sedex-Baker, Fernández-Martínez, Large, Lawrie, Wen, Xia Silver-Alderton, Beaudoin, Camprubi, Cao, Chapman,

Chen. Choi. Costagliola. Coutinho. Dietrich. Dobes. Essarraj. Faure. Gál. Garrido, Giles. Gilg. Gunn. Ishizuka, Ji, Jiyuan, Khin Zaw, Konéev, Kontak, Kozlóv, Kyle, Mach, Maeda, Maglambayan, McCandless, Noya, Pivec, Polya, Rios, Rohrlach, Shimizu, Spry, Sun, Takahashi, Taylor, Thieben, Thompson, Tsói, Vavelldis, Vazquez, Vikre, Wang, Wei, Wilkinson, Williams, Wu, Xu, Yang, Zhang, Zhao

Tantalum-Beurlen, Linnen

Tellurium—Alderton, Allen, Cao, Chen, Coutinho, Furong, Gál, Gao, Hedenquist, Maglambayan, Pivec, Plotinskaya, Spry, Thieben, Thompson, Wei

Tin—Audétat. Baker. Beurlen. Dietrich. Dominy. Fogliata. Halter, Khin Zaw, Linnen. Liu. Marignac. Ogata, Pal, Polya, Ryzhenko. Shail. Somarin. Traxel, Wang. Zeng

Tungsten—Audétat, Baker, Bortnikov, Chen, Gray, Ismailov, Ji, Khin Zaw, Lee, Linnen, Liu, Mallard, Marignac, Mikulski, Ogata, Polya, Sardi, Shail, Singoyi, Somarin, Walker, Xu, Yang, Zeng, Zhang

Uranium—André, Cannell, Chabiron, Cunningham, Dobes, Egle, Li, Liu, Luo, Min, Romer, Taylor, Yardley, Zhai Vanadium—Frimmel

Zinc-Bailly, Essarraj, Heimbach, Ma, Peter, Rankin, Wang, Wen

Zirconium-Fogliata

Modeling of ore deposits and basins. See also Computer-Beaudoin. Cathelineau

Movement of inclusions or bubbles-Clocchiatti, den Brok. Kornushin, Stipp

Nuclear waste sites—Blyth. Bukata. Devidal. Diamond. Dublyansky, Hill. Milodowski. Osenbrück. Prohl. Roedder, Steinmann

Organic compounds, bitumen, vitrinite, coal, etc.—Andresen. Barker, Bigge, Brennan, Buick, Cesaretti, Chen, Compagnoni, Giuliani, Goebel, Grishina, Guo, Hao, Kontak, Laier, MacGowan, Muchez, Munz, Okubo, Randell, Richard, Shanina, Vapnik, Wang, Yemane

Organic compounds, oil and gas fields, maturation, migration, exploration—Akande, Andresen, Awwiller, Bakker, Bigge, Brennan, Buick, Cesaretti, Chen, Chi, Darling, Duval, Feng, Guilhaumou, Guo, Hall, Hao, He, Jarmolowicz-Szulc, Li, Lisk, MacGowan, McNeil, Munz, Okubo, O'Reilly, Parnell, Pottorf, Qing, Rock, Sum, Sun, Vapnik, Voznyak, Warren, Wilkinson, Worden, Yemane, Zhang, Zheng, Zhou

Organic compounds, General. See also Analysis data, higher hydrocarbons. acetate. etc.—Dublyansky, Dutkiewicz, Fournier, Gassymova, Giuliani, Helgeson, Kasimova, Pironon, Lu, Mathez, Richard, Ridley, Sum, Yardley

Organic compounds in ore deposits—Bechtel, Cathelineau, Cepedal, Chang, Chen, Chi, Cline, Gaunt, Giuliani, Ji, Kontak, Lawrie, Linnen, Lu, Randell, Sangster, Souissi, Sun, Zeng, Zhang, Zhautikov

Origin and Changes in inclusions: See also Synthethic inclusions.

Chronology of generations-Brauer

Cracking of rocks or minerals, decrepitation in nature or laboratory, hydrolytic weakening. See also Fluid Flow.—Bakker, Bargar, Bayuk, Bodnar, Boiron, Brauer, Bureau, den Brok, Ferrill, Giles, Golovko, Herms, Levin, Liu, Mernagh, Nielsen, Onasch, Pletsch-Rivera, Riller, Sausse, Schmidt, Sharma, Zhao

Crystal growth phenomena—Abe. Bonev. Cmiral. Collyer. Davis, Gál, Johnson, Cloechiatti, Smirnov, Sunagawa, Wiltschko

Deformation, dislocations-Bonev, den Brok, Ferrill, Onasch, Riller, Stipp, Varela, Vityk, Zhang Leakage (in or out). refilling—Bakker, Brennan, Fonarev, Gibert, Gleeson, Nielsen, Polya, Richards, Savoye, Stipp, Zak

Recrystallization and re-equilibration effects-necking down-Bakker, Faure, Giles, Golden, Herms, Invernizzi, Kaindl, Pasteris, Riller, Vityk

Stretching (and collapse)—Brennan. Deneele. Fonarev. Hansteen. Invernizzi, Lowenstein. Schmidt. Sharma, Vityk, Zhang

Trapping mechanisms—Cmiral, Davis, Della-Pasqua, Golden, Minarik, Nakamura

Wetting phenomena—Cmiral, Gibert, Minarik Paleoatmosphere and paleoclimates, paleoseawater See also

Inclusions in ice: Inclusions in rocks. speleotherms—Benison, Burnard, Burns, Cendón, Dennis, Dutkiewicz, Fanlo, Halliday, Kamijo, Kovalevich, Lowenstein, Muchez, Osenbrück, Petrichenko, Qing, Sangster, Timofeeff, Vengosh, Verheyden, Wang, Willan, Zhang

Partial pressure (also fugacity, activity) H<sub>2</sub> (and pH)—Benison, Lewis, Liu, Lvov, McKeagney, Peng, Roberts, Taylor, Thieben, Tunks, Wang, Xia, Yusupov

