University of Alberta

Geochemistry and geochronology of the Precambrian Basement Domains in the Vicinity of Fort McMurray, Alberta: A Geothermal Perspective.

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of

Master of Science

Department of Earth and Atmospheric Sciences

Spring 2013
Edmonton, Alberta

Dedication

For my family.
Mom, Dad, and Jayna

Abstract

The geochemistry and geochronology of the Precambrian basement in the vicinity of Fort McMurray was investigated to evaluate the feasibility of geothermal heat production. The basement is composed of older (1.95-1.98 Ga) and younger (1.92-1.94 Ga) granitoids suites of the Taltson Magmatic Zone that have intruded the 2.25 to 2.40 Ga gneisses and amphibolites of Taltson Basement Complex. Thermal conductivities (TC) calculated for 35 samples yielded an average of 3.1±0.43 W/m K. Average radiogenic heat production (RHP) of the same samples is 2.9±2.8 $\mu W/m^3$. Geothermal modeling using these values indicates that at 5 km depth, a one standard deviation shift in TC changes temperature by only ~25 °C. However, a one standard deviation shift in RHP at the same depth changes temperature by ~70 °C. The feasibility of using geothermal heat in oil sands processing will depend on RHP values in the crustal column near oil sands processing sites.

Acknowledgements

Funding for this project was provided by the Helmholtz-Alberta Initiative (HAI). A large amount of my samples were from the collection of the late Dr. Ron Burwash, a man with whom I had the pleasure of meeting once before he passed away. His work in the 1950's and 1960's provided this study with many more samples than were currently available at ERCB. Andrew Locock was very helpful in helping me obtain these samples from the U of A collections. Preparation of these samples was assisted by Mark Labbe, who was always a pleasure to talk to when teaching me how to use the department's facilities.

Dinu Pană and Matt Grobe from the Alberta Geological Survey were both essential with providing Hunt Well samples, additional basement data, and useful advice for this project. A big thank you to Andy DuFrane for his help with obtaining U-Pb data as well as reducing that data. Sergei Matveev was very supportive of my microprobe analysis and imaging work. John Duke is thanked for his contribution to this project with SLOWPOKE reactor analyses. My officemates Greg Melton, Shauna Coombs, Jesse Reimink, and Natasha Oviatt all provided me with assistance on topics from Adobe Illustrator to newspaper crossword puzzles for which I am very grateful. They made the 2 years fly by very quickly.

The geothermal chapter of this thesis was assisted significantly by Jacek Majorowicz, who made himself available to answer questions about a subject I previously knew little about. Valuable information on monazite grains was obtained with the help of Hans-Jürgen Förster using EPMA at the GFZ in Potsdam, Germany. He is thanked for his support on this project. As members of my supervisory committee, Larry Heaman and Martyn Unsworth provided me with feedback to improve this thesis that I appreciate very much.

The last (but certainly not least) person to thank is my supervisor Tom Chacko. Tom has suffered through many edits of this thesis and I am very appreciative of his comments. He has always found time in the past 2 years to assist me with thesis challenges and steer me in the right direction. His enthusiasm for this project greatly influenced me and helped to keep my interest in the subject for the whole 2 years.

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List of Abbreviations

A	**Radiogenic heat production**
BSE	**backscatter electron**
BHT	**Buffalo Head Terrane**
ca.	**circa**
D	**Crustal layer of radiogenic heat production**
EDS	**energy dispersive spectroscopy**
EGS	**Engineered Geothermal Systems**
EPMA	**Electron Probe Microanalyser**
Ga	**billion years ago**
INAA	**Instrumental Neutron Activation Analysis**
K	**Thermal conductivity**
LA-MC-ICP-MS	**laser ablation-multi collector-inductively coupled plasma-mass spectrometry**
Ma	**million years ago**
MSWD	**mean square weighted deviation**
NAA	**Neutron Activation Analysis**
Q	**Mantle heat flow**
RHP	**Radiogenic Heat Production**
Ry	**Rimbey Domain**
SLOWPOKE	**Safe Low-Power Kritical Experiment**
STZ	**Snowbird Tectonic Zone**
T	**Temperature**
TBC	**Taltson Basement Complex**
TC	**Thermal Conductivity**
TMZ	**Taltson Magmatic Zone**
U-Pb	**Uranium-lead dating**
WDS	**wavelength dispersive spectroscopy**

Chapter 1 – Introduction

Current oil sands processing in the area of Fort McMurray accounts for approximately 6% of Canada's annual natural gas consumption (Majorowicz et al., 2012). To reduce energy consumption and CO_2 emissions, a study was recently initiated under the auspices of the Helmholtz-Alberta Initiative to examine the possibility of a cheaper source of hot water for oil sands processing in northeastern Alberta by geothermal methods. The particular geothermal method being considered is known as Engineered Geothermal Systems (EGS). As defined by the U.S. Department of Energy, EGS are "engineered reservoirs that have been created to extract economical amounts of heat from low permeability and/or porosity geothermal resources." EGS are currently being developed and tested in Europe, Australia, Japan, and the United States as alternative energy sources (MIT report, Tester et al., 2006). The present study is the geochemical/petrological component of a larger investigation into the feasibility of using EGS as a hot water source for oil sands processing in the Fort McMurray area. Developing an EGS would involve drilling 1 deep injection well (~ 5 km deep), fracturing of subsurface rock, and drilling 1 or 2 production wells to recover the hot water.

The economic feasibility of EGS in northern Alberta is strongly dependent on the geothermal gradient in the Fort McMurray area. The geothermal gradient is in turn controlled by heat flow in the continental crust, which is generally controlled by two processes, upward conduction of heat to the crust from the mantle, and heat generated by radioactive element decay in the crust. Heat flow at a given location is determined by the thermal conductivity of the material multiplied by the geothermal gradient at that location. Because the Phanerozoic sedimentary cover is relatively thin in the Fort McMurray region (~500 m), the underlying Precambrian basement rocks exercise the main control on radioactive heat generation in the upper crust. More information about the characteristics of the Precambrian basement rocks is required to assess the feasibility of developing an EGS in northeastern Alberta. Specifically, when combined with petrologic and geochronologic data, geochemical data for the basement rocks can help in the determination of optimal locations for siting the EGS. An EGS would need to be relatively close to the Fort McMurray oil sands processing facilities (Fort McKay specifically) to minimize heat loss during transportation of the hot water.

1.1 Objectives

This M.Sc. research project is focused on documenting the petrography, geochemistry, and geochronology of the Precambrian basement rocks in the vicinity of Fort McMurray, Alberta. The study comprises an investigation of basement core samples from that area recovered during petroleum exploration. The three primary objectives are to:

1. Document the mineralogy and mineral abundances of the basement samples, and use these data calculate their thermal conductivites.
2. Provide additional geochronological data for basement domains encompassed within a 100 km radius of Fort McMurray.
3. Determine the whole-rock major- and trace-element chemical composition of the basement samples, including the levels of heat-producing elements potassium, uranium, and thorium (K, U, and Th).

This thesis builds on previous studies of the Precambrian basement rocks that underlie the sedimentary rocks of the Western Canadian Sedimentary Basin (Burwash et al., 1962; Burwash and Cumming, 1976; Burwash, 1979; Ross et al., 1991) and on geological mapping and supporting geochronological studies conducted on the exposed part of the Precambrian basement in northeastern Alberta (Godfrey, 1986; McDonough et al., 2000; McNicoll et al., 2000; Stern et al., 2003; Pana, 2010). However, the present study provides much more detailed information on basement rocks in the vicinity of Fort McMurray than was reported in the earlier studies. This localized information is critical for evaluating the feasibility of using an Engineered Geothermal System for oil-sands processing in northeastern Alberta. A thorough study of local basement geology is essential given the large regional variations in the basement and its accompanying geothermal parameters.

The general approach taken in my study is to use uranium-lead geochronology to subdivide basement rock units in the Fort McMurray area according to their age and then delineate which of these units has the highest average concentration of heat-producing elements and thereby are the best targets for EGS. This study also models how measured variations in heat-producing element concentrations and thermal conductivities of the basement rocks might effect geothermal gradients at 0 to 10 km depths.

In order to achieve the objectives outlined above, this project required obtaining core samples previously collected in petroleum exploration and stored at various locations. Some samples from the study region, in particular those from the Alberta Precambrian basement collection of Dr. R. Burwash, were archived at the University of Alberta. Other samples were part of the Alberta Geological Survey collection or housed at the Energy Resources Conservation Board core and sample repository. Analytical work was carried out using EAS facilities at the University of Alberta by the author. Exceptions are whole-rock geochemistry analysis, which were done at Activation Laboratories in Ancaster, Ontario and neutron activation analyses of U and Th contents made by Dr. John Duke of the SLOWPOKE reactor facility at the University of Alberta.

1.2 Precambrian Basement Geology of Northeast Alberta

The crystalline basement geology of the Fort McMurray area consists of the Taltson Magmatic Zone (TMZ) the Buffalo Head Terrane (BHT), and the Rimbey Domain (Ry), three of the basement domains that make up the western part of the Canadian Shield **(Figure 1-1)**. The TMZ and BHT are bounded to the north by the Great Slave Lake Shear Zone and to the south by the Snowbird Tectonic Zone. The TMZ is bounded to the east by the Archean Rae province and to the west by the BHT. Each of these domains is discussed in turn below.

The BHT occupies the western edge of this study area and is entirely covered by approximately 1 to 2 km of Phanerozoic sediments and thus has only been studied from drill core material. The BHT is noted for its sinuous aeromagnetic patterns and wide range of rock types including felsic to intermediate metaplutonics dated at 1.9 to 2.3 Ga. Also present are high-grade gneisses and metavolcanics (Villeneuve et al., 1993).

The majority of the present study area is occupied by the TMZ, which is part of a 3200 km long, north-south trending belt consisting primarily of granitic plutons and uppermost amphibolite- and granulite-facies gneisses **(Fig. 1-1)**. The rocks of the TMZ outcrop in the southern part of the Northwest Territories and in northeastern Alberta. However, most of the TMZ, in particular the western and southern portions of the belt, is buried beneath Phanerozoic sedimentary rocks. The majority of current oil sands processing in northern Alberta is carried out in areas underlain by rocks of the TMZ.

The exposed TMZ **(Fig 1-2)** is composed of the 3.2-2.0 Ga Taltson Basement Complex (TBC), which has been intruded by several suites of granitoid plutons ranging in age from 1.99-1.92 Ga (Bostock et al., 1987; Bostock and van Breeman, 1994; McDonough et al., 2000; McNicoll et al., 2000). The TBC is an Archean to Paleoproterozoic domain of massive and banded gneisses that include pelitic metasediments, amphibolites and felsic orthogneisses (McNicoll et al. 2000; De et al. 2000). The TBC comprises approximately 15% of the exposed TMZ in northeast Alberta and is divided into basement blocks by the intruding plutons and major shear zones. The Berrigan Lake, Andrew Lake, Potts Lake, Cornwall Lake, Dore Lake, Mercredi Lake, and Leland Lakes basement blocks are truncated by the Charles Lake and Leland Lakes shear zones, which trend approximately north-south (McNicoll et al., 2000). Various pelitic xenoliths of the TBC are found within the younger intruding plutonic bodies (McDonough et al., 1993). The rocks of the TBC have been extensively intruded by older (1.986-1.963 Ga) and younger (1.955-1.928 Ga) suites of granitoids. The southeast TMZ has the eastern group of granitoid plutons including the 1.971 Ga Colin Lake (McDonough and McNicoll, 1997) and 1.963 Wylie Lake (McDonough et al., 1995) suites consisting of biotite and hornblende-biotite granites and granodiorites. The western plutons include the 1.986 Ga Deskenetlanta pluton (Bostock et al., 1987) and the Slave granitoid plutons composed of weakly to moderately deformed granites 1960 to 1935 Ma in age (Bostock et al., 1987, 1991; Hanmer et al., 1992; McDonough et al., 2000). Also in the west are the Arch Lake granitoids composed of weakly to moderately foliated granites to augen gneisses with K-feldspar megacrysts, and crystallization ages of 1.938 Ga (McDonough et al., 2000).

The southern TMZ has three main shear zones trending roughly north-south **(Fig 1-2)**. They are the Leland Lakes shear zone (LLSZ) in the west, the Charles Lake shear zone (CLSZ) in the central, and the Andrew Lake shear zone (ALSZ) in the east. The CLSZ is the most extensive, with over 300 km of strike length exposed and a width of 3-

12 km. Metamorphic grade in the CLSZ is granulite to upper amphibolite facies involving many granitic plutons, basement gneisses, and the Rutledge paragneisses, whose protoliths are interpreted to be the remnant of 2.13-2.09 Ga sedimentary basin that was deposited on the western margin of the Churchill Province (Bostock and van Breemen, 1994). The ALSZ is a poorly exposed, 40 km long, gently to moderately dipping thrust zone placing basement gneisses and supracrustal gneisses onto the younger 1.96 Ga Andrew Lake pluton (McNicoll et al., 2000). The LLSZ is a 150 km long, 500 m wide zone that has been truncated by the Slave pluton. Both the CLSZ and the LLSZ have been locally overprinted by amphibolite- to greenschist- grade shear fabrics (McNicoll et al., 2000).

The Rimbey domain is a northeast trending domain consisting mainly of 1.85 to 1.78 Ga biotite granites that appear to follow the Snowbird Tectonic Zone east into western Saskatchewan (Ross et al. 1991). It has been interpreted as a magmatic arc based on the occurrence of granites, aeromagnetic highs, and arcuate shape (Villeneuve et al., 1993).

1.3 Previous Research in the Study Area

The basement rocks in the vicinity of Fort McMurray was also included in a geochronological and geophysical study by the Geological Survey of Canada (Ross et al., 1991; Villeneuve et al., 1993), which included nine of the samples studied in this project. One other study (Theriault and Ross, 1991) examined the samarium-neodyanium (Sm-Nd) isotope composition for evidence of crustal recycling, which included six samples also studied in this project. These studies reported Taltson U-Pb zircon ages grouped from 1932 to 1973 Ma with one older sample dated at 2174 Ma. The samples have strongly negative initial εNd values of -3.7 to -9.8 and depleted mantle model ages from 2.6 to 2.7 Ga, interpreted to indicate a recycling of crustal material during the Early Proterozoic.

Determination of the abundance of heat-producing elements (potassium, thorium, uranium) in the Precambrian basement rocks of the Fort McMurray area is an important focus of this project because the concentrations of these elements exert a major control on the geothermal gradient in the area. The radioactive isotopes of these elements all release heat energy to their respective daughter isotopes of argon, lead, and lead. Average concentrations of heat-producing elements have been estimated for the upper continental crust worldwide with values of K=2.80 wt%, U=2.7 ppm, and Th 10.5 ppm (Rudnick and Gao, 2003). The middle continental crust was estimated by the same authors to have K=2.30 wt%, U=1.3 ppm, and Th=6.5 ppm. The exposed Canadian Shield has average values of K=3.10 wt%, U=2.45 ppm, and Th=10.3 ppm (Shaw et al., 1986), while the Precambrian basement of Alberta as a whole has been studied to have concentrations of U=4.13 ppm and Th=21.1 ppm (Burwash and Cumming, 1976). Large variations in the concentrations of these elements has required that detailed analyses be made in the Fort McMurray area for this project.

Geochemical studies into the geothermal potential of the Fort McMurray region (Burwash and Cumming, 1976; Burwash, 1979) have yielded a strong heat producing potential with average values (n=12) of 3.32 ppm for Uranium and 40.1 ppm for Thorium with a standard deviation of 4.89 and 46.4 respectively. These values are much higher than average Canadian Shield abundances. Since these particular studies were completed, additional samples that have become available including a large number of core samples from a deep well (~2365 m), known as the Hunt Well, drilled in the immediate vicinity of Fort McMurray town site.

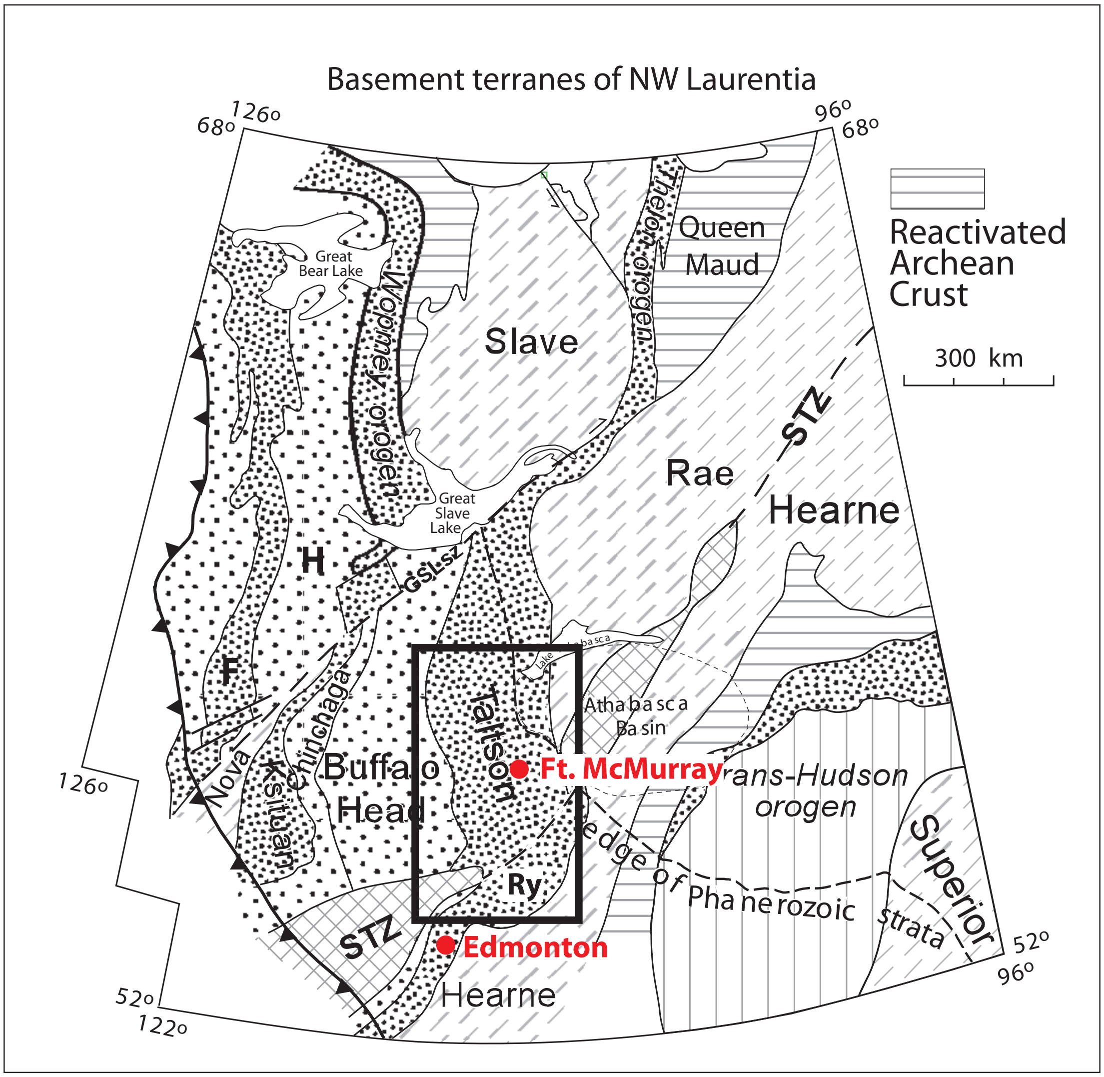


Figure 1-1: Map of Precambrian domains of the western Canadian Shield. The study area is located inside the black box. STZ=Snowbird Tectonic Zone, GSLSZ=Great Slave Lake Shear Zone, H=Hottah Terrane, F=Fort Simpson Arc, Ry=Rimbey Domain (modified after Pana et al., 2007).

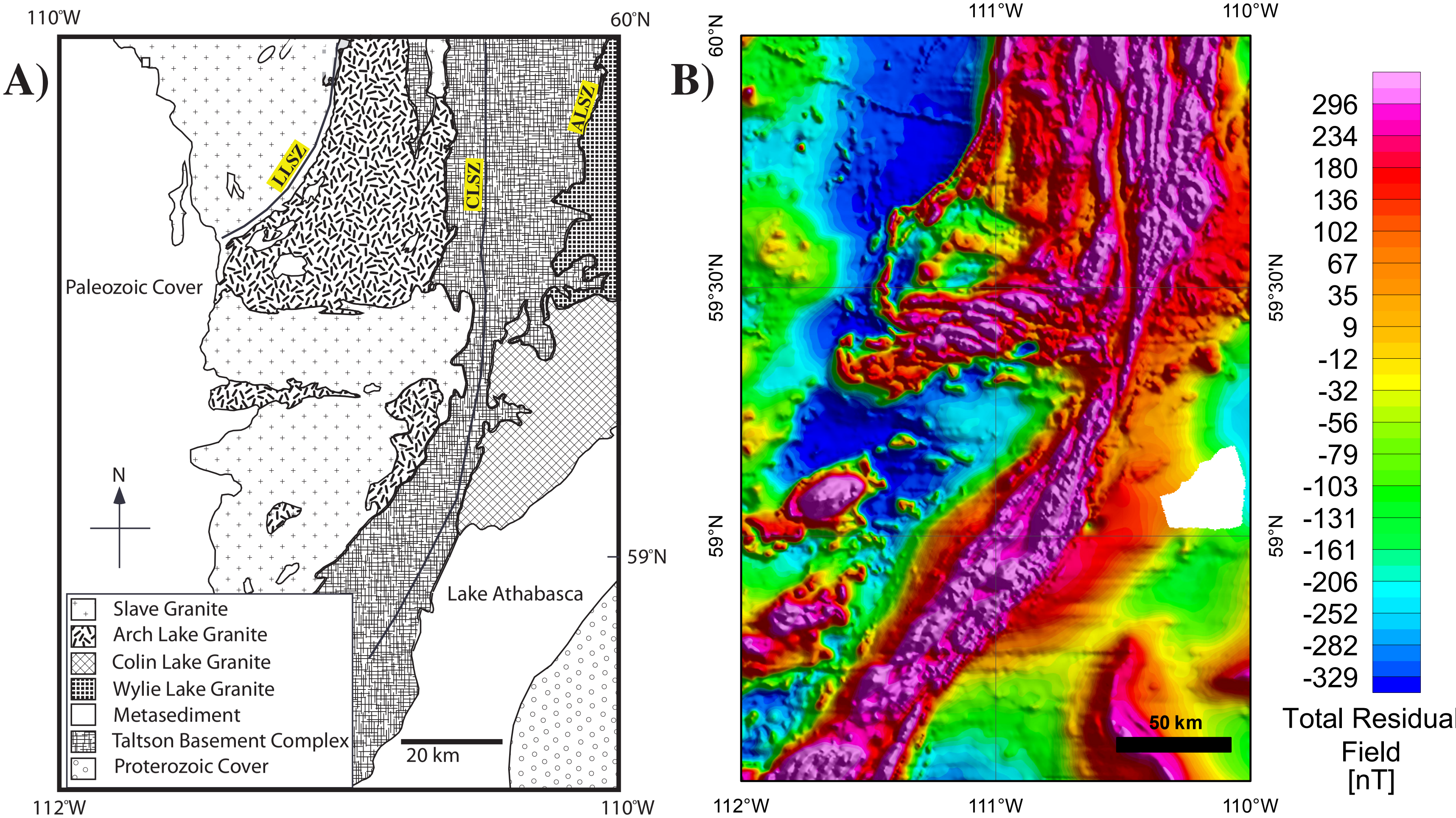


Figure 1-2: **(A)** Regional geology map of exposed Taltson Magmatic Zone (modified from De et al., 2000). **(B)** Aeromagnetic map displaying the total residual magnetic field in the exposed Taltson magmatic zone.

Chapter 2 – Petrology

Basement drill core samples for this study were obtained in the fall of 2010 and summer of 2011. The size of the drill core samples ranges from 1 cm to greater than 1 m in length. Well locations are displayed in **Figure 2-1**. All but six of the samples were granitoids or deformed granitoids. Outliers to the main granitoid group are a hornblende-rich mafic granulite, a biotite-bearing amphibolite, two granitic gneisses, a hercynite-biotite-garnet gneiss, and a granitic pegmatite. The mineralogy of these samples is summarized in **Table 2-1** and a more detailed set of sample description is given in **Appendix F**.

The 22 granitoid samples vary in composition from granitic **(Figure 2-2e and f; Figure 2-3a and b)** to quartz dioritic with the majority of these being syenogranite and monzogranite. Besides quartz, plagioclase, and potassium feldspar, minerals such as biotite, garnet, pyroxene, and oxide minerals are present. The majority of the granitoids are pink in color (n=14), with the remainder white (n=5) or grey (n=4). Five of the granitoids are moderately to strongly altered (observed as major mineral alteration), 13 have minor alteration (mainly alteration of biotite to chlorite), and 4 samples are essentially unaltered.

All but two of the granitoid samples show some degree of deformation. Weak foliation is observed in 16 of the granitoids, typically as slightly elongated quartz and feldspars and aligned biotite crystals. Deformation also manifests itself as kinked or bent albite twin planes in plagioclase and granulated quartz crystals. Three granites display moderate foliation with more prominent elongation of grains. The remaining 2 granitoids are undeformed.

Feldspar grains are typically 1-4 mm in diameter. Plagioclase commonly displays an antiperithitic texture where potassium feldspar has exsolved into small blebs within host plagioclase grains **(Figure 2-3e and f)**. Myrmekite is commonly observed at plagioclase grain boundaries and many grains show minor to moderate sericitic alteration. Quartz grains are generally 2-5 mm in diameter but many larger grains have been granulated by deformation into smaller subgrains **(Fig. 2-3b)**.

Biotite is present in 16 of the granitoid samples. It commonly exhibits partial to complete alteration to chlorite and other alteration products. This chlorite alteration is present in 11 of the granitoids. Garnet is present in only one granitoid (M12636) as 2 to 5 mm subhedral crystals. Samples from the 2300 m depth of the Hunt Well are the only pyroxene-bearing granitoid (charnockite) samples. Nearly all the pyroxene is orthopyroxene (up to 2 mm in diameter) with clinopyroxene **(Figure 2-3c)** only found in very small quantities in one sample (HW-1A).

The common oxide minerals present in the granitoid group are ilmenite (n=3) and magnetite (n=4). Seven samples contain the oxide mineral pseudorutile ($Fe_2Ti_3O_9$), which is likely an alteration product of ilmenite (Grey et al., 1994). Also present as an oxide alteration product is hematite (n=6). Apatite occurs as a trace phase in all samples. Zircon is found as an accessory mineral in all but one of the samples in the granitoid group. Zircon grains are typically 25 to 250 μm and euhedral to subhedral. Monazite is present in 8 samples of this group. They are mostly 50 to 200 μm in diameter, anhedral, and display patchy zonation.

Of the six non-granitoid samples included in this study, two were mafic in composition. One is a mafic granulite **(Figure 2-2c)**, which contains 0.5 to 3 mm-long hornblende and orthopyroxene crystals, albite-twinned plagioclase, and quartz. The other was an amphibolite with up to 2 mm long hornblende and plagioclase crystals and minor quantities of quartz. Neither of these mafic samples display strong foliation or secondary alteration.

Three gneisses are present. One is a biotite- and garnet-bearing granitic gneiss (M12352B) with poikiloblastic garnets, preferred alignment of mineral grains and compositional banding. The second is a small granitic gneiss fragment (N02) that is strongly altered. The third gneissic sample, which is from the 1600 m level of the Hunt Well, is a hercynite-biotite-garnet gneiss that, given its strongly peraluminous mineralogy, likely has a metasedimentary origin **(Figure 2-2a)**. This sample displays compositional bands consisting of alternating layers of garnet and felsic minerals (quartz and both feldspars). The garnet grains contain inclusions of biotite and hercynite. Sample M12352A is a granitic pegmatite that intruded one of the gneissic samples (M12352B). This pegmatite displays minor foliation and alteration. Minor minerals in this sample include biotite, hematite, and pseudorutile.

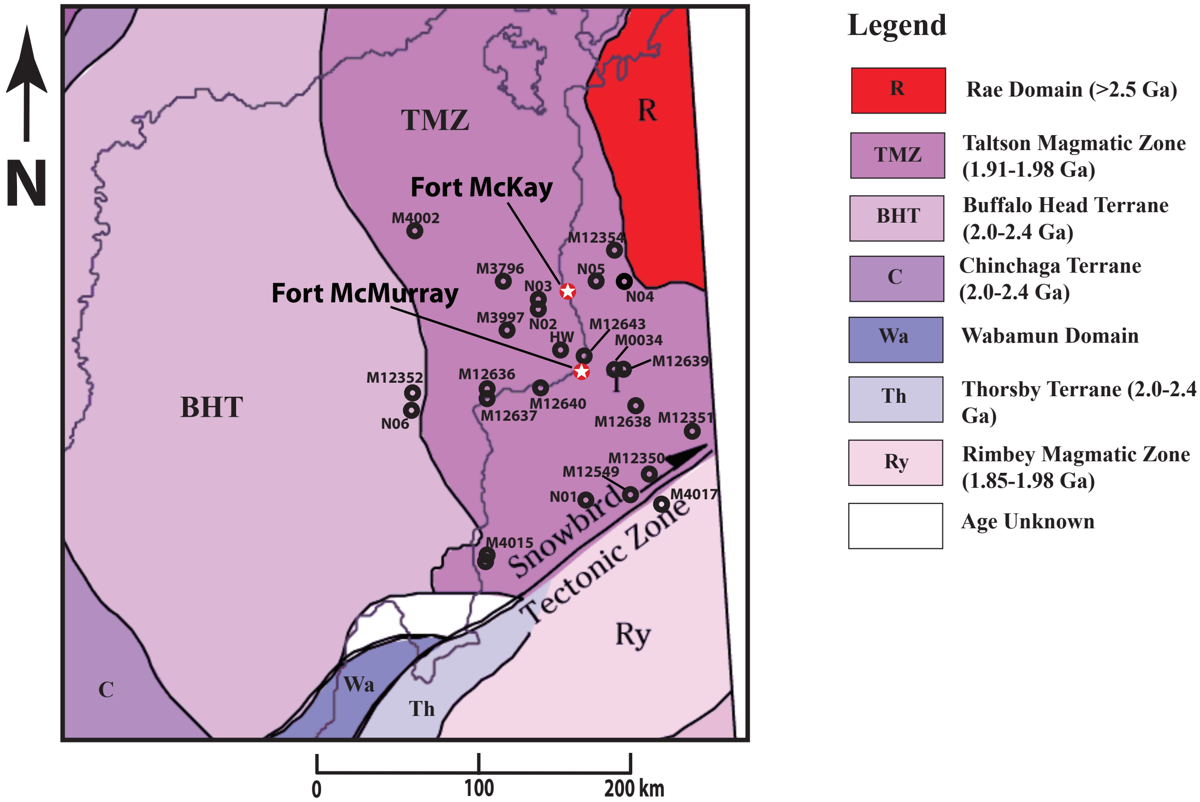


Figure 2-1: Map displaying Precambrian basement domains with well locations of samples analyzed in this thesis plotted (modified from Hoffman, 1989). More detail of well locations is provided in **APPENDIX A**.

Table 2-1: Summary of rock samples investigated in this study

Sample Name	Rock Type	Major minerals	Minor minerals	Accessory minerals	Alteration	Foliation	Comments
Granitoids							
M0034	biotite monzogranite	qtz, kfs, plag	bt, chl, rt	zrc, mnz	minor	minor	
M3796	biotite monzogranite	qtz, kfs, plag	bt, hm, mt, chl	zrc, apt	strongly altered	minor	
M3997	monzogranite	qtz, kfs, plag	p-rut, chl	zrc, mnz	minor	minor	
M4002A	syenogranite	qtz, kfs, plag	chl, p-rut, rt	zrc	moderate	minor	
M4002B	syenogranite	qtz, kfs, plag	chl, ilm, rt	zrc	moderate	minor	
M4015A	biotite monzogranite	qtz, kfs, plag	bt	zrc	minor	moderate	
M4017	biotite granite	qtz, kfs, plag	bt, chl	zrc	minor	moderate	
M12350	biotite quartz diorite	qtz, plag	bt, mt	zrc, apt	none	minor	
M12351	biotite monzogranite	qtz, kfs, plag	bt, chl	zrc	minor	moderate	
M12354	monzogranite	qtz, kfs, plag	chl	zrc	minor	minor	
M12549	biotite monzogranite	qtz, kfs, plag	bt, hm	zrc	minor	minor	
M12636	garnet monzogranite	qtz, kfs, plag	bt, grt, calc	zrc, mnz	minor	minor	
M12637	biotite syenogranite	qtz, kfs, plag	bt	zrc	none	none	very coarse grained
M12638	syenogranite	qtz, kfs, plag	bt, hm, chl, p-rut	zrc	minor	minor	
M12639	biotite granodiorite	qtz, kfs, plag	bt, chl	zrc, mnz	minor	minor	
M12640	biotite syenogranite	qtz, kfs, plag	bt	zrc, mnz	moderate	minor	
M12643	biotite syenogranite	qtz, kfs, plag	bt, p-rut	zrc, mnz	minor	minor	
N03	biotite granite	qtz, kfs, plag	bt	zrc	strongly altered	n/a	fragment
N04	monzogranite	qtz, kfs, plag	none	none	none	none	
N05B	biotite quartz monzonite	qtz, kfs, plag	bt, chl, ilm, p-rut	zrc, mnz, apt	minor	minor	
N06	monzogranite	qtz, kfs, plag	mt, hm	zrc	minor	minor	
HW3526/3528/3530	orthopyroxene granite	qtz, kfs, plag	bt, opx, cpx, hm, mt, ilm, p-rut	zrc, mnz, apt	none	minor	some display schlieren texture
Mafics							
M4015B	hornblende-rich mafic granulite	plag, hbl, opx	qtz	zrc	none	minor	
N01A	biotite amphibolite	qtz, plag, hbl	bt	zrc, apt	minor	minor	
Gneisses							
M12352B	biotite garnet granitic gneiss	qtz, kfs, plag	bt, grt, ilm	zrc	none	gneissosity	
N02B	granitic gneiss	qtz, kfs, plag	bt	zrc, mnz	strongly altered	gneissosity	fragment
HW3521/3522/3523	hercynite biotite garnet gneiss	qtz, kfs, plag, grt	bt, herc	zrc, mnz	none	gneissosity	
Other							
M12352A	granitic pegmatite	qtz, kfs, plag	bt, hm, p-rut	zrc, mnz	minor	minor	

Minerals: qtz = quartz, kfs = potassium feldspar, plag = plagioclase feldspar, bt = biotite, hbl= hornblende, opx = orthopyroxene, cpx = clinopyroxene, grt = garnet, herc = hercynite, chl = chlorite, mt = magnetite, ilm = ilmenite, hm = hematite, rt = rutile, p-rut = pseudorutile, calc = calcite, zrc = zircon, mnz = monazite, apt = apatite

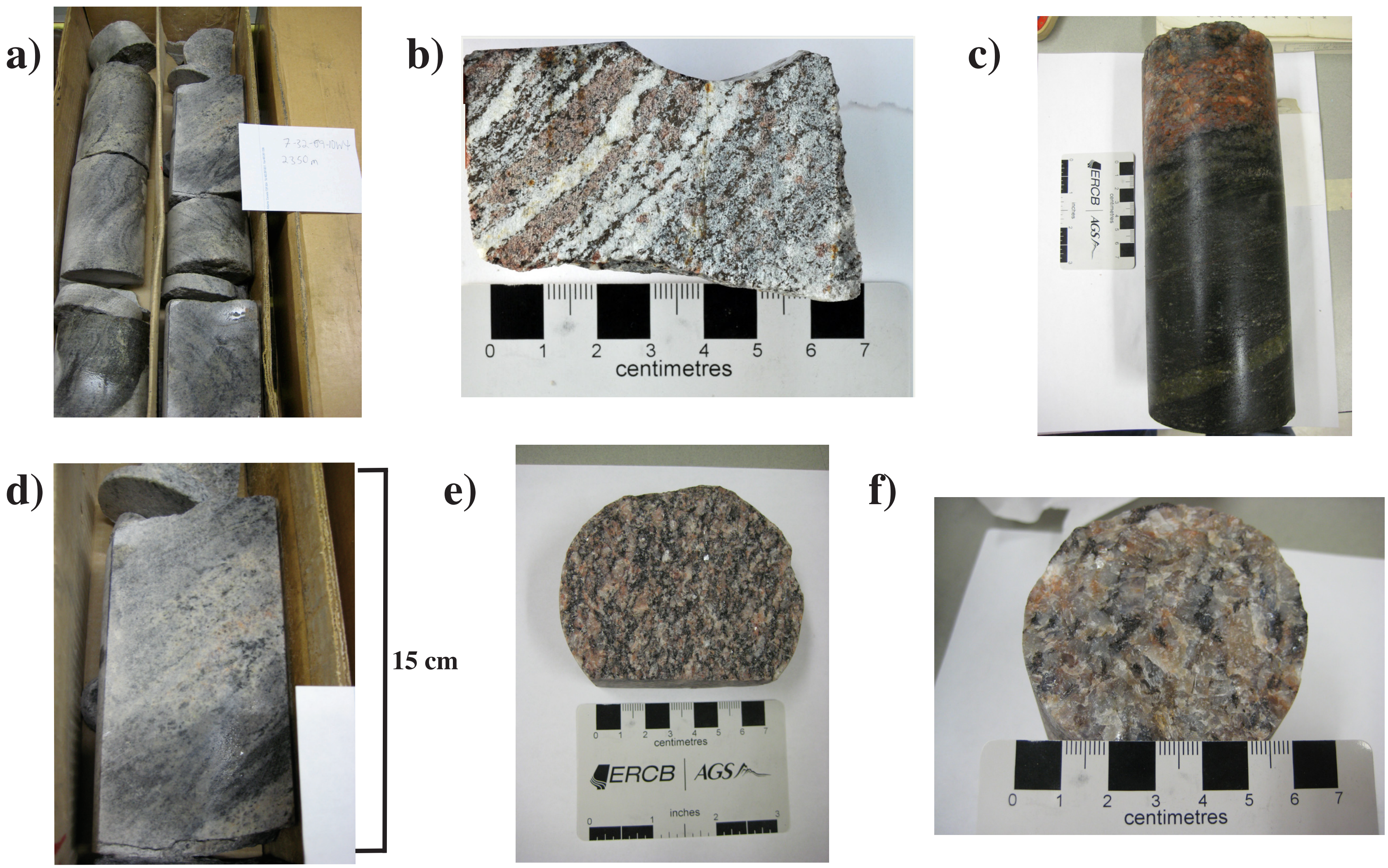


Figure 2-2: (a) and (d) Hunt Well core at 2350 m depth. Core is granitic with mafic schlieren textures present. (b) Hand sample of Hunt Well from a depth of 1657.4 m. Sample is likely of meta-sedimentary origin. (c) Sample M4015 has two components, a 2.3 Ga mafic granulite and a 2.0 Ga granitoid. (e) Sample M4017, a 1.83 Ga foliated granite from the Rimbey Domain. This was the youngest sample investigated in this study. (f) Sample M12637 consists of a coarse-grained granite from the younger (1.92-1.94 Ga) TMZ intrusion suite.

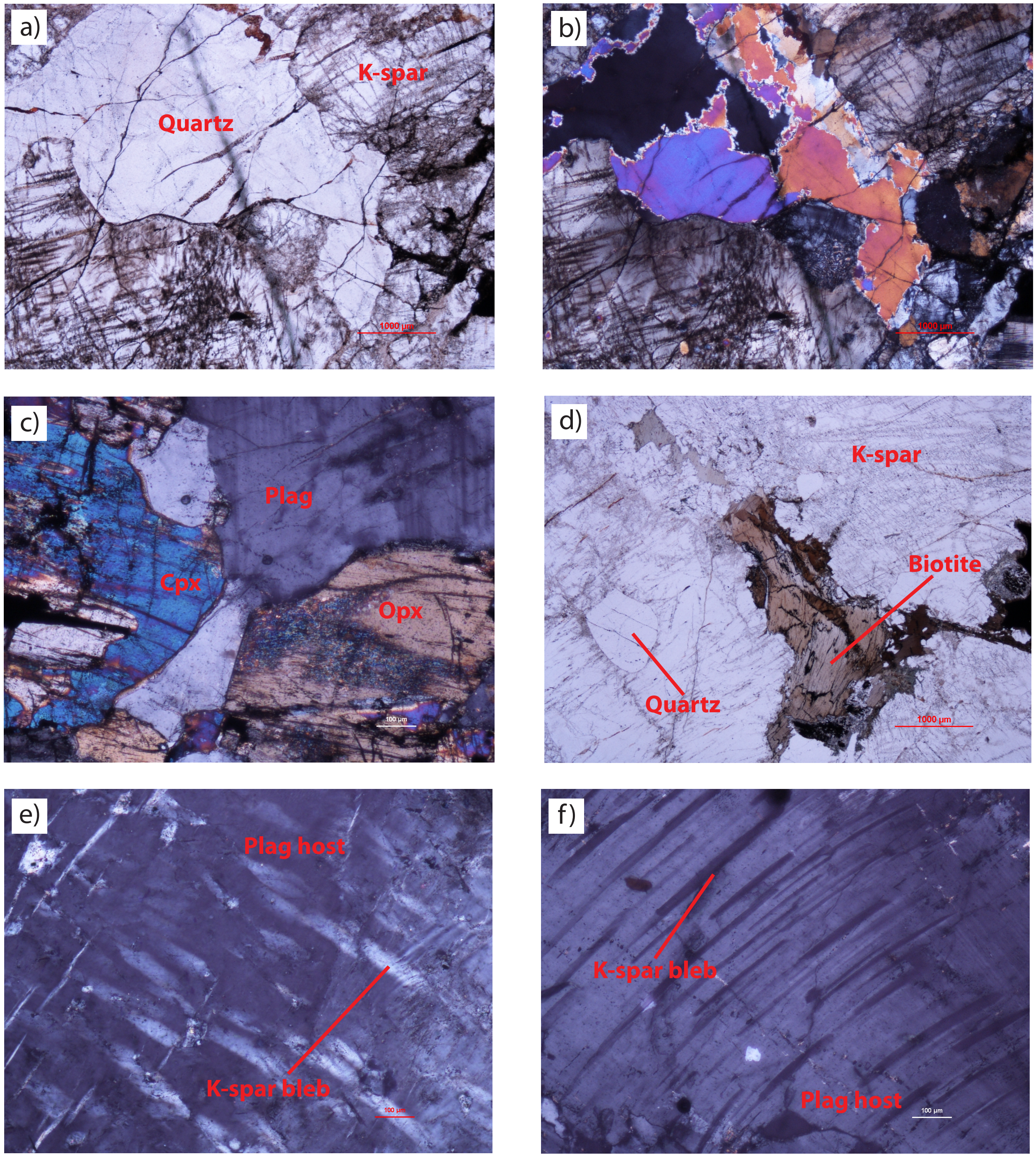


Figure 2-3 (1 of 2): a) plane and b) crossed-polarized light image of a typical younger granite with minor alteration (sample M0034). c) Sample HW1-A from a depth of 2364 m containing both orthopyroxene and clinopyroxene. (crossed-polarized light) d) Typical granitoid sample displaying a deformed biotite crystal (Sample N05). Plane-polarized light e) Antiperithitic texture seen on many granitic samples (sample M4017 from the Rimbey Domain). Plagioclase feldspar host minerals have exsolved potassium feldspar lamellae (Crossed-polarized light).
f) Antiperithitic texture which has undergone a later derformation event, seen in crossed-polarized light (Sample HW-1A).

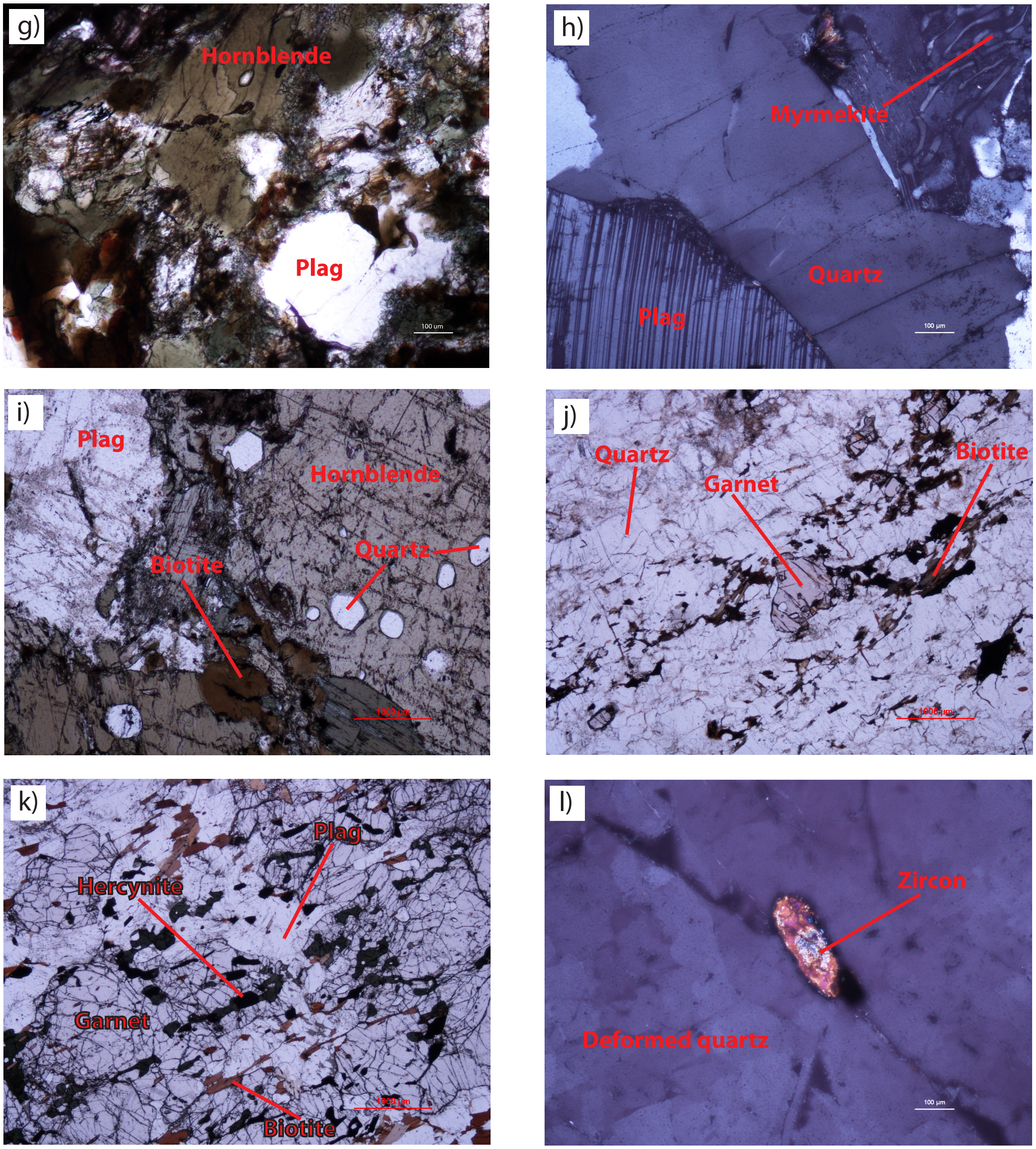


Figure 2-3 (2 of 2): g) Hornblende-rich mafic granulite sample M4015B displaying hornblende and plagioclase feldspar (plane-polarized light). h) Myrmekitic texture seen within one of the granitoid samples (M12354) (cross-polarized light). i) An amphibolite sample displaying a mineral assembledge of plagioclase feldspar, hornblende (with quartz inclusions), and biotite. (plane-polarized light). j) Gneissic sample M12352B with quartz, garnet, and aligned biotite grains (plane-polarized light). k) Gneissic sample of meta-sedimentary origins (HW3523). This sample contains garnet grains with inclusions of biotite and hercynite (plane-polarized light). l) Metamict zircon included in a deformed quartz grain (sample N06) displaying undulatory extinction (crossed-polarized light).

CHAPTER 3 – U-Pb geochronology

The uranium-lead (U-Pb) dating of zircon and monazite grains of 30 samples from 23 separate wells was completed at the department of Earth and Atmospheric Sciences Radiogenic Isotope Facility. The U-Pb system is well suited to dating Precambrian rocks because of its high precision and generally high resistance to resetting. The purpose of dating the samples was a) to better define the geologic history of the Precambrian basement, and b) to group the samples into rock suites in order to identify regions with favorable geothermal parameters. Rock suites with similar ages may have geothermal parameters unique to that suite. A limited number of basement samples from this study area have been the subject of previous geochronological studies (Ross et al., 1991; Villeneuve et al., 1993).

3.1 – Methodology

Isotopic analyses were performed on standard polished petrographic thin-sections using laser-ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICP-MS). Instruments used in measuring samples were the NuPlasma MC-ICP-MS, manufactured by Nu Instruments (Wrexham, UK), combined with the New Wave Research (Fremont, CA) UP213 laser ablation system with a SuperCell^{TM} sample holder that allows simultaneous loading of thin-sections and standard mineral grains mounted on a separate glass slide. The analytical parameters and procedures used in the present study are described by Simonetti et al. (2005, 2006). The data were collected over 11 analytical sessions in August 2011, February 2012, and May 2012.

The petrographic thin-sections chosen for U-Pb dating contained multiple zircon and/or monazite grains that were at least 30 μm in their smallest dimension due to the size of the analyzing beam. Thirty zircon-bearing and twelve monazite-bearing samples were found to be suitable for in-situ dating. Once appropriate grains were identified in thin section, backscatter electron (BSE) images of these grains were obtained using the Department's JEOL 8900 Electron Microprobe. BSE imaging serves two purposes: first, to determine the size and quality of grains in terms of fracturing and radiation damage, and second, to examine the internal structure within grains (e.g., core-rim relationships).

Samples containing grains or parts of grains with relatively little radiation damage are essential for obtaining concordant results and precise ages.

Zircon and monazite analyses were conducted using a 30-μm and 12-μm diameter laser spot size, respectively. Data collection consisted of one-second integrations carried out over 30 seconds. Analyses in which there were significant changes in $^{207}Pb/^{206}Pb$ during the 30 integrations were omitted in age determinations. Common lead (^{204}Pb) concentrations were measured, but no common Pb correction was made to samples because of uncertainties related to applying this correction. The measured $^{207}Pb/^{206}Pb$ and $^{206}Pb/^{238}U$ ratios were normalized using the in-house LH94-15 zircon standard (Ashton et al., 1999) and the 'Western Australia' monazite standard (Simonetti et al., 2006). Plotting of U-Pb data and error calculations were done using Isoplot 3.0 software (Ludwig, 2003). Error ellipses shown on concordia plots are at the two-sigma level uncertainty and age uncertainties are reported at the 95% confidence level. A secondary zircon standard, OG-1 (Stern et al., 2009), of Archean age was run at the beginning of each analytical session to verify accuracy **(Appendix B)**.

3.2 – U-Pb age dating results

The age data are summarized in Table 3-1 and the full geochronological dataset is given in **Appendix B**. On the basis of the U-Pb data, the samples can be divided into 5 age suites: 1) 1.83 Ga suite; 2) 1.92-1.94 Ga suite; 3) 1.95-1.99 Ga suite; 4) 2.0-2.1 Ga suite; and 5) 2.25-2.40 Ga suite. The data for each suite is reported in turn below.

3.2.1 Suite 1 – 1.83 Ga

Sample M4017

M4017 is a biotite monzogranite **(Fig. 3-1)** from which I obtained eleven U-Pb analyses from four zircon grains. Zircons are euhedral to subhedral and range in size from 25-150 μm. All grains display oscillatory zonation but have undergone strong radiation damage (rock sample has a U concentration of 15.40 ppm). Individual analyses have large uncertainties (high ^{204}Pb cps) due to the radiation damage suffered by the zircon grains. Analyses vary from slightly (4%) to strongly (86%) discordant and yield a discordia array with an upper intercept age of 1836 ± 13 Ma and a lower intercept age of

52 ± 24 Ma with an MSWD of 2.4. The upper intercept is interpreted to be the age of magma crystallization and the lower intercept is interpreted as a recent lead loss event.

3.2.2 Suite 2 – 1.92 to 1.94 Ga

Sample M3796

This sample is an extensively altered biotite monzogranite **(Fig. 3-2)** from which I obtained 42 analyses on 9 zircon grains. The zircons are 50 to 250 μm in length, euhedral to subhedral, display faint oscillatory zoning, and show fracturing and little radiation damage. The great majority of analyses are <5% discordant and all analyses are <10% discordant. A weighted mean $^{207}Pb/^{206}Pb$ age of 1926.4 ± 2.8 Ma (MSWD of 1.1) calculated from the full dataset is interpreted as the crystallization age of the granite magma.

Sample M4002A

This sample is a syenogranite **(Fig. 3-3)**. Twenty-seven U-Pb analyses of nine zircon grains were made. The grains ranged in size from 50-250 μm and are subhedral to euhedral. Many are extensively fractured but preserve primary oscillatory zoning. Most analyses are <5% discordant and all 27 analyses yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1928.9 ± 8.1 Ma (MSWD = 4.7), which I interpret to be the igneous crystallization age of the zircon.

Sample M4002B

This sample is a syenogranite **(Fig. 3-3)**. Nine zircon U-Pb analyses were obtained from four grains. The grains are 50-75 μm in size, subhedral to anhedral, and have undergone significant radiation damage. Two of the grains have euhedral cores with fractured rims. Analyses, which range from concordant to moderately discordant, yield an upper intercept age of 1927±20 Ma (MSWD = 4.2). Removal of one younger analysis from the regression yields a somewhat more precise upper intercept age 1931 ± 16 Ma with a smaller MSWD of 2.3. This latter age is identical to the weighted mean $^{207}Pb/^{206}Pb$ age 1931 ± 19 Ma (MSWD = 3.8) calculated from a cluster of the six most concordant analyses. This is interpreted as the age of crystallization of the granite magma.

Sample M12354

This sample is a monzogranite **(Fig. 3-4)** from which I obtained 41 analyses on 14 zircon grains. Zircon grains are 50 to 200 μm in length, subhedral to euhedral, with most grains having undergone radiation damage. A regression line fit through all (n=40) but the most discordant point yields an upper intercept age of 1942 ± 28 Ma (MSWD = 4.3). Although $^{207}Pb/^{206}Pb$ ages derived from these analyses range from ~1550 to ~1940 Ma, the single largest age peak (n=18) is at the upper end of this range and yields a weighted mean age of 1935.4 ± 6.6 Ma (MSWD = 1.4). This is the best current estimate of the crystallization age of this monzogranite but, as suggested by the large spread in the data, it is possible that the true crystallization age is somewhat older than 1935 Ma.

Sample M12637

M12637 is a biotite syenogranite **(Fig. 3-5)**, which yielded a total of eighteen analyses from six zircon grains. The grains are anhedral, 50-200 μm in size, and display core/rim relationships with both the cores and rims exhibiting oscillatory zoning. All analyses are concordant with fourteen analyses yielding a younger $^{207}Pb/^{206}Pb$ age cluster of 1920.8 ± 4.2 Ma (MSWD = 1.10). Four analyses of zircon cores yielded an older concordant $^{207}Pb/^{206}Pb$ age of 1952 ± 19 Ma with an MSWD of 2.2. Due to both cores and rims having oscillatory zonation, the four core ages are interpreted to be inherited zircons whereas the younger (rim) cluster is interpreted as the crystallization age of the magma.

3.2.3 Suite 3 – 1.95 to 1.99 Ga

Sample M0034

M0034 is a biotite monzogranite **(Fig. 3-6)** with minor amounts of chlorite. I obtained five analyses from two zircon grains in this sample. These irregularly-shaped grains are 70-150 μm in size and show minor radiation damage. One grain displays a core and rim. Analyses range from concordant to moderately discordant with an upper intercept of 1948 ± 33 Ma (MSWD = 3.8). Monazite is far more abundant in this sample with nine grains yielding thirty-one analyses. Grain size ranges from 50-125 μm with grains irregularly shaped with strong patchy zoning profiles. Monazite analyses were all concordant or only slightly discordant with all analyses yielding a weighted mean $^{207}Pb/^{206}Pb$ age of 1981.1 ± 7.1 Ma (MSWD = 4.8). The large MSWD associated with the 1981 Ma monazite age suggests that there may be more than one episode of monazite growth recorded in these grains, possibly related to closely spaced magmatic, metamorphic, and fluid influx events experienced by the rock. Nevertheless, I take the 1981 Ma age as a minimum estimate of the crystallization age of the granite magma.

Sample M3997

This sample is a monzogranite **(Fig. 3-7)** from which I obtained 13 analyses on 5 zircon grains. The zircons are 50 to 100 μm in length, anhedral to subhedral, and mostly unzoned. All but one grain show strong radiation damage. Eleven of the 13 analyses are <6% discordant with two particular grains (grain 2A and 2B) producing the oldest cluster of near concordant analyses. These six analyses yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1960.1 ± 7.3 Ma (MSWD = 0.95). Fifteen analyses were conducted on 2 monazite grains. Both grains are approximately 100 μm in length, anhedral, and have poorly defined patchy zonation. All monazites are concordant and form a fifteen-point cluster with a weighted mean $^{207}Pb/^{206}Pb$ age of 1949.9 ± 6.6 Ma (MSWD = 1.3). This age is within analytical uncertainty of the zircon age and suggest that the magmatic crystallization age of the sample is somewhere between 1960 and 1950 Ma.

Sample M12350

This sample is a biotite quartz diorite **(Fig. 3-8)** with minor amounts of magnetite. I obtained 24 analyses from seven zircon grains in the sample. Grain size varies from 50 to 250 μm with all grains relatively free of radiation damage. All grains show patchy zonation with some displaying narrow overgrowths. No rims were analyzed due to their small size. All but one of the analyses are <10% discordant and most are <5% discordant. The weighted mean $^{207}Pb/^{206}Pb$ age of 1970.6 ± 5.3 Ma (MSWD = 0.65) and upper intercept age of 1970.2 ± 5.4 Ma (MSWD = 0.67) calculated for this data set are identical within error and are interpreted to be the age of magma crystallization.

Sample M12351

This sample is a biotite monzogranite **(Fig. 3-9)**. A total of 41 U-Pb analyses were conducted on 12 zircon grains. The grains are 50 to 400 μm in length, anhedral to euhedral, strongly radiation damaged, and many show distinct cores and rims. Most of the analyses are <5% discordant and yield $^{207}Pb/^{206}Pb$ ages ranging from ~1.9 Ga to ~3.0 Ga. On a probability density plot of $^{207}Pb/^{206}Pb$ ages, there are small age peaks from 2000 Ma to 3000 Ma but the major peak is at ~1.95 Ga. A weighted mean $^{207}Pb/^{206}Pb$ age calculated from the 23 analyses belonging to this dominant age peak is 1957.2 ± 8.7 Ma (MSWD = 3.6). This age is interpreted as the current best estimate of the crystallization age of the granite. Zircons yielding older ages may represent grains inherited from the source or incorporated from country rocks through which the magma passed.

Sample M12549

This sample is a leucocratic biotite monzogranite **(Fig. 3-10)**. Thirteen analyses from six zircon grains were obtained for this sample. Zircons range from 50-200 μm in diameter, display anhedral to subhedral habit, and are relatively free of radiation damage. Most grains have a core and rim with both the core and rim displaying oscillatory zoning. Most analyses are <10% discordant with one strongly discordant analysis (20.7%). Regression of all the data yields an upper intercept age of 1956.3 ± 9.9 Ma (MSWD = 2.8). A weighted mean calculated from the 7 most concordant analyses (<5% discordant) yields an identical age of 1956 ± 13 Ma (MSWD = 3.1). I take the upper intercept age to be the current best estimate of the crystallization age of the granite.

Sample M12636

This sample is a biotite-garnet monzogranite **(Fig. 3-11)**. Nineteen analyses were conducted on 6 zircon grains in this specimen. Zircon grains are 50-200 μm in length, anhedral to euhedral, and exhibit poorly developed oscillatory zoning. The analyses are all <15% discordant and most are <10% discordant. One analysis taken from a zircon core is distinctly older than the other analyses and was not included in the calculations described below. A regression fit through the older analyses yields an upper intercept age of 1933 ± 10 Ma (MSWD = 3.3). The same analyses yielded a weighted mean $^{207}Pb/^{206}Pb$

age of 1930.4 ± 7.6 Ma (MSWD = 3.6). Given the relatively high MSWD, its age is uncertain. Twenty-four analyses were conducted on four monazite grains in this sample. Monazite grains are 150 to 300 µm in length, anhedral, and display weakly developed patchy zoning. Analyses yielded a concordant cluster with weighted mean $^{207}Pb/^{206}Pb$ age of 1955.4 ± 5.5 Ma (MSWD = 0.56). On the basis of the lower MSWD associated with the monazite data, I suggest that monazite is likely providing a better estimate of the true crystallization age of the monzogranite magma. However, the ~25 Ma difference in ages given by zircon and monazite in the sample remains unsolved.

<u>Sample M12638</u>

M12638 is a syenogranite **(Fig. 3-12)**, which yielded twenty analyses from six zircon grains. Grains are 50-200 µm with some displaying fine-scale oscillatory zoning, whereas others display patchy zonation. Minimal radiation damage is visible. The analyses are concordant to moderately discordant. Nineteen of the twenty analyses yield a well-defined discordant array with an upper intercept age of 1955.8 ± 4.4 Ma (MSWD = 0.55) and a weighted mean $^{207}Pb/^{206}Pb$ age of 1956.1 ± 4.0 Ma (MSWD = 0.54). The upper intercept age is interpreted as the crystallization age of the granite magma. One slightly older analysis spot (1997 ± 18 Ma), which I interpret to be taken from an inherited core, was omitted from age calculations.

<u>Sample M12640</u>

This sample is a biotite syenogranite **(Fig. 3-13)** that contains both zircon and monazite. Five spots from two zircon grains were analyzed for this sample. Zircon grain size ranges from 50 to 100 µm with euhedral to subhedral habit and one grain showing oscillatory zoning in its core. Analyses are concordant to slightly discordant with a fifth more strongly discordant analysis omitted from age determinations. A weighted mean $^{207}Pb/^{206}Pb$ age of 1949 ±16 Ma (MSWD = 1.3) is within error of an upper intercept of 1950 ± 10 Ma (MSWD = 0.55). Monazite grains in the sample are 100 to 200 µm in length, anhedral in shape, and display patchy zonation. Twenty-five analyses obtained from two monazite grains were all <10% discordant and most were <5% discordant. The analyses yielded a weighted mean $^{207}Pb/^{206}Pb$ age of 1949.1 ± 4.0 Ma (MSWD = 0.40).

This age is identical to the zircon upper intercept age for this sample and both are interpreted as the time of crystallization of the granite.

Sample M4015A

This sample is a leucocratic biotite monzogranite **(Fig. 3-14)** from which 11 analyses from 5 zircon grains were obtained. Zircons are 50-100 μm in size and are euhedral to subhedral. All display oscillatory zoning and have undergone strong radiation damage. The analyses range from moderately (12.7%) to strongly (79.8%) discordant and yield lower and upper intercept ages of -18 ± 87 Ma and 1997 ± 37 Ma (MSWD = 15), respectively. The upper intercept, although poorly constrained, is interpreted to approximate the crystallization age of the granite magma. The lower intercept is interpreted to be the result of recent lead-loss. However, due to the large uncertainty associated with this date, it is not clear if this sample belongs in Suite 3 or Suite 4.

3.2.4 Suite 4 – 2.0 to 2.1 Ga

Samples HW3521 and HW3522

These samples from the 1600 meter level of the Hunt Well comprise hercynite-biotite-garnet gneiss of pelitic to semi-pelitic composition **(Fig. 3-15)**. Thirty-nine U-Pb analyses were conducted on 18 zircon grains. The grains are 50 to 125 μm in length, anhedral, show faint oscillatory zoning, and are strongly radiation damaged. All but one of the analyses are <10% discordant and most are <5% discordant. A regression line fit through the data array yield an upper intercept age of 2037±26 Ma (MSWD = 2.3), which is interpreted to be the approximate time of zircon crystallization. Sixteen monazite analyses were produced from 4 grains. The monazite grains are 50 to 100 μm in length, anhedral to subhedral, and display weak patchy zonation. All but one of the analyses is <10% discordant and yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1939.5 ± 3.9 Ma (MSWD = 1.1). The highly aluminous nature of this sample (see petrography in appendix) suggests that it had a sedimentary protolith. As such, the zircons are likely detrital in origin and reflecting the age of source rocks of the sediment. I interpret the monazite age to record the time of high-grade metamorphism.

3.2.5 Suite 5 – 2.25 to 2.40 Ga

Sample M4015B

This sample is a hornblende-rich mafic granulite **(Fig. 3-16)** from which 25 analyses on five zircon grains were obtained. Zircons range in size from 100 to 250 μm, are subhedral to anhedral shape, and exhibit faint oscillatory zoning. The zircons are in pristine condition with no grain fractured or radiation damaged. U-Pb isotopic analyses were all <10% discordant and most were <4% discordant. A weighted mean $^{207}Pb/^{206}Pb$ age of 2307.7 ± 5.0 Ma of a twenty-five point cluster with a MSWD of 0.60. The faint oscillatory zoning seen in the zircons suggests that they are of igneous origin, which in turn implies that the zircons record the crystallization age of the magmatic protolith of this mafic granulite. However, it should be noted that the low ^{206}Pb cps (and associated low U content) of these zircons are not typical of primary zircon crystallizing from a mafic melt.

Sample M12352B

This sample is a biotite garnet granitic gneiss (M12352B) cut by a granitic pegmatite (M12352A). I obtained 13 analyses on 7 zircon grains from the gneiss **(Fig. 3-17)**. The grains are 50 to 100 μm in length, anhedral to subhedral, show faint oscillatory zoning, and are moderately radiation damaged. All but one of the U-Pb analyses from the gneiss are <10% discordant and the data form two broad age groups. A younger group has $^{207}Pb/^{206}Pb$ ages from ~1.99 Ga to ~2.06 Ga and the older group has $^{207}Pb/^{206}Pb$ ages from ~2.15 to ~2.40 Ga. The data are largely inconclusive but it is possible that the zircons initially crystallized at ~2.4 Ga and then experienced a lead-loss event associated with the intrusion of the granite pegmatite. I obtained 10 analyses on 2 zircon grains from the pegmatite **(Fig. 3-18)**. The grains are 50 to 150 μm in length, anhedral, unzoned, and moderately radiation damaged. All but one of the pegmatite U-Pb analyses are <10% discordant. A regression fit through the analyses yields an upper intercept age of 1982 ± 11 Ma (MSWD = 1.7). The same analyses yielded a weighted mean $^{207}Pb/^{206}Pb$ age of 2000 ± 11 Ma (MSWD = 3.9). On the basis of its lower MSWD, I propose that the upper intercept age provides the best estimate of the time of pegmatite crystallization. I obtained 40 analyses on 6 monazite grains of the pegmatite phase. The grains are 50 to

200 μm in length, anhedral, and unzoned. 28 of the 40 analyses are reversely discordant with the remain less than <15% discordant. All analyses form a cluster with a weighted mean $^{207}Pb/^{206}Pb$ age of 1983.6 ± 5.4 Ma (MSWD = 2.1). This age matches the zircon upper intercept age of the pegmatite and likely the crystallization age of the pegmatite.

<u>Sample M12639</u>

This sample is a biotite granodiorite **(Fig. 3-19)** containing both zircon and monazite. I obtained 31 analyses from 8 zircon grains. The grains are 100 to 250 μm in length, range from anhedral to euhedral in shape, and are relatively free of radiation damage. Of the 8 grains, all but one display oscillatory zoning. The analyses are all <10% discordant and, except for a small gap in ages between ~2.16 and 2.06 Ga, spread more or less continuously along concordia from ~2.35 Ga to ~1.99 Ga. Data arrays such as these can be interpreted in three ways: 1) crystallization of zircon from magma at ca. 2.35 Ga followed by partial to complete Pb loss during a ca. 2.0 Ga metamorphic event; 2) extensive inheritance of ca. 2.35 Ga zircons by a magma that crystallized at ca. 2.0 Ga; and 3) periodic crystallization of zircon from ca. 2.35 to 2.0 Ga during multiple magmatic or metamorphic events. The following observations would appear to rule out scenario 2. Many of the younger ages in the data array (2.06-1.99 Ga) were obtained from irregularly shaped zones that cut across some zircon grains (e.g., Fig 3-19D). These zones, which are generally bright on BSE images, do not show oscillatory zoning or other textural evidence of having crystallized from a magma. Instead, the zones may represent strongly radiation damaged parts of the pre-existing zircon grains that underwent extensive recrystallization and associated Pb loss during ca. 2.0 Ga metamorphism. The high ^{206}Pb counts (>1,000,000 cps) recorded in analyses taken from these 'bright' areas indicate that they do in fact have high U contents and therefore would be the most susceptible to experiencing severe radiation damage. Because of the low precision of individual U-Pb isotope analyses acquired with the MC-ICP-MS technique, the shallow discordia line produced in scenario 1 cannot be distinguished from concordant analyses of zircons that crystallized continuously or episodically from ca. 2.35 to 2.0 Ga (i.e., scenario 3). However, scenario 3 would imply that there was more or less continuous crystallization of zircon over a ~190 m.y. time interval from 2.35 to 2.16 Ga (Fig 3-19A), which seems unlikely. I therefore favor scenario 1 as the most plausible interpretation of this dataset. A ~2.35 Ga crystallization age for the granodiorite magma is similar to the age obtained for sample M12643 and also generally matches the 2.3-2.4 Ga ages previously reported for rocks of the Taltson Basement Complex (McNicoll et al., 2000).

I also obtained twenty-five analyses from five monazite grains in this sample **(Fig 3-19B)**. The monazite grains are 100-200 μm in length. Four of the five grains are irregularly shaped and display patchy zonation whereas the other grain is euhedral and does not show patchy internal zonation **(Fig. 3-19E,F)**. When plotted on a concordia diagram, two age clusters can be seen. The euhedral grain yielded six reversely discordant analyses with a weighted mean $^{207}Pb/^{206}Pb$ age of 2377 ± 31 Ma (MSWD = 4.9). This grain is either a magmatic monazite that formed during the initial crystallization of the rock, or else a xenocryst; I favor the former interpretation. The remaining 19 analyses from the other four grains yielded a much younger weighted mean $^{207}Pb/^{206}Pb$ age of 1987.7 ± 5.2 Ma (MSWD = 1.1). I interpret these grains to be recording a younger metamorphic event experienced by the granodiorite. Taken together, the U-Pb data obtained from zircon and monazite in this granodiorite sample are consistant with the hypothesis that a granodiorite magma crystallized at ca. 2.35-2.38 Ga and then experienced a high-grade metamorphic event at ca. 1.99 Ga. The metamorphism caused Pb loss or recrystallization in pre-existing zircon grains as well as new monazite growth.

Sample M12643

This sample is a biotite syenogranite **(Fig. 3-20)** containing both zircon and monazite. I obtained 9 analyses from 4 zircon grains. Zircons are 50 to 200 μm in length, vary from anhedral to euhedral, and display oscillatory zoning. All grains are radiation damaged and fractured. All analyses are <10% discordant, but spread along the concordia curve from ~2.3 Ga to ~2.0 Ga. This data array may be describing a crystallization age of ~2.3 Ga, followed by a lead-loss event at ~2.0 Ga. A ~2.3 Ga crystallization age is consistent with the range of ages reported for the Taltson Basement Complex, and the lead-loss event could be attributed to post-2.0 Ga granitic intrusions. An alternative interpretation for this data array is crystallization of the granodiorite magma at ca. 2.0 Ga along with incorporation of older zircons from the magma source or from country rocks through which the magma past. I suggest, however, that this latter interpretation would likely produce a much greater proportion of ages close to the time of magma crystallization rather that the largely continuous spread of ages from 2.3-2.0 Ga seen in the data array. I also obtained 30 analyses from 3 monazite grains. The monazites are 100 to 250 μm in length, anhedral, and show patchy internal zonation. All of the analyses are <11% discordant and most are <5% discordant. Regression of the data yield an upper intercept of 1961.5 ± 6.4 Ma (MSWD = 0.63) and the weighted mean $^{207}Pb/^{206}Pb$ age of 1968.9 ± 3.8 Ma (MSWD = 0.77). Given the clustered nature of the data, the weighted mean $^{207}Pb/^{206}Pb$ age likely gives the best estimate of the crystallization age of the monazite. This age could reflect the time of a metamorphic event, which produced the Pb loss observed in the zircon U-Pb data.

<u>Sample N01A</u>

This sample is a biotite-bearing amphibolite. **(Fig. 3-21)** Twenty-four analyses were produced from 7 zircon grains. Grains are 50 to 200 μm in length, anhedral to subhedral, are mostly free of radiation damage, and display faint oscillatory zoning. The analyses are mostly <5% discordant and yield a weighted mean $^{207}Pb/^{206}Pb$ age of 2278.1 ± 7.7 Ma (MSWD = 2.3). This interpreted as the crystallization age of the magma but there is the possibility that it represents a metamorphic age.

<u>Sample N02B</u>

This sample is a strongly altered fragment of biotite granite gneiss. **(Fig. 3-22)** Twenty analyses were conducted on ten zircon grains. U-Pb analyses from this sample are noted for having much higher counts per second (cps) at the 204Pb mass (~140 to ~390) than other samples (~50-100 cps). If these elevated counts at mass 204 do in fact reflect high common Pb in zircons then the ages reported here must be taken as maximum ages as no common Pb correction was made to these data. Grains are 50 to 150 μm in length, euhedral to subhedral, and all display oscillatory zoning. Whereas all analyses are concordant or only slightly discordant, they define a broad array along concordia from ~2160 Ma to ~2300 Ma. When displayed on a probability density plot

(Fig. 3-22C), we see a weak clustering of the data at 2180 Ma and 2300 Ma, and a somewhat larger cluster at ~2250 Ma. The zircon data are inconclusive but may represent and reflect crystallization of the granitic protolith of the sample sometime between 2180 and 2300 Ma and most probably between 2250 and 2300 Ma. Thirty-five monazite analyses were obtained from seven grains. Grains are 50 to 150 μm in length, anhedral to subhedral, and weakly display patchy zonation. The analyses, which are mostly <5% discordant, yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1949 ± 3.8 Ma (MSWD = 0.91). This age is interpreted to reflect a metamorphic event experienced by the sample.

<u>Sample N03</u>

This small sample is a biotite granite fragment **(Fig. 3-23)** for which I was able to obtain 7 analyses from a single zircon. The grain is 100 μm in length, subhedral, free of radiation damage and unzoned. All 7 analyses are <5% discordant and define a range of $^{207}Pb/^{206}Pb$ ages from 2140 to 2290 Ma. The five oldest analyses form a cluster with a weighted mean $^{207}Pb/^{206}Pb$ age of 2266 ± 11 Ma (MSWD = 2.0). This age may represent the time of magma crystallization but, given that the data were all obtained from a single grain, I cannot rule out the possibility that the zircon is a xenocryst in a younger magma.

<u>Sample N05B</u>

This sample is a biotite quartz monzonite **(Fig. 3-24)**. Twelve analyses were conducted on 3 zircon grains. The grains are 50 to 150 μm in length, anhedral to subhedral, and exhibit faint oscillatory zoning. Although the data are all <6% discordant, the $^{207}Pb/^{206}Pb$ ages range from approximately 2450 Ma to 2200 Ma. The ~2450 Ma age is interpreted as the crystallization age of the magmatic protolith and the ~2200 Ma age, as the age of metamorphic event during which there was partial or complete Pb loss or new zircon growth. Nine monazite analyses were obtained from a single grain, which is 100 μm in length, euhedral, and unzoned. The analyses are mostly <5% discordant and yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1962.8 ± 9.6 Ma (MSWD = 0.23). Monazite growth at this time could be associated with the 1.92-2.0 Ga granitic intrusions of the TMZ.

Sample N06

This sample is a monzogranite **(Fig. 3-25)** from which I obtained 15 analyses on 4 zircon grains. Three of the four grains are 50 to 100 µm in length, anhedral to subhedral, display weak oscillatory zoning, and appear to be a magmatic origin. The 3 grains yielded nine nearly concordant analyses with $^{207}Pb/^{206}Pb$ ages ranging from ~2300 to ~2200 Ma. This is interpreted as a crystallization age for the sample at ~2300 Ma. A fourth zircon yielded a much younger age. It is 100 µm in length, anhedral, and appears as homogeneous except for a magmatic core surrounded by a metamorphic overgrowth. Five analyses from this grain produced a weighted mean $^{207}Pb/^{206}Pb$ concordant age of 1992 ± 10 Ma (MSWD = 1.2). This is interpreted as a metamorphic age for the sample.

Samples HW3526, HW3528, and HW 3530

These samples are deformed orthopyroxene-bearing granites (charnockites) from a depth of 2350-2360 meter level of the Hunt Well. I obtained 16 analyses on 6 zircon grains of samples HW3526 and HW3530 **(Fig. 3-26)**. Zircons are anhedral, 50 to 100 µm in length, radiation damaged, and display oscillatory zonation. The analyses are all <10% discordant and yield $^{207}Pb/^{206}Pb$ ages ranging from 2395 Ma to 1935 Ma. The analyses with ages of ~2400 Ma are interpreted as the crystallization age. This would match other ~2.3-2.4 Ga samples in the TBC. The ~1950 Ma age is interpreted as Pb-loss or new zircon growth related to regional metamorphism and/or ~1.95 Ga granitoid intrusion. Thirty-seven monazite analyses from three grains were obtained. Grains are 100 to 250 µm in length, anhedral, and appear to be homogeneous in composition. All thirty-seven analyses were concordant or only slightly discordant and yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1967.2 ± 6.6 Ma (MSWD = 4.2). However, there are significant age differences (1947±12, 1964.6±6.3, 1991±10) between the three grains, suggesting there may have been multiple episodes of monazite growth during metamorphic or fluid influx events.

3.3 Discussion

3.3.1 Comparison of Ages

As stated in the results section, five rock suites have been identified in this study on the basis of U-Pb ages. Suite 1, which comprises a single granitic sample from the Rimbey Domain **(Fig. 3-1)**, yielded an age of 1.83 Ga. Suites 2 and 3 comprise granitic samples from the Taltson Magmatic Zone which yielded ages of 1.92 to 1.94 Ga and 1.95 to 1.99 Ga, respectively. Suite 4 is a single metasedimentary sample from the 1600 meter level of the Hunt Well (TMZ) which yielded what I interpret to be a detrital zircon age of approximately 2.04 Ga. Suite 5 is a collection of 10 gneisses, granites, amphibolites, and mafic granulites dated to be 2.2 to 2.5 Ga that are mostly from the TMZ but also include 2 samples (M12352 and N06) from the Buffalo Head terrane.