Partial pressure (also fugacity, activity) O<sub>2</sub>—Beaudoin, Blamey, Cannell, Divaev, Fan, Frank, Gilg, Halter, Holloway, Hurai, Ji, Larsen, Lawrie, Liu, Maglambayan, Molnár, Orsoev, Pasteris, Peng, Pokróvsky, Ramambazafy, Righter, Rotherham, Simakov, Spandler, Taylor, Thieben, Wang, Xia, Xu, Yardley, Zacharias, Zhaútikov, Zhang

Partial pressure (also fugacity, activity) S<sub>2</sub>, H<sub>2</sub>S, etc.—Blamey, Ji, Liu, Maeda, Maglambayan, Peng, Taylor, Xia, Zhang, Zhao

Partitioning between phases. See also Isotopes. general: Analysis. REE—Ayers, Brenan, Frank, Heinrich, Hurai, Killawee, Quartz, Siemann, Stalder, Steinmann, Uchida

Petrography of inclusions; artifacts, sample preparation-Bodnar, Johnson, Khamrabaev, Komov, Kormushin, Rosin

Reviews, introductions and bibliographies. See also Books-Barnes, Benison, Bernikov, Brown, Dúnin-Barkovskaya, Groves, Haggerty, He, Huston, Irwin, Khamrabaev, Kovalenker, Kozlóv, Linnen, Lydon, Mallard, Marignac, Master, McCuaig, Ménez, Polickovsky, Ragnarsdottir, Shen, Shepherd, Sloan, Smirnov, Walshaw, Wiesheu, Williams, Witt

Rock-water interaction (alteration, exchange rates, etc.)— Bargar, Cathelineau, Deneele, Diváev, Deneele, Edraki, Fan, Giuliani, Halter, Hanor, Lewis, Lin, Lodemann, Maineri, McKeagney, Mysen, Peng, Prol-Ledesma, Vançon, Vazquez, Xu, Zeng, Zhang

Silicate melt inclusions, homogenization, data and techniques— Audétat. Belkin. Crawford. Della-Pasqua, Ducea. Gioncada. Koval. Ling. Poutiainen. Prokof'ev. Rawat. Ryabchikov. Solovova, Turkov. Vapnik. Varela. Webster, Yang

Silicate melt inclusions, Interpretation—Dingwell, Golovko, Nielsen, Prokof'ev, Rawat, Ryabchikov, Schiano, Shmulovich, Thomas, Turkov

Structural geology, use of inclusions in. See also Inclusions in rocks. metamorphic. P-T paths: Origin of Inclusions, chronology: Fluid. flow—Altamura, Avé Lallemant, André, Board, Brauer, Craw, Diamond, Dugdale, Evans, Ferrill, Field, González, Goodman, Jelsma, Marignac, Min, Montomoli, Morris, Mresah, Neumayr, Parnell, Parry, Riller, Schimmrich, Sibson, Sillitoe, Slobodník, Svara, Wawrzyniec, Wayne, Wendte, Wiltschko, Wyder, Xu, Zhang

Synthetic inclusions; inclusions in synthetic materials, including gems—Abe, Amthauer, Baldassaro, Chazallon, Darling, Davis, den Brok, Dennis, Dubessy, Ellendorff, Fabre, Fedorov, Gibert, Irwin, Ishiyama, Krüger, Leng, Lowenstein, Ménez, Philippot, Schmidt, Sharma, Smirnov, Tomilenko, Vityk, Walker, Zhao

Vesiculation-Cartigny. Wilson. Linnen. Martel

- Water (and OH) in magmas and minerals. See also 3. Water-Dingwell, Gioncada, Guilhaumou, Heath. Moore, Pineau. Pokróvsky, Poutiainen, Richet, Vapnik, Webster, Zavel'skii
- Water (liquid and salts) in silicate melt inclusions—Belkin. Hauri. Koval. Moriizumi. Prokot'ev. Richet
- Xenoliths. See also Inclusions in rocks—Altamura. Bernardo. Bureau, Burnard, Dristas. Ducea. Eggins. Fulignati, Hansteen. Hopp, Hurai, , Klügel, Mathez, McInnes, Metrich, Métrich, Neumayr, Ninomiya, Perinelli, Schiano, Simakov, Sutherland, Szabö, Taylor, Xu

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## Locality Index

Notes: See head of Subject Index. Individual deposit place names are indexed only when significant data are presented. Inexact place names (e.g., "Soviet Far East") are not entered, nor are individual mines in districts knowy by a district name, although some may be so entered, in error. Cyrillic (and Chinese) place names are listed as they were given in the original transliteration: various transliterationprocedures yield different spellings, e.g., Polykovsky and Polyckovsky. For place names starting with an adjective (e.g., North Pennines), see main entry also. Names starting with M., Mt., Monte, and Mount are alphabetized exactly as spelled.

#### A

Abitibi Au, Québec, Canada-Boullier Afghanistan emeralds-Giuliani Ailaoshan Au, China-Burnard Ailaoshan Au, West Yunnan. China-Hu Akcha-Talbulak OD. Uzbekistan-Smirnóva Albian carbonate reservoirs. Angola margin-Walgenwitz Albigeois CaF2. France-Rowan Albigeos Pb-Zn-F-B. Massif Central. France-Bruce Allende chondrite-Varela Alpine Monte Rosa Au. Italy-Pettke Amritpur granite. Lesser Himalaya, India-Rawat Anambra basin-Akande Anatolia geothermal. Turkey-Mutlu Antarctica meteorites-Genge Aouelloul Crater, Mauritania-Koeberl Appalachian Basin bentonites-Briggs Apuseni Mountains Au-Ag-Te. Romania-Alderton Archaean oil. Australia-Dutkiewicz Archean lode-Au-Mikucki Archean oil-bearing sandstones. Australia-Buick Ascension Island-Irwin Ashanti Belt Au. Ghana-Klemd, Schmidt Mumm Ashele massive sulfide Cu-Zn. Xinjiang. China-Wang Au-Ag-Te OD, Mt. USA-Thieben Auminzatau-Kul'dzhuktau Au, Kyzylkumy, CIS-Lizorkina Australia North West Shelf oil-Lisk

## B

Bacon-Manito geothermal, Philippines-Hedenquist Badenian. Poland-Rosell Baffin Island lavas, Canada-Kent Baia Mare Au-Cu-Zn-Sb, Romania-Bailly Bainiuchang Ag polymetallic. Yunnan. PRC-Chen Baivinchang Cu-polymetallic. PRC-Ren Balazuc borehole. France-Aquilina Bald Hill Au-Cu. NSW Australia-Lawrie Bald Mountain VMS. Me. USA-Foley Ballynoe barite. Ireland-Mullane Baltic Shield lamproites. Central Karelia-Lokhov Baltic Shield lamproites. Kola Peninsula-Lokhov Banble granulite. Norway-Nijalnd Bancanghe Au, Huanglin, Hubei, PRC-Chang Bandipur, Karnataka-Narasimha Bankuan Au. China-Chen Bannock basin, Mediterranean Sea-Vengosh Barberton greenstone. S. Africa-de Ronde Batan Island. Philippines-Metrich Bathurst Island Pb-Zn. NWT, Canada-Rose Bayan Obo Fe-REE-Nb. China-Smith Bayan Obo REE-Nb-Fe. Inner Mongolia. China-Campbell Bayan Obo. China-Buehn Bendigo Au, Victoria, Australia-Li

Benue Trough, Nigeria-Akande Berezov Au. Russia-Bortnikov Berezovsk Au, Middle Urals-Baksheev Berezovsk Au. Urals-Baksheev Berg Pb-Zn(-V)-type, Namibia-Frimmel Bestyube Au. N. Kazakhstan-Baksheev Bichanzor Au. Uzbekistan-Kozlóv Big Maria Mountains, Ca. USA-Hoisch Biggenden Fe. Southeast Queensland-Edraki Bigham porphyry Cu, Ut. USA-Schedl Bingham porph. Cu. Ut. USA-Kendrick Bingham-Irwin Bishop Tuff, Ca. USA-Boyce Bohemian massif. CSSR-Dobes Bohemian massif-Lodemann Bokan Mountain, Ak. USA-Philpotts Bolivian Sn-Traxel Borborema Be-Ta pegmatites. Brazil-Beurlen Bostraze-Balleswidden kaolin. Comwall. UK-Dominy Bou Grine Zn/Pb, Tunisia-Bechtel Bouvet Triple Junction-Simonov Brad-Sacaramb epithermal Au-Ag-Te. Romania-Gál Brazil emeralds-Giuliani Brent Group oil, North Sea-Wilkinson Brent Group, North Sea-Guilhaumou Broadlands geothermal. NZ-Hedenquist. Norman Broken Hill, Australia-Gunn Broken Hill-type Pb-Zn-Ag deposits, Australia-Williams Bronzewing Au. Australia-Dugdale Brusson Au, NW Alps-Ménez Brusson Au. Western Alps-Philippot Bukit Koman Au. Malaysia-Khin Zaw Bulawan Au-Ag-Te. Philippines-Maglampayan Bushveld stratiform pyroxenites. S. Africa-Johan Bushveld upper critical zone, S. Africa-Johan Butte-Irwin

# C

Cadillac Mo-Bi. Québec. Canada Taner Calabrian Arc metamorphics. Italy-Invernizzi Caledonides. Norway-Svensen Cambrian evaporites. East Siberia-Grishina Canary Islands xenoliths-Hansteen Candelaria Cu-Au, Chile-Ullrich Cannington Ag-Pb-Zn. Cloncurry. Queensland. Australia-Chapman Cannington Pb-Zn-Ag. Australia-Williams Cape Fold Belt Au. S. Africa-Egle Capitan Mountains. NM. USA-Campbell Carlin Au, Nv. USA-Brake Carlin-type Au. Nv. USA-Shigehiro Carlin-type Au-Liu

Carpathians pegmatites, Romania-Dragusanu Cash porph. Cu. Yukon, Canada-Selby Casino porph. Cu, Yukon, Canada-Selby Catatumbo basins. Colombia-Awwiller Catskill, NY, USA-Zangrilli Celtic Sea basins, Ireland-O'Reilly Central African copperbelt-Master Central City district, Co, USA-Taylor Central Okinawa Trough geothermal, Japan Central Tennessee Zn-Misra Central Victoria Au, Australia-Ramsay Cerro Blanco pegmatites. Argentine-Mas Cerro Viejo, Argentina-Krekeler Chadak Au-Ag, Uzbekistan-Kozlov Chalk River, Canada-Bukata Changkeng Au-Ag, Guangdong, China-Sun, Zhang Changkeng, China-Norman Chino, NM. USA-Armstrong Cikidang Au, West Java, Indonesia-Basuki Cikotok Au, West Java, Indonesia-Nova Cloncurry Cu-Au, Australia-Williams Cloncurry, Australia-Williams Cobar Au-Cu-Ag-Pb-Zn, Australia-Lawrie Colombian emeralds-Giuliani. Ménez Comstock Lode, Nv. USA-Vikre Congo Basin NaCl. Africa-Timofeetf Copeton diamonds. Australia-Milledge Corcoesto Au. Coruña. Portugal-Urbano Cornish Sn. UK-Rankin Costa Rica rift geothermal-Vanko Cow Ark-Marl Hill Moor Pb-Zn. UK-Gaunt Creede-Irwin Cripple Creek Au. Nv. USA-Thompson Croydon goldfield, N. Queensland, Australia-Lawrie

# D

Dabeiwu Au, Jiangxi, PRC-Wang Daejang Cu-Zn-Pb. Korea-Choi Dalongshan U. Anhui Province, China-Zhai Dalu bastnaesite, Sichuan, PRC-Liu Damara orogen. Namibia-Frimmel Danzhai Au-Hg. PRC-Lu Daging Cu. Yunnan, PRC-Zhang Daginshan Au, Inner Mongolia, China-Xu Dashuigou Te. PRC-Wei Dashuigou Te-Au-Ag. PRC-Cao Datuanshan Cu. Anhui, PRC-Li Dead Bullock Soak Au, Australia-Smith Death Valley, Ca. USA-Lowenstein Diamond-bearing carbonatites. Uzbekistan-Divaev Dianfang Ag-Au. Henan. PRC-Zhao Diaspri Di M. Mn. Italy-Marescotti Dinantian dolomites. Belgium-Nielsen Dinkidi porph. Cu-Au, Luzon-Crawford Disu Pb-Zn. PRC-hu Dizon porph. Cu-Au. Philippines-Aquino Dongbeizhhai Au, Sichuan, China-Lu Donghuofang Au, Inner Mongolia, PRC-Shi Donglinshan Au. PRC-Li Dongping Au. Hebei. PRC-Nie Dronning Maud Land, Antarctica-Markl