The Suite 1 age in this study (1836±13 Ma), agrees with three ages between 1.85 and 1.78 Ga reported by Villeneuve et al. (1993) for biotite granites from the Rimbey Domain. Samples from this domain are noted for having a large population of metamict zircons and strongly discordant analyses. The high degree of metamictization in the zircons, which is a consequence of their high U content, likely reflects the high U content of the magma from which the zircon (whole rock U of 15.40 ppm) crystallized. The age obtained for the Rimbey suite broadly coincides with syn- to post-collisional plutonism documented in various parts of the Trans-Hudson Orogen to the east (Ansdell et al., 2005; Corrigan et al., 2005).

The majority of samples dated in the present study, including most of the samples of Suites 2-5, are from the TMZ. In fact, this study reports many more ages for the buried portion of the TMZ **(Fig. 1-1)** than had been previously available. These new data can be compared to ages reported in earlier studies for the buried TMZ. The most direct comparison can be made to the results of Villeneuve et al. (1993), who, using conventional thermal ionization mass spectrometric of zircon, monazite, and titanite mineral separates, reported U-Pb data for some of the same drill core samples analyzed in the present study. More specifically, there are 5 samples that were investigated in both studies. For sample M4002A (California Standard Mikkwa), Villeneuve et al. reported an imprecise zircon age of 1937 +61/-45 Ma, which within analytical uncertainty is the same as the more precise weighted mean $^{207}Pb/^{206}Pb$ age of 1928.9 ± 8.1 Ma obtained in this study. No age was reported by Villeneuve et al. (1993), for sample M12640 (Bear Vampire #1). My results yielded a weighted mean $^{207}Pb/^{206}Pb$ monazite age of 1949.1 ± 4.0 Ma and zircon upper intercept age of 1950 ± 10 Ma. Both are interpreted as the crystallization age of the granite. The Villeneuve et al. study reported an inconclusive zircon age for sample M12351 (ROC Watchusk Lake) with zircon inheritance from ~2250 to >2500 Ma. They do, however, report a monazite age of 1949 ± 2 Ma and interpret it as a minimum crystallization age. My weighted mean $^{207}Pb/^{206}Pb$ zircon age of 1957.2 ± 8.7 Ma for this sample is within error of the minimum crystallization age reported in Villeneuve et al. This sample's age interpretation is complex due to the large inherited zircon population present. Sample M12549 (Merrill Arab Chard) was reported by Villenueve et al. to have an upper intercept zircon age of 1972 ± 5 Ma. My zircon age for this sample is slightly younger (weighted mean $^{207}Pb/^{206}Pb$ age of 1956.3 ± 9.9 Ma). The reason for this small discrepancy is unknown. Sample M4015A (Imperial Wolverine) was also analyzed by both the Villeneuve et al. study and this study. Villeneuve et al. reported an inconclusive zircon age and a monazite age of 1968 ± 1 Ma. The monazite age is interpreted as a minimum crystallization age and inherited zircon components were present as well. My study yielded an imprecise upper intercept zircon age of 1997 ± 37 Ma. The zircon age complexity (slightly to strongly discordant analyses) makes age interpretations difficult. No inherited zircon components were found in my study. Overall this study has built on the Villeneuve et al. work and produced similar results on samples analyzed in both studies.

The results obtained in my study for the TMZ samples also generally agree with ages reported in previous studies of the exposed TMZ. TMZ outcrops in Alberta and the Northwest Territories are characterized by an older (2.14-3.2 Ga) suite of gneisses and amphibolites, the Taltson Basement Complex (TBC), which is intruded by two suites of granitic plutons, an early (1.96 to 1.99 Ga) suite and a late (1.925 to 1.95 Ga) suite (Bostock et al., 1987; Bostock and van Breeman, 1994; McDonough et al., 2000; McNicoll et al., 2000). The rocks of age Suite 2 (1.92-1.94 Ga) and Suite 3 (1.95-1.98 Ga) in the present study correspond closely to the younger and older granitoid suites, respectively, of the exposed TMZ. Thus my study confirms that the major plutonic units documented in outcrop in the northern and central TMZ extend for ~300 km southward in the subsurface to the Snowbird Tectonic Zone.

There is also a broad correspondence between ages obtained for Suite 4 and 5 rocks in the present study and those reported for the Taltson Basement Complex. However, the variety of rock types and ages reported for the TBC makes the comparison with the present data less straightforward. The most precise ages obtained in this study on Suite 4 and 5 samples were on two rocks of mafic composition, a biotite-bearing amphibolite (N01A) and a hornblende-rich mafic granulite (M4015B), which yielded ages of 2278.1 ± 7.7 Ma and 2307.7 ± 5.0 Ma, respectively. These two samples are of similar age to a 2295 ± 5 Ma age reported for biotite-bearing amphibolitic gneisses of the Potts Lake block observed in the exposed TMZ (McNicoll et al., 2000). Both the present study and that of McNicoll et al. (2000) interpret the zircons in these mafic rocks to be of magmatic origin. If correct, this interpretation implies a significant episode of mafic magmatism in the TMZ at ~2.3 Ga.

A comparison can also be made between the one metapelite sample (HW3521/3522/3523) investigated in this study and broadly similar samples documented in the exposed TMZ. These metasedimentary samples may be part of an early Paleoproterozoic sedimentary basin called the Rutledge River basin, which closed between 2.13 Ga, the age of the youngest detrital zircon, and 2.09 Ga, the age of a high-grade metamorphic event (Bostock and van Breeman, 1994). Enclaves of this metasedimentary rock suite are typically found in exposed TMZ granitic plutons west of the Charles Lake Shear Zone. The U-Pb zircon age of 2037 ± 26 Ma obtained for the metapelite sample of this study is within analytical error of some of the youngest zircon ages (2044 Ma) reported by Bostock and van Breeman (1994). However, unlike the present study, which interpreted the 2.04 Ga zircons to be detrital origin, Bostock and van Breeman interpret their post-2.09 Ga zircons to have formed during metamophism. This discrepancy suggests either that the paragenetic model for zircon (metamorphic versus detrital origin) in one of the studies is incorrect or that the protolith of the metapelite sample of the present study was deposited in a sedimentary basin that was younger than the Rutledge River basin.

Suite 5 has ages of ~2.2 to ~2.5 Ga, which are similar to ages reported from the Taltson Basement Complex of the exposed TMZ (McNicoll et al, 2000). Zircon analyses from this suite are typically concordant or near concordant but can give a 300 million year range of ages in a single sample. The relative imprecision of individual LA-ICP-MS analyses makes it impossible to distinguish between concordant analyses of zircon that crystallized episodically over that time period and a data array of slightly discordant analyses that plot along a shallow discordia line between 2.5 and 2.2 Ga. My preferred interpretation is that the rock crystallized at the oldest concordant age and there is a lead-loss event at the youngest concordant age with a shallow discordia line connecting the ages. This oldest suite is possibly related to the Arrowsmith Orogeny, a 2.26 to 2.4 Ga orogenic event that occurred at the western margin of the Churchill craton (Berman et al., 2005; Hartlaub et al., 2007; Schultz et al., 2007). Older Archean gneissic rocks up to 3.2 Ga have been reported in the exposed TMZ but no samples in this study were Archean with the exception of inherited zircon cores. The oldest inherited core from this study is ~3.0 Ga (M12351). Samples of suite 5 (TBC) appear to be far more abundant in the subsurface south TMZ than in the northern exposed TMZ based on the aeromagnetic signatures.

The results of the present study indicate that there are many parallels between the rock units and ages documented in the exposed part of the TMZ and those occurring further south in the buried segment of the TMZ **(Figure 3-27)**. The older rock suites of the Taltson Basement Complex appear to occupy a north-south trending belt from the vicinity of Fort McKay in the north to the Snowbird Tectonic Zone in the south. There are 5 well locations in the south-east TMZ of the older (1.95-1.98 Ga) granitoid suite with 3 additional ones to the west of Fort McMurray. The younger (1.92-1.94 Ga) granitoid suite has 4 well locations that are separated laterally by large distances, 3 of which occupy the western TMZ. This roughly matches the exposed TMZ in northeastern Alberta where the younger granite suites occupy the region west of the Charles Lake Shear Zone and the older granites occupy the east. However the presence of some older granites (suite 3) in the southwest TMZ complicates a simple east-west age relationship.

Monazite U-Pb data can be useful in constraining the timing of igneous, metamorphic and secondary fluid influx events. With the exception of one suspected older magmatic grain (2377±31 Ma), all monazite analyses yielded ages of 1940 to 1990 Ma. The monazite grains interpreted to be of igneous origin yielded ages of ~2380, 1980-85 and 1950-55 Ma. These ages are broadly consistent with the range of magma crystallization ages recorded by zircons in this study. Monazite grains interpreted to be of metamorphic origin yielded ages of ~1940, 1950, 1970 and 1990 Ma. The age groups could be related to a sequence of 3 metamorphic events. There does not, however, appear to be systematic regional trends in the monazite ages in the study area. For example, monazite in a metasedimentary rock from the 1600 m level of the Hunt Well records a 1940 Ma age whereas monazite in the charnockite at 2350 m level of the well records an older age of 1967 Ma.

Villeneuve et al. (1993) reported monazite ages of 1949±2 and 1968±1 Ma in the Fort McMurray area. They interpreted the latter age to represent the time of magma crystallization but did not provide their preferred interpretation for the 1949 Ma age. Bostock and van Breeman, (1987) interpreted a 1955 Ma age of monazite in a monzogranite as the age of magma crystallization. On the basis of U-Pb dating of monazite, zircon, and titanite in pelitic and granitic gneisses and granitoids, granulite-facies metamorphism in the exposed TMZ is inferred to have occurred at or slightly before 1932 Ma followed by cooling below the titanite closure temperature by 1917 Ma (McDonough et al., 2000; McNicoll et al., 2000). Thus, the drill core samples of the present study record older monazite growth events, which may correspond to earlier metamorphic events than have been reported from the exposed TMZ.

Figure 3-28 summarizes U-Pb zircon and monazite ages obtained in the present study for the TMZ, Rimbey Domain, and Buffalo Head terrane and compares these ages to previously published ages for these domains in northern Alberta. The striking features are: 1) the predominance of 1.98-1.92 Ga zircon U-Pb ages for TMZ granitoids; 2) abundance of monazite U-Pb ages between 1.90 and 1.99 Ga; and 3) widespread 2.2-2.4 Ga magmatism in the TMZ and Buffalo Head terrane. The Buffalo Head terrane has many of the features of the TMZ but lacks evidence for the abundant 1.98-1.92 Ga granitic magmatism that characterizes the TMZ. If granitoids of this age are discovered in the Buffalo Head terrane then the rationale for considering the TMZ and BHT as two separate domains largely goes away.

3.1.2 Combined Geochronological and Aeromagnetic Mapping

The combination of geochronological and regional aeromagnetic data has been useful in subdividing the buried Precambrian basement of Alberta into a series of crustal domains (Ross et al., 1991). On a somewhat finer scale, it may be possible to use regional aeromagnetic data available for northern Alberta (Lyatsky et al., 2004) and geochronological data obtained in this study to extrapolate rock units mapped in the exposed part of the TMZ southward to my field area. The aeromagnetic map of Lyatsky et al. (2004) shows a complex pattern of magnetic highs and lows in the basement units **(Fig. 3-29)**. Magnetic highs (purple, red and orange) are indicative of basement units enriched in magnetite, whereas magnetic lows (green and blue) are indicative of units depleted in this mineral. For broader-scale trends, the aeromagnetic data is useful for differentiating major crustal domains from one another. For example, the boundaries of the TMZ as a whole are generally defined by sharp changes in the magnetic response (e.g. the abrupt change from magnetic high in the southern TMZ to a magnetic low in the Rimbey Domain).

In the exposed TMZ in northeast Alberta, McDonough et al. (2000) pointed out that the magnetite-bearing Taltson Basement Complex gneisses form a prominent linear magnetic high that extends from the Northwest Territories boundary southward to Lake Athabasca. Some of the plutonic rocks that intrude the TBC such as the Arch Lake pluton, and the Chipewyan granite also have a high aeromagnetic signature whereas other plutons such as the Slave, Wylie Lake, Colin Lake, and Andrew Lake plutons and high strain zones within the TBC form aeromagnetic lows. If the correlation between the highest magnetic response and the TBC gneisses noted by McDonough et al. in the exposed TMZ can be extrapolated into the subsurface then the TBC may widen southward and extend continuously to the latitude of Fort McKay **(Fig. 3-29)**. In fact, two of the drill core samples (N02, N03) that yield TBC-like ages form the southern terminus of this magnetic anomaly. Extrapolating the TBC still further south, however, is problematic. The aeromagnetic highs in the southernmost TMZ are patchy rather than belt like and there is no obvious correlation between rock units observed in drill core samples and the magnetic signatures on the map **(Fig. 3-29)**. For example, three 1.96-1.97 Ga granitic samples of Suite 3 (M12549, M12350, M12351) from the southern margin are located on a strong aeromagnetic high similar to the TBC in the exposed TMZ. This observation suggests that the southernmost TMZ may comprise a complex interfingering of TBC rocks and both magnetite-bearing and magnetite-free granitoids that intrude these rocks.

Table 3-1: Summary of U-Pb ages acquired through in-situ LA-ICP-MS dating

Sample Name	Suite	Rock Type	Min*	Age (Ma)	Age Type	Interpretation	n (a)	n (g)	MSWD
M00034	3	biotite monzogranite	zrc	1948 ± 33	Upper Intercept	Igneous?	5	2	3.8
			mnz	1981.1 ± 7.1	$^{207}Pb/^{206}Pb$ mean	Igneous?	31	9	4.8
M03796	2	biotite monzogranite	zrc	1926.4 ± 2.8	$^{207}Pb/^{206}Pb$ mean	Igneous	42	9	1.1
M03997	3	monzogranite	zrc	1960.1 ± 7.3	$^{207}Pb/^{206}Pb$ mean	Igneous	6	3	0.95
			mnz	1949.9 ±6	$^{207}Pb/^{206}Pb$ mean	Igneous	15	2	1.3
M04002A	2	syenogranite	zrc	1928.9 ± 8.1	$^{207}Pb/^{206}Pb$ mean	Igneous	27	9	4.7
M04002B	2	syenogranite	zrc	1931 ± 16	Upper Intercept	Igneous	8	4	2.3
M04015A	3	biotite monzogranite	zrc	1997 ±37	Upper Intercept	~Igneous Age	11	5	15
M04015B	5	hornblende-rich mafic granulite	zrc	2307.7 ± 5.0	$^{207}Pb/^{206}Pb$ mean	Igneous	25	5	0.6
M04017	1	biotite granite	zrc	1836 ± 13	Upper Intercept	Igneous	11	4	2.4
M12350	3	biotite quartz diorite	zrc	1970.6 ± 5.3	$^{207}Pb/^{206}Pb$ mean	Igneous	24	7	0.65
M12351	3	biotite monzogranite	zrc	1957.2 ± 8.7	$^{207}Pb/^{206}Pb$ mean	Igneous	23	9	3.6
M12352A	-	granitic pegmatite	zrc	1982 ± 11	Upper Intercept	Igneous	10	2	1.7
			mnz	1983.6 ± 5.4	$^{207}Pb/^{206}Pb$ mean	Igneous	40	6	2.1
M12352B	5	biotite garnet granitic gneiss	zrc	~2400	$^{207}Pb/^{206}Pb$	Igneous?	13	7	
M12354	2	monzogranite	zrc	1935.4 ± 6.6	$^{207}Pb/^{206}Pb$ mean	Igneous	18	7	1.4
M12549	3	biotite monzogranite	zrc	1956.3 ± 9.9	Upper Intercept	Igneous	13	6	2.8
M12636	3	biotite garnet monzogranite	zrc	1930.4 ± 7.6	$^{207}Pb/^{206}Pb$ mean	Igneous?	18	6	3.6
			mnz	1955.4 ± 5.5	$^{207}Pb/^{206}Pb$ mean	Igneous?	24	4	0.56
M12637	2	biotite syenogranite	zrc	1920.8 ± 4.2	$^{207}Pb/^{206}Pb$ mean	Igneous	14	6	4.2
			zrc	1952 ± 19	$^{207}Pb/^{206}Pb$ mean	Inheritance	4	4	2.2
M12638	3	syenogranite	zrc	1955.8 ± 4.4	Upper Intercept	Igneous	20	6	0.55
M12639	5	biotite granodiorite	zrc	~2400	$^{207}Pb/^{206}Pb$	Igneous	31	8	
			mnz	2377 ± 31	$^{207}Pb/^{206}Pb$ mean	Inheritance	6	1	4.9
			mnz	1987.7 ± 5.2	$^{207}Pb/^{206}Pb$ mean	Metamorphic	19	4	1.1
M12640	3	biotite syenogranite	zrc	1950 ± 10	Upper Intercept	Igneous	4	2	0.55
			mnz	1949.1 ± 4.0	$^{207}Pb/^{206}Pb$ mean	Igneous	25	2	0.4
M12643	5	biotite syenogranite	zrc	~2300	$^{207}Pb/^{206}Pb$	Igneous	9	4	
			mnz	1968.9 ± 3.8	$^{207}Pb/^{206}Pb$ mean	Metamorphic	30	3	0.77
N01A	5	biotite amphibolite	zrc	2278.1 ± 7.7	$^{207}Pb/^{206}Pb$ mean	Igneous	24	7	2.3
N02B	5	granitic gneiss	zrc	~2300	$^{207}Pb/^{206}Pb$	Igneous	20	10	
			mnz	1949 ± 3.8	$^{207}Pb/^{206}Pb$ mean	Metamorphic	35	7	0.91
N03	5	biotite granite	zrc	2266 ± 11	$^{207}Pb/^{206}Pb$ mean	Igneous?	7	1	2
N05B	5	biotite quartz monzonite	zrc	~2450	$^{207}Pb/^{206}Pb$	Igneous	12	3	
			mnz	1962.8 ± 9.6	$^{207}Pb/^{206}Pb$ mean	Fluid influx?	9	1	0.23
N06	5	monzogranite	zrc	~2300	$^{207}Pb/^{206}Pb$	Igneous	10	3	
			zrc	1992 ± 10	$^{207}Pb/^{206}Pb$ mean	Metamorphic	5	1	1.2
HW3521/3522	4	hercynite biotite garnet gneiss	zrc	2037 ± 26	Upper Intercept	Igneous	39	18	2.3
			mnz	1939.5 ± 3.9	$^{207}Pb/^{206}Pb$ mean	Metamorphic	16	4	1.1
HW3526/3528/3530	5	orthopyroxene granite	zrc	~2395	$^{207}Pb/^{206}Pb$	Igneous	16	6	
			mnz	1967 ± 6.6	$^{207}Pb/^{206}Pb$ mean	Metamorphic	37	3	4.2

*Min = mineral, zrc = zircon, mnz = monazite, n (a) =number of analysis, n (g) = number of grains analyzed

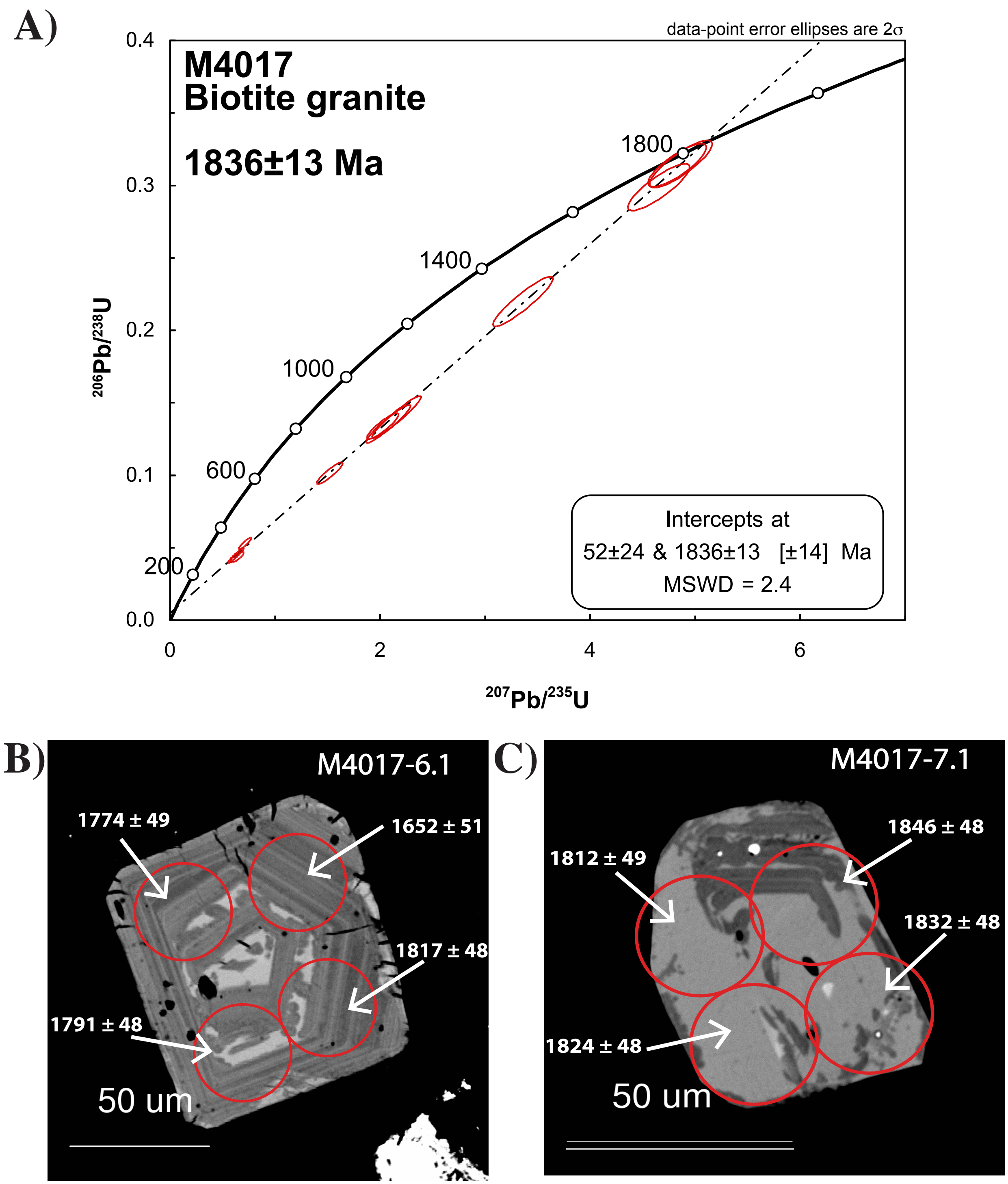


Figure 3-1: Sample M4017 geochronology summary. Concordia plot **(A)** and select BSE images of zircon grains 6.1 **(B)** and 7.1 **(C)** from a biotite granite. The grains display oscillatory zonation and have undergone radiation damage. Analyses are slightly to strongly discordant with an upper intercept of 1836 ± 13 Ma and is interpreted as the crystallization age of the granite.

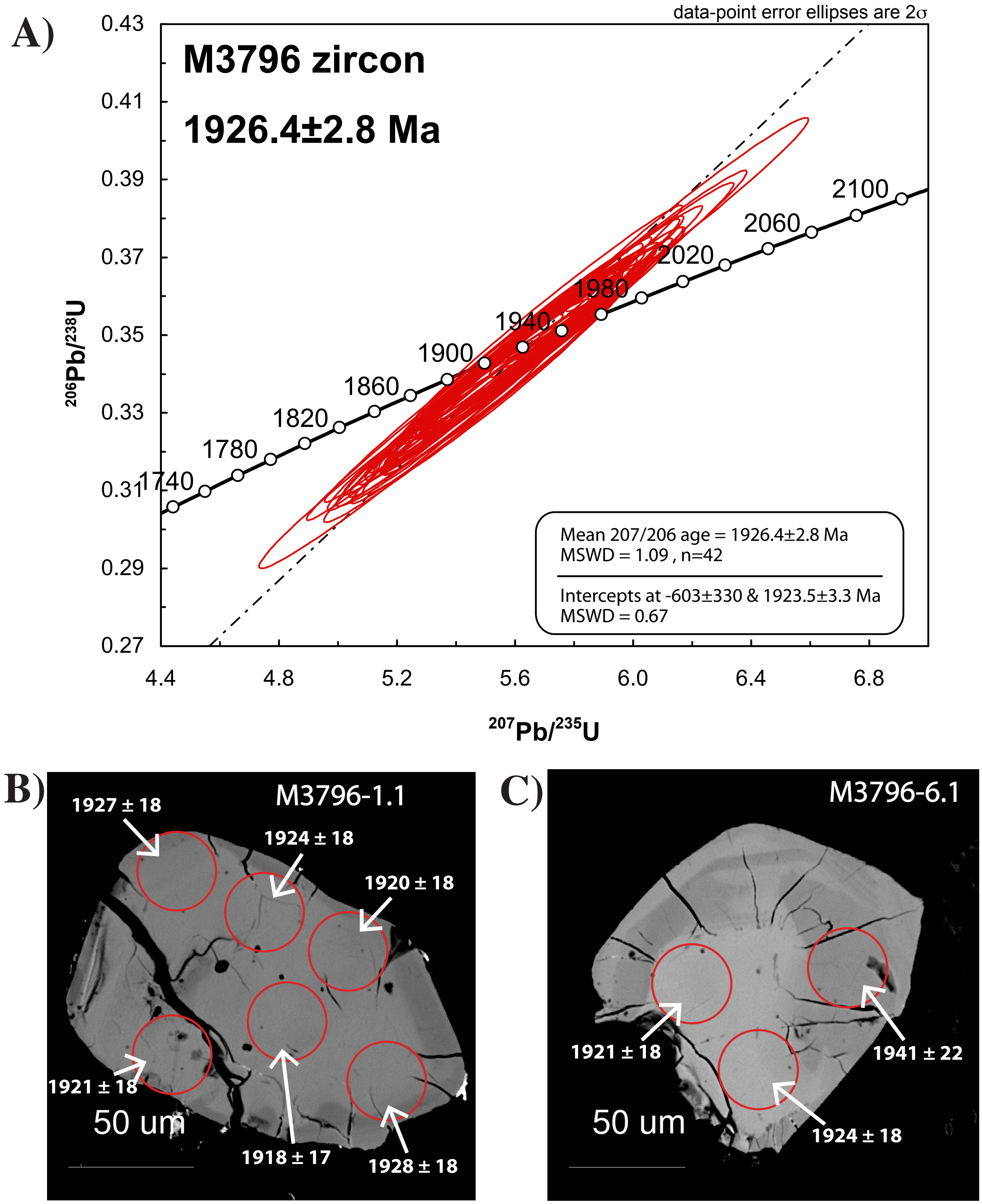


Figure 3-2: Sample M3796 geochronology summary. Concordia plot **(A)** and select BSE images of zircon grains 1.1 **(B)** and 6.1 **(C)** from a biotite monzogranite. The grains display faint oscillatory zonation and show little fracturing. Analyses are slightly discordant with a weighted mean $^{207}Pb/^{206}Pb$ age of 1926.4 ± 2.8 Ma. This is interpreted as the crystallization age of the granite magma.

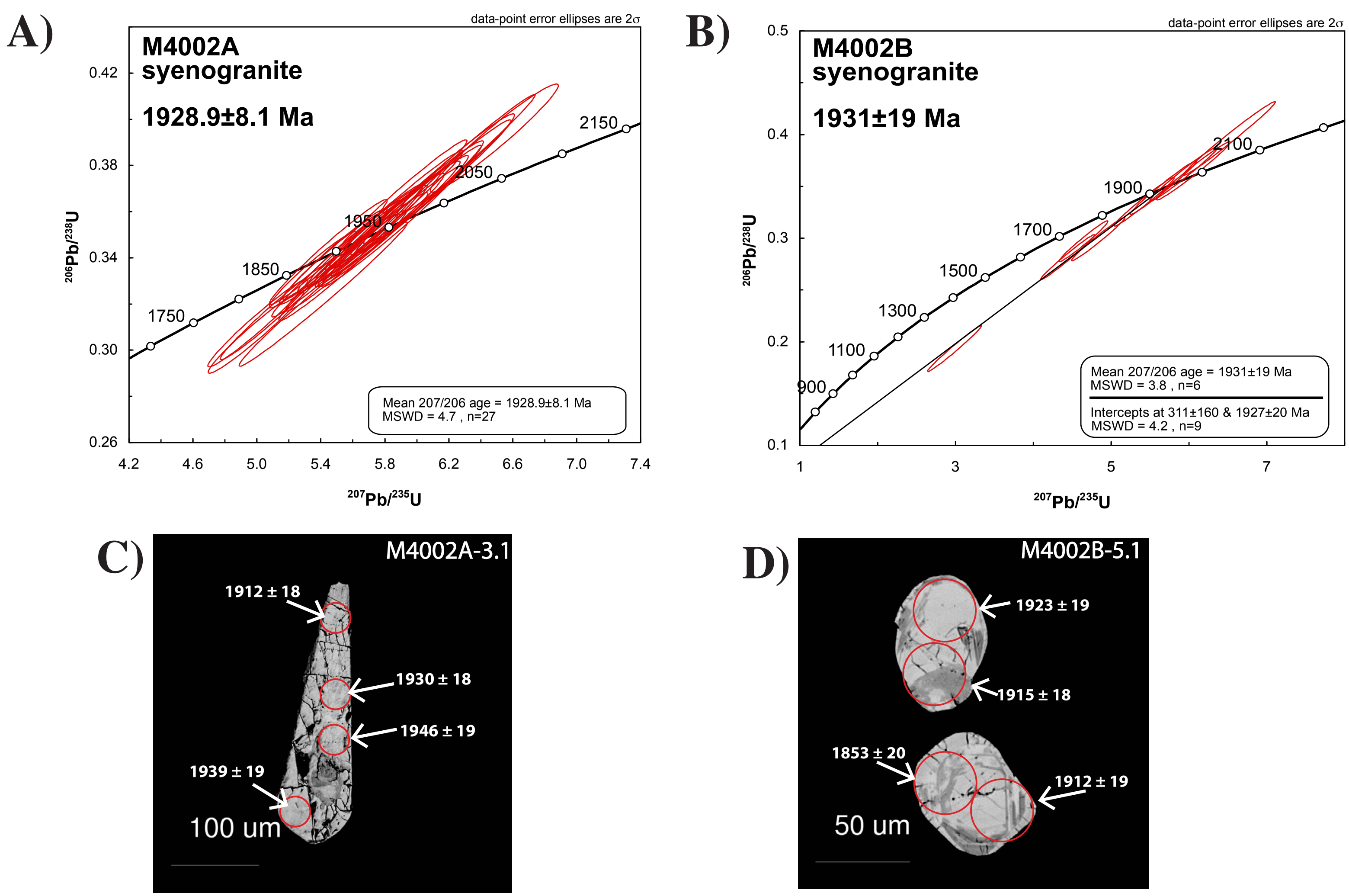


Figure 3-3: Samples M4002A and M4002B geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon grains 3.1 **(C)** and 6.1 **(D)** from a syenogranite. The grains display faint oscillatory zonation and show significant radiation damage. Analyses for M4002A are slightly discordant with a weighted mean $^{207}Pb/^{206}Pb$ age of 1928.9 ± 8.1 Ma. Analyses for M4002B yielded an upper intercept age of 1931 ± 16 Ma from 4 zircon grains. The age for M4002A is interpreted as the crystallization age of the granite magma.

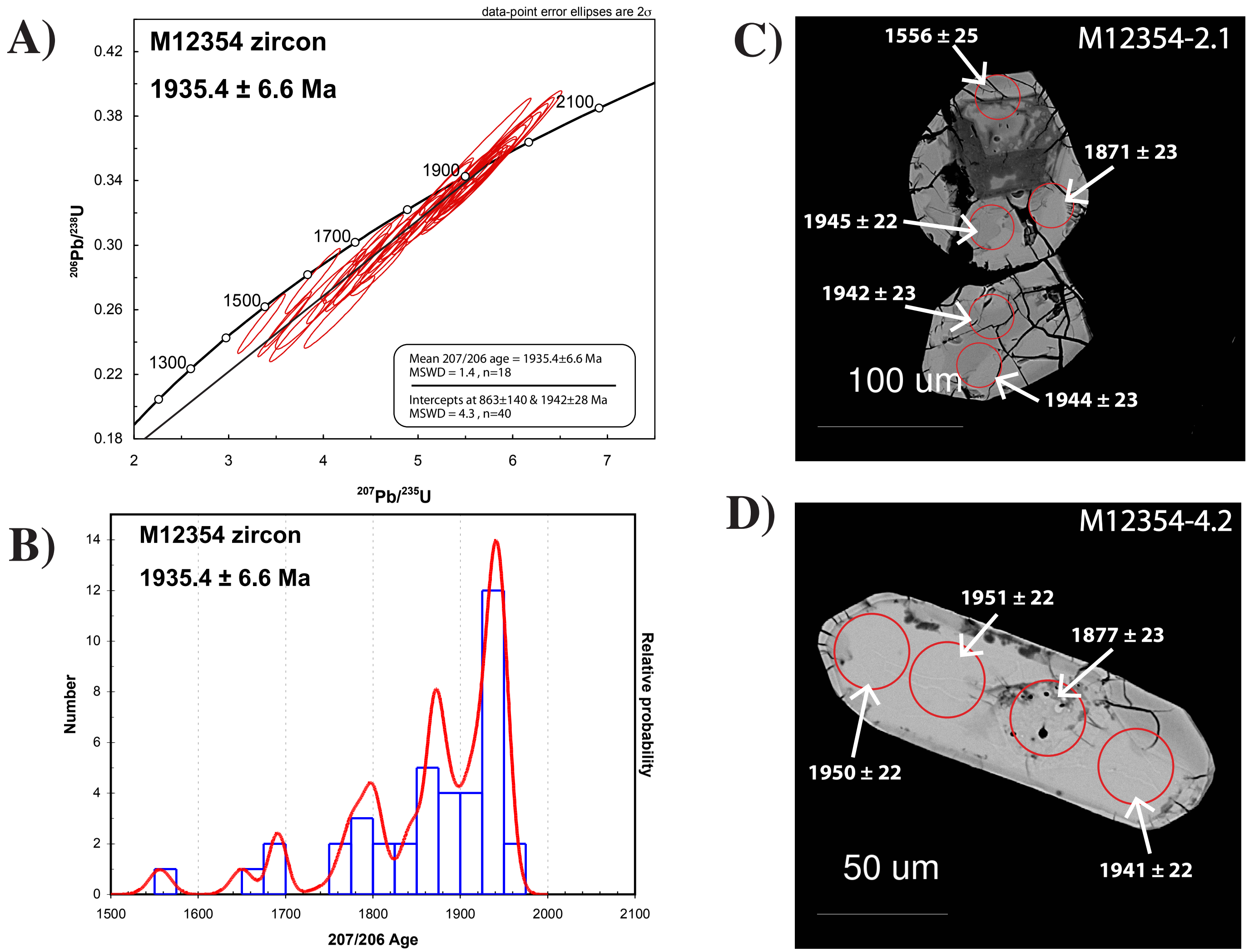


Figure 3-4: Sample M12354 geochronology summary. Concordia plot (**A**), probability density plot of $^{207}Pb/^{206}Pb$ ages (**B**) and select BSE images of zircon grains 2.1 (**C**) and 4.2 (**D**). The grains show significant radiation damage. Analyses yield $^{207}Pb/^{206}Pb$ ages from ~1550 to ~1940 Ma. A regression line fit through all (n=40) but the most disconcordant point yields an upper intercept of 1942 ± 28 Ma. As displayed in the probability density plot, a large cluster exists at ~1940 Ma. A weighted mean $^{207}Pb/^{206}Pb$ age of the 18 analyses in that cluster yields an age of 1935.4 ± 6.6 Ma and is interpreted as the crystallization age of the magma.

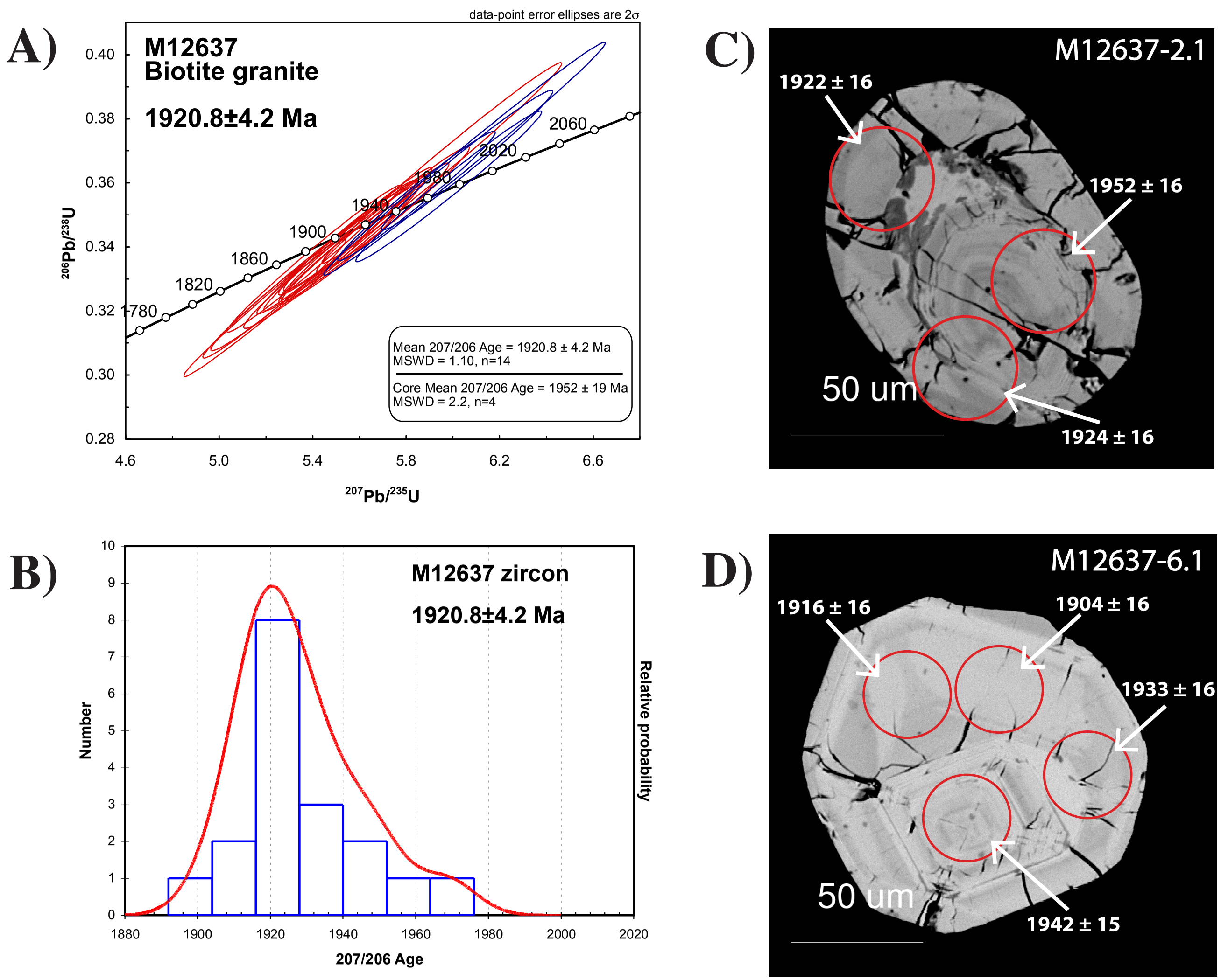


Figure 3-5: Sample M12637 geochronology summary. Concordia plot **(A)**, probability density plot of $^{207}Pb/^{206}Pb$ ages **(B)** and select BSE images of zircon grains 2.1 **(C)** and 6.1 **(D)**. Blue ellipses are analyses omitted from age calculations. The grains show core/rim relationships with cores exhibiting oscillatory zoning. Analyses are concordant with a large cluster existing at ~1920 Ma as displayed on a probability density plot. A weighted mean age of 14 analyses in that cluster yields an age of 1920.8 ± 4.2 Ma and is interpreted as the crystallization age of the magma. 4 analyses of cores are older ages and interpreted as inherited zircons.

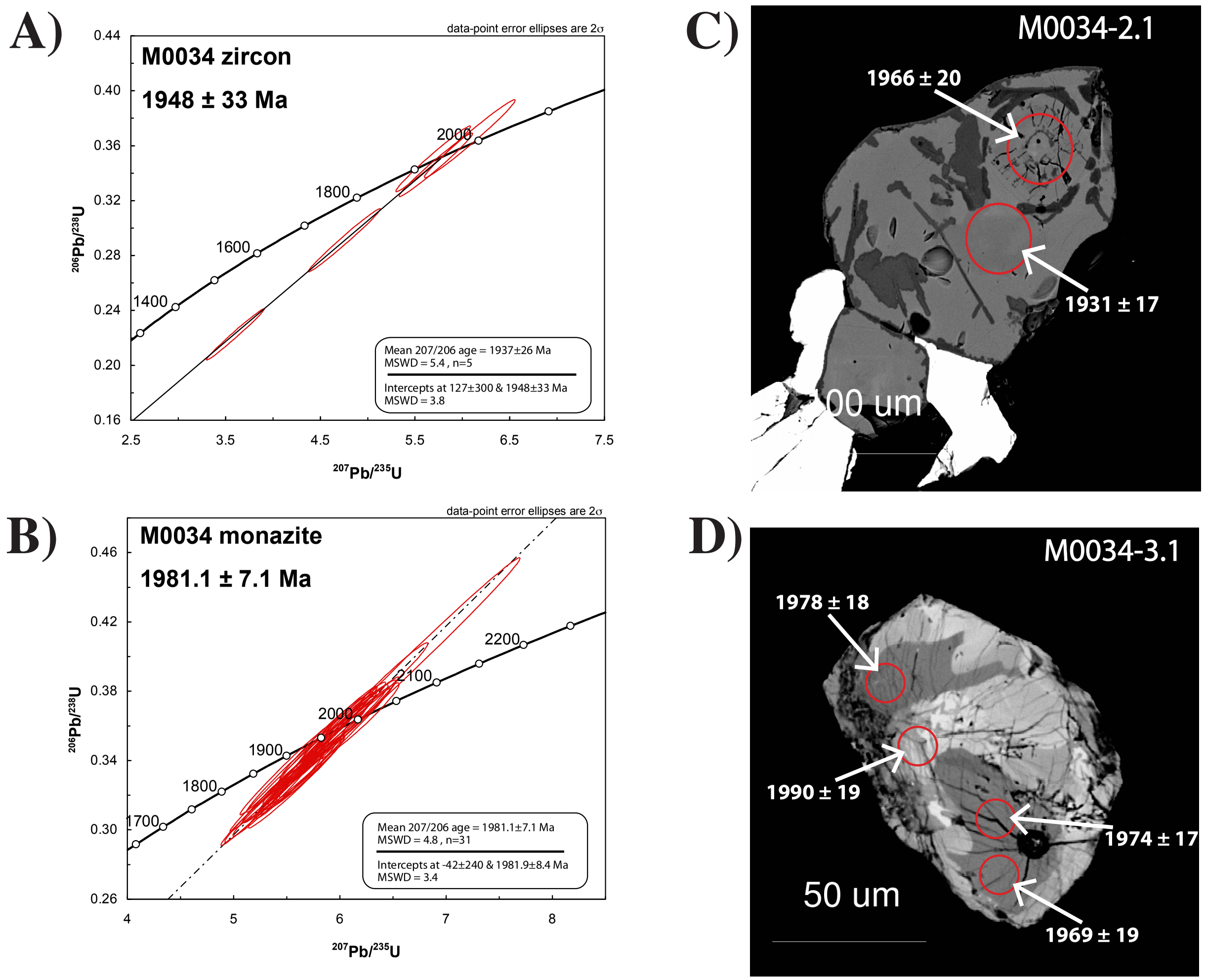


Figure 3-6: Sample M0034 geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (2.1) **(C)** and monazite (3.1) **(D)**. An upper intercept of 1948 ± 33 Ma was yielded. 31 monazite analyses were completed on 9 grains. A weighted mean $^{207}Pb/^{206}Pb$ age of 1981.1 ± 7.1 Ma was yielded for all monazite analyses (MSWD =4.8). There is a large age discrepancy between monazite grains for this sample and thus it is difficult to interpret. The zircon and monazite ages agree within analytical uncertainties and thus the monazite age is interpreted as the best estimate of crystallization age.

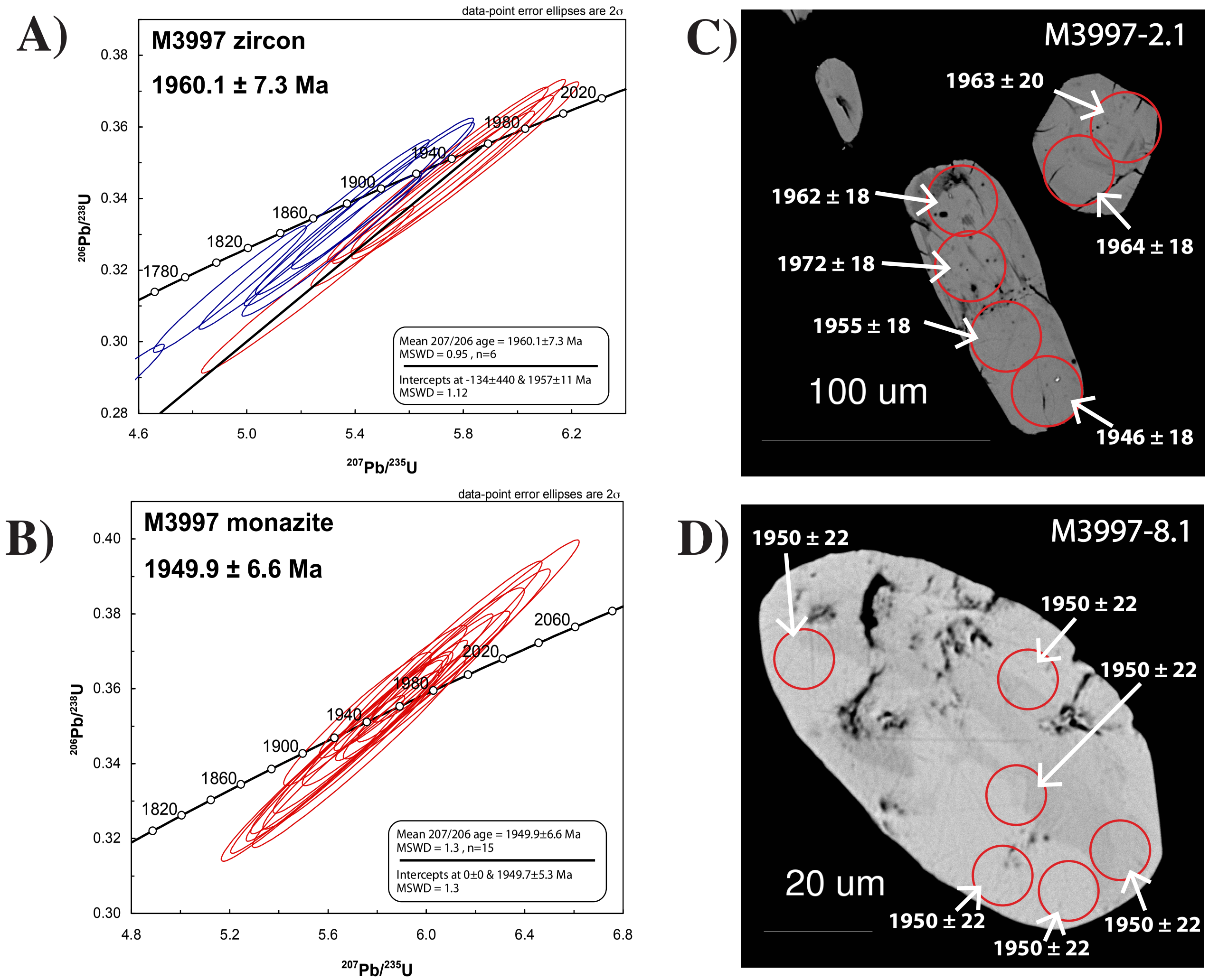


Figure 3-7: Sample M3997 geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (2.1) **(C)** and monazite (8.1) **(D)**. Blue error ellipses are omitted from age calculations. These particular zircon grains produced the oldest set of ages with six analyses yielding a weighted mean $^{207}Pb/^{206}Pb$ age of 1960.1 ± 7.3 Ma (MSWD = 0.95). 15 monazite analyses were completed on 2 grains. A weighted mean $^{207}Pb/^{206}Pb$ age of 1949.9 ± 6.6 Ma was yielded for monazite analyses (MSWD =1.3). The zircon and monazite ages agree within analytical uncertainties and thus the crystallization age is likely between 1950 and 1960 Ma.

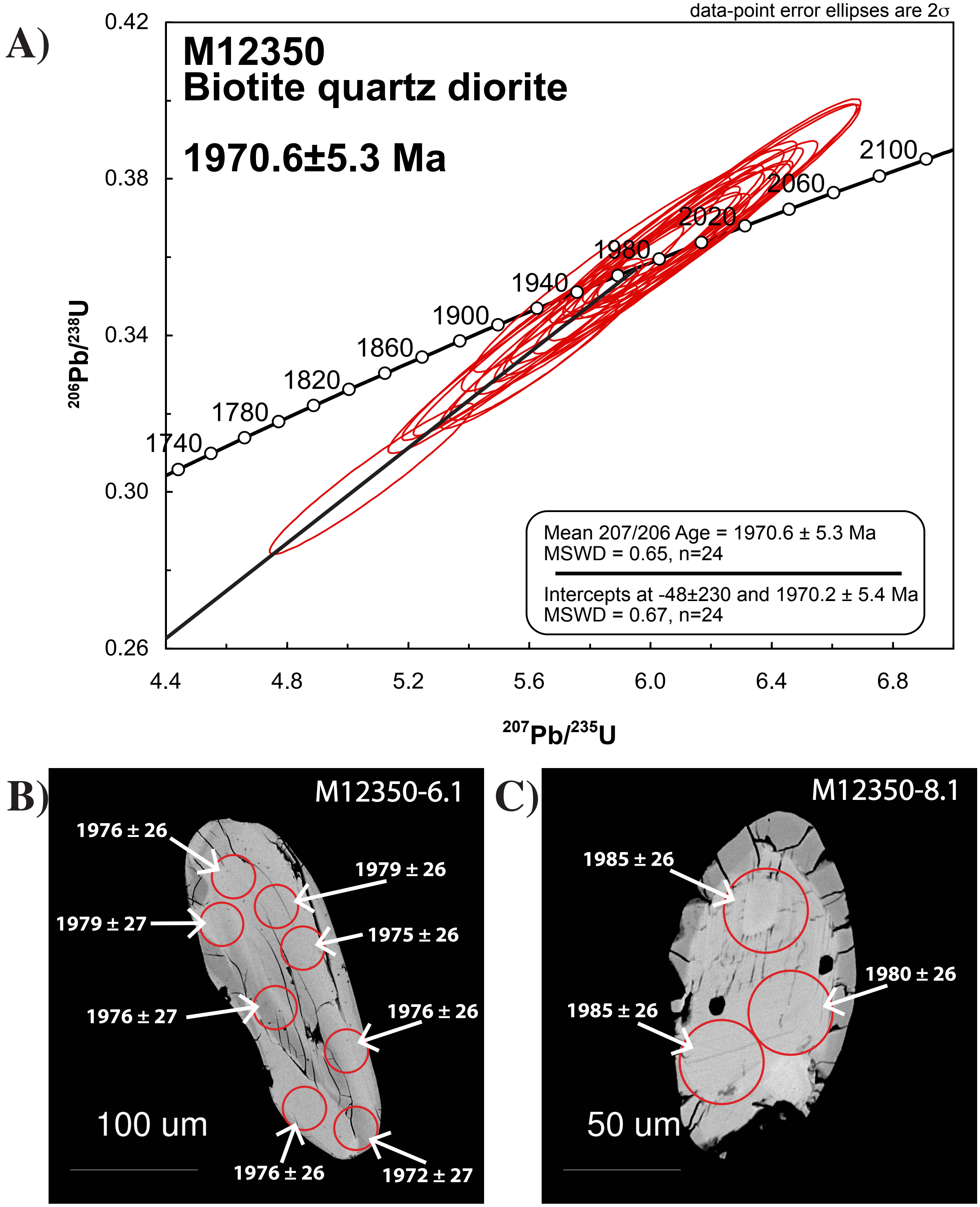


Figure 3-8: Sample M12350 geochronology summary. Concordia plot **(A)** and select BSE images of zircons (6.1 **(B)** and 8.1 **(C)**). All zircon grains show patchy zonation with some displaying narrow overgrowths. 24 zircon analyses were completed on 7 grains. Most analyses were <5% discordant. The weighted mean $^{207}Pb/^{206}Pb$ age of 1970.6 ± 5.3 Ma (MSWD = 0.65) and upper intercept age of 1970.2 ± 5.4 Ma (MSWD = 0.67) calculated for this data set are identical within error and are interpreted to be the age of magma crystallization.

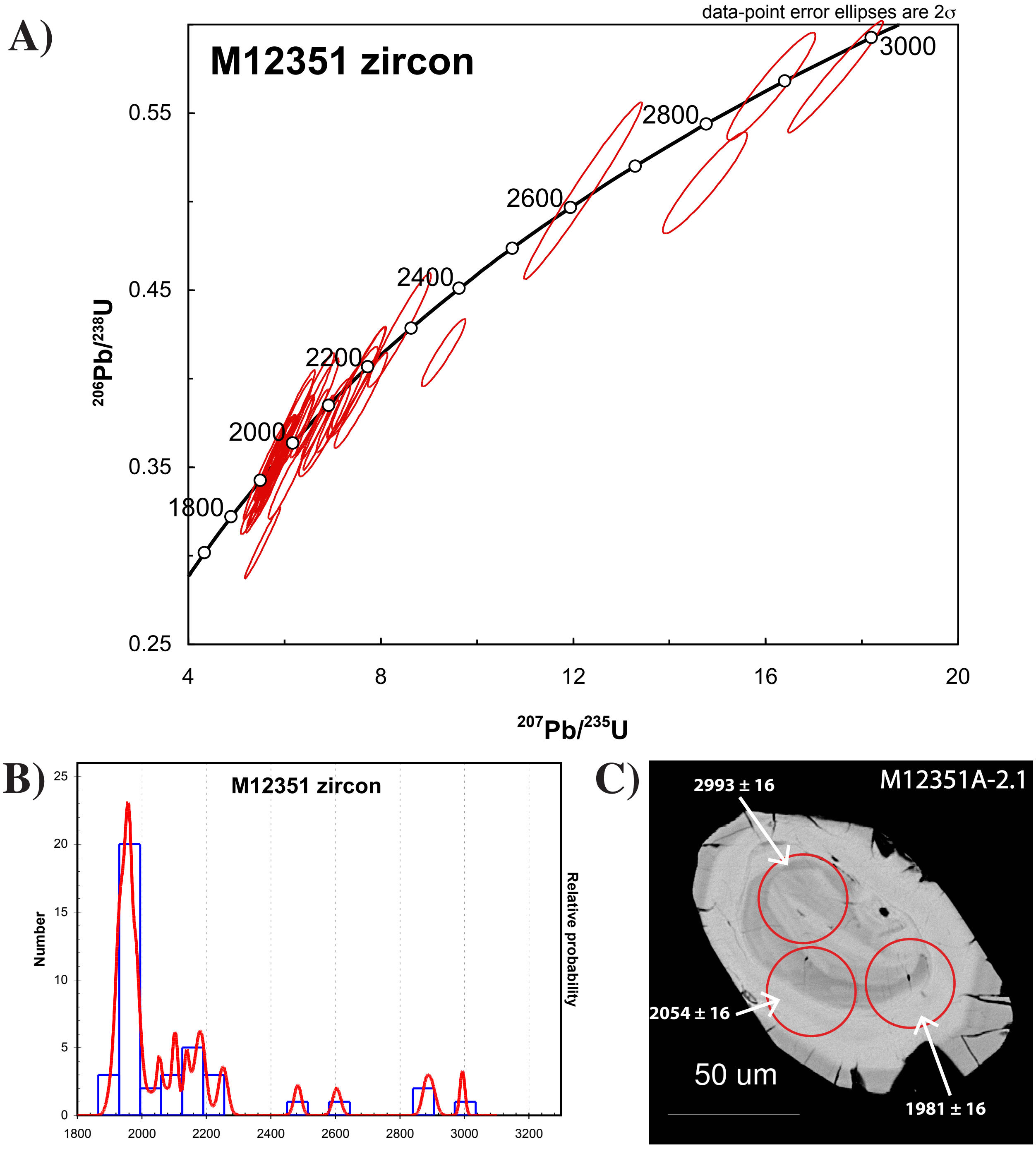


Figure 3-9: Sample M12351 geochronology summary. Concordia plot **(A)**, probability density plot **(B)**, and select BSE image of zircon (2.1) **(C)**. All zircon grains are radiation damaged, and many show distinct cores and rims. 41 zircon analyses were completed on 12 grains. Most analyses were <5% discordant. On a probability density plot of $^{207}Pb/^{206}Pb$ ages, there are small age peaks from 2000 Ma to 3000 Ma but the major peak is at ~1.95 Ga. 23 analyses of the dominant age peak yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1957.2 ± 8.7 Ma which is interpreted as the best estimate of the crystallization age. Zircons yielding older ages may represent grains inherited from the source.

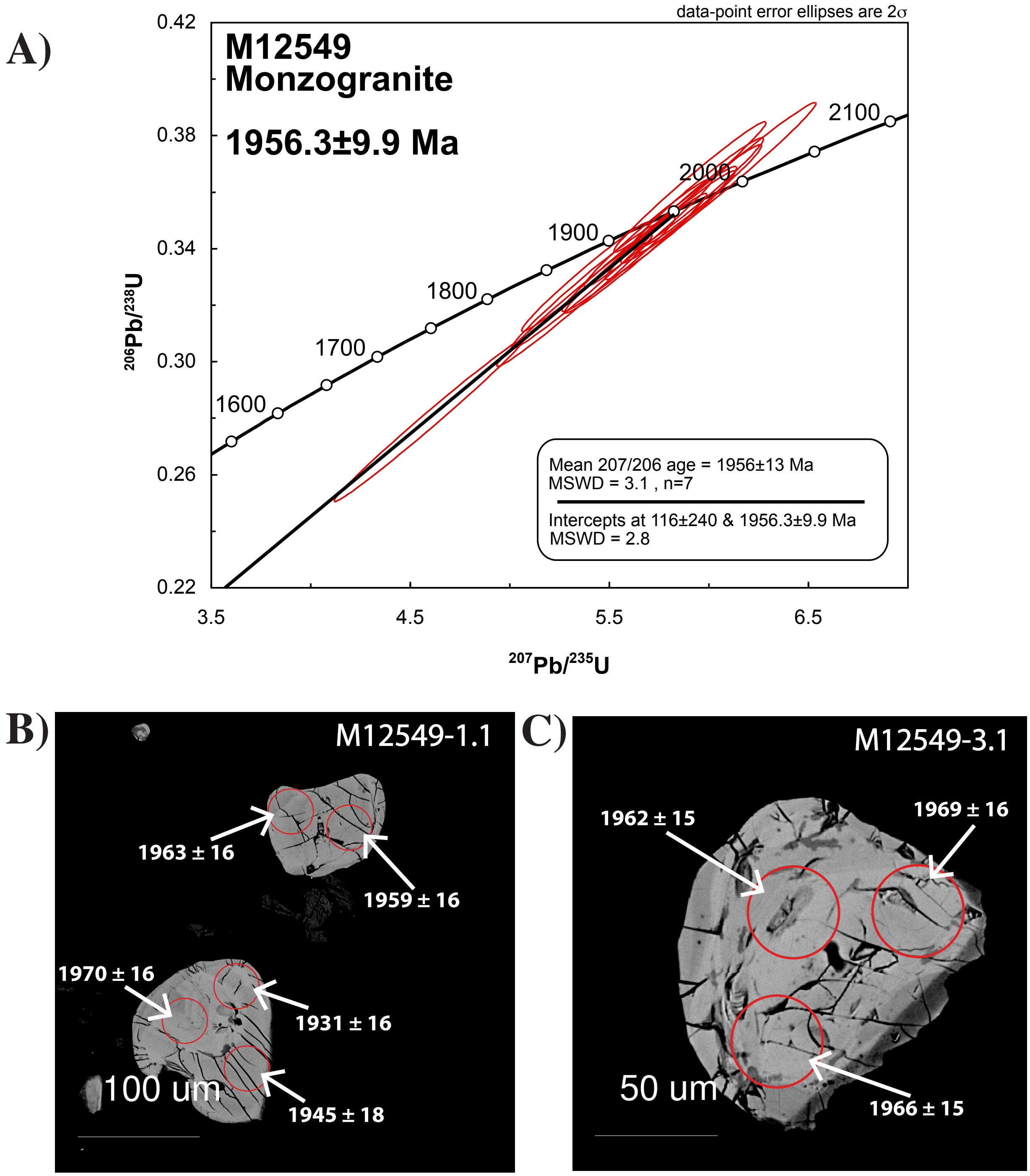


Figure 3-10: Sample M12549 geochronology summary. Concordia plot **(A)** and select BSE images of zircons (1.1 **(B)** and 3.1 **(C)**). All zircon grains are mostly free of radiation damage and many show distinct cores and rims. 13 zircon analyses were completed on 6 grains. With the exception of one analysis, most analyses were <10% discordant. Regression of all the data yields an upper intercept age of 1956.3 ± 9.9 Ma (MSWD = 2.8). I take the upper intercept age to be the current best estimate of the crystallization age of the granite.

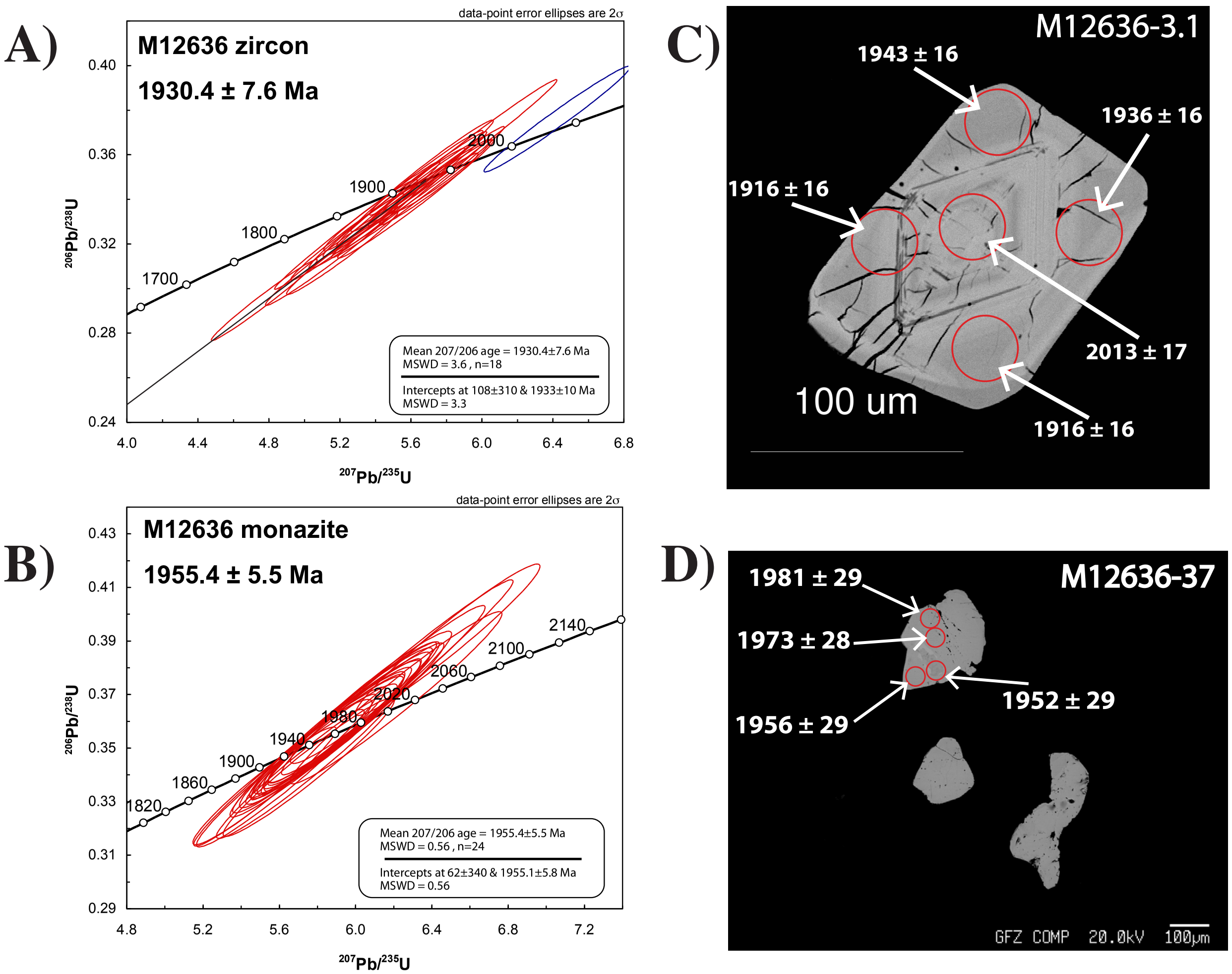


Figure 3-11: Sample M12636 geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (3.1) **(C)** and monazite (37) **(D)**. All zircon grains exhibit poorly developed oscillatory zoning. One analysis taken from a zircon core is distinctly older than the other analyses and was not included in the calculations. 19 zircon analyses were completed on 6 grains and yielded a weighted mean $^{207}Pb/^{206}Pb$ age of 1930.4 ± 7.6 Ma (MSWD = 3.6). Twenty-four analyses were conducted on four monazite grains in this sample. Analyses yielded a concordant cluster with weighted mean $^{207}Pb/^{206}Pb$ age of 1955.4 ± 5.5 Ma (MSWD = 0.56). This monazite age is more reliable than the zircon age due to its low MSWD and analytical error and thus is more likely to reflect crystallization age of the sample.

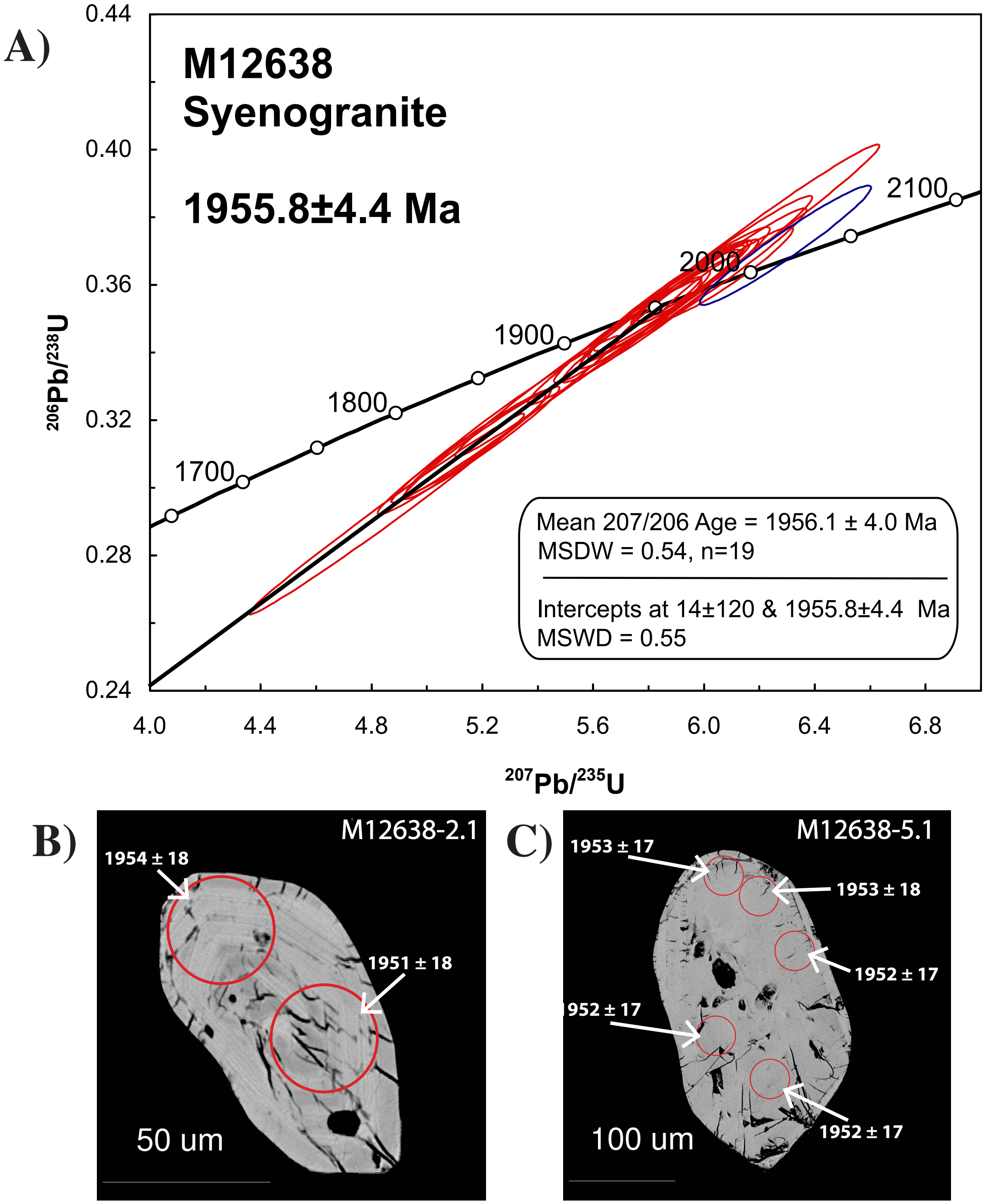


Figure 3-12: Sample M12638 geochronology summary. Concordia plot **(A)** and select BSE images of zircons (2.1 **(B)** and 5.1 **(C)**). This sample has some grains displaying fine-scale oscillatory zoning, whereas others display patchy zonation. 20 zircon analyses were completed on 6 grains. One analysis (blue ellipse) was omitted from age calculations on the basis of it's appearance as an inherited core. Nineteen of the twenty analyses yield a well-defined discordant array with an upper intercept age of 1955.8 ± 4.4 Ma (MSWD = 0.55) and a weighted mean $^{207}Pb/^{206}Pb$ age of 1956.1 ± 4.0 Ma (MSWD = 0.54). The upper intercept age is interpreted as the crystallization age of the granite magma.

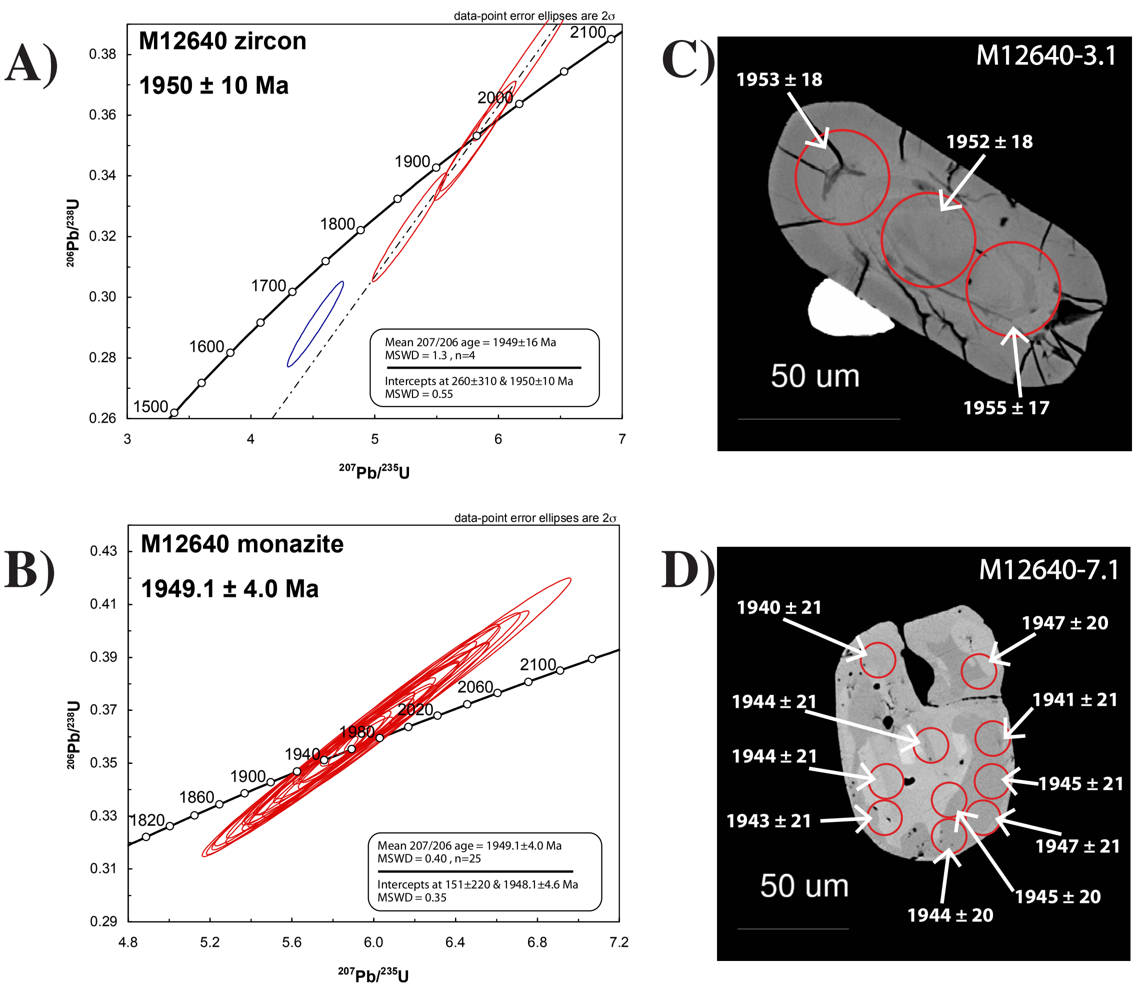


Figure 3-13: Sample M12640 geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (3.1) **(C)** and monazite (7.1) **(D)**. 5 zircon analyses were completed on 2 grains and yielded an upper intercept age of 1950 ± 10 Ma (MSWD = 0.55) with one omitted spot. Twenty-five analyses were conducted on two monazite grains in this sample. Monazites display a patchy zonation and are anhedral in shape. Analyses yielded a concordant to slightly discordant cluster with weighted mean $^{207}Pb/^{206}Pb$ age of 1949.1 ± 4.0 Ma (MSWD = 0.40). This age is identical to the zircon upper intercept age for this sample and both are interpreted as the time of crystallization of the granite.

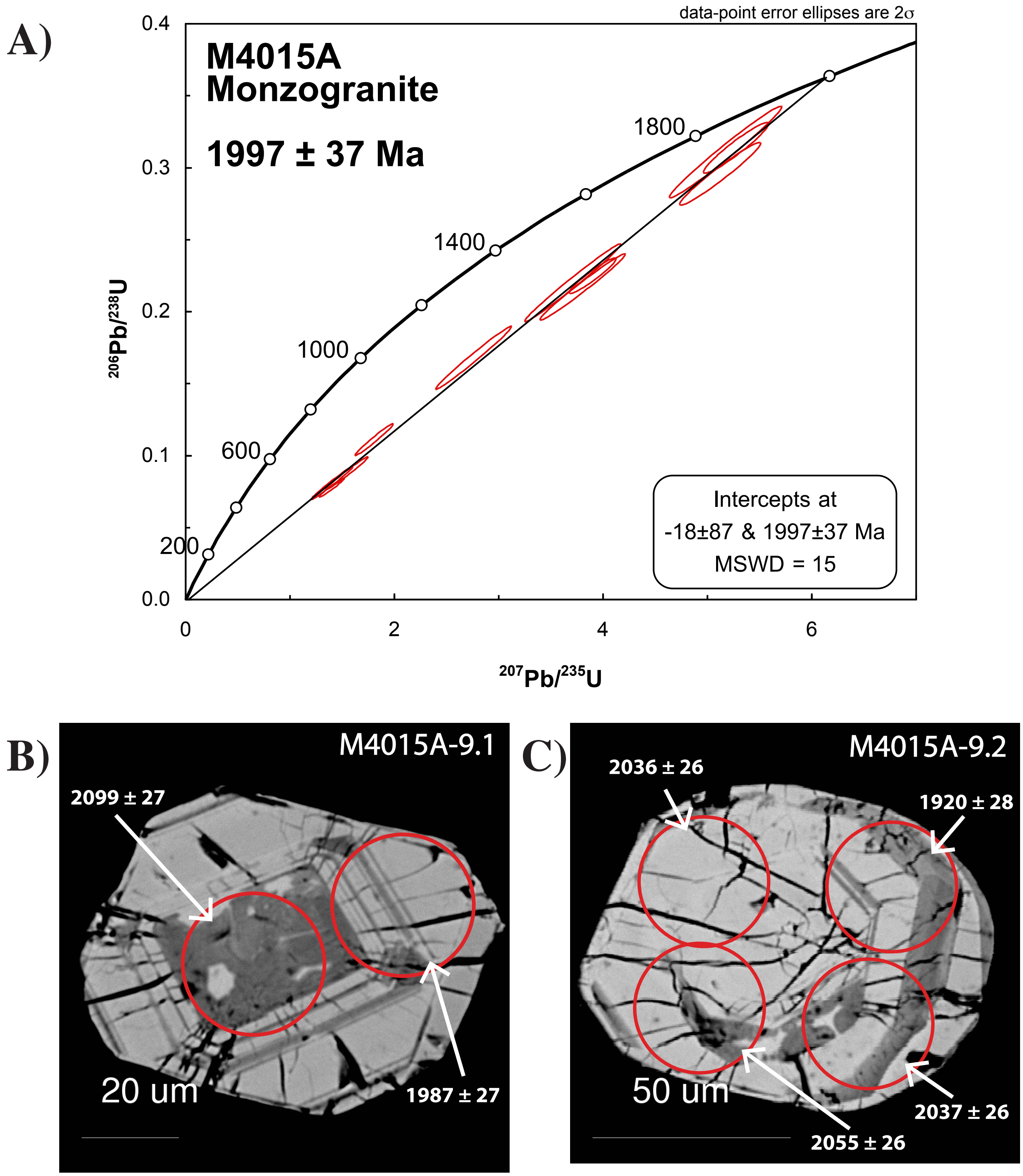


Figure 3-14: Sample M4015A geochronology summary. Concordia plot (**A**) and select BSE images of zircon (9.1 (**B**) and 9.2 (**C**)). All zircon grains display oscillatory zoning and have undergone strong radiation damage. 11 zircon analyses were completed on 5 grains. Analyses range from moderately to strongly discordant with an upper intercept age of 1997 ± 37 (MSWD = 15). This poorly constrained age is intercepted as the approximate crystallization age of the granite magma.