Duluth complex. Mn. USA-Ripley Dylen U. CSSR-Dobes Dzhelambet-Centre Au. N. Kazakhstan-Baksheev Dzhelambet-North Au. N. Kazakhstan-Baksheev

### E

E. African Rift gases-Darling East Kemptville Sn. Nova Scotia-Halter East Pacific Rise-Stuart, Vanko East Tennessee Zn-Misra Ehrenfriedersdorf Sn. Germany-Thomas El Abra limestone, Mexico-Brennan El Críollo Genthelvite. Córdoba. Argentine-Mas El Joyazo xenoliths. SE Spain-Bernardo El Mochito Zn-Pb-(Ag), Honduras-Vázquez El Muerto pegmatite. Oaxaca. Mexico-Morales-Alvarado El Oro, Mexico-Norman Eloise Cu-Au, Cloncurry District, Queensland, Australia-Baker Embla oil field. North Sea-Munz Emperor Au, Fiji-Poliquin Ermi Cu. Jilin. China-Feng Esker Mississippi Valley-type, NWT, Canada-Wachowiak Esztramos Hill calcite, Hungary-Gatter Etheridge Goldfield Au. Queensland. Australia Bain Etykin rare-metal deposit, Russia-Prokof'ev Eureka polymetallic. Nv. USA-Vikre

## F

Famous basalt ALV519-4-1, Mid-Atlantic Ridge-Shimizu Fort Knox. Ak. USA-Baker Fortyseven Creek Au-As-Sb-W. Ak. USA-Gray Fosterville Au. Australia-Mernagh Francoeur Au. Québec. Canada-Gao Fresnillo, Mexico-Norman Fukasawa Kuroko deposits. Japan-Ishizuka Funiu Mountain Au, Henan, PRC-Zhang

# G

Galapagos Platform-Sours-Page Galway granite. Ireland-Jenkin Gardiner ultramafic complex, E. Greenland-Veksler Gays River Zn-Pb. Nova Scotia, Canada-Kontak, Sangster, Savard Genesis Au. Nv. USA-Brake Geothermal fields. Japan-Taguchi Getchel Creek, Nv. USA-Norman Getchell Carlin-type gold. Nv. USA-Cline Gies Au-Ag-Te. Mt. USA-Spry Gilman, Co. USA-Mach Glen Eden Mo-Sn-W. NSW. Australia-Somarin Glenorchy Au. NZ-Baksheev Globe Miami porph. Cu. Az. USA-Kendrick Golden Butterfly Au. N. Queensland, Australia-Lawrie Golden Mile Au. Australia-Lee Golden Sunlight Au-Ag-Te. Mt. USA-Spry Goldfield. Nv. USA-Vikre Gorda Ridge-Sours-Page Gran Canaria, Canary Islands-Gurenko Green River oil basin. Wy. USA-MacGowan Green Tuff epithermal, Japan-Imai Greenhills PGE, NZ-Spandler

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Greenland picrite-Turkov Gretla siderite, Slovakia-Hurai Grotta di Ernesto, NE Italy-Huang Guaniamo diamond, Guyana shield, Venezuela-Sobolev Guantian Te, China-Furong Guizhou Au-Sb, China-Zhu Guizhou, PRC-Su Gulf Coast Zn-Pb-Sheppard Gyeongsang basin Cu, Korea-Choi

## H

Hahajima Cu, Japan-Armstrong Haigou Au, Jilin. PRC-Feng Hannuoba xenoliths, China-Xu Hansonburg, NM. USA-Chomiak. Irwin Harney Peak granite, SD, USA-Sirbescu Hartford-Deerfield oil basins-Parnell Hatu Au. Xinjiang. China-Fan Haulalai volcano, Hawaii-Mathez Heletz-Kokhav oil field. Israel-Vapnik Hellyer VHMS. Tasmania. Australia-Khin Zaw Hermosa District. Sierra County, New Mexico, USA-McLemore Hishikari Au. Japan-Imai Hishikari Au-Ag, Japan-Takahashi Hishikari Au-Ag, Kyushu, Japan-Faure Hogeqi Cu-polymetallic. Inner Mongolia. PRC-Yang Hokko epithermal Au. Hokkaido. Japan-Scott Hollinger Au, N. America-Baksheev Hongshan porph. Cu. Huichang Jiangxi. PRC-Chen Hoti Cave speleothems. Oman-Burns Houdidong Au, Jilin. PRC-Wang Huashugou Au. north Qilian Mt .- Yang Hudson Valley Fold-Thrust Belt, NY, USA-Schimmrich Humber Zone oil. Québec-Chi Hunan-Jiangxi U. PRC-Li Huogeqi Cu-polymetalli, Inner Mongolia, China-Wang Hutchinson halite. Ks.USA-Timofeeff HYC Pb-Zn. Australia-Large HYC Zn-Pb-Ag. Australia-Davidson

# I

Ilimausaq intrusion, Greenland-Laier Ilkwang Cu-W. Kyongsang basin, Korea-Yang Indarama Au, Zimbabwe-McKeagney Indian Ocean Basaltic glasses-Cartigny Ioko-Dovyren PGE, north Baikal-Orsoev Irazú Volcano, Costa Rica-Clark Irish deposits-Wilkinson Irish Zn-Pb-(Ba) oretield-Hitzman

## J

Jacinto Au, Cuba–Simon Jade hydrothermal, Okinawa trough–Hou Jebel Stah CaF<sub>2</sub>, Tunisia–Souissi Jedl'ovec siderite–Hurai Jianfengliing pegmatoid, Hunan Province, PRC–Chang Jiaojia Au, PRC–Xu Jílové Au, Czech Republic–Fricová Jinchangyu Au, Hebei, China–Zhang Jínchuan complex, China–Yang Jinman Cu, Yunnan, China–Ji Jinshan Au, Jiangxi, PRC-Zhang Juan de Fuca Ridge geothermal-Kadko, Peter, Sours-Page Jubilee Zn-Pb, Nova Scotia, Canada-Fallara, Sangster, Savard Junction Au, Australia-Polito Juneau Au, Ak, USA-Sibson Jwaneng kimberlite, Botswana-Cartigny

## K

Kaba chondrite-Varela Kakkonda geothermal system. Japan-Kasai Kakkonda geothermal, Japan-Komatsu, Muramatsu, Muraoka, Sawaki Kakkonda granite. Japan-Sasaki Kalgoorlie Au, Australia-Lee Kalkfeld carbonatite. Namibia-Buehn Kamineichi dolomitic skarns. Iwate. Japan Ishiyama Kangunkunde. Malawi-Buehn Kara W. Tasmania-Singoyi Karashokho Diatreme Au, CIS-Golóvko Karashokho Diatreme shonkinite. CIS-Golóvko Karoo Basin Au, S. Africa-Egle Karvakh NaCl. Yemen-Shanina Kashi Depression oil. China-Li Kasperské Hory Au, CSSR-Dobes, Zak Kazakhstan Au-Rafaílovich Kechmes NaCl, Komi-Shanina Kerala charnockite. India-Satish-Kumar Khibina complexes. CIS-Potter Khomas trough. Namibia-Dombrowski Kidston Au. Australia-Baker Kilauea volcano, Hi, USA-Crocket Kilauea, Hi, USA-Hauri, Wallace Kimberlite pipe Mir. CIS-Kasimova Kingking CuAu. Mindanao. Philippines-Fortuna Klodava NaCl. Poland-Shanina Knaumühle, Germany-Anderson Kobuk fault. Ak. USA-Avé Lallemant Kokchetav massif diamonds. Kazakhstan-De Corte Kokomo massive sulfide-Mach Kokpatas Au. CIS-Dúnin-Barkóvskaya Kola Alkaline Province. Russia-Nivin Kola CIS carbonatites-Marty Kola Granulite area. CIS-Fonarev Kola igneous province. CIS-Potter Kola Peninsula CIS-Orsoev Kon Kollo Au. Bolivia-Baker Koolau. Hi. USA-Hauri Kori Kollo Au. Bolivia-Petersen Korvu Au-Ag. Hokkaido, Japan-Shimizu Koudiet el Ahrach Au. Algeria-Aissa Kovdor complexes. CIS-Potter Kovdor ultramafic compex. CIS-Veksler KTB Continental Deep Drilling Project. Germany-Drescher KTB deep drill hole. Germany-Pasteris KTB. Germany-Lodemann Kudryavy volcano. Kurile Islands-Fischer Kuoer Zhengkuona Au. Xingjiang. PRC-Zhang Kuraminsk porph.-Cu. Uzbekistan-Turesebekov Kurihashi pluton. Japan-Sasaki Kuroko, Akita, Japan-Maglambayan Kuttara volcano, Japan-Moriizumi

Kyaukpahto Au, Myanmar-Khin Zaw Kyzylcheku Au, Uzbekistan-Kozlóv

#### L

La Bragada Au. Cordoba. Argentina-González La Candelaria Au. Argentina-González La Crocetta mine. Isola D'Elba-Maineri La Descubridora Sn. Argentina-Fogliata La Guitarra Au-Ag polymetallic. Temascaltepec. Mexico-Camprubi La Higuerita Au. Córdoba. Argentina-González La Palma (Canary Islands)-Klügel La Pampa trachyte, Argentina-Dristas La Primavera hydrothermal. Mexico-Prol-Ledesma La Rioja W, Argentina-Sardi La Ronge domain. Saskatchewan. Canada-Field La Tinaja delOso borate. Sonora, Mexico-Miranda-Gasca La Voluntad Cu. Argentina-Garrido Laacher See, East Eifel, Germany-Harms Lac Fortune Au. Québec-Gao Lachland Fold Belt, Australia-Mernagh Ladolam Au, Lihir Island, Papua, New Guinea-McInnes La'erma Au, Qinling, PRC-Liu Lake Manyara emerald, Tanzania-Moroz Lake Shortt Au, Abitibi, Quebec-See Langban Pb-Mn-As-Sb. Sweden-Jonsson Lannigou AuHgSb. Guizhou, PRC-Zhang Lannigoug Carlin-type Au. China-Su Lantern Au, Nv, USA-Brake Lantern Hill fault, Ct. USA-Altamura Laowangzhai Au, Yunnan, PRC-Huang Larderello geothermal, Italy-Magro Las Tres Virgenes geothermal, Mexico-Viggiano Lau Basin backare-Danyushevsky Lau basin-Bach Leadville. Co. USA-Mach Leduc Simonette Pool. Alberta-Rock Leek oil field. North Sea-Bigge Lepanto Cu-Au, Philippines-Lindaas Lepanto epithermal Cu-Au, Philippines-Hedenquist Lepanto porph. Cu. Philippines-Hedenquist Lesser Antilles island arc-van Soest Lichuan oil-gas. Hubei-Chen Limpopo Belt, S. Africa-Chupin Limpopo metamorphics. Zimbabwe-Tojo Linglong Au. PRC-Xu Liudou Au. Hubei. PRC-Tian Liugou Au. Henan. PRC-Zhang Llanos Basin, Colombia-Awwiller Llanos Foothills oil, Colombia-Warren Lockne impact. Jämtland, Sweden-Sturkell Lofoten Islands granulites, Norway-Markl Loihi, Hi, USA-Hauri Lombok olivine, Indonesia-Della-Pasqua Lomonosov diamond. CIS-Garanin Lone Tree Au, Nv. USA-Young Lorraine evaporite basin. Spain-Fanlo Los Humeros geothermal, Mexico-Prol-Ledesma Lovozero complexes. CIS-Potter Lower carboniferous Zn-Pb-(Ba). Ireland-Everett Lower Windsor Group Zn-Pb, Nova Scotia, Canada-Chi Lower Windsor Zn-Pb. Nova Scotia, Canada-Sangster