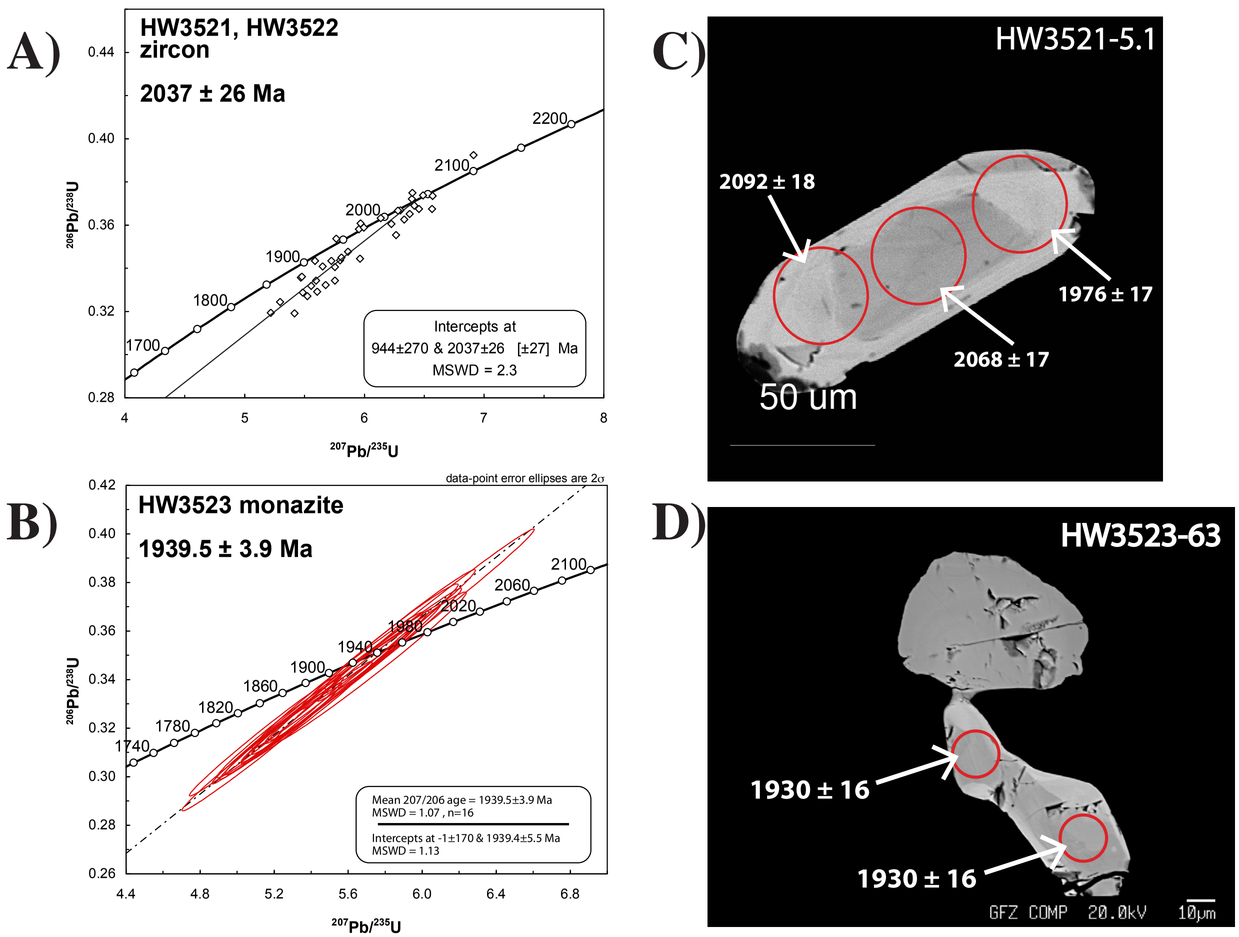


Figure 3-15: Samples HW3521, HW3522, HW3523 geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (5.1) **(C)** and monazite (63) **(D)**. Zircon grains display faint oscillatory zonation and are strongly radiation damaged. 39 zircon analyses were completed on 18 grains and yielded an upper intercept age of 2037 ± 26 Ma (MSWD = 2.3). Error elipses are removed from this plot to better display the linear nature of the data. This poorly-constrained age is likely the crystallization age for the zircon. Due to the metasediment nature of these samples, the zircons appear to be detrital and are not displaying a deposition age for the samples. Sixteen analyses were conducted on four monazite grains in this sample. Monazites display a weak patchy zonation and are anhedral to subhedral in shape. Analyses yielded a concordant to slightly discordant cluster with weighted mean $^{207}Pb/^{206}Pb$ age of 1939.5 ± 3.9 Ma (MSWD = 1.1). This age is likely related to a event of high-grade metamorphism experienced by the sample.

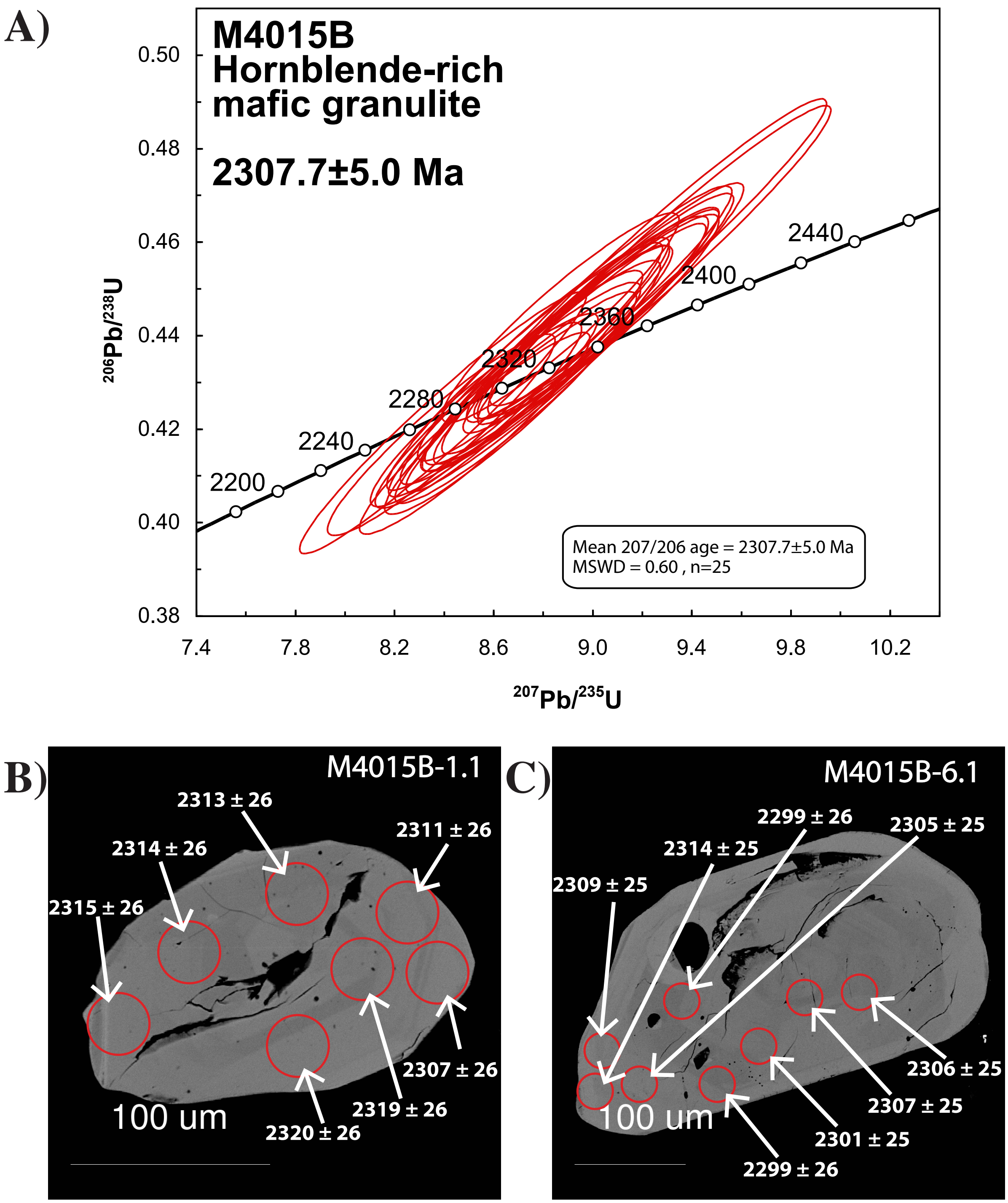


Figure 3-16: Sample M4015B geochronology summary. Concordia plot **(A)** and select BSE images of zircons (1.1 **(B)** and 6.1(**C**)). This sample has zircon grains displaying subhedral to anhedral shape, and faint oscillatory zoning. 25 zircon analyses were completed on 5 grains. Most analyses were <4% discordant and yielded a weighted mean $^{207}Pb/^{206}Pb$ age of 2307.7 ± 5.0 Ma (MSWD = 0.60). This age is likely magmatic due to oscillatory zoning seen in zircons.

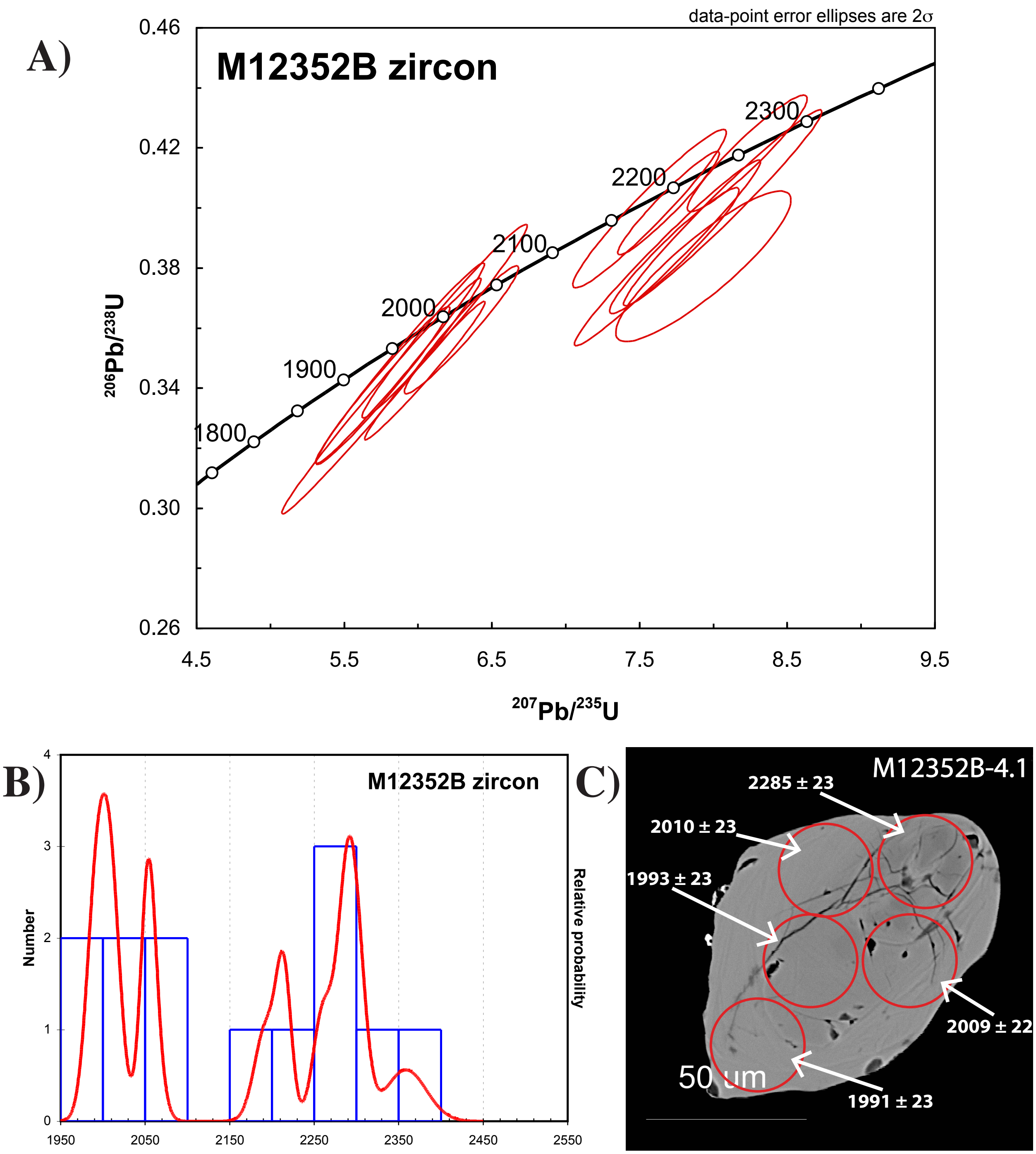


Figure 3-17: Sample M12352B geochronology summary. Concordia plot **(A)**, probability density plot **(B)**, and select BSE image of a zircon grain (4.1) **(C)**. Zircon grains in this sample show faint oscillatory zoning, and have moderate radiation damage. 13 zircon analyses were completed on 7 grains. Nearly all of the analyses were <10% discordant and yielded two broad age groups. A younger group has ^{207}Pb/^{206}Pb ages from ~1.99 Ga to ~2.06 Ga and the older group has ^{207}Pb/^{206}Pb ages from ~2.15 to ~2.40 Ga. This is interpreted as a crystallization age likely at ~2.4 Ga and a lead-loss event occurring at ~1.99 Ga possibly related to the granite pegmatite phase (M12352A).

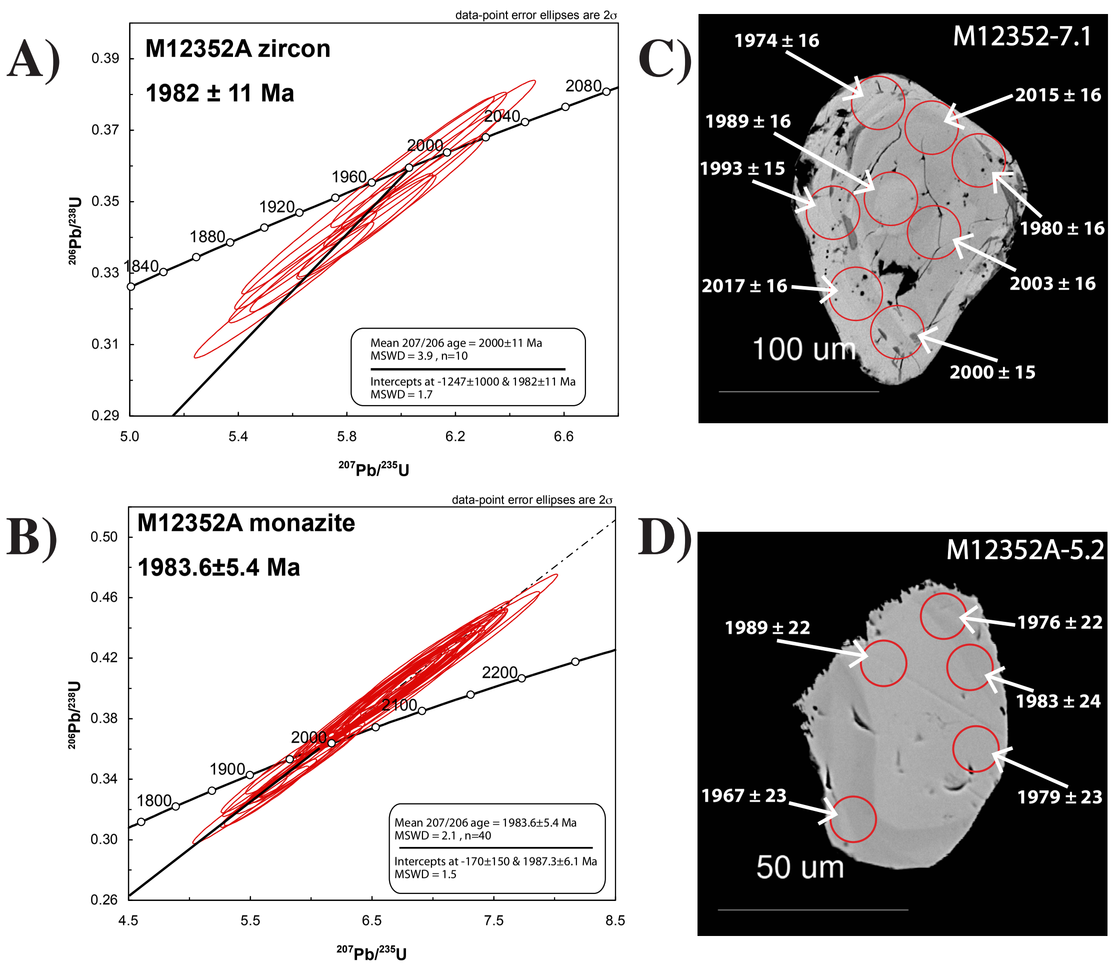


Figure 3-18: Sample M12352A geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (7.1) **(C)** and monazite (5.2) **(D)**. 10 zircon analyses were completed on 2 grains and yielded an upper intercept age of 1982 ± 11 Ma (MSWD = 1.7) with the same analyses yielding a weighted mean $^{207}Pb/^{206}Pb$ age of 2000 ± 11 Ma (MSWD = 3.9). The smaller MSWD of the upper intercept age makes it the likely pegmatite intrusion age. Forty analyses were conducted on six monazite grains in this sample. 28 of the 40 analyses are reversely discordant with the remain less than <15% discordant. All analyses form a cluster with a weighted mean $^{207}Pb/^{206}Pb$ age of 1983.6 ± 5.4 Ma (MSWD = 2.1). This age is in agreement with the zircon upper intercept age and is likely the crystallization age of the pegmatite intrusion.

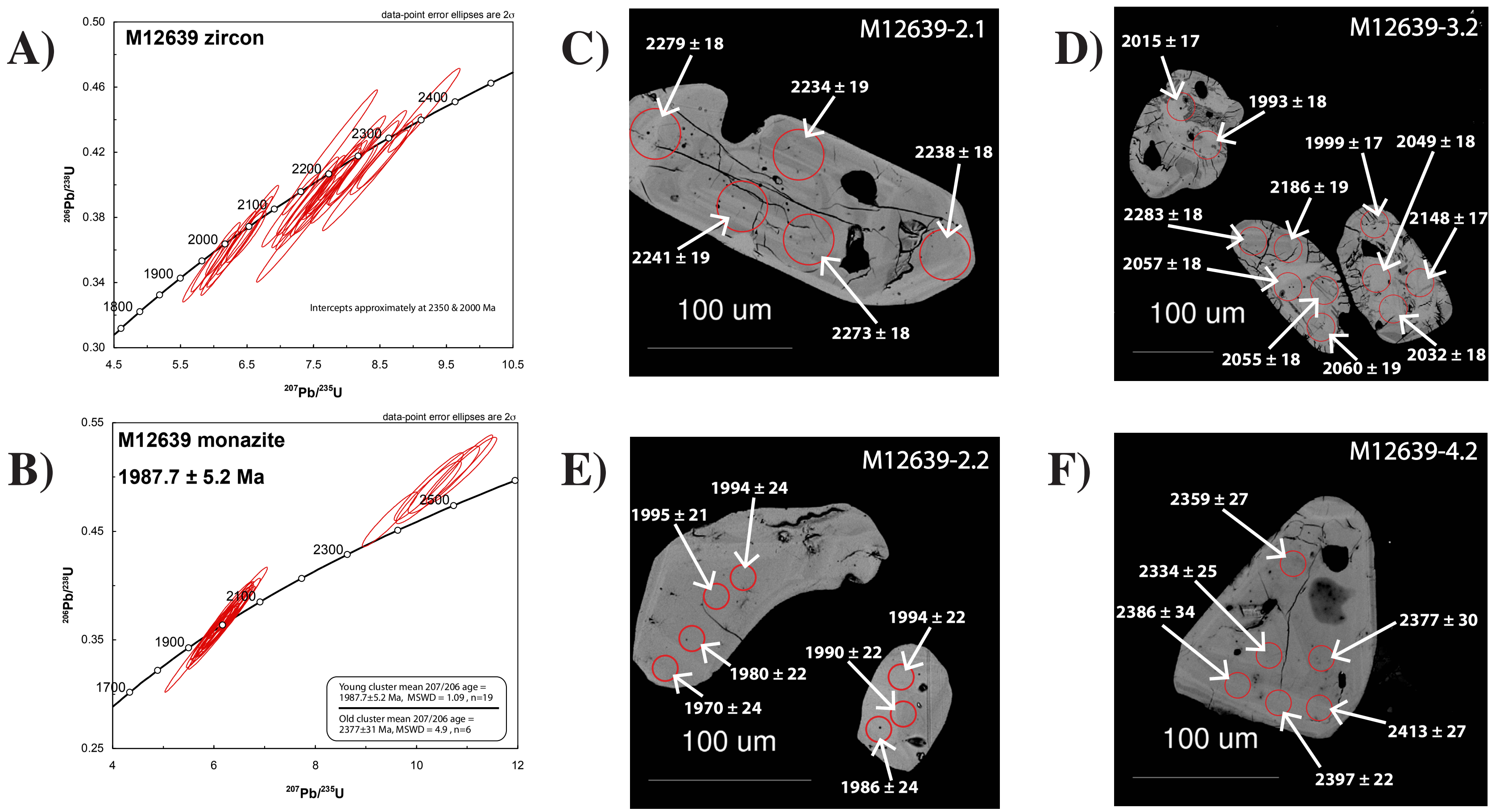


Figure 3-19: Sample M12639 geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (2.1 **(C)** and 3.2 **(D)**) and monazite (2.2 **(E)** and 4.2 **(F)**). 31 zircon analyses were completed on 8 grains and yield a spread along concordia from ~2.4 Ga to ~2.0 Ga. This is likely implying a ~2.35 Ga crystallization age yielded in the exposed 2.3-2.5 Ga Taltson Basement Complex, and a ~2.0 Ga lead-loss event possibly attributed to the ~1.9 Ga granitic intrusions. Twenty-five analyses were conducted on five monazite grains in this sample. When plotted, two clusters are seen. One cluster of six analyses from a single grain (4.2) is reversely discordant with a weighted mean $^{207}Pb/^{206}Pb$ age of 2377 ± 31 Ma (MSWD = 4.9). This is likely a xenocryst or possibly a magmatic monazite. The younger cluster is from nineteen analyses from four grains. It is a concordant group with a weighted mean $^{207}Pb/^{206}Pb$ age of 1987.7 ± 5.2 Ma (MSWD = 1.1). This age could be related to a metamorphic event described by the lead-loss event at ~2.0 Ga by the zircon analyses.

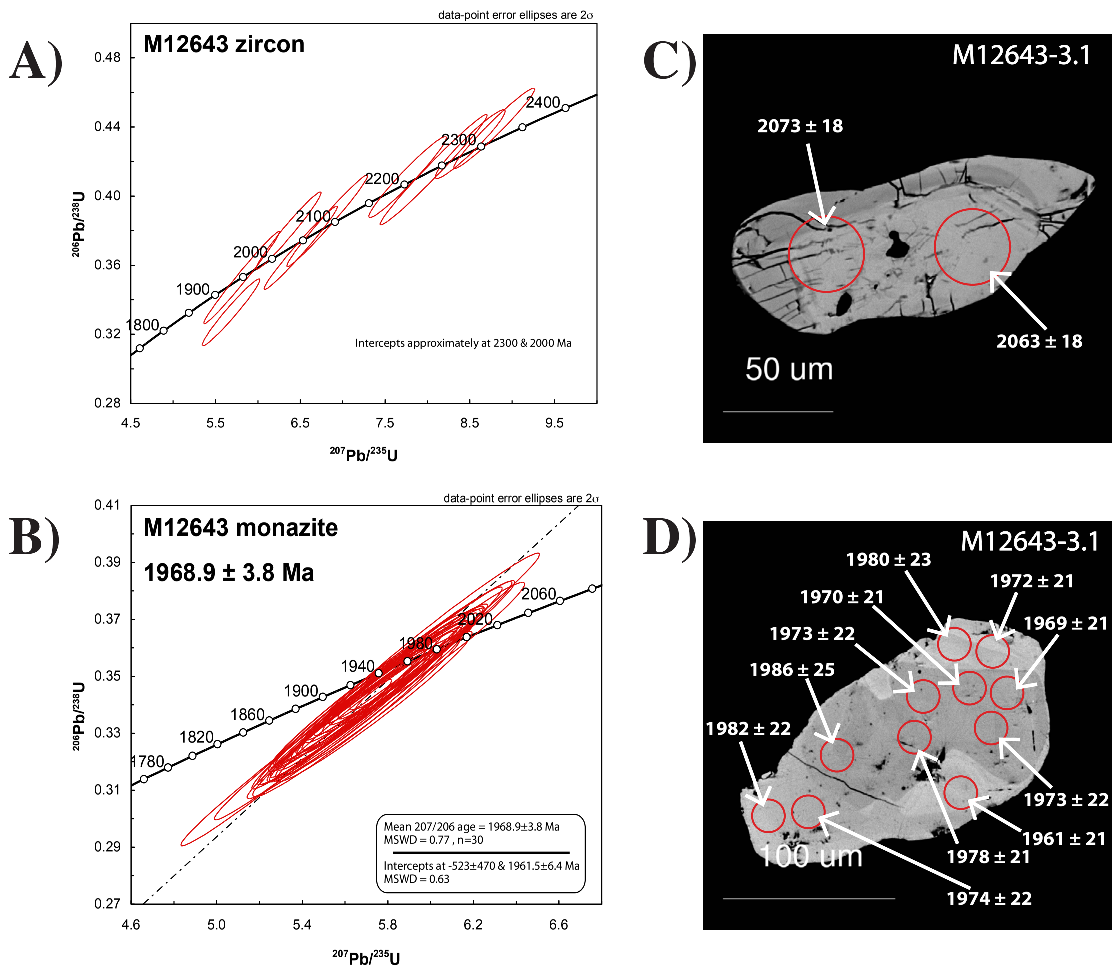


Figure 3-20: Sample M12643 geochronology summary. Concordia plots **(A)** **(B)** and select BSE images of zircon (3.1) **(C)** and monazite (3.1) **(D)**. 9 zircon analyses were completed on 4 grains and yield a spread along concordia from ~2.3 Ga to ~2.0 Ga. This is likely describing a ~2.3 Ga crystallization age yielded in the exposed 2.3-2.5 Ga Taltson Basement Complex, and a ~2.0 Ga lead-loss event possibly attributed to the two suites of ~1.9 Ga granitic intrusions. Thirty analyses were conducted on three monazite grains in this sample. When plotted, a slightly discordant cluster is seen with a weighted mean $^{207}Pb/^{206}Pb$ age of 1968.9 ± 3.8 Ma (MSWD = 0.77). This age is likely a metamorphic age, related to the granitic intrusion event at ~2.0 Ga described by zircon analysis.

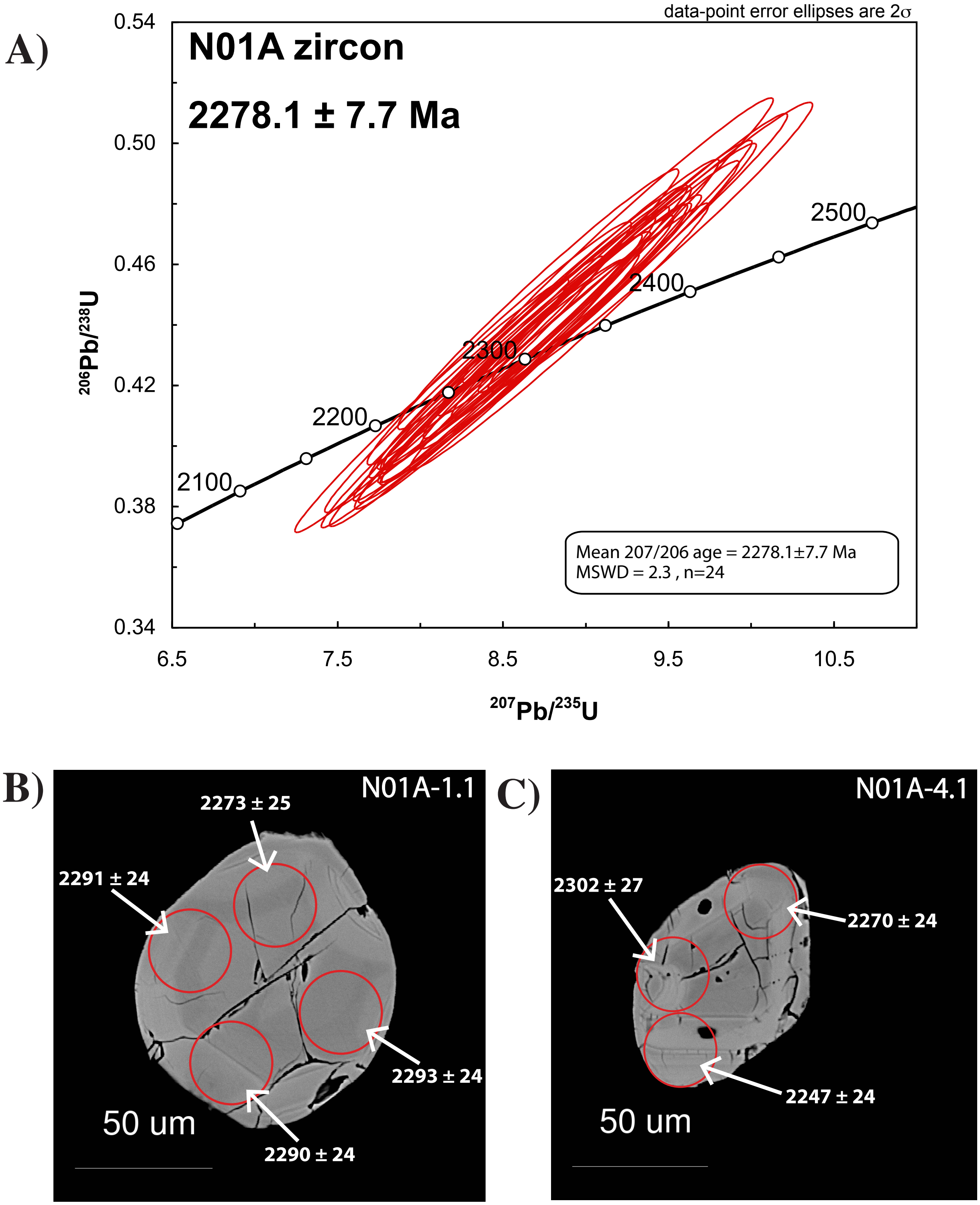


Figure 3-21: Sample N01A geochronology summary. Concordia plot **(A)** and select BSE images of zircon grains (1.1 **(B)** and 4.1 **(C)**). Zircon grains in this sample show faint oscillatory zoning, and are mostly free of radiation damage. 24 zircon analyses were completed on 7 grains. The analyses are mostly <5% discordant and yield a weighted mean $^{207}Pb/^{206}Pb$ age of 2278.1 ± 7.7 Ma (MSWD = 2.3). This interpreted as the crystallization age of the magma.

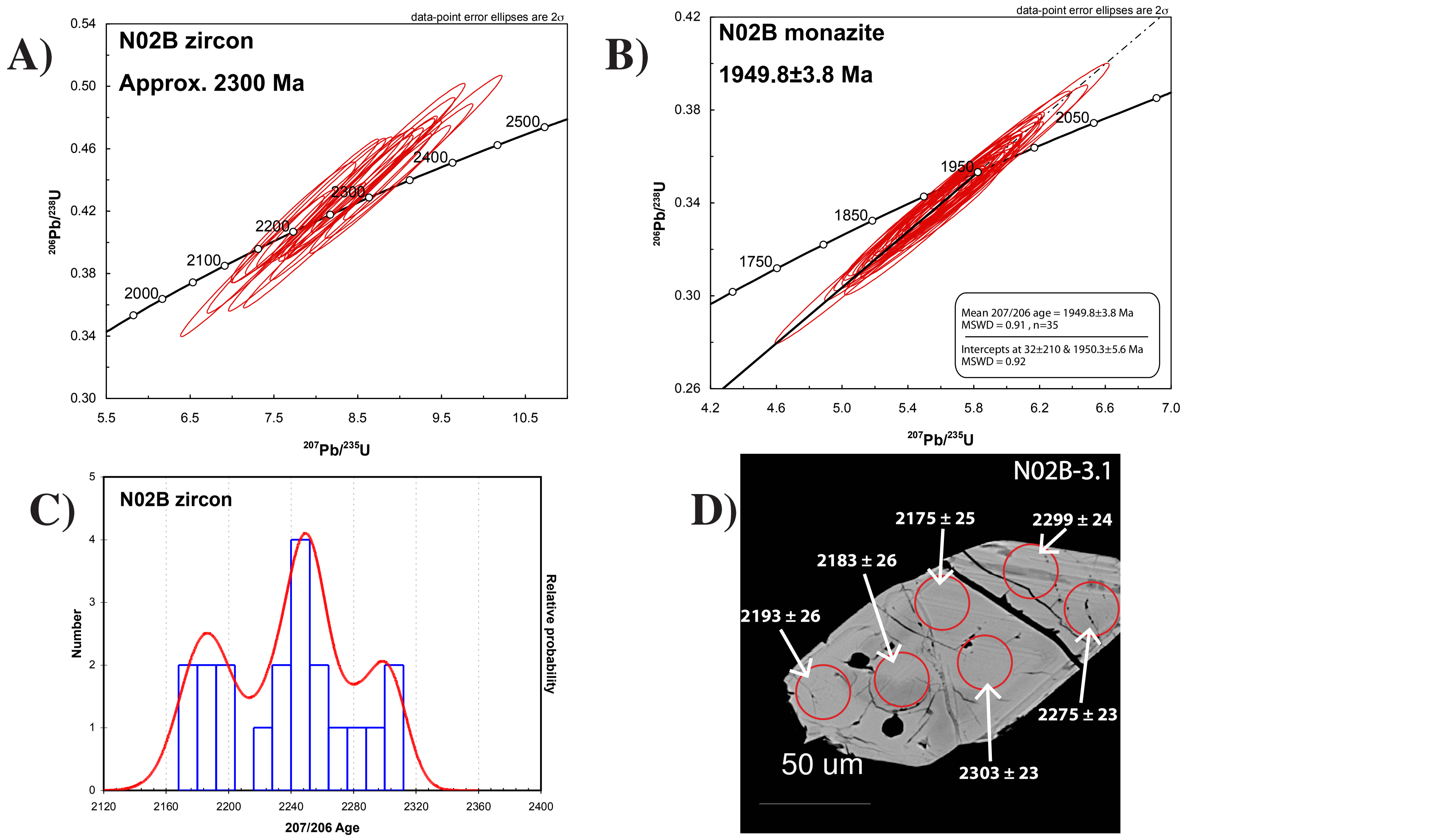


Figure 3-22: Sample N02B geochronology summary. Concordia plots **(A)** **(B)**, probability density plot **(C)**, and select BSE image of a zircon grain (3.1) **(D)**. All zircon grains in this sample display oscillatory zoning. 20 zircon analyses were completed on 10 grains. Analyses were either concordant or slightly discordant and display a set of data from ~2160 Ma to ~2300 Ma. When displayed on a probability density plot, we see two small clusters at 2180 Ma and 2300 Ma, and one large cluster at ~2250 Ma. This data is largely inconclusive but likely the crystallization age is ~2300 Ma. The monazite grains are anhedral to subhedral, and display patchy zonation. They yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1949 ± 3.8 Ma (MSWD = 0.91). This age is interpreted as metamorphic age of the sample.

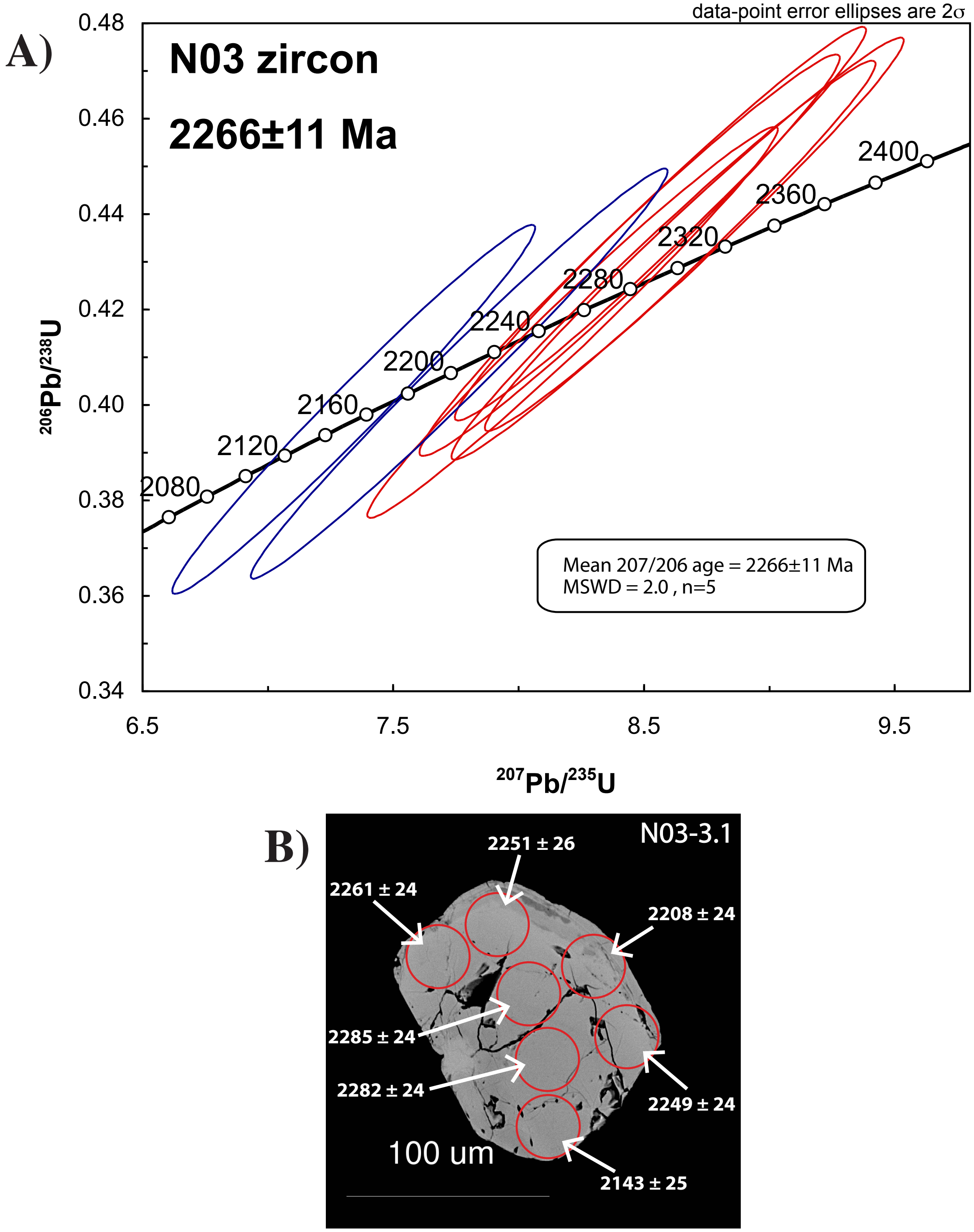


Figure 3-23: Sample N03 geochronology summary. Concordia plot **(A)** and BSE image of the zircon grain (3.1) **(B)**. The grains in this sample is free of radiation damage and is unzoned. 24 zircon analyses were completed on 7 grains. All 7 analyses are <5% discordant with the oldest five analyses (red ellipses) forming a cluster with a weighted mean $^{207}Pb/^{206}Pb$ age of 2266 ± 11 Ma (MSWD = 2.0). The younger analyses (blue ellipses) are omited from age calculations. While it is possible this age is the crystallization age, it may also be a xenocryst as all data is from a single crystal.

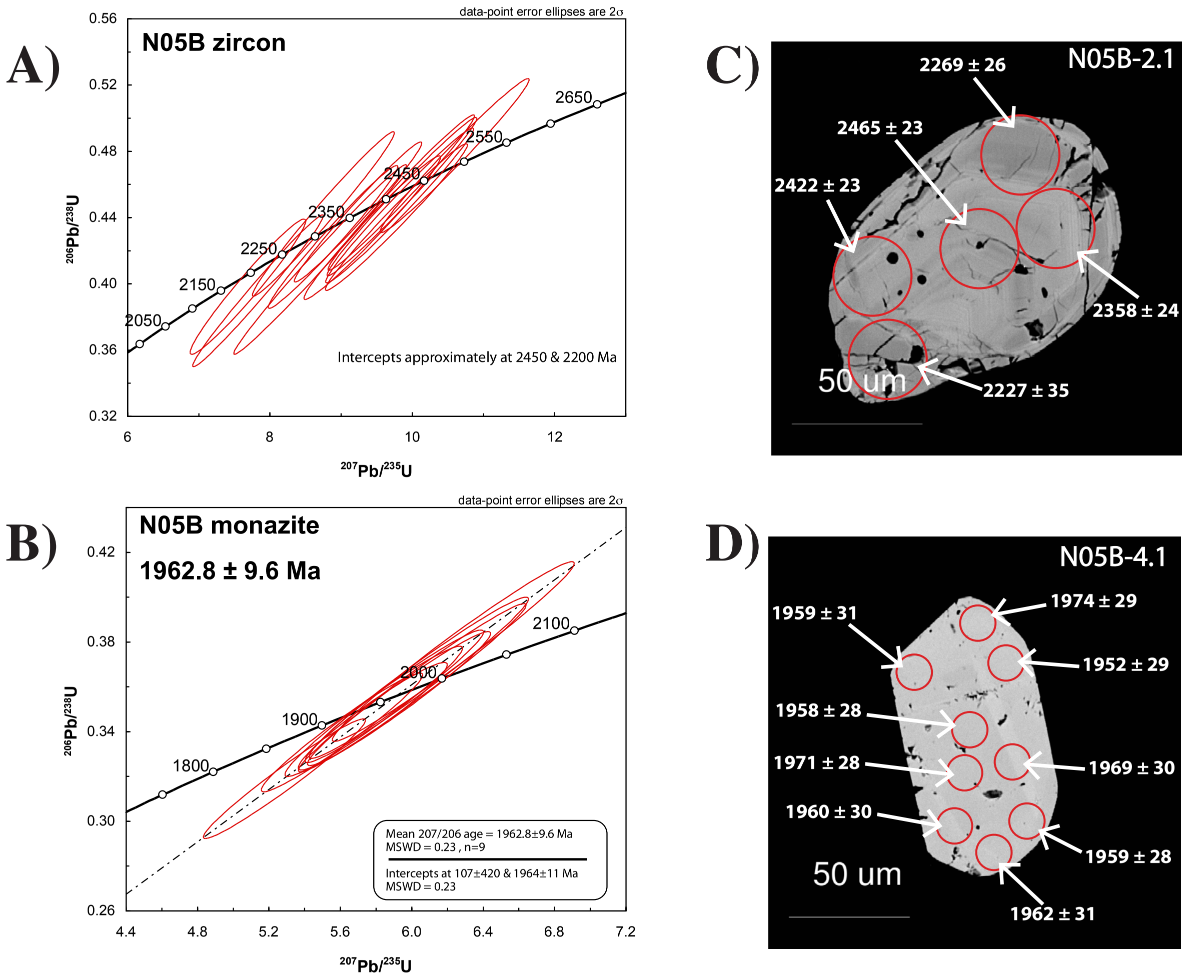


Figure 3-24: Sample N05B geochronology summary. Concordia plots **(A)** **(B)** and BSE images of zircon grain (2.1) **(C)** and monazite grain (4.1) **(D)**. The zircon grains in this sample exhibit faint oscillatory zoning. 12 zircon analyses were completed on 3 grains. All 12 analyses are <6% discordant and yield $^{207}Pb/^{206}Pb$ ages ranging from approximately 2450 Ma to 2200 Ma. The ~2450 Ma age is interpreted as the crystallization age and the ~2200 Ma age is considered a metamorphic event. 9 monazite analyses were obtained from a single unzoned grain. This yielded a weighted mean $^{207}Pb/^{206}Pb$ age of 1962.8 ± 9.6 Ma (MSWD = 0.23) that may be associated with the 1.92-2.0 Ga granitic intrusions of the TMZ.

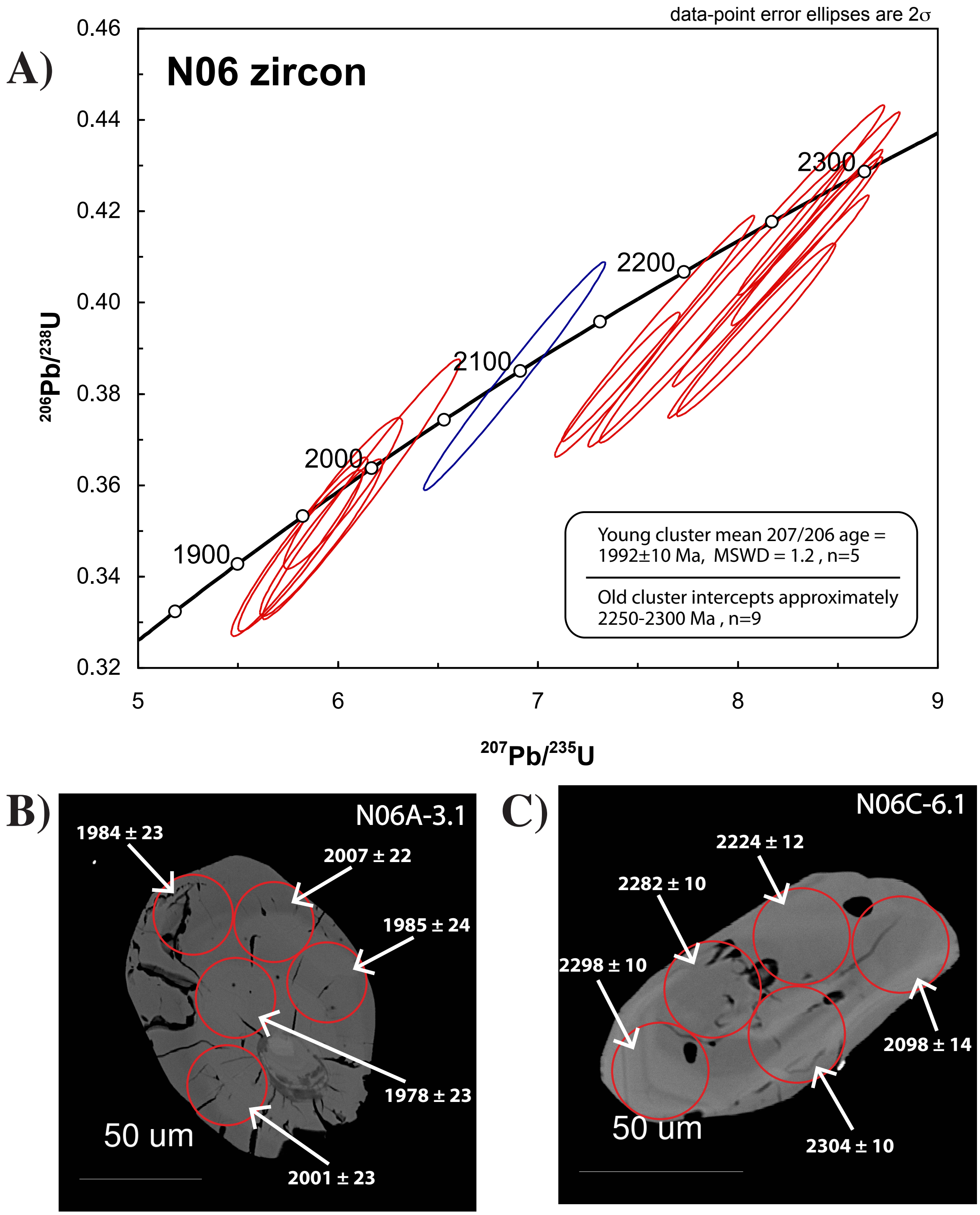


Figure 3-25: Sample N06 geochronology summary. Concordia plot **(A)** and BSE images of zircon grains (3.1 **(B)** and 6.1 **(C)**). Three of the four grains display weak oscillatory zoning (e.g. 6.1) and appear to be a magmatic origin. 9 nearly concordant analyses were obtained from the 3 grains and yielded $^{207}Pb/^{206}Pb$ ages ranging from ~2300 to ~2200 Ma. This is interpreted as a crystallization age for the sample at ~2300 Ma. The fourth zircon grain (3.1) appears homogeneous except for a magmatic core surrounded by a metamorphic overgrowth. This grain yielded a much younger age with 5 analyses producing a weighted mean $^{207}Pb/^{206}Pb$ concordant age of 1992 ± 10 Ma (MSWD = 1.2). This is interpreted as a metamorphic age for the sample.

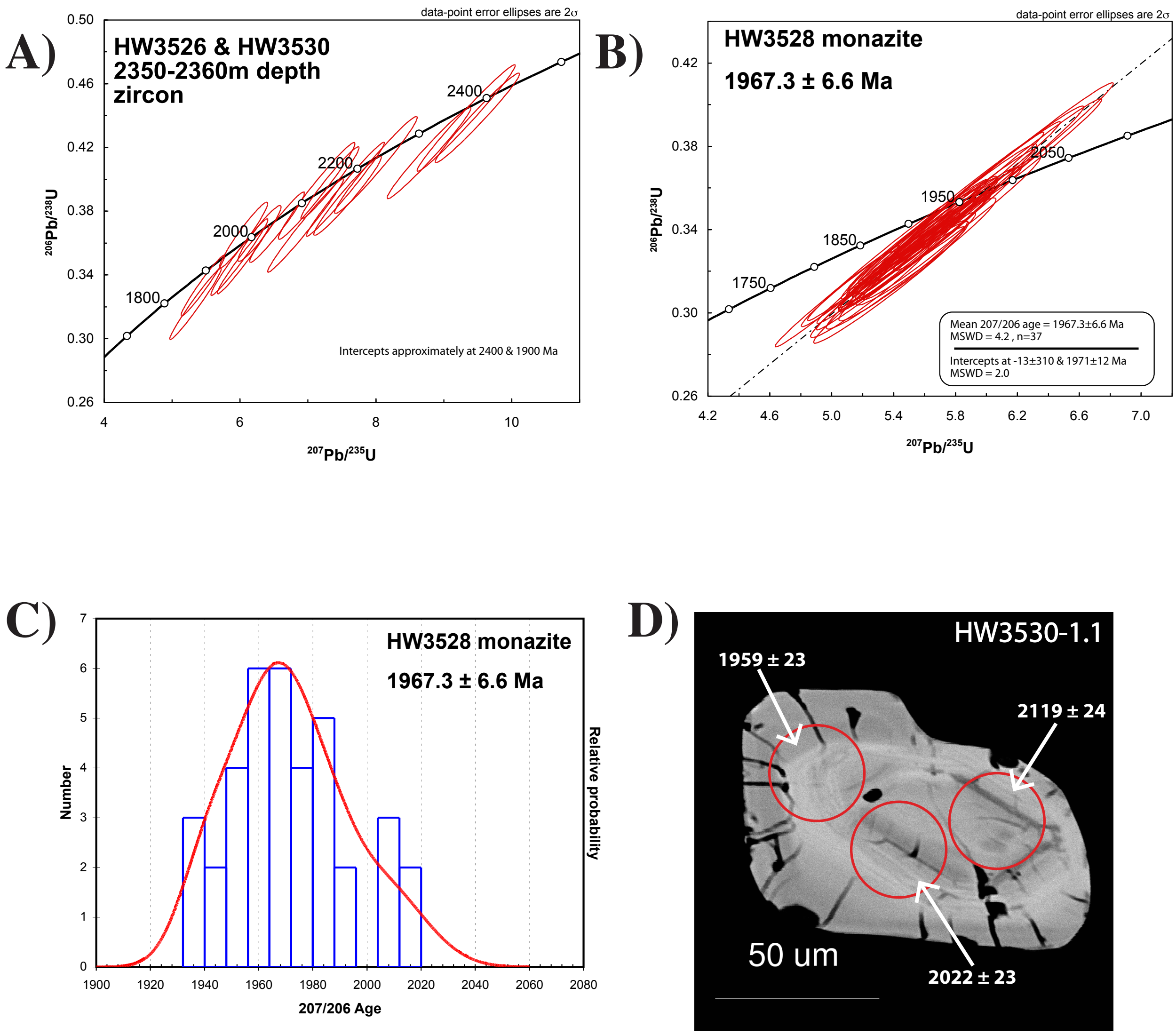


Figure 3-26: 2300m depth of Hunt Well geochronology summary of HW3526, HW3528, HW3530. Concordia plots **(A)** **(B)**, probability density plot **(C)**, and select BSE image of zircon grain (1.1) **(D)**. 16 analyses were made from 6 zircon grains with all analyses <10% discordant. This yielded $^{207}Pb/^{206}Pb$ ages ranging from 2395 Ma to 1935 Ma with the ~2400 Ma analyses interpreted as the crystallization age and the ~1950 Ma analyses are interpreted as the lead-loss event related to regional metamorphism and/or ~1.95 Ga granitoid intrusion. 37 concordant to slightly discordant analyses were obtained from 3 monazite grains. The monazite grains appear to be homogeneous in composition and yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1967.2 ± 6.6 Ma (MSWD = 4.2). Thus this age is interpreted as an approximate metamorphic age or fluid influx event or events occurring simultaneously with the ~1950 Ma zircon lead-loss event.

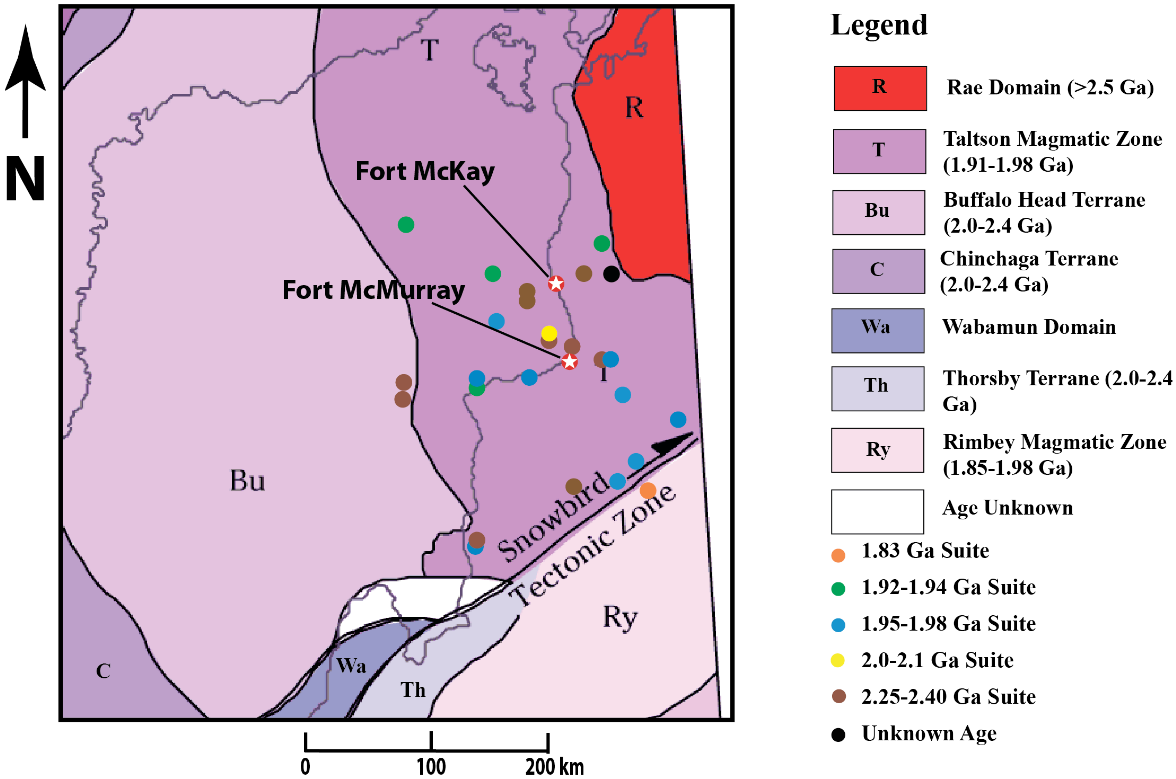


Figure 3-27: Well locations and ages plotted on map of precambrian basement domains (modified from Hoffman, 1989)

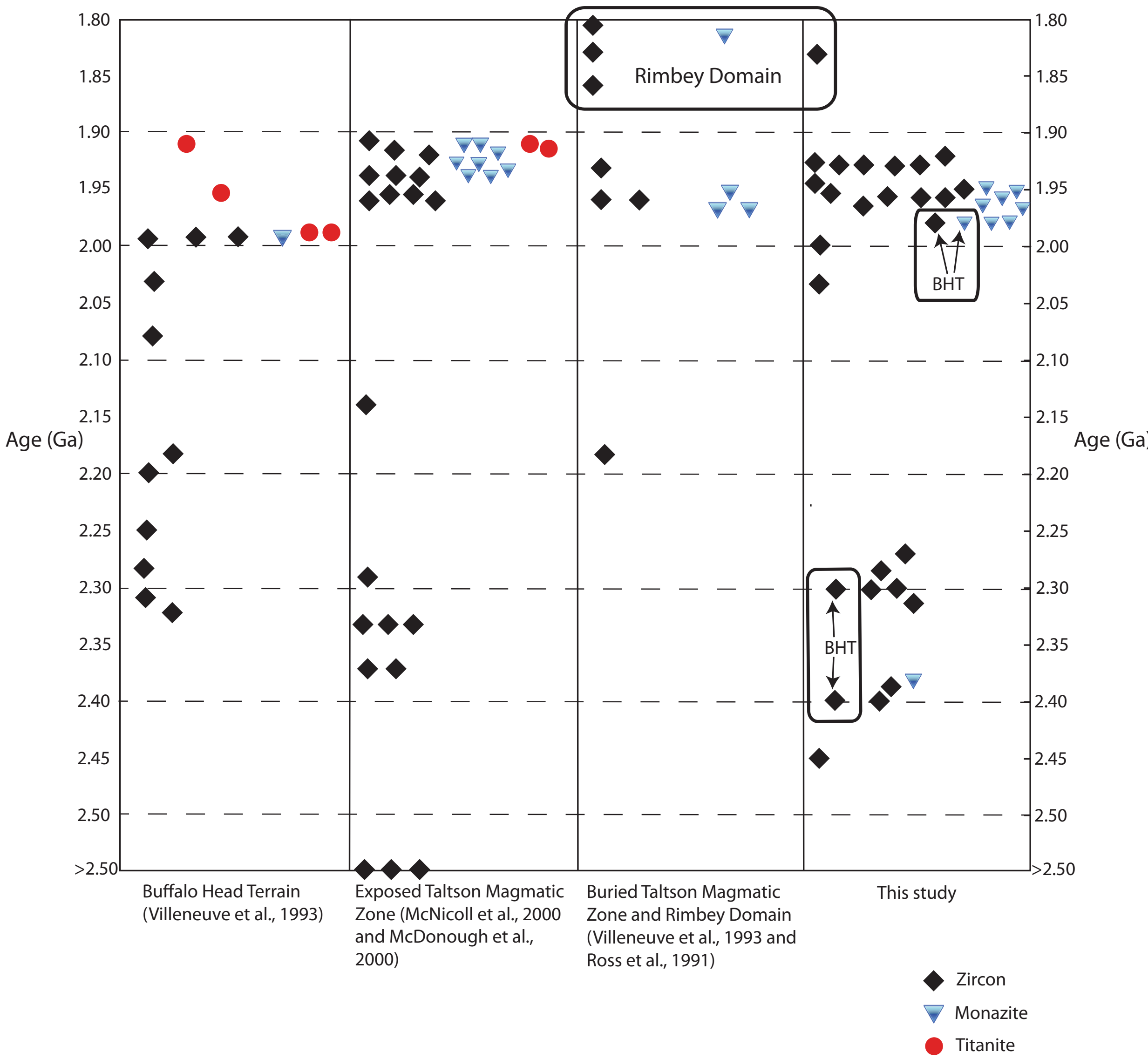


Figure 3-28: Age compilation plot of basement samples in northern Alberta.

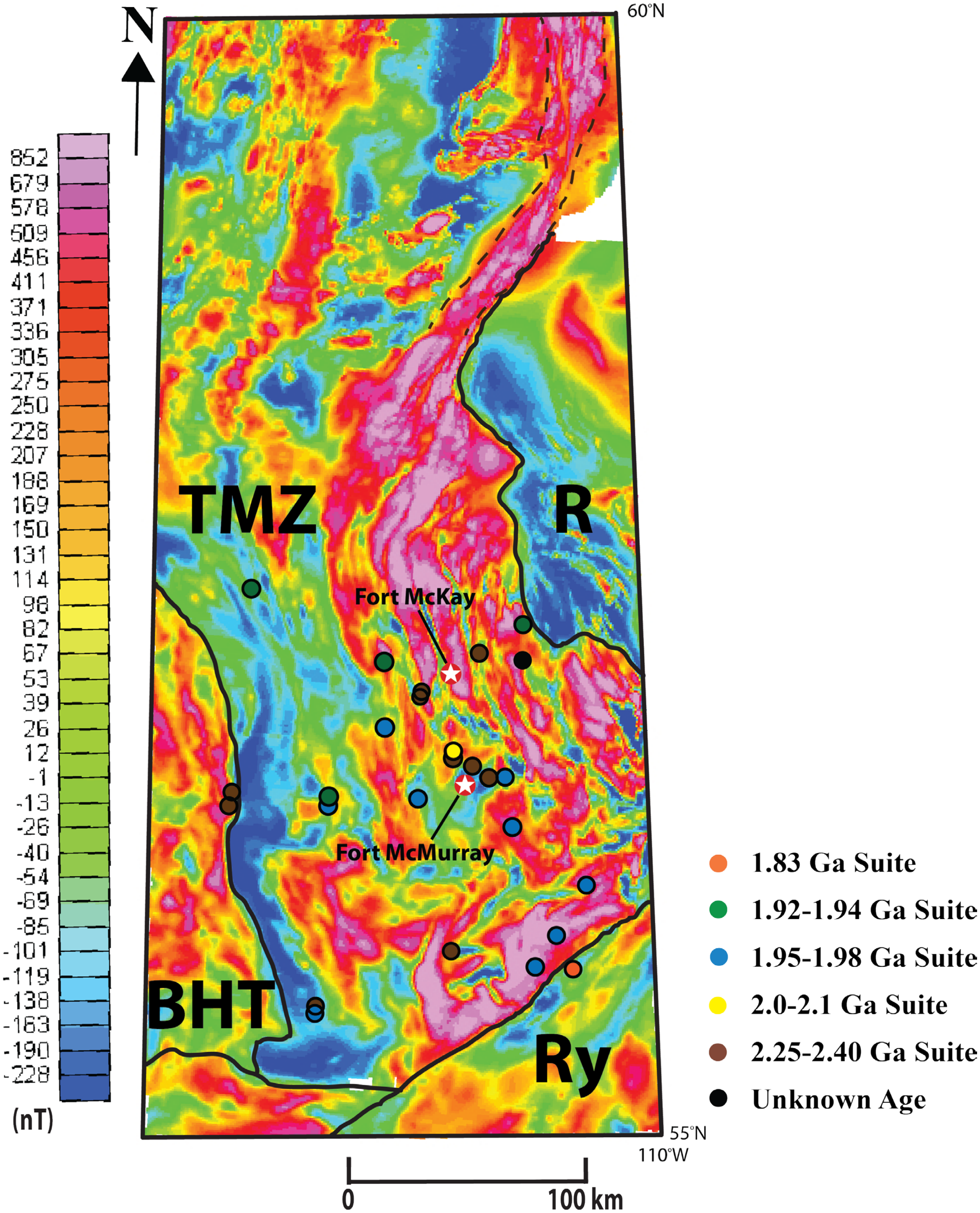


Figure 3-29: Total-field aeromagnetic anomaly map o study area with plotted well locations. Dashed lines are boundaries of the exposed TBC. TMZ = Taltson Magmatic Zone, BHT = Buffalo Head Terrane, Ry = Rimbey Domain, R = Rae craton (modified from Lyatsky et al., 2004).

CHAPTER 4 – Thermal Properties of Rock Samples

Assessment of the geothermal potential of the Fort McMurray area requires an understanding of heat production and heat flow in the continental crust. Heat in the crust comes from two sources. The first is heat locked in the Earth's interior at the time of planetary formation, which is transferred by convection or conduction up through the mantle and crust to the surface. The transport of heat through the crust is strongly influenced by the thermal conductivities of rocks in the crustal column. The second is heat generation within the crust created from the decay of radioactive elements. Because the concentration of the main heat-producing elements, U, Th, and K, generally decrease with depth in the crust due to their incompatibility with respect to the mantle and lower crust (Rudnick and Gao, 2003), radiogenic heat production is highest in upper and mid-crustal rocks and relatively low in the rocks of the lower crust.

4.1 Thermal Conductivities of Drill Core Samples

To accurately predict the geothermal gradient at a given location, thermal conductivities of rocks that make up the crust at that location must be known. These conductivity data can be determined by direct measurements made on basement drill core samples (e.g., by heat impulse or laser optical scanner methods (Popov et al., 1999)) or by combining tabulated values of the thermal conductivities of individual minerals with estimates of the mineral proportions in each sample. In this study, I used the latter approach to estimate conductivities but compare my results to direct measurements made on some drill core samples by other investigators associated with the HAI project (Verveda et al. 2012).

4.1.1 – Methodology

Part of the input data needed for the thermal conductivity calculations are the proportions of different minerals in each drill core sample (i.e., the mineral mode of each sample). In turn, the modal data were obtained by combining chemical compositional data for individual minerals in the samples with the whole-rock chemical compositions of those samples. The mode calculations were done using the MINSQ spreadsheet developed by Herrmann and Berry (2002) for a Microsoft Excel™ platform. The program uses a least-squares approach to solve the system of linear equations formulated from the 9 oxide components (SiO_2, TiO_2, Al_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O) that comprise the major- and minor-element compositions of the minerals and the whole rocks. Specifically, the *Solver* tool in Excel is used to adjust the mineral modes of a sample so as to minimize the sum of squares deviations between the measured whole-rock chemical composition of a sample and the composition of that sample calculated from a weighted average of the mineral compositions. The difference between measured and calculated weight percent proportions for each major and minor oxide component for a given sample is the residual; the smaller the residual, the more reliable the modal estimate.

In order to obtain the mineral composition data needed for modal calculations, individual mineral grains identified in thin section were quantitatively analyzed using wavelength dispersive spectroscopy (WDS) on the JEOL 8900 Electron Probe Microanalyzer (EPMA) at the University of Alberta. For these analyses, I used an accelerating voltage of 15 kV, a beam diameter of 3-4 um, and a current of 15 nA. Standardization of elements analyzed was done with in-house mineral standards. Quartz was assumed to be 100 wt.% SiO_2. When possible for each sample, an average of 4 grains were analyzed of each mineral with an average of 3 points per grain **(Table 4-1)**.

Samples for whole-rock analysis were cut from drill core, weighed, and then crushed in a shatterbox for 4 minutes. The majority of the samples were crushed in an alumina mill to minimize tungsten contamination of the sample, which effects U and Th analyses by instrumental neutron activation analyses (see below). However, 3 samples (HW1, HW2, and HW3) were crushed in a tungsten-carbide ring-and-puck mill (WC mill). Major and minor elements (reported as oxide weight percentages; wt.%) and select trace-elements (reported in parts per million; ppm) were analyzed by fusion inductively coupled plasma mass spectrometry[1] (ICP-MS) and instrumental neutron activation analysis[2] (INAA) at Actlabs (Ancaster, Ontario, Canada). Some trace elements were also analyzed using quadrupole inductively coupled plasma mass spectrometry[3] (Q-ICP-MS) using a Perkins-Elmer Elan 6100 instrument at the Radiogenic Isotope Facility (RIF), at the University of Alberta. Processing of the rock powders prior to Q-ICP-MS analysis followed the Na_2O_2 sintering technique developed by Longerich et al. (1990).

To test the accuracy of the MINSQ method for estimating modes, I prepared a synthetic granite rock powder by combining weighed amounts of pure mineral separates of potassium feldspar, plagioclase, biotite, hornblende, and ilmenite. Grains of all of those same minerals except quartz were also mounted in epoxy for analysis by EPMA. The mix of minerals was ground in an alumina disk mill for 120 seconds in order to ensure a homogeneous rock powder and that rock powder sent for whole-rock chemical analysis by fusion ICP-MS as described above. Using these input data, **Table 4-2** shows the calculated mode for the synthetic powder obtained with the MINSQ method versus the actual proportions of minerals mixed for the test. The mineral modes listed in the table are given in weight percent proportions of each mineral. In general, there is good agreement between the actual and calculated modes with deviations less than ~12% relative and 2% absolute for all minerals.

Once mineral modes for each sample are determined, sample thermal conductivity can be calculated by utilizing a number of different mathematical models that predict the thermal conductivity of a sample based on its mineralogical components. The most popular model used is the geometric model where the thermal conductivity mean is achieved by multiplication as opposed to by addition (Jessop, 1990). The mathematical expression used for the geometric model is:

$$\mathbf{K_s = exp(\, n_1 lnK_1 + n_2 lnK_2 + n_3 lnK_3 \ldots)}$$

where:

Ks	= Rock sample thermal conductivity in W/m K
n1	=Abundance of specific mineral
K1	=Individual mineral thermal conductivity in W/m K

Individual mineral thermal conductivity values as determined by Horai and Simmons, 1969 are listed in **Table 4-3**. Thermal conductivities vary between minerals due to mineral density, crystal structure, and chemical composition (Horai, 1971). Plagioclase feldspar, having a thermal conductivity value that changes with varying compositions, has been assigned a K value for each individual sample based on sample anorthite content as measured by EPMA. This was achieved by fitting plagioclase conductivity data to a linear equation relating the anorthite content of the plagioclase to its thermal conductivity. Plagioclase K values and the linear equation are listed in **Appendix E**.

4.1.2 Results

Thermal conductivity values were calculated for 35 samples using the geometric model discussed above **(Table 4-4)**. Thermal conductivity values range from 2.22 to 4.09 W/mK and are largely determined by the quartz abundance of the samples. The samples with the highest K values all have greater than 35 wt. % quartz. To obtain an average K value for the study area, I assigned all samples a weight of 1 for the data set with the exception of the Hunt Well samples. For the Hunt Well samples, I averaged the results of all the samples investigated from this well and assigned a weight of 1 to that average value. The calculations yield an average K value for the 35 samples of 3.1 ± 0.43 W/mK (1σ) and a median K value of 3.2 W/mK.

Calculated whole-rock thermal conductivity values can then be compared to direct measurement methods such as the heat impulse method or laser method. **Figure 4-1** compares the thermal conductivities given by the calculations with those measured directly on the same samples using the heat-impulse method (Verveda et al., 2012). There is generally good agreement between calculated and measured conductivities although the calculated values are on average slightly lower than measured values.

Younger samples (1.83 to 2.03 Ga) have a more consistent thermal conductivity value compared to older (2.1 to 2.5 Ga) samples. All but one of the younger samples have a K values between 2.9 and 3.6 W/m K which is due to most being granitic in composition. The older samples have much more variation with K values ranging from ~2.2 to ~3.6 W/m K.

4.2 Radiogenic Heat Production (RHP)

Heat is generated within a rock as a by-product of the radioactive decay of an unstable parent isotope to a stable daughter isotope. Whereas many radiogenic isotopes produce heat in nature, only 4 are geologically significant. These are the ^{238}U, ^{235}U, ^{232}Th, and ^{40}K, which decay to ^{206}Pb, ^{207}Pb, ^{208}Pb, and ^{40}Ar respectively. Areas of high concentrations of U, Th, and K are likely associated with high heat flow values and are regarded as good locations for geothermal energy production.

4.2.1 Methodology

To determine the RHP of a rock sample, the concentrations of uranium, thorium, and potassium must be precisely measured. Potassium is generally found in major rock-forming minerals such as feldspars and micas, whereas uranium and thorium are found primarily in a variety of accessory minerals including zircon and monazite. Once the concentrations are known, the RHP for a sample (in $\mu W/m^3$) is given by:

$$\mathbf{RHP = 10^{-5}\, \rho(9.52C_U + 2.56C_{Th} + 3.48C_K)} \qquad \text{(Rybach, 1988)}$$

where: ρ = density of the rock (kg/m3), assigned as 2.8 (Vila et al., 2010)
C_U = concentration of uranium (in ppm)
C_{Th} = concentration of thorium (in ppm)
C_K = concentration of potassium (in wt.%)

Rock powders analyzed for RHP were crushed using methods described above. Potassium concentrations were measured by fusion inductively coupled plasma mass spectrometry (ICP-MS) and are reported as wt. % K_2O. This K_2O value is then converted to K (wt.%) by multiplying by 0.83. Uranium and thorium concentrations in all samples except samples M12640 and M12643 were analyzed by both Neutron Activation Analysis (NAA) using the SLOWPOKE Nuclear Reactor Facility at the University of Alberta and by Instrumental Neutron Activation Analysis (INAA) at Activation Laboratories. NAA with the SLOWPOKE reactor is the preferred method because of its higher precision. This method relies on the absorption of neutrons by U and Th, which causes the elements to form artificial radioactive isotopes. Gamma ray spectrometry then measures the resulting gamma ray emissions when these elements undergo radioactive decay. The method is non-destructive and allows for simultaneous multi-element analysis. U and Th concentrations obtained by NAA and INAA techniques are in excellent agreement yielding R^2 - values of 0.979 and 0.998, respectively **(Figure 4-2)**.

4.2.2 Results

There is a large variation in the RHP values of the drill core samples investigated in the present study **(Table 4-5)**. In particular, all the Hunt Well samples have low RHP values because of low U and Th contents. Sample M3796 has the highest RHP value at 13.48 $\mu W/m^3$, which is mostly due to its anomalously high Th concentration (172 ppm). This high Th value should be regarded with caution from a regional geology perspective, as the thorium is located in alteration patches of this sample as observed by EPMA.Thus, high Th may be the product of a localized fluid alteration and not representative of the RHP of the well as a whole. Sample M4017, which is from the Rimbey domain, has the second highest RHP value owing to its very high uranium content (15.40 ppm). This sample is relatively unaltered and would be from at least a heat generation perspective, a good location to site a geothermal well. In contrast to these high RHP values, 12 Hunt Well samples collected from ~1600 and 2300 meter depths, have anomalously low RHP (0.71 ± 0.38 $\mu W/m^3$ (1σ)). These low RHP values reflect the low Th and very low U contents of the analyzed samples. Down-hole gamma ray logging of the Hunt Well suggests that the samples analyzed in the present study may not be representative of the well as a whole (Majorowicz, 2012). The average sample U and Th concentrations for this study are 2.15 and 26.3 ppm respectively. This is comparable to average global upper crustal averages of 2.7 ppm for U and 10.5 ppm for Th (Rudnick and Gao, 2003).

To obtain an average and median RHP values for the basement samples from the Fort McMurray area, I combined a single averaged value for the Hunt Well samples with the RHP results. Then I took all other well samples from the study area. This resulted in an average of 2.88 ± 2.79 $\mu W/m^3$ (1σ) and a median RHP of 2.01 $\mu W/m^3$. Altogether, the RHP of a sample is mostly controlled by uranium and thorium. Potassium contributes relatively little to the total RHP. **Figure 4-4** plots RHP values against the age of the samples. Although there is a great deal of variation in the RHP values, on average, the post-2.0 Ga samples have somewhat higher RHP values than the older samples.

4.3 Discussion

With regional knowledge of thermal conductivities and radiogenic heat production in the crystalline basement samples, we can evaluate how the geothermal gradient for our study area may be influenced by variations in these parameters. Specifically, I model how a one standard deviation variation from the average thermal conductivity and RHP values of the basement samples would affect the geothermal gradient in the upper 7 km of crust. It must be emphasized that the modeling is not intended to accurately represent actual temperatures in the crust but rather to assess temperature differences in the crust with the expected variations in RHP and thermal conductivity values.

I used two different models to calculate geothermal gradient. The first **(Figure 4-4a)** is referred to as the "one-layer crust" model (Spear, 1993), where the crustal layer of radiogenic heat production is assumed to have a thickness (D) and a homogeneous distribution of heat-producing elements and thermal conductivity throughout the crust. This model assumes that D is the depth below which radiogenic heat production ceases (i.e., the mantle and lower crust is assumed to produce no radiogenic heat), and that mantle heat flow (Q) is consistent throughout the study area. Surface temperature is assumed to be 0°C. In the one-layer model, temperature varies as a function of depth according to the following equation:

$$T = \left(\frac{Az^2}{2K}\right) + \left(\frac{Q}{K} + \frac{(AD)}{K}\right)z$$

Where:
T= temperature (°C)
A= radiogenic heat production ($\mu W/m^3$)
Z= depth (km)
K= thermal conductivity (W/m K)
Q= reduced heat flow, assumed to be 33 mW/m^2 (Majorowicz and Grasby, 2010b)
D= thickness of the heat-producing layer: assumed to be 10 km in the present calculations (Majorowicz and Grasby, 2010b)

The second model **(Figure 4-4b)** is the 'exponential distribution model' (Spear, 1993), which assumes RHP is greatest at the surface and decreases exponentially with depth. In this model, D is the length scale over which the heat production drops off. For example, if D is 10 km then heat production at 10 and 20 km depths will be 1/e and $1/e^2$ respectively, of its surface value.

$$T = \left(\frac{Qz}{K}\right) + \left[\left(\frac{A_0 D^2}{K}\right)\left(1 - e^{-z/D}\right)\right]$$

Where: T = temperature (°C)
A_0= radiogenic heat production at surface (μW/m^3)
z= depth (km)
K= thermal conductivity (W/m K)
Q= reduced heat flow, assumed to be 33 mW/m^2 (Majorowicz and Grasby, 2010b)
D= length scale of exponential heat-production drop off: assumed to be 10 km in the present calculations (Majorowicz and Grasby, 2010b)

Both models produce similar results although the exponential distribution model yields slightly higher temperatures than the one-layer crust model. The modeling indicates that varying thermal conductivity by ± 1 standard deviation from the average value only produces a ~25°C temperature difference at a depth of 5 km in both models. In contrast, varying radiogenic heat production by ± 1 standard deviation from the average value produces a ~69°C difference in temperature at 5 km depth. Clearly RHP is the variable that has the largest effect in yielding higher temperatures in the study area. Based on the models, crust with average thermal conductivity and an RHP that is one standard deviation above the average value would produce a temperature of ~122-125°C at 5 km depth compared to 88-90 °C at that depth with an average RHP value. Thus, locating basement rocks with high radiogenic heat production is of upmost importance for optimal siting of geothermal wells.

Both models predict temperatures very close to what is actually measured in the Hunt Well at a depth of 2.35 km (47°C) (Majorowicz et al., 2012). At 2.35 km with average RHP and TC, the one-layer crust and exponential distribution models predict temperatures of 44°C and 45°C, respectively **(Figure 4-4)**. Because the Hunt Well samples have the lowest RHP values encountered in the present study, it may be that this location represents the worst-case scenario for an EGS site in the Fort McMurray area. Alternatively, as discussed further below, the RHP values of the Hunt Well samples investigated in this study may not be representative of the RHP of the entire basement column at this site.

It is important to note that the modeling undertaken here has significant limitations. A critical assumption made in the modeling is that the well samples that I investigated are representative of rocks present at deeper levels of the basement at each locality. Nearly all of the core samples of the present study were acquired from only about 1 m below the basement-sediment interface. In contrast, a geothermal well in the Fort McMurray area would need to penetrate 4 to 5 km into the basement in order to reach the temperatures needed for oil sands processing. Thus it is possible that rocks near the top of the Precambrian basement are unlike those present at greater depths. This is best displayed by the Hunt Well where two cored units at 1650 m and 2350 m depths have two very different lithologies. The rock unit at 1650 m is a hercynite (spinel) biotite garnet gneiss whereas the rock unit at 2350 m is a orthopyroxene granite (charnockite). Modeling shows that the 100°C isotherm is encountered at a wide range of depths (~4 to 10 km) depending of the RHP values of the crust. Due to the cost of drilling, this is significant as every additional 1 km of drilling adds greatly to the total project cost. Another assumption is that the mantle reduced heat flow and depth of active RHP is homogeneous in the study area. Previous studies have reported mantle reduced heat flow to vary regionally in Canada from 33 to 60 mW/m^2 whereas layers of active RHP can vary from 8 to 12 km (Majorowicz and Grasby, 2010b). Despite these limitations, the two models described above do yield reasonable temperatures at various depths with the given variables.

Table 4-1: Average mineral compositions

Weight % oxide averages											Cation totals averages										
M0034																					
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	64.25	0.03	18.80	0.02	0.01	0.01	0.01	0.28	2.50	13.20	99.10	avg	2.978	0.001	1.027	0.001	0.000	0.000	0.001	0.014	0.224	0.747	4.993
Pl avg	62.83	0.02	23.04	0.01	0.03	0.01	0.01	4.11	9.24	0.18	99.48	avg	2.793	0.001	1.207	0.000	0.001	0.001	0.001	0.196	0.796	0.010	5.006
Bt avg	37.47	4.48	14.82	0.00	20.90	0.15	9.41	0.05	0.14	9.61	97.03	avg	2.832	0.255	1.320	0.000	1.321	0.010	1.060	0.004	0.021	0.886	7.707
M3796																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.45	0.03	18.25	0.01	0.04	0.00	0.00	0.05	1.01	15.34	98.18	avg	2.992	0.001	1.014	0.000	0.002	0.000	0.000	0.002	0.093	0.882	4.987
Pl avg	63.21	0.01	22.01	0.02	0.08	0.01	0.02	3.17	9.70	0.24	98.47	avg	2.834	0.000	1.163	0.001	0.003	0.001	0.001	0.152	0.844	0.014	5.013
Bt avg	38.22	3.05	12.50	0.00	14.16	0.20	15.17	0.05	0.12	9.66	93.12	avg	2.924	0.175	1.127	0.000	0.906	0.013	1.730	0.004	0.018	0.901	7.797
Hm avg	0.14	0.08	0.09	0.02	88.45	0.05	0.05	0.02	0.03	0.01	88.92	avg	0.006	0.002	0.004	0.000	2.970	0.002	0.003	0.001	0.002	0.000	2.991
M3997																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.51	0.04	18.60	0.02	0.02	0.01	0.01	0.09	0.93	15.15	98.37	avg	2.984	0.001	1.030	0.001	0.001	0.000	0.001	0.004	0.084	0.868	4.975
Pl avg	59.04	0.02	25.37	0.03	0.04	0.01	0.02	7.03	7.27	0.34	99.17	avg	2.655	0.001	1.345	0.001	0.001	0.000	0.001	0.339	0.634	0.020	4.997
P-rut avg*	0.15	59.63	0.15	0.03	39.40	0.07	0.05	0.07	0.05	0.00	99.60	avg	0.010	2.990	0.012	0.002	1.976	0.004	0.005	0.005	0.006	0.000	5.009
M4002A																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.53	0.03	18.30	0.01	0.01	0.00	0.02	0.06	0.65	15.88	98.51	avg	2.991	0.001	1.016	0.000	0.000	0.000	0.001	0.003	0.060	0.912	4.985
Pl avg	57.63	0.03	25.93	0.01	0.03	0.01	0.03	7.89	6.85	0.18	98.59	avg	2.613	0.001	1.386	0.000	0.001	0.000	0.002	0.384	0.602	0.010	5.000
Chl avg	27.76	0.01	16.32	0.03	29.08	0.28	12.36	0.19	0.06	0.04	86.13	avg	2.391	0.001	1.658	0.002	2.095	0.021	1.587	0.018	0.010	0.004	7.786
P-rut avg*	0.10	59.90	0.09	0.09	37.42	2.27	0.04	0.03	0.03	0.01	99.98	avg	0.007	3.007	0.007	0.005	1.879	0.128	0.004	0.002	0.004	0.001	5.043
M4002B																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.71	0.04	18.50	0.01	0.03	0.01	0.01	0.10	0.63	15.99	99.03	avg	2.986	0.001	1.022	0.000	0.001	0.000	0.001	0.005	0.057	0.914	4.988
Pl avg	66.86	0.00	19.95	0.01	0.08	0.00	0.02	0.57	11.07	0.65	99.20	avg	2.958	0.000	1.040	0.000	0.003	0.000	0.001	0.027	0.949	0.037	5.015
Chl avg	25.89	0.13	20.13	0.01	28.41	0.23	12.48	0.04	0.07	0.04	87.43	avg	2.186	0.008	2.004	0.001	2.006	0.016	1.571	0.004	0.011	0.004	7.811
Ru avg	0.71	100.64	0.43	0.03	0.82	0.03	0.17	0.11	0.04	0.03	103.00	avg	0.009	0.978	0.007	0.000	0.009	0.000	0.003	0.002	0.001	0.000	1.010
M4015A																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.64	0.01	18.40	0.01	0.01	0.01	0.02	0.05	1.05	15.28	98.49	avg	2.990	0.000	1.019	0.000	0.000	0.001	0.001	0.002	0.096	0.876	4.986
Pl avg	61.58	0.00	23.43	0.02	0.04	0.02	0.01	4.86	8.62	0.23	98.81	avg	2.762	0.000	1.239	0.001	0.002	0.001	0.001	0.234	0.750	0.013	5.000
Bt avg	36.09	4.40	14.72	0.04	23.16	0.17	7.96	0.09	0.10	9.38	96.11	avg	2.793	0.256	1.343	0.002	1.499	0.011	0.918	0.007	0.015	0.886	7.730
M4015B																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Pl avg	58.10	0.01	25.95	0.03	0.05	0.01	0.02	7.81	6.89	0.19	99.05	avg	2.620	0.000	1.380	0.001	0.002	0.000	0.001	0.377	0.603	0.011	4.996
Opx avg	52.04	0.08	0.66	0.05	29.90	1.00	15.93	0.77	0.03	0.00	100.47	avg	2.003	0.002	0.030	0.001	0.962	0.033	0.914	0.032	0.002	0.000	3.980
Hbl avg	45.39	1.39	8.28	0.08	15.87	0.27	10.51	13.43	1.19	0.89	97.32	avg	6.526	0.152	1.412	0.009	1.914	0.033	2.253	2.063	0.333	0.165	14.861
M4017																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.92	0.01	18.37	0.02	0.01	0.01	0.01	0.01	0.62	16.17	99.17	avg	2.993	0.001	1.014	0.001	0.000	0.000	0.001	0.000	0.056	0.924	4.990
Pl avg	63.96	0.01	21.99	0.01	0.02	0.02	0.01	3.09	9.81	0.10	99.01	avg	2.847	0.000	1.153	0.000	0.001	0.001	0.001	0.147	0.846	0.006	5.002
Bt avg	35.73	3.23	16.41	0.03	24.84	0.46	5.22	0.04	0.08	9.58	95.63	avg	2.802	0.191	1.516	0.002	1.629	0.031	0.611	0.003	0.013	0.916	7.713
M12350																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Pl avg	56.65	0.02	26.84	0.01	0.22	0.01	0.06	8.97	5.60	1.04	99.41	avg	2.564	0.001	1.431	0.000	0.008	0.000	0.004	0.435	0.491	0.060	4.995
Bt avg	38.27	5.16	13.82	0.27	11.90	0.05	15.03	0.06	0.08	9.73	94.37	avg	2.853	0.289	1.214	0.016	0.742	0.003	1.671	0.004	0.011	0.885	7.690
Ti-rich hematite avg	0.08	13.25	0.19	0.33	78.12	0.10	0.23	0.01	0.03	0.01	92.36	avg	0.003	0.345	0.008	0.009	2.262	0.003	0.012	0.001	0.002	0.000	2.645
M12351																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.47	0.02	18.64	0.00	0.04	0.01	0.01	0.07	1.29	14.83	98.38	avg	2.984	0.001	1.029	0.000	0.002	0.001	0.001	0.002	0.105	0.857	4.981
Pl avg	60.01	0.02	24.78	0.01	0.09	0.01	0.02	6.23	7.82	0.26	99.26	avg	2.672	0.001	1.328	0.001	0.003	0.000	0.001	0.320	0.662	0.013	5.000
Bt avg	37.15	3.82	14.15	0.04	18.17	0.06	11.62	0.07	0.10	9.45	94.61	avg	2.846	0.220	1.277	0.002	1.164	0.004	1.327	0.006	0.015	0.883	7.744
M12352A																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.89	0.02	19.04	0.00	0.02	0.01	0.02	0.09	1.43	14.66	99.18	avg	2.965	0.001	1.042	0.000	0.001	0.001	0.001	0.004	0.129	0.868	5.011
Pl avg	59.96	0.01	25.44	0.02	0.03	0.01	0.02	6.79	7.64	0.21	100.12	avg	2.668	0.000	1.334	0.001	0.001	0.000	0.001	0.324	0.659	0.012	5.000
Bt avg	35.74	4.93	15.51	0.01	18.27	0.12	10.98	0.03	0.11	9.60	95.30	avg	2.723	0.283	1.393	0.000	1.165	0.008	1.247	0.003	0.016	0.933	7.772
P-Rut avg*	0.62	52.03	0.56	0.02	38.55	1.30	0.19	0.03	0.02	0.05	93.37	avg	0.044	2.807	0.047	0.001	2.080	0.079	0.020	0.002	0.003	0.005	5.088
Hm avg	0.25	0.16	0.51	0.12	86.92	0.01	0.05	0.02	0.07	0.03	88.14	avg	0.010	0.005	0.024	0.004	2.921	0.000	0.003	0.001	0.005	0.001	2.974
M12352B																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	64.32	0.02	18.66	0.01	0.01	0.00	0.01	0.12	1.49	14.78	99.43	avg	2.986	0.001	1.021	0.000	0.000	0.000	0.001	0.006	0.134	0.837	4.988
Pl avg	60.54	0.02	24.69	0.00	0.02	0.02	0.02	6.02	7.94	0.21	99.47	avg	2.704	0.001	1.300	0.000	0.001	0.001	0.001	0.288	0.688	0.012	4.995
Grt avg	38.32	0.03	21.50	0.01	34.35	1.83	4.25	1.64	0.03	0.00	101.97	avg	3.003	0.002	1.986	0.001	2.252	0.121	0.497	0.138	0.005	0.000	8.004
Bt avg	36.71	4.44	15.63	0.01	18.58	0.06	9.66	0.07	0.12	9.47	94.76	avg	2.803	0.257	1.411	0.000	1.197	0.004	1.107	0.006	0.019	0.883	7.686
M12354																							
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**No.**	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
Kfs avg	63.85	0.04	18.46	0.01	0.02	0.01	0.01	0.14	1.34	14.54	98.43	avg	2.991	0.002	1.019	0.000	0.001	0.001	0.001	0.007	0.122	0.831	4.974
Pl avg	59.95	0.00	24.43	0.02	0.11	0.00	0.02	6.04	7.84	0.18	98.59	avg	2.703	0.000	1.298	0.001	0.004	0.000	0.001	0.292	0.686	0.011	4.995

Table 4-1 continued

Weight % oxide averages

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
M12549											
Kfs avg	64.06	0.03	18.54	0.01	0.02	0.01	0.02	0.05	1.37	14.50	98.61
Pl avg	58.38	0.02	25.42	0.01	0.12	0.01	0.02	7.01	7.26	0.23	98.48
Bt avg	37.92	4.28	13.79	0.02	13.32	0.16	14.57	0.09	0.07	9.20	93.42
Hm avg	0.25	0.02	0.34	0.10	88.32	0.02	0.04	0.03	0.04	0.01	89.16
M12636											
Kfs avg	63.97	0.03	18.58	0.02	0.01	0.01	0.02	0.14	1.62	14.18	98.57
Pl avg	57.43	0.03	26.36	0.03	0.02	0.01	0.02	8.01	6.69	0.27	98.85
Grt avg	38.09	0.04	21.89	0.02	32.65	0.74	6.18	1.52	0.02	0.00	101.15
Bt avg	36.32	3.83	15.86	0.04	15.49	0.03	12.58	0.05	0.12	9.45	93.76
M12637											
Kfs avg	64.88	0.03	18.83	0.01	0.01	0.01	0.01	0.19	1.76	14.43	100.16
Pl avg	58.10	0.02	26.63	0.01	0.02	0.00	0.02	8.15	6.74	0.29	99.97
Bt avg	37.12	4.23	15.75	0.05	17.26	0.05	11.52	0.03	0.09	9.74	95.86
M12638											
Kfs avg	63.73	0.03	18.56	0.01	0.02	0.01	0.01	0.15	1.41	14.67	98.59
Pl avg	59.25	0.01	25.26	0.01	0.06	0.01	0.02	6.87	7.41	0.24	99.14
P-rut avg*	0.15	60.86	0.14	0.02	35.43	0.52	0.09	0.05	0.06	0.01	97.33
Hm avg	0.28	0.11	0.41	0.08	87.66	0.03	0.06	0.03	0.05	0.02	88.72
M12639											
Kfs avg	63.52	0.04	18.32	0.00	0.04	0.01	0.02	0.16	1.34	14.78	98.23
Pl avg	60.94	0.01	24.11	0.00	0.10	0.01	0.02	6.24	7.75	0.25	99.43
Bt avg	37.98	5.52	12.73	0.01	14.73	0.08	14.14	0.03	0.09	10.02	95.33
M12640											
Kfs avg	64.00	0.02	18.35	0.01	0.02	0.01	0.01	0.19	1.20	15.22	99.01
Pl avg	60.06	0.01	24.31	0.01	0.03	0.01	0.01	6.55	7.62	0.23	98.84
Bt avg	36.15	5.55	14.73	0.03	19.15	0.05	10.33	0.03	0.06	9.85	95.93
M12643											
Kfs avg	64.16	0.03	18.57	0.01	0.02	0.01	0.02	0.11	1.60	14.56	99.09
Pl avg	60.64	0.02	24.14	0.01	0.20	0.02	0.14	5.61	7.99	0.50	99.27
Bt avg	36.13	5.21	13.32	0.00	21.98	0.09	9.13	0.08	0.10	9.37	95.41
N01A											
Pl avg	57.79	0.01	27.11	0.01	0.07	0.01	0.01	8.7	6.64	0.09	100.44
Hbl avg	44.10	1.85	10.12	0.05	17.46	0.27	9.96	11.60	1.32	1.29	98.03
N04											
Kfs avg	64.39	0.01	18.72	0.00	0.01	0.00	0.01	0.01	0.54	16.20	99.91
Pl avg	66.72	0.01	20.40	0.00	0.05	0.01	0.10	0.69	10.62	0.85	99.45
N05											
Kfs avg	63.97	0.03	18.78	0.00	0.01	0.01	0.02	0.10	1.50	14.37	98.79
Pl avg	60.32	0.02	25.00	0.01	0.03	0.01	0.01	6.49	7.85	0.20	99.94
Bt avg	55.61	0.09	2.00	0.03	17.75	0.02	6.97	0.02	0.03	10.39	92.90
P-rut avg*	0.09	59.70	0.39	0.03	37.66	1.60	0.07	0.02	0.02	0.01	99.59
N06											
Kfs avg	63.64	0.03	18.84	0.00	0.01	0.00	0.01	0.07	1.02	15.24	98.85
Pl avg	61.78	0.01	24.16	0.01	0.02	0.01	0.01	5.49	8.43	0.26	100.19
Hm avg	0.07	0.06	0.43	0.03	87.75	0.03	0.04	0.00	0.02	0.01	88.44
HW3521											
Kfs avg	64.60	0.03	18.74	0.01	0.01	0.01	0.01	0.17	1.45	14.84	99.88
Pl avg	60.39	0.02	25.14	0.01	0.03	0.01	0.01	6.85	7.62	0.22	100.30
Grt avg	38.55	0.05	21.78	0.08	32.30	0.95	6.39	1.55	0.01	0.00	101.66
Bt avg	37.33	5.35	14.01	0.15	14.51	0.02	13.72	0.02	0.10	10.03	95.23
HW3522											
Kfs avg	64.06	0.02	18.44	0.00	0.01	0.01	0.02	0.12	0.78	15.79	99.25
Pl avg	59.98	0.03	24.86	0.01	0.02	0.01	0.02	6.77	7.54	0.30	99.54
Grt avg	38.23	0.04	21.82	0.07	32.01	0.93	6.53	1.44	0.01	0.00	101.07
Bt avg	37.08	5.22	13.67	0.08	15.59	0.03	13.44	0.01	0.05	10.03	95.19

Cation totals averages

Sample	No.	Si	Ti	Al	Cr	Fe	Mn	Mg	Ca	Na	K	Total
M12549 Kfs	avg	2.993	0.001	1.021	0.000	0.001	0.000	0.001	0.002	0.125	0.827	4.971
M12549 Pl	avg	2.645	0.001	1.357	0.000	0.005	0.001	0.001	0.340	0.638	0.013	5.001
M12549 Bt	avg	2.868	0.243	1.230	0.001	0.843	0.011	1.642	0.007	0.010	0.849	7.703
M12549 Hm	avg	0.010	0.001	0.016	0.003	2.944	0.001	0.003	0.001	0.003	0.000	2.982
M12636 Kfs	avg	2.988	0.001	1.023	0.001	0.001	0.000	0.001	0.007	0.146	0.808	4.976
M12636 Pl	avg	2.598	0.001	1.406	0.001	0.001	0.000	0.001	0.388	0.587	0.016	4.999
M12636 Grt	avg	2.973	0.002	2.013	0.001	2.131	0.049	0.719	0.127	0.003	0.000	8.019
M12636 Bt	avg	2.771	0.220	1.427	0.003	0.989	0.002	1.430	0.004	0.018	0.880	7.743
M12637 Kfs	avg	2.985	0.001	1.021	0.000	0.000	0.001	0.001	0.009	0.157	0.810	4.986
M12637 Pl	avg	2.599	0.001	1.404	0.000	0.001	0.000	0.001	0.391	0.585	0.016	4.998
M12637 Bt	avg	2.792	0.240	1.396	0.003	1.086	0.004	1.292	0.003	0.013	0.894	7.723
M12638 Kfs	avg	2.984	0.001	1.024	0.000	0.001	0.000	0.001	0.008	0.128	0.838	4.985
M12638 Pl	avg	2.663	0.000	1.338	0.000	0.002	0.000	0.001	0.331	0.646	0.014	4.997
M12638 P-rut*	avg	0.010	3.102	0.011	0.001	1.807	0.030	0.009	0.004	0.008	0.001	4.983
M12638 Hm	avg	0.011	0.003	0.019	0.003	2.930	0.001	0.003	0.001	0.004	0.001	2.977
M12639 Kfs	avg	2.981	0.002	1.014	0.000	0.002	0.000	0.001	0.008	0.122	0.885	5.014
M12639 Pl	avg	2.724	0.000	1.270	0.000	0.004	0.000	0.001	0.299	0.672	0.014	4.984
M12639 Bt	avg	2.847	0.311	1.125	0.001	0.924	0.005	1.579	0.002	0.013	0.958	7.765
M12640 Kfs	avg	2.984	0.001	1.008	0.000	0.001	0.000	0.001	0.009	0.108	0.905	5.018
M12640 Pl	avg	2.704	0.000	1.290	0.000	0.001	0.000	0.001	0.316	0.665	0.013	4.991
M12640 Bt	avg	2.751	0.318	1.321	0.002	1.219	0.003	1.172	0.002	0.009	0.957	7.753
M12643 Kfs	avg	2.987	0.001	1.019	0.000	0.001	0.000	0.001	0.005	0.144	0.827	4.987
M12643 Pl	avg	2.718	0.001	1.276	0.000	0.008	0.001	0.010	0.270	0.695	0.029	5.005
M12643 Bt	avg	2.806	0.305	1.220	0.000	1.428	0.006	1.057	0.007	0.015	0.888	7.731
N01A Pl	avg	2.576	0.000	1.425	0.000	0.003	0.001	0.001	0.416	0.574	0.005	5.000
N01A Hbl	avg	6.623	0.209	1.791	0.006	2.193	0.034	2.230	1.867	0.384	0.247	15.585
N04 Kfs	avg	2.981	0.000	1.022	0.000	0.000	0.000	0.001	0.000	0.048	0.957	5.010
N04 Pl	avg	2.944	0.000	1.061	0.000	0.002	0.000	0.007	0.033	0.908	0.048	5.003
N05 Kfs	avg	2.989	0.001	1.022	0.000	0.000	0.000	0.001	0.004	0.085	0.878	4.981
N05 Pl	avg	2.713	0.000	1.286	0.000	0.001	0.000	0.001	0.283	0.711	0.007	5.003
N05 Bt	avg	4.174	0.005	0.176	0.002	1.115	0.001	0.779	0.002	0.004	0.952	7.210
N05 P-rut*	avg	0.006	3.000	0.031	0.020	1.893	0.091	0.007	0.001	0.003	0.001	5.033
N06 Kfs	avg	2.977	0.001	1.039	0.000	0.000	0.000	0.001	0.003	0.092	0.870	4.984
N06 Pl	avg	2.787	0.001	1.213	0.000	0.002	0.000	0.003	0.207	0.768	0.019	5.000
N06 Hm	avg	0.003	0.002	0.021	0.001	2.954	0.001	0.002	0.000	0.002	0.000	2.986
HW3521 Kfs	avg	2.979	0.001	1.019	0.000	0.000	0.001	0.001	0.008	0.129	0.873	5.012
HW3521 Pl	avg	2.681	0.001	1.316	0.000	0.001	0.000	0.001	0.326	0.656	0.012	4.995
HW3521 Grt	avg	2.989	0.003	1.990	0.005	2.094	0.062	0.738	0.129	0.002	0.000	8.012
HW3521 Bt	avg	2.798	0.302	1.238	0.009	0.910	0.001	1.533	0.002	0.015	0.959	7.764
HW3522 Kfs	avg	2.984	0.001	1.013	0.000	0.001	0.000	0.001	0.006	0.070	0.939	5.014
HW3522 Pl	avg	2.684	0.001	1.311	0.000	0.001	0.000	0.001	0.325	0.655	0.017	4.995
HW3522 Grt	avg	2.978	0.003	2.003	0.004	2.086	0.061	0.759	0.120	0.002	0.000	8.016
HW3522 Bt	avg	2.797	0.296	1.216	0.004	0.984	0.002	1.511	0.001	0.007	0.965	7.783

Table 4-1 continued

Weight % oxide averages

HW3523										
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	64.97	0.04	19.09	0.01	0.01	0.01	0.01	0.22	2.17	13.43	99.97
Pl avg	60.30	0.03	25.63	0.01	0.03	0.01	0.02	7.00	7.66	0.20	100.88
Grt avg	38.75	0.05	21.77	0.04	31.26	0.82	7.28	1.28	0.03	0.00	101.26
Bt avg	37.26	4.99	14.70	0.14	13.68	0.03	14.42	0.04	0.12	9.84	95.22
HW3524											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	64.62	0.04	19.19	0.02	0.02	0.01	0.01	0.27	2.08	13.44	99.71
Pl avg	61.03	0.01	25.20	0.01	0.03	0.01	0.01	6.39	7.99	0.16	100.85
Grt avg	38.53	0.05	21.78	0.05	31.55	0.90	7.01	1.39	0.05	0.00	101.31
Bt avg	37.34	4.58	14.34	0.12	13.64	0.04	14.88	0.04	0.16	9.64	94.77
HW3525											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	64.23	0.04	18.84	0.00	0.03	0.01	0.01	0.04	0.91	15.07	99.16
Pl avg	62.35	0.02	24.27	0.01	0.07	0.01	0.01	5.55	8.19	0.38	100.86
Opx avg	53.30	0.06	0.61	0.01	25.66	0.55	20.31	0.65	0.02	0.00	101.17
Ilm avg	0.04	48.26	0.06	0.04	48.73	0.40	1.12	0.01	0.03	0.00	98.68
HW3526											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	64.52	0.04	18.87	0.00	0.02	0.01	0.01	0.07	1.47	14.54	99.56
Pl avg	62.68	0.02	23.85	0.01	0.08	0.01	0.01	5.15	8.59	0.26	100.66
Opx avg	53.47	0.07	0.69	0.01	25.58	0.51	20.62	0.65	0.02	0.01	101.63
Ilm avg	0.04	48.40	0.08	0.03	48.72	0.27	1.23	0.01	0.04	0.00	98.82
HW3527											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	64.05	0.04	18.97	0.01	0.02	0.02	0.01	0.07	1.57	14.55	99.30
Pl avg	62.23	0.01	24.20	0.01	0.06	0.01	0.02	5.18	8.55	0.28	100.55
Bt avg	38.30	4.68	13.36	0.03	11.93	0.06	16.49	0.03	0.04	10.11	95.03
Mt avg	0.07	0.06	0.55	0.48	91.53	0.02	0.07	0.01	0.02	0.00	92.82
HW3530											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	64.02	0.05	18.87	0.00	0.01	0.01	0.01	0.10	2.22	13.41	98.70
Pl avg	61.99	0.01	23.96	0.01	0.06	0.00	0.02	5.18	8.62	0.20	100.04
Ilm avg	0.03	48.12	0.07	0.00	47.98	1.24	0.87	0.02	0.03	0.01	98.35
Hm avg	0.24	0.16	0.45	0.02	86.62	0.02	0.08	0.01	0.04	0.00	87.64
HW1											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	63.43	0.03	18.79	0.01	0.02	0.01	0.02	0.08	0.80	15.67	98.88
Pl avg	60.93	0.02	24.32	0.01	0.08	0.01	0.01	5.57	8.22	0.35	99.52
Opx avg	52.06	0.10	0.71	0.02	26.05	0.83	17.95	0.96	0.03	0.00	98.71
Cpx avg	52.33	0.19	1.59	0.01	10.91	0.37	11.80	22.65	0.59	0.01	100.44
Ilm avg	0.03	52.67	0.05	0.06	47.85	0.99	1.10	0.00	0.00	0.00	102.76
HW2											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	63.00	0.03	18.92	0.01	0.02	0.01	0.01	0.24	0.83	15.53	98.58
Pl avg	60.77	0.01	24.55	0.02	0.06	0.02	0.02	5.69	8.20	0.28	99.62
Opx avg	52.63	0.13	0.78	0.01	25.94	0.74	18.16	0.83	0.03	0.00	99.26
P-rut avg*	0.36	62.53	0.29	0.34	29.15	0.03	0.09	0.24	0.07	0.00	91.08
Mt avg	0.16	0.06	0.27	0.38	90.81	0.02	0.01	0.02	0.01	0.00	91.75
HW3											
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
Kfs avg	63.38	0.03	18.82	0.00	0.02	0.02	0.01	0.03	0.80	15.71	98.81
Pl avg	60.24	0.02	24.24	0.01	0.07	0.01	0.01	5.57	8.03	0.54	98.74
P-rut avg*	0.47	66.25	0.41	0.03	29.55	0.02	0.14	0.22	0.06	0.01	97.15

Cation totals averages

HW3523											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.975	0.001	1.031	0.000	0.001	0.000	0.001	0.011	0.192	0.785	4.997
avg	2.664	0.001	1.335	0.000	0.001	0.001	0.001	0.331	0.656	0.011	5.001
avg	2.997	0.003	1.984	0.002	2.022	0.054	0.839	0.106	0.004	0.000	8.010
avg	2.777	0.280	1.292	0.008	0.853	0.002	1.602	0.003	0.017	0.936	7.769
HW3524											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.968	0.002	1.039	0.001	0.001	0.001	0.001	0.013	0.185	0.788	4.998
avg	2.692	0.000	1.310	0.001	0.001	0.001	0.001	0.302	0.683	0.009	4.999
avg	2.986	0.003	1.990	0.003	2.045	0.059	0.810	0.115	0.008	0.000	8.019
avg	2.794	0.257	1.265	0.007	0.853	0.002	1.659	0.004	0.023	0.920	7.785
HW3525											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.981	0.001	1.030	0.000	0.001	0.000	0.000	0.002	0.081	0.892	4.990
avg	2.743	0.001	1.258	0.001	0.002	0.000	0.001	0.262	0.698	0.021	4.987
avg	1.990	0.002	0.027	0.000	0.801	0.017	1.130	0.026	0.001	0.000	3.995
avg	0.001	0.942	0.002	0.001	1.058	0.009	0.043	0.000	0.001	0.000	2.057
HW3526											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.978	0.002	1.027	0.000	0.001	0.000	0.001	0.004	0.131	0.856	5.000
avg	2.760	0.001	1.238	0.001	0.003	0.000	0.001	0.243	0.733	0.015	4.994
avg	1.986	0.002	0.030	0.000	0.794	0.016	1.142	0.026	0.001	0.000	3.998
avg	0.001	0.942	0.003	0.001	1.055	0.006	0.047	0.000	0.002	0.000	2.056
HW3527											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.968	0.001	1.036	0.000	0.001	0.001	0.001	0.003	0.141	0.860	5.013
avg	2.745	0.000	1.258	0.000	0.002	0.000	0.001	0.245	0.731	0.016	4.999
avg	2.838	0.261	1.167	0.002	0.739	0.004	1.822	0.003	0.005	0.956	7.797
avg	0.003	0.002	0.025	0.015	2.926	0.001	0.004	0.000	0.002	0.000	2.977
HW3530											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.972	0.002	1.032	0.000	0.000	0.001	0.001	0.005	0.199	0.794	5.007
avg	2.748	0.000	1.252	0.000	0.002	0.000	0.001	0.246	0.741	0.011	5.002
avg	0.001	0.943	0.002	0.000	1.046	0.027	0.034	0.001	0.001	0.000	2.056
avg	0.010	0.005	0.021	0.001	2.931	0.001	0.005	0.001	0.003	0.000	2.976
HW1											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.974	0.001	1.039	0.000	0.001	0.000	0.001	0.004	0.073	0.896	4.990
avg	2.721	0.001	1.280	0.000	0.003	0.000	0.001	0.266	0.712	0.020	5.004
avg	2.004	0.003	0.032	0.001	0.839	0.027	1.030	0.040	0.002	0.000	3.978
avg	1.967	0.005	0.070	0.000	0.343	0.012	0.661	0.912	0.043	0.000	4.014
avg	0.001	0.975	0.001	0.001	0.984	0.021	0.040	0.000	0.000	0.000	2.024
HW2											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.964	0.001	1.049	0.000	0.001	0.000	0.001	0.012	0.076	0.891	4.994
avg	2.711	0.000	1.291	0.001	0.002	0.001	0.001	0.272	0.709	0.016	5.005
avg	2.009	0.004	0.035	0.000	0.828	0.024	1.034	0.034	0.002	0.000	3.971
avg	0.025	3.279	0.024	0.019	1.529	0.002	0.009	0.018	0.010	0.000	4.915
avg	0.006	0.002	0.012	0.012	2.946	0.001	0.001	0.001	0.001	0.000	2.981
HW3											
No.	**Si**	**Ti**	**Al**	**Cr**	**Fe**	**Mn**	**Mg**	**Ca**	**Na**	**K**	**Total**
avg	2.974	0.001	1.041	0.000	0.001	0.001	0.001	0.001	0.072	0.899	4.991
avg	2.714	0.001	1.287	0.000	0.003	0.001	0.001	0.269	0.702	0.031	5.008
avg	0.031	3.316	0.032	0.002	1.480	0.001	0.014	0.016	0.008	0.001	4.900

*Pseudorutile iron wt. (%) totals are Fe2O3

Table 4-2: Comparison of calculated vs. actual mode

Mineral	Actual Mode	Calculated Mode (Unormalized)	Calculated Mode (Normalized)	% Relative Error (Unormalized)	% Relative Error (Normalized)
Quartz	25.0	23.1	23.5	7.5	5.8
Plagioclase	30.0	30.6	31.2	2.2	4.0
K-feldspar	20.0	18.3	18.6	8.3	6.6
Biotite	13.0	13.2	13.4	1.4	3.2
Hornblende	10.0	11.0	11.2	10.1	12.1
Ilmenite	2.1	2.0	2.0	5.7	3.9
Total	100	98.2	100.0	1.8	0.0
Residual SSQ		0.050			

Table 4-3: Mineral K values

Mineral	K (W/ m K)
Quartz	7.69
K-feldspar	2.37
Plagioclase	-
Opx	2.75
Cpx	3.39
Garnet	3.31
Hornblende	2.54
Biotite	2.00
Ilmenite	2.20
Rutile	5.12
Hematite	11.28
Magnetite	5.10

From Horai and Simmons, 1969

Table 4-4: Sample mineral abundances with calculated and measured K

Sample	Quartz	K-feldspar	Plagioclase	Opx	Cpx	Garnet	Hornblende	Biotite	Ilmenite	Pseudorutile	Rutile	Hematite	Magnetite	Residual SSQ	Calculated K (W/m K)	Measured K (W/m K)
M0034	32.4	43.8	17.3	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.037	**3.29**	**3.0**
M3796	19.5	29.1	27.1	0.0	0.0	0.0	0.0	9.7	0.0	0.0	0.0	12.5	0.0	1.856	**3.36**	**3.3**
M3997	29.2	34.8	32.7	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	3.869	**3.07**	**3.3**
M4002A	37.8	46.6	9.4	0.0	0.0	0.0	0.0	4.9	0.0	0.1	0.0	0.0	0.0	0.280	**3.55**	**2.8**
M4002B	36.9	46.2	10.1	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.2	0.0	0.0	0.454	**3.55**	**3.7**
M4015A	32.3	33.0	32.2	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.378	**3.26**	**3.1**
M4015B	3.7	0.0	59.2	13.9	0.0	0.0	21.8	0.0	0.0	0.0	0.0	0.0	0.0	2.297	**2.22**	**2.5**
M4017	30.5	29.4	33.4	0.0	0.0	0.0	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.094	**3.19**	**3.6**
M12350	15.8	0.0	65.4	0.0	0.0	0.0	0.0	10.5	0.0	0.0	0.0	0.0	3.9	1.949	**2.34**	**2.0**
M12351	33.7	30.8	27.3	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.060	**3.28**	**2.7**
M12352A	38.7	28.5	23.1	0.0	0.0	0.0	0.0	5.8	0.0	0.3	0.0	2.4	0.0	0.087	**3.62**	**3.6**
M12352B	41.3	21.0	19.7	0.0	0.0	5.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.166	**3.62**	**2.8**
M12354	16.3	39.8	29.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.235	**2.38**	**3.2**
M12549	34.6	35.9	25.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	1.4	0.0	0.044	**3.43**	**3.3**
M12636	31.1	44.0	18.8	0.0	0.0	5.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.097	**3.33**	**2.9**
M12637	27.7	55.7	8.6	0.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.090	**3.13**	**3.6**
M12638	25.1	47.8	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	2.4	0.0	0.605	**3.10**	**3.0**
M12639	26.4	15.1	39.7	0.0	0.0	0.0	0.0	18.6	0.0	0.0	0.0	0.0	0.0	4.856	**2.89**	**2.5**
M12640	23.0	52.4	10.3	0.0	0.0	0.0	0.0	13.6	0.0	0.0	0.0	0.0	0.0	1.537	**2.95**	**2.7**
M12643	33.7	38.7	16.3	0.0	0.0	0.0	0.0	9.8	0.0	0.0	0.0	0.0	0.0	0.206	**3.31**	**3.0**
N01A	9.7	0.0	40.0	0.0	0.0	0.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	5.540	**2.39**	**2.6**
N04	30.1	33.5	34.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.653	**3.17**	**2.8**
N05	7.4	36.8	35.5	0.0	0.0	0.0	0.0	18.7	0.0	1.4	0.0	0.0	0.0	0.505	**2.33**	**2.4**
N06	28.0	33.6	32.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	3.031	**3.20**	**3.1**
HW3521	45.9	15.6	18.1	0.0	0.0	15.2	0.0	5.2	0.0	0.0	0.0	0.0	0.0	0.039	**4.08**	**2.7**
HW3522	51.5	4.2	31.5	0.0	0.0	6.3	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.036	**4.09**	**2.7**
HW3523	17.4	16.9	24.1	0.0	0.0	28.0	0.0	10.8	0.0	0.0	0.0	0.0	0.0	0.418	**2.91**	**2.7**
HW3524	11.7	19.5	9.8	0.0	0.0	43.6	0.0	11.9	0.0	0.0	0.0	0.0	0.0	1.109	**2.93**	**2.7**
HW3525	24.6	13.1	53.1	6.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.276	**2.84**	**2.7**
HW3526	10.7	21.7	52.9	10.5	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.770	**2.43**	**2.7**
HW3527	28.9	24.5	40.5	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	1.5	0.070	**3.10**	**2.7**
HW3530	34.5	34.8	29.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.8	0.0	0.092	**3.39**	**2.7**
HW1	19.6	7.5	57.0	5.6	7.1	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	1.462	**2.74**	**2.7**
HW2	29.9	5.9	56.1	5.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	1.4	0.630	**3.05**	**2.7**
HW3	48.6	4.3	43.3	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	1.916	**3.76**	**2.7**

Measured K values from Verveda et al., 2012

Pseudorutile is assumed to have the same conductivity as ilmenite (the mineral that it is closest to chemically)

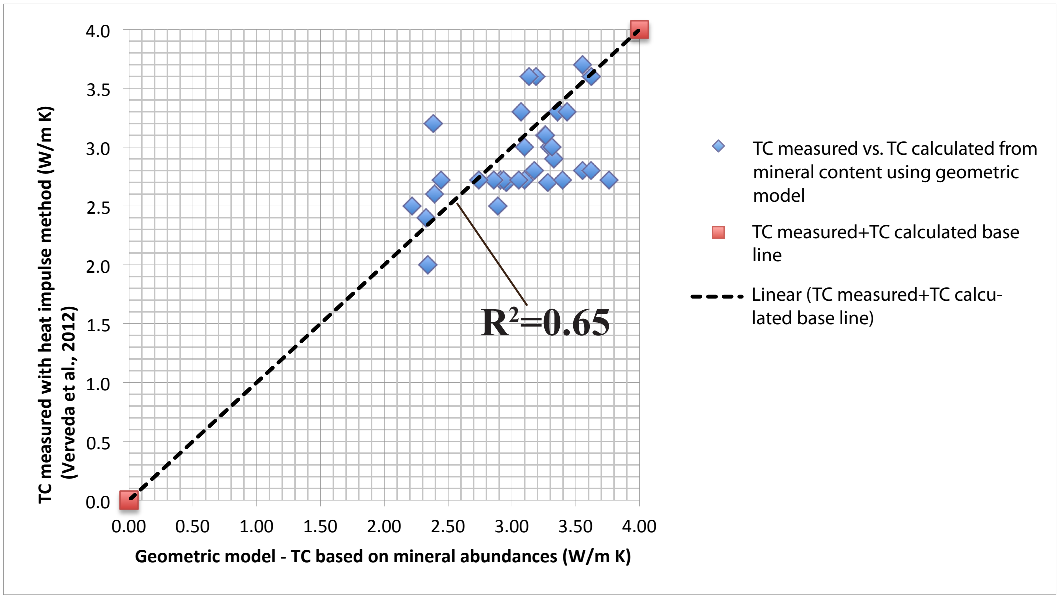
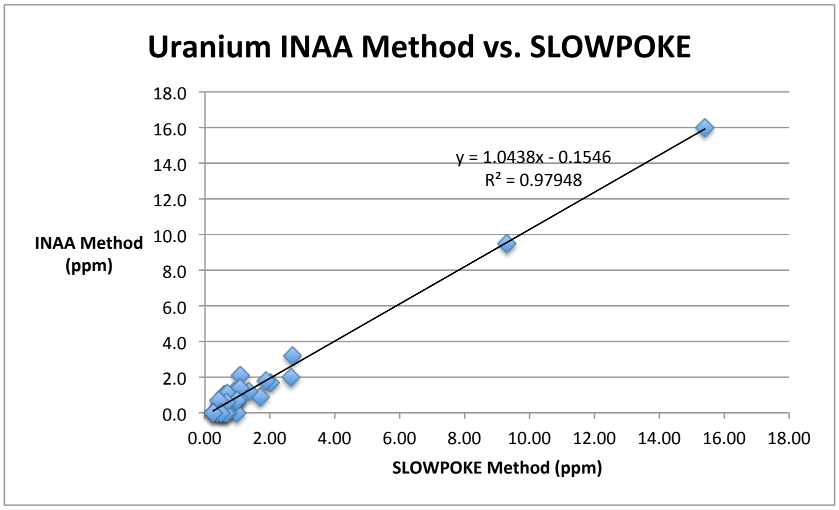


Figure 4-1: Comparison of thermal conductivity of basement drill core samples as indicated by the calculations of the present study and those measured by Verveda et al. (2012) using the heat impulse method.



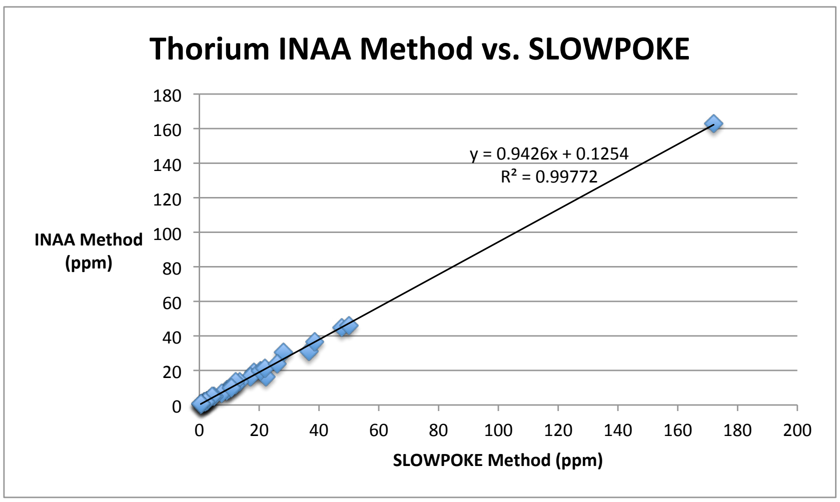


Figure 4-2: Comparison of INAA and SLOWPOKE measurements of U and Th. There is very good agreement between the two methods.

Table 4-5 : All K, U, and Th results

Sample	K (wt.%)	Th (ppm)	U (ppm)	µW/m^3
M0034	5.17	47.6	9.30	6.39
M3796	4.54	172	2.65	13.48
M3997	4.24	10	1.05	1.41
M4002A	6.06	36.6	0.90	3.45
M4002B	5.99	26	0.98	2.71
M4015A	4.54	13.5	0.70	1.60
M4015B	1.22	9.13	1.08	1.06
M4017	4.43	50.0	15.40	8.12
M12350	1.16	2.7	2.02	0.85
M12351	4.52	28.1	0.46	2.58
M12352A	3.89	18.2	1.09	1.97
M12352B	3.50	22.2	1.70	2.39
M12354	4.82	0.45	0.95	0.76
M12549	4.64	1.56	0.49	0.69
M12636	5.25	17.1	0.61	1.90
M12637	7.10	9.25	0.88	1.59
M12638	5.80	20.4	1.35	2.39
M12639	3.44	21.9	0.59	2.06
M12640*	6.10	44.4	3.10	4.60
M12643*	5.50	46.2	2.90	4.62
N01A	1.15	3.65	0.53	0.51
N04C	4.34	12.1	2.70	2.01
N05	5.89	0.61	0.62	0.78
N06	4.06	38.6	0.95	3.42
HW3521	2.41	2.57	0.69	0.60
HW3522	1.13	0.845	0.70	0.36
HW3523	2.76	7.4	0.99	1.06
HW3524	3.31	4.85	1.88	1.17
HW3525	1.83	2.6	0.59	0.52
HW3526	2.73	1.78	0.64	0.56
HW3527	3.41	4.3	0.66	0.82
HW3528	3.72	1.97	0.38	0.60
HW3530	3.90	12.1	0.42	1.36
HW1	1.09	10.7	0.49	1.00
HW2	0.93	0.71	0.25	0.21
HW3	0.75	0.59	0.26	0.18

* = Concentrations of U and Th determined by INAA

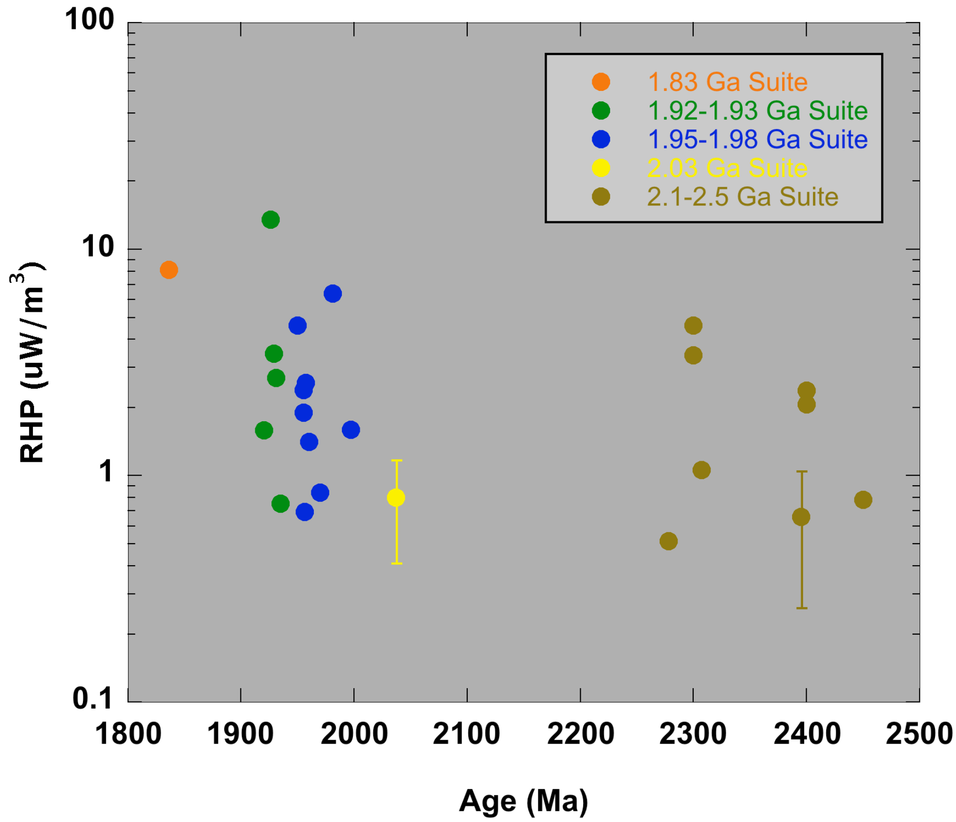


Figure 4-3: Plot of sample age vs. sample radiogenic heat production with RHP plotted logarithmically. Average values for the two Hunt Well suites are included with associated standard deviations. The average global RHP value for the upper crust is 1.70 µW/m^3 (Rudnick and Gao, 2003).

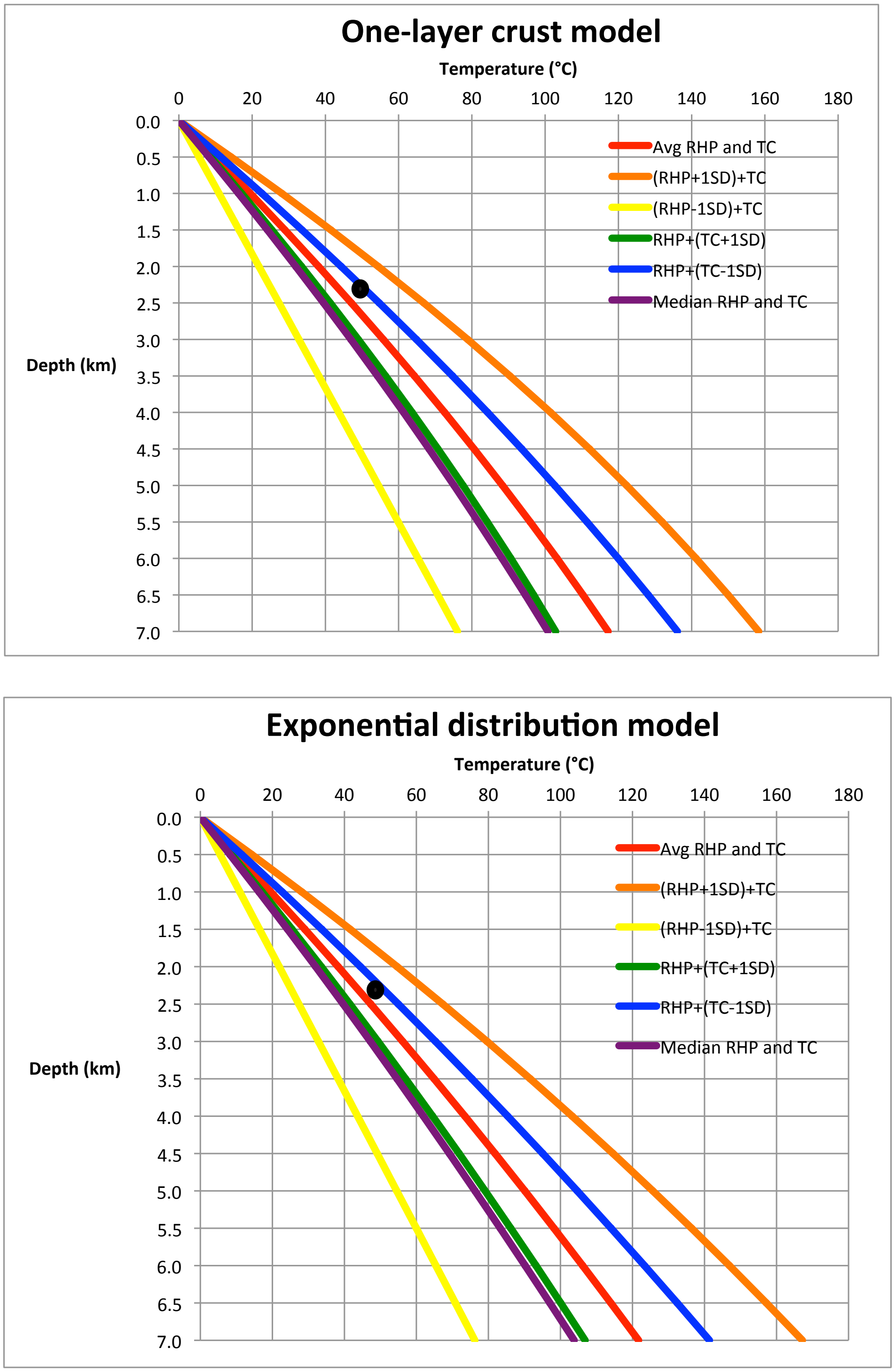


Figure 4-4: a) Temperature vs. depth profiles calculated using one-layer and b) exponential models for RHP distribution in the crust (see text). Red and purple curves are geothermal gradients calculated assuming average and median, respectively, RHP and TC values for the study area. Also plotted are gradients that would be produced if RHP and TC values were 1 standard deviation above or below the average values. The black dots are the temperatures recorded at a 2.3 km depth of the Hunt Well near Fort McMurray (Majorowicz et al., 2012). Average RHP = 2.88 ± 2.79 $\mu W/m^3$ (1σ), Average TC = 3.1 ± 0.43 W/mK (1σ).

Chapter 5 – Conclusions

As stated in Chapter 1, the goal of this thesis was to better understand the geology of the Precambrian basement rocks in the vicinity of Fort McMurray, Alberta and employ this information to evaluate the possibility of using these rocks as part of an Engineered Geothermal System (EGS) for heating water for oil sands processing. The specific objectives of this thesis were: 1) to document the mineralogical and petrological characteristics of available basement drill core samples in our study area, 2) to complete a U-Pb geochronological study for our samples, and 3) to determine the chemical composition of these samples, particularly the concentration of heat-producing elements. All three objectives were achieved and provide valuable information about both the Proterozoic evolution of the basement near Fort McMurray, as well as the geothermal potential in the study area. This chapter will summarize the results obtained in this thesis and also provide suggestions for potential future research in the area.

5.1 Summary

5.1.1 Petrology

The drill core samples studied in this project are all Precambrian basement rocks recovered during previous petroleum exploration in northeast Alberta. Most of the samples are deformed granitoids of the Taltson Magmatic Zone. There are also two samples from the Buffalo Head Terrane to the west and one sample from the Rimbey Domain to the south of the TMZ. Of the total 35 samples investigated in the present study, more than two-thirds were monzogranites and syenogranites. The remaining granitoid samples include quartz diorite, quartz monzonite, and granodiorite. Minor minerals in the granitoids are biotite, garnet, orthopyroxene, ilmenite, magnetite, and apatite. Zircon and monazite are the common accessory minerals and likely a major repository of the heat-producing elements, U and Th, in many of the samples. Remaining samples include a biotite-garnet granitic gneiss, a granitic gneiss fragment, a pelitic composition hercynite-biotite-garnet gneiss, a hornblende-rich mafic granulite, and an amphibolite. Minor alteration is common in many of samples with biotite partially or completely altering to chlorite and primary oxide minerals magnetite and ilmenite to hematite and pseudo-rutile.

5.1.2 Geochronology

On the basis of U-Pb dating of 30 zircon-bearing and 14 monazite-bearing samples, a much more exhaustive geochronological dataset is now available for the Fort McMurray area. In particular, far more dates were obtained for rocks of the southern TMZ than were previously reported.

The U-Pb data generated in this study enabled subdivision of the basement rocks into 5 age suites. Suite 1, which comprises a single granite sample from the Rimbey domain south of Fort McMurray, yielded an upper intercept discordia age of 1836 ± 13 Ma. This Rimbey domain granite is the youngest sample identified in my study and is noted for having strongly metamict zircons and discordant analyses. Suites 2 and 3 are granitoids from the Taltson Magmatic Zone that yielded igneous crystallization ages of 1.92-1.94 and 1.95-1.98 Ga respectively. This same two-fold grouping of Taltson granitoids into older and younger suites has been documented in the exposed part of the belt in northeastern Alberta and the southern Northwest Territories (Bostock et al., 1987; McDonough et al., 2000). The zircons from these two suites are characteristically concordant to slightly discordant zircon analyses but a few samples include zircon grains with older (2.0-3.0 Ga) inherited cores. Suite 4 is a 2.037 Ga (detrital zircon age) pelitic gneiss of metasedimentary origin also located in the TMZ. This sample is possibly from an early Proterozoic basin that was later metamorphosed. Suite 5 is an older 2.25-2.40 Ga basement suite of gneisses, deformed granites, and granulites that has the same general age range as the Taltson Basement Complex documented in the exposed part of the Taltson Magmatic Zone (McNicol et al., 2000). Most samples from this suite are located in the TMZ with the exception of 2 located in the Buffalo Head Terrane. Analyses of zircons in this study reveal a very complex Proterozoic history in the TMZ with many older samples experiencing lead-loss events at ~1.9 Ga.

In contrast to the wide range of ages given by zircon, all but one (M12639) of the monazite analyses conducted in this study yielded ages between 1935 and 1990 Ma. There are monazite age groupings at ~1950, ~1960, and ~1985 Ma. All three age groups may be related to a sequence of regional metamorphic events occurring in the southern TMZ and Buffalo Head Terrane. The exposed Taltson Magmatic Zone in northern Alberta has younger monazite ages from 1917 to 1935 Ma (McDonough et al., 2000; McNicoll et al., 2000).

5.1.3 Geothermal Results

I calculated thermal conductivities (K) for 35 samples using mineral modes determined for these samples and the 'geometric model' of Jessop (1990). The average K value for the 35 samples is 3.09 W/m K with a standard deviation of 0.43 W/m K. Thermal conductivity values for our samples are largely determined by their quartz contents as quartz has a significantly higher K value (7.69 W/m K) than the other abundant minerals in the basement rocks. The older samples of the Taltson Basement Complex (Suite 5) tend to have large variations for K values due to the fact that these rocks include both felsic and mafic compositions with variable quartz content. Thermal conductivities calculated in the present study using the geometric model are generally in good agreement with direct measurements of thermal conductivity for our samples (Verveda et al., 2012).

Radiogenic heat production (RHP) values were calculated for the basement samples on the basis of chemical determinations of their K, U, and Th contents. The samples have an average of 2.9 $\mu W/m^3$ with a large standard deviation of 2.8 $\mu W/m^3$. RHP is largely controlled by concentrations of uranium and thorium with the potassium contribution being relatively minor. When RHP values are plotted against sample age it is noted that while there is no obvious suites of high RHP, the higher RHP values tend to occur with younger samples. The older rocks of the Taltson Basement Complex (Suite 5) have more variable and, on average, lower RHP values.

Using the above calculations for geothermal parameters, two temperature vs. depth models were calculated using assumed input values of mantle heat flow and crustal layer thickness of active RHP. Also included were the calculated average values of radiogenic heat production and thermal conductivities of the basement rocks. The first model assumed a homogeneous concentration of RHP in a 10 km thick heat-producing layer in the upper crust whereas the second model assumed an exponential decrease in

RHP with depth (Spear, 1993). Both models produce similar geothermal gradients with the exponential model producing slightly higher temperatures at a given depth. In the modeling, a one standard deviation shift of thermal conductivities above and below the average value produces only a ~25°C variation in temperature at a 5 km depth. In contrast, because of the intrinsic variability in the RHP values of the basement rocks, a one standard deviation shift in RHP values produces a ~69°C variation in temperature at 5 km depth. Thus the ideal EGS location would take advantage of a high RHP value basement location, and in particular a location where RHP values were high not just at the basement-sediment interface but remained high at depth.

5.2 Future Work

Recent EGS research in the Fort McMurray (including this study) area has built upon previous research worldwide examining the geothermal potential in 'hot-dry rocks'. Previous study locations of hot-dry rocks include the Cooper Basin in Australia (Tester et al., 2006), the Erzgebirge in Germany (Forster and Forster, 2000), and Soultz-sous-Forêts in France (Genter, 2009).

The major disadvantage of drill core studies is the lack of sample material and questions of representative sampling. Most of the drill core samples investigated in this study were obtained from the very top of the Precambrian basement, only a few meters below the basement-sediment interface. The single deep well, the Hunt Well, was only cored at 2 depths; 1650 m and 2350-64 m. To further understand the deep basement geology required for an EGS, a more comprehensive study involving one or more deep test wells is required. A region of high RHP is the ideal target for greater geothermal gradients as RHP appears to be the largest contributing variable in the upper crust. Direct temperature measurements of a deep test well can confirm the validity of temperature as a function of depth models described in Chapter 4. These wells, and any future production wells, should be located near Fort McKay (location of the Athabasca oil sands processing facilities) to minimize heat loss during surface transport of hot water.

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APPENDIX A

Well Name	Sample Name	Latitude (N)	Longitude (W)	Township & Range	Sample Depth (m)
Alberta Government Salt Well No. 2	M0034	56.673431	111.251597	5-32-88-8W4	240.5
Baysel Birch Hills #9-34	M3796	57.200718	112.155512	9-34-94-14W4	609.6
Amerada Mink Lake S.T.H. No. 5	M3997	56.895369	112.135379	10-14-91-14W4	735.8
California Standard Mikkwa #12-23	M4002A	57.520666	113.307480	12-23-98-21W4	1169.8
California Standard Mikkwa #12-23	M4002B	57.520666	113.307480	12-23-98-21W4	1170.4
Imperial Wolverine #7-24	M4015A	55.597217	112.654919	7-24-76-18W4	1412.0
Imperial Wolverine #7-24	M4015B	55.597217	112.654919	7-24-76-18W4	1414.0
Mobil Oil Chard #12-27	M4017	55.789887	110.545963	12-27-78-4W4	782.4
RO Corp Janvier	M12350	55.946221	110.681010	5-23-80-5W4	692.5
RO Corp Watchusk Lake	M12351	56.179030	110.437187	7-8-83-3W4	575.2
Fina IOE Buffalo Creek	M12352	56.560652	113.391577	10-23-87-22 W4	1198.0
Shell Eatha EV	M12354	57.378911	110.978430	13-31-96-6W4	264.7
Merrill Arab Chard 5-34	M12549	55.800799	110.856542	5-34-78-6W4	873.3
Bear Biltmore No. 1	M12636	56.527973	112.593936	7-11-87-17W4	870.8
Bear Biltmore No. 1	M12637	56.527973	112.593936	7-11-87-17W4	868.7
Bear Westmount No. 1	M12638	56.448073	111.049705	14-9-86-7W4	546.2
Bear Westmount No. 2	M12639	56.673408	111.125351	8-36-88-8W4	283.2
Bear Vampire No. 1	M12640	56.571604	111.849635	7-28-87-12W4	701.6
Bear Rodeo No. 1	M12643	56.724359	111.391074	16-17-89-9W4	347.8
Thornbury	N01A	55.869798	111.548925	1-30-79-10W4	1140.3
Undefined-Alta	N02	57.037129	111.846865	6-3-93-12W4	513.0
Undefined-Alta	N03	57.055305	111.833444	9-10-93-12W4	502.5
Undefined-Alta	N04B	57.215348	110.971682	11-6-95-06W4	443.2
Undefined-Alta	N04C	57.215348	110.971682	11-6-95-06W4	445.4
Undefined-Alta	N05C	57.229896	111.303397	12-7-95-08W4	310.9
Undefined-Alta	N06C	56.513396	113.424805	6-3-87-22W4	1225.0
AOC Granite (Hunt Well)	HW3521	56.760667	111.557302	7-32-89-10W4	1656.5
AOC Granite (Hunt Well)	HW3522	56.760667	111.557302	7-32-89-10W4	1657.0
AOC Granite (Hunt Well)	HW3523	56.760667	111.557302	7-32-89-10W4	1657.5
AOC Granite (Hunt Well)	HW3524	56.760667	111.557302	7-32-89-10W4	1657.0
AOC Granite (Hunt Well)	HW3525	56.760667	111.557302	7-32-89-10W4	2350.4
AOC Granite (Hunt Well)	HW3526	56.760667	111.557302	7-32-89-10W4	2350.6
AOC Granite (Hunt Well)	HW3527	56.760667	111.557302	7-32-89-10W4	2350.1
AOC Granite (Hunt Well)	HW3528	56.760667	111.557302	7-32-89-10W4	2355.0
AOC Granite (Hunt Well)	HW3530	56.760667	111.557302	7-32-89-10W4	2364.0
AOC Granite (Hunt Well)	HW-1B	56.760667	111.557302	7-32-89-10W4	2364.0
AOC Granite (Hunt Well)	HW-2B	56.760667	111.557302	7-32-89-10W4	2364.0
AOC Granite (Hunt Well)	HW-3B	56.760667	111.557302	7-32-89-10W4	2364.0

APPENDIX B - U-Pb Geochronological Data

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains

											Ages (Ma)						
Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M4017-5A	30	667066	681	0.09738	0.00273	0.71391	0.04791	0.05317	0.00324	0.90840	1575	52	547	28	334	20	80.8
M4017-6.1A	30	701886	574	0.10848	0.00297	1.51745	0.10140	0.10145	0.00618	0.91212	1774	49	937	40	623	36	68.0
M4017-6.1B	30	470050	905	0.10154	0.00283	0.62362	0.06225	0.04454	0.00427	0.96011	1652	51	492	38	281	26	84.8
M4017-6.1C	30	948151	443	0.11106	0.00296	2.07651	0.17329	0.13560	0.01072	0.94765	1817	48	1141	56	820	61	58.3
M4017-6.1D	30	845217	506	0.10950	0.00295	2.02351	0.12395	0.13403	0.00737	0.89813	1791	48	1123	41	811	42	58.2
M4017-6.2A	30	882560	553	0.11139	0.00299	2.15540	0.19027	0.14034	0.01180	0.95256	1822	48	1167	59	847	66	57.0
M4017-6.2B	30	399827	1167	0.10582	0.00502	0.63529	0.05197	0.04354	0.00290	0.81483	1729	85	499	32	275	18	85.8
M4017-7.1A	30	1938375	0	0.11150	0.00297	4.82841	0.22656	0.31409	0.01213	0.82339	1824	48	1790	39	1761	59	4.0
M4017-7.1B	30	1837537	4	0.11202	0.00299	4.86373	0.24337	0.31490	0.01333	0.84609	1832	48	1796	41	1765	65	4.2
M4017-7.1C	30	1539617	340	0.11075	0.00301	3.35812	0.23353	0.21992	0.01408	0.92035	1812	49	1495	53	1281	74	32.2
M4017-7.1D	30	2434582	120	0.11289	0.00303	4.65284	0.23982	0.29892	0.01316	0.85392	1846	48	1759	42	1686	65	9.9
M3796-1A	30	224202	14	0.11814	0.00118	5.50286	0.35429	0.33783	0.02149	0.98791	1928	18	1901	54	1876	103	3.1
M3796-1B	30	207578	6	0.11743	0.00113	5.69632	0.37621	0.35181	0.02299	0.98938	1918	17	1931	56	1943	109	-1.6
M3796-1C	30	123758	3	0.11758	0.00121	5.56756	0.32291	0.34341	0.01960	0.98424	1920	18	1911	49	1903	93	1.0
M3796-1D	30	81596	4	0.11806	0.00121	5.57363	0.31755	0.34241	0.01919	0.98360	1927	18	1912	48	1898	91	1.7
M3796-1E	30	145738	4	0.11785	0.00120	5.77075	0.37846	0.35515	0.02301	0.98792	1924	18	1942	55	1959	109	-2.1
M3796-1F	30	182224	2	0.11766	0.00116	5.67002	0.30297	0.34951	0.01835	0.98281	1921	18	1927	45	1932	87	-0.7
M3796-2A	30	54948	5	0.11855	0.00140	5.34715	0.28833	0.32712	0.01721	0.97560	1935	21	1876	45	1824	83	6.5
M3796-2B	30	96107	1	0.11802	0.00118	5.49177	0.29592	0.33749	0.01787	0.98274	1926	18	1899	45	1875	86	3.1
M3796-2C	30	91971	0	0.11841	0.00128	5.59170	0.33445	0.34250	0.02015	0.98363	1932	19	1915	50	1899	96	2.0
M3796-2D	30	82233	3	0.11832	0.00120	5.61768	0.37755	0.34436	0.02288	0.98852	1931	18	1919	56	1908	109	1.4
M3796-2E	30	109266	1	0.11778	0.00117	5.60122	0.29901	0.34493	0.01809	0.98254	1923	18	1916	45	1910	86	0.7
M3796-2F	30	72391	6	0.11859	0.00131	5.43410	0.32566	0.33232	0.01957	0.98283	1935	20	1890	50	1850	94	5.1
M3796-2G	30	115501	0	0.11748	0.00114	5.57323	0.27511	0.34407	0.01665	0.98045	1918	17	1912	42	1906	79	0.7
M3796-2H	30	57884	0	0.11935	0.00125	5.50200	0.37570	0.33436	0.02256	0.98824	1946	19	1901	57	1859	108	5.1
M3796-2I	30	56663	1	0.11818	0.00129	5.31773	0.28970	0.32636	0.01742	0.97982	1929	19	1872	46	1821	84	6.4
M3796-2J	30	47742	0	0.11825	0.00125	5.42095	0.26905	0.33248	0.01612	0.97712	1930	19	1888	42	1850	78	4.7
M3796-2K	30	31185	0	0.11944	0.00137	5.47950	0.32459	0.33273	0.01934	0.98117	1948	20	1897	50	1852	93	5.7
M3796-2L	30	54121	0	0.11911	0.00136	5.34812	0.32429	0.32565	0.01939	0.98206	1943	20	1877	51	1817	94	7.4
M3796-2M	30	72457	3	0.11851	0.00123	5.64160	0.40081	0.34527	0.02426	0.98920	1934	19	1922	59	1912	115	1.3
M3796-3A	30	286539	1	0.11812	0.00116	5.70812	0.29743	0.35049	0.01793	0.98200	1928	18	1933	44	1937	85	-0.5
M3796-3B	30	226570	1	0.11700	0.00115	5.62842	0.33020	0.34890	0.02018	0.98597	1911	17	1920	49	1929	96	-1.1
M3796-3C	30	203869	0	0.11744	0.00114	5.32712	0.35504	0.32898	0.02169	0.98941	1918	17	1873	55	1833	104	5.0
M3796-3D	30	218270	0	0.11799	0.00116	5.92575	0.33867	0.36424	0.02051	0.98505	1926	18	1965	48	2002	96	-4.6
M3796-3E	30	184759	0	0.11788	0.00116	5.51536	0.40727	0.33935	0.02483	0.99101	1924	18	1903	62	1884	118	2.4
M3796-4A	30	133168	0	0.11739	0.00114	5.58021	0.30928	0.34476	0.01881	0.98460	1917	17	1913	47	1910	90	0.4
M3796-5A	30	228967	2	0.11766	0.00116	5.52018	0.34531	0.34027	0.02102	0.98745	1921	18	1904	52	1888	100	2.0
M3796-5B	30	129107	0	0.11710	0.00119	5.50805	0.45270	0.34114	0.02782	0.99235	1912	18	1902	68	1892	132	1.2
M3796-5C	30	98421	0	0.11746	0.00116	5.75032	0.34372	0.35505	0.02093	0.98617	1918	18	1939	50	1959	99	-2.5
M3796-6A	30	126723	1	0.11764	0.00122	6.18147	0.33608	0.38109	0.02034	0.98166	1921	18	2002	46	2081	94	-9.8
M3796-6B	30	228137	0	0.11789	0.00116	5.97978	0.33099	0.36789	0.02004	0.98409	1924	18	1973	47	2019	94	-5.8
M3796-6C	30	42037	0	0.11895	0.00145	5.52272	0.31000	0.33673	0.01845	0.97628	1941	22	1904	47	1871	88	4.1
M3796-7A	30	70726	0	0.11839	0.00136	5.73613	0.35873	0.35141	0.02160	0.98304	1932	20	1937	53	1941	102	-0.6
M3796-7B	30	86045	0	0.11847	0.00124	5.69018	0.33779	0.34834	0.02035	0.98431	1933	19	1930	50	1927	97	0.4
M3796-7C	30	94816	1	0.11816	0.00120	5.53607	0.33872	0.33982	0.02050	0.98620	1929	18	1906	51	1886	98	2.6

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	$^{207}Pb/^{206}Pb$	±2 s	$^{207}Pb/^{235}U$	±2 s	$^{206}Pb/^{238}U$	±2 s	r	Ages (Ma) $^{207}Pb^*/^{206}Pb^*$	±2 s	$^{207}Pb^*/^{235}U$	±2 s	$^{206}Pb^*/^{238}U$	±2 s	% Disc.
M3796-7D	30	77508	0	0.11823	0.00124	5.52449	0.31637	0.33890	0.01908	0.98315	1930	19	1904	48	1881	91	2.9
M3796-7E	30	86322	0	0.11863	0.00121	5.66752	0.30986	0.34650	0.01861	0.98239	1936	18	1926	46	1918	88	1.1
M3796-7F	30	117841	0	0.11792	0.00119	5.67329	0.33631	0.34893	0.02038	0.98528	1925	18	1927	50	1929	97	-0.3
M3796-7G	30	110522	0	0.11829	0.00116	5.71616	0.36890	0.35048	0.02235	0.98833	1931	18	1934	54	1937	106	-0.4
M3796-8A	30	298521	18	0.11913	0.00117	5.57496	0.34482	0.33939	0.02073	0.98735	1943	17	1912	52	1884	99	3.5
M3796-8B	30	236251	20	0.11852	0.00160	5.16866	0.35726	0.31630	0.02144	0.98072	1934	24	1847	57	1772	104	9.6
M3796-9.2A	30	249205	0	0.11719	0.00116	5.57309	0.30212	0.34491	0.01838	0.98323	1914	18	1912	46	1910	88	0.2
M3796-9.2B	30	351334	0	0.11654	0.00113	5.71002	0.37342	0.35536	0.02298	0.98899	1904	17	1933	55	1960	108	-3.4
M4002A-1.1A	30	426676	35	0.11898	0.00123	6.24387	0.29917	0.38060	0.01781	0.97650	1941	18	2011	41	2079	83	-8.3
M4002A-1.1B	30	495974	43	0.11692	0.00122	5.89537	0.34105	0.36569	0.02081	0.98359	1910	19	1961	49	2009	97	-6.1
M4002A-2.1A	30	763464	70	0.11757	0.00134	4.99395	0.24496	0.30808	0.01470	0.97250	1920	20	1818	41	1731	72	11.2
M4002A-2.1C	30	739840	63	0.11642	0.00131	5.00534	0.25530	0.31183	0.01551	0.97532	1902	20	1820	42	1750	76	9.1
M4002A-2.1E	30	517608	49	0.11529	0.00123	5.44496	0.30112	0.34253	0.01858	0.98108	1884	19	1892	46	1899	89	-0.9
M4002A-3.1A	30	219834	2	0.11887	0.00126	5.92751	0.27872	0.36166	0.01657	0.97412	1939	19	1965	40	1990	78	-3.0
M4002A-3.1B	30	968923	4	0.11930	0.00125	5.72373	0.28049	0.34796	0.01666	0.97701	1946	19	1935	41	1925	79	1.2
M4002A-3.1C	30	684627	3	0.11823	0.00122	5.71225	0.28670	0.35042	0.01721	0.97870	1930	18	1933	42	1937	82	-0.4
M4002A-3.1D	30	435228	5	0.11705	0.00120	5.11492	0.28228	0.31694	0.01719	0.98273	1912	18	1839	46	1775	84	8.2
M4002A-4.1A	30	445674	3	0.11984	0.00124	5.84337	0.36017	0.35364	0.02149	0.98573	1954	18	1953	52	1952	102	0.1
M4002A-4.1B	30	525271	16	0.11934	0.00123	5.93279	0.38479	0.36057	0.02309	0.98721	1946	18	1966	55	1985	108	-2.3
M4002A-4.1C	30	1037758	63	0.11913	0.00134	5.86984	0.36922	0.35734	0.02212	0.98389	1943	20	1957	53	1970	104	-1.6
M4002A-4.1D	30	309184	3	0.11939	0.00124	6.09868	0.40051	0.37049	0.02403	0.98746	1947	18	1990	56	2032	112	-5.1
M4002A-4.1E	30	472591	8	0.11895	0.00123	6.04186	0.30605	0.36839	0.01827	0.97905	1940	18	1982	43	2022	85	-4.9
M4002A-4.1F	30	589686	7	0.11785	0.00122	5.85775	0.35098	0.36050	0.02128	0.98504	1924	18	1955	51	1985	100	-3.7
M4002A-5.1B	30	871714	532	0.12106	0.00138	5.41377	0.43038	0.32433	0.02552	0.98972	1972	20	1887	66	1811	123	9.4
M4002A-5.1C	30	244822	30	0.11998	0.00150	6.48334	0.32688	0.39190	0.01914	0.96887	1956	22	2044	43	2132	88	-10.6
M4002A-6.1B	30	987118	31	0.11585	0.00121	5.34900	0.22253	0.33487	0.01348	0.96788	1893	19	1877	35	1862	65	1.9
M4002A-6.1C	30	942496	49	0.11758	0.00127	5.56466	0.38693	0.34323	0.02358	0.98788	1920	19	1911	58	1902	112	1.1
M4002A-6.1D	30	299921	1	0.11668	0.00128	5.46903	0.26905	0.33996	0.01630	0.97486	1906	20	1896	41	1886	78	1.2
M4002A-7.1A	30	702805	2	0.11742	0.00121	5.58823	0.27438	0.34516	0.01657	0.97755	1917	18	1914	41	1911	79	0.4
M4002A-7.1C	30	1374150	8	0.11784	0.00126	5.67401	0.29500	0.34921	0.01777	0.97857	1924	19	1927	44	1931	84	-0.4
M4002A-7.1D	30	334712	0	0.11865	0.00125	5.83108	0.27807	0.35643	0.01658	0.97546	1936	19	1951	41	1965	78	-1.7
M4002A-8.1D	30	1427060	36	0.11649	0.00119	5.48740	0.26521	0.34166	0.01614	0.97723	1903	18	1899	41	1895	77	0.5
M4002A-9.1A	30	316387	3	0.11865	0.00121	5.52909	0.28567	0.33797	0.01712	0.98017	1936	18	1905	43	1877	82	3.5
M4002A-9.1B	30	366624	3	0.11923	0.00124	5.53588	0.32642	0.33674	0.01954	0.98429	1945	18	1906	49	1871	94	4.4
M4002A-9.1C	30	292274	0	0.11891	0.00126	6.05132	0.56274	0.36910	0.03410	0.99347	1940	19	1983	78	2025	159	-5.1
M4002B-1.2A	30	494756	39	0.11924	0.00127	6.51497	0.48460	0.39627	0.02917	0.98965	1945	19	2048	63	2152	133	-12.5
M4002B-1.2B	30	632239	70	0.11879	0.00129	5.92817	0.35836	0.36194	0.02152	0.98382	1938	19	1965	51	1991	101	-3.2
M4002B-1.2C	30	468190	17	0.12025	0.00135	6.05362	0.38674	0.36510	0.02296	0.98450	1960	20	1984	54	2006	108	-2.7
M4002B-5.1A	30	442279	1	0.11710	0.00122	4.83077	0.27860	0.29920	0.01697	0.98346	1912	19	1790	47	1687	84	13.4
M4002B-5.1B	30	629832	1	0.11331	0.00125	4.64171	0.25747	0.29712	0.01615	0.98001	1853	20	1757	45	1677	80	10.8
M4002B-5.1C	30	374297	0	0.11781	0.00124	5.66940	0.35142	0.34901	0.02132	0.98543	1923	19	1927	52	1930	101	-0.4
M4002B-5.1D	30	443259	0	0.11726	0.00121	5.42146	0.31661	0.33533	0.01928	0.98428	1915	18	1888	49	1864	92	3.0
M4002B-6.1A	30	495023	0	0.11420	0.00121	4.43650	0.28322	0.28176	0.01774	0.98622	1867	19	1719	52	1600	89	16.1
M4002B-6.1B	30	661421	3	0.11184	0.00166	2.98346	0.28461	0.19347	0.01823	0.98780	1830	27	1403	70	1140	98	41.0