Lucky Strike site (MAR 37 17 N)-Jean-Baptiste M Machangqing Cu. West Yunnan, China-Hu Machangging Cu-Mo. Yunnan. China-Peng Madagascar granulites-Ramambazafy Madagascar skarns-Ramambazafy Magdala Au, Victoria, Australia-Mapani Maha Sarakham Formation NaCl. Thailand-Timofeeff Małkangiri District Sn. Orissa, India-Pal Manantial Espejo Au. Argentina-Rios Mangaia Island basalts-Saal Manto Verde Cu. Chile-Vila Manus back-arc basin geothermal, western Pacific-Yang Maracaibo basin. Venezuela-Awwiller Mariana arc lavas-Lee Mariana Trough basalts-Sano Maritimes Basin Zn-Pb. Canada-Chi Marysvale U-Mo-F. Ut. USA-Cunningham Masaya Volcano. Nicaragua-St.-Almand Massif Central Pb-Zn-F\*B. France-Bruce Masupa Au, E. Kalimantan, Indonesia-Abidin Matahachi Pb-Zn. Hokkaido, Japan-Ishiyama Matalla-Santa Rosa Au. Peru-Brake Matsukawa geothermal, Sengan, Japan-Imai Mauna Kea volcano, Hi, USA-Jochum Mauna Loa volcano, Hi, USA-Jochum Mauna Loa, Hi, USA-Hauri, Sobolev McArthur Basin volcanics, Northern Territory, Canada-Cooke McArthur River Pb-Zn. Australia-Large McArthur River, Australia-Williams McDame Au, Cassiar, BC, Canada-Ball Meatiq metamorphic dome. Egypt-Neumayr Meguma Au, Nova Scotia-Kontak Melechov massif, CSSR-Dobes Mendoza, Spain-Garrido Messinian basins. SE Spain-Rosell Messinian basins, Sicily-Rosell Mid-Atlantic Ridge-Charlou, Kamenetsky, Vanko Midlands greenstone belt Au. Zimbabwe-Buchholz Mid-ocean ridge basalt-Kunz, Marty Milos Island Pb-Zn-Ba-Ag-Au. Greece-Vavelldis Mir diamond, CIS-Gassymova Mir kimberlite pipe. Yakutia-Sobolev Mir kimberlite, Yakutia, Russia-Tavlor Mission porph. Cu. Az. USA-Kendrick Mississippi Valley-type Pb-Zn-Muchez Mississippi Valley-type. Wi. USA-Luczaj MITI-Mishima oil well. Japan-Okubo Mokrsko Au. Bohemia-Boiron Mole Sn Granite. Australia-Audétat Monarch Pb-Zn. Canada-Nesbitt Mongolia-Okhotsk granite. CIS-Koval Mont Chemin Au, Switzerland-Marshall Montana sapphire-Garland Mont-Blanc massif, Switzerland-Marshall Morenci porph. Cu. Az. USA-Armstrong Morsleben, Germany-Osenbrück Mother Lode-Irwin Motoyama Kuroko, Japan-Mizuta Mt. Brussilof Pb-Zn. Canada-Nesbitt

Mt. Capanne pegmatites. Elba. Italy-Tonarini Mt. Emilius, Italian western Alps-Scambelluri Mt. Erebus. Ross Island, Antarctica-Eschenbacher Mt. Etna volcano. Italy-Clocchiatti Mt. Etna, Italy-D'Alessandro Mt. Isa, Australia-Williams Mt. Kare Au. Papua New Guinea-Richards Mt. Mazama, Crater Lake, Or. USA-Mandeville Mt. Nansen porph. Cu. Yukon. Canada-Selby Mt. Pelée, Martinique-Martel Mt. Pinatubo, Philippines-Aquino Mt. Pleasant W-Mo pegmatite. Australia-Walker Mt. Simon Sandstone, II. USA-Chen Mt. Simon Sandstone, In. USA-Chen Mt. Simon Sandstone, Wi, USA-Chen Mt. Sinivit Au, Australia-Lindley Mt. Skukum epithermal Au. Yukon Territory, Canada-Love Mt. Somma-Vesuvius, Italy-Belkin Mt. Vesuvius, Italy-Tedesco, Webster Mulongtao Au, PRC-Long Muray chondrite-Varela Murchison chondrite-Varela Muribeca Formation NaCl, Brazil-Timofeeff Muruntau Au, Middle Asia-Baksheev Muruntau Au, Uzbekistan-Graupner Mushugai-Khuduk carbonatite, Southern Mongolia-Andreeva Mutenin Cu. CSSR-Dobes Myanmar pegmatites-Khin Zaw Myutenbai Au, Uzbekistan-Graupner

#### N

N. Tunisian Zn-Pb-Charef Naboomspruit hot springs. South Africa-McDonald Navan Zn-Pb-Ag. Ireland-Wilkinson Naxos marble. Greece-Lewis Newer Volcanics. Australia-Matsumoto Ngatamariki diorite gcothermal. NZ-Christenson Nippewalla Group. Ks. USA-Benison Nojima geothermal. Japan North China Platform sediments-Feng North Fiji basin basalt-Nishio North Hebai Ag. PRC-Yang North Peak Au. Nv. USA-Young North Qilian Mountains eclogites-Liu North Sea oil-Andresen North Victoria Land. Antarctica-Frezzotti

#### 0

ODP Sites. Irminger Basin, offshore Greenland–Zhang Okete basanite. NZ–Ninomiya Olkiluoto nuclear waste site. Finland–Blyth Oman ophiolite geothermal–Vanko Onikobe geothermal. Japan–Sawaki Opeche Shale. ND. USA–Benison Orcadian oil–Parnell Oregon 3 pegmatite. South Platte. Co, USA–Samson Oriskany. Central Appalachians–Evans Osikonmaki Au. Finland–Liimatainen Osilo Au. Sardinia–Simeone Otago Au. NZ–Sibson Otoge caldera–Hotta