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

											Ages (Ma)						
Analysis	Spot Size µm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12354-1A	30	2066831	385	0.10149	0.00104	2.00715	0.12011	0.14344	0.00846	0.98535	1651	19	1118	40	864	48	50.9
M12354-1B	30	1639704	215	0.10393	0.00104	3.57419	0.21982	0.24942	0.01513	0.98657	1695	18	1544	48	1435	78	17.1
M12354-3A	30	188356	74	0.11680	0.00203	4.16771	0.30442	0.25879	0.01836	0.97134	1908	31	1668	58	1484	93	24.9
M12354-4A	30	409254	73	0.11743	0.00140	5.19165	0.25429	0.32064	0.01523	0.96981	1917	21	1851	41	1793	74	7.4
M12354-4B	30	930960	79	0.11415	0.00104	5.29570	0.23294	0.33648	0.01448	0.97830	1866	16	1868	37	1870	69	-0.2
M12354-4C	30	839152	62	0.10886	0.00125	4.51372	0.16681	0.30073	0.01056	0.95018	1780	21	1734	30	1695	52	5.5
M12354-4D	30	1416437	103	0.10343	0.00103	3.62580	0.20332	0.25426	0.01403	0.98404	1686	18	1555	44	1460	72	15.0
M12354-5A	30	915846	114	0.10999	0.00109	4.54443	0.24323	0.29965	0.01576	0.98255	1799	18	1739	44	1690	78	6.9
M12354-5B	30	999780	107	0.11449	0.00100	5.03918	0.20542	0.31922	0.01271	0.97683	1872	16	1826	34	1786	62	5.3
M12354-5C	30	1219669	180	0.10819	0.00140	4.20860	0.19815	0.28213	0.01277	0.96169	1769	23	1676	38	1602	64	10.7
M12354 1-1A	30	1679134	1198	0.11342	0.00201	4.58735	0.39519	0.29333	0.02473	0.97864	1855	32	1747	69	1658	122	12.0
M12354 1-1B	30	1062322	552	0.11468	0.00157	5.32942	0.70507	0.33706	0.04435	0.99461	1875	25	1874	107	1873	210	0.1
M12354 1-1C	30	1373618	558	0.11547	0.00146	4.65787	0.22061	0.29257	0.01335	0.96377	1887	23	1760	39	1654	66	14.0
M12354 1-1D	30	1417894	833	0.11275	0.00146	4.34067	0.26271	0.27922	0.01651	0.97694	1844	23	1701	49	1587	83	15.7
M12354 1-1E	30	432524	21	0.11884	0.00148	5.57671	0.29971	0.34033	0.01779	0.97274	1939	22	1913	45	1888	85	3.0
M12354 1-1F	30	1488294	665	0.11040	0.00151	4.16506	0.28216	0.27362	0.01816	0.97949	1806	25	1667	54	1559	91	15.4
M12354 1-1G	30	151558	22	0.11673	0.00148	5.25279	0.42944	0.32638	0.02636	0.98792	1907	23	1861	67	1821	127	5.2
M12354 1-1H	30	168147	22	0.11732	0.00150	5.47160	0.32470	0.33824	0.01960	0.97649	1916	23	1896	50	1878	94	2.3
M12354 2-1A	30	356343	25	0.11923	0.00151	6.04563	0.38366	0.36775	0.02287	0.97989	1945	22	1982	54	2019	107	-4.4
M12354 2-1B	30	303421	23	0.11446	0.00147	5.22630	0.27341	0.33116	0.01680	0.96957	1871	23	1857	44	1844	81	1.7
M12354 2-1C	30	266337	22	0.11920	0.00153	5.76472	0.43353	0.35076	0.02599	0.98542	1944	23	1941	63	1938	123	0.4
M12354 2-1D	30	310347	28	0.11903	0.00151	5.33965	0.22627	0.32534	0.01315	0.95387	1942	23	1875	36	1816	64	7.4
M12354 2-1E	30	552783	24	0.09644	0.00132	3.34365	0.20597	0.25146	0.01510	0.97496	1556	25	1491	47	1446	77	7.9
M12354 3-1A	30	1027528	106	0.11608	0.00210	4.58347	0.24366	0.28638	0.01431	0.94004	1897	32	1746	43	1623	71	16.3
M12354 3-1B	30	1554233	201	0.10946	0.00171	3.72842	0.24415	0.24705	0.01571	0.97118	1790	28	1577	51	1423	81	22.8
M12354 3-1C	30	661475	101	0.11264	0.00157	4.64213	0.23093	0.29890	0.01427	0.95991	1842	25	1757	41	1686	70	9.7
M12354 4-1A	30	336085	24	0.11900	0.00149	5.86324	0.41647	0.35736	0.02499	0.98437	1941	22	1956	60	1970	118	-1.7
M12354 4-1B	30	501364	13	0.11016	0.00164	4.33956	0.27743	0.28572	0.01777	0.97260	1802	27	1701	51	1620	88	11.4
M12354 4-1C	30	636745	878	0.10802	0.00290	3.91919	0.35024	0.26313	0.02243	0.95373	1766	48	1618	70	1506	113	16.5
M12354 4-1D	30	446968	25	0.11489	0.00147	4.99610	0.31796	0.31538	0.01966	0.97958	1878	23	1819	52	1767	96	6.8
M12354 4-1E	30	251249	14	0.11825	0.00150	5.82816	0.31141	0.35746	0.01855	0.97145	1930	23	1951	45	1970	88	-2.4
M12354 4-1F	30	547924	25	0.11934	0.00152	5.67424	0.29090	0.34484	0.01712	0.96847	1946	23	1927	43	1910	82	2.2
M12354 4-1G	30	395142	25	0.11896	0.00149	5.87921	0.45340	0.35843	0.02727	0.98666	1941	22	1958	65	1975	128	-2.0
M12354 4-1H	30	450405	20	0.11908	0.00151	5.45552	0.34932	0.33228	0.02085	0.98012	1942	23	1894	54	1849	100	5.5
M12354 4-2A	30	507057	14	0.11959	0.00150	5.56951	0.32987	0.33776	0.01955	0.97725	1950	22	1911	50	1876	94	4.4
M12354 4-2B	30	588732	23	0.11967	0.00152	5.56092	0.29223	0.33701	0.01719	0.97048	1951	22	1910	44	1872	82	4.7
M12354 4-2C	30	1089180	100	0.11481	0.00150	4.91227	0.27546	0.31030	0.01692	0.97246	1877	23	1804	46	1742	83	8.2
M12354 4-2D	30	435969	12	0.11896	0.00148	5.70070	0.27468	0.34756	0.01618	0.96610	1941	22	1931	41	1923	77	1.1
M12354 5-1A	30	720122	22	0.11833	0.00149	5.51721	0.30744	0.33816	0.01835	0.97403	1931	22	1903	47	1878	88	3.2
M12354 5-1B	30	575545	11	0.11854	0.00149	5.80823	0.26781	0.35538	0.01577	0.96228	1934	22	1948	39	1960	75	-1.6
M12354 6-1A	30	836193	88	0.10141	0.00139	3.88602	0.23701	0.27793	0.01652	0.97440	1650	25	1611	48	1581	83	4.7
M12637-1A	30	179026	1	0.11720	0.00110	5.32781	0.32564	0.32970	0.01991	0.98810	1914	17	1873	51	1837	96	4.6
M12637-1B	30	1645322	70	0.11936	0.00106	6.04968	0.49231	0.36760	0.02974	0.99405	1947	16	1983	69	2018	139	-4.3
M12637-2A	30	410994	36	0.11972	0.00107	6.06031	0.29917	0.36713	0.01782	0.98338	1952	16	1985	42	2016	83	-3.8

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	Ages (Ma) ^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12637-2B	30	385354	27	0.11772	0.00105	5.53893	0.28606	0.34125	0.01736	0.98492	1922	16	1907	43	1893	83	1.8
M12637-2C	30	342144	24	0.11786	0.00106	5.95240	0.41889	0.36629	0.02556	0.99172	1924	16	1969	59	2012	119	-5.3
M12637-3A	30	198264	17	0.11842	0.00110	5.52191	0.22009	0.33819	0.01311	0.97247	1933	17	1904	34	1878	63	3.3
M12637-4A	30	133299	13	0.11782	0.00111	5.37583	0.22185	0.33091	0.01330	0.97356	1923	17	1881	35	1843	64	4.8
M12637-4B	30	500783	32	0.11739	0.00103	5.53566	0.30617	0.34201	0.01868	0.98728	1917	16	1906	46	1896	89	1.2
M12637-4C	30	567049	21	0.11737	0.00103	5.52916	0.22509	0.34168	0.01358	0.97666	1916	16	1905	34	1895	65	1.3
M12637-4D	30	186983	35	0.11716	0.00108	5.25243	0.23567	0.32515	0.01428	0.97862	1913	16	1861	38	1815	69	5.9
M12637-4E	30	239402	41	0.11745	0.00109	5.34470	0.40615	0.33004	0.02489	0.99255	1918	17	1876	63	1839	120	4.7
M12637-4F	30	275670	19	0.11802	0.00106	5.55899	0.24222	0.34161	0.01457	0.97854	1927	16	1910	37	1894	70	1.9
M12637-5A	30	622947	80	0.12085	0.00107	5.98167	0.32485	0.35899	0.01923	0.98659	1969	16	1973	46	1977	91	-0.5
M12637-5B	30	160397	31	0.11838	0.00106	5.62453	0.29263	0.34459	0.01766	0.98502	1932	16	1920	44	1909	84	1.4
M12637-6A	30	436679	41	0.11907	0.00103	5.84351	0.27531	0.35594	0.01648	0.98284	1942	15	1953	40	1963	78	-1.2
M12637-6B	30	324152	27	0.11736	0.00104	5.56091	0.23384	0.34367	0.01413	0.97759	1916	16	1910	36	1904	67	0.7
M12637-6C	30	492731	47	0.11654	0.00101	5.40452	0.30458	0.33635	0.01873	0.98806	1904	16	1886	47	1869	90	2.1
M12637-6D	30	500197	34	0.11843	0.00105	5.74347	0.26690	0.35173	0.01604	0.98158	1933	16	1938	39	1943	76	-0.6
M0034-1A	30	512378	47	0.11981	0.00117	5.71906	0.31815	0.34619	0.01896	0.98451	1953	17	1934	47	1916	90	2.2
M0034-1B	30	516049	40	0.11732	0.00115	3.60083	0.25025	0.22259	0.01531	0.98998	1916	17	1550	54	1296	80	35.7
M0034-1C	30	613695	34	0.11772	0.00116	5.68970	0.32242	0.35053	0.01956	0.98487	1922	17	1930	48	1937	93	-0.9
M0034-2A	30	2212672	161	0.12068	0.00134	6.07652	0.39197	0.36520	0.02321	0.98510	1966	20	1987	55	2007	109	-2.4
M0034-2B	30	734100	53	0.11835	0.00116	4.75178	0.31108	0.29119	0.01885	0.98866	1931	17	1776	53	1647	93	16.6
M3997-1A	30	398568	31	0.11535	0.00112	5.24817	0.34762	0.32998	0.02162	0.98921	1885	17	1860	55	1838	104	2.9
M3997-1B	30	313570	10	0.11684	0.00116	5.34874	0.29392	0.33201	0.01794	0.98349	1908	18	1877	46	1848	86	3.6
M3997-2A	30	368775	15	0.11933	0.00119	5.70468	0.33330	0.34673	0.01996	0.98534	1946	18	1932	49	1919	95	1.6
M3997-2B	30	440696	0	0.11991	0.00119	5.74700	0.35173	0.34760	0.02099	0.98684	1955	18	1938	52	1923	100	1.9
M3997-2C	30	468704	2	0.12105	0.00125	5.80683	0.34254	0.34793	0.02021	0.98449	1972	18	1947	50	1925	96	2.8
M3997-2D	30	481812	143	0.12041	0.00123	5.22397	0.32148	0.31466	0.01909	0.98605	1962	18	1857	51	1764	93	11.6
M3997-2E	30	352926	25	0.12046	0.00134	5.75863	0.30665	0.34673	0.01806	0.97801	1963	20	1940	45	1919	86	2.6
M3997-2F	30	364990	20	0.12053	0.00123	5.64951	0.33768	0.33996	0.02002	0.98523	1964	18	1924	50	1886	96	4.6
M3997-5A	30	1375869	16	0.11777	0.00121	5.31345	0.27141	0.32723	0.01637	0.97961	1923	18	1871	43	1825	79	5.8
M3997-5B	30	2109352	157	0.11360	0.00128	4.38660	0.25175	0.28006	0.01576	0.98056	1858	20	1710	46	1592	79	16.2
M3997-7A	30	1090345	0	0.11709	0.00123	5.50223	0.27603	0.34083	0.01672	0.97791	1912	19	1901	42	1891	80	1.3
M3997-7B	30	1389270	0	0.11664	0.00129	5.43404	0.32972	0.33788	0.02016	0.98315	1905	20	1890	51	1876	96	1.8
M3997-7C	30	968029	0	0.11376	0.00111	4.93679	0.23140	0.31473	0.01443	0.97814	1860	17	1809	39	1764	70	5.9
M12350-1A	30	1068154	38	0.12068	0.00181	6.07504	0.24508	0.36509	0.01368	0.92868	1966	26	1987	35	2006	64	-2.4
M12350-1B	30	956885	43	0.12036	0.00179	6.09591	0.31587	0.36732	0.01823	0.95797	1962	26	1990	44	2017	85	-3.3
M12350-1C	30	709433	41	0.12013	0.00180	6.01902	0.28801	0.36339	0.01651	0.94979	1958	26	1979	41	1998	78	-2.4
M12350-2A	30	423208	49	0.12020	0.00181	6.07811	0.29497	0.36676	0.01692	0.95073	1959	27	1987	41	2014	79	-3.3
M12350-3A	30	433490	32	0.12006	0.00182	5.67335	0.24455	0.34272	0.01383	0.93614	1957	27	1927	37	1900	66	3.4
M12350-3B	30	213538	14	0.11908	0.00180	5.83906	0.34640	0.35562	0.02040	0.96695	1943	27	1952	50	1961	96	-1.1
M12350-3C	30	354383	23	0.12016	0.00180	5.64378	0.37964	0.34066	0.02234	0.97501	1959	26	1923	56	1890	107	4.0
M12350-3D	30	241724	21	0.12054	0.00181	5.75521	0.44137	0.34629	0.02604	0.98055	1964	27	1940	64	1917	123	2.8
M12350-3E	30	316856	24	0.12100	0.00181	5.91765	0.31101	0.35471	0.01787	0.95881	1971	26	1964	45	1957	84	0.8
M12350-3F	30	370809	32	0.12091	0.00180	6.29077	0.32853	0.37735	0.01889	0.95848	1970	26	2017	45	2064	88	-5.6
M12350-4A	30	528486	101	0.12041	0.00182	5.54415	0.33580	0.33394	0.01959	0.96847	1962	27	1907	51	1857	94	6.2

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

											Ages (Ma)						
Analysis	Spot Size µm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12350-4B	30	347421	81	0.12169	0.00183	6.04044	0.34993	0.36000	0.02014	0.96585	1981	26	1982	49	1982	95	-0.1
M12350-4C	30	595658	72	0.12175	0.00182	6.11437	0.28351	0.36424	0.01599	0.94648	1982	26	1992	40	2002	75	-1.2
M12350-6A	30	371023	59	0.12133	0.00182	6.24894	0.36124	0.37354	0.02086	0.96592	1976	26	2011	49	2046	97	-4.1
M12350-6B	30	196886	52	0.12153	0.00185	5.88310	0.30184	0.35110	0.01720	0.95504	1979	27	1959	44	1940	82	2.3
M12350-6C	30	174062	50	0.12135	0.00184	5.07808	0.27461	0.30350	0.01575	0.95987	1976	27	1832	45	1709	77	15.4
M12350-6D	30	468923	67	0.12157	0.00182	6.17570	0.30591	0.36844	0.01740	0.95313	1979	26	2001	42	2022	81	-2.5
M12350-6E	30	366243	65	0.12127	0.00181	6.07625	0.27544	0.36339	0.01555	0.94414	1975	26	1987	39	1998	73	-1.4
M12350-6F	30	199710	72	0.12131	0.00182	5.72853	0.25259	0.34248	0.01420	0.94037	1976	26	1936	37	1899	68	4.5
M12350-6G	30	316987	65	0.12136	0.00181	5.99275	0.41709	0.35814	0.02435	0.97670	1976	26	1975	59	1973	115	0.2
M12350-6H	30	360634	65	0.12107	0.00185	6.25180	0.35039	0.37450	0.02020	0.96217	1972	27	2012	48	2051	94	-4.6
M12350-8A	30	634624	103	0.12198	0.00182	5.62927	0.26596	0.33470	0.01500	0.94886	1985	26	1921	40	1861	72	7.2
M12350-8B	30	865205	132	0.12196	0.00182	5.61616	0.22925	0.33398	0.01269	0.93105	1985	26	1919	35	1858	61	7.4
M12350-8C	30	968185	83	0.12160	0.00181	5.99413	0.27171	0.35753	0.01531	0.94482	1980	26	1975	39	1970	72	0.5
M12351A-2A	30	484092	160	0.22175	0.00216	17.44746	0.80637	0.57065	0.02578	0.97755	2993	16	2960	43	2910	105	3.4
M12351A-2B	30	563837	148	0.12679	0.00113	6.56035	0.27336	0.37528	0.01528	0.97693	2054	16	2054	36	2054	71	0.0
M12351A-2C	30	402814	143	0.12168	0.00108	5.76849	0.26055	0.34383	0.01523	0.98037	1981	16	1942	38	1905	73	4.4
M12351A-3A	30	1441680	542	0.13065	0.00116	5.53927	0.30386	0.30749	0.01665	0.98684	2107	15	1907	46	1728	82	20.4
M12351A-8A	30	1059284	147	0.11968	0.00103	5.83034	0.26185	0.35331	0.01557	0.98133	1951	15	1951	38	1950	74	0.1
M12351A-8B	30	1234474	159	0.12029	0.00104	5.92311	0.26865	0.35713	0.01590	0.98180	1960	15	1965	39	1969	75	-0.5
M12351A-8C	30	114220	136	0.11969	0.00113	5.55870	0.27693	0.33682	0.01648	0.98200	1952	17	1910	42	1871	79	4.7
M12351A-8D	30	104797	136	0.12017	0.00112	5.84236	0.38245	0.35262	0.02285	0.98985	1959	17	1953	55	1947	108	0.7
M12351A-8E	30	128057	150	0.12056	0.00110	5.45230	0.20889	0.32800	0.01221	0.97133	1965	16	1893	32	1829	59	7.9
M12351A-8F	30	840883	185	0.12058	0.00104	5.66417	0.22892	0.34069	0.01345	0.97681	1965	15	1926	34	1890	64	4.4
M12351A-8G	30	113516	146	0.12150	0.00124	5.85689	0.25122	0.34961	0.01456	0.97107	1978	18	1955	37	1933	69	2.7
M12351A-9A	30	1166101	138	0.16261	0.00220	9.30079	0.37187	0.41484	0.01561	0.94101	2483	23	2368	36	2237	71	11.7
M12351A-9B	30	1138082	137	0.13006	0.00116	6.68134	0.27575	0.37258	0.01501	0.97640	2099	16	2070	36	2042	70	3.2
M12351A-9C	30	1093628	195	0.13302	0.00121	6.75581	0.30374	0.36835	0.01622	0.97925	2138	16	2080	39	2022	76	6.3
M12351B-2A	30	1642535	63	0.12227	0.00186	6.25503	0.29234	0.37104	0.01640	0.94561	1990	27	2012	40	2034	77	-2.6
M12351B-2B	30	933087	41	0.12249	0.00192	6.56753	0.37358	0.38888	0.02127	0.96140	1993	28	2055	49	2118	98	-7.4
M12351B-3A	30	649983	35	0.12833	0.00197	6.03810	0.30830	0.34125	0.01661	0.95350	2075	27	1981	44	1893	79	10.1
M12351B-3B	30	617688	35	0.11926	0.00182	5.83248	0.33175	0.35469	0.01944	0.96338	1945	27	1951	48	1957	92	-0.7
M12351B-3C	30	468987	8	0.12225	0.00185	6.23547	0.28548	0.36994	0.01598	0.94377	1989	27	2009	39	2029	75	-2.3
M12351B-3D	30	66977	0	0.11829	0.00181	5.81094	0.28290	0.35628	0.01647	0.94947	1931	27	1948	41	1965	78	-2.0
M12351B-3E	30	129906	2	0.11807	0.00179	5.81577	0.29825	0.35725	0.01750	0.95518	1927	27	1949	43	1969	83	-2.5
M12351B-3F	30	50452	2	0.11977	0.00199	5.81069	0.26094	0.35186	0.01468	0.92886	1953	29	1948	38	1943	70	0.6
M12351B-3G	30	98033	2	0.11846	0.00184	5.80009	0.33469	0.35510	0.01974	0.96319	1933	28	1946	49	1959	93	-1.5
M12351B-3H	30	498718	11	0.11666	0.00176	5.59950	0.37354	0.34811	0.02262	0.97419	1906	27	1916	56	1926	107	-1.2
M12351B-3I	30	1247107	36	0.13651	0.00207	7.49061	0.50195	0.39796	0.02598	0.97413	2183	26	2172	58	2160	119	1.3
M12351B-5A	30	222266	29	0.11868	0.00179	5.85063	0.31150	0.35753	0.01826	0.95907	1936	27	1954	45	1970	86	-2.0
M12351B-5B	30	683556	73	0.13641	0.00206	7.53073	0.45467	0.40040	0.02340	0.96808	2182	26	2177	53	2171	107	0.6
M12351B-5C	30	383033	21	0.13315	0.00299	6.83997	0.44298	0.37256	0.02263	0.93781	2140	39	2091	56	2041	105	5.4
M12351B-6A	30	157799	44	0.12102	0.00183	5.60324	0.26215	0.33580	0.01487	0.94621	1971	27	1917	40	1866	71	6.1
M12351B-6B	30	462939	56	0.13515	0.00226	7.15084	0.40203	0.38376	0.02060	0.95481	2166	29	2130	49	2094	95	3.9
M12351B-6C	30	584491	87	0.14179	0.00225	7.58314	0.44803	0.38789	0.02207	0.96319	2249	27	2183	52	2113	102	7.1
M12351B-8A	30	225384	21	0.11807	0.00179	5.68091	0.25541	0.34895	0.01477	0.94135	1927	27	1928	38	1930	70	-0.1

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	Ages (Ma) ^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12351B-8B	30	98018	39	0.11859	0.00181	5.39888	0.25301	0.33018	0.01463	0.94548	1935	27	1885	39	1839	71	5.7
M12351B-8C	30	709538	45	0.20675	0.00318	16.11136	0.74898	0.56517	0.02479	0.94360	2880	25	2883	43	2888	101	-0.3
M12351B-9A	30	237465	43	0.11916	0.00187	6.19936	0.31928	0.37732	0.01851	0.95266	1944	28	2004	44	2064	86	-7.2
M12351B-9B	30	397784	71	0.12516	0.00224	6.62080	0.40973	0.38366	0.02273	0.95743	2031	31	2062	53	2093	105	-3.6
M12351B-10A	30	353448	46	0.17478	0.00267	12.20042	1.00070	0.50628	0.04080	0.98246	2604	25	2620	74	2641	172	-1.7
M12351B-10B	30	660079	96	0.14219	0.00236	8.38193	0.53404	0.42755	0.02630	0.96543	2254	28	2273	56	2295	118	-2.1
M12351B-10C	30	1446299	160	0.13706	0.00278	7.41893	0.42200	0.39258	0.02086	0.93435	2190	35	2163	50	2135	96	3.0
M12351B-11A	30	148487	25	0.11842	0.00181	6.17552	0.37035	0.37821	0.02193	0.96704	1933	27	2001	51	2068	102	-8.2
M12351B-11B	30	462905	59	0.20921	0.00349	14.73338	0.71774	0.51077	0.02337	0.93937	2899	27	2798	45	2660	99	10.1
M12549-1A	30	289640	66	0.12091	0.00110	6.08694	0.36751	0.36512	0.02179	0.98858	1970	16	1988	51	2006	102	-2.2
M12549-1B	30	498482	157	0.11924	0.00120	4.59003	0.38790	0.27918	0.02343	0.99294	1945	18	1747	68	1587	117	20.7
M12549-1C	30	582955	74	0.11829	0.00103	5.90328	0.31281	0.36195	0.01892	0.98632	1931	16	1962	45	1991	89	-3.7
M12549-1D	30	145649	53	0.12044	0.00111	5.84740	0.23823	0.35211	0.01397	0.97410	1963	16	1953	35	1945	66	1.1
M12549-1E	30	253586	63	0.12020	0.00107	5.54511	0.23180	0.33458	0.01366	0.97689	1959	16	1908	35	1861	66	5.8
M12549-3A	30	902921	61	0.12041	0.00105	5.95445	0.25370	0.35865	0.01496	0.97896	1962	15	1969	36	1976	71	-0.8
M12549-3B	30	1256612	93	0.12083	0.00106	5.80395	0.26724	0.34837	0.01575	0.98177	1969	16	1947	39	1927	75	2.5
M12549-3C	30	917010	79	0.12067	0.00105	5.63148	0.29306	0.33846	0.01737	0.98594	1966	15	1921	44	1879	83	5.1
M12549-5A	30	856535	187	0.11981	0.00113	5.93825	0.27412	0.35947	0.01624	0.97875	1953	17	1967	39	1980	77	-1.6
M12549-5C	30	1294590	147	0.11817	0.00107	5.37922	0.26225	0.33015	0.01582	0.98270	1929	16	1882	41	1839	76	5.3
M12549-5D	30	2440454	263	0.11929	0.00107	5.37288	0.29908	0.32666	0.01794	0.98682	1946	16	1881	47	1822	87	7.3
M12549-6B	30	1072348	195	0.12001	0.00105	5.32409	0.31948	0.32175	0.01910	0.98926	1956	16	1873	50	1798	92	9.3
M12549-6C	30	1513944	115	0.11943	0.00104	5.69494	0.26342	0.34585	0.01571	0.98198	1948	16	1931	39	1915	75	2.0
M12636-1A	30	57399	6	0.11961	0.00117	5.21167	0.25633	0.31603	0.01523	0.98011	1950	17	1855	41	1770	74	10.6
M12636-1B	30	55981	3	0.11865	0.00118	5.15125	0.30358	0.31488	0.01829	0.98564	1936	18	1845	49	1765	89	10.1
M12636-2A	30	2139426	41	0.12005	0.00111	5.58186	0.32317	0.33721	0.01927	0.98715	1957	16	1913	49	1873	92	4.9
M12636-2B	30	162790	9	0.11810	0.00122	5.33531	0.25294	0.32766	0.01516	0.97604	1928	18	1875	40	1827	73	6.0
M12636-3A	30	622893	13	0.12387	0.00118	6.42323	0.33679	0.37609	0.01939	0.98337	2013	17	2035	45	2058	90	-2.6
M12636-3B	30	190394	7	0.11731	0.00107	5.63325	0.30374	0.34827	0.01851	0.98570	1916	16	1921	45	1926	88	-0.6
M12636-3C	30	325310	10	0.11913	0.00105	5.63899	0.39790	0.34331	0.02403	0.99213	1943	16	1922	59	1903	114	2.4
M12636-3D	30	241722	6	0.11863	0.00107	5.70016	0.27787	0.34848	0.01669	0.98265	1936	16	1931	41	1927	79	0.5
M12636-3E	30	541739	5	0.11736	0.00103	4.77279	0.24428	0.29494	0.01487	0.98509	1916	16	1780	42	1666	74	14.8
M12636-4A	30	2724481	26	0.11980	0.00104	5.74292	0.26304	0.34766	0.01563	0.98183	1953	15	1938	39	1923	74	1.8
M12636-4B	30	263353	5	0.11700	0.00103	5.71528	0.28511	0.35430	0.01740	0.98437	1911	16	1934	42	1955	82	-2.7
M12636-4C	30	1340771	27	0.11860	0.00102	5.48796	0.27038	0.33562	0.01628	0.98453	1935	15	1899	41	1866	78	4.1
M12636-4F	30	266718	7	0.11702	0.00105	5.37159	0.21641	0.33293	0.01307	0.97475	1911	16	1880	34	1853	63	3.5
M12636-5A	30	705186	8	0.11949	0.00104	5.77851	0.22458	0.35075	0.01329	0.97478	1949	15	1943	33	1938	63	0.6
M12636-5B	30	297677	8	0.11821	0.00108	5.89450	0.43126	0.36166	0.02625	0.99214	1929	16	1960	62	1990	123	-3.7
M12636-5C	30	811329	10	0.11699	0.00104	5.29731	0.38141	0.32840	0.02346	0.99238	1911	16	1868	60	1831	113	4.8
M12636-6A	30	417412	10	0.11786	0.00105	5.50391	0.32634	0.33870	0.01986	0.98871	1924	16	1901	50	1880	95	2.6
M12636-6B	30	254265	10	0.11762	0.00105	5.24117	0.26117	0.32317	0.01584	0.98382	1920	16	1859	42	1805	77	6.9
M12636-6C	30	267200	5	0.11789	0.00108	5.60365	0.34598	0.34473	0.02105	0.98896	1925	16	1917	52	1909	100	0.9
M12638-1A	30	1784210	102	0.12132	0.00120	6.08104	0.19512	0.36355	0.01110	0.95155	1976	17	1988	28	1999	52	-1.4
M12638-1B	30	1909150	102	0.11949	0.00117	5.87877	0.22686	0.35682	0.01332	0.96703	1949	17	1958	33	1967	63	-1.1

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	Ages (Ma) ^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12638-1C	30	1314303	86	0.12056	0.00117	6.02259	0.28310	0.36231	0.01666	0.97828	1965	17	1979	40	1993	78	-1.7
M12638-1E	30	1712273	122	0.11998	0.00120	5.67642	0.25697	0.34313	0.01515	0.97527	1956	18	1928	38	1902	72	3.2
M12638-2A	30	675977	65	0.11982	0.00119	5.85510	0.22481	0.35441	0.01314	0.96578	1954	18	1955	33	1956	62	-0.1
M12638-2B	30	510516	47	0.11966	0.00118	6.19465	0.35712	0.37547	0.02133	0.98523	1951	18	2004	49	2055	99	-6.2
M12638-3.1A	30	263264	33	0.12032	0.00122	5.80496	0.26005	0.34990	0.01527	0.97419	1961	18	1947	38	1934	73	1.6
M12638-3.1B	30	275679	45	0.12016	0.00119	5.87206	0.26531	0.35444	0.01563	0.97570	1959	18	1957	38	1956	74	0.2
M12638-3.1C	30	314237	54	0.11973	0.00117	5.86276	0.25096	0.35514	0.01480	0.97348	1952	17	1956	36	1959	70	-0.4
M12638-4A	30	260089	97	0.11963	0.00124	5.28343	0.33700	0.32032	0.02016	0.98680	1951	18	1866	53	1791	98	9.4
M12638-4B	30	551040	97	0.12043	0.00123	4.85354	0.40647	0.29230	0.02430	0.99257	1963	18	1794	68	1653	120	17.9
M12638-4C	30	468915	82	0.12025	0.00119	5.19516	0.23134	0.31334	0.01361	0.97519	1960	17	1852	37	1757	66	11.8
M12638-5A	30	719138	75	0.11977	0.00118	5.54610	0.36381	0.33584	0.02178	0.98872	1953	17	1908	55	1867	104	5.1
M12638-5B	30	785928	67	0.11978	0.00118	6.06634	0.26436	0.36733	0.01559	0.97404	1953	18	1985	37	2017	73	-3.8
M12638-5C	30	561396	44	0.11974	0.00117	5.86713	0.22802	0.35536	0.01336	0.96760	1952	17	1956	33	1960	63	-0.5
M12638-5D	30	467388	33	0.11973	0.00118	5.98692	0.20454	0.36265	0.01187	0.95778	1952	17	1974	29	1995	56	-2.5
M12638-5E	30	651058	47	0.11972	0.00117	5.73914	0.23047	0.34768	0.01354	0.97000	1952	17	1937	34	1924	64	1.7
M12638-7A	30	894415	90	0.11987	0.00123	5.13396	0.25613	0.31062	0.01516	0.97848	1954	18	1842	42	1744	74	12.3
M12638-7B	30	787566	102	0.11992	0.00118	5.17634	0.20525	0.31306	0.01203	0.96897	1955	17	1849	33	1756	59	11.6
M12640-3.1A	30	830393	88	0.11258	0.00123	4.51999	0.18562	0.29118	0.01153	0.9641	1842	20	1735	34	1647	57	11.9
M12640-3.1B	30	568224	64	0.11851	0.00117	5.27999	0.24556	0.32312	0.01469	0.97735	1934	18	1866	39	1805	71	7.6
M12640-3.2A	30	731477	58	0.11977	0.00121	5.83169	0.25079	0.35314	0.01476	0.97186	1953	18	1951	37	1950	70	0.2
M12640-3.2B	30	280063	23	0.11974	0.00118	6.21393	0.34074	0.37637	0.02030	0.98364	1952	18	2006	47	2059	94	-6.4
M12640-3.2C	30	554453	18	0.11994	0.00118	5.78864	0.25099	0.35004	0.01478	0.97387	1955	17	1945	37	1935	70	1.2
M4015A-2A	30	528710	522	0.12726	0.00224	1.54304	0.16657	0.08794	0.00937	0.98666	2060	31	948	64	543	55	76.6
M4015A-2B	30	548157	523	0.12522	0.00217	1.40039	0.16489	0.08111	0.00945	0.98909	2032	30	889	67	503	56	78.1
M4015A-3A	30	1368814	591	0.11896	0.00195	2.75542	0.29709	0.16800	0.01790	0.98836	1941	29	1344	77	1001	98	52.2
M4015A-3B	30	884559	228	0.12061	0.00184	5.17148	0.43905	0.31099	0.02597	0.98376	1965	27	1848	70	1746	126	12.7
M4015A-5B	30	598546	83	0.12181	0.00182	5.27302	0.25431	0.31395	0.01439	0.95060	1983	26	1865	40	1760	70	12.8
M4015A-9.1A	30	505694	167	0.12211	0.00185	3.70697	0.37582	0.22017	0.02207	0.98877	1987	27	1573	78	1283	116	39.0
M4015A-9.1B	30	1409596	1158	0.13011	0.00201	1.39742	0.09996	0.07789	0.00544	0.97642	2099	27	888	41	484	32	79.8
M4015A-9.2A	30	405484	110	0.12548	0.00188	5.11936	0.31672	0.29589	0.01776	0.97021	2036	26	1839	51	1671	88	20.3
M4015A-9.2B	30	415337	178	0.12558	0.00189	3.89775	0.18415	0.22510	0.01008	0.94813	2037	26	1613	37	1309	53	39.4
M4015A-9.2C	30	342742	206	0.11761	0.00186	1.80329	0.14989	0.11120	0.00908	0.98182	1920	28	1047	53	680	52	68.0
M4015A-9.2D	30	324498	170	0.12690	0.00192	3.80192	0.33365	0.21730	0.01878	0.98499	2055	26	1593	68	1268	99	42.1
HW3521 1-1B	30	648691	156	0.12738	0.00161	6.45555	0.32636	0.36756	0.01799	0.96839	2062	22	2040	44	2018	84	2.5
HW3521 2-1A	30	1670874	176	0.12227	0.00155	5.79528	0.28349	0.34375	0.01624	0.96602	1990	22	1946	42	1905	77	4.9
HW3521 2-1B	30	1436100	190	0.12477	0.00159	5.75279	0.30554	0.33439	0.01724	0.97079	2026	22	1939	45	1860	83	9.4
HW3521 4-1A	30	2954287	712	0.12304	0.00170	5.41600	0.21926	0.31924	0.01214	0.93971	2001	24	1887	34	1786	59	12.3
HW3521 4-2A	30	2512115	284	0.12085	0.00152	5.72395	0.30579	0.34352	0.01784	0.97191	1969	22	1935	45	1904	85	3.8
HW3521 4-2B	30	1193611	215	0.12463	0.00162	6.39465	0.44651	0.37214	0.02553	0.98245	2023	23	2032	60	2039	119	-0.9
HW3521 4-3A	30	1564679	258	0.12351	0.00156	5.60559	0.38320	0.32918	0.02212	0.98279	2007	22	1917	57	1834	106	9.9
HW3521 5-1A	30	2155303	225	0.12208	0.00163	5.80715	0.36193	0.34501	0.02101	0.97686	1987	24	1947	53	1911	100	4.4
HW3521 5-1C	30	2890368	250	0.12054	0.00150	5.95336	0.29446	0.35821	0.01715	0.96786	1964	22	1969	42	1974	81	-0.6
HW3521-1.1B	30	212614	96	0.11816	0.00119	5.76356	0.29426	0.35377	0.01771	0.98035	1929	18	1941	43	1953	84	-1.4
HW3521-1.1C	30	796249	111	0.11834	0.00114	5.29481	0.32093	0.32450	0.01942	0.98718	1931	17	1868	50	1812	94	7.1

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	$^{207}Pb/^{206}Pb$	±2 s	$^{207}Pb/^{235}U$	±2 s	$^{206}Pb/^{238}U$	±2 s	r	Ages (Ma) $^{207}Pb^*/^{206}Pb^*$	±2 s	$^{207}Pb^*/^{235}U$	±2 s	$^{206}Pb^*/^{238}U$	±2 s	% Disc.
HW3521-1.2A	30	667140	96	0.12663	0.00178	6.37615	0.41011	0.36519	0.02292	0.97588	2052	25	2029	55	2007	107	2.6
HW3521-1.2B	30	795110	91	0.11843	0.00114	5.21760	0.27232	0.31953	0.01639	0.98278	1933	17	1855	44	1787	80	8.6
HW3521-1.2C	30	232951	76	0.11810	0.00117	5.46722	0.29838	0.33576	0.01802	0.98343	1928	18	1895	46	1866	86	3.7
HW3521-2A	30	1087223	76	0.11990	0.00117	5.96653	0.29469	0.36091	0.01748	0.98046	1955	17	1971	42	1986	82	-1.9
HW3521-2B	30	994317	71	0.11794	0.00114	5.58587	0.29162	0.34349	0.01762	0.98262	1925	17	1914	44	1903	84	1.3
HW3521-2C	30	730389	69	0.11817	0.00113	5.47761	0.29077	0.33619	0.01755	0.98356	1929	17	1897	45	1868	84	3.6
HW3521-3A	30	441105	109	0.12661	0.00125	6.33055	0.38559	0.36262	0.02179	0.98672	2051	17	2023	52	1995	102	3.2
HW3521-3B	30	175458	92	0.12751	0.00131	6.56863	0.39907	0.37362	0.02237	0.98564	2064	18	2055	52	2046	104	1.0
HW3521-3C	30	443054	80	0.12015	0.00118	5.64902	0.33135	0.34100	0.01972	0.98595	1958	17	1924	49	1891	94	3.9
HW3521-4B	30	352137	52	0.12549	0.00133	5.96180	0.46546	0.34457	0.02665	0.99070	2036	19	1970	66	1909	127	7.2
HW3521-4C	30	357990	62	0.12249	0.00165	5.75287	0.40614	0.34064	0.02360	0.98153	1993	24	1939	59	1890	113	6.0
HW3521-5A	30	622996	226	0.12954	0.00132	6.56396	0.42330	0.36751	0.02340	0.98742	2092	18	2055	55	2018	109	4.1
HW3521-5B	30	281592	105	0.12779	0.00126	6.26380	0.41676	0.35549	0.02339	0.98888	2068	17	2013	57	1961	110	6.0
HW3521-5C	30	783785	230	0.12136	0.00118	5.55452	0.38039	0.33193	0.02250	0.98980	1976	17	1909	57	1848	108	7.5
HW3521-6A	30	309323	94	0.12452	0.00144	6.29967	0.31896	0.36693	0.01809	0.97351	2022	20	2018	43	2015	85	0.4
HW3521-7A	30	338555	110	0.12249	0.00125	6.13662	0.34362	0.36336	0.02000	0.98317	1993	18	1995	48	1998	94	-0.3
HW3521-7D	30	157435	72	0.12419	0.00122	6.28013	0.36378	0.36675	0.02094	0.98553	2017	17	2016	50	2014	98	0.2
HW3521-9A	30	313646	105	0.12093	0.00121	5.48384	0.34574	0.32889	0.02047	0.98740	1970	18	1898	53	1833	99	8.0
HW3521-9B	30	246733	80	0.12768	0.00128	6.91061	0.44894	0.39256	0.02520	0.98811	2066	18	2100	56	2135	116	-3.9
HW3521-9C	30	249895	60	0.12586	0.00129	6.48875	0.35144	0.37392	0.01989	0.98189	2041	18	2044	47	2048	93	-0.4
HW3522 1-1A	30	1715057	211	0.12227	0.00159	5.86274	0.28719	0.34776	0.01643	0.96427	1990	23	1956	42	1924	78	3.8
HW3522 1-1B	30	1336105	118	0.12136	0.00152	5.59577	0.32666	0.33441	0.01907	0.97667	1976	22	1915	49	1860	91	6.8
HW3522 1-1C	30	1545293	129	0.12241	0.00165	5.52310	0.35378	0.32724	0.02049	0.97760	1992	24	1904	54	1825	99	9.6
HW3522 1-1D	30	1172990	134	0.12378	0.00158	6.40022	0.44214	0.37500	0.02546	0.98283	2011	22	2032	59	2053	118	-2.4
HW3522 3-1A	30	766053	149	0.12388	0.00157	5.67556	0.28969	0.33229	0.01643	0.96886	2013	22	1928	43	1849	79	9.3
HW3522 3-1B	30	775971	148	0.12604	0.00157	6.41547	0.27886	0.36916	0.01537	0.95805	2043	22	2034	37	2025	72	1.0
HW3522 3-1C	30	1638027	163	0.12112	0.00150	5.99433	0.31216	0.35895	0.01816	0.97134	1973	22	1975	44	1977	86	-0.3
HW3522 3-1D	30	467324	139	0.12522	0.00157	6.22493	0.34502	0.36056	0.01947	0.97407	2032	22	2008	47	1985	92	2.7
M4015B-1A	30	188562	19	0.14763	0.00222	8.68840	0.39796	0.42683	0.01847	0.94483	2319	26	2306	41	2291	83	1.4
M4015B-1B	30	173637	15	0.14775	0.00222	8.63466	0.38905	0.42387	0.01800	0.94251	2320	26	2300	40	2278	81	2.1
M4015B-1C	30	226957	32	0.14660	0.00220	8.74216	0.46318	0.43250	0.02197	0.95889	2307	26	2311	47	2317	98	-0.5
M4015B-1D	30	212768	24	0.14699	0.00221	8.78763	0.39566	0.43360	0.01840	0.94242	2311	26	2316	40	2322	82	-0.6
M4015B-1E	30	168454	22	0.14713	0.00222	8.94885	0.45756	0.44111	0.02155	0.95553	2313	26	2333	46	2356	96	-2.2
M4015B-1F	30	151743	32	0.14719	0.00221	8.75112	0.36026	0.43120	0.01653	0.93102	2314	26	2312	37	2311	74	0.1
M4015B-1G	30	215433	36	0.14735	0.00222	9.24741	0.58264	0.45516	0.02785	0.97109	2315	26	2363	56	2418	122	-5.3
M4015B-3A	30	210121	53	0.14446	0.00215	8.39393	0.47244	0.42141	0.02287	0.96435	2281	25	2275	50	2267	103	0.8
M4015B-3B	30	262106	55	0.14524	0.00222	8.38757	0.37518	0.41884	0.01761	0.93968	2291	26	2274	40	2255	79	1.8
M4015B-3C	30	209852	40	0.14745	0.00220	8.85002	0.49499	0.43531	0.02346	0.96364	2317	25	2323	50	2330	105	-0.7
M4015B-4A	30	278815	57	0.14746	0.00220	8.52231	0.38005	0.41916	0.01762	0.94241	2317	25	2288	40	2257	80	3.1
M4015B-4C	30	936361	36	0.14696	0.00218	9.02396	0.36121	0.44536	0.01656	0.92870	2311	25	2340	36	2375	73	-3.3
M4015B-4D	30	426017	60	0.14490	0.00224	8.86839	0.39049	0.44390	0.01830	0.93647	2287	26	2325	39	2368	81	-4.3
M4015B-4E	30	457279	51	0.14666	0.00220	9.23052	0.58198	0.45646	0.02795	0.97119	2307	26	2361	56	2424	123	-6.1
M4015B-4F	30	494733	70	0.14753	0.00220	9.04148	0.38143	0.44450	0.01754	0.93554	2317	25	2342	38	2371	78	-2.7
M4015B-6.2A	30	550478	58	0.14701	0.00219	9.07035	0.43925	0.44748	0.02062	0.95163	2311	25	2345	43	2384	91	-3.8

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

											Ages (Ma)						
Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M4015B-6.2B	30	264049	32	0.14708	0.00220	9.02146	0.44572	0.44484	0.02094	0.95291	2312	25	2340	44	2372	93	-3.1
M4015B-6.1A	30	302642	59	0.14660	0.00220	8.56972	0.36714	0.42397	0.01702	0.93687	2307	25	2293	38	2278	77	1.4
M4015B-6.1B	30	245196	64	0.14654	0.00219	8.71101	0.39960	0.43113	0.01870	0.94534	2306	25	2308	41	2311	84	-0.3
M4015B-6.1D	30	313354	56	0.14616	0.00219	8.52761	0.34854	0.42316	0.01609	0.93050	2301	25	2289	36	2275	72	1.4
M4015B-6.1E	30	261923	52	0.14596	0.00219	8.72371	0.45457	0.43347	0.02163	0.95772	2299	26	2310	46	2321	97	-1.2
M4015B-6.1F	30	428401	63	0.14598	0.00219	8.79879	0.41449	0.43714	0.01952	0.94809	2299	26	2317	42	2338	87	-2.0
M4015B-6.1G	30	540935	56	0.14678	0.00220	8.82072	0.40862	0.43586	0.01911	0.94639	2309	25	2320	41	2332	85	-1.2
M4015B-6.1H	30	572233	85	0.14649	0.00219	9.02486	0.43776	0.44681	0.02062	0.95154	2305	25	2341	43	2381	91	-3.9
M4015B-6.1I	30	867437	97	0.14727	0.00220	8.93153	0.47052	0.43985	0.02222	0.95891	2314	25	2331	47	2350	99	-1.8
M12352A-7A	30	350745	112	0.12223	0.00107	5.68243	0.24236	0.33716	0.01407	0.97852	1989	16	1929	36	1873	67	6.7
M12352A-7B	30	355857	111	0.12158	0.00109	6.06419	0.26480	0.36174	0.01546	0.97862	1980	16	1985	37	1990	73	-0.6
M12352A-7C	30	255326	110	0.12403	0.00113	5.96315	0.28054	0.34870	0.01609	0.98105	2015	16	1970	40	1928	76	5.0
M12352A-7D	30	1509545	117	0.12298	0.00107	6.04655	0.27184	0.35660	0.01573	0.98103	2000	15	1983	38	1966	74	2.0
M12352A-7E	30	1697366	114	0.12414	0.00111	5.56768	0.27073	0.32529	0.01555	0.98308	2017	16	1911	41	1816	75	11.4
M12352A-7F	30	636766	92	0.12117	0.00109	5.87737	0.38035	0.35179	0.02255	0.99032	1974	16	1958	55	1943	107	1.8
M12352A-7G	30	1047405	127	0.12254	0.00107	6.13630	0.29261	0.36319	0.01703	0.98317	1993	15	1995	41	1997	80	-0.2
M12352A-7H	30	341716	104	0.12322	0.00109	5.63688	0.22241	0.33177	0.01276	0.97465	2003	16	1922	33	1847	61	9.0
M12352A-10A	30	2398206	262	0.12419	0.00108	5.87133	0.20967	0.34290	0.01188	0.96999	2017	15	1957	31	1901	57	6.7
M12352A-10B	30	2561462	254	0.12380	0.00114	5.77893	0.27533	0.33856	0.01583	0.98119	2012	16	1943	40	1880	76	7.6
M12352B-1A	30	514924	37	0.12675	0.00118	6.04434	0.33368	0.34587	0.01882	0.98578	2053	16	1982	47	1915	90	7.8
M12352B-2A	30	761052	73	0.13893	0.00144	7.69462	0.28098	0.40169	0.01407	0.95905	2214	18	2196	32	2177	64	2.0
M12352B 4-1A	30	259977	8	0.14476	0.00192	7.68675	0.51396	0.38511	0.02524	0.98017	2285	23	2195	58	2100	116	9.5
M12352B 4-1B	30	252315	11	0.12365	0.00162	6.17879	0.45607	0.36241	0.02632	0.98404	2010	23	2001	63	1994	123	0.9
M12352B 4-1C	30	162563	3	0.12253	0.00163	5.76063	0.37005	0.34096	0.02143	0.97832	1993	23	1941	54	1891	102	5.9
M12352B 4-1D	30	272963	6	0.12360	0.00158	5.75079	0.55194	0.33745	0.03210	0.99113	2009	22	1939	80	1874	153	7.7
M12352B 4-1E	30	328298	3	0.12233	0.00158	5.87500	0.46687	0.34831	0.02731	0.98669	1991	23	1958	67	1927	129	3.7
M12352B 4-2A	30	75716	1	0.14611	0.00199	8.06069	0.54876	0.40012	0.02669	0.97986	2301	23	2238	60	2170	122	6.7
M12352B 4-2B	30	375172	1	0.12695	0.00162	6.29241	0.31608	0.35948	0.01746	0.96719	2056	22	2017	43	1980	82	4.3
M12352B 4-2C	30	351070	0	0.15110	0.00438	7.93033	0.48438	0.38064	0.02047	0.88043	2358	49	2223	54	2079	95	13.8
M12352B 5-1A	30	91646	1	0.13724	0.00214	7.56637	0.42396	0.39987	0.02152	0.96068	2193	27	2181	49	2168	98	1.3
M12352B 6-1A	30	133933	0	0.14268	0.00194	8.22756	0.33159	0.41821	0.01586	0.94121	2260	23	2256	36	2252	72	0.4
M12352B 6-1B	30	109646	0	0.14536	0.00193	7.73372	0.35833	0.38587	0.01713	0.95795	2292	23	2201	41	2104	79	9.6
M12639-1A	30	78620	14	0.14905	0.00158	8.37848	0.60847	0.40770	0.02929	0.98928	2335	18	2273	64	2204	133	6.6
M12639-1B	30	108795	5	0.14902	0.00150	9.15985	0.44329	0.44579	0.02110	0.97809	2335	17	2354	43	2377	93	-2.1
M12639-1C	30	127637	6	0.14479	0.00150	8.25292	0.43250	0.41341	0.02124	0.98034	2285	18	2259	46	2230	96	2.8
M12639-1D	30	167053	8	0.13493	0.00144	7.14758	0.34835	0.38419	0.01827	0.97567	2163	19	2130	43	2096	85	3.6
M12639-2A	30	90151	5	0.14054	0.00155	7.95595	0.51300	0.41058	0.02608	0.98522	2234	19	2226	57	2218	118	0.9
M12639-2B	30	94865	14	0.14379	0.00153	7.92564	0.38692	0.39978	0.01905	0.97609	2273	18	2223	43	2168	87	5.5
M12639-2C	30	166175	10	0.14086	0.00145	7.72677	0.47379	0.39784	0.02405	0.98576	2238	18	2200	54	2159	110	4.1
M12639-2D	30	124182	16	0.14116	0.00155	7.93437	0.44725	0.40767	0.02254	0.98075	2241	19	2224	50	2204	102	2.0
M12639-2E	30	305433	15	0.14425	0.00148	8.08217	0.31024	0.40636	0.01503	0.96386	2279	18	2240	34	2198	69	4.2
M12639-3.1A	30	336561	11	0.13973	0.00138	7.38125	0.36612	0.38313	0.01862	0.97988	2224	17	2159	43	2091	86	7.0
M12639-3.1B	30	144056	6	0.13991	0.00145	7.79810	0.34973	0.40423	0.01764	0.97280	2226	18	2208	40	2188	80	2.0
M12639-3.1C	30	85182	6	0.13849	0.00146	7.41218	0.30981	0.38819	0.01570	0.96757	2208	18	2162	37	2114	72	5.0

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

Analysis	Spot Size µm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	Ages (Ma) ^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12639-3.1D	30	94067	29	0.14172	0.00147	7.28174	0.52332	0.37265	0.02650	0.98953	2248	18	2147	62	2042	123	10.7
M12639-3.2A	30	2297456	60	0.12401	0.00121	6.12273	0.20221	0.35808	0.01130	0.95559	2015	17	1993	28	1973	53	2.4
M12639-3.2B	30	2162231	49	0.12247	0.00122	5.84002	0.25033	0.34584	0.01442	0.97257	1993	18	1952	36	1915	69	4.5
M12639-3.2C	30	1758778	60	0.12726	0.00136	6.39135	0.28564	0.36425	0.01580	0.97089	2060	19	2031	38	2002	74	3.3
M12639-3.2D	30	1693300	60	0.12689	0.00129	6.34271	0.44009	0.36252	0.02488	0.98927	2055	18	2024	59	1994	117	3.5
M12639-3.2E	30	1489215	44	0.12702	0.00128	6.35569	0.37426	0.36290	0.02106	0.98535	2057	18	2026	50	1996	99	3.5
M12639-3.2F	30	174145	29	0.13671	0.00151	7.40965	0.38003	0.39309	0.01969	0.97647	2186	19	2162	45	2137	90	2.6
M12639-3.2G	30	173799	27	0.14461	0.00149	8.37240	0.42933	0.41991	0.02109	0.97965	2283	18	2272	45	2260	95	1.2
M12639-3.2H	30	1107381	35	0.12640	0.00126	6.53947	0.35561	0.37522	0.02006	0.98296	2049	18	2051	47	2054	93	-0.3
M12639-3.2I	30	1309073	45	0.12525	0.00129	6.21107	0.34558	0.35966	0.01966	0.98262	2032	18	2006	48	1981	93	3.0
M12639-3.2J	30	1275743	47	0.13375	0.00131	7.74564	0.58433	0.42000	0.03141	0.99147	2148	17	2202	66	2260	141	-6.2
M12639-3.2K	30	1657916	50	0.12293	0.00121	6.02727	0.30177	0.35561	0.01746	0.98041	1999	17	1980	43	1961	82	2.2
M12639-5.1A	30	109697	40	0.14837	0.00155	8.51921	0.38528	0.41643	0.01832	0.97294	2327	18	2288	40	2244	83	4.2
M12639-5.1B	30	1152832	56	0.14074	0.00143	7.89083	0.26399	0.40663	0.01296	0.95275	2236	17	2219	30	2199	59	1.9
M12639-5.1C	30	71063	75	0.14892	0.00152	8.53686	0.31284	0.41575	0.01463	0.96046	2334	17	2290	33	2241	66	4.7
M12639-5.2A	30	170022	73	0.14081	0.00166	7.77075	0.29611	0.40024	0.01450	0.95101	2237	20	2205	34	2170	66	3.5
M12639-5.2B	30	141136	73	0.13808	0.00144	7.42194	0.44802	0.38984	0.02318	0.98505	2203	18	2164	53	2122	107	4.3
M12639-5.2C	30	123222	59	0.14149	0.00154	7.66335	0.36918	0.39281	0.01843	0.97413	2246	19	2192	42	2136	85	5.7
M12639-5.2D	30	285399	53	0.12768	0.00178	6.48295	0.24549	0.36825	0.01296	0.92952	2066	24	2044	33	2021	61	2.5
M12643-1A	30	73377	46	0.14336	0.00167	8.50253	0.33667	0.43015	0.01628	0.95599	2268	20	2286	35	2306	73	-2.0
M12643-1B	30	87920	44	0.12381	0.00142	5.68135	0.27677	0.33280	0.01576	0.97205	2012	20	1929	41	1852	76	9.1
M12643-1C	30	281748	30	0.12135	0.00126	6.36002	0.31200	0.38011	0.01823	0.97743	1976	18	2027	42	2077	85	-6.0
M12643-1D	30	131491	25	0.13699	0.00161	7.76440	0.37344	0.41109	0.01917	0.96965	2189	20	2204	42	2220	87	-1.6
M12643-2A	30	368693	34	0.14506	0.00146	8.78586	0.39009	0.43929	0.01900	0.97406	2288	17	2316	40	2347	85	-3.1
M12643-3A	30	505516	49	0.12743	0.00129	6.50282	0.35198	0.37010	0.01968	0.98238	2063	18	2046	47	2030	92	1.9
M12643-3B	30	477488	56	0.12816	0.00130	6.81687	0.38975	0.38579	0.02171	0.98419	2073	18	2088	49	2103	100	-1.7
M12643-4A	30	686294	47	0.11933	0.00120	5.80684	0.36428	0.35292	0.02185	0.98699	1946	18	1947	53	1949	103	-0.1
M12643-4B	30	247110	38	0.14093	0.00153	8.07150	0.51489	0.41539	0.02611	0.98548	2239	19	2239	56	2239	118	0.0
N01A 1-1A	30	306691	70	0.14547	0.00201	8.95906	0.79033	0.44667	0.03892	0.98762	2293	24	2334	78	2380	171	-4.5
N01A 1-1B	30	329508	66	0.14374	0.00210	8.70734	0.76175	0.43934	0.03789	0.98592	2273	25	2308	77	2348	168	-3.9
N01A 1-1C	30	322569	65	0.14528	0.00202	9.10767	0.75322	0.45469	0.03707	0.98574	2291	24	2349	73	2416	162	-6.5
N01A 1-1D	30	463113	60	0.14517	0.00200	9.28392	0.76434	0.46381	0.03765	0.98589	2290	24	2366	73	2456	164	-8.8
N01A 2-1B	30	1677555	127	0.14695	0.00203	8.83771	0.73998	0.43618	0.03602	0.98629	2311	24	2321	74	2334	160	-1.2
N01A 2-1C	30	582565	77	0.14320	0.00208	8.67524	0.76754	0.43937	0.03834	0.98637	2266	25	2304	78	2348	169	-4.3
N01A 3-1A	30	284472	68	0.14544	0.00201	8.72577	0.79390	0.43514	0.03913	0.98844	2293	24	2310	80	2329	173	-1.9
N01A 3-1A1	30	270470	78	0.14167	0.00210	8.47666	0.65282	0.43396	0.03280	0.98134	2248	25	2283	68	2324	146	-4.0
N01A 3-1C	30	196033	67	0.14401	0.00199	8.36914	0.79346	0.42150	0.03953	0.98928	2276	24	2272	83	2267	177	0.5
N01A 3-1D	30	203543	73	0.14500	0.00203	8.63733	0.73121	0.43203	0.03607	0.98623	2288	24	2300	74	2315	160	-1.4
N01A 3-1E	30	225305	77	0.14556	0.00202	8.46076	0.70304	0.42157	0.03454	0.98597	2294	24	2282	73	2268	155	1.4
N01A 3-1F	30	255263	59	0.14520	0.00202	8.61935	0.81430	0.43054	0.04023	0.98912	2290	24	2299	83	2308	179	-0.9
N01A 3-1G	30	215856	58	0.14535	0.00203	8.70167	0.76486	0.43419	0.03768	0.98734	2292	24	2307	77	2325	167	-1.7
N01A 3-1H	30	266771	103	0.14461	0.00203	9.00901	0.81249	0.45184	0.04025	0.98780	2283	24	2339	79	2403	176	-6.3
N01A 4-1A	30	468946	101	0.14354	0.00199	8.95412	0.69615	0.45243	0.03461	0.98403	2270	24	2333	69	2406	152	-7.2
N01A 4-1B	30	1109509	131	0.14158	0.00196	8.06850	0.67641	0.41334	0.03417	0.98623	2247	24	2239	73	2230	154	0.9

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

Analysis	Spot Size µm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	Ages (Ma) ^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
N01A 4-1C	30	627822	158	0.14617	0.00235	9.38814	0.80160	0.46583	0.03906	0.98205	2302	27	2377	75	2465	170	-8.6
N01A 5-1A	30	626558	76	0.14341	0.00200	8.55587	0.70761	0.43269	0.03527	0.98571	2269	24	2292	73	2318	157	-2.6
N01A 5-1B	30	738472	78	0.14444	0.00199	8.49185	0.73380	0.42639	0.03637	0.98719	2281	24	2285	76	2289	162	-0.4
N01A 5-2A	30	289067	33	0.14491	0.00203	8.34248	0.72938	0.41755	0.03604	0.98712	2287	24	2269	76	2249	162	1.9
N01A 5-2B	30	552768	16	0.14086	0.00203	8.71156	0.69393	0.44853	0.03514	0.98355	2238	25	2308	70	2389	155	-8.1
N01A 5-2C	30	375922	36	0.14260	0.00202	8.26515	0.68965	0.42038	0.03457	0.98548	2259	24	2261	73	2262	155	-0.2
N01A 5-2D	30	384513	20	0.14369	0.00199	8.63020	0.71363	0.43559	0.03551	0.98590	2272	24	2300	73	2331	158	-3.1
N01A 6-1A	30	667114	45	0.14246	0.00204	9.19210	0.76758	0.46798	0.03850	0.98525	2257	24	2357	74	2475	167	-11.6
N02B 2-1A	30	920513	142	0.14103	0.00215	8.92028	0.69985	0.45873	0.03531	0.98102	2240	26	2330	69	2434	154	-10.4
N02B 2-1B	30	965412	171	0.14191	0.00204	8.50938	0.62940	0.43488	0.03155	0.98099	2251	25	2287	65	2328	140	-4.1
N02B 3-1A	30	524600	146	0.14395	0.00197	8.47283	0.83763	0.42688	0.04179	0.99033	2275	23	2283	86	2292	186	-0.9
N02B 3-1B	30	617111	157	0.14596	0.00202	9.27324	0.77300	0.46079	0.03788	0.98619	2299	24	2365	74	2443	165	-7.5
N02B 3-1C	30	915789	169	0.13585	0.00196	7.87188	0.71347	0.42026	0.03761	0.98728	2175	25	2216	79	2262	168	-4.7
N02B 3-1D	30	806250	185	0.14627	0.00201	8.98997	0.72109	0.44576	0.03523	0.98521	2303	23	2337	71	2376	155	-3.8
N02B 3-1E	30	595484	183	0.13651	0.00205	7.24189	0.70042	0.38475	0.03676	0.98789	2183	26	2142	83	2098	169	4.6
N02B 3-1F	30	992021	210	0.13724	0.00211	7.46029	0.62147	0.39426	0.03228	0.98283	2193	26	2168	72	2143	148	2.7
N02B 3-2A	30	2037934	222	0.13701	0.00217	7.99421	0.68440	0.42318	0.03560	0.98273	2190	27	2230	74	2275	159	-4.6
N02B 4-1A	30	633984	244	0.14467	0.00202	8.25633	0.91765	0.41392	0.04564	0.99208	2284	24	2260	96	2233	205	2.6
N02B 4-1B	30	699587	228	0.13953	0.00194	8.24478	0.66056	0.42854	0.03381	0.98484	2221	24	2258	70	2299	151	-4.2
N02B 4-1C	30	491592	247	0.14226	0.00198	8.55585	0.72827	0.43619	0.03663	0.98661	2255	24	2292	75	2334	162	-4.2
N02B 5-1B	30	978541	389	0.14190	0.00204	7.77277	0.66841	0.39728	0.03368	0.98596	2250	25	2205	75	2157	154	4.9
N02B 5-2B	30	1829042	243	0.14190	0.00196	8.79945	0.70104	0.44974	0.03529	0.98485	2251	24	2317	70	2394	155	-7.6
N02B 5-2C	30	1913921	291	0.14226	0.00205	8.51933	0.73299	0.43434	0.03684	0.98590	2255	25	2288	75	2325	163	-3.7
N02B 6-1B	30	1611790	230	0.14152	0.00197	8.35750	0.65429	0.42830	0.03300	0.98403	2246	24	2271	69	2298	147	-2.8
N02B 6-1C	30	1205381	229	0.13577	0.00262	7.72933	0.60982	0.41289	0.03158	0.96956	2174	33	2200	69	2228	143	-2.9
N02B 6-1D	30	975134	219	0.14034	0.00198	8.35506	0.66523	0.43180	0.03384	0.98421	2231	24	2270	70	2314	151	-4.4
N02B 7-1A	30	1447041	320	0.13796	0.00215	8.09981	0.66149	0.42582	0.03414	0.98162	2202	27	2242	71	2287	153	-4.6
N02B 7-2A	30	454999	237	0.14646	0.00203	8.76615	0.68635	0.43409	0.03345	0.98419	2305	24	2314	69	2324	149	-1.0
N03 3-1A	30	614259	158	0.14476	0.00200	8.69908	0.68310	0.43583	0.03369	0.98443	2285	24	2307	69	2332	150	-2.5
N03 3-1B	30	327726	129	0.14452	0.00206	8.57602	0.69143	0.43038	0.03415	0.98419	2282	24	2294	71	2307	152	-1.3
N03 3-1C	30	1409338	261	0.14191	0.00214	8.44166	0.68468	0.43144	0.03438	0.98256	2251	26	2280	71	2312	153	-3.3
N03 3-1D	30	817927	191	0.14273	0.00197	8.21362	0.66895	0.41738	0.03350	0.98551	2261	24	2255	71	2249	151	0.6
N03 3-1E	30	571616	125	0.13340	0.00196	7.34145	0.59143	0.39914	0.03162	0.98328	2143	25	2154	70	2165	144	-1.2
N03 3-1F	30	868820	150	0.14180	0.00200	8.56442	0.66992	0.43804	0.03370	0.98361	2249	24	2293	69	2342	149	-4.9
N03 3-1G	30	1432240	295	0.13845	0.00196	7.76216	0.67919	0.40663	0.03511	0.98681	2208	24	2204	76	2199	159	0.4
N05B 2-1A	30	427916	141	0.14344	0.00216	7.83008	0.74990	0.39590	0.03744	0.98754	2269	26	2212	83	2150	171	6.2
N05B 2-1B	30	772515	46	0.16088	0.00222	10.59288	0.85587	0.47753	0.03802	0.98533	2465	23	2488	72	2517	164	-2.5
N05B 2-1C	30	776910	43	0.15103	0.00210	9.23560	0.73157	0.44350	0.03458	0.98441	2358	24	2362	70	2366	153	-0.4
N05B 2-1D	30	594869	33	0.15682	0.00216	9.84172	0.84047	0.45516	0.03836	0.98686	2422	23	2420	76	2418	168	0.2
N05B 2-1E	30	521740	60	0.13997	0.00286	7.68865	0.66292	0.39839	0.03337	0.97145	2227	35	2195	75	2162	152	3.4
N05B 3-1A	30	171549	20	0.15214	0.00232	8.70238	0.99048	0.41486	0.04679	0.99098	2370	26	2307	99	2237	210	6.6
N05B 3-1C	30	202103	30	0.15040	0.00228	8.88405	0.74312	0.42842	0.03524	0.98339	2350	26	2326	74	2299	157	2.6
N05B 3-1D	30	334747	22	0.15781	0.00217	9.85189	0.86042	0.45279	0.03905	0.98748	2432	23	2421	77	2408	171	1.2
N05B 3-1E	30	159716	23	0.16097	0.00237	9.77421	0.81532	0.44040	0.03616	0.98433	2466	25	2414	74	2352	160	5.5

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains (continued)

											Ages (Ma)						
Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	$^{207}Pb/^{206}Pb$	±2 s	$^{207}Pb/^{235}U$	±2 s	$^{206}Pb/^{238}U$	±2 s	r	$^{207}Pb^*/^{206}Pb^*$	±2 s	$^{207}Pb^*/^{235}U$	±2 s	$^{206}Pb^*/^{238}U$	±2 s	% Disc.
N05B 3-1F	30	281838	24	0.14344	0.00227	8.74774	0.81423	0.44229	0.04057	0.98545	2269	27	2312	81	2361	179	-4.8
N05B 4-1A	30	281027	27	0.15767	0.00250	9.43529	0.78411	0.43402	0.03540	0.98157	2431	27	2381	74	2324	157	5.2
N05B 4-1B	30	295895	30	0.15917	0.00231	9.81970	0.84989	0.44744	0.03818	0.98578	2447	24	2418	77	2384	168	3.1
N06A 3-1A	30	173986	308	0.12308	0.00160	5.91518	0.25051	0.34856	0.01405	0.95180	2001	23	1963	36	1928	67	4.3
N06A 3-1B	30	174788	310	0.12194	0.00163	6.02386	0.24140	0.35827	0.01353	0.94237	1985	24	1979	34	1974	64	0.6
N06A 3-1C	30	193568	315	0.12149	0.00158	5.80559	0.27853	0.34659	0.01601	0.96259	1978	23	1947	41	1918	76	3.5
N06A 3-1D	30	91268	321	0.12189	0.00161	5.81063	0.25455	0.34573	0.01444	0.95357	1984	23	1948	37	1914	69	4.1
N06A 3-1D.1	30	407605	333	0.12349	0.00153	6.11564	0.40346	0.35918	0.02327	0.98212	2007	22	1992	56	1978	109	1.7
N06C 2-1A	30	388117	125	0.14360	0.00135	7.92473	0.50519	0.40025	0.02524	0.98906	2271	16	2222	56	2170	115	5.2
N06C 2-1B	30	322165	118	0.14040	0.00098	7.39664	0.25581	0.38210	0.01294	0.97934	2232	12	2161	30	2086	60	7.7
N06C 2-1C	30	388690	136	0.14278	0.00125	7.99049	0.60657	0.40590	0.03061	0.99332	2261	15	2230	66	2196	139	3.4
N06C 2-1D	30	447842	202	0.14887	0.00117	8.08973	0.32363	0.39412	0.01546	0.98059	2333	13	2241	36	2142	71	9.6
N06C 5-1A	30	344800	140	0.14811	0.00087	8.15196	0.41046	0.39918	0.01996	0.99316	2324	10	2248	45	2165	91	8.0
N06C 6-1A	30	433343	181	0.12999	0.00105	6.88148	0.37085	0.38394	0.02046	0.98874	2098	14	2096	47	2095	95	0.2
N06C 6-1B	30	273228	152	0.13977	0.00097	7.60034	0.39362	0.39439	0.02024	0.99089	2224	12	2185	45	2143	93	4.3
N06C 6-1C	30	673495	143	0.14635	0.00086	8.34384	0.30797	0.41350	0.01507	0.98711	2304	10	2269	33	2231	68	3.7
N06C 6-1D	30	345239	138	0.14455	0.00081	8.40551	0.33003	0.42174	0.01639	0.98979	2282	10	2276	35	2268	74	0.7
N06C 6-1E	30	544184	159	0.14585	0.00084	8.19669	0.42888	0.40760	0.02120	0.99394	2298	10	2253	46	2204	96	4.8
HW3526-1A	30	998533	33	0.12036	0.00138	5.34102	0.30887	0.32184	0.01824	0.98024	1962	20	1875	48	1799	88	9.5
HW3526-1B	30	1074894	23	0.11860	0.00131	5.45184	0.26231	0.33340	0.01561	0.97318	1935	20	1893	40	1855	75	4.8
HW3526-1C	30	219303	6	0.13607	0.00153	6.96314	0.45640	0.37113	0.02396	0.98515	2178	19	2107	57	2035	112	7.7
HW3526-2A	30	1232759	23	0.13346	0.00143	7.32304	0.34967	0.39795	0.01852	0.97442	2144	19	2152	42	2160	85	-0.9
HW3526-2B	30	709539	5	0.12824	0.00154	6.54327	0.32857	0.37005	0.01805	0.97115	2074	21	2052	43	2030	84	2.5
HW3526-2C	30	1224998	16	0.12362	0.00143	5.98892	0.34329	0.35135	0.01973	0.97949	2009	20	1974	49	1941	93	3.9
HW3526-3A	30	1455054	27	0.12531	0.00132	6.04224	0.31089	0.34970	0.01761	0.97876	2033	19	1982	44	1933	84	5.7
HW3526-3B	30	936450	20	0.13902	0.00149	7.54870	0.46961	0.39383	0.02414	0.98512	2215	18	2179	54	2141	111	3.9
HW3526-4A	30	424846	16	0.15283	0.00171	8.78028	0.50277	0.41667	0.02340	0.98083	2378	19	2315	51	2245	106	6.6
HW3526-4B	30	680574	16	0.15694	0.00163	9.49407	0.50682	0.43874	0.02297	0.98086	2423	18	2387	48	2345	102	3.8
HW3526-4C	30	358548	15	0.15425	0.00165	9.32871	0.58870	0.43862	0.02728	0.98558	2394	18	2371	56	2344	121	2.5
HW3530 1-1A	30	902365	246	0.13157	0.00180	7.12535	0.46034	0.39279	0.02480	0.97729	2119	24	2127	56	2136	114	-0.9
HW3530 1-1B	30	1278873	241	0.12451	0.00164	6.28515	0.25926	0.36612	0.01431	0.94757	2022	23	2016	36	2011	67	0.6
HW3530 1-1C	30	629635	319	0.12017	0.00155	6.05116	0.28892	0.36521	0.01679	0.96265	1959	23	1983	41	2007	79	-2.9
HW3530 2-1A	30	1192871	286	0.14106	0.00178	7.58104	0.40638	0.38980	0.02031	0.97182	2240	22	2183	47	2122	94	6.2
HW3530 2-1B	30	1179000	319	0.14180	0.00180	7.99866	0.49650	0.40911	0.02486	0.97877	2249	22	2231	55	2211	113	2.0