# P

Overlook Au, Wa, USA-Rasmussen

Pacific Rim Au-Goldfarb Paddington Au, W. Australia-Lee Pakistan emeralds-Giuliani Palabora, RSA-Buchn Palaborwa carbonatite, S. Africa-Solovova Palo Duro Bains, Tx, USA-Ghazi Panasqueira W-Sn, Portugal-Polya Pangea evaporites. Ukraine-Kovalevich Parana Basin, Brazil-De Ros Luiz Parbat metamorphics. Pakistan-Craw Patagonia. Argentina-Varela Pegmont Pb-Zn. Cloncurry, Queensland, Australia-Williams Penedono Au-Urbano Penggou Au, Henan, PRC-Zhang Permian evaporites. Germany-Siemann Permian Paradox, Tx, USA-Ghazi Persani Mountains xenoliths, Romania-Althaus Petráchkova hora porph. Au, Czech Republic-Yazdi Pikes Peak granite. Co. USA-Samson Pine Point Pb-Zn. Canada-Qing Pino Au. Zamora. Portugal-Urbano Pinto Valley porph. Cu. Az. USA-Kendrick Piton de la Fournaise volcano, Réunion Island-Bureau Polaris Zn-Pb. Canada-Randell Pollone Ph-Zn-Ag, Tuscany, Italy-Costagliola Polynesian basalts-Saal Porgera Au, Papua New Guinea-Richards Porphyry-Cu. Uzbekistan-Nikoláeva Pozo Escondido oil. Argentina-Cesaretti Prairie evaporites. Canada-Horita. Kovalevich PRC Au-Liu Presqu'ile barrier reef, western Canada-Qing Pribram. CSSR-Dobes Pripyat-Dnipro-Donets evaporite basins, Ukraine-Belarus-Petrichenko

## Q

Qiaogashan Au, Xinjiang, PRC-Yang Qinling Au, PRC-Zhang Qixia Au, PRC-Zhai Qixia Au, Shandong, China-Xu Quebrada Blanca porph-Cu, Chile-Rowland Questa Mo-Vanko

# \$

Ramsey, Nv. USA-Vikre Ray porph. Cu. Az, USA-Kendrick Recsk-Parádfürð Au. Hungary-Gatter Red Chris porph. Cu-Au. BC. Canada-Baker REE carbonatite. Namibia-Rankin Renazzo chondrite-Varela Réunion Island-Hopp Rio Grande Do Sul geodes. Brazil-Lueth Rio Narcea Au-Cu. Asturias. Spain-Martin-Izard Rocciavre massif, Italian Alps-Philippot Rosebery Massive sulfide. Tasmania-Khin Zaw Rotliegend sandstones. North Sea-McNeil Rotliegendes sediments. SW Poland-Jarmolowicz-Szulc

Roztoky Pb-Zn-Cu (Ag. Te). Czech Republic-Pivec Ruapehu Volcano, NZ-Thordarson Ruby Hill polymetallic, Nv. USA-Vikre Rudnany siderite, Slovakia-Hurai Ryuo Au-Ag, Hokkaido, Japan-Maeda

#### S

Salado Formation NaCl. NM, USA-Timofeeff Salar de Hombre Muerto. Argentina-Lowenstein Salave Au, Spain-Baker Salmi Batholith, Karelia. Russia-Poutiainen Salton Sea-Irwin Samoa xenoliths-Burnard San Joaquin oil basin, Ca. USA-MacGowan San Matin skarns-Norman Sanbagi U. PRC-Min Sandia pluton, NM, USA-Pletsch-Rivera Sangilinvi U. PRC-Min Santiago basin, Peru-Awwiller São Geraldo Do Araguaia quartz vein. Pará-Brazil-Collyer Sagisan U, PRC-Min Schellerhau granite-Müller Schirmacher leucogneisses. east Antarctica-Rao SE Australia peridotite xenoliths-Eggins SE Seamount-Stuart Selinsing Au, Malaysia-Khin Zaw Sellafield Ba, Cumbria, UK-Milodowski Serido belt Au. NE Brazil-Silva Seto Porcelain Clay Formation. Japan-Mizota Shamva Au, Zimbabwe-Jelsma Shandong Au. PRC-Sun Shanggong Au. Henan. PRC-Fan Shavaz Li, Uzbekistan-Saidygániev Shengli oil-field, China-He Shengli oil-gas province, China-Li Shershnevsk Au, Urals-Baksheev Shetland Island volcanics-Willan Shibangou Au, Henan, PRC-Wei Shimanto sedimentary complex, Shikoku, Japan-Sakaguchi Shizhuvuan W-polymetallic, PRC-Liu Shizuoyuan W-Au, Hunan. China-Ji Shkol'noe Au. Uzbekistan-Kozlóv Sichuan basin oil. PRC-Zhang Sichuan basin. PRC-Wang Sierra Nevada xenoliths, Ca. USA-Ducea Silesia-Cracow Zn-Pb. Poland-Leach Sirte Basin, Libya-Mresah Smackover Formation. Ms. USA-Barker Smoky Butte lamproites, Mt. USA-Sharygin Snowbird REE, Mineral County, Mt, USA-Wood Sopron-area Eastern Alps metamorphics-Török Soufriere volcano, St. Vincent, Lesser Antilles-Heath Soultz Granite, Rhine Graben, Germany-Cathelineau Soultz-sous-Forêts granite. France-Sausse. Vançon South Norway pegmatites-Larsen South West Massif Central, France-Bruce Southern Alps metamorphics. NZ-Craw Southwest England fluids-Gleeson Spain Zn-Pb-Tomos Specogna Au. Canada-Kataoka Spotted Horse-Kentucky Favorite Au-Ag-Te. Mt. USA-Spry St. Austell, Comwall, UK-Irwin St. Cloud, New Mexico, USA-Norman Statte-Flemalle Anticline. Belgium-Slobodnik Stepnyak Au, N. Kazakhstan-Baksheev Stribo Pb-Zn, CSSR-Dobes Stripa-Irwin Subiza potash. Navarra. Spain-Cendón Subpolar Ural quartz, CIS-Lokhov Sudbury Basin, Ontario, Canada-Riller Sudbury complex. Ontario. Canada-Warner Sudbury Ni. Canada-Molnár Sudbury Ni. Ontario-McCormick Sukhoi Log Au-PGE. Russia-Prokofyev Sumbawanga emerald, Tanzania-Moroz Suria evaporite. Spain-Cendon SW England W-Sn-Cu-Shail SW Tauern window. Switzerland-Poletti Swan Hills Ante Creek pools. Alberta-Rock Swan Hills platform, Alberta, Canada-Wendte Sweet Home Au-Reynolds