APPENDIX B - U-Pb Geochronological Data

In-situ LA-MC-ICP-MS U-Pb dating of monazite grains

											Ages (Ma)						
Analysis	Spot Size µm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M0034-1.2A	12	1868392	61	0.12174	0.00127	5.93649	0.25280	0.35365	0.01460	0.970	1982	18	1967	36	1952	69	1.7
M0034-1.2B	12	1822425	58	0.12385	0.00140	5.58448	0.36662	0.32703	0.02115	0.985	2012	20	1914	55	1824	102	10.7
M0034-1.2C	12	1880030	68	0.12327	0.00123	5.62357	0.34031	0.33086	0.01975	0.986	2004	18	1920	51	1843	95	9.3
M0034-1.2D	12	1505041	61	0.12174	0.00132	6.08902	0.29701	0.36275	0.01725	0.975	1982	19	1989	42	1995	81	-0.8
M0034-1.2E	12	1317706	69	0.12180	0.00125	5.75989	0.24282	0.34297	0.01403	0.970	1983	18	1940	36	1901	67	4.8
M0034-1.2F	12	1169527	49	0.12167	0.00110	5.21437	0.27423	0.31084	0.01611	0.985	1981	16	1855	44	1745	79	13.6
M0034-1.2G	12	532403	56	0.12033	0.00114	5.86355	0.36344	0.35342	0.02165	0.988	1961	17	1956	52	1951	102	0.6
M0034-1.2H	12	974475	67	0.12174	0.00115	5.31841	0.33050	0.31686	0.01946	0.988	1982	17	1872	52	1774	95	12.0
M0034-1.2I	12	939735	65	0.12163	0.00115	5.58280	0.25297	0.33290	0.01475	0.978	1980	17	1913	38	1852	71	7.4
M0034-1.2J	12	820754	70	0.12120	0.00108	5.42585	0.28013	0.32469	0.01651	0.985	1974	16	1889	43	1813	80	9.4
M0034-1.2M	12	1405208	59	0.12143	0.00128	5.42166	0.27611	0.32383	0.01614	0.978	1977	19	1888	43	1808	78	9.8
M0034-2.2A	12	1383094	72	0.12329	0.00165	6.16673	0.31847	0.36275	0.01809	0.966	2004	24	2000	44	1995	85	0.5
M0034-2.2B	12	1512417	102	0.12357	0.00124	5.73613	0.25253	0.33666	0.01443	0.974	2008	18	1937	37	1871	69	7.9
M0034-2.2C	12	1501550	74	0.12226	0.00125	5.34688	0.29012	0.31719	0.01690	0.982	1989	18	1876	45	1776	82	12.3
M0034-2.2D	12	785660	56	0.12050	0.00110	5.50248	0.43791	0.33118	0.02618	0.993	1964	16	1901	66	1844	126	7.0
M0034-2.2E	12	1605036	82	0.12223	0.00124	6.00154	0.44954	0.35611	0.02643	0.991	1989	18	1976	63	1964	124	1.5
M0034-2.2F	12	1262575	102	0.12200	0.00143	6.75830	0.76626	0.40176	0.04531	0.995	1986	21	2080	96	2177	205	-11.4
M0034-2.2G	12	1474557	80	0.12299	0.00134	5.61783	0.28125	0.33128	0.01619	0.976	2000	19	1919	42	1845	78	8.9
M0034-2.2J	12	793609	81	0.12105	0.00113	6.03701	0.24967	0.36171	0.01457	0.974	1972	17	1981	35	1990	69	-1.1
M0034-3.1A	12	1443036	81	0.12148	0.00122	5.85801	0.38009	0.34975	0.02242	0.988	1978	18	1955	55	1933	106	2.6
M0034-3.1B	12	1462259	85	0.12083	0.00128	6.00950	0.34129	0.36072	0.02012	0.982	1969	19	1977	48	1986	95	-1.0
M0034-3.1C	12	1386203	89	0.12121	0.00115	6.45018	0.30912	0.38594	0.01813	0.980	1974	17	2039	41	2104	84	-7.7
M0034-3.1D	12	2169249	104	0.12229	0.00135	6.12457	0.32728	0.36324	0.01899	0.979	1990	19	1994	46	1998	89	-0.4
M0034-6.1A	12	2351068	134	0.12296	0.00142	5.52511	0.24503	0.32590	0.01396	0.966	2000	20	1905	37	1818	67	10.4
M0034-6.1B	12	2142713	117	0.12390	0.00119	5.62142	0.17855	0.32907	0.00996	0.953	2013	17	1919	27	1834	48	10.2
M0034-6.1C	12	2076500	65	0.12293	0.00133	5.89777	0.47005	0.34796	0.02748	0.991	1999	19	1961	67	1925	130	4.3
M0034-6.1E	12	2009577	81	0.12388	0.00123	5.67418	0.27367	0.33220	0.01568	0.978	2013	18	1927	41	1849	75	9.4
M0034-7.1A	12	1227996	123	0.12015	0.00110	6.00451	0.28214	0.36246	0.01671	0.981	1958	16	1976	40	1994	79	-2.1
M0034-7.1B	12	1086428	86	0.11977	0.00109	5.51719	0.32481	0.33409	0.01943	0.988	1953	16	1903	49	1858	93	5.6
M0034-7.1C	12	661319	48	0.11890	0.00106	5.49219	0.35579	0.33501	0.02150	0.990	1940	16	1899	54	1863	103	4.6
M0034-7.1D	12	1385802	94	0.11982	0.00116	5.83265	0.32401	0.35305	0.01931	0.985	1954	17	1951	47	1949	91	0.3
M3997-4.1A	12	854357	61	0.12101	0.00146	5.72605	0.35541	0.34318	0.02089	0.98081	1971	21	1935	52	1902	99	4.1
M3997-4.1B	12	836729	87	0.12013	0.00141	6.11083	0.32084	0.36895	0.01888	0.97462	1958	21	1992	45	2024	88	-3.9
M3997-4.1C	12	1113127	98	0.12053	0.00140	6.00002	0.27694	0.36103	0.01613	0.96779	1964	21	1976	39	1987	76	-1.4
M3997-4.1D	12	524839	94	0.11998	0.00143	6.12575	0.40499	0.37031	0.02408	0.98358	1956	21	1994	56	2031	112	-4.5
M3997-4.1E	12	1090970	76	0.11963	0.00149	6.08775	0.25314	0.36906	0.01464	0.95426	1951	22	1988	36	2025	69	-4.4
M3997-4.1F	12	637098	88	0.11891	0.00135	6.04707	0.34604	0.36883	0.02069	0.98015	1940	20	1983	49	2024	97	-5.0
M3997-4.1G	12	615570	78	0.11836	0.00136	5.86325	0.24604	0.35928	0.01450	0.96176	1932	20	1956	36	1979	68	-2.8
M3997-4.1H	12	640774	91	0.11785	0.00138	5.71959	0.24597	0.35199	0.01457	0.96246	1924	21	1934	37	1944	69	-1.2
M3997-4.1I	12	663039	95	0.11954	0.00145	5.73672	0.43605	0.34807	0.02612	0.98723	1949	21	1937	64	1925	124	1.4
M3997-8.1A	12	451812	103	0.11950	0.00135	5.73237	0.29148	0.34792	0.01725	0.97493	1949	20	1936	43	1925	82	1.4
M3997-8.1B	12	382034	79	0.12016	0.00143	5.69263	0.29267	0.34359	0.01719	0.97299	1959	21	1930	43	1904	82	3.2
M3997-8.1C	12	442847	75	0.11949	0.00141	5.53784	0.30508	0.33613	0.01809	0.97675	1949	21	1906	46	1868	87	4.8
M3997-8.1D	12	637579	69	0.11976	0.00141	5.71633	0.36822	0.34619	0.02193	0.98319	1953	21	1934	54	1916	104	2.1
M3997-8.1E	12	312244	70	0.11948	0.00140	5.67483	0.31906	0.34448	0.01894	0.97803	1948	21	1928	47	1908	90	2.4
M3997-8.1F	12	442912	70	0.11951	0.00139	5.80074	0.25016	0.35203	0.01462	0.96294	1949	21	1947	37	1944	69	0.3

In-situ LA-MC-ICP-MS U-Pb dating of monazite grains (continued)

											Ages (Ma)						
Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12636-2.2F	12	82374	44	0.11975	0.00195	5.92639	0.33785	0.35893	0.01961	0.95849	1953	29	1965	48	1977	92	-1.5
M12636-2.2G	12	76449	46	0.12014	0.00184	5.98312	0.39169	0.36118	0.02299	0.97211	1958	27	1973	55	1988	108	-1.7
M12636-2.2H	12	84297	49	0.12024	0.00181	5.86858	0.28504	0.35399	0.01635	0.95100	1960	27	1957	41	1954	77	0.4
M12636-2.2I	12	62560	51	0.11959	0.00189	5.82394	0.35477	0.35319	0.02078	0.96593	1950	28	1950	51	1950	98	0.0
M12636-2.2J	12	71008	58	0.11985	0.00184	5.83936	0.34033	0.35338	0.01986	0.96452	1954	27	1952	49	1951	94	0.2
M12636-2.2K	12	103055	43	0.11921	0.00183	5.52221	0.30709	0.33596	0.01796	0.96118	1944	27	1904	47	1867	86	4.6
M12636-2.2L	12	183732	50	0.11951	0.00187	6.08039	0.34561	0.36900	0.02017	0.96153	1949	28	1987	48	2025	94	-4.5
M12636-2.2M	12	187178	44	0.11955	0.00182	5.98950	0.36710	0.36336	0.02157	0.96855	1950	27	1974	52	1998	101	-2.9
M12636-2.2N	12	239452	31	0.11941	0.00178	5.62795	0.39083	0.34184	0.02319	0.97679	1947	26	1920	58	1896	110	3.1
M12636-2.2O	12	300287	58	0.11934	0.00181	5.93321	0.40126	0.36059	0.02377	0.97459	1946	27	1966	57	1985	112	-2.3
M12636-2.2P	12	244280	55	0.11951	0.00180	5.75616	0.32800	0.34933	0.01920	0.96434	1949	27	1940	48	1931	91	1.0
M12636-2.2Q	12	200123	55	0.11989	0.00179	6.14448	0.43703	0.37172	0.02585	0.97779	1955	26	1997	60	2037	120	-5.0
M12636-2.2R	12	219424	68	0.12039	0.00182	6.48235	0.39598	0.39051	0.02311	0.96897	1962	27	2044	52	2125	106	-9.8
M12636-2.2S	12	148505	61	0.11971	0.00182	6.13765	0.56167	0.37185	0.03356	0.98614	1952	27	1996	77	2038	156	-5.1
M12636-2.2T	12	136192	71	0.12213	0.00202	6.21078	0.45440	0.36884	0.02629	0.97417	1988	29	2006	62	2024	123	-2.1
M12636-3.2A	12	83063	31	0.12168	0.00201	5.75347	0.36727	0.34294	0.02115	0.96603	1981	29	1939	54	1901	101	4.7
M12636-3.2B	12	71105	41	0.12110	0.00189	5.74346	0.38798	0.34397	0.02260	0.97281	1973	28	1938	57	1906	108	3.9
M12636-3.2C	12	56012	21	0.11997	0.00198	5.60495	0.35922	0.33885	0.02099	0.96633	1956	29	1917	54	1881	100	4.4
M12636-3.2D	12	66498	27	0.11974	0.00199	5.84224	0.41015	0.35386	0.02413	0.97143	1952	29	1953	59	1953	114	0.0
M12636-2.2A	12	125137	25	0.11953	0.00184	5.97227	0.35079	0.36238	0.02054	0.96516	1949	27	1972	50	1993	96	-2.6
M12636-2.2B	12	82627	45	0.11945	0.00187	5.77476	0.25337	0.35062	0.01437	0.93438	1948	28	1943	37	1938	68	0.6
M12636-2.2C	12	76937	38	0.11981	0.00182	5.96460	0.34820	0.36106	0.02035	0.96543	1953	27	1971	50	1987	96	-2.0
M12636-2.2D	12	72540	53	0.11973	0.00187	5.87180	0.34392	0.35568	0.02008	0.96388	1952	28	1957	50	1962	95	-0.6
M12636-2.2E	12	68812	57	0.11993	0.00189	5.86597	0.31314	0.35474	0.01809	0.95522	1955	28	1956	45	1957	86	-0.1
M12640-6.1B	12	483535	46	0.12007	0.00139	6.26727	0.40090	0.37856	0.02381	0.98342	1957	21	2014	55	2070	110	-6.7
M12640-6.1C	12	374804	33	0.11983	0.00139	5.78015	0.41285	0.34984	0.02465	0.98667	1954	21	1943	60	1934	117	1.2
M12640-6.1D	12	1401180	29	0.12021	0.00143	6.00833	0.45116	0.36250	0.02688	0.98742	1959	21	1977	63	1994	126	-2.1
M12640-6.1E	12	661967	11	0.11953	0.00138	6.07801	0.27714	0.36881	0.01627	0.96745	1949	20	1987	39	2024	76	-4.5
M12640-6.1F	12	610549	9	0.11899	0.00135	6.10891	0.41216	0.37235	0.02476	0.98573	1941	20	1992	57	2040	115	-6.0
M12640-6.1G	12	597521	11	0.11952	0.00141	6.26465	0.36822	0.38014	0.02189	0.97978	1949	21	2014	50	2077	101	-7.7
M12640-6.1H	12	739033	12	0.11964	0.00140	6.02910	0.31467	0.36550	0.01859	0.97458	1951	21	1980	44	2008	87	-3.4
M12640-6.1I	12	909011	18	0.12006	0.00156	6.40962	0.45229	0.38718	0.02686	0.98301	1957	23	2034	60	2110	124	-9.1
M12640-6.1J	12	364383	15	0.12039	0.00141	5.92467	0.31510	0.35692	0.01851	0.97534	1962	21	1965	45	1968	87	-0.3
M12640-6.1K	12	690248	9	0.11985	0.00138	5.77598	0.34333	0.34952	0.02038	0.98116	1954	20	1943	50	1932	97	1.3
M12640-6.1L	12	615378	23	0.11914	0.00136	5.71983	0.29685	0.34820	0.01763	0.97558	1943	20	1934	44	1926	84	1.0
M12640-6.1M	12	504218	14	0.11928	0.00139	6.12524	0.40248	0.37245	0.02408	0.98406	1945	21	1994	56	2041	112	-5.7
M12640-6.1N	12	338595	6	0.11974	0.00136	5.89896	0.41785	0.35729	0.02498	0.98698	1952	20	1961	60	1969	118	-1.0
M12640-6.1O	12	421711	8	0.12004	0.00138	5.73835	0.28892	0.34670	0.01700	0.97367	1957	20	1937	43	1919	81	2.2
M12640-7.1A	12	1176610	6	0.11936	0.00139	5.86622	0.35565	0.35644	0.02121	0.98139	1947	21	1956	51	1965	100	-1.1
M12640-7.1B	12	1295581	7	0.11923	0.00138	5.58328	0.30693	0.33962	0.01825	0.97758	1945	21	1914	46	1885	87	3.6
M12640-7.1C	12	1032502	7	0.11898	0.00138	5.60263	0.31096	0.34153	0.01854	0.97796	1941	21	1917	47	1894	88	2.8
M12640-7.1D	12	803104	4	0.11939	0.00137	5.98680	0.39094	0.36369	0.02338	0.98445	1947	20	1974	55	2000	110	-3.1
M12640-7.1E	12	731326	0	0.11917	0.00137	5.71047	0.27969	0.34755	0.01655	0.97198	1944	20	1933	41	1923	79	1.2

In-situ LA-MC-ICP-MS U-Pb dating of monazite grains (continued)

Analysis	Spot Size µm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	Ages (Ma) ^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12640-7.1F	12	502142	11	0.11928	0.00137	5.58184	0.32720	0.33940	0.01951	0.98073	1945	20	1913	49	1884	93	3.7
M12640-7.1G	12	836914	14	0.11916	0.00138	5.85881	0.27772	0.35660	0.01639	0.96952	1944	21	1955	40	1966	77	-1.3
M12640-7.1H	12	356394	7	0.11909	0.00139	5.54122	0.31153	0.33746	0.01856	0.97811	1943	21	1907	47	1874	89	4.0
M12640-7.1I	12	666982	6	0.11918	0.00139	5.74008	0.37649	0.34930	0.02255	0.98413	1944	21	1937	55	1931	107	0.8
M12640-7.1J	12	694991	15	0.11895	0.00138	5.95695	0.44594	0.36322	0.02686	0.98792	1940	21	1970	63	1997	126	-3.4
M12640-6.1A	12	300917	32	0.12013	0.00138	6.09727	0.38181	0.36811	0.02266	0.98305	1958	20	1990	53	2021	106	-3.7
HW3523-65A	12	441721	88	0.119229	0.001081	5.694386	0.423852	0.346387	0.025591	0.992558	1945	16	1931	62	1917	121	1.6
HW3523-65B	12	469233	104	0.119074	0.001037	6.019083	0.479211	0.366616	0.029013	0.993996	1942	15	1979	67	2013	135	-4.3
HW3523-65C	12	367322	111	0.119128	0.001036	5.496661	0.389491	0.334645	0.023534	0.992447	1943	15	1900	59	1861	113	4.9
HW3523-65D	12	536737	115	0.119158	0.001060	5.527421	0.367995	0.336432	0.022197	0.991028	1944	16	1905	56	1869	106	4.4
HW3523-65E	12	832334	111	0.118797	0.001075	5.449785	0.479787	0.332715	0.029136	0.994699	1938	16	1893	73	1852	139	5.1
HW3523-65F	12	752729	143	0.118488	0.001074	5.231585	0.278829	0.320228	0.016819	0.985432	1934	16	1858	44	1791	82	8.4
HW3523-65G	12	455242	142	0.119467	0.001098	5.375729	0.288556	0.326353	0.017259	0.985241	1948	16	1881	45	1821	83	7.5
HW3523-65H	12	580660	121	0.119036	0.001063	5.248802	0.257913	0.319801	0.015453	0.983354	1942	16	1861	41	1789	75	9.0
HW3523-65I	12	369156	143	0.120159	0.001316	5.719153	0.424095	0.345203	0.025317	0.989032	1959	19	1934	62	1912	120	2.8
HW3523-65J	12	486069	135	0.119125	0.001067	5.623176	0.387749	0.342357	0.023408	0.991535	1943	16	1920	58	1898	111	2.7
HW3523-65K	12	451671	128	0.119062	0.001043	5.414128	0.415777	0.329804	0.025162	0.993474	1942	16	1887	64	1837	121	6.2
HW3523-65L	12	559323	133	0.119309	0.001115	5.124778	0.346114	0.311531	0.020838	0.990383	1946	17	1840	56	1748	102	11.6
HW3523-64A	12	901359	123	0.118301	0.001069	5.541368	0.377494	0.339724	0.022938	0.991160	1931	16	1907	57	1885	109	2.7
HW3523-64B	12	629580	139	0.117799	0.001046	5.151052	0.335054	0.317140	0.020435	0.990638	1923	16	1845	54	1776	99	8.8
HW3523-63A	12	1017565	133	0.118255	0.001044	5.833961	0.293520	0.357801	0.017723	0.984490	1930	16	1951	43	1972	84	-2.5
HW3523-63B	12	726657	140	0.118236	0.001060	5.813756	0.387160	0.356619	0.023532	0.990892	1930	16	1948	56	1966	111	-2.2
M12352A 1-1A	12	184118	41	0.121614	0.001531	6.947079	0.526511	0.414301	0.030963	0.986102	1980	22	2105	65	2235	140	-15.2
M12352A 1-1B	12	307472	45	0.122339	0.001595	6.525296	0.557859	0.386843	0.032685	0.988303	1991	23	2049	73	2108	150	-6.9
M12352A 1-1C	12	54114	58	0.122868	0.001864	7.208046	0.546128	0.425478	0.031584	0.979754	1998	27	2137	65	2285	141	-17.1
M12352A 1-1E	12	130541	45	0.121238	0.001569	6.763152	0.474576	0.404585	0.027903	0.982854	1975	23	2081	60	2190	127	-12.9
M12352A 1-1G	12	414661	55	0.121296	0.001518	6.538664	0.482915	0.390969	0.028457	0.985530	1975	22	2051	63	2127	131	-9.0
M12352A 1-1H	12	86149	59	0.120771	0.001688	6.779819	0.601433	0.407150	0.035667	0.987511	1968	25	2083	76	2202	161	-14.1
M12352A 1-1I	12	139028	39	0.121284	0.001550	6.767814	0.405765	0.404709	0.023707	0.977029	1975	23	2082	52	2191	108	-12.9
M12352A 1-1J	12	208782	49	0.121358	0.001524	6.631877	0.491153	0.396338	0.028928	0.985526	1976	22	2064	63	2152	132	-10.5
M12352A 3-1A	12	75331	40	0.120198	0.001611	5.800340	0.277429	0.349989	0.016069	0.959948	1959	24	1946	41	1935	76	1.5
M12352A 3-1B	12	107099	49	0.120289	0.001591	5.598078	0.277004	0.337530	0.016094	0.963610	1961	23	1916	42	1875	77	5.0
M12352A 3-1C	12	366000	54	0.122888	0.001555	5.937287	0.313346	0.350411	0.017954	0.970819	1999	22	1967	45	1937	85	3.6
M12352A 3-1D	12	371917	45	0.123453	0.001608	6.006383	0.354879	0.352866	0.020336	0.975395	2007	23	1977	50	1948	96	3.4
M12352A 3-1E	12	386013	51	0.123366	0.001562	5.779204	0.320551	0.339760	0.018347	0.973583	2005	22	1943	47	1886	88	6.9
M12352A 3-1F	12	245886	43	0.122752	0.001596	5.413898	0.316884	0.319874	0.018255	0.975032	1997	23	1887	49	1789	89	11.9
M12352A 3-1G	12	239209	29	0.121307	0.001542	5.763138	0.403315	0.344566	0.023712	0.983354	1976	22	1941	59	1909	113	3.9
M12352A 3-1H	12	433646	30	0.123823	0.001589	5.649506	0.322613	0.330909	0.018413	0.974408	2012	23	1924	48	1843	89	9.7
M12352A 3-1I	12	461846	26	0.124115	0.001594	5.632440	0.284043	0.329133	0.016051	0.967024	2016	23	1921	43	1834	77	10.4
M12352A 3-1J	12	327466	21	0.123436	0.001547	5.906641	0.316959	0.347055	0.018108	0.972333	2006	22	1962	46	1921	86	5.0
M12352A 3-1K	12	458379	22	0.123791	0.001575	6.003134	0.337872	0.351712	0.019283	0.974123	2012	22	1976	48	1943	91	4.0
M12352A 3-1L	12	337468	15	0.122776	0.001579	5.875093	0.333930	0.347055	0.019215	0.974078	1997	23	1958	48	1921	91	4.4
M12352A 5-2A	12	110771	18	0.121327	0.001541	6.394790	0.393622	0.382268	0.023024	0.978490	1976	22	2032	53	2087	106	-6.6
M12352A 5-2B	12	72622	18	0.121786	0.001660	6.842724	0.478508	0.407501	0.027950	0.980821	1983	24	2091	60	2203	127	-13.2

In-situ LA-MC-ICP-MS U-Pb dating of monazite grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	Ages (Ma) ^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
M12352A 5-2C	12	66702	33	0.121517	0.001610	6.676303	0.485075	0.398471	0.028466	0.983230	1979	23	2069	62	2162	130	-10.9
M12352A 5-2D	12	384774	57	0.122228	0.001524	7.267584	0.617928	0.431238	0.036270	0.989193	1989	22	2145	73	2311	161	-19.3
M12352A 5-2E	12	152752	37	0.120741	0.001543	6.852481	0.633322	0.411615	0.037677	0.990391	1967	23	2093	79	2222	170	-15.3
M12352A 6-1A	12	128876	42	0.120593	0.001682	6.484242	0.519405	0.389974	0.030761	0.984732	1965	25	2044	68	2123	141	-9.4
M12352A 6-1B	12	38408	36	0.121285	0.001665	6.692662	0.451232	0.400212	0.026418	0.979058	1975	24	2072	58	2170	120	-11.6
M12352A 6-1C	12	54290	31	0.120672	0.001831	6.659981	0.596784	0.400280	0.035350	0.985554	1966	27	2067	76	2170	161	-12.2
M12352A 6-1D	12	58223	39	0.121067	0.001599	6.269356	0.320409	0.375574	0.018543	0.966034	1972	23	2014	44	2056	86	-5.0
M12352A 6-1E	12	78711	45	0.122250	0.001566	6.941172	0.539414	0.411797	0.031564	0.986315	1989	23	2104	67	2223	143	-13.9
M12352A 6-1F	12	48709	45	0.121691	0.001713	7.009167	0.493478	0.417741	0.028817	0.979812	1981	25	2113	61	2250	130	-16.1
M12352A 6-1G	12	48558	46	0.122678	0.001792	6.789881	0.523185	0.401417	0.030370	0.981862	1996	26	2084	66	2176	138	-10.6
M12352A 6-1H	12	47595	44	0.122080	0.001680	6.826795	0.449396	0.405574	0.026108	0.977896	1987	24	2089	57	2195	119	-12.4
M12352A 6-1I	12	65652	35	0.121994	0.001600	6.899278	0.583414	0.410170	0.034265	0.987899	1986	23	2099	72	2216	155	-13.7
M12352A 7-1C	12	646127	41	0.123565	0.001615	6.687889	0.433644	0.392546	0.024930	0.979474	2008	23	2071	56	2135	114	-7.4
M12352A 7-1D	12	81149	43	0.120545	0.001623	6.607558	0.374484	0.397549	0.021886	0.971375	1964	24	2060	49	2158	100	-11.6
M12352A 7-1E	12	37984	50	0.120111	0.001850	6.832688	0.417817	0.412580	0.024416	0.967766	1958	27	2090	53	2227	110	-16.3
M12352A 7-1F	12	52503	53	0.121348	0.001591	6.556850	0.372706	0.391888	0.021675	0.973024	1976	23	2054	49	2132	100	-9.2
M12352A 7-1G	12	172119	58	0.120074	0.001596	6.484727	0.515837	0.391691	0.030720	0.985940	1957	24	2044	68	2131	141	-10.4
M12352A 7-1H	12	213676	82	0.120487	0.001632	6.955681	0.462622	0.418694	0.027264	0.979055	1963	24	2106	57	2255	123	-17.6
M12639-2.2A	12	103278	12	0.12096	0.00164	6.04056	0.28142	0.36218	0.01615	0.95691	1970	24	1982	40	1992	76	-1.3
M12639-2.2B	12	72910	7	0.12161	0.00153	6.28612	0.33630	0.37489	0.01949	0.97185	1980	22	2017	46	2052	91	-4.3
M12639-2.2C	12	70496	14	0.12266	0.00147	6.10741	0.28715	0.36111	0.01642	0.96716	1995	21	1991	40	1987	77	0.5
M12639-2.2D	12	71462	6	0.12259	0.00166	6.28198	0.41173	0.37166	0.02384	0.97848	1994	24	2016	56	2037	111	-2.5
M12639-2.2E	12	86283	23	0.12260	0.00156	6.06983	0.35263	0.35907	0.02035	0.97564	1994	22	1986	49	1978	96	1.0
M12639-2.2F	12	69400	20	0.12230	0.00156	6.11091	0.27496	0.36240	0.01564	0.95905	1990	22	1992	39	1994	74	-0.2
M12639-2.2G	12	108011	15	0.12204	0.00168	5.93099	0.39193	0.35247	0.02278	0.97811	1986	24	1966	56	1946	108	2.3
M12639-4.1A	12	91908	22	0.12099	0.00147	5.63943	0.49806	0.33805	0.02957	0.99044	1971	22	1922	73	1877	141	5.5
M12639-4.1B	12	74979	14	0.12127	0.00149	5.95869	0.34465	0.35636	0.02014	0.97704	1975	22	1970	49	1965	95	0.6
M12639-4.1C	12	103478	12	0.12110	0.00146	5.95409	0.33442	0.35659	0.01956	0.97662	1973	21	1969	48	1966	92	0.4
M12639-4.1D	12	55954	10	0.12282	0.00174	6.20528	0.43358	0.36643	0.02507	0.97918	1998	25	2005	59	2013	117	-0.9
M12639-4.1F	12	63080	7	0.12098	0.00170	6.30090	0.36468	0.37772	0.02121	0.97021	1971	25	2019	49	2066	98	-5.6
M12639-4.1G	12	47568	8	0.12277	0.00172	5.96093	0.31007	0.35213	0.01764	0.96301	1997	25	1970	44	1945	84	3.0
M12639-4.1H	12	88376	18	0.12277	0.00158	6.15325	0.28055	0.36352	0.01590	0.95958	1997	23	1998	39	1999	75	-0.1
M12639-4.1I	12	75178	17	0.12330	0.00169	6.21671	0.37816	0.36567	0.02167	0.97434	2005	24	2007	52	2009	101	-0.3
M12639-4.2A	12	23433	8	0.15600	0.00254	10.88395	0.56842	0.50600	0.02511	0.95020	2413	27	2513	47	2640	107	-11.5
M12639-4.2B	12	40105	22	0.15457	0.00199	10.80190	0.57438	0.50683	0.02615	0.97035	2397	22	2506	48	2643	111	-12.5
M12639-4.2C	12	47989	5	0.15358	0.00307	10.53718	0.57604	0.49762	0.02532	0.93079	2386	34	2483	49	2604	108	-11.1
M12639-4.2D	12	21212	4	0.15279	0.00274	10.23682	0.52727	0.48594	0.02346	0.93730	2377	30	2456	47	2553	101	-9.0
M12639-4.2E	12	28538	11	0.15115	0.00238	10.23809	0.55690	0.49127	0.02558	0.95724	2359	27	2457	49	2576	110	-11.2
M12639-4.2F	12	39427	8	0.14898	0.00218	9.47238	0.44522	0.46113	0.02060	0.95038	2334	25	2385	42	2445	90	-5.7
M12639-5.3B	12	58545	28	0.12161	0.00150	6.33323	0.36646	0.37770	0.02135	0.97689	1980	22	2023	50	2066	99	-5.0
M12639-5.3C	12	57412	19	0.12349	0.00174	6.15153	0.53822	0.36129	0.03120	0.98687	2007	25	1998	74	1988	146	1.1
M12639-5.3D	12	61898	23	0.12302	0.00160	6.49494	0.34312	0.38290	0.01961	0.96933	2001	23	2045	45	2090	91	-5.2
M12639-5.3E	12	55904	45	0.12240	0.00174	6.51959	0.43508	0.38631	0.02519	0.97696	1992	25	2049	57	2106	116	-6.7

In-situ LA-MC-ICP-MS U-Pb dating of monazite grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	$^{207}Pb/^{206}Pb$	±2 s	$^{207}Pb/^{235}U$	±2 s	$^{206}Pb/^{238}U$	±2 s	r	Ages (Ma) $^{207}Pb^*/^{206}Pb^*$	±2 s	$^{207}Pb^*/^{235}U$	±2 s	$^{206}Pb^*/^{238}U$	±2 s	% Disc.
M12643-2.1	12	512774	37	0.12078	0.00148	5.65767	0.40344	0.33972	0.02387	0.98521	1968	22	1925	60	1885	114	4.8
M12643-2.1B	12	153253	28	0.11994	0.00142	5.62053	0.30227	0.33988	0.01783	0.97539	1955	21	1919	45	1886	85	4.1
M12643-2.1C	12	100248	41	0.12078	0.00143	5.32437	0.40245	0.31972	0.02387	0.98772	1968	21	1873	63	1788	116	10.4
M12643-2.1D	12	90975	28	0.12085	0.00149	5.59594	0.33207	0.33583	0.01949	0.97807	1969	22	1915	50	1867	93	6.0
M12643-2.1E	12	94046	35	0.12035	0.00140	5.62203	0.28834	0.33881	0.01692	0.97397	1961	21	1919	43	1881	81	4.7
M12643-2.1F	12	72781	42	0.12094	0.00143	5.80674	0.33486	0.34822	0.01965	0.97873	1970	21	1947	49	1926	93	2.6
M12643-2.1G	12	201511	57	0.12077	0.00142	5.80794	0.35878	0.34879	0.02115	0.98175	1968	21	1948	52	1929	100	2.3
M12643-2.1H	12	172031	56	0.12068	0.00140	5.97958	0.33759	0.35936	0.01986	0.97876	1966	21	1973	48	1979	93	-0.8
M12643-2.1I	12	230251	51	0.12035	0.00140	5.77724	0.29817	0.34817	0.01751	0.97417	1961	21	1943	44	1926	83	2.1
M12643-2.1J	12	148786	63	0.12054	0.00138	5.95284	0.34878	0.35817	0.02058	0.98069	1964	20	1969	50	1973	97	-0.5
M12643-2.1K	12	294934	66	0.12075	0.00140	5.92654	0.24874	0.35596	0.01436	0.96096	1967	21	1965	36	1963	68	0.3
M12643-2.1L	12	229283	54	0.12030	0.00139	5.89412	0.35962	0.35533	0.02129	0.98198	1961	20	1960	52	1960	100	0.0
M12643-2.1M	12	180797	66	0.12089	0.00143	5.45058	0.37784	0.32700	0.02234	0.98535	1969	21	1893	58	1824	108	8.5
M12643-2.1N	12	203361	107	0.11990	0.00142	5.66041	0.32384	0.34240	0.01916	0.97826	1955	21	1925	48	1898	91	3.3
M12643-2.1O	12	197911	94	0.11988	0.00142	6.00462	0.41171	0.36327	0.02454	0.98505	1954	21	1977	58	1998	115	-2.6
M12643-2.1P	12	248417	111	0.12000	0.00140	5.79226	0.30963	0.35008	0.01826	0.97578	1956	21	1945	45	1935	87	1.3
M12643-3.1A	12	235440	105	0.12085	0.00143	5.88003	0.31485	0.35290	0.01843	0.97514	1969	21	1958	45	1948	87	1.2
M12643-3.1B	12	127280	118	0.12093	0.00145	5.76028	0.33665	0.34548	0.01976	0.97875	1970	21	1940	49	1913	94	3.3
M12643-3.1C	12	120955	117	0.12115	0.00150	5.74867	0.30567	0.34415	0.01780	0.97262	1973	22	1939	45	1907	85	3.9
M12643-3.1D	12	121228	110	0.12111	0.00149	5.69091	0.39819	0.34080	0.02348	0.98451	1973	22	1930	59	1891	112	4.8
M12643-3.1E	12	100730	141	0.12147	0.00146	5.61513	0.31121	0.33527	0.01814	0.97621	1978	21	1918	47	1864	87	6.6
M12643-3.1F	12	67522	149	0.12160	0.00159	5.67199	0.43358	0.33830	0.02548	0.98528	1980	23	1927	64	1878	122	5.9
M12643-3.1G	12	121405	133	0.12110	0.00146	5.77082	0.39544	0.34562	0.02331	0.98432	1972	21	1942	58	1914	111	3.4
M12643-3.1H	12	91765	154	0.12205	0.00173	5.61228	0.36314	0.33351	0.02106	0.97574	1986	25	1918	54	1855	101	7.6
M12643-3.1I	12	38319	173	0.12176	0.00153	5.63796	0.32114	0.33582	0.01866	0.97537	1982	22	1922	48	1867	89	6.7
M12643-3.1J	12	73585	173	0.12121	0.00148	5.69762	0.36584	0.34092	0.02149	0.98185	1974	22	1931	54	1891	103	4.9
M12643-3.1K	12	135700	161	0.12029	0.00144	5.63339	0.32026	0.33965	0.01888	0.97760	1961	21	1921	48	1885	90	4.4
M12643-4.1A	12	34630	169	0.12198	0.00179	5.70864	0.35405	0.33943	0.02045	0.97153	1985	26	1933	52	1884	98	5.9
M12643-4.1B	12	39560	187	0.12256	0.00175	5.73527	0.37424	0.33939	0.02161	0.97585	1994	25	1937	55	1884	103	6.4
M12643-4.1D	12	270046	204	0.12172	0.00146	6.03893	0.32670	0.35982	0.01898	0.97500	1982	21	1981	46	1981	89	0.0
N02B 1-1A	12	406409	49	0.119007	0.001509	5.299216	0.285617	0.322953	0.016918	0.971928	1941	23	1869	45	1804	82	8.1
N02B 1-1B	12	460629	56	0.119255	0.001472	5.492740	0.303246	0.334051	0.017976	0.974690	1945	22	1899	46	1858	86	5.2
N02B 1-1C	12	556999	59	0.119287	0.001551	5.106397	0.421238	0.310469	0.025291	0.987497	1946	23	1837	68	1743	123	11.9
N02B 1-1D	12	510282	46	0.119541	0.001482	5.520137	0.277216	0.334913	0.016298	0.969040	1949	22	1904	42	1862	78	5.1
N02B 1-1E	12	630541	69	0.120703	0.001496	5.540521	0.350498	0.332914	0.020652	0.980612	1967	22	1907	53	1852	99	6.7
N02B 1-2A	12	333984	57	0.118442	0.001470	5.611720	0.338901	0.343629	0.020310	0.978668	1933	22	1918	51	1904	97	1.7
N02B 1-2B	12	486483	66	0.118527	0.001491	5.357834	0.289133	0.327846	0.017204	0.972442	1934	22	1878	45	1828	83	6.3
N02B 1-2C	12	345177	58	0.118850	0.001489	5.556562	0.299621	0.339083	0.017784	0.972632	1939	22	1909	45	1882	85	3.4
N02B 2-1A	12	564275	61	0.119390	0.001516	5.586328	0.403683	0.339357	0.024142	0.984450	1947	23	1914	60	1884	115	3.8
N02B 2-1B	12	455873	60	0.119009	0.001499	5.638406	0.469365	0.343619	0.028275	0.988490	1941	22	1922	69	1904	134	2.2
N02B 2-1C	12	567212	89	0.119155	0.001504	5.960720	0.348610	0.362816	0.020719	0.976431	1944	22	1970	50	1996	97	-3.1
N02B 2-1D	12	331907	78	0.119383	0.001526	5.613215	0.391906	0.341012	0.023406	0.983091	1947	23	1918	58	1892	112	3.3
N02B 2-1E	12	447883	91	0.118951	0.001515	5.716495	0.309405	0.348547	0.018335	0.971914	1941	23	1934	46	1928	87	0.8
N02B 2-1F	12	607378	88	0.120313	0.001518	6.034672	0.374323	0.363780	0.022093	0.979101	1961	22	1981	53	2000	104	-2.3
N02B 2-1G	12	403985	78	0.119234	0.001509	5.408646	0.422312	0.328992	0.025348	0.986779	1945	22	1886	65	1833	122	6.6

In-situ LA-MC-ICP-MS U-Pb dating of monazite grains (continued)

Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	$^{207}Pb/^{206}Pb$	±2 s	$^{207}Pb/^{235}U$	±2 s	$^{206}Pb/^{238}U$	±2 s	r	Ages (Ma) $^{207}Pb^*/^{206}Pb^*$	±2 s	$^{207}Pb^*/^{235}U$	±2 s	$^{206}Pb^*/^{238}U$	±2 s	% Disc.
N02B 2-1H	12	316068	96	0.118997	0.001513	5.729099	0.379006	0.349180	0.022669	0.981354	1941	23	1936	56	1931	107	0.6
N02B 2-1I	12	575481	85	0.120251	0.001535	5.627540	0.487074	0.339413	0.029056	0.989066	1960	23	1920	72	1884	138	4.5
N02B 2-1J	12	438775	71	0.118956	0.001509	5.574514	0.340952	0.339876	0.020336	0.978247	1941	23	1912	51	1886	97	3.2
N02B 2-1K	12	321263	93	0.119445	0.001485	5.668090	0.304101	0.344164	0.017962	0.972774	1948	22	1927	45	1907	86	2.4
N02B 2-1L	12	516414	105	0.119861	0.001526	6.161026	0.377149	0.372798	0.022322	0.978127	1954	23	1999	52	2043	104	-5.3
N02B 7-1A	12	282695	112	0.119578	0.001584	5.675064	0.252478	0.344205	0.014619	0.954630	1950	23	1928	38	1907	70	2.6
N02B 7-1B	12	183363	82	0.119275	0.001525	5.314682	0.258706	0.323166	0.015179	0.964911	1945	23	1871	41	1805	74	8.3
N02B 7-1C	12	264782	62	0.119380	0.001568	5.707401	0.311400	0.346741	0.018362	0.970575	1947	23	1932	46	1919	87	1.7
N02B 7-1D	12	342615	87	0.119486	0.001535	5.561191	0.255540	0.337560	0.014892	0.960108	1949	23	1910	39	1875	71	4.4
N02B 7-1E	12	254890	88	0.119687	0.001517	5.826024	0.305507	0.353042	0.017964	0.970355	1952	22	1950	44	1949	85	0.1
N02B 7-1F	12	267199	87	0.120360	0.001551	5.708281	0.272106	0.343970	0.015786	0.962746	1962	23	1933	40	1906	75	3.3
N02B 7-1G	12	312268	89	0.120115	0.001559	5.706833	0.304495	0.344586	0.017833	0.969958	1958	23	1932	45	1909	85	2.9
N02B 7-1H	12	174203	70	0.120278	0.001603	5.590096	0.260175	0.337080	0.015032	0.958131	1960	24	1915	39	1873	72	5.2
N02B 7-1I	12	202289	78	0.119607	0.001595	5.439322	0.286635	0.329829	0.016815	0.967445	1950	24	1891	44	1838	81	6.6
N02B 7-1J	12	226662	77	0.119976	0.001531	5.688015	0.253305	0.343848	0.014671	0.958075	1956	23	1930	38	1905	70	3.0
N02B 7-1K	12	160941	66	0.118927	0.001581	5.807684	0.343773	0.354179	0.020429	0.974442	1940	24	1948	50	1955	97	-0.9
N02B 7-1L	12	186686	71	0.118521	0.001571	5.421925	0.317125	0.331786	0.018901	0.973966	1934	24	1888	49	1847	91	5.2
N02B 7-1M	12	227901	61	0.121307	0.001558	5.643656	0.258884	0.337423	0.014859	0.959978	1976	23	1923	39	1874	71	5.9
N02B 7-1N	12	231938	68	0.120682	0.001536	5.729266	0.283289	0.344314	0.016452	0.966326	1966	23	1936	42	1907	78	3.5
N02B 7-1P	12	289041	78	0.121250	0.001547	5.396040	0.312079	0.322770	0.018207	0.975359	1975	23	1884	48	1803	88	9.9
N05B-4.1A	12	102919	104	0.121171	0.001986	5.927493	0.419239	0.354790	0.024410	0.972767	1974	29	1965	60	1957	115	0.9
N05B-4.1B	12	59672	107	0.120202	0.002078	5.786318	0.406310	0.349132	0.023761	0.969223	1959	31	1944	59	1930	113	1.7
N05B-4.1C	12	73531	111	0.119733	0.001965	5.608652	0.369136	0.339737	0.021654	0.968409	1952	29	1917	55	1885	103	3.9
N05B-4.1D	12	76142	102	0.120838	0.002044	5.780480	0.340950	0.346943	0.019605	0.958012	1969	30	1943	50	1920	93	2.9
N05B-4.1E	12	90414	89	0.120143	0.001899	5.285706	0.370974	0.319083	0.021820	0.974323	1958	28	1867	58	1785	106	10.1
N05B-4.1F	12	63208	98	0.120200	0.001935	5.913224	0.399061	0.356795	0.023384	0.971131	1959	28	1963	57	1967	110	-0.5
N05B-4.1G	12	48175	104	0.120362	0.002116	6.026692	0.511146	0.363152	0.030131	0.978275	1962	31	1980	71	1997	141	-2.1
N05B-4.1H	12	69223	115	0.120279	0.002037	6.232236	0.553632	0.375795	0.032771	0.981651	1960	30	2009	75	2057	152	-5.7
N05B-4.1I	12	74053	109	0.121025	0.001947	6.001690	0.521398	0.359663	0.030705	0.982706	1971	28	1976	73	1981	144	-0.5
HW3528-32A	12	89687	18	0.120163	0.001424	5.872475	0.368988	0.354444	0.021871	0.982053	1959	21	1957	53	1956	103	0.2
HW3528-32B	12	89304	18	0.121023	0.001286	5.484082	0.361058	0.328651	0.021354	0.986883	1971	19	1898	55	1832	103	8.1
HW3528-32C	12	55985	11	0.120928	0.001312	5.479490	0.284885	0.328634	0.016710	0.977976	1970	19	1897	44	1832	81	8.1
HW3528-32D	12	133138	18	0.120204	0.001104	5.439190	0.284497	0.328182	0.016899	0.984451	1959	16	1891	44	1830	82	7.6
HW3528-32E	12	70586	11	0.121186	0.001294	5.588015	0.284797	0.334429	0.016666	0.977805	1974	19	1914	43	1860	80	6.6
HW3528-32F	12	102316	22	0.120506	0.001127	5.714232	0.289861	0.343912	0.017146	0.982849	1964	17	1934	43	1905	82	3.4
HW3528-32G	12	80305	18	0.121247	0.001232	5.715490	0.383419	0.341885	0.022670	0.988456	1975	18	1934	56	1896	108	4.6
HW3528-32H	12	63628	19	0.121021	0.001191	5.556550	0.421080	0.333000	0.025021	0.991531	1971	17	1909	63	1853	120	6.9
HW3528-32I	12	103023	23	0.120529	0.001218	5.646820	0.348326	0.339790	0.020677	0.986494	1964	18	1923	52	1886	99	4.6
HW3528-32J	12	141753	37	0.119064	0.001053	5.471488	0.298323	0.333291	0.017932	0.986763	1942	16	1896	46	1854	86	5.2
HW3528-32K	12	124691	39	0.119533	0.001168	5.551818	0.371886	0.336857	0.022323	0.989296	1949	17	1909	56	1872	107	4.6
HW3528-32L	12	164859	43	0.119714	0.001152	5.564339	0.298523	0.337108	0.017792	0.983784	1952	17	1911	45	1873	85	4.7
HW3528-32M	12	193350	104	0.120345	0.001484	6.115724	0.574942	0.368568	0.034350	0.991360	1961	22	1992	79	2023	160	-3.6
HW3528-32N	12	122751	71	0.121283	0.001280	6.255431	0.399422	0.374072	0.023557	0.986237	1975	19	2012	54	2049	110	-4.3
HW3528-32O	12	136230	77	0.119773	0.001200	5.890597	0.478699	0.356697	0.028766	0.992367	1953	18	1960	68	1966	135	-0.8
HW3528-32P	12	75439	55	0.120174	0.001228	5.736302	0.269888	0.346194	0.015899	0.976114	1959	18	1937	40	1916	76	2.5

In-situ LA-MC-ICP-MS U-Pb dating of monazite grains (continued)

											Ages (Ma)						
Analysis	Spot Size µm	^{206}Pb (cps)	^{204}Pb (cps)	$^{207}Pb/^{206}Pb$	±2 s	$^{207}Pb/^{235}U$	±2 s	$^{206}Pb/^{238}U$	±2 s	r	$^{207}Pb^*/^{206}Pb^*$	±2 s	$^{207}Pb^*/^{235}U$	±2 s	$^{206}Pb^*/^{238}U$	±2 s	% Disc.
HW3528-32Q	12	45126	79	0.122486	0.001635	5.874724	0.388204	0.347856	0.022513	0.979396	1993	24	1958	56	1924	107	4.0
HW3528-32R	12	47982	58	0.121574	0.001299	5.411237	0.298007	0.322816	0.017440	0.980991	1979	19	1887	46	1803	84	10.2
HW3528-32S	12	52865	86	0.122654	0.001708	5.244107	0.311688	0.310091	0.017917	0.972156	1995	25	1860	49	1741	88	14.5
HW3528-33A	12	62305	140	0.123274	0.001534	5.563336	0.298821	0.327312	0.017102	0.972782	2004	22	1910	45	1825	83	10.2
HW3528-33B	12	58041	163	0.121890	0.001477	5.564633	0.543583	0.331106	0.032094	0.992273	1984	21	1911	81	1844	154	8.1
HW3528-33C	12	58802	170	0.121781	0.001395	5.424841	0.312537	0.323078	0.018241	0.980024	1982	20	1889	48	1805	88	10.3
HW3528-33D	12	44584	148	0.124251	0.001819	5.369649	0.398672	0.313432	0.022814	0.980358	2018	26	1880	62	1758	111	14.7
HW3528-33E	12	47621	170	0.123420	0.001995	5.607862	0.369710	0.329543	0.021063	0.969488	2006	28	1917	55	1836	101	9.7
HW3528-33F	12	48355	166	0.123477	0.001938	5.419626	0.372473	0.318334	0.021300	0.973575	2007	28	1888	57	1782	103	12.8
HW3528-33G	12	53497	164	0.122062	0.001216	5.570879	0.374310	0.331009	0.021995	0.988950	1987	18	1912	56	1843	106	8.3
HW3528-33H	12	53427	186	0.123828	0.001883	5.464722	0.342847	0.320072	0.019482	0.970168	2012	27	1895	52	1790	94	12.6
HW3528-33I	12	50612	181	0.122145	0.001444	5.568569	0.377752	0.330649	0.022087	0.984691	1988	21	1911	57	1842	106	8.5
HW3528-33J	12	82087	150	0.121992	0.001359	5.596240	0.363378	0.332709	0.021284	0.985182	1986	20	1916	54	1851	102	7.8
HW3528-33K	12	95081	120	0.120716	0.001224	5.293129	0.317813	0.318015	0.018820	0.985627	1967	18	1868	50	1780	91	10.9
HW3528-34B	12	137956	39	0.119847	0.001460	5.511833	0.368822	0.333555	0.021947	0.983298	1954	22	1902	56	1856	105	5.8
HW3528-34C	12	129890	31	0.118838	0.001185	5.105518	0.247913	0.311589	0.014808	0.978695	1939	18	1837	40	1749	72	11.2
HW3528-34D	12	126578	31	0.119365	0.001197	5.769333	0.492312	0.350549	0.029706	0.993074	1947	18	1942	71	1937	140	0.6
HW3528-34E	12	129908	21	0.120222	0.001553	6.008157	0.506681	0.362457	0.030206	0.988205	1960	23	1977	71	1994	141	-2.0
HW3528-34F	12	130709	28	0.120856	0.001243	5.808895	0.411643	0.348598	0.024442	0.989409	1969	18	1948	60	1928	116	2.4
HW3528-34G	12	138825	30	0.118644	0.001289	5.334723	0.402433	0.326110	0.024344	0.989573	1936	19	1874	63	1819	117	6.9
HW3528-34H	12	118288	23	0.118563	0.001128	5.035452	0.328803	0.308027	0.019899	0.989337	1935	17	1825	54	1731	97	12.0

APPENDIX B - U-Pb Geochronological Standard Data (OG1)

In-situ LA-MC-ICP-MS U-Pb dating of zircon grains

											Ages (Ma)						
Analysis	Spot Size μm	^{206}Pb (cps)	^{204}Pb (cps)	^{207}Pb/^{206}Pb	±2 s	^{207}Pb/^{235}U	±2 s	^{206}Pb/^{238}U	±2 s	r	^{207}Pb*/^{206}Pb*	±2 s	^{207}Pb*/^{235}U	±2 s	^{206}Pb*/^{238}U	±2 s	% Disc.
03-Aug-11																	
OG1-1	30	291100	62	0.29721	0.00294	29.23406	1.06561	0.71339	0.02503	0.962	3456	15	3461	35	3471	93	-0.6
OG1-2	30	640894	48	0.29856	0.00292	29.56079	0.91333	0.71810	0.02105	0.949	3463	15	3472	30	3489	78	-1.0
OG1-3	30	481251	23	0.29833	0.00290	29.13576	0.76328	0.70833	0.01723	0.928	3462	15	3458	25	3452	65	0.4
OG1-4	30	539248	85	0.29990	0.00293	28.77143	1.18111	0.69580	0.02774	0.971	3470	15	3446	40	3405	105	2.4
OG1-5	30	105448	65	0.30059	0.00296	29.71601	1.01527	0.71698	0.02346	0.958	3473	15	3477	33	3485	87	-0.4
04-Aug-11																	
OG1-1	30	70707	0	0.29651	0.00268	29.05183	1.64375	0.71060	0.03969	0.987	3452	14	3455	54	3461	148	-0.3
OG1-2	30	440553	9	0.29609	0.00260	29.70765	1.25070	0.72769	0.02996	0.978	3450	14	3477	41	3525	111	-2.8
OG1-3	30	246214	64	0.29808	0.00262	28.79839	1.11452	0.70071	0.02641	0.974	3460	14	3447	37	3423	99	1.4
05-Aug-11																	
OG1-1	30	267073	17	0.29534	0.00440	30.52978	1.26923	0.74973	0.02910	0.933	3446	23	3504	40	3607	106	-6.1
OG1-2	30	588159	61	0.29882	0.00445	30.53810	1.22859	0.74120	0.02770	0.929	3464	23	3504	39	3575	102	-4.2
OG1-3	30	432706	81	0.30045	0.00447	29.91509	1.18966	0.72213	0.02664	0.928	3473	23	3484	38	3504	99	-1.2
OG1-4	30	769865	51	0.30265	0.00455	28.68138	1.06398	0.68732	0.02331	0.914	3484	23	3443	36	3372	88	4.1
16-Aug-11																	
OG1-1	30	315902	11	0.30060	0.00799	30.65371	1.52833	0.73959	0.03119	0.846	3473	41	3508	48	3569	115	-3.6
OG1-2	30	663316	40	0.29726	0.00323	29.19170	1.30456	0.71223	0.03087	0.970	3456	17	3460	43	3467	115	-0.4
OG1-3	30	242496	54	0.29676	0.00320	29.03774	1.26071	0.70966	0.02985	0.969	3453	17	3455	42	3457	112	-0.1
OG1-4	30	173717	3	0.29683	0.00323	26.76044	1.43670	0.65387	0.03438	0.979	3454	17	3375	51	3243	133	7.7
17-Aug-11																	
OG1-1	30	303018	0	0.29621	0.00282	27.81585	1.16649	0.68108	0.02782	0.974	3450	15	3413	40	3348	106	3.8
OG1-2	30	126216	0	0.29787	0.00291	28.62810	1.46125	0.69706	0.03492	0.982	3459	15	3441	49	3409	131	1.8
OG1-3	30	243082	21	0.29910	0.00286	29.17982	1.53364	0.70756	0.03657	0.983	3466	15	3460	50	3449	137	0.6
24-Feb-12																	
OG1-1	30	707317	166	0.30051	0.00376	28.89589	1.65200	0.69740	0.03891	0.976	3473	19	3450	55	3411	146	2.3
OG1-2	30	1116409	197	0.30114	0.00377	29.45962	2.26910	0.70952	0.05392	0.987	3476	19	3469	73	3457	200	0.7
OG1-3	30	291417	83	0.29899	0.00372	30.50302	1.60196	0.73992	0.03775	0.972	3465	19	3503	50	3570	138	-4.0
OG1-4	30	158309	87	0.29906	0.00371	31.48248	1.47991	0.76350	0.03462	0.965	3465	19	3534	45	3657	125	-7.3
OG1-5	30	68355	26	0.29906	0.00386	31.32728	1.93095	0.75973	0.04579	0.978	3465	20	3529	59	3643	166	-6.7
OG1-6	30	152676	303	0.30438	0.00400	29.97042	2.39730	0.71412	0.05634	0.986	3493	20	3486	76	3474	208	0.7
27-Feb-12																	
OG1-1	30	282260	48	0.29770	0.00410	30.74848	2.64795	0.74910	0.06368	0.987	3458	21	3511	81	3604	231	-5.5
OG1-2	30	280072	51	0.29744	0.00410	28.74463	2.49104	0.70090	0.05997	0.987	3457	21	3445	82	3424	223	1.2
OG1-3	30	375255	38	0.29722	0.00412	31.16852	2.48300	0.76057	0.05966	0.985	3456	21	3524	75	3646	215	-7.2
OG1-4	30	195361	33	0.29657	0.00411	30.52120	2.61552	0.74640	0.06312	0.987	3452	21	3504	81	3594	229	-5.4
OG1-5	30	287122	68	0.29812	0.00410	31.83039	2.44725	0.77437	0.05858	0.984	3460	21	3545	73	3697	209	-9.0
OG1-6	30	179411	34	0.29640	0.00408	30.49654	2.30729	0.74621	0.05551	0.983	3452	21	3503	72	3594	202	-5.4
OG1-7	30	166129	246	0.29645	0.00408	30.16841	2.63149	0.73808	0.06357	0.987	3452	21	3492	82	3563	232	-4.2
OG1-8	30	244092	102	0.29553	0.00409	30.12704	2.39469	0.73936	0.05787	0.985	3447	21	3491	75	3568	211	-4.6
28-Feb-12																	
OG1-1	30	230995	73	0.29908	0.00179	29.51753	0.89283	0.71580	0.02122	0.980	3465	9	3471	29	3480	79	-0.6
OG1-2	30	205507	88	0.29857	0.00177	28.91270	1.03136	0.70234	0.02471	0.986	3463	9	3451	34	3430	93	1.2
OG1-3	30	194857	152	0.29747	0.00168	28.47976	1.28619	0.69437	0.03111	0.992	3457	9	3436	43	3399	117	2.2

APPENDIX C - Compiled Geochem Data

	Sample ID: Domain	M0034 Taltson	M3796 Taltson	M3997 Taltson	M4002A Taltson	M4002B Taltson	M4015A Taltson	M4015B Taltson	M4017 Rimbey	M12350 Taltson
	wt.%									
FUS-ICP	SiO2	73.62	58.88	70.55	74.21	74.47	74.19	55.19	73.11	56.89
FUS-ICP	TiO2	0.165	1.588	0.373	0.181	0.192	0.112	0.783	0.198	0.435
FUS-ICP	Al2O3	12.96	12.52	15.00	11.87	11.89	14.23	17.51	14.02	18.69
FUS-ICP	Fe2O3(T)	0.94	12.50	1.93	1.34	1.34	0.87	7.47	1.69	4.52
FUS-ICP	MnO	0.008	0.053	0.011	0.008	0.012	0.010	0.117	0.040	0.033
FUS-ICP	MgO	0.54	1.23	1.12	0.80	0.88	0.27	4.83	0.37	2.25
FUS-ICP	CaO	0.89	1.27	1.89	0.35	0.41	1.27	7.38	1.06	6.85
FUS-ICP	Na2O	2.57	2.78	2.29	1.06	1.02	3.44	3.67	3.24	3.67
FUS-ICP	K2O	6.23	5.47	5.11	7.30	7.21	5.47	1.47	5.34	1.40
FUS-ICP	P2O5	0.04	0.37	0.04	0.05	0.06	< 0.01	0.20	0.04	0.29
FUS-ICP	LOI	1.18	1.60	1.57	1.34	1.53	0.69	0.82	0.51	2.51
FUS-ICP	Total	99.26	99.66	100.10	98.66	99.18	100.60	100.30	99.81	98.05
Trace element (ppm)										
FUS-ICP	Ba	700	1038	2009	1519	1395	2016	766	551	501
INAA	Cr	< 0.5	116	115	10	129	126	163	106	60
TD-ICP	Cu	4	6	8	3	10	5	3	7	7
TD-ICP	Ni	3	4	7	2	4	4	31	5	22
INAA	Sc	1.58	18.10	5.81	3.99	4.67	1.57	25.40	3.72	9.92
FUS-ICP	V	8	57	35	34	30	9	175	13	89
MULT INAA / TD-ICP	Zn	12	117	28	20	18	13	72	44	77
Q-ICP-MS	Ga	19.1	27.5	16.2	13.2	12.5	14.4	20.5	21.2	25.6
INAA	Rb	220	120	90	170	190	100	90	370	< 10
FUS-ICP	Sr	96	366	369	199	193	357	454	122	607
FUS-ICP	Y	14	50	4	3	4	2	21	13	12
FUS-ICP	Zr	136	642	167	112	108	61	163	172	177
Q-ICP-MS	Li	29.0	27.6	40.2	34.4	38.1	8.3	8.8	55.0	20.8
Q-ICP-MS	Be	0.6	1.4	1.0	0.7	0.2	1.1	2.8	2.4	2.6
Q-ICP-MS	Co	1.92	12.97	6.37	3.52	5.28	2.31	24.19	4.95	14.39
Q-ICP-MS	Ge	1.25	1.45	0.91	1.06	1.14	0.81	1.75	1.26	1.18
Q-ICP-MS	Nb	8.44	13.47	5.98	2.99	2.90	1.98	8.73	14.96	5.15
Q-ICP-MS	Mo	0.71	2.67	1.01	0.66	0.44	0.54	0.22	0.95	1.91
Q-ICP-MS	Ru	<DL	<DL	0.04	0.03	0.03	0.03	0.11	0.03	0.12
Q-ICP-MS	Pd	3.48	14.2	4.12	2.50	3.12	2.02	5.25	4.20	3.98
Q-ICP-MS	Ag	0.07	0.45	<DL	0.08	<DL	<DL	0.05	0.40	0.12
Q-ICP-MS	Cd	0.50	0.37	0.48	0.29	0.50	0.23	0.56	0.47	0.79
Q-ICP-MS	Sn	1.76	4.90	1.84	1.52	1.62	1.56	4.63	3.83	2.66
Q-ICP-MS	Sb	0.06	0.08	0.04	0.05	0.06	0.05	0.02	0.08	0.02
Q-ICP-MS	Te	<DL	<DL	0.99	<DL	<DL	0.86	<DL	<DL	<DL
Q-ICP-MS	Cs	0.25	0.28	0.12	0.24	0.22	0.31	1.55	3.62	0.07
Q-ICP-MS	La	39.8	297.6	24.4	44.0	33.6	16.2	27.5	35.0	37.8
Q-ICP-MS	Ce	49.2	167.2	26.4	37.0	26.5	13.9	53.4	37.5	51.0
Q-ICP-MS	Pr	8.21	57.58	4.45	7.79	5.74	2.93	7.09	7.06	8.75
Q-ICP-MS	Nd	27.0	176	15.7	27.4	19.9	11.2	27.1	22.7	32.1
Q-ICP-MS	Sm	5.06	20.93	2.39	3.76	2.76	1.86	5.17	3.86	5.35
Q-ICP-MS	Eu	0.70	1.78	1.82	1.43	1.18	1.19	1.50	0.61	1.79
Q-ICP-MS	Gd	3.78	14.6	1.75	2.32	1.78	1.15	4.87	3.31	4.12
Q-ICP-MS	Tb	0.41	1.21	0.12	0.15	0.12	0.06	0.62	0.36	0.41
Q-ICP-MS	Dy	2.43	6.50	0.73	0.84	0.74	0.37	3.93	2.10	2.40
Q-ICP-MS	Ho	0.42	1.16	0.13	0.13	0.13	0.06	0.81	0.39	0.47
Q-ICP-MS	Er	1.06	3.22	0.36	0.37	0.35	0.14	2.44	0.99	1.30
Q-ICP-MS	Tm	0.139	0.375	0.043	0.047	0.046	0.018	0.342	0.129	0.166

	Sample ID: Domain	M0034 Taltson	M3796 Taltson	M3997 Taltson	M4002A Taltson	M4002B Taltson	M4015A Taltson	M4015B Taltson	M4017 Rimbey	M12350 Taltson
Trace element (ppm)										
Q-ICP-MS	Yb	0.85	2.52	0.39	0.31	0.33	0.11	2.28	0.84	1.05
Q-ICP-MS	Lu	0.13	0.35	0.06	0.05	0.05	0.04	0.03	0.13	0.15
INAA	Hf	4.9	13.5	4.0	4.1	3.1	2.0	3.8	4.6	5.8
Q-ICP-MS	Ta	0.34	0.63	0.46	0.59	0.24	0.19	0.73	1.35	0.46
Q-ICP-MS	W	2.54	12.07	11.52	5.49	12.09	8.90	11.07	10.30	2.19
Q-ICP-MS	Re	<DL	0.004	0.006	<DL	<DL	0.004	<DL	0.036	<DL
Q-ICP-MS	Os	0.23	0.14	0.11	0.53	0.14	0.09	0.10	1.20	0.37
Q-ICP-MS	Ir	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Q-ICP-MS	Pt	0.02	0.30	0.07	0.04	0.04	0.05	0.29	0.19	0.03
Q-ICP-MS	Au	0.06	0.69	0.15	0.50	0.12	0.16	0.42	0.90	0.35
Q-ICP-MS	Tl	1.67	0.56	0.51	1.08	0.90	0.54	0.32	2.58	0.24
Q-ICP-MS	Pb	43.7	21.7	30.3	26.8	24.6	39.9	11.9	43.8	11.5
SLOWPOKE	Th	47.6	172.0	10.0	36.6	26.0	13.5	9.1	50.0	2.7
SLOWPOKE	U	9.30	2.65	1.05	0.90	0.98	0.70	1.08	15.40	2.02

	Sample ID:	M12351	M12352A	M12352B	M12354	M12549	M12636	M12637	M12638	M12639
	Domain	Taltson	Buffalo Head	Buffalo Head	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson
	wt.%									
FUS-ICP	SiO2	72.46	72.87	72.54	59.19	73.41	72.39	71.05	68.74	67.26
FUS-ICP	TiO2	0.285	0.458	0.543	0.588	0.211	0.124	0.336	0.256	0.896
FUS-ICP	Al2O3	13.66	12.30	11.43	14.56	13.55	14.61	13.83	14.56	14.76
FUS-ICP	Fe2O3(T)	1.56	3.27	3.68	5.06	1.81	1.93	1.00	2.27	4.31
FUS-ICP	MnO	0.011	0.038	0.018	0.044	0.011	0.034	0.003	0.012	0.032
FUS-ICP	MgO	0.86	0.62	1.13	3.60	0.57	0.61	0.72	0.76	1.10
FUS-ICP	CaO	1.72	1.34	1.66	2.7	1.76	1.57	0.68	1.47	2.66
FUS-ICP	Na2O	2.62	2.13	1.82	1.79	2.36	1.95	1.35	2.19	2.96
FUS-ICP	K2O	5.44	4.68	4.22	5.81	5.59	6.33	8.55	6.99	4.14
FUS-ICP	P2O5	0.03	0.15	0.08	0.18	0.07	0.04	0.07	0.17	0.18
FUS-ICP	LOI	1.30	0.43	1.42	4.27	0.79	0.46	0.70	0.89	1.38
FUS-ICP	Total	100.10	98.65	98.95	98.36	100.30	100.30	98.40	98.55	100.20
Trace element (ppm)										
FUS-ICP	Ba	3738	1517	1873	730	2002	602	915	1497	2563
INAA	Cr	8	18	21	93	6	230	11	175	166
TD-ICP	Cu	< 1	8	2	4	< 1	5	2	10	7
TD-ICP	Ni	12	7	12	61	3	7	5	8	11
INAA	Sc	3.34	9.53	8.52	9.11	1.54	6.35	0.96	3.85	10.00
FUS-ICP	V	21	34	48	93	30	18	43	36	46
MULT INAA / TD-ICP	Zn	26	20	20	43	23	16	25	24	25
Q-ICP-MS	Ga	17.2	16.3	17.8	20.5	15.7	14.1	15.0	16.6	19.4
INAA	Rb	110	140	50	40	150	150	220	170	70
FUS-ICP	Sr	344	124	146	188	362	156	165	271	348
FUS-ICP	Y	2	34	13	9	2	29	3	13	33
FUS-ICP	Zr	184	213	185	132	97	63	66	211	455
Q-ICP-MS	Li	9.4	27.9	8.4	98.1	12.2	16.9	19.9	30.0	30.1
Q-ICP-MS	Be	0.8	0.6	1.2	1.5	1.1	0.6	0.4	1.2	1.5
Q-ICP-MS	Co	4.42	6.92	4.48	12.76	2.71	5.01	3.82	7.88	8.12
Q-ICP-MS	Ge	0.81	1.35	1.47	1.29	1.20	1.19	1.10	1.13	1.27
Q-ICP-MS	Nb	1.97	2.92	5.87	5.83	0.77	1.51	4.77	3.21	25.65
Q-ICP-MS	Mo	0.42	0.99	1.16	1.16	0.68	2.08	0.77	1.82	1.72
Q-ICP-MS	Ru	0.04	<DL	<DL	0.03	0.04	0.01	0.02	0.02	<DL
Q-ICP-MS	Pd	2.27	3.75	5.07	2.74	2.37	2.18	1.71	5.17	8.81
Q-ICP-MS	Ag	0.06	0.05	0.10	0.09	0.05	<DL	0.04	<DL	0.29
Q-ICP-MS	Cd	0.38	0.50	0.48	0.36	0.65	0.32	0.37	0.41	0.26
Q-ICP-MS	Sn	1.11	1.96	3.79	2.21	0.96	2.49	1.61	2.69	2.69
Q-ICP-MS	Sb	0.04	0.08	0.04	0.06	0.04	0.13	0.05	0.11	0.11
Q-ICP-MS	Te	<DL	<DL	0.16	<DL	<DL	<DL	<DL	<DL	0.98
Q-ICP-MS	Cs	0.11	0.18	0.63	0.39	0.15	0.26	0.43	0.19	0.17
Q-ICP-MS	La	49.9	36.1	36.5	16.6	19.0	30.9	22.6	42.1	121.4
Q-ICP-MS	Ce	25.8	24.1	33.4	31.8	20.0	38.2	19.9	68.8	230.4
Q-ICP-MS	Pr	7.22	6.83	7.99	3.83	2.89	6.23	3.69	10.99	29.26
Q-ICP-MS	Nd	24.6	26.6	30.7	14.2	9.77	21.3	12.5	41.9	96.0
Q-ICP-MS	Sm	2.78	4.68	6.28	2.51	1.30	3.69	2.08	9.23	14.05
Q-ICP-MS	Eu	2.57	1.76	1.45	1.17	1.65	0.95	1.21	1.75	3.19
Q-ICP-MS	Gd	1.54	4.22	6.71	2.12	0.87	3.67	1.27	6.50	10.02
Q-ICP-MS	Tb	0.08	0.39	0.93	0.28	0.06	0.61	0.09	0.62	1.10
Q-ICP-MS	Dy	0.49	2.59	6.74	1.76	0.44	4.91	0.58	3.08	6.41
Q-ICP-MS	Ho	0.07	0.50	1.48	0.36	0.08	1.11	0.10	0.48	1.19
Q-ICP-MS	Er	0.21	1.41	4.41	1.00	0.26	3.48	0.27	1.08	3.24
Q-ICP-MS	Tm	0.026	0.195	0.603	0.136	0.035	0.522	0.034	0.114	0.402

	Sample ID: Domain	M12351 Taltson	M12352A Buffalo Head	M12352B Buffalo Head	M12354 Taltson	M12549 Taltson	M12636 Taltson	M12637 Taltson	M12638 Taltson	M12639 Taltson
Trace element (ppm)										
Q-ICP-MS	Yb	0.20	1.34	3.79	0.87	0.25	3.58	0.23	0.64	2.39
Q-ICP-MS	Lu	<DL	0.21	0.54	0.13	0.05	0.53	<DL	0.09	0.31
INAA	Hf	5.1	6.5	5.7	3.9	3.7	2.5	2.3	5.9	9.1
Q-ICP-MS	Ta	0.25	0.28	0.48	0.35	0.18	0.22	0.23	0.32	1.77
Q-ICP-MS	W	3.20	2.79	2.90	2.63	4.57	9.26	2.81	9.97	5.09
Q-ICP-MS	Re	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.008
Q-ICP-MS	Os	0.31	0.23	0.29	0.24	0.24	0.28	0.28	0.19	0.18
Q-ICP-MS	Ir	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Q-ICP-MS	Pt	0.03	0.03	0.08	0.03	0.01	0.10	0.02	0.08	0.09
Q-ICP-MS	Au	0.19	0.20	0.18	0.17	0.09	0.26	0.09	0.11	0.13
Q-ICP-MS	Tl	0.74	0.34	0.83	0.26	0.68	0.98	1.23	1.10	0.31
Q-ICP-MS	Pb	21.8	16.8	20.9	7.5	20.5	39.8	39.6	45.2	14.9
SLOWPOKE	Th	28.1	18.2	22.2	0.5	1.6	17.1	9.3	20.4	21.9
SLOWPOKE	U	0.46	1.09	1.70	0.95	0.49	0.61	0.88	1.35	0.59

	Sample ID: Domain	M12640 Taltson	M12643 Taltson	N01A Taltson	N04B Taltson	N04C Taltson	N05C Taltson	N06C Buffalo Head	HW3521 Taltson	HW3522 Taltson
	wt.%									
FUS-ICP	SiO2	68.58	71.93	52.92	72.49	74.46	62.71	69.14	74.61	77.69
FUS-ICP	TiO2	0.441	0.360	1.036	0.031	0.097	0.808	0.505	0.479	0.487
FUS-ICP	Al2O3	14.8	12.46	16.13	13.52	13.69	16.35	14.37	11.48	10.80
FUS-ICP	Fe2O3(T)	2.55	2.09	8.49	0.94	0.92	4.05	3.00	6.28	3.27
FUS-ICP	MnO	0.016	0.019	0.149	0.060	0.020	0.035	0.016	0.138	0.035
FUS-ICP	MgO	1.58	1.26	5.09	0.30	0.62	1.03	1.47	1.64	1.13
FUS-ICP	CaO	0.76	1.11	6.83	0.57	0.81	2.16	1.43	1.49	2.26
FUS-ICP	Na2O	1.31	1.75	2.97	2.49	2.95	2.91	2.47	1.64	2.40
FUS-ICP	K2O	7.35	6.62	1.38	6.63	5.23	7.10	4.89	2.90	1.36
FUS-ICP	P2O5	0.05	0.07	0.31	0.04	0.04	0.26	0.06	0.02	< 0.01
FUS-ICP	LOI	1.94	1.68	2.19	0.76	1.03	1.77	1.73	0.29	0.76
FUS-ICP	Total	99.67	99.59	98.44	97.94	99.97	99.64	99.39	101.00	100.20
Trace element (ppm)										
FUS-ICP	Ba	1820	1938	413	301	1101	3750	1523	1126	483
INAA	Cr	195	229	158	< 0.5	2	12	18	84	57
TD-ICP	Cu	4	3	20	< 1	< 1	3	6	33	66
TD-ICP	Ni	12	8	31	1	1	4	16	27	38
INAA	Sc	5.08	3.38	23.40	6.28	3.03	13.40	6.62	16.70	5.38
FUS-ICP	V	53	20	208	< 5	< 5	55	57	89	88
MULT INAA / TD-ICP	Zn	24	29	111	9	17	32	28	164	51
Q-ICP-MS	Ga	19.0	15.6	22.9	15.7	19.2	24.1	20.3	14.5	14.9
INAA	Rb	130	160	30	130	100	120	60	70	40
FUS-ICP	Sr	228	201	485	95	138	440	239	151	157
FUS-ICP	Y	10	12	20	35	10	24	12	24	5
FUS-ICP	Zr	192	278	165	49	115	438	271	236	331
Q-ICP-MS	Li	63.9	29.4	22.6	10.4	21.9	21.57	46.9	11.7	9.3
Q-ICP-MS	Be	0.7	1.1	1.4	0.4	0.7	1.3	0.7	0.1	0.3
Q-ICP-MS	Co	9.10	7.32	19.39	2.17	1.46	6.32	9.14	9.97	11.09
Q-ICP-MS	Ge	1.09	1.02	1.53	1.75	1.30	1.27	1.13	1.22	0.95
Q-ICP-MS	Nb	8.88	6.08	9.26	0.74	3.19	10.60	7.71	10.85	9.61
Q-ICP-MS	Mo	1.43	1.82	0.52	0.45	0.65	1.29	1.06	10.89	2.58
Q-ICP-MS	Ru	0.01	<DL	0.13	<DL	<DL	0.03	0.01	<DL	<DL
Q-ICP-MS	Pd	4.92	6.24	3.95	1.75	2.29	9.07	4.20	6.54	7.79
Q-ICP-MS	Ag	<DL	<DL	0.20	0.06	0.08	0.09	0.05	0.77	0.42
Q-ICP-MS	Cd	0.23	0.32	0.70	0.11	0.35	0.37	0.16	0.28	0.27
Q-ICP-MS	Sn	1.96	1.83	3.60	1.14	1.28	1.22	1.67	1.55	1.34
Q-ICP-MS	Sb	0.11	0.12	0.05	0.05	0.04	0.04	0.05	0.15	0.06
Q-ICP-MS	Te	0.87	0.77	<DL	<DL	<DL	<DL	0.12	<DL	<DL
Q-ICP-MS	Cs	0.13	0.10	0.41	0.15	0.15	0.36	0.18	0.11	0.10
Q-ICP-MS	La	64.6	104.7	21.4	11.0	30.3	45.6	57.0	14.6	15.8
Q-ICP-MS	Ce	122.8	104.0	51.5	14.8	23.1	62.7	40.4	21.8	27.3
Q-ICP-MS	Pr	15.43	17.99	7.37	2.25	5.17	12.1	9.80	2.60	3.13
Q-ICP-MS	Nd	51.9	56.9	30.2	7.9	17.5	51.8	35.6	8.8	9.9
Q-ICP-MS	Sm	8.26	7.42	6.08	1.67	2.54	10.04	5.72	1.95	1.39
Q-ICP-MS	Eu	1.55	1.76	1.81	0.62	1.20	4.50	1.38	1.38	1.26
Q-ICP-MS	Gd	5.71	4.98	5.68	1.92	1.76	8.61	4.90	2.50	1.26
Q-ICP-MS	Tb	0.48	0.37	0.70	0.40	0.17	0.93	0.41	0.44	0.16
Q-ICP-MS	Dy	2.42	2.32	4.27	4.31	1.35	5.63	2.60	3.18	0.93
Q-ICP-MS	Ho	0.36	0.39	0.85	1.26	0.31	1.03	0.46	0.77	0.17
Q-ICP-MS	Er	0.84	0.90	2.46	4.71	1.07	2.67	1.12	2.56	0.50
Q-ICP-MS	Tm	0.088	0.091	0.346	0.801	0.170	0.309	0.120	0.407	0.076

	Sample ID:	M12640	M12643	N01A	N04B	N04C	N05C	N06C	HW3521	HW3522
	Domain	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Buffalo Head	Taltson	Taltson
Trace element (ppm)										
Q-ICP-MS	Yb	0.60	0.58	2.28	5.40	1.15	1.77	0.72	2.71	0.53
Q-ICP-MS	Lu	0.08	0.08	0.33	0.82	0.18	0.23	0.10	0.43	0.09
INAA	Hf	5.5	8.2	4.6	2.6	3.5	11.1	7.6	5.7	8.3
Q-ICP-MS	Ta	0.41	0.36	0.66	0.17	0.51	0.57	0.49	0.58	0.34
Q-ICP-MS	W	9.56	39.00	1.42	1.70	1.50	2.49	2.14	2.96	1.19
Q-ICP-MS	Re	0.007	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Q-ICP-MS	Os	0.17	0.10	0.27	0.22	0.56	0.37	0.30	0.33	0.23
Q-ICP-MS	Ir	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.04	<DL
Q-ICP-MS	Pt	0.06	0.09	0.06	0.01	0.03	0.06	0.04	0.10	0.10
Q-ICP-MS	Au	0.12	0.07	0.16	0.05	0.51	0.29	0.25	0.87	0.48
Q-ICP-MS	Tl	0.61	0.76	0.32	0.74	0.64	0.73	0.38	0.43	0.33
Q-ICP-MS	Pb	33.5	31.1	23.6	53.9	29.6	23.9	17.6	32.6	15.8
SLOWPOKE	Th	44.4*	46.2*	3.7	7.4	12.1	0.6	38.6	2.6	0.8
SLOWPOKE	U	3.1*	2.9*	0.53	15.60	2.70	0.62	0.95	0.69	0.70

* Samples M12640 and M12643: Th and U analysis performed using INAA

	Sample ID:	HW3523	HW3524	HW3525	HW3526	HW3527	HW3528	HW3530	HW1B	HW2B	HW3B
	Domain	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson
	wt.%										
FUS-ICP	SiO2	57.57	51.22	69.34	63.14	71.50	66.70	75.23	66.02	70.71	77.84
FUS-ICP	TiO2	1.155	1.388	0.319	0.660	0.206	0.288	0.079	0.617	0.692	0.192
FUS-ICP	Al2O3	17.03	17.08	15.29	16.74	15.08	16.00	13.75	15.59	14.99	11.50
FUS-ICP	Fe2O3(T)	11.29	17.09	2.61	4.54	2.16	2.27	0.82	4.30	3.04	1.60
FUS-ICP	MnO	0.226	0.307	0.035	0.051	0.029	0.033	0.006	0.050	0.039	0.019
FUS-ICP	MgO	3.37	4.40	1.09	1.68	0.75	0.79	0.09	1.05	0.90	0.35
FUS-ICP	CaO	1.97	1.52	3.31	3.16	2.22	2.90	1.56	5.03	3.94	2.81
FUS-ICP	Na2O	2.10	1.58	4.22	4.51	3.61	3.68	3.04	4.46	4.25	3.20
FUS-ICP	K2O	3.33	3.99	2.21	3.29	4.11	4.48	4.70	1.31	1.12	0.90
FUS-ICP	P2O5	0.02	0.03	0.08	0.15	0.05	0.41	< 0.01	0.78	0.06	< 0.01
FUS-ICP	LOI	0.16	0.43	0.27	0.30	0.27	0.45	0.25	0.42	0.52	0.42
FUS-ICP	Total	98.22	99.03	98.77	98.24	99.98	98.01	99.53	99.63	100.30	98.84
Trace element (ppm)											
FUS-ICP	Ba	1242	1382	1428	1731	2730	2905	3230	428	427	316
INAA	Cr	196	273	18	27	17	11	3	14	17	< 0.5
TD-ICP	Cu	22	235	5	10	10	6	6	4	2	< 1
TD-ICP	Ni	40	184	13	18	13	11	2	11	9	7
INAA	Sc	28.50	33.70	3.65	6.27	3.40	3.35	0.40	5.16	5.17	2.00
FUS-ICP	V	206	264	46	53	32	29	16	85	46	30
MULT INAA / TD-ICP	Zn	218	123	34	58	34	32	8	48	31	13
Q-ICP-MS	Ga	22.3	21.9	20.4	22.7	18.7	20.1	15.6	26.4	22.3	17.4
INAA	Rb	90	110	30	40	60	60	70	< 10	30	< 10
FUS-ICP	Sr	166	158	461	469	469	491	467	422	399	304
FUS-ICP	Y	29	44	3	5	3	12	2	23	2	< 1
FUS-ICP	Zr	292	569	109	202	76	125	89	51	60	72
Q-ICP-MS	Li	11.6	15.2	7.6	7.4	6.9	7.1	6.2	N.D.	N.D.	N.D.
Q-ICP-MS	Be	0.2	0.2	0.9	1.1	0.7	0.9	0.6	0.9	1.2	1.0
Q-ICP-MS	Co	18.55	43.55	8.42	10.94	5.57	8.00	2.90	78.68	89.52	108.48
Q-ICP-MS	Ge	1.68	2.06	0.82	0.93	0.83	0.97	0.73	1.24	0.90	1.24
Q-ICP-MS	Nb	22.82	29.73	2.72	5.85	1.97	3.04	0.51	7.15	9.72	2.94
Q-ICP-MS	Mo	2.40	12.76	0.43	0.41	0.32	0.15	0.30	1.87	1.99	2.82
Q-ICP-MS	Ru	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.04	0.05	0.03
Q-ICP-MS	Pd	10.46	17.35	3.28	5.73	2.44	2.71	1.90	1.54	1.87	1.72
Q-ICP-MS	Ag	0.83	0.99	0.13	0.21	0.09	0.11	0.07	0.28	0.32	0.14
Q-ICP-MS	Cd	0.36	0.37	0.12	0.13	<DL	0.08	<DL	0.10	0.15	0.16
Q-ICP-MS	Sn	1.81	1.39	1.15	1.31	0.95	0.85	0.51	2.48	2.61	1.71
Q-ICP-MS	Sb	0.03	0.04	0.04	0.04	0.06	0.06	0.05	0.13	0.11	0.12
Q-ICP-MS	Te	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Q-ICP-MS	Cs	0.15	0.14	0.02	0.02	0.04	0.04	0.04	0.03	0.02	<DL
Q-ICP-MS	La	27.2	22.9	23.6	27.5	21.2	43.3	24.6	79.6	22.4	14.4
Q-ICP-MS	Ce	42.1	41.6	43.9	55.3	40.7	97.6	41.0	188.4	41.2	24.3
Q-ICP-MS	Pr	5.15	4.64	4.33	5.90	4.14	12.2	3.61	23.9	3.95	2.03
Q-ICP-MS	Nd	18.0	16.1	13.5	19.8	13.6	46.0	9.7	89.2	12.4	5.4
Q-ICP-MS	Sm	4.09	4.55	1.90	3.06	1.89	7.56	0.96	14.72	1.71	0.52
Q-ICP-MS	Eu	1.68	1.63	1.35	1.55	1.60	2.19	1.72	1.45	1.10	0.77
Q-ICP-MS	Gd	4.61	6.64	1.34	2.29	1.31	5.56	0.54	10.78	1.23	0.32
Q-ICP-MS	Tb	0.71	1.27	0.12	0.21	0.11	0.50	0.02	0.98	0.11	<DL
Q-ICP-MS	Dy	4.64	8.17	0.63	1.13	0.57	2.59	0.14	5.50	0.66	0.15
Q-ICP-MS	Ho	1.01	1.72	0.12	0.21	0.10	0.44	0.03	0.95	0.13	0.03
Q-ICP-MS	Er	3.09	5.20	0.33	0.59	0.28	1.12	0.09	2.27	0.35	0.10
Q-ICP-MS	Tm	0.459	0.782	0.042	0.072	0.035	0.120	0.009	0.261	0.051	0.017

	Sample ID:	HW3523	HW3524	HW3525	HW3526	HW3527	HW3528	HW3530	HW1B	HW2B	HW3B
	Domain	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson	Taltson
Trace element (ppm)											
Q-ICP-MS	Yb	3.17	5.21	0.29	0.47	0.25	0.69	0.08	1.40	0.30	0.13
Q-ICP-MS	Lu	0.48	0.85	0.04	0.07	0.04	0.09	<DL	0.17	0.05	<DL
INAA	Hf	7.4	13.8	3.0	5.5	3.3	3.6	2.9	<0.2	<0.2	<0.2
Q-ICP-MS	Ta	1.10	1.31	0.16	0.27	0.12	0.15	0.07	N.D.	N.D.	N.D.
Q-ICP-MS	W	1.70	1.41	1.01	1.34	1.66	0.97	0.74	726.79	894.55	1216.32
Q-ICP-MS	Re	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.021	0.023	0.030
Q-ICP-MS	Os	0.20	0.18	0.12	0.17	0.13	0.15	0.12	0.72	0.57	0.40
Q-ICP-MS	Ir	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Q-ICP-MS	Pt	0.13	0.19	0.03	0.05	0.02	<DL	<DL	0.10	0.10	0.06
Q-ICP-MS	Au	1.05	0.65	0.32	0.23	0.20	0.16	0.13	0.35	0.38	0.27
Q-ICP-MS	Tl	0.53	0.85	0.26	0.38	0.51	0.55	0.53	0.15	0.13	0.08
Q-ICP-MS	Pb	29.3	27.6	20.5	26.0	26.2	28.7	27.6	19.3	15.7	12.0
SLOWPOKE	Th	7.4	4.9	2.6	1.8	4.3	2.0	12.1	10.7	0.7	0.5
SLOWPOKE	U	0.99	1.88	0.59	0.64	0.66	0.38	0.42	0.49	0.25	0.26

APPENDIX D - Electron Microprobe Analyses of Samples
Potassium Feldspar Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Sample
1	63.89	0.01	18.47	0.05	0.00	0.00	0.00	0.06	1.36	15.04	98.89	M0034-1Kfs
2	64.45	0.03	18.88	0.00	0.02	0.00	0.02	0.30	2.67	12.89	99.26	M0034-1Kfs
3	64.00	0.00	20.49	0.04	0.01	0.00	0.00	1.75	6.17	6.74	99.18	M0034-1Kfs
23	64.92	0.02	18.79	0.01	0.00	0.00	0.02	0.16	3.11	12.36	99.39	M0034-3Kfs
24	63.44	0.01	18.33	0.03	0.00	0.02	0.00	0.07	1.33	15.09	98.31	M0034-3Kfs
25	64.02	0.04	18.52	0.00	0.00	0.00	0.02	0.09	1.47	14.63	98.79	M0034-3Kfs
29	63.76	0.03	18.71	0.00	0.02	0.00	0.00	0.35	2.67	12.84	98.38	M0034-3Kfs
30	63.60	0.03	18.47	0.00	0.01	0.02	0.03	0.13	2.28	13.66	98.22	M0034-4Kfs
31	64.48	0.01	18.90	0.01	0.00	0.00	0.01	0.27	3.08	12.45	99.20	M0034-4Kfs
35	64.98	0.03	18.96	0.00	0.00	0.00	0.01	0.33	2.97	12.51	99.78	M0034-5Kfs
36	64.63	0.06	18.78	0.00	0.00	0.00	0.01	0.19	2.59	13.37	99.62	M0034-5Kfs
37	64.44	0.04	18.90	0.02	0.02	0.01	0.00	0.30	2.90	12.59	99.20	M0034-5Kfs
41	64.15	0.06	18.50	0.00	0.00	0.04	0.00	0.03	1.11	15.36	99.25	M0034-6Kfs
42	64.36	0.02	18.68	0.05	0.00	0.00	0.02	0.10	1.83	14.33	99.37	M0034-6Kfs
43	64.69	0.02	18.69	0.02	0.00	0.02	0.02	0.12	1.93	14.18	99.68	M0034-6Kfs
Kfs avg	64.25	0.03	18.80	0.02	0.01	0.01	0.01	0.28	2.50	13.20	99.10	
std dev	0.46	0.02	0.50	0.02	0.01	0.01	0.01	0.42	1.23	2.07	0.49	
60	63.50	0.06	18.31	0.00	0.05	0.00	0.00	0.04	1.28	14.93	98.17	M3796-2Kfs
61	63.48	0.03	18.16	0.00	0.04	0.00	0.00	0.01	0.74	15.76	98.22	M3796-2Kfs
67	63.42	0.02	18.11	0.01	0.04	0.00	0.01	0.00	0.51	16.16	98.29	M3796-2Kfs
71	63.40	0.03	18.41	0.03	0.02	0.01	0.00	0.13	1.52	14.51	98.05	M3796-3Kfs
Kfs avg	63.45	0.03	18.25	0.01	0.04	0.00	0.00	0.05	1.01	15.34	98.18	
std dev	0.05	0.02	0.14	0.01	0.01	0.00	0.00	0.06	0.47	0.76	0.10	
92	63.45	0.01	18.62	0.02	0.05	0.03	0.01	0.12	0.92	15.09	98.32	M3997-2Kfs
93	63.45	0.04	18.70	0.00	0.01	0.00	0.01	0.11	1.01	15.08	98.41	M3997-2Kfs
94	63.61	0.08	18.54	0.00	0.00	0.00	0.02	0.08	0.80	15.33	98.46	M3997-2Kfs
107	63.50	0.03	18.57	0.05	0.04	0.02	0.00	0.04	0.93	15.19	98.37	M3997-5Kfsbleb
109	63.54	0.02	18.58	0.01	0.00	0.00	0.03	0.08	0.98	15.04	98.28	M3997-5Kfsbleb
Kfs avg	63.51	0.04	18.60	0.02	0.02	0.01	0.01	0.09	0.93	15.15	98.37	
std dev	0.07	0.03	0.06	0.02	0.02	0.01	0.01	0.03	0.08	0.12	0.07	
110	63.56	0.04	18.23	0.03	0.04	0.00	0.02	0.02	0.56	16.14	98.63	M4002a-1Kfs
111	63.42	0.02	18.31	0.02	0.02	0.00	0.04	0.07	0.41	16.27	98.57	M4002a-1Kfs
113	63.77	0.02	18.37	0.00	0.00	0.01	0.00	0.07	1.31	14.94	98.48	M4002a-2Kfs
115	63.26	0.05	18.07	0.00	0.00	0.00	0.02	0.00	0.42	16.41	98.23	M4002a-2Kfs
120	63.67	0.04	18.45	0.00	0.00	0.00	0.01	0.10	0.56	15.86	98.67	M4002a-4Kfs
121	63.74	0.00	18.45	0.04	0.02	0.01	0.02	0.10	0.78	15.70	98.86	M4002a-4Kfs
122	63.22	0.05	18.19	0.00	0.00	0.00	0.02	0.03	0.45	16.19	98.15	M4002a-4Kfs
126	63.35	0.03	18.34	0.01	0.02	0.00	0.02	0.10	0.56	15.95	98.38	M4002a-5Kfs
127	63.83	0.05	18.28	0.00	0.02	0.01	0.01	0.08	0.84	15.49	98.61	M4002a-5Kfs
Kfs avg	63.53	0.03	18.30	0.01	0.01	0.00	0.02	0.06	0.65	15.88	98.51	
std dev	0.23	0.02	0.12	0.02	0.01	0.01	0.01	0.04	0.29	0.46	0.22	
50	63.06	0.06	18.50	0.03	0.00	0.00	0.01	0.09	0.89	15.65	98.29	M4002b-2Kfs
52	64.01	0.04	18.69	0.00	0.00	0.00	0.02	0.07	0.76	15.72	99.31	M4002b-2Kfs
53	64.21	0.04	18.54	0.02	0.00	0.03	0.00	0.01	0.71	15.86	99.41	M4002b-2Kfs
54	64.05	0.04	18.75	0.02	0.01	0.01	0.01	0.09	0.94	15.60	99.52	M4002b-2Kfs
55	64.38	0.05	18.57	0.00	0.04	0.00	0.01	0.02	0.61	16.02	99.69	M4002b-4Kfs
56	62.96	0.04	18.38	0.02	0.04	0.00	0.04	0.20	0.38	16.33	98.38	M4002b-4Kfs
57	63.67	0.03	18.64	0.00	0.01	0.03	0.02	0.20	0.60	15.98	99.17	M4002b-4Kfs
58	63.61	0.03	18.87	0.03	0.04	0.04	0.01	0.41	1.71	14.20	98.94	M4002b-4Kfs
59	63.94	0.09	18.56	0.00	0.00	0.02	0.01	0.04	0.60	16.20	99.46	M4002b-4Kfs
60	63.91	0.02	18.42	0.00	0.03	0.02	0.02	0.00	0.40	16.32	99.13	M4002b-5Kfs
61	64.28	0.02	18.39	0.00	0.00	0.00	0.01	0.04	0.30	16.42	99.46	M4002b-5Kfs
63	64.32	0.00	18.26	0.00	0.02	0.00	0.01	0.03	0.41	16.38	99.43	M4002b-5Kfs
72	62.85	0.00	17.99	0.04	0.22	0.01	0.02	0.13	0.26	16.53	98.05	M4002b-7Kfs
73	62.73	0.03	18.45	0.00	0.01	0.00	0.02	0.01	0.25	16.69	98.18	M4002b-7Kfs
Kfs avg	63.71	0.04	18.50	0.01	0.03	0.01	0.01	0.10	0.63	15.99	99.03	
std dev	0.58	0.02	0.22	0.02	0.06	0.01	0.01	0.11	0.38	0.62	0.56	
1	63.38	0.02	18.23	0.00	0.01	0.00	0.02	0.04	0.69	15.87	98.26	M4015a-1Kfs
2	63.40	0.01	18.38	0.00	0.03	0.01	0.02	0.07	1.08	15.27	98.27	M4015a-1Kfs
3	63.19	0.00	18.51	0.03	0.01	0.00	0.02	0.16	0.81	15.50	98.22	M4015a-1Kfs
4	63.64	0.05	18.58	0.01	0.00	0.04	0.02	0.06	1.48	14.64	98.50	M4015a-1Kfs
5	63.97	0.02	18.53	0.00	0.04	0.03	0.02	0.07	1.51	14.57	98.75	M4015a-1Kfs
13	63.96	0.00	18.47	0.00	0.00	0.01	0.00	0.02	1.09	15.25	98.81	M4015a-2Kfs
14	63.71	0.00	18.29	0.01	0.00	0.01	0.01	0.01	1.06	15.31	98.41	M4015a-2Kfs
15	63.64	0.01	18.35	0.00	0.03	0.00	0.02	0.03	0.66	15.95	98.68	M4015a-2Kfs
16	63.72	0.00	18.42	0.02	0.00	0.00	0.03	0.04	0.95	15.54	98.72	M4015a-2Kfs
17	63.74	0.01	18.33	0.00	0.02	0.04	0.01	0.04	0.72	15.69	98.60	M4015a-2Kfs
28	63.85	0.00	18.26	0.00	0.00	0.03	0.03	0.02	1.10	15.08	98.38	M4015a-4Kfs
30	63.46	0.00	18.31	0.00	0.01	0.00	0.00	0.02	1.08	15.35	98.22	M4015a-4Kfs
36	63.70	0.01	18.53	0.00	0.00	0.02	0.03	0.06	1.51	14.66	98.51	M4015a-6Kfs

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Sample
Kfs avg	63.64	0.01	18.40	0.01	0.01	0.01	0.02	0.05	1.05	15.28	98.49	
std dev	0.23	0.01	0.11	0.01	0.01	0.02	0.01	0.04	0.30	0.45	0.21	
144	64.91	0.00	18.66	0.00	0.01	0.01	0.01	0.03	1.89	14.56	100.08	M4017-1Kfs
145	63.64	0.01	18.23	0.04	0.02	0.02	0.01	0.00	0.45	16.48	98.89	M4017-1Kfs
146	64.23	0.00	18.43	0.03	0.01	0.00	0.01	0.00	0.44	16.52	99.68	M4017-1Kfs
151	63.82	0.02	18.41	0.00	0.02	0.00	0.01	0.00	0.38	16.45	99.11	M4017-2Kfs
152	63.79	0.03	18.46	0.03	0.00	0.00	0.01	0.00	0.35	16.55	99.22	M4017-2Kfs
153	63.76	0.00	18.28	0.01	0.03	0.00	0.01	0.00	0.28	16.63	98.99	M4017-2Kfs
159	62.80	0.03	18.26	0.03	0.02	0.00	0.00	0.01	0.61	16.35	98.11	M4017-3Kfs
164	63.74	0.04	18.22	0.03	0.00	0.01	0.02	0.00	0.47	16.40	98.92	M4017-5Kfs
165	64.51	0.01	18.38	0.00	0.00	0.05	0.00	0.02	1.23	15.16	99.36	M4017-5Kfs
169	63.79	0.02	18.42	0.03	0.00	0.00	0.01	0.04	0.74	15.86	98.91	M4017-6Kfs
170	64.28	0.01	18.36	0.01	0.00	0.00	0.02	0.00	0.29	16.60	99.56	M4017-6Kfs
171	63.83	0.00	18.37	0.05	0.03	0.00	0.02	0.00	0.34	16.55	99.19	M4017-6Kfs
Kfs avg	63.92	0.01	18.37	0.02	0.01	0.01	0.01	0.01	0.62	16.17	99.17	
std dev	0.52	0.01	0.12	0.02	0.01	0.01	0.01	0.01	0.48	0.66	0.49	
181	63.22	0.05	18.49	0.00	0.00	0.00	0.00	0.05	0.88	15.37	98.07	M12350-1Kfs
Kfs norm	64.47	0.06	18.86	0.00	0.00	0.00	0.00	0.05	0.89	15.68	100.00	
84	63.40	0.02	18.53	0.00	0.05	0.02	0.01	0.04	1.20	14.83	98.09	M12351a-1Kfs
85	63.52	0.04	18.60	0.00	0.03	0.01	0.02	0.02	1.34	14.88	98.46	M12351a-1Kfs
86	64.01	0.08	18.62	0.00	0.04	0.00	0.03	0.02	1.23	15.19	99.22	M12351a-1Kfs
101	63.48	0.00	18.45	0.00	0.03	0.01	0.02	0.02	0.83	15.27	98.11	M12351a-3Kfs
102	63.58	0.05	18.53	0.00	0.00	0.03	0.01	0.01	0.67	15.48	98.35	M12351a-3Kfs
103	63.85	0.02	18.54	0.01	0.06	0.01	0.01	0.03	1.18	14.90	98.60	M12351a-3Kfs
108	63.50	0.04	18.68	0.02	0.04	0.03	0.00	0.06	1.32	14.65	98.34	M12351a-4Kfs
109	63.14	0.01	18.78	0.00	0.21	0.02	0.01	0.15	1.40	14.61	98.33	M12351a-4Kfs
114	63.76	0.03	18.63	0.02	0.01	0.00	0.00	0.02	1.20	14.96	98.63	M12351a-5Kfs
Kfs avg	63.58	0.03	18.60	0.01	0.05	0.01	0.01	0.04	1.15	14.97	98.46	
std dev	0.26	0.02	0.10	0.01	0.06	0.01	0.01	0.05	0.24	0.29	0.34	
126	63.28	0.02	18.64	0.01	0.03	0.02	0.00	0.17	1.42	14.47	98.06	M12351b-2Kfs
127	63.14	0.00	18.67	0.00	0.03	0.00	0.03	0.14	1.60	14.46	98.08	M12351b-2Kfs
128	63.61	0.03	18.65	0.00	0.02	0.00	0.00	0.07	1.26	14.99	98.64	M12351b-2Kfs
140	63.11	0.00	18.40	0.01	0.03	0.01	0.00	0.01	0.42	16.09	98.06	M12351b-4Kfs
141	63.23	0.03	18.73	0.00	0.04	0.02	0.02	0.10	1.80	14.18	98.13	M12351b-5Kfs
142	63.32	0.04	18.86	0.00	0.01	0.01	0.01	0.06	1.68	14.42	98.40	M12351b-5Kfs
143	63.75	0.00	18.82	0.00	0.04	0.04	0.04	0.10	1.78	14.23	98.80	M12351b-5Kfs
Kfs avg	63.35	0.02	18.68	0.00	0.03	0.01	0.01	0.09	1.42	14.69	98.31	
std dev	0.24	0.02	0.15	0.00	0.01	0.01	0.02	0.05	0.48	0.67	0.31	
323	63.97	0.01	19.10	0.00	0.03	0.05	0.00	0.08	1.41	14.61	99.25	M12352a-1Kfs1
324	63.93	0.02	19.12	0.00	0.02	0.02	0.02	0.06	1.38	14.77	99.33	M12352a-1Kfs2
325	64.17	0.07	18.98	0.00	0.01	0.01	0.00	0.09	1.40	14.75	99.47	M12352a-1Kfs3
332	64.26	0.01	19.11	0.00	0.05	0.00	0.02	0.08	1.39	14.80	99.73	M12352a-2Kfs1
333	64.13	0.02	19.06	0.00	0.01	0.00	0.03	0.07	1.33	14.77	99.43	M12352a-2Kfs2
334	63.97	0.02	19.18	0.00	0.00	0.00	0.04	0.08	1.33	14.82	99.44	M12352a-2Kfs3
341	63.28	0.03	18.61	0.00	0.02	0.04	0.02	0.10	1.30	14.60	98.00	M12352a-3Kfs1
342	63.92	0.03	18.87	0.00	0.00	0.01	0.01	0.07	1.41	14.54	98.86	M12352a-3Kfs2
353	63.72	0.02	19.06	0.01	0.00	0.00	0.01	0.12	1.67	14.39	99.00	M12352a-4Kfs1
354	63.82	0.00	19.21	0.00	0.05	0.02	0.01	0.11	1.69	14.31	99.21	M12352a-4Kfs2
355	63.67	0.00	19.18	0.00	0.01	0.00	0.00	0.10	1.42	14.90	99.28	M12352a-4Kfs3
Kfs avg	63.89	0.02	19.04	0.00	0.02	0.01	0.02	0.09	1.43	14.66	99.18	
std dev	0.27	0.02	0.17	0.00	0.02	0.02	0.01	0.02	0.13	0.19	0.46	
41	64.14	0.06	18.65	0.03	0.01	0.00	0.01	0.13	1.90	14.20	99.12	M12352b-2Kfs
42	64.16	0.02	18.64	0.00	0.00	0.00	0.03	0.08	1.72	14.47	99.12	M12352b-2Kfs
43	63.87	0.00	18.67	0.01	0.02	0.00	0.02	0.11	1.60	14.39	98.69	M12352b-2Kfs
44	64.01	0.03	18.62	0.00	0.01	0.01	0.02	0.11	1.70	14.25	98.75	M12352b-2Kfs
67	64.23	0.00	18.49	0.03	0.02	0.00	0.01	0.06	1.29	15.20	99.33	M12352b-6Kfs
68	64.28	0.04	18.55	0.03	0.00	0.01	0.03	0.10	1.18	15.29	99.51	M12352b-6Kfs
69	64.27	0.01	18.59	0.00	0.02	0.01	0.01	0.12	1.45	14.75	99.21	M12352b-6Kfs
70	64.90	0.00	18.58	0.00	0.01	0.00	0.00	0.11	1.23	15.24	100.07	M12352b-7Kfs
71	64.60	0.02	18.70	0.00	0.00	0.02	0.02	0.13	1.51	14.92	99.92	M12352b-7Kfs
72	64.33	0.05	18.56	0.01	0.01	0.00	0.00	0.12	1.12	15.39	99.59	M12352b-7Kfs
73	64.91	0.02	18.92	0.03	0.00	0.00	0.02	0.36	2.65	13.03	99.94	M12352b-7Kfs
74	64.76	0.02	18.64	0.00	0.02	0.00	0.02	0.04	1.29	15.39	100.18	M12352b-8Kfs
76	63.66	0.00	19.00	0.00	0.02	0.01	0.01	0.15	0.76	15.62	99.21	M12352b-8Kfs
Kfs avg	64.32	0.02	18.66	0.01	0.01	0.00	0.01	0.12	1.49	14.78	99.43	
std dev	0.38	0.02	0.14	0.01	0.01	0.01	0.01	0.08	0.46	0.71	0.48	

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Sample
105	63.78	0.04	18.39	0.00	0.00	0.02	0.00	0.06	1.16	14.97	98.43	M12354-2Kfs
106	63.81	0.03	18.50	0.00	0.07	0.02	0.02	0.19	1.20	14.46	98.28	M12354-2Kfs
108	63.95	0.06	18.50	0.03	0.01	0.00	0.03	0.17	1.67	14.18	98.59	M12354-2Kfs
Kfs avg	63.85	0.04	18.46	0.01	0.02	0.01	0.01	0.14	1.34	14.54	98.43	
std dev	0.09	0.01	0.06	0.02	0.04	0.01	0.01	0.07	0.28	0.40	0.16	
55	64.41	0.04	18.52	0.01	0.00	0.00	0.03	0.03	1.59	14.39	99.02	M12549-2Kfs
56	63.99	0.01	18.53	0.00	0.01	0.00	0.01	0.07	1.20	14.75	98.56	M12549-2Kfs
57	63.98	0.06	18.55	0.00	0.00	0.01	0.01	0.04	1.16	14.70	98.51	M12549-2Kfs
58	64.12	0.04	18.36	0.02	0.00	0.00	0.01	0.01	1.32	14.68	98.57	M12549-2Kfs
59	64.32	0.00	18.64	0.01	0.02	0.01	0.01	0.05	1.51	14.22	98.80	M12549-2Kfs
60	64.22	0.00	18.69	0.00	0.01	0.00	0.04	0.08	1.53	14.30	98.87	M12549-3Kfs
61	63.77	0.05	18.54	0.02	0.05	0.04	0.00	0.07	1.49	14.27	98.32	M12549-3Kfs
62	64.06	0.05	18.56	0.00	0.06	0.01	0.01	0.05	1.41	14.55	98.76	M12549-3Kfs
63	63.64	0.03	18.48	0.02	0.02	0.00	0.02	0.03	1.17	14.69	98.09	M12549-3Kfs
Kfs avg	64.06	0.03	18.54	0.01	0.02	0.01	0.02	0.05	1.37	14.50	98.61	
std dev	0.25	0.02	0.09	0.01	0.02	0.01	0.01	0.02	0.17	0.21	0.29	
12	63.89	0.00	18.57	0.03	0.04	0.02	0.02	0.17	1.51	14.16	98.39	M12636-8Kfs
15	64.10	0.00	18.58	0.01	0.00	0.03	0.03	0.09	1.68	13.98	98.49	M12636-8Kfs
16	64.21	0.04	18.57	0.04	0.02	0.00	0.03	0.17	1.58	14.28	98.94	M12636-7Kfs
17	63.93	0.06	18.53	0.00	0.02	0.00	0.01	0.23	1.73	14.05	98.55	M12636-7Kfs
18	64.00	0.04	18.45	0.05	0.02	0.01	0.01	0.11	1.30	14.70	98.68	M12636-7Kfs
44	64.04	0.03	18.74	0.02	0.01	0.01	0.02	0.12	1.68	14.20	98.87	M12636-2Kfs
45	63.87	0.03	18.58	0.00	0.00	0.00	0.02	0.08	1.67	14.17	98.41	M12636-2Kfs
46	63.70	0.07	18.65	0.00	0.00	0.02	0.00	0.14	1.77	13.87	98.22	M12636-2Kfs
Kfs avg	63.97	0.03	18.58	0.02	0.01	0.01	0.02	0.14	1.62	14.18	98.57	
std dev	0.16	0.02	0.08	0.02	0.01	0.01	0.01	0.05	0.15	0.25	0.25	
1	64.94	0.05	18.76	0.00	0.00	0.00	0.01	0.14	1.64	15.14	100.68	M12637-1Kfs
2	64.80	0.02	18.81	0.02	0.00	0.01	0.00	0.19	1.57	14.53	99.95	M12637-1Kfs
3	65.94	0.00	18.97	0.00	0.00	0.01	0.04	0.18	1.61	14.60	101.35	M12637-1Kfs
8	64.18	0.05	18.91	0.05	0.01	0.00	0.03	0.25	1.63	14.52	99.63	M12637-2Kfs
9	65.35	0.04	18.90	0.00	0.01	0.04	0.00	0.07	1.82	14.30	100.53	M12637-2Kfs
10	64.40	0.00	18.73	0.01	0.00	0.01	0.01	0.17	1.41	14.80	99.54	M12637-2Kfs
11	64.58	0.06	18.69	0.00	0.01	0.04	0.00	0.21	1.74	14.39	99.71	M12637-3Kfs
12	64.07	0.01	18.67	0.00	0.00	0.00	0.02	0.15	1.60	14.64	99.15	M12637-3Kfs
13	64.13	0.06	18.78	0.00	0.04	0.00	0.01	0.38	2.16	13.64	99.21	M12637-3Kfs
32	65.47	0.02	18.71	0.00	0.00	0.01	0.02	0.08	1.66	14.65	100.62	M12637-7Kfs
33	65.07	0.02	18.96	0.00	0.01	0.05	0.02	0.37	2.13	13.79	100.39	M12637-7Kfs
34	65.62	0.02	18.89	0.04	0.01	0.01	0.02	0.12	2.04	14.13	100.90	M12637-7Kfs
35	64.87	0.01	18.98	0.00	0.00	0.03	0.01	0.19	1.83	14.51	100.42	M12637-7Kfs
Kfs avg	64.88	0.03	18.83	0.01	0.01	0.01	0.01	0.19	1.76	14.43	100.16	
std dev	0.60	0.02	0.11	0.02	0.01	0.02	0.01	0.09	0.23	0.40	0.68	
144	63.78	0.01	18.66	0.00	0.01	0.01	0.00	0.17	1.93	13.91	98.49	M12638-2Kfs
145	63.39	0.05	18.37	0.00	0.04	0.00	0.02	0.11	1.20	15.04	98.22	M12638-2Kfs
146	63.73	0.05	18.65	0.03	0.00	0.01	0.01	0.12	1.26	14.99	98.86	M12638-2Kfs
147	63.29	0.05	18.56	0.00	0.03	0.02	0.00	0.15	1.35	14.77	98.22	M12638-2Kfs
151	64.09	0.02	18.53	0.00	0.02	0.02	0.02	0.19	1.65	14.29	98.84	M12638-3Kfs
152	63.72	0.04	18.69	0.05	0.01	0.00	0.00	0.26	1.81	14.05	98.63	M12638-3Kfs
153	63.25	0.03	18.55	0.00	0.03	0.00	0.03	0.20	1.65	14.29	98.03	M12638-3Kfs
157	63.75	0.04	18.47	0.00	0.00	0.00	0.01	0.06	0.76	15.62	98.70	M12638-4Kfs
158	64.16	0.02	18.57	0.00	0.02	0.01	0.03	0.13	1.25	14.79	98.98	M12638-4Kfs
159	64.12	0.02	18.50	0.00	0.01	0.00	0.02	0.11	1.21	14.91	98.91	M12638-4Kfs
Kfs avg	63.73	0.03	18.56	0.01	0.02	0.01	0.01	0.15	1.41	14.67	98.59	
std dev	0.34	0.02	0.10	0.02	0.01	0.01	0.01	0.06	0.35	0.52	0.33	
8	63.76	0.07	18.27	0.00	0.04	0.00	0.02	0.10	1.59	14.50	98.35	M12639-3Kfs1
9	63.80	0.04	18.41	0.00	0.03	0.00	0.00	0.16	1.63	14.46	98.52	M12639-3Kfs2
10	63.52	0.02	18.46	0.02	0.07	0.00	0.01	0.35	1.88	13.83	98.13	M12639-3Kfs3
28	63.50	0.07	18.20	0.00	0.04	0.02	0.01	0.06	1.02	15.15	98.07	M12639-6Kfs1
30	63.37	0.06	18.34	0.00	0.04	0.02	0.01	0.08	0.95	15.28	98.14	M12639-6Kfs3
31	63.16	0.02	18.25	0.00	0.03	0.00	0.05	0.18	0.99	15.44	98.13	M12639-6Kfs4
avg	63.52	0.04	18.32	0.00	0.04	0.01	0.02	0.16	1.34	14.78	98.23	
std dev	0.24	0.02	0.10	0.01	0.01	0.01	0.02	0.10	0.40	0.62	0.17	
44	64.44	0.02	18.52	0.00	0.00	0.04	0.01	0.11	1.20	15.46	99.80	M12640-2Kfs1
45	63.56	0.00	18.28	0.01	0.06	0.00	0.01	0.07	1.07	15.46	98.52	M12640-2Kfs2
46	64.13	0.04	18.42	0.00	0.00	0.01	0.00	0.08	1.17	15.46	99.31	M12640-2Kfs3
51	64.04	0.02	18.29	0.01	0.02	0.00	0.00	0.06	0.96	15.64	99.03	M12640-4Kfs1
52	63.94	0.05	18.78	0.02	0.02	0.00	0.03	0.48	1.44	14.91	99.67	M12640-4Kfs2
53	63.81	0.01	18.22	0.00	0.00	0.00	0.02	0.17	1.22	15.06	98.51	M12640-4Kfs3
54	63.90	0.04	18.46	0.01	0.01	0.01	0.01	0.34	1.31	14.86	98.94	M12640-4Kfs4
60	64.50	0.02	17.91	0.01	0.01	0.00	0.01	0.20	1.24	14.90	98.79	M12640-6Kfs2
61	63.70	0.00	18.27	0.00	0.03	0.00	0.01	0.16	1.17	15.21	98.55	M12640-6Kfs3
avg	64.00	0.02	18.35	0.01	0.02	0.01	0.01	0.19	1.20	15.22	99.01	
std dev	0.31	0.02	0.24	0.01	0.02	0.01	0.01	0.14	0.14	0.30	0.49	
81	64.04	0.06	18.56	0.00	0.03	0.00	0.00	0.05	1.39	15.10	99.21	M12643-1Kfs

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Sample
84	64.32	0.05	18.61	0.00	0.04	0.00	0.02	0.15	2.01	13.73	98.92	M12643-1Kfs
91	64.23	0.04	18.58	0.00	0.02	0.02	0.03	0.13	1.67	14.55	99.26	M12643-2Kfs bleb
92	64.40	0.02	18.52	0.04	0.01	0.00	0.02	0.14	1.71	14.26	99.11	M12643-2Kfs bleb
98	63.84	0.00	18.61	0.00	0.03	0.02	0.02	0.08	1.20	15.17	98.96	M12643-4Kfs
Kfs avg	64.16	0.03	18.57	0.01	0.02	0.01	0.02	0.11	1.60	14.56	99.09	
std dev	0.23	0.02	0.04	0.02	0.01	0.01	0.01	0.04	0.31	0.60	0.15	
362	64.56	0.00	18.73	0.00	0.02	0.00	0.01	0.00	0.66	16.09	100.06	N04c-1Kfs
363	64.23	0.00	18.72	0.03	0.04	0.00	0.00	0.00	0.20	16.67	99.90	N04c-1Kfs
364	64.41	0.01	18.71	0.00	0.00	0.00	0.00	0.00	0.55	16.21	99.88	N04c-1Kfs
365	64.27	0.00	18.54	0.02	0.00	0.00	0.02	0.00	0.60	16.10	99.55	N04c-2Kfs1
366	64.42	0.04	18.40	0.00	0.00	0.00	0.02	0.01	0.75	15.78	99.42	N04c-2Kfs2
367	64.51	0.03	18.62	0.00	0.02	0.02	0.03	0.07	0.54	15.99	99.82	N04c-2Kfs3
371	64.29	0.00	18.91	0.00	0.00	0.00	0.02	0.00	0.35	16.78	100.34	N04c-3Kfs1
372	64.56	0.00	18.71	0.00	0.00	0.00	0.02	0.00	0.54	16.16	100.00	N04c-3Kfs2
376	63.87	0.00	18.95	0.00	0.00	0.00	0.00	0.00	0.52	16.17	99.51	N04c-4Kfs1
377	64.48	0.02	18.76	0.00	0.00	0.01	0.00	0.00	0.66	16.21	100.13	N04c-4Kfs2
378	64.69	0.05	18.93	0.00	0.01	0.02	0.00	0.00	0.57	16.09	100.36	N04c-4Kfs3
Kfs avg	64.39	0.01	18.72	0.00	0.01	0.00	0.01	0.01	0.54	16.20	99.91	
std dev	0.22	0.02	0.17	0.01	0.01	0.01	0.01	0.02	0.15	0.29	0.32	
4	64.65	0.00	18.99	0.00	0.03	0.04	0.00	0.13	1.88	14.22	99.94	N05a-1Kfs
5	64.55	0.05	19.05	0.00	0.03	0.02	0.02	0.13	2.06	14.01	99.91	N05a-1Kfs
6	64.11	0.02	18.57	0.02	0.00	0.00	0.02	0.02	0.84	15.81	99.42	N05a-1Kfs
13	64.52	0.04	18.40	0.00	0.02	0.00	0.01	0.00	0.39	16.26	99.65	N05a-2Kfs
14	64.13	0.04	18.55	0.04	0.00	0.00	0.01	0.12	0.94	15.18	99.01	N05a-2Kfs
15	64.55	0.05	18.56	0.00	0.03	0.02	0.02	0.08	0.90	15.53	99.72	N05a-2Kfs
22	64.23	0.02	18.67	0.00	0.01	0.02	0.03	0.03	0.68	16.01	99.71	N05a-2Kfs
23	64.15	0.04	18.69	0.00	0.01	0.00	0.02	0.14	0.82	15.60	99.47	N05a-3Kfs
24	64.24	0.00	18.76	0.00	0.01	0.00	0.02	0.18	1.23	15.16	99.59	N05a-3Kfs
32	64.11	0.02	18.70	0.04	0.00	0.00	0.00	0.02	0.24	16.56	99.69	N05a-5Kfs
33	64.38	0.01	18.76	0.00	0.00	0.02	0.02	0.13	0.94	15.32	99.58	N05a-5Kfs
34	64.49	0.02	18.31	0.00	0.00	0.00	0.01	0.00	0.39	16.28	99.50	N05a-5Kfs
Kfs avg	64.34	0.03	18.67	0.01	0.01	0.01	0.01	0.08	0.94	15.50	99.60	
std dev	0.20	0.02	0.21	0.02	0.01	0.01	0.01	0.06	0.56	0.79	0.25	
41	64.10	0.01	18.88	0.00	0.00	0.03	0.02	0.12	1.70	14.18	99.03	N05c-1Kfs
42	63.55	0.05	18.81	0.00	0.03	0.01	0.02	0.06	1.45	14.52	98.51	N05c-1Kfs
43	63.23	0.05	18.91	0.00	0.00	0.01	0.03	0.18	1.71	14.06	98.17	N05c-1Kfs
50	64.17	0.03	18.91	0.00	0.02	0.01	0.01	0.19	1.78	13.97	99.09	N05c-2Kfs
51	64.27	0.03	18.78	0.01	0.00	0.03	0.01	0.11	1.70	14.10	99.03	N05c-2Kfs
52	64.00	0.02	18.40	0.00	0.02	0.00	0.03	0.07	1.37	14.55	98.44	N05c-2Kfs
62	64.37	0.00	18.86	0.02	0.03	0.00	0.02	0.11	1.52	14.28	99.20	N05c-3Kfs
63	64.32	0.03	18.67	0.00	0.01	0.02	0.01	0.07	1.52	14.39	99.03	N05c-3Kfs
71	64.08	0.01	18.79	0.00	0.00	0.01	0.01	0.09	1.45	14.38	98.82	N05c-4Kfs
72	63.97	0.08	18.63	0.00	0.00	0.03	0.02	0.09	1.40	14.35	98.55	N05c-4Kfs
73	63.63	0.02	18.89	0.00	0.00	0.00	0.03	0.05	0.94	15.30	98.87	N05c-4Kfs
Kfs avg	63.97	0.03	18.78	0.00	0.01	0.01	0.02	0.10	1.50	14.37	98.79	
std dev	0.36	0.02	0.16	0.00	0.01	0.01	0.01	0.04	0.23	0.36	0.33	
78	63.62	0.06	18.24	0.00	0.01	0.01	0.01	0.16	0.79	15.35	98.25	N06b-1Kfs
79	64.01	0.03	18.63	0.00	0.02	0.03	0.01	0.08	1.77	14.18	98.75	N06b-1Kfs
83	64.49	0.02	18.78	0.04	0.00	0.00	0.00	0.14	1.73	14.22	99.40	N06b-2Kfs
84	63.84	0.02	18.57	0.00	0.00	0.03	0.01	0.14	1.28	14.72	98.61	N06b-2Kfs
85	62.89	0.05	18.86	0.00	0.03	0.01	0.01	0.04	0.87	15.77	98.53	N06b-2Kfs
89	64.59	0.06	18.66	0.01	0.00	0.03	0.01	0.23	2.44	12.85	98.88	N06b-3Kfs
90	64.72	0.02	18.80	0.00	0.00	0.01	0.00	0.13	2.46	13.09	99.22	N06b-3Kfs
91	63.42	0.01	18.83	0.00	0.00	0.00	0.02	0.04	1.29	15.01	98.63	N06b-3Kfs
95	63.91	0.02	18.85	0.00	0.01	0.01	0.00	0.07	1.41	14.86	99.14	N06b-4Kfs
96	63.86	0.00	18.45	0.01	0.00	0.00	0.00	0.01	0.51	15.91	98.76	N06b-4Kfs
97	64.20	0.02	18.86	0.00	0.04	0.00	0.01	0.12	1.77	14.13	99.15	N06b-4Kfs
105	63.98	0.08	18.45	0.00	0.00	0.00	0.01	0.06	1.36	14.60	98.54	N06b-5Kfs
106	63.83	0.07	18.70	0.00	0.03	0.00	0.01	0.10	1.31	14.59	98.65	N06b-5Kfs
Kfs avg	63.95	0.03	18.67	0.00	0.01	0.01	0.01	0.10	1.46	14.56	98.81	
std dev	0.49	0.02	0.19	0.01	0.01	0.01	0.01	0.06	0.58	0.90	0.33	
110	62.97	0.02	18.91	0.00	0.01	0.00	0.01	0.05	0.71	15.91	98.59	N06c-1Kfs
111	63.29	0.02	18.89	0.01	0.00	0.00	0.02	0.08	0.95	15.43	98.69	N06c-1Kfs
112	63.07	0.01	19.03	0.00	0.02	0.00	0.00	0.06	0.79	15.90	98.87	N06c-1Kfs
115	64.11	0.02	19.06	0.00	0.00	0.01	0.01	0.11	1.51	14.64	99.46	N06c-2Kfs
117	64.17	0.04	19.07	0.00	0.00	0.00	0.01	0.10	1.28	14.74	99.40	N06c-2Kfs
124	63.78	0.01	18.41	0.00	0.00	0.00	0.02	0.07	0.98	14.94	98.22	N06c-3Kfs
133	63.62	0.01	18.59	0.00	0.00	0.00	0.02	0.02	1.02	15.08	98.37	N06c-4Kfs
134	63.88	0.04	18.80	0.00	0.05	0.01	0.03	0.08	1.07	15.04	99.00	N06c-4Kfs
135	63.84	0.06	18.77	0.00	0.00	0.02	0.00	0.04	0.87	15.45	99.03	N06c-4Kfs
Kfs avg	63.64	0.03	18.84	0.00	0.01	0.00	0.01	0.07	1.02	15.24	98.85	
std dev	0.43	0.02	0.22	0.00	0.02	0.01	0.01	0.03	0.25	0.47	0.43	
26	64.67	0.02	18.55	0.00	0.03	0.02	0.00	0.12	1.32	15.15	99.89	HW3521-2Kfs1
27	64.58	0.00	18.41	0.00	0.00	0.04	0.03	0.09	0.95	15.48	99.56	HW3521-2Kfs2

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Sample
28	64.50	0.02	18.39	0.00	0.00	0.03	0.02	0.06	0.92	15.64	99.58	HW3521-2Kfs3
29	64.63	0.07	19.02	0.03	0.02	0.00	0.01	0.08	1.10	15.50	100.44	HW3521-3Kfs1
30	64.34	0.04	18.86	0.00	0.00	0.02	0.02	0.16	1.75	14.21	99.40	HW3521-3Kfs2
31	64.60	0.05	18.70	0.00	0.02	0.02	0.01	0.11	1.25	15.13	99.88	HW3521-3Kfs3
38	64.68	0.02	18.92	0.01	0.03	0.02	0.02	0.47	1.98	13.96	100.10	HW3521-4Kfs1
39	64.93	0.00	18.75	0.00	0.02	0.01	0.00	0.19	2.05	14.01	99.95	HW3521-4Kfs2
40	64.83	0.05	18.86	0.00	0.00	0.01	0.01	0.13	1.40	15.08	100.36	HW3521-4Kfs3
50	64.50	0.02	19.24	0.03	0.00	0.00	0.00	0.47	2.07	13.62	99.95	HW3521-5Kfs1
51	64.68	0.04	18.86	0.00	0.03	0.01	0.00	0.11	1.30	15.07	100.09	HW3521-5Kfs2
52	64.30	0.05	18.38	0.00	0.00	0.01	0.01	0.09	1.31	15.27	99.42	HW3521-5Kfs3
Kfs avg	64.60	0.03	18.74	0.01	0.01	0.01	0.01	0.17	1.45	14.84	99.88	
std dev	0.18	0.02	0.27	0.01	0.01	0.01	0.01	0.14	0.41	0.69	0.34	
59	63.67	0.01	18.31	0.00	0.02	0.00	0.02	0.04	0.66	16.02	98.75	HW3522-1Kfs1
60	63.70	0.00	18.46	0.00	0.02	0.04	0.01	0.05	0.73	15.93	98.93	HW3522-1Kfs2
61	64.70	0.00	18.33	0.01	0.01	0.02	0.03	0.01	0.59	16.38	100.06	HW3522-1Kfs3
77	64.47	0.02	18.33	0.00	0.00	0.00	0.03	0.14	0.91	15.51	99.42	HW3522-3Kfs1
78	64.10	0.04	18.29	0.00	0.04	0.00	0.01	0.11	0.90	15.63	99.12	HW3522-3Kfs2
79	63.88	0.02	18.29	0.00	0.00	0.00	0.01	0.10	0.67	15.90	98.87	HW3522-3Kfs3
89	63.85	0.01	18.61	0.00	0.00	0.04	0.01	0.24	1.02	15.37	99.13	HW3522-4Kfs1
90	64.07	0.05	18.79	0.00	0.03	0.00	0.01	0.15	0.73	15.71	99.54	HW3522-4Kfs2
91	64.06	0.02	18.60	0.00	0.01	0.01	0.02	0.22	0.76	15.71	99.40	HW3522-4Kfs3
Kfs avg	64.06	0.02	18.44	0.00	0.01	0.01	0.02	0.12	0.78	15.79	99.25	
std dev	0.34	0.02	0.18	0.00	0.01	0.01	0.01	0.08	0.14	0.30	0.41	
101	64.30	0.04	19.03	0.00	0.00	0.00	0.01	0.10	1.56	14.29	99.33	HW3523-1Kfs1
102	64.90	0.01	19.08	0.00	0.02	0.02	0.02	0.10	1.69	14.25	100.09	HW3523-1Kfs2
103	64.77	0.06	18.99	0.00	0.00	0.01	0.00	0.22	1.81	13.97	99.83	HW3523-1Kfs3
110	65.25	0.04	19.02	0.00	0.01	0.03	0.00	0.35	3.15	11.73	99.57	HW3523-2Kfs1
111	64.73	0.06	19.14	0.00	0.00	0.00	0.02	0.22	1.97	13.68	99.82	HW3523-2Kfs2
112	64.77	0.04	19.28	0.00	0.04	0.02	0.02	0.28	2.09	13.41	99.95	HW3523-2Kfs3
122	65.50	0.03	19.36	0.01	0.01	0.00	0.01	0.28	2.72	12.49	100.42	HW3523-3Kfs1
123	65.34	0.00	19.43	0.00	0.03	0.00	0.02	0.44	3.20	11.91	100.37	HW3523-3Kfs2
124	64.59	0.05	18.90	0.00	0.01	0.01	0.02	0.12	1.72	13.98	99.41	HW3523-3Kfs3
125	65.25	0.05	18.96	0.00	0.03	0.02	0.00	0.17	2.21	13.63	100.31	HW3523-4Kfs1
126	65.23	0.03	19.01	0.02	0.01	0.02	0.01	0.19	2.00	13.80	100.31	HW3523-4Kfs2
127	65.06	0.04	18.94	0.04	0.03	0.01	0.02	0.16	1.91	13.97	100.17	HW3523-4Kfs3
Kfs avg	64.97	0.04	19.09	0.01	0.01	0.01	0.01	0.22	2.17	13.43	99.97	
std dev	0.35	0.02	0.17	0.01	0.01	0.01	0.01	0.10	0.56	0.88	0.38	
134	64.63	0.10	19.35	0.00	0.01	0.00	0.01	0.34	4.06	10.12	98.62	HW3524-1Kfs1
135	65.18	0.06	19.32	0.03	0.03	0.02	0.02	0.15	2.39	13.01	100.20	HW3524-1Kfs2
136	65.00	0.01	18.81	0.02	0.03	0.04	0.00	0.12	1.56	14.33	99.91	HW3524-1Kfs3
153	64.32	0.05	19.08	0.02	0.03	0.03	0.01	0.07	1.26	14.82	99.69	HW3524-3Kfs1
154	64.26	0.01	18.92	0.00	0.02	0.00	0.02	0.11	1.39	14.73	99.45	HW3524-3Kfs2
155	64.35	0.07	19.45	0.00	0.03	0.00	0.02	0.48	2.22	13.16	99.78	HW3524-3Kfs3
160	64.40	0.02	18.95	0.00	0.03	0.01	0.01	0.13	1.44	14.42	99.40	HW3524-4Kfs2
161	64.80	0.04	19.64	0.07	0.01	0.00	0.01	0.76	2.37	12.96	100.66	HW3524-4Kfs3
Kfs avg	64.62	0.04	19.19	0.02	0.02	0.01	0.01	0.27	2.08	13.44	99.71	
std dev	0.35	0.03	0.29	0.02	0.01	0.02	0.01	0.25	0.92	1.55	0.60	
171	64.17	0.05	18.79	0.00	0.03	0.00	0.02	0.05	0.94	14.99	99.03	HW3525-1Kfs1
172	64.38	0.04	18.77	0.00	0.01	0.00	0.01	0.02	0.83	15.29	99.35	HW3525-1Kfs2
173	64.75	0.03	18.83	0.00	0.03	0.00	0.00	0.03	0.85	15.32	99.83	HW3525-1Kfs3
180	63.85	0.04	18.83	0.00	0.03	0.01	0.00	0.07	0.95	14.88	98.65	HW3525-2Kfs1
181	64.06	0.04	19.07	0.00	0.02	0.01	0.00	0.06	0.97	14.85	99.07	HW3525-2Kfs2
182	64.19	0.04	18.74	0.00	0.04	0.03	0.01	0.03	0.90	15.10	99.05	HW3525-2Kfs3
Kfs avg	64.23	0.04	18.84	0.00	0.03	0.01	0.01	0.04	0.91	15.07	99.16	
std dev	0.31	0.01	0.12	0.00	0.01	0.01	0.01	0.02	0.06	0.20	0.39	
204	64.56	0.04	18.82	0.00	0.05	0.01	0.03	0.15	1.49	14.58	99.73	HW3526-1Kfs1
205	64.38	0.02	18.74	0.00	0.03	0.02	0.02	0.06	1.40	14.72	99.38	HW3526-1Kfs2
206	64.53	0.04	18.89	0.01	0.00	0.00	0.01	0.08	1.20	15.03	99.78	HW3526-1Kfs3
213	64.47	0.08	18.89	0.00	0.00	0.00	0.00	0.07	1.49	14.31	99.30	HW3526-2Kfs1
214	64.31	0.06	18.80	0.00	0.01	0.02	0.02	0.09	1.66	14.16	99.12	HW3526-2Kfs2
215	64.42	0.02	18.97	0.00	0.04	0.01	0.00	0.06	1.47	14.44	99.43	HW3526-2Kfs3
216	64.87	0.04	18.87	0.01	0.02	0.04	0.02	0.07	1.47	14.62	100.04	HW3526-3Kfs1
217	64.86	0.07	18.96	0.00	0.00	0.00	0.01	0.05	1.44	14.53	99.92	HW3526-3Kfs2
218	64.29	0.04	18.94	0.00	0.00	0.00	0.02	0.05	1.28	14.71	99.34	HW3526-3Kfs3
228	64.38	0.06	18.93	0.00	0.03	0.00	0.00	0.08	1.95	13.83	99.26	HW3526-4Kfs1
229	64.81	0.05	18.89	0.00	0.00	0.01	0.01	0.07	1.74	14.32	99.88	HW3526-4Kfs2
230	64.39	0.03	18.77	0.00	0.01	0.03	0.00	0.04	1.05	15.26	99.59	HW3526-4Kfs3
Kfs avg	64.52	0.04	18.87	0.00	0.02	0.01	0.01	0.07	1.47	14.54	99.56	
std dev	0.21	0.02	0.08	0.00	0.02	0.01	0.01	0.03	0.24	0.38	0.30	
242	64.09	0.05	18.98	0.01	0.00	0.00	0.03	0.10	1.56	14.56	99.38	HW3527-1Kfs1
243	64.06	0.04	18.89	0.00	0.03	0.03	0.01	0.04	1.85	14.27	99.21	HW3527-1Kfs2
244	64.39	0.05	18.93	0.00	0.04	0.03	0.03	0.03	1.23	14.91	99.65	HW3527-1Kfs3
260	63.99	0.08	18.86	0.02	0.04	0.03	0.00	0.06	1.28	15.11	99.45	HW3527-2Kfs1
261	63.74	0.06	18.95	0.00	0.03	0.01	0.00	0.03	1.14	15.23	99.17	HW3527-2Kfs2

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Sample
262	64.12	0.01	19.15	0.00	0.05	0.02	0.02	0.06	1.76	14.37	99.56	HW3527-2Kfs3
269	64.18	0.05	19.19	0.00	0.04	0.01	0.00	0.16	1.69	14.30	99.61	HW3527-3Kfs1
270	64.04	0.06	19.12	0.00	0.01	0.04	0.02	0.06	1.77	14.32	99.46	HW3527-3Kfs2
271	64.07	0.02	18.90	0.00	0.00	0.00	0.01	0.10	2.04	13.93	99.08	HW3527-3Kfs3
284	64.05	0.01	19.08	0.04	0.01	0.02	0.00	0.07	1.55	14.52	99.33	HW3527-4Kfs1
285	63.89	0.04	18.98	0.00	0.01	0.00	0.02	0.08	1.56	14.45	99.03	HW3527-4Kfs2
286	63.95	0.04	18.59	0.00	0.01	0.00	0.01	0.04	1.48	14.59	98.70	HW3527-4Kfs3
Kfs avg	64.05	0.04	18.97	0.01	0.02	0.02	0.01	0.07	1.57	14.55	99.30	
std dev	0.16	0.02	0.16	0.01	0.02	0.01	0.01	0.04	0.27	0.37	0.28	
290	64.84	0.03	19.00	0.00	0.01	0.00	0.00	0.25	4.31	10.21	98.65	HW3530-1Kfs1
291	63.86	0.04	18.73	0.00	0.00	0.01	0.01	0.06	1.75	14.11	98.57	HW3530-1Kfs2
292	63.96	0.00	18.73	0.01	0.01	0.02	0.03	0.09	2.10	13.63	98.56	HW3530-1Kfs3
302	64.13	0.07	18.97	0.00	0.00	0.03	0.02	0.08	1.93	13.92	99.16	HW3530-2Kfs1
303	63.90	0.10	19.01	0.00	0.00	0.02	0.02	0.08	2.09	13.91	99.12	HW3530-2Kfs2
304	63.59	0.07	18.93	0.00	0.00	0.01	0.01	0.07	1.71	14.15	98.53	HW3530-2Kfs3
311	63.96	0.06	19.13	0.00	0.04	0.00	0.01	0.10	1.82	14.12	99.23	HW3530-3Kfs1
312	63.94	0.05	18.62	0.03	0.01	0.02	0.02	0.12	2.64	12.75	98.19	HW3530-3Kfs2
313	63.97	0.06	18.77	0.00	0.01	0.02	0.02	0.07	2.21	13.26	98.40	HW3530-3Kfs3
317	63.91	0.04	18.91	0.00	0.00	0.04	0.01	0.09	1.86	13.74	98.60	HW3530-4Kfs1
318	64.14	0.06	18.87	0.00	0.00	0.00	0.01	0.10	2.10	13.63	98.92	HW3530-4Kfs2
319	64.01	0.05	18.75	0.00	0.01	0.00	0.02	0.07	2.10	13.51	98.51	HW3530-4Kfs3
Kfs avg	64.02	0.05	18.87	0.00	0.01	0.01	0.01	0.10	2.22	13.41	98.70	
std dev	0.29	0.02	0.15	0.01	0.01	0.01	0.01	0.05	0.70	1.09	0.33	
10	63.43	0.00	18.67	0.00	0.03	0.00	0.03	0.03	0.61	15.82	98.61	HW-1A-1Kfsbleb
11	63.06	0.03	18.77	0.00	0.04	0.01	0.01	0.33	0.60	15.82	98.67	HW-1A-1Kfsbleb
12	63.64	0.04	18.86	0.05	0.03	0.00	0.01	0.05	0.56	16.03	99.26	HW-1A-1Kfsbleb
28	63.40	0.02	18.96	0.00	0.03	0.03	0.01	0.03	0.65	15.88	99.00	HW-1A-5Kfs
30	63.70	0.02	18.65	0.02	0.02	0.00	0.01	0.00	0.95	15.59	98.96	HW-1A-5Kfs
31	63.01	0.03	18.72	0.02	0.00	0.05	0.02	0.02	0.80	15.79	98.46	HW-1A-5Kfs
35	63.93	0.08	18.98	0.00	0.01	0.00	0.03	0.13	1.14	15.13	99.43	HW-1A-6Kfs
36	63.29	0.05	18.93	0.00	0.03	0.00	0.02	0.10	1.15	15.23	98.80	HW-1A-6Kfs
37	63.45	0.02	18.60	0.00	0.03	0.00	0.03	0.04	0.75	15.79	98.70	HW-1A-6Kfs
Kfs avg	63.43	0.03	18.79	0.01	0.02	0.01	0.02	0.08	0.80	15.67	98.88	
std dev	0.30	0.02	0.14	0.02	0.01	0.02	0.01	0.10	0.23	0.30	0.31	
44	62.92	0.06	18.85	0.00	0.02	0.02	0.01	0.04	0.54	16.03	98.48	HW-2A-1Kfs
45	63.27	0.03	18.77	0.01	0.02	0.00	0.02	0.14	0.72	15.74	98.71	HW-2A-1Kfs
46	63.72	0.02	18.54	0.03	0.03	0.01	0.01	0.00	0.55	16.31	99.22	HW-2A-1Kfs
50	62.17	0.00	19.66	0.00	0.02	0.01	0.01	1.13	2.22	12.82	98.03	HW-2A-2Kfs
52	63.07	0.01	18.72	0.00	0.01	0.01	0.01	0.03	0.66	15.83	98.35	HW-2A-2Kfs
62	62.65	0.01	18.95	0.00	0.02	0.00	0.00	0.30	0.62	15.70	98.24	HW-2A-5Kfs
63	63.21	0.05	18.96	0.00	0.03	0.02	0.01	0.03	0.48	16.27	99.05	HW-2A-5Kfs
Kfs avg	63.00	0.03	18.92	0.01	0.02	0.01	0.01	0.24	0.83	15.53	98.58	
std dev	0.50	0.02	0.36	0.01	0.01	0.01	0.01	0.41	0.62	1.22	0.43	
77	63.35	0.05	18.90	0.00	0.02	0.03	0.02	0.05	1.11	15.27	98.79	HW-3A-2Kfs
78	63.58	0.03	18.88	0.00	0.03	0.04	0.01	0.02	0.87	15.52	98.97	HW-3A-2Kfs
79	63.06	0.04	18.78	0.00	0.02	0.00	0.02	0.01	0.83	15.72	98.48	HW-3A-2Kfs
88	63.35	0.04	18.64	0.00	0.01	0.03	0.00	0.00	0.63	15.87	98.56	HW-3A-3Kfs
98	64.24	0.02	18.89	0.00	0.02	0.02	0.02	0.04	0.62	16.15	100.02	HW-3A-5Kfs
100	62.70	0.03	18.82	0.00	0.02	0.00	0.00	0.05	0.73	15.70	98.07	HW-3A-5Kfs
Kfs avg	63.38	0.03	18.82	0.00	0.02	0.02	0.01	0.03	0.80	15.71	98.81	
std dev	0.52	0.01	0.10	0.00	0.01	0.01	0.01	0.02	0.18	0.30	0.67	

Plagioclase Feldspar Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
4	62.80	0.03	23.29	0.00	0.03	0.02	0.00	4.33	9.13	0.17	99.81	M0034-1Pl
5	62.94	0.02	23.10	0.01	0.01	0.04	0.02	4.13	9.28	0.13	99.68	M0034-1Pl
6	62.35	0.00	23.46	0.02	0.06	0.00	0.01	4.61	9.01	0.25	99.77	M0034-1Pl
26	62.95	0.02	23.06	0.03	0.03	0.01	0.02	4.16	9.05	0.25	99.59	M0034-3Pl
27	63.04	0.02	23.04	0.00	0.06	0.00	0.00	4.20	9.17	0.13	99.65	M0034-3Pl
28	63.06	0.04	23.29	0.00	0.04	0.00	0.02	4.24	9.45	0.15	100.28	M0034-3Pl
32	62.41	0.04	23.20	0.00	0.01	0.00	0.01	4.27	9.03	0.20	99.18	M0034-4Pl
33	62.84	0.02	22.97	0.00	0.01	0.00	0.00	4.04	9.49	0.16	99.53	M0034-4Pl
34	62.05	0.02	23.09	0.00	0.03	0.00	0.00	4.25	9.04	0.25	98.72	M0034-4Pl
38	63.08	0.01	22.96	0.00	0.04	0.01	0.00	3.99	9.43	0.09	99.62	M0034-5Pl
39	62.92	0.01	22.76	0.00	0.01	0.02	0.01	3.85	9.45	0.08	99.10	M0034-5Pl
40	62.81	0.00	23.07	0.02	0.01	0.05	0.03	4.21	9.13	0.11	99.44	M0034-5Pl
44	62.79	0.00	22.92	0.07	0.01	0.02	0.01	4.11	9.19	0.12	99.23	M0034-6Pl
45	62.95	0.02	22.95	0.01	0.04	0.03	0.02	3.80	9.22	0.46	99.49	M0034-6Pl
46	63.49	0.01	22.38	0.02	0.01	0.02	0.03	3.49	9.52	0.10	99.06	M0034-6Pl
Pl avg	62.83	0.02	23.04	0.01	0.03	0.01	0.01	4.11	9.24	0.18	99.48	
std dev	0.35	0.01	0.25	0.02	0.02	0.02	0.01	0.26	0.18	0.10	0.38	
56	62.33	0.00	22.52	0.04	0.07	0.04	0.04	3.93	9.36	0.09	98.42	M3796-1Pl
57	62.40	0.00	22.47	0.04	0.07	0.00	0.04	3.96	9.24	0.14	98.35	M3796-1Pl
58	65.13	0.00	20.58	0.05	0.03	0.01	0.01	1.51	10.96	0.09	98.39	M3796-1Pl

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
74	62.63	0.00	22.71	0.02	0.09	0.00	0.00	3.97	9.36	0.15	98.93	M3796-3Pl
75	63.13	0.00	22.11	0.00	0.10	0.00	0.04	2.79	9.60	0.41	98.18	M3796-3Pl
76	65.64	0.04	19.97	0.00	0.17	0.03	0.01	1.27	10.80	0.32	98.24	M3796-3Pl
80	62.10	0.00	23.07	0.00	0.05	0.01	0.00	3.91	8.98	0.49	98.61	M3796-5Pl
82	62.34	0.01	22.67	0.00	0.06	0.01	0.02	4.00	9.34	0.22	98.66	M3796-5Pl
Pl avg	63.21	0.01	22.01	0.02	0.08	0.01	0.02	3.17	9.70	0.24	98.47	
std dev	1.38	0.01	1.12	0.02	0.04	0.01	0.02	1.17	0.75	0.15	0.25	
86	58.71	0.03	25.45	0.06	0.05	0.00	0.00	6.99	7.40	0.24	98.92	M3997-1Pl
87	58.96	0.00	25.05	0.04	0.02	0.00	0.03	6.97	7.24	0.17	98.49	M3997-1Pl
88	59.39	0.02	25.40	0.01	0.03	0.00	0.01	7.07	7.37	0.20	99.50	M3997-1Pl
89	58.94	0.02	25.34	0.00	0.01	0.00	0.00	7.05	7.29	0.25	98.91	M3997-2Pl
90	58.87	0.00	25.53	0.00	0.01	0.05	0.00	7.10	7.20	0.24	99.00	M3997-2Pl
91	59.63	0.05	25.41	0.00	0.04	0.00	0.02	7.03	7.40	0.29	99.89	M3997-2Pl
98	58.65	0.00	25.14	0.04	0.15	0.00	0.17	6.28	6.58	1.40	98.40	M3997-3Pl
99	59.44	0.05	25.39	0.03	0.03	0.02	0.01	6.91	7.45	0.37	99.70	M3997-3Pl
100	59.91	0.01	25.89	0.00	0.06	0.00	0.00	7.17	7.17	0.33	100.53	M3997-3Pl
101	58.29	0.01	24.93	0.01	0.03	0.01	0.00	7.35	7.50	0.37	98.49	M3997-4Pl
102	59.44	0.04	25.13	0.00	0.06	0.01	0.02	6.78	7.34	0.26	99.07	M3997-4Pl
103	58.59	0.04	25.21	0.05	0.03	0.00	0.01	6.96	7.34	0.25	98.50	M3997-4Pl
104	58.64	0.02	25.59	0.05	0.03	0.02	0.02	7.27	7.15	0.27	99.05	M3997-5Pl
105	59.31	0.02	25.33	0.06	0.00	0.00	0.00	7.01	7.35	0.31	99.38	M3997-5Pl
106	58.86	0.02	25.79	0.06	0.04	0.01	0.01	7.53	7.19	0.19	99.71	M3997-5Pl
Pl avg	59.04	0.02	25.37	0.03	0.04	0.01	0.02	7.03	7.27	0.34	99.17	
std dev	0.45	0.02	0.26	0.03	0.03	0.01	0.04	0.28	0.22	0.30	0.61	
129	57.74	0.01	25.92	0.02	0.03	0.00	0.04	7.90	6.92	0.20	98.77	M4002a-6Pl
130	57.45	0.03	25.96	0.00	0.04	0.01	0.02	7.94	6.65	0.19	98.27	M4002a-6Pl
131	57.68	0.05	25.93	0.00	0.03	0.03	0.02	7.85	6.99	0.15	98.72	M4002a-6Pl
Pl avg	57.63	0.03	25.93	0.01	0.03	0.01	0.03	7.89	6.85	0.18	98.59	
std dev	0.15	0.02	0.02	0.01	0.00	0.01	0.01	0.04	0.18	0.03	0.27	
77	66.47	0.00	19.67	0.01	0.07	0.00	0.03	0.46	10.77	1.01	98.48	M4002b-7Pl
78	67.26	0.00	20.22	0.01	0.09	0.00	0.01	0.69	11.37	0.28	99.93	M4002b-7Pl
Pl Avg	66.86	0.00	19.95	0.01	0.08	0.00	0.02	0.57	11.07	0.65	99.20	
std dev	0.56	0.00	0.39	0.00	0.01	0.00	0.01	0.16	0.43	0.51	1.03	
39	61.52	0.01	23.39	0.00	0.05	0.02	0.02	4.82	8.72	0.17	98.70	M4015a-6Pl
42	61.85	0.00	23.36	0.00	0.03	0.01	0.00	4.88	8.56	0.29	98.98	M4015a-6Pl
43	61.38	0.00	23.55	0.05	0.05	0.02	0.01	4.90	8.58	0.23	98.75	M4015a-6Pl
Pl avg	61.58	0.00	23.43	0.02	0.04	0.02	0.01	4.86	8.62	0.23	98.81	
std dev	0.24	0.01	0.10	0.03	0.01	0.01	0.01	0.04	0.09	0.06	0.15	
171	57.52	0.03	25.82	0.04	0.05	0.00	0.01	7.73	6.82	0.22	98.23	M4015b-1Pl
184	57.95	0.00	25.81	0.00	0.09	0.01	0.03	7.63	6.94	0.16	98.62	M4015b-3Pl
185	57.20	0.01	26.11	0.06	0.04	0.00	0.03	8.06	6.76	0.17	98.44	M4015b-3Pl
186	58.34	0.01	25.78	0.06	0.04	0.00	0.02	7.76	6.94	0.19	99.14	M4015b-3Pl
188	58.15	0.00	26.21	0.04	0.04	0.00	0.00	8.09	6.73	0.18	99.43	M4015b-4Pl
189	57.78	0.00	26.17	0.00	0.04	0.01	0.03	8.07	6.64	0.18	98.92	M4015b-4Pl
196	58.63	0.00	25.92	0.02	0.07	0.00	0.00	7.75	7.03	0.21	99.64	M4015b-5Pl
197	59.44	0.03	25.50	0.03	0.05	0.01	0.03	7.20	7.31	0.23	99.83	M4015b-5Pl
198	57.87	0.01	26.23	0.03	0.02	0.01	0.01	7.98	6.86	0.21	99.22	M4015b-5Pl
Pl avg	58.10	0.01	25.95	0.03	0.05	0.01	0.02	7.81	6.89	0.19	99.05	
std dev	0.66	0.01	0.25	0.02	0.02	0.01	0.01	0.29	0.20	0.02	0.55	
147	63.23	0.02	22.18	0.02	0.00	0.00	0.01	3.34	9.65	0.07	98.53	M4017-2Pl
156	63.73	0.00	21.75	0.04	0.05	0.02	0.00	2.74	9.98	0.12	98.43	M4017-3Pl
166	64.36	0.01	22.06	0.00	0.03	0.06	0.03	3.26	9.69	0.13	99.61	M4017-5Pl
167	64.13	0.02	22.32	0.00	0.02	0.01	0.01	3.38	9.71	0.11	99.72	M4017-5Pl
168	63.91	0.00	22.47	0.00	0.02	0.01	0.00	3.60	9.64	0.14	99.78	M4017-5Pl
172	63.70	0.00	21.63	0.00	0.01	0.00	0.01	2.79	9.86	0.08	98.07	M4017-6Pl
173	63.81	0.02	22.27	0.00	0.02	0.01	0.02	3.29	9.63	0.07	99.12	M4017-6Pl
174	64.80	0.00	21.23	0.02	0.00	0.02	0.03	2.34	10.31	0.11	98.86	M4017-6Pl
Pl avg	63.96	0.01	21.99	0.01	0.02	0.02	0.01	3.09	9.81	0.10	99.01	
std dev	0.47	0.01	0.42	0.02	0.02	0.02	0.01	0.42	0.24	0.03	0.65	
178	58.14	0.00	25.08	0.00	0.10	0.00	0.03	7.07	4.21	4.75	99.37	M12350-1Pl
179	56.78	0.03	27.11	0.00	0.18	0.02	0.05	9.26	6.06	0.27	99.75	M12350-1Pl
180	56.38	0.00	26.40	0.01	0.14	0.00	0.06	8.59	4.42	2.97	98.97	M12350-1Pl
187	56.51	0.03	27.04	0.01	0.10	0.00	0.02	9.09	6.09	0.28	99.16	M12350-2Pl
188	56.54	0.03	27.23	0.00	0.12	0.03	0.02	9.32	6.18	0.20	99.66	M12350-2Pl
189	56.71	0.00	27.42	0.01	0.14	0.01	0.02	9.42	5.84	0.29	99.87	M12350-2Pl
193	55.97	0.00	27.11	0.02	0.41	0.00	0.29	9.55	5.66	0.29	99.29	M12350-3Pl
194	56.69	0.00	27.58	0.04	0.15	0.01	0.04	9.66	5.91	0.23	100.31	M12350-3Pl
195	56.99	0.03	27.11	0.05	0.14	0.02	0.02	9.12	6.13	0.26	99.85	M12350-3Pl
204	56.23	0.03	27.15	0.00	0.23	0.03	0.01	9.29	5.89	0.32	99.17	M12350-4Pl
205	56.87	0.02	27.05	0.06	0.19	0.01	0.02	9.00	5.98	0.30	99.48	M12350-4Pl
206	56.25	0.02	27.34	0.00	0.20	0.02	0.03	9.56	5.80	0.29	99.51	M12350-4Pl
207	56.34	0.03	26.73	0.00	0.19	0.00	0.02	8.95	5.96	0.32	98.54	M12350-5Pl
208	57.42	0.05	24.64	0.00	0.16	0.00	0.02	6.97	2.84	6.65	98.74	M12350-5Pl

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
209	56.01	0.01	26.92	0.00	0.83	0.00	0.42	9.11	6.00	0.31	99.59	M12350-5Pl
210	56.47	0.00	27.13	0.02	0.37	0.01	0.03	9.20	5.93	0.36	99.51	M12350-6Pl
211	56.37	0.00	27.00	0.01	0.19	0.02	0.03	9.24	6.01	0.22	99.08	M12350-6Pl
212	57.02	0.03	27.00	0.03	0.13	0.02	0.03	9.09	5.88	0.35	99.58	M12350-6Pl
Pl avg	56.65	0.02	26.84	0.01	0.22	0.01	0.06	8.97	5.60	1.04	99.41	
std dev	0.52	0.01	0.76	0.02	0.17	0.01	0.11	0.75	0.88	1.84	0.43	
80	59.25	0.01	25.30	0.03	0.07	0.00	0.01	6.76	7.42	0.27	99.12	M12351a-1Pl
81	59.44	0.03	25.33	0.00	0.07	0.00	0.02	6.85	7.50	0.25	99.49	M12351a-1Pl
82	58.89	0.00	25.13	0.00	0.06	0.00	0.01	6.67	7.52	0.20	98.49	M12351a-1Pl
93	59.65	0.02	25.07	0.00	0.03	0.03	0.01	6.56	7.61	0.18	99.16	M12351a-2Pl
94	59.75	0.03	25.10	0.04	0.01	0.03	0.02	6.59	7.64	0.19	99.38	M12351a-2Pl
95	59.17	0.05	25.08	0.04	0.11	0.01	0.01	6.56	7.67	0.18	98.89	M12351a-2Pl
96	59.05	0.03	24.87	0.00	0.14	0.01	0.00	6.62	7.49	0.23	98.44	M12351a-2Pl
97	60.22	0.03	25.22	0.05	0.09	0.00	0.03	6.67	7.44	0.27	100.01	M12351a-3Pl
98	60.08	0.01	24.99	0.03	0.25	0.00	0.02	6.58	7.70	0.24	99.90	M12351a-3Pl
99	59.81	0.01	25.08	0.00	0.05	0.00	0.04	6.69	7.74	0.21	99.63	M12351a-3Pl
100	59.75	0.01	25.07	0.00	0.10	0.00	0.00	6.64	7.58	0.24	99.38	M12351a-3Pl
110	59.02	0.01	24.93	0.00	0.04	0.00	0.02	6.58	7.78	0.16	98.54	M12351a-5Pl
111	59.14	0.02	24.82	0.02	0.10	0.02	0.02	6.60	7.72	0.23	98.69	M12351a-5Pl
112	59.14	0.00	24.92	0.04	0.12	0.04	0.03	6.65	7.46	0.29	98.69	M12351a-5Pl
Pl avg	59.45	0.02	25.06	0.02	0.09	0.01	0.02	6.64	7.59	0.22	99.13	
std dev	0.42	0.01	0.15	0.02	0.06	0.01	0.01	0.08	0.12	0.04	0.52	
119	59.56	0.01	25.03	0.00	0.08	0.00	0.02	6.59	7.80	0.28	99.37	M12351b-1Pl
120	59.60	0.00	25.08	0.00	0.05	0.00	0.02	6.54	7.78	0.17	99.24	M12351b-1Pl
121	59.83	0.02	24.99	0.00	0.13	0.01	0.01	6.59	7.51	0.31	99.39	M12351b-1Pl
129	59.66	0.00	25.11	0.00	0.02	0.01	0.02	6.59	7.75	0.19	99.34	M12351b-3Pl
130	59.51	0.00	25.16	0.01	0.09	0.03	0.01	6.60	7.56	0.17	99.14	M12351b-3Pl
131	66.16	0.02	20.60	0.00	0.22	0.01	0.14	0.35	10.56	0.85	98.90	M12351b-3Pl
136	59.99	0.00	25.20	0.03	0.07	0.00	0.00	6.83	7.73	0.21	100.05	M12351b-4Pl
137	60.21	0.08	24.87	0.02	0.03	0.00	0.02	6.43	7.78	0.23	99.66	M12351b-4Pl
Pl avg	60.56	0.01	24.50	0.01	0.09	0.01	0.03	5.82	8.06	0.30	99.39	
std dev	2.27	0.03	1.58	0.01	0.06	0.01	0.04	2.21	1.02	0.23	0.35	
326	59.87	0.00	25.68	0.04	0.02	0.02	0.01	6.78	7.60	0.20	100.24	M12352a-1Pl1
327	60.62	0.02	25.60	0.01	0.04	0.00	0.00	6.71	7.58	0.22	100.80	M12352a-1Pl2
328	60.30	0.05	25.62	0.00	0.03	0.01	0.01	6.79	7.88	0.20	100.88	M12352a-1Pl3
329	60.46	0.00	25.54	0.00	0.01	0.00	0.04	6.76	7.72	0.26	100.80	M12352a-2Pl1
330	60.00	0.01	25.48	0.01	0.03	0.00	0.01	6.87	7.45	0.27	100.13	M12352a-2Pl2
331	59.75	0.03	25.35	0.05	0.04	0.00	0.02	6.74	7.56	0.28	99.82	M12352a-2Pl3
344	59.48	0.02	25.23	0.01	0.05	0.00	0.01	6.79	7.63	0.21	99.44	M12352a-3Pl1
345	59.86	0.01	25.42	0.00	0.03	0.00	0.02	6.85	7.66	0.22	100.07	M12352a-3Pl2
346	59.57	0.00	25.17	0.05	0.04	0.00	0.02	6.81	7.60	0.23	99.48	M12352a-3Pl3
356	59.55	0.00	25.40	0.03	0.03	0.00	0.03	6.73	7.67	0.16	99.60	M12352a-4Pl1
357	59.80	0.00	25.33	0.00	0.02	0.00	0.01	6.81	7.57	0.14	99.67	M12352a-4Pl2
358	60.23	0.00	25.46	0.03	0.01	0.03	0.01	6.85	7.72	0.13	100.47	M12352a-4Pl3
Pl avg	59.96	0.01	25.44	0.02	0.03	0.01	0.02	6.79	7.64	0.21	100.12	
std dev	0.37	0.02	0.16	0.02	0.01	0.01	0.01	0.05	0.11	0.05	0.53	
46	60.73	0.03	24.74	0.00	0.00	0.02	0.02	6.03	7.91	0.19	99.66	M12352b-2Pl
49	60.41	0.02	24.78	0.00	0.02	0.05	0.01	6.03	7.86	0.23	99.39	M12352b-2Pl
50	60.49	0.00	24.54	0.01	0.05	0.00	0.02	5.99	8.06	0.21	99.36	M12352b-2Pl
Pl avg	60.54	0.02	24.69	0.00	0.02	0.02	0.02	6.02	7.94	0.21	99.47	
std dev	0.17	0.01	0.12	0.00	0.02	0.02	0.01	0.03	0.10	0.02	0.17	
100	59.95	0.00	24.57	0.00	0.10	0.01	0.02	6.12	7.69	0.18	98.63	M12354-2Pl
101	59.84	0.00	24.40	0.02	0.09	0.01	0.01	5.99	7.90	0.19	98.45	M12354-2Pl
102	59.59	0.01	24.39	0.02	0.10	0.00	0.01	5.97	8.00	0.17	98.26	M12354-2Pl
115	60.51	0.00	24.55	0.00	0.14	0.00	0.01	6.08	7.83	0.21	99.32	M12354-4Pl
116	59.89	0.00	24.23	0.05	0.09	0.00	0.03	6.03	7.81	0.18	98.30	M12354-4Pl
Pl avg	59.95	0.00	24.43	0.02	0.11	0.00	0.02	6.04	7.84	0.18	98.59	
std dev	0.34	0.01	0.14	0.02	0.02	0.00	0.01	0.06	0.11	0.02	0.43	
72	58.30	0.03	25.60	0.00	0.11	0.02	0.04	7.14	7.15	0.25	98.63	M12549-6Pl
73	58.79	0.03	25.55	0.01	0.15	0.00	0.02	7.11	7.14	0.24	99.06	M12549-6Pl
74	58.44	0.03	25.63	0.03	0.11	0.00	0.01	7.04	7.45	0.19	98.92	M12549-6Pl
75	58.65	0.00	25.50	0.00	0.10	0.00	0.01	7.03	7.20	0.19	98.67	M12549-6Pl
80	58.55	0.02	25.31	0.00	0.09	0.03	0.03	6.92	7.24	0.29	98.47	M12549-7Pl
81	58.57	0.00	25.19	0.00	0.12	0.03	0.02	6.89	7.28	0.26	98.35	M12549-7Pl
82	58.14	0.03	25.35	0.00	0.11	0.03	0.01	7.00	7.33	0.16	98.16	M12549-7Pl
83	58.39	0.00	25.04	0.00	0.09	0.00	0.01	6.84	7.41	0.22	98.01	M12549-7Pl
86	57.62	0.00	25.58	0.05	0.21	0.03	0.02	7.16	7.12	0.24	98.03	M12549-8Pl
Pl avg	58.38	0.02	25.42	0.01	0.12	0.01	0.02	7.01	7.26	0.23	98.48	
std dev	0.34	0.01	0.20	0.02	0.04	0.01	0.01	0.11	0.12	0.04	0.38	
32	57.45	0.03	26.31	0.00	0.02	0.02	0.02	7.91	6.61	0.29	98.66	M12636-4Pl
33	57.00	0.02	26.26	0.00	0.00	0.00	0.01	7.95	6.68	0.31	98.23	M12636-4Pl
34	57.66	0.00	26.40	0.00	0.02	0.00	0.02	8.06	6.77	0.28	99.20	M12636-4Pl
35	57.66	0.06	26.40	0.00	0.01	0.02	0.02	8.06	6.77	0.30	99.29	M12636-4Pl