## 1

TAG hydrothermal, N. Mid-Atlantic Ridge-Hopkinson Taibei Au. PRC-Xu Taihang Mountains-Feng Taihangshan Au, PRC-Zhu Takidani geothermal. Japan-Sekine Talapoosa. Nv. USA-Vikre Tanami Au. NT. Australia-Tunks Tangshan Cave. Nanjing, PRC-Wang Tanjianshan Au, Qinghai. PRC-Yu Tasmanian speleothem-Goede Tavetsch basement rocks. Swiss Alps-Wyder Taylorsville Basin, Va. USA-Omar Tavoltita. Mexico-Norman Tennant Creek Au, Australia-Khin Zaw Thailand Sn belt-Linnen The Geysers geothermal. Ca. USA-Moore, Norman Tiarnwan Ag-Au. Sichuan. PRC-Wu Timna Igneous complex, southern Israel-Vapnik Tiwi geothermal, Philippines-Moore, Norman Tocota As-Cu-Au, Argentina-Wetten Togo polymetallic. Central City. Co. USA-Taylor Tokaj Mts. epithermal Au. NE Hungary-Molnár Tombstone Au, Yukon, Nv. USA-Baker Tomiño Au, Pontevedra, Portugal-Urbano Tonga forearc-Danvushevsky Tongling skarn. Anhui. PRC-Ling Transdanubia. Hungary-Tamai Trenton Canyon Au. Nv. USA-Young Tri-state Mississippi Valley-type-Goebel. Ragan Troodos ophiolite. Cyprus-Prichard Troodos Ophiolite-Danyushevsky Troya Zn-Pb. Spain-Fernandez Tsagaan tsakhir uul Au. Mongolia-Jargalan Tsumeb-type Pb-Zn-Cu-Frimmel Turk Au. Zimbabwe-Dziggel Turquoise Ridge Au. Nv. USA-Shigehiro Tuscan domain, northern Apennines, Italy-Montomoli Twin Creek, NV. USA-Norman

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#### U

Udachnaya diamond. CIS-Gassymova Ukrainian shield Au-Bobrov Uksichan Volcano, Kamchatka, Russia-Prokofyev Ulakan (Bali) ankaramite-Della-Pasqua Uluguru Mts. granulites. Tanzania Urania basin. Mediterranean Sea-Vengosh Uwamuki. Akita, Japan-Maglambayan

#### V

Vacikov-Petrackova hory Au. Czech Republic-Zacharias Val D'Aosta rodingite. Italy-Compagnoni Vanuatu arc ankaramite-Della-Pasqua Vaulry Sn-W. France-Marignac Velence Mts. Mo, Hungary-Molnár Velence Mts., W. Hungary-Molnár Venezuela oil basin-Goodman Vesuvius, Italv-Belkin, Fulignati Viburnum Trend, Mo. USA-Appold Victoria Au, Australia-Sibson Victoria Land xenoliths, Antarctica-Perinelli Vitkov U. CSSR-Dobes Vizcachitas porphyry Cu. Chile-Willard Vulcano. Aeolian Islands. Italy-Gioncada Vulsini Volcanic District, Italy-Metrich Vyhne-Kloko Fe skarn. Western Carpathians-Kodera

### W

Walford Creek Zn-Pb-Cu-Ag, Mt. Isa Basin. Australia–Rohrlach Walton Ba-Pb-Zn-Cu-Ag. Nova Scotia. Canada–Kontak Walton Zn-Pb. Nova Scotia. Canada–Sangster Wangfeng Au. Xinjiang. PRC–Chen Waulsortian limestone. Ireland–Hitzman Wendeng Au-polymetallic. PRC–Lu West Cumbrian hematite. UK–Rowe West of Shetland oil region–Parnell Western Gneiss. Norway–Larsen Winnats Head Cave. Peak District. UK–Richards Witwatersrand basin Au. S. Africa–Yardley Witwatersrand basin. S. Africa–Blamey Witwatersrand Supergroup. S. Africa–Chupin Woodcutters Pb-Zn-Ag. Northern Territory–Giles

# X

Xianghualing area. Hunan. PRC-Liu Xiaoqinling Au, China-Bai Xiaoqinling Au, Henan, PRC-Xie, Xu Xiaorequanzi Cu, Xinjing, China-Wen Xiazhuang U, Guangdong, PRC-Liu Xiazhuang U, Jiangxi, PRC-Liu Xikuangshan Sb, China-Yang Xinjiang pegmatites, Hunan, China-Li Xinjiang pegmatites, Yunnan, China-Li Xuguang U, Guangdong, PRC-Luo

#### Y

YA13-1 gas field. S. China Sea-Chen Yacheng gas field. South China Sea-Hao Yamaguchi W-Cu skarn. Japan-Ogata Yanacoya W. La Rioja. Argentine-Fogliata Yangla Cu.Yunnan. China-Lu

Yata Carlin-type Au. China-Su YC 13-1 gas field, South China-Guo Yellowstone geothermal Wy. USA-Xu Yellowstone Nat'l. Park, Wy. USA-Lewis Yilgam Craton Au. Australia-Cassidy Yilgarn Craton Au, W. Australia-Lee Yilgarn Craton, Australia-Witt Yinggehai oil basin. South China Sea-Sum Yingshan corundum. Hubei, PRC-Wu Yingzuishan Au, Gansu, PRC-Mao Yinshan polymetallic, Jiangxi, China-Zhang Yinshan polymetallic, Jiangxi, PRC-Wei Yucca Mountain, Nv. USA-Dublyansky Yucca Mountain, Nv. USA-Roedder Yuerva Au, Hebei, China-Liao Yukon porph. Cu. Canada-Selby Yukon ZN, Canada-Heimbach Yuxi Ag, Xinjiang, China-Jiyuan

# Z

Zacatecas. Mexico-Norman Zaire diamond-Wada Zarnowiec oil. N. Poland-Jarmolowicz-Szulc Zentralgneis. Tauern Window, Italian Eastern Alps-Poletti Zgounder Ag. Anti-Atlas. Morocco-Essarraj Zhang Quan Zhuang Au. He Bei Province. China-Li Zhangjiagou pyrite. Liaoning. PRC-Xia Zhengcha Pb-Zn. Jilin. China-Feng Zijinshan Cu-Au, Fujian. China-So Zijinshan Cu-Au, PRC-Wei Zimapán Pb-Zn. Mexico-Mango Zimapán skarns-Norman Zimbabwe emeralds-Giuliani Zinkgruvan Pb-Zn-Ag. Sweden-Gunn Zortman/Landusky Au-Ag-Te, Mt. USA-Spry

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