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
36	57.40	0.03	26.46	0.00	0.03	0.01	0.03	8.07	6.67	0.29	98.98	M12636-4Pl
47	57.65	0.02	26.53	0.09	0.04	0.01	0.00	8.09	6.75	0.24	99.41	M12636-1Pl
48	57.34	0.03	26.34	0.03	0.02	0.00	0.03	8.05	6.70	0.23	98.76	M12636-1Pl
49	57.28	0.04	26.20	0.08	0.00	0.01	0.00	7.86	6.59	0.24	98.30	M12636-1Pl
Pl avg	57.43	0.03	26.36	0.03	0.02	0.01	0.02	8.01	6.69	0.27	98.85	
std dev	0.23	0.02	0.11	0.04	0.01	0.01	0.01	0.09	0.07	0.03	0.44	
4	58.36	0.03	26.68	0.04	0.01	0.00	0.01	8.26	6.73	0.25	100.36	M12637-1Pl
6	57.87	0.02	26.56	0.00	0.00	0.00	0.01	7.82	6.74	0.50	99.52	M12637-1Pl
7	58.54	0.06	26.76	0.00	0.02	0.01	0.02	8.08	7.05	0.14	100.66	M12637-1Pl
14	57.97	0.00	26.54	0.03	0.03	0.00	0.01	8.12	6.84	0.29	99.83	M12637-4Pl
15	58.51	0.03	26.81	0.00	0.00	0.02	0.02	8.14	6.73	0.25	100.49	M12637-4Pl
16	58.21	0.02	26.69	0.01	0.00	0.00	0.00	8.08	6.81	0.21	100.04	M12637-4Pl
21	58.27	0.04	26.54	0.00	0.03	0.00	0.00	8.14	6.84	0.29	100.16	M12637-5Pl
22	57.52	0.02	26.57	0.01	0.01	0.02	0.01	8.16	6.48	0.21	98.99	M12637-5Pl
23	57.97	0.01	26.93	0.03	0.03	0.01	0.03	8.40	6.71	0.28	100.39	M12637-5Pl
28	57.85	0.00	26.42	0.00	0.07	0.01	0.00	8.22	6.70	0.33	99.60	M12637-6Pl
29	58.20	0.02	26.57	0.00	0.00	0.00	0.03	8.20	6.66	0.30	99.97	M12637-6Pl
30	57.98	0.00	26.61	0.02	0.01	0.00	0.02	8.14	6.56	0.34	99.67	M12637-6Pl
31	58.03	0.04	26.54	0.00	0.01	0.00	0.04	8.23	6.77	0.32	99.98	M12637-6Pl
Pl avg	58.10	0.02	26.63	0.01	0.02	0.00	0.02	8.15	6.74	0.29	99.97	
std dev	0.29	0.02	0.14	0.01	0.02	0.01	0.01	0.13	0.14	0.09	0.46	
135	59.82	0.02	25.21	0.01	0.07	0.00	0.02	6.75	7.47	0.23	99.60	M12638-1Pl
136	59.29	0.00	25.48	0.00	0.04	0.03	0.01	7.21	7.32	0.26	99.64	M12638-1Pl
137	59.17	0.00	24.94	0.00	0.04	0.01	0.03	6.72	7.41	0.32	98.63	M12638-1Pl
148	59.20	0.00	25.40	0.00	0.03	0.01	0.02	6.87	7.40	0.16	99.08	M12638-2Pl
149	59.06	0.03	25.42	0.07	0.03	0.02	0.00	6.90	7.38	0.17	99.08	M12638-2Pl
150	59.11	0.02	25.20	0.01	0.04	0.03	0.01	6.72	7.41	0.18	98.72	M12638-2Pl
154	59.40	0.00	25.05	0.00	0.10	0.01	0.02	6.66	7.46	0.35	99.06	M12638-4Pl
155	59.14	0.01	25.49	0.02	0.06	0.00	0.02	7.02	7.50	0.31	99.57	M12638-4Pl
156	58.55	0.00	25.47	0.00	0.13	0.00	0.02	7.23	7.08	0.40	98.90	M12638-4Pl
163	59.33	0.00	24.80	0.00	0.06	0.00	0.02	6.62	7.49	0.18	98.51	M12638-5Pl
164	59.55	0.02	25.34	0.00	0.01	0.02	0.02	6.96	7.50	0.18	99.60	M12638-5Pl
165	59.37	0.00	25.32	0.00	0.04	0.01	0.02	6.85	7.54	0.16	99.29	M12638-5Pl
Pl avg	59.25	0.01	25.26	0.01	0.06	0.01	0.02	6.87	7.41	0.24	99.14	
std dev	0.31	0.01	0.23	0.02	0.03	0.01	0.01	0.20	0.12	0.09	0.40	
32	61.03	0.00	23.99	0.00	0.08	0.00	0.02	6.21	7.70	0.27	99.29	M12639-6Pl1
33	61.32	0.01	24.09	0.00	0.08	0.00	0.02	6.10	7.88	0.29	99.80	M12639-6Pl2
34	60.81	0.03	24.22	0.01	0.06	0.00	0.01	6.30	7.70	0.26	99.39	M12639-6Pl3
35	60.94	0.00	24.15	0.00	0.05	0.01	0.00	6.27	7.74	0.21	99.36	M12639-6Pl4
12	61.08	0.03	24.16	0.03	0.13	0.00	0.02	6.27	7.76	0.16	99.63	M12639-3Pl1
13	60.85	0.00	24.35	0.00	0.12	0.00	0.09	6.36	7.68	0.25	99.70	M12639-3Pl2
14	61.21	0.02	24.22	0.00	0.11	0.00	0.01	6.25	7.89	0.26	99.96	M12639-3Pl3
15	61.08	0.00	24.20	0.00	0.11	0.01	0.02	6.31	7.71	0.22	99.65	M12639-3Pl4
16	60.91	0.02	23.95	0.00	0.10	0.01	0.02	6.11	7.75	0.29	99.16	M12639-4Pl1
17	60.93	0.04	24.07	0.00	0.10	0.03	0.00	6.19	7.70	0.31	99.37	M12639-4Pl2
18	61.07	0.00	23.94	0.00	0.18	0.00	0.02	6.17	7.77	0.30	99.45	M12639-4Pl3
19	60.10	0.01	23.94	0.01	0.09	0.00	0.01	6.37	7.71	0.16	98.39	M12639-4Pl4
avg	60.94	0.01	24.11	0.00	0.10	0.01	0.02	6.24	7.75	0.25	99.43	
std dev	0.30	0.01	0.13	0.01	0.03	0.01	0.02	0.09	0.07	0.05	0.40	
40	60.23	0.01	24.40	0.00	0.04	0.02	0.01	6.69	7.57	0.23	99.20	M12640-2Pl1
41	60.06	0.03	24.33	0.00	0.01	0.00	0.03	6.62	7.40	0.22	98.68	M12640-2Pl2
42	59.92	0.02	24.50	0.00	0.02	0.00	0.00	6.58	7.58	0.27	98.88	M12640-2Pl3
43	60.14	0.01	24.35	0.02	0.05	0.01	0.01	6.66	7.56	0.27	99.07	M12640-2Pl4
63	59.69	0.00	24.12	0.00	0.01	0.05	0.00	6.43	7.69	0.23	98.22	M12640-6Pl1
64	60.36	0.00	24.15	0.02	0.04	0.00	0.02	6.31	7.96	0.15	99.01	M12640-6Pl2
avg	60.06	0.01	24.31	0.01	0.03	0.01	0.01	6.55	7.62	0.23	98.84	
std dev	0.24	0.01	0.15	0.01	0.02	0.02	0.01	0.15	0.19	0.04	0.35	
87	60.97	0.03	24.26	0.00	0.02	0.02	0.02	5.64	8.12	0.29	99.37	M12643-2Pl
88	60.42	0.05	24.06	0.00	0.08	0.02	0.01	5.65	8.00	0.27	98.56	M12643-2Pl
89	61.12	0.00	24.33	0.02	0.08	0.02	0.03	5.65	8.13	0.30	99.67	M12643-2Pl
90	59.78	0.00	23.86	0.03	0.06	0.03	0.01	5.70	8.36	0.32	98.15	M12643-2Pl
94	61.13	0.03	24.38	0.03	0.04	0.00	0.00	5.60	8.07	0.20	99.48	M12643-3Pl
96	61.74	0.03	24.60	0.00	0.09	0.02	0.02	5.65	8.23	0.14	100.51	M12643-3Pl
97	59.80	0.01	23.72	0.00	1.35	0.00	0.77	5.18	7.50	0.61	98.94	M12643-3Pl
101	60.03	0.00	24.24	0.00	0.05	0.00	0.01	5.87	6.86	2.18	99.22	M12643-4Pl
102	60.74	0.00	23.83	0.01	0.09	0.04	0.42	5.56	8.66	0.21	99.56	M12643-4Pl
Pl avg	60.64	0.02	24.14	0.01	0.20	0.02	0.14	5.61	7.99	0.50	99.27	
std dev	0.68	0.02	0.29	0.01	0.43	0.01	0.27	0.18	0.53	0.64	0.68	
382	57.95	0.00	27.12	0.02	0.06	0.01	0.00	8.55	6.67	0.09	100.47	N01a-1Pl1
383	58.15	0.01	27.11	0.00	0.04	0.03	0.01	8.61	6.81	0.10	100.86	N01a-1Pl2
384	58.02	0.00	26.46	0.03	0.08	0.03	0.00	8.51	6.68	0.14	99.94	N01a-1Pl3
388	57.91	0.02	27.23	0.00	0.04	0.01	0.01	8.79	6.56	0.08	100.63	N01a-2Pl1
389	57.75	0.01	27.19	0.03	0.04	0.03	0.00	8.77	6.65	0.11	100.59	N01a-2Pl2
390	57.75	0.00	27.06	0.02	0.11	0.00	0.00	8.72	6.57	0.09	100.32	N01a-2Pl3

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
391	57.65	0.02	27.34	0.00	0.05	0.01	0.01	8.68	6.62	0.10	100.48	N01a-3Pl1
392	57.66	0.01	27.31	0.02	0.05	0.00	0.03	8.57	6.63	0.07	100.33	N01a-3Pl2
393	58.10	0.04	27.44	0.00	0.04	0.00	0.02	8.62	6.69	0.06	101.01	N01a-3Pl3
397	57.74	0.03	27.24	0.00	0.06	0.00	0.02	8.89	6.48	0.09	100.53	N01a-4Pl1
398	57.38	0.00	26.88	0.00	0.22	0.04	0.01	8.84	6.67	0.06	100.10	N01a-4Pl2
399	57.43	0.00	26.95	0.00	0.03	0.02	0.03	8.84	6.65	0.07	100.00	N01a-4Pl3
Pl avg	57.79	0.01	27.11	0.01	0.07	0.01	0.01	8.70	6.64	0.09	100.44	
std dev	0.24	0.01	0.26	0.01	0.05	0.01	0.01	0.13	0.08	0.02	0.32	
368	68.37	0.01	20.01	0.00	0.00	0.00	0.02	0.16	11.47	0.17	100.21	N04c-2Pl1
369	67.76	0.00	20.08	0.00	0.01	0.02	0.03	0.41	11.04	0.15	99.50	N04c-2Pl2
370	64.59	0.00	21.84	0.00	0.13	0.00	0.38	0.34	9.47	1.89	98.64	N04c-2Pl3
373	68.36	0.03	19.78	0.00	0.04	0.00	0.00	0.31	11.00	0.79	100.31	N04c-3Pl1
374	63.76	0.00	20.80	0.00	0.07	0.02	0.15	2.46	9.73	1.56	98.54	N04c-3Pl2
375	67.50	0.01	19.86	0.01	0.04	0.00	0.04	0.48	11.00	0.55	99.49	N04c-3Pl3
Pl avg	66.72	0.01	20.40	0.00	0.05	0.01	0.10	0.69	10.62	0.85	99.45	
std dev	2.02	0.01	0.79	0.00	0.05	0.01	0.15	0.87	0.81	0.73	0.75	
7	61.22	0.02	24.69	0.03	0.00	0.00	0.02	5.98	8.20	0.07	100.24	N05a-1Pl
8	61.07	0.00	24.81	0.02	0.00	0.00	0.01	5.94	8.23	0.11	100.18	N05a-1Pl
9	60.85	0.03	24.90	0.00	0.02	0.02	0.00	5.99	8.30	0.07	100.18	N05a-1Pl
25	60.92	0.02	24.81	0.00	0.03	0.00	0.03	6.13	8.11	0.13	100.18	N05a-3Pl
26	60.85	0.00	24.75	0.03	0.03	0.00	0.00	6.11	8.05	0.14	99.96	N05a-3Pl
27	60.41	0.00	24.19	0.00	0.00	0.02	0.00	6.19	8.28	0.11	99.21	N05a-3Pl
28	61.21	0.00	24.88	0.00	0.04	0.00	0.01	6.15	8.19	0.22	100.70	N05a-3Pl
35	61.00	0.03	24.40	0.03	0.00	0.02	0.00	5.95	8.30	0.22	99.94	N05a-5Pl
36	61.05	0.00	24.28	0.00	0.02	0.00	0.04	5.79	8.37	0.19	99.72	N05a-5Pl
37	61.97	0.00	23.89	0.00	0.02	0.01	0.00	5.32	8.55	0.05	99.80	N05a-5Pl
Pl avg	61.05	0.01	24.56	0.01	0.02	0.01	0.01	5.95	8.26	0.13	100.01	
std dev	0.40	0.01	0.35	0.02	0.01	0.01	0.01	0.25	0.14	0.06	0.39	
44	60.61	0.00	25.07	0.00	0.04	0.01	0.00	6.55	7.85	0.16	100.29	N05c-1Pl
45	60.64	0.01	24.86	0.02	0.03	0.00	0.03	6.26	8.13	0.14	100.12	N05c-1Pl
46	60.25	0.01	25.03	0.00	0.02	0.02	0.02	6.47	7.78	0.16	99.76	N05c-1Pl
53	60.22	0.02	24.51	0.00	0.08	0.00	0.01	6.38	7.72	0.28	99.21	N05c-2Pl
54	59.60	0.00	24.19	0.03	0.03	0.02	0.02	6.47	7.80	0.25	98.41	N05c-2Pl
55	60.33	0.03	24.97	0.00	0.03	0.01	0.02	6.57	7.63	0.28	99.86	N05c-2Pl
65	60.63	0.02	25.15	0.00	0.00	0.00	0.00	6.52	7.86	0.19	100.38	N05c-3Pl
66	60.32	0.00	25.15	0.00	0.01	0.00	0.01	6.47	7.94	0.15	100.05	N05c-3Pl
67	60.15	0.03	25.19	0.02	0.04	0.02	0.01	6.53	7.89	0.24	100.14	N05c-3Pl
74	60.30	0.03	25.31	0.00	0.05	0.02	0.02	6.57	7.81	0.19	100.30	N05c-4Pl
75	60.40	0.04	25.42	0.03	0.01	0.02	0.00	6.62	7.86	0.16	100.56	N05c-4Pl
76	60.39	0.00	25.18	0.00	0.05	0.02	0.00	6.53	7.92	0.15	100.23	N05c-4Pl
Pl avg	60.32	0.02	25.00	0.01	0.03	0.01	0.01	6.49	7.85	0.20	99.94	
std dev	0.28	0.01	0.35	0.01	0.02	0.01	0.01	0.10	0.12	0.05	0.60	
80	61.40	0.03	24.44	0.04	0.02	0.00	0.01	5.51	8.57	0.19	100.20	N06b-1Pl
81	61.86	0.01	24.36	0.02	0.02	0.02	0.01	5.44	8.38	0.11	100.22	N06b-1Pl
82	61.68	0.01	24.11	0.00	0.01	0.03	0.00	5.26	8.63	0.16	99.88	N06b-1Pl
86	65.20	0.00	20.68	0.00	0.50	0.00	0.31	1.41	9.60	1.46	99.17	N06b-2Pl
87	67.00	0.03	20.50	0.01	0.03	0.00	0.01	1.27	10.90	0.06	99.83	N06b-2Pl
88	65.66	0.03	21.47	0.00	0.06	0.01	0.04	2.22	10.09	0.48	100.06	N06b-2Pl
92	62.23	0.02	23.68	0.01	0.03	0.01	0.03	5.11	8.62	0.24	99.97	N06b-3Pl
93	62.11	0.01	23.59	0.00	0.02	0.03	0.01	5.03	8.51	0.29	99.62	N06b-3Pl
94	61.47	0.00	23.31	0.01	0.01	0.04	0.02	5.09	8.41	0.30	98.67	N06b-3Pl
101	62.27	0.02	23.83	0.00	0.06	0.02	0.01	5.26	8.44	0.29	100.19	N06b-5Pl
102	62.02	0.04	24.17	0.00	0.03	0.00	0.00	5.34	8.43	0.26	100.29	N06b-5Pl
103	61.53	0.00	24.32	0.00	0.02	0.00	0.01	5.38	8.69	0.19	100.15	N06b-5Pl
Pl avg	62.87	0.02	23.20	0.01	0.07	0.01	0.04	4.36	8.94	0.34	99.85	
std dev	1.92	0.01	1.45	0.01	0.14	0.01	0.09	1.66	0.81	0.37	0.49	
107	61.56	0.00	24.56	0.00	0.02	0.00	0.01	5.56	8.25	0.30	100.26	N06c-1Pl
108	61.23	0.00	24.58	0.00	0.00	0.00	0.01	5.55	8.51	0.35	100.22	N06c-1Pl
109	61.75	0.03	24.49	0.00	0.02	0.00	0.00	5.59	8.32	0.28	100.48	N06c-1Pl
118	62.89	0.01	23.83	0.00	0.02	0.00	0.03	4.91	8.99	0.27	100.96	N06c-2Pl
119	61.89	0.00	24.41	0.00	0.02	0.00	0.03	5.63	8.51	0.29	100.78	N06c-2Pl
120	61.79	0.00	24.37	0.03	0.00	0.02	0.01	5.44	8.26	0.22	100.13	N06c-2Pl
127	61.51	0.04	23.76	0.03	0.03	0.02	0.00	5.43	8.37	0.25	99.44	N06c-3Pl
128	61.90	0.01	23.99	0.02	0.03	0.00	0.02	5.50	8.46	0.21	100.14	N06c-3Pl
129	61.70	0.03	23.89	0.00	0.03	0.03	0.02	5.62	8.46	0.26	100.05	N06c-3Pl
136	61.71	0.00	24.17	0.00	0.04	0.00	0.01	5.54	8.33	0.21	100.02	N06c-4Pl
137	61.63	0.00	24.00	0.03	0.01	0.01	0.00	5.56	8.48	0.22	99.93	N06c-4Pl
138	61.82	0.01	23.90	0.01	0.03	0.01	0.00	5.57	8.27	0.31	99.91	N06c-4Pl
Pl avg	61.78	0.01	24.16	0.01	0.02	0.01	0.01	5.49	8.43	0.26	100.19	
std dev	0.39	0.01	0.30	0.01	0.01	0.01	0.01	0.19	0.20	0.04	0.40	
5	60.57	0.00	25.36	0.00	0.04	0.00	0.01	7.00	7.59	0.24	100.80	HW3521-1Pl1
6	60.72	0.01	24.21	0.01	0.05	0.00	0.01	6.49	7.76	0.16	99.43	HW3521-1Pl2
7	60.97	0.01	25.25	0.05	0.07	0.00	0.00	6.57	7.73	0.20	100.85	HW3521-1Pl3
23	61.36	0.02	25.30	0.00	0.00	0.01	0.01	6.55	7.91	0.30	101.47	HW3521-2Pl1

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
24	60.52	0.03	25.21	0.00	0.00	0.00	0.01	6.89	7.66	0.20	100.52	HW3521-2Pl2
25	60.30	0.03	25.70	0.00	0.00	0.01	0.00	6.58	7.92	0.21	100.75	HW3521-2Pl3
32	60.23	0.03	24.54	0.01	0.02	0.03	0.01	6.75	7.51	0.21	99.33	HW3521-3Pl1
33	60.16	0.03	25.36	0.00	0.04	0.00	0.03	7.00	7.56	0.17	100.35	HW3521-3Pl2
34	60.54	0.01	24.50	0.01	0.01	0.03	0.01	6.54	7.97	0.13	99.75	HW3521-3Pl3
44	59.89	0.02	25.19	0.00	0.05	0.00	0.02	7.19	7.36	0.27	99.98	HW3521-5Pl1
45	60.02	0.02	25.70	0.02	0.02	0.00	0.02	7.30	7.28	0.28	100.66	HW3521-5Pl2
46	59.37	0.01	25.41	0.03	0.02	0.00	0.02	7.40	7.25	0.27	99.77	HW3521-5Pl3
Pl avg	60.39	0.02	25.14	0.01	0.03	0.01	0.01	6.85	7.62	0.22	100.30	
std dev	0.52	0.01	0.47	0.02	0.02	0.01	0.01	0.32	0.25	0.05	0.65	
56	60.69	0.04	25.30	0.01	0.04	0.00	0.03	6.75	7.60	0.36	100.80	HW3522-1Pl1
57	60.00	0.02	24.56	0.04	0.03	0.00	0.01	6.57	7.62	0.30	99.15	HW3522-1Pl2
58	59.94	0.01	25.31	0.00	0.01	0.01	0.00	6.82	7.55	0.29	99.95	HW3522-1Pl3
68	59.88	0.03	25.04	0.00	0.03	0.01	0.02	6.91	7.40	0.37	99.68	HW3522-2Pl1
69	59.67	0.02	24.64	0.02	0.00	0.01	0.01	6.88	7.45	0.38	99.07	HW3522-2Pl2
70	60.14	0.05	24.99	0.00	0.04	0.04	0.02	6.88	7.38	0.39	99.94	HW3522-2Pl3
74	59.56	0.00	24.69	0.00	0.02	0.00	0.03	6.92	7.33	0.33	98.87	HW3522-3Pl1
75	60.10	0.02	24.38	0.00	0.03	0.00	0.01	6.53	7.60	0.30	98.96	HW3522-3Pl2
76	59.26	0.03	24.57	0.01	0.03	0.01	0.02	6.77	7.45	0.21	98.36	HW3522-3Pl3
86	60.19	0.01	24.87	0.05	0.01	0.00	0.03	6.65	7.77	0.28	99.85	HW3522-4Pl1
87	60.06	0.07	24.47	0.00	0.00	0.00	0.03	6.76	7.72	0.20	99.30	HW3522-4Pl2
88	60.27	0.02	25.50	0.00	0.02	0.00	0.01	6.79	7.69	0.24	100.54	HW3522-4Pl3
Pl avg	59.98	0.03	24.86	0.01	0.02	0.01	0.02	6.77	7.54	0.30	99.54	
std dev	0.37	0.02	0.37	0.02	0.01	0.01	0.01	0.13	0.14	0.07	0.72	
95	60.66	0.00	25.16	0.02	0.02	0.01	0.02	6.79	8.04	0.19	100.91	HW3523-1Pl1
96	60.46	0.02	25.57	0.02	0.02	0.01	0.02	6.93	7.75	0.21	101.00	HW3523-1Pl2
97	60.59	0.04	24.95	0.01	0.01	0.01	0.02	6.43	7.71	0.28	100.04	HW3523-1Pl3
107	58.35	0.04	27.10	0.00	0.00	0.03	0.03	8.53	6.64	0.18	100.89	HW3523-2Pl1
108	58.27	0.02	26.99	0.00	0.04	0.02	0.01	8.52	6.73	0.17	100.77	HW3523-2Pl2
109	60.16	0.04	26.06	0.00	0.03	0.01	0.01	7.14	7.60	0.21	101.27	HW3523-2Pl3
119	60.03	0.04	25.28	0.00	0.01	0.00	0.03	6.57	7.94	0.16	100.06	HW3523-3Pl1
120	60.24	0.03	25.93	0.00	0.05	0.00	0.01	7.20	7.47	0.22	101.15	HW3523-3Pl2
121	60.70	0.00	25.81	0.00	0.02	0.03	0.01	6.94	7.75	0.16	101.41	HW3523-3Pl3
128	61.32	0.03	24.81	0.02	0.01	0.01	0.00	6.31	8.16	0.23	100.89	HW3523-4Pl1
129	61.44	0.05	24.99	0.00	0.04	0.01	0.01	6.35	7.94	0.28	101.10	HW3523-4Pl2
130	61.34	0.03	24.94	0.02	0.06	0.04	0.02	6.27	8.15	0.16	101.02	HW3523-4Pl3
Pl avg	60.30	0.03	25.63	0.01	0.03	0.01	0.02	7.00	7.66	0.20	100.88	
std dev	1.04	0.02	0.78	0.01	0.02	0.01	0.01	0.78	0.50	0.04	0.42	
137	61.50	0.00	25.13	0.04	0.00	0.00	0.00	6.20	8.09	0.11	101.07	HW3524-1Pl1
138	61.56	0.01	25.06	0.00	0.04	0.00	0.02	6.01	8.24	0.10	101.04	HW3524-1Pl2
139	61.40	0.04	24.98	0.02	0.00	0.00	0.01	5.97	8.32	0.12	100.86	HW3524-1Pl3
150	60.31	0.04	25.76	0.00	0.00	0.03	0.01	6.87	7.77	0.24	101.01	HW3524-3Pl1
152	60.21	0.00	25.86	0.04	0.02	0.01	0.01	7.03	7.43	0.28	100.89	HW3524-3Pl3
162	61.04	0.00	24.70	0.02	0.02	0.02	0.00	6.25	8.15	0.13	100.33	HW3524-4Pl1
163	61.11	0.01	25.06	0.00	0.09	0.02	0.01	6.42	8.01	0.14	100.86	HW3524-4Pl2
164	61.13	0.01	25.07	0.00	0.06	0.04	0.05	6.35	7.91	0.14	100.77	HW3524-4Pl3
Pl avg	61.03	0.01	25.20	0.01	0.03	0.01	0.01	6.39	7.99	0.16	100.85	
std dev	0.51	0.02	0.40	0.02	0.03	0.01	0.02	0.38	0.29	0.06	0.24	
168	62.76	0.00	24.25	0.00	0.06	0.00	0.00	5.42	8.42	0.23	101.15	HW3525-1Pl1
169	62.53	0.02	24.36	0.02	0.06	0.00	0.00	5.53	8.22	0.26	101.00	HW3525-1Pl2
170	61.99	0.02	24.42	0.01	0.07	0.00	0.01	5.80	8.29	0.21	100.84	HW3525-1Pl3
177	62.64	0.01	24.24	0.03	0.08	0.00	0.03	5.44	8.16	0.35	100.99	HW3525-2Pl1
178	62.61	0.01	24.27	0.04	0.08	0.01	0.03	5.44	8.43	0.28	101.21	HW3525-2Pl2
179	62.62	0.00	23.99	0.00	0.06	0.00	0.01	5.39	8.34	0.33	100.75	HW3525-2Pl3
189	62.08	0.04	24.24	0.00	0.04	0.03	0.01	5.73	8.11	0.31	100.57	HW3525-3Pl1
190	61.88	0.06	24.27	0.00	0.03	0.01	0.01	5.71	8.05	0.29	100.29	HW3525-3Pl2
191	62.08	0.01	24.38	0.02	0.13	0.00	0.01	5.52	7.67	1.15	100.97	HW3525-3Pl3
Pl avg	62.35	0.02	24.27	0.01	0.07	0.01	0.01	5.55	8.19	0.38	100.86	
std dev	0.34	0.02	0.12	0.02	0.03	0.01	0.01	0.15	0.23	0.29	0.29	
201	62.81	0.02	23.54	0.03	0.07	0.00	0.01	5.03	8.58	0.23	100.32	HW3526-1Pl1
202	62.78	0.03	23.89	0.00	0.15	0.03	0.03	5.26	8.52	0.26	100.94	HW3526-1Pl2
203	62.56	0.03	24.01	0.07	0.05	0.00	0.01	5.19	8.68	0.23	100.82	HW3526-1Pl3
210	62.66	0.02	23.88	0.04	0.19	0.01	0.00	5.04	8.62	0.33	100.79	HW3526-1Pl1
211	62.86	0.02	23.85	0.00	0.17	0.00	0.00	5.08	8.53	0.33	100.85	HW3526-1Pl2
212	62.71	0.02	23.85	0.00	0.05	0.00	0.00	5.04	8.76	0.28	100.70	HW3526-1Pl3
219	62.53	0.03	23.71	0.00	0.04	0.00	0.00	5.30	8.71	0.18	100.51	HW3526-3Pl1
220	62.55	0.00	23.74	0.03	0.04	0.03	0.01	5.20	8.40	0.24	100.24	HW3526-3Pl2
221	62.40	0.01	24.08	0.00	0.05	0.00	0.00	5.35	8.41	0.18	100.49	HW3526-3Pl3
225	62.88	0.00	23.92	0.00	0.06	0.02	0.02	5.16	8.59	0.29	100.93	HW3526-4Pl1
226	63.02	0.00	23.90	0.01	0.04	0.03	0.00	5.01	8.66	0.36	101.03	HW3526-4Pl2
227	62.46	0.02	23.86	0.00	0.03	0.00	0.02	5.11	8.60	0.26	100.36	HW3526-4Pl3
Pl avg	62.68	0.02	23.85	0.01	0.08	0.01	0.01	5.15	8.59	0.26	100.66	
std dev	0.19	0.01	0.14	0.02	0.06	0.01	0.01	0.11	0.11	0.06	0.27	
239	62.60	0.00	24.34	0.00	0.09	0.00	0.02	5.14	8.65	0.34	101.16	HW3527-1Pl1

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
240	62.24	0.02	24.21	0.03	0.07	0.02	0.00	5.00	8.57	0.37	100.52	HW3527-1Pl2
241	62.42	0.00	24.28	0.00	0.04	0.00	0.03	5.05	8.79	0.19	100.79	HW3527-1Pl3
257	62.50	0.00	24.02	0.00	0.06	0.00	0.02	5.26	8.37	0.43	100.66	HW3527-2Pl1
258	62.21	0.01	24.14	0.00	0.07	0.00	0.01	5.38	8.62	0.27	100.71	HW3527-2Pl2
259	62.28	0.04	24.20	0.00	0.03	0.01	0.02	5.23	8.49	0.24	100.55	HW3527-2Pl3
275	62.51	0.02	24.04	0.00	0.05	0.00	0.01	5.20	8.33	0.34	100.49	HW3527-3Pl1
276	61.75	0.00	24.10	0.00	0.13	0.02	0.02	5.28	8.54	0.42	100.26	HW3527-3Pl2
277	62.68	0.02	24.11	0.00	0.02	0.04	0.01	5.24	8.46	0.29	100.87	HW3527-3Pl3
287	62.33	0.00	24.00	0.00	0.06	0.00	0.03	5.19	8.61	0.22	100.44	HW3527-4Pl1
288	61.17	0.00	24.84	0.00	0.06	0.00	0.03	4.81	8.61	0.14	99.66	HW3527-4Pl2
289	62.05	0.02	24.08	0.03	0.07	0.01	0.00	5.45	8.59	0.14	100.45	HW3527-4Pl3
Pl avg	62.23	0.01	24.20	0.01	0.06	0.01	0.02	5.18	8.55	0.28	100.55	
std dev	0.42	0.01	0.23	0.01	0.03	0.01	0.01	0.17	0.13	0.10	0.37	
293	61.84	0.04	23.86	0.00	0.07	0.00	0.03	5.23	8.58	0.22	99.86	HW3530-1Pl1
294	61.86	0.00	24.09	0.00	0.05	0.00	0.02	5.33	8.53	0.18	100.05	HW3530-1Pl2
295	62.13	0.04	24.04	0.03	0.04	0.00	0.03	5.22	8.56	0.22	100.30	HW3530-1Pl3
305	62.09	0.00	24.20	0.01	0.02	0.01	0.04	5.01	8.63	0.21	100.22	HW3530-2Pl1
306	62.18	0.02	23.99	0.00	0.04	0.00	0.00	5.20	8.62	0.22	100.27	HW3530-2Pl2
307	62.12	0.00	24.10	0.02	0.01	0.01	0.02	5.25	8.55	0.17	100.24	HW3530-2Pl3
308	62.19	0.00	23.93	0.00	0.21	0.01	0.03	4.94	8.61	0.32	100.24	HW3530-3Pl1
309	62.37	0.02	23.73	0.00	0.06	0.00	0.01	5.14	8.59	0.32	100.25	HW3530-3Pl2
310	62.08	0.00	24.06	0.02	0.06	0.02	0.00	5.27	8.52	0.16	100.20	HW3530-3Pl3
314	61.73	0.02	23.76	0.00	0.01	0.00	0.01	5.17	8.79	0.13	99.61	HW3530-4Pl1
315	61.79	0.01	23.83	0.00	0.06	0.00	0.01	5.22	8.84	0.12	99.88	HW3530-4Pl2
316	61.46	0.01	23.88	0.03	0.04	0.01	0.02	5.19	8.62	0.10	99.35	HW3530-4Pl3
Pl avg	61.99	0.01	23.96	0.01	0.06	0.00	0.02	5.18	8.62	0.20	100.04	
std dev	0.25	0.01	0.15	0.01	0.05	0.01	0.01	0.11	0.10	0.07	0.30	
7	61.48	0.04	24.36	0.01	0.07	0.00	0.03	5.42	8.34	0.39	100.13	HW-1A-1Pl
8	61.64	0.00	24.48	0.01	0.09	0.00	0.00	5.66	7.95	0.47	100.30	HW-1A-1Pl
9	61.62	0.00	24.45	0.01	0.06	0.02	0.00	5.53	8.19	0.31	100.19	HW-1A-1Pl
22	60.43	0.01	24.37	0.00	0.06	0.03	0.02	5.65	8.23	0.30	99.09	HW-1A-3Pl
23	60.89	0.03	24.46	0.00	0.05	0.00	0.02	5.74	8.17	0.25	99.62	HW-1A-3Pl
24	60.88	0.03	24.03	0.00	0.07	0.01	0.01	5.25	8.28	0.43	98.99	HW-1A-3Pl
25	60.29	0.02	24.33	0.04	0.08	0.00	0.01	5.76	8.17	0.29	98.98	HW-1A-4Pl
26	60.00	0.04	24.30	0.00	0.05	0.00	0.02	5.74	8.25	0.31	98.70	HW-1A-4Pl
27	61.42	0.01	24.28	0.00	0.07	0.00	0.02	5.59	8.32	0.39	100.10	HW-1A-4Pl
32	61.14	0.01	24.11	0.03	0.11	0.02	0.02	5.44	8.08	0.38	99.33	HW-1A-6Pl
33	61.09	0.05	24.26	0.00	0.11	0.00	0.02	5.49	8.29	0.37	99.67	HW-1A-6Pl
34	60.33	0.05	24.37	0.03	0.09	0.00	0.01	5.53	8.38	0.37	99.13	HW-1A-6Pl
Pl avg	60.93	0.02	24.32	0.01	0.08	0.01	0.01	5.57	8.22	0.35	99.52	
std dev	0.56	0.02	0.14	0.01	0.02	0.01	0.01	0.15	0.12	0.06	0.56	
41	61.01	0.00	24.49	0.00	0.10	0.00	0.03	5.63	8.25	0.23	99.74	HW-2A-1Pl
42	60.48	0.00	24.38	0.03	0.02	0.03	0.01	5.69	8.09	0.32	99.05	HW-2A-1Pl
43	59.64	0.03	24.89	0.02	0.08	0.04	0.03	6.08	7.97	0.23	99.00	HW-2A-1Pl
47	59.99	0.00	24.52	0.02	0.05	0.04	0.00	5.79	8.12	0.21	98.73	HW-2A-2Pl
48	60.98	0.03	24.39	0.00	0.08	0.00	0.03	5.54	8.09	0.37	99.52	HW-2A-2Pl
49	60.88	0.02	24.26	0.04	0.06	0.04	0.00	5.37	8.37	0.41	99.44	HW-2A-2Pl
56	60.81	0.01	24.54	0.02	0.07	0.00	0.00	5.74	8.14	0.34	99.68	HW-2A-4Pl
57	60.73	0.04	24.53	0.00	0.04	0.00	0.01	5.71	8.34	0.28	99.69	HW-2A-4Pl
58	60.11	0.00	24.90	0.05	0.03	0.01	0.03	5.97	8.03	0.25	99.38	HW-2A-4Pl
65	61.88	0.02	24.32	0.01	0.06	0.03	0.02	5.31	8.41	0.32	100.37	HW-2A-5Pl
66	61.28	0.00	24.94	0.01	0.05	0.00	0.01	6.00	8.20	0.15	100.63	HW-2A-5Pl
67	61.49	0.02	24.50	0.00	0.06	0.00	0.02	5.47	8.36	0.26	100.18	HW-2A-5Pl
Pl avg	60.77	0.01	24.55	0.02	0.06	0.02	0.02	5.69	8.20	0.28	99.62	
std dev	0.64	0.01	0.23	0.02	0.02	0.02	0.01	0.25	0.15	0.07	0.57	
68	60.33	0.01	24.40	0.00	0.08	0.01	0.02	5.65	8.16	0.36	99.02	HW-3A-1Pl
69	60.33	0.03	24.24	0.00	0.10	0.02	0.00	5.51	8.33	0.37	98.93	HW-3A-1Pl
70	60.21	0.03	24.31	0.01	0.07	0.05	0.02	5.58	8.11	0.32	98.70	HW-3A-1Pl
74	60.67	0.03	24.04	0.01	0.08	0.00	0.01	5.43	8.05	0.39	98.72	HW-3A-2Pl
76	60.24	0.02	24.10	0.00	0.11	0.01	0.03	5.50	8.10	0.38	98.50	HW-3A-2Pl
83	60.43	0.00	23.99	0.03	0.03	0.00	0.01	5.41	7.20	1.95	99.06	HW-3A-3Pl
85	60.19	0.00	24.48	0.00	0.05	0.01	0.01	5.75	8.11	0.30	98.89	HW-3A-3Pl
95	59.50	0.00	24.34	0.00	0.08	0.01	0.01	5.76	8.18	0.25	98.14	HW-3A-5Pl
Pl avg	60.24	0.02	24.24	0.01	0.07	0.01	0.01	5.57	8.03	0.54	98.74	
std dev	0.33	0.01	0.18	0.01	0.02	0.02	0.01	0.14	0.34	0.57	0.31	

Orthopyroxene Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
178	52.01	0.09	0.68	0.07	29.88	1.02	16.13	0.84	0.03	0.00	100.75	M4015b-2Opx1
179	52.32	0.06	0.62	0.00	29.97	1.03	16.31	0.68	0.01	0.00	101.00	M4015b-2Opx2
180	52.23	0.07	0.65	0.05	29.80	1.01	15.89	0.82	0.05	0.01	100.58	M4015b-2Opx3
199	51.62	0.13	0.65	0.07	29.69	0.97	15.79	0.73	0.00	0.00	99.65	M4015b-6Opx1
200	51.93	0.08	0.71	0.01	30.09	1.02	15.63	0.79	0.04	0.00	100.29	M4015b-6Opx2
201	52.13	0.06	0.66	0.08	29.98	0.97	15.84	0.78	0.05	0.01	100.56	M4015b-6Opx3
Opx avg	52.04	0.08	0.66	0.05	29.90	1.00	15.93	0.77	0.03	0.00	100.47	

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
std dev	0.25	0.03	0.03	0.03	0.14	0.03	0.25	0.06	0.02	0.00	0.46	
14	49.89	0.14	4.06	0.07	29.78	0.32	16.46	0.18	0.06	0.00	100.94	HW3521-1Opx1
15	50.36	0.16	3.97	0.05	29.69	0.29	16.65	0.21	0.00	0.01	101.39	HW3521-1Opx2
16	50.73	0.06	3.54	0.08	29.32	0.28	17.12	0.17	0.00	0.00	101.29	HW3521-1Opx3
35	50.18	0.11	3.96	0.14	30.05	0.33	16.11	0.13	0.00	0.00	101.01	HW3521-3Opx1
36	49.58	0.08	4.02	0.11	29.90	0.30	16.13	0.15	0.01	0.01	100.30	HW3521-3Opx2
37	49.92	0.13	3.98	0.11	29.89	0.30	16.45	0.17	0.04	0.00	100.97	HW3521-3Opx3
Opx avg	50.11	0.11	3.92	0.09	29.77	0.30	16.49	0.17	0.02	0.00	100.98	
std dev	0.41	0.04	0.19	0.03	0.25	0.02	0.37	0.03	0.02	0.00	0.38	
174	53.13	0.03	0.83	0.00	25.78	0.51	20.16	0.47	0.03	0.00	100.94	HW3525-1Opx1
175	53.40	0.06	0.59	0.03	25.50	0.59	20.30	0.71	0.03	0.00	101.21	HW3525-1Opx2
176	53.03	0.09	0.69	0.00	26.13	0.54	20.13	0.59	0.02	0.00	101.21	HW3525-1Opx3
183	53.28	0.05	0.60	0.01	25.59	0.57	20.42	0.81	0.01	0.01	101.35	HW3525-2Opx1
184	53.57	0.05	0.41	0.03	25.09	0.58	20.85	0.68	0.00	0.00	101.26	HW3525-2Opx2
185	53.46	0.07	0.47	0.00	25.74	0.52	20.50	0.54	0.02	0.01	101.32	HW3525-2Opx3
192	53.20	0.12	0.71	0.00	25.79	0.54	19.78	0.78	0.02	0.00	100.93	HW3525-3Opx1
Opx avg	53.30	0.06	0.61	0.01	25.66	0.55	20.31	0.65	0.02	0.00	101.17	
std dev	0.19	0.03	0.15	0.01	0.32	0.03	0.34	0.13	0.01	0.00	0.17	
198	53.66	0.09	0.64	0.02	25.55	0.46	20.41	0.79	0.01	0.01	101.65	HW3526-1Opx1
199	53.63	0.11	0.67	0.02	25.85	0.49	20.33	0.75	0.01	0.00	101.86	HW3526-1Opx2
200	53.93	0.00	0.36	0.00	25.92	0.53	20.80	0.39	0.00	0.01	101.95	HW3526-1Opx3
222	53.14	0.11	0.93	0.00	25.24	0.52	20.81	0.62	0.01	0.01	101.39	HW3526-3Opx1
223	53.71	0.05	0.82	0.00	25.17	0.56	20.93	0.48	0.00	0.00	101.72	HW3526-3Opx2
224	53.28	0.11	0.80	0.00	25.66	0.51	20.59	0.62	0.00	0.01	101.57	HW3526-3Opx3
231	53.45	0.07	0.64	0.02	25.39	0.52	20.76	0.91	0.04	0.00	101.81	HW3526-4Opx1
232	53.21	0.09	0.69	0.02	25.74	0.54	20.45	0.66	0.05	0.00	101.44	HW3526-4Opx2
233	53.27	0.03	0.62	0.00	25.69	0.48	20.52	0.61	0.05	0.00	101.26	HW3526-4Opx3
Opx avg	53.47	0.07	0.69	0.01	25.58	0.51	20.62	0.65	0.02	0.01	101.63	
std dev	0.27	0.04	0.16	0.01	0.26	0.03	0.21	0.16	0.02	0.01	0.23	
248	53.16	0.04	0.59	0.05	24.95	0.70	20.83	0.65	0.03	0.01	101.01	HW3527-1Opx1
249	53.59	0.08	0.58	0.01	25.06	0.66	20.87	0.60	0.03	0.01	101.48	HW3527-1Opx2
250	53.38	0.05	0.70	0.00	25.31	0.61	20.81	0.53	0.02	0.01	101.42	HW3527-1Opx3
263	52.41	0.09	0.89	0.00	25.46	0.73	20.34	0.56	0.03	0.00	100.51	HW3527-2Opx1
264	52.65	0.07	0.69	0.00	25.47	0.67	20.19	0.57	0.00	0.02	100.31	HW3527-2Opx2
265	52.03	0.06	0.55	0.00	25.43	0.71	19.99	0.49	0.01	0.00	99.27	HW3527-2Opx3
272	53.05	0.10	0.68	0.00	26.40	0.68	19.73	0.71	0.05	0.00	101.39	HW3527-3Opx1
273	52.28	0.12	0.87	0.01	25.20	0.68	19.96	0.76	0.05	0.01	99.94	HW3527-3Opx2
274	53.16	0.06	0.53	0.00	25.65	0.64	20.21	0.72	0.02	0.00	101.00	HW3527-3Opx3
Opx avg	52.86	0.08	0.67	0.01	25.44	0.68	20.32	0.62	0.03	0.01	100.70	
std dev	0.54	0.03	0.13	0.02	0.42	0.04	0.42	0.09	0.02	0.01	0.76	
13	51.48	0.06	0.74	0.02	25.83	0.79	17.89	1.19	0.03	0.00	98.02	HW-1A-2Opx
14	51.44	0.07	0.58	0.04	25.63	0.84	17.89	1.17	0.00	0.00	97.65	HW-1A-2Opx
15	52.24	0.12	0.73	0.02	25.62	0.78	18.16	1.19	0.03	0.00	98.88	HW-1A-2Opx
19	52.45	0.12	0.73	0.04	26.50	0.85	18.14	0.68	0.03	0.01	99.54	HW-1A-3Opx
20	52.33	0.11	0.72	0.00	26.32	0.86	17.72	0.78	0.04	0.00	98.89	HW-1A-3Opx
21	52.43	0.10	0.75	0.00	26.37	0.89	17.90	0.78	0.06	0.01	99.29	HW-1A-3Opx
Opx avg	52.06	0.10	0.71	0.02	26.05	0.83	17.95	0.96	0.03	0.00	98.71	
std dev	0.47	0.03	0.06	0.02	0.40	0.04	0.17	0.24	0.02	0.00	0.73	
59	52.40	0.14	0.79	0.02	26.14	0.81	18.01	0.69	0.06	0.01	99.06	HW-2A-4Opx
60	52.68	0.13	0.82	0.00	26.10	0.72	18.26	0.71	0.02	0.00	99.43	HW-2A-4Opx
61	52.82	0.12	0.74	0.00	25.58	0.70	18.23	1.08	0.02	0.00	99.30	HW-2A-4Opx
Opx avg	52.63	0.13	0.78	0.01	25.94	0.74	18.16	0.83	0.03	0.00	99.26	
std dev	0.22	0.01	0.04	0.01	0.31	0.06	0.14	0.22	0.02	0.01	0.18	

Clinopyroxene Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
16	52.21	0.27	1.61	0.00	11.14	0.35	11.47	22.69	0.64	0.00	100.38	HW-1A-3Cpx
17	52.33	0.19	1.66	0.01	11.46	0.38	11.88	22.07	0.60	0.01	100.57	HW-1A-3Cpx
18	52.45	0.12	1.50	0.03	10.12	0.36	12.07	23.19	0.52	0.01	100.37	HW-1A-3Cpx
Cpx avg	52.33	0.19	1.59	0.01	10.91	0.37	11.80	22.65	0.59	0.01	100.44	
std dev	0.12	0.07	0.08	0.01	0.70	0.01	0.31	0.56	0.06	0.01	0.11	

Garnet Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
36	38.32	0.06	21.49	0.00	34.37	1.79	4.25	1.65	0.03	0.00	101.97	M12352B-1Grt
37	38.28	0.04	21.42	0.00	34.45	1.78	4.14	1.69	0.01	0.01	101.80	M12352B-1Grt
38	37.88	0.01	21.37	0.04	33.83	1.82	4.40	1.67	0.03	0.00	101.05	M12352B-1Grt
39	38.43	0.03	21.53	0.02	34.35	1.79	4.44	1.64	0.03	0.01	102.26	M12352B-1Grt
40	38.43	0.00	21.58	0.00	35.04	1.75	3.93	1.59	0.01	0.00	102.32	M12352B-1Grt
54	38.43	0.07	21.47	0.00	33.66	1.91	4.44	1.66	0.03	0.00	101.66	M12352B-4Grt
55	38.36	0.05	21.60	0.00	33.94	1.84	4.39	1.68	0.05	0.01	101.91	M12352B-4Grt
56	38.07	0.00	21.36	0.00	34.27	1.91	4.13	1.66	0.06	0.00	101.46	M12352B-4Grt

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
57	38.22	0.06	21.55	0.01	33.75	1.93	4.40	1.63	0.04	0.00	101.59	M12352B-4Grt
58	38.54	0.02	21.52	0.03	34.09	1.84	4.48	1.68	0.04	0.00	102.22	M12352B-4Grt
62	38.40	0.03	21.55	0.00	34.84	1.73	4.14	1.61	0.04	0.00	102.33	M12352B-5Grt
63	38.53	0.00	21.49	0.01	34.82	1.76	4.19	1.59	0.02	0.01	102.42	M12352B-5Grt
64	38.32	0.02	21.56	0.00	34.62	1.85	4.22	1.65	0.04	0.00	102.28	M12352B-5Grt
65	38.28	0.05	21.58	0.00	34.88	1.88	4.01	1.63	0.04	0.00	102.36	M12352B-5Grt
Grt avg	38.32	0.03	21.50	0.01	34.35	1.83	4.25	1.64	0.03	0.00	101.97	
std dev	0.18	0.02	0.08	0.01	0.45	0.06	0.17	0.03	0.02	0.00	0.41	
22	38.87	0.04	21.83	0.00	32.92	0.75	6.06	1.51	0.00	0.01	101.98	M12636-5Grt
23	38.59	0.03	21.56	0.04	32.95	0.74	5.90	1.52	0.05	0.00	101.40	M12636-5Grt
24	38.76	0.00	21.46	0.01	33.81	0.81	5.31	1.63	0.00	0.00	101.80	M12636-5Grt
25	38.78	0.05	21.59	0.02	33.26	0.72	5.92	1.49	0.01	0.00	101.85	M12636-5Grt
26	38.17	0.07	21.97	0.03	32.94	0.76	6.06	1.51	0.01	0.00	101.52	M12636-5Grt
37	38.62	0.06	21.98	0.04	31.77	0.71	6.94	1.56	0.02	0.00	101.70	M12636-3Grt
38	38.02	0.05	22.09	0.00	31.60	0.66	6.90	1.49	0.00	0.01	100.83	M12636-3Grt
39	36.90	0.07	22.18	0.00	32.73	0.70	6.19	1.49	0.05	0.00	100.30	M12636-3Grt
40	36.77	0.02	22.07	0.07	32.88	0.79	5.70	1.54	0.05	0.00	99.88	M12636-3Grt
41	37.39	0.04	22.16	0.00	31.68	0.73	6.78	1.47	0.04	0.00	100.30	M12636-3Grt
Grt avg	38.09	0.04	21.89	0.02	32.65	0.74	6.18	1.52	0.02	0.00	101.15	
std dev	0.80	0.02	0.26	0.02	0.73	0.04	0.54	0.05	0.02	0.00	0.76	
11	38.58	0.06	21.63	0.04	32.75	0.80	6.02	1.62	0.00	0.00	101.49	HW3521-1Grt1
12	38.36	0.03	21.82	0.08	33.15	0.88	6.09	1.60	0.01	0.00	102.02	HW3521-1Grt2
13	38.67	0.00	21.53	0.10	32.75	0.87	6.22	1.60	0.03	0.00	101.77	HW3521-1Grt3
20	38.38	0.09	22.04	0.12	31.96	1.02	6.71	1.37	0.03	0.00	101.71	HW3521-2Grt1
21	38.81	0.08	21.65	0.12	32.29	1.03	6.48	1.42	0.02	0.00	101.88	HW3521-2Grt2
22	38.11	0.09	21.76	0.11	33.82	1.01	5.32	1.48	0.00	0.00	101.70	HW3521-2Grt3
53	38.93	0.00	21.91	0.02	31.28	0.96	6.89	1.66	0.00	0.00	101.64	HW3521-5Grt1
54	38.53	0.04	21.67	0.04	31.29	1.02	6.84	1.63	0.03	0.02	101.10	HW3521-5Grt2
55	38.60	0.06	22.04	0.07	31.37	0.97	6.90	1.59	0.00	0.01	101.62	HW3521-5Grt3
Grt avg	38.55	0.05	21.78	0.08	32.30	0.95	6.39	1.55	0.01	0.00	101.66	
std dev	0.25	0.03	0.18	0.04	0.90	0.08	0.53	0.10	0.01	0.01	0.26	
80	38.36	0.06	21.95	0.06	31.61	0.91	6.92	1.39	0.03	0.00	101.29	HW3522-3Grt1
81	37.86	0.04	21.74	0.07	31.80	0.91	6.64	1.39	0.03	0.00	100.48	HW3522-3Grt2
82	38.15	0.02	21.70	0.04	31.71	0.94	6.76	1.41	0.02	0.00	100.74	HW3522-3Grt3
83	38.51	0.04	21.91	0.04	31.85	0.93	6.73	1.45	0.00	0.00	101.46	HW3522-4Grt1
84	38.08	0.02	21.63	0.13	32.79	0.96	5.72	1.55	0.00	0.00	100.87	HW3522-4Grt2
85	38.41	0.08	21.96	0.06	32.28	0.93	6.43	1.46	0.00	0.00	101.60	HW3522-4Grt3
Grt avg	38.23	0.04	21.82	0.07	32.01	0.93	6.53	1.44	0.01	0.00	101.07	
std dev	0.24	0.02	0.14	0.03	0.45	0.02	0.43	0.06	0.01	0.00	0.44	
92	38.48	0.07	21.79	0.06	31.48	0.83	6.88	1.25	0.02	0.00	100.84	HW3523-1Grt1
93	38.85	0.00	21.86	0.00	31.93	0.87	6.84	1.27	0.04	0.01	101.66	HW3523-1Grt2
94	38.47	0.07	21.73	0.01	31.62	0.89	6.91	1.31	0.01	0.01	101.02	HW3523-1Grt3
104	38.75	0.09	21.79	0.00	30.76	0.79	7.82	1.18	0.02	0.00	101.18	HW3523-2Grt1
105	38.75	0.06	21.96	0.02	31.00	0.78	7.56	1.31	0.02	0.00	101.45	HW3523-2Grt2
106	38.97	0.01	21.77	0.03	31.00	0.84	7.61	1.27	0.04	0.01	101.54	HW3523-2Grt3
116	38.97	0.03	21.78	0.07	31.15	0.79	7.47	1.26	0.04	0.01	101.56	HW3523-3Grt1
117	38.80	0.08	21.56	0.09	31.31	0.78	7.16	1.31	0.02	0.00	101.09	HW3523-3Grt2
118	38.74	0.04	21.66	0.05	31.11	0.82	7.24	1.34	0.04	0.00	101.03	HW3523-3Grt3
Grt avg	38.75	0.05	21.77	0.04	31.26	0.82	7.28	1.28	0.03	0.00	101.26	
std dev	0.18	0.03	0.11	0.03	0.36	0.04	0.36	0.05	0.01	0.01	0.29	
140	38.58	0.02	21.74	0.03	31.79	0.93	6.92	1.38	0.04	0.00	101.43	HW3524-2Grt1
141	38.72	0.07	21.75	0.11	31.43	0.89	6.95	1.37	0.06	0.00	101.34	HW3524-2Grt2
142	38.74	0.05	21.81	0.07	31.81	0.86	6.83	1.38	0.07	0.01	101.62	HW3524-2Grt3
143	38.98	0.04	21.84	0.04	31.32	0.94	7.11	1.38	0.03	0.00	101.67	HW3524-3Grt1
144	38.69	0.07	21.49	0.07	31.20	0.89	7.33	1.39	0.07	0.00	101.20	HW3524-3Grt2
145	38.85	0.07	22.29	0.07	31.50	0.90	6.91	1.43	0.08	0.00	102.09	HW3524-3Grt3
237	37.81	0.05	21.69	0.03	31.88	0.90	6.97	1.40	0.02	0.00	100.73	HW3524-2Grt1a
238	37.86	0.04	21.65	0.02	31.46	0.87	7.10	1.37	0.07	0.01	100.43	HW3524-2Grt1b
Grt avg	38.53	0.05	21.78	0.05	31.55	0.90	7.01	1.39	0.05	0.00	101.31	
std dev	0.44	0.02	0.23	0.03	0.25	0.03	0.16	0.02	0.02	0.00	0.53	

Hornblende Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
166	44.33	1.61	9.54	0.03	16.51	0.24	10.57	11.78	1.32	1.01	96.93	M4015b-1Hbl
167	44.17	1.51	9.72	0.15	16.75	0.22	10.35	11.88	1.32	1.06	97.12	M4015b-1Hbl
168	43.97	1.66	9.49	0.05	16.63	0.26	10.41	11.72	1.39	1.04	96.63	M4015b-1Hbl
172	44.02	1.72	9.63	0.07	16.59	0.22	10.36	11.72	1.42	1.10	96.85	M4015b-2Hbl
173	43.54	1.88	9.62	0.07	16.77	0.23	9.98	11.62	1.49	1.11	96.31	M4015b-2Hbl
181	43.87	1.98	9.85	0.09	16.89	0.24	10.01	11.79	1.50	1.14	97.35	M4015b-3Hbl
182	43.80	1.80	9.97	0.05	17.17	0.27	9.94	11.77	1.46	1.11	97.33	M4015b-3Hbl
183	43.49	1.80	10.17	0.10	16.79	0.24	9.93	11.95	1.41	1.15	97.01	M4015b-3Hbl
190	45.48	1.20	8.82	0.05	16.60	0.28	10.85	11.82	1.13	0.89	97.12	M4015b-4Hbl
191	45.52	1.32	8.60	0.13	16.50	0.27	10.46	12.08	1.15	0.85	96.87	M4015b-4Hbl
192	51.74	0.09	0.95	0.04	10.81	0.39	11.58	23.07	0.27	0.00	98.94	M4015b-4Hbl

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
193	45.06	1.37	8.95	0.12	16.14	0.23	10.63	12.17	1.20	0.95	96.83	M4015b-5Hbl
194	43.88	1.49	9.84	0.17	16.93	0.25	10.00	11.66	1.30	1.09	96.63	M4015b-5Hbl
195	52.57	0.07	0.81	0.03	11.18	0.47	12.11	23.02	0.29	0.00	100.56	M4015b-5Hbl
Hbl avg	45.39	1.39	8.28	0.08	15.87	0.27	10.51	13.43	1.19	0.89	97.32	
std dev	2.95	0.60	3.17	0.05	2.08	0.07	0.64	4.07	0.40	0.39	1.11	
379	44.05	1.82	10.29	0.08	17.51	0.26	9.95	11.69	1.32	1.34	98.30	N01a-1Hbl1
380	44.05	1.75	10.20	0.02	17.41	0.29	9.80	11.82	1.23	1.31	97.88	N01a-1Hbl2
381	44.09	1.91	10.28	0.07	17.50	0.22	9.64	11.78	1.32	1.33	98.16	N01a-1Hbl3
385	44.08	1.84	9.95	0.04	17.27	0.19	10.14	11.43	1.36	1.20	97.49	N01a-2Hbl1
386	44.24	1.90	9.90	0.00	17.37	0.26	10.12	11.40	1.40	1.21	97.80	N01a-2Hbl2
387	44.13	1.89	9.97	0.10	17.54	0.27	10.19	11.74	1.33	1.25	98.39	N01a-2Hbl3
394	43.53	1.94	10.57	0.05	17.46	0.39	9.60	11.56	1.25	1.35	97.69	N01a-3Hbl1
395	44.34	1.93	10.19	0.03	17.53	0.26	9.86	11.55	1.27	1.30	98.26	N01a-3Hbl2
396	43.63	1.74	10.53	0.05	17.62	0.28	9.83	11.49	1.33	1.37	97.86	N01a-3Hbl3
400	44.40	1.90	9.80	0.05	17.34	0.30	10.10	11.50	1.43	1.29	98.12	N01a-4Hbl1
401	44.44	1.83	9.81	0.10	17.41	0.29	10.31	11.54	1.37	1.24	98.35	N01a-4Hbl2
402	44.26	1.77	9.90	0.01	17.61	0.29	10.02	11.69	1.19	1.30	98.03	N01a-4Hbl3
Hbl avg	44.10	1.85	10.12	0.05	17.46	0.27	9.96	11.60	1.32	1.29	98.03	
std dev	0.28	0.07	0.27	0.03	0.11	0.05	0.22	0.14	0.07	0.06	0.28	

Btite Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
14	37.87	3.97	14.75	0.00	20.22	0.19	10.22	0.09	0.18	9.46	96.95	M0034-2Bt
15	37.52	3.86	14.68	0.00	20.16	0.13	10.24	0.09	0.15	9.53	96.36	M0034-2Bt
16	37.53	4.22	14.87	0.01	20.27	0.13	9.98	0.01	0.12	9.81	96.96	M0034-2Bt
20	37.17	4.95	14.77	0.00	21.55	0.16	8.95	0.02	0.15	9.58	97.29	M0034-3Bt
21	37.51	5.05	15.02	0.00	21.42	0.14	8.51	0.03	0.12	9.64	97.45	M0034-3Bt
22	37.25	4.84	14.84	0.00	21.76	0.15	8.56	0.02	0.14	9.64	97.20	M0034-3Bt
Bt avg	37.47	4.48	14.82	0.00	20.90	0.15	9.41	0.05	0.14	9.61	97.03	
std dev	0.25	0.53	0.12	0.00	0.75	0.02	0.83	0.04	0.02	0.12	0.38	
50	37.74	3.18	12.43	0.00	14.54	0.25	15.10	0.05	0.13	9.43	92.85	M3796-1Bt
51	38.94	3.03	12.68	0.00	14.14	0.15	15.45	0.05	0.12	9.81	94.36	M3796-1Bt
52	37.98	2.93	12.40	0.00	13.79	0.19	14.96	0.04	0.11	9.74	92.15	M3796-1Bt
Bt avg	38.22	3.05	12.50	0.00	14.16	0.20	15.17	0.05	0.12	9.66	93.12	
std dev	0.63	0.13	0.15	0.00	0.37	0.05	0.25	0.00	0.01	0.20	1.13	
116	27.88	0.00	16.45	0.03	29.20	0.30	12.02	0.20	0.03	0.03	86.13	M4002a-3Chl
117	27.05	0.01	15.97	0.00	28.79	0.29	12.26	0.24	0.07	0.04	84.71	M4002a-3Chl
118	27.91	0.00	16.66	0.06	29.41	0.27	12.51	0.15	0.09	0.05	87.11	M4002a-3Chl
119	28.19	0.05	16.22	0.02	28.90	0.28	12.63	0.20	0.05	0.04	86.56	M4002a-3Chl
Chl avg	27.76	0.01	16.32	0.03	29.08	0.28	12.36	0.19	0.06	0.04	86.13	
std dev	0.49	0.02	0.30	0.03	0.28	0.01	0.27	0.04	0.02	0.01	1.03	
64	25.99	0.06	20.08	0.03	28.53	0.24	12.66	0.07	0.13	0.05	87.83	M4002b-6Bt
65	25.91	0.03	20.34	0.01	28.78	0.22	12.40	0.02	0.04	0.02	87.76	M4002b-6Bt
66	25.78	0.39	19.94	0.00	28.40	0.24	12.35	0.02	0.03	0.04	87.18	M4002b-6Bt
68	25.88	0.05	20.16	0.02	27.93	0.22	12.51	0.06	0.07	0.06	86.94	M4002b-6Bt
Chl avg	25.89	0.13	20.13	0.01	28.41	0.23	12.48	0.04	0.07	0.04	87.43	
std dev	0.09	0.17	0.17	0.01	0.36	0.01	0.14	0.03	0.04	0.02	0.43	
21	35.65	4.51	14.64	0.00	23.57	0.13	8.15	0.15	0.14	9.02	95.94	M4015a-3Bt
22	35.98	4.46	14.85	0.00	23.68	0.09	8.17	0.02	0.09	9.62	96.98	M4015a-3Bt
44	35.24	4.43	14.41	0.07	23.25	0.24	8.25	0.14	0.08	9.04	95.15	M4015a-4Bt
45	37.54	3.95	15.01	0.06	21.59	0.17	7.13	0.06	0.12	9.74	95.35	M4015a-4Bt
46	36.06	4.63	14.69	0.06	23.74	0.23	8.09	0.07	0.08	9.51	97.15	M4015a-4Bt
Bt avg	36.09	4.40	14.72	0.04	23.16	0.17	7.96	0.09	0.10	9.38	96.11	
std dev	0.87	0.26	0.22	0.03	0.90	0.06	0.47	0.06	0.03	0.34	0.92	
175	35.74	3.31	16.31	0.00	24.87	0.42	5.15	0.05	0.06	9.60	95.51	M4017-7Bt
176	35.70	3.28	16.39	0.02	24.71	0.48	5.34	0.06	0.10	9.48	95.55	M4017-7Bt
177	35.74	3.11	16.52	0.06	24.95	0.49	5.18	0.02	0.09	9.67	95.82	M4017-7Bt
Bt avg	35.73	3.23	16.41	0.03	24.84	0.46	5.22	0.04	0.08	9.58	95.63	
std dev	0.02	0.11	0.10	0.03	0.12	0.04	0.10	0.02	0.02	0.10	0.17	
190	37.74	4.90	13.65	0.28	11.70	0.07	15.27	0.04	0.07	9.85	93.56	M12350-2Bt
191	38.75	5.55	14.01	0.25	12.30	0.05	14.97	0.06	0.09	9.74	95.77	M12350-2Bt
192	38.31	5.03	13.79	0.29	11.71	0.03	14.86	0.07	0.07	9.61	93.78	M12350-2Bt
Bt avg	38.27	5.16	13.82	0.27	11.90	0.05	15.03	0.06	0.08	9.73	94.37	
std dev	0.50	0.34	0.18	0.02	0.35	0.02	0.21	0.02	0.01	0.12	1.22	
87	37.03	3.82	14.07	0.02	18.01	0.05	11.61	0.06	0.13	9.54	94.34	M12351a-1Bt
88	36.73	3.77	14.06	0.00	18.18	0.06	11.70	0.07	0.06	9.51	94.15	M12351a-1Bt
104	37.24	3.82	14.16	0.06	17.55	0.06	11.86	0.06	0.11	9.41	94.32	M12351a-3Bt
105	37.45	3.72	14.15	0.03	17.59	0.05	12.10	0.06	0.08	9.40	94.62	M12351a-3Bt
106	36.87	3.78	14.35	0.02	17.41	0.08	11.98	0.10	0.16	9.11	93.85	M12351a-3Bt
116	37.53	3.92	14.15	0.02	19.03	0.06	11.33	0.07	0.09	9.67	95.87	M12351a-5Bt
117	36.73	3.88	13.96	0.15	18.78	0.10	11.05	0.07	0.07	9.42	94.21	M12351a-5Bt

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
118	37.58	3.82	14.27	0.00	18.78	0.05	11.35	0.09	0.10	9.53	95.56	M12351a-5Bt
Bt avg	37.15	3.82	14.15	0.04	18.17	0.06	11.62	0.07	0.10	9.45	94.61	
std dev	0.35	0.06	0.12	0.05	0.63	0.02	0.36	0.01	0.03	0.16	0.72	
335	35.50	5.01	15.25	0.00	18.32	0.13	10.99	0.05	0.13	9.34	94.73	M12352a-2Bt1
336	35.71	4.89	15.21	0.01	18.39	0.12	11.27	0.05	0.11	9.41	95.16	M12352a-2Bt2
359	35.91	5.07	15.76	0.00	18.13	0.14	10.91	0.00	0.11	9.88	95.91	M12352a-4Bt1
360	35.51	4.66	15.48	0.01	18.21	0.10	11.04	0.02	0.10	9.65	94.78	M12352a-4Bt2
361	36.06	5.02	15.87	0.01	18.30	0.12	10.68	0.05	0.10	9.73	95.94	M12352a-4Bt3
Bt avg	35.74	4.93	15.51	0.01	18.27	0.12	10.98	0.03	0.11	9.60	95.30	
std dev	0.25	0.16	0.30	0.01	0.10	0.01	0.21	0.02	0.01	0.22	0.59	
51	37.05	4.92	15.73	0.00	19.39	0.05	10.10	0.04	0.09	9.79	97.16	M12352b-3Bt
52	36.29	4.74	15.22	0.00	19.30	0.10	10.26	0.07	0.14	9.46	95.57	M12352b-3Bt
53	37.92	5.13	16.39	0.00	20.05	0.08	9.61	0.07	0.12	9.73	99.10	M12352b-3Bt
59	36.33	4.48	15.53	0.00	18.90	0.00	10.43	0.09	0.14	9.38	95.28	M12352b-4Bt
60	28.77	3.85	14.04	0.00	19.49	0.05	9.03	0.13	0.16	7.54	83.06	M12352b-4Bt
61	36.07	4.36	15.81	0.01	19.65	0.02	10.50	0.11	0.10	8.65	95.27	M12352b-4Bt
77	36.54	4.81	15.68	0.00	18.15	0.10	9.66	0.02	0.10	9.67	94.73	M12352b-9Bt
78	36.18	4.97	15.35	0.01	18.69	0.11	10.02	0.03	0.13	9.70	95.19	M12352b-9Bt
80	45.22	2.74	16.87	0.04	13.63	0.03	7.38	0.07	0.15	11.33	97.46	M12352b-9Bt
Bt avg	36.71	4.44	15.63	0.01	18.58	0.06	9.66	0.07	0.12	9.47	94.76	
std dev	4.15	0.75	0.79	0.01	1.94	0.04	0.97	0.04	0.03	1.01	4.61	
96	31.40	0.00	15.82	0.01	21.60	0.32	16.02	0.13	0.07	0.28	85.64	M12354-1Bt
97	30.71	0.00	15.47	0.04	18.53	0.25	18.32	0.10	0.08	0.11	83.60	M12354-1Bt
98	30.56	0.00	16.05	0.00	21.27	0.29	15.95	0.15	0.09	0.12	84.49	M12354-1Bt
99	30.99	0.00	14.78	0.01	15.63	0.28	20.24	0.19	0.07	0.10	82.28	M12354-1Bt
Chl avg	30.91	0.00	15.53	0.01	19.26	0.28	17.63	0.14	0.08	0.15	84.00	
std dev	0.37	0.00	0.56	0.02	2.78	0.03	2.06	0.04	0.01	0.09	1.42	
64	38.13	4.28	13.14	0.00	12.84	0.25	15.97	0.08	0.08	9.57	94.34	M12549-4Bt
67	38.37	4.12	13.03	0.00	12.39	0.30	16.32	0.08	0.08	9.59	94.29	M12549-4Bt
92	37.19	4.50	13.60	0.00	14.07	0.15	14.09	0.10	0.07	9.18	92.95	M12549-10Bt
93	37.38	4.73	13.68	0.04	14.19	0.11	13.73	0.07	0.09	8.98	92.98	M12549-10Bt
94	38.49	3.85	14.96	0.06	13.32	0.13	13.42	0.11	0.02	8.82	93.17	M12549-10Bt
95	37.99	4.19	14.34	0.00	13.08	0.05	13.91	0.09	0.06	9.07	92.78	M12549-10Bt
Bt avg	37.92	4.28	13.79	0.02	13.32	0.16	14.57	0.09	0.07	9.20	93.42	
std dev	0.53	0.31	0.74	0.03	0.70	0.09	1.24	0.02	0.03	0.32	0.71	
1	36.52	4.54	15.87	0.00	17.13	0.05	10.88	0.07	0.13	9.31	94.50	M12636-8Bt
2	35.93	4.15	15.79	0.05	17.16	0.01	11.43	0.06	0.10	9.18	93.86	M12636-8Bt
3	35.61	4.43	15.72	0.08	17.30	0.04	10.73	0.00	0.10	9.22	93.23	M12636-8Bt
4	36.31	4.21	15.79	0.07	17.01	0.05	11.21	0.07	0.10	9.41	94.22	M12636-8Bt
5	35.60	4.28	15.67	0.05	17.54	0.00	11.03	0.05	0.10	9.21	93.53	M12636-8Bt
27	36.92	3.34	16.22	0.03	13.73	0.04	14.42	0.03	0.14	9.84	94.72	M12636-5Bt
28	36.78	3.19	15.76	0.06	13.50	0.01	14.10	0.07	0.13	9.53	93.13	M12636-5Bt
29	36.96	3.13	16.17	0.05	13.98	0.01	14.01	0.04	0.13	9.66	94.13	M12636-5Bt
30	35.76	3.51	15.53	0.02	13.71	0.01	14.06	0.04	0.18	9.70	92.52	M12636-5Bt
31	36.77	3.49	16.11	0.02	13.83	0.03	13.89	0.07	0.10	9.45	93.77	M12636-5Bt
Bt avg	36.32	3.83	15.86	0.04	15.49	0.03	12.58	0.05	0.12	9.45	93.76	
std dev	0.55	0.55	0.23	0.02	1.84	0.02	1.62	0.02	0.03	0.23	0.67	
17	37.55	4.32	15.66	0.02	17.22	0.06	11.45	0.04	0.08	9.91	96.31	M12637-4Bt
18	38.12	4.28	16.72	0.06	16.60	0.07	10.66	0.03	0.06	9.30	95.88	M12637-4Bt
19	36.77	4.67	15.88	0.07	17.16	0.04	11.33	0.02	0.08	9.82	95.84	M12637-4Bt
20	35.70	4.34	14.74	0.04	17.52	0.04	11.79	0.00	0.08	9.68	93.92	M12637-4Bt
24	36.83	4.09	15.51	0.03	17.49	0.09	11.48	0.03	0.10	9.78	95.43	M12637-5Bt
25	37.41	4.16	15.82	0.07	17.51	0.04	11.71	0.03	0.12	9.87	96.74	M12637-5Bt
26	37.00	4.13	15.92	0.08	17.31	0.07	11.61	0.03	0.13	9.78	96.06	M12637-5Bt
27	37.61	3.87	15.75	0.03	17.27	0.03	12.15	0.07	0.08	9.81	96.67	M12637-5Bt
Bt avg	37.12	4.23	15.75	0.05	17.26	0.05	11.52	0.03	0.09	9.74	95.86	
std dev	0.73	0.23	0.54	0.02	0.30	0.02	0.43	0.02	0.02	0.19	0.89	
1	37.83	5.67	12.51	0.00	14.95	0.09	13.98	0.01	0.07	10.20	95.31	M12639-1Bt1
2	37.85	5.51	12.68	0.00	14.90	0.11	14.03	0.01	0.06	9.99	95.15	M12639-1Bt2
3	37.78	5.84	12.53	0.04	15.15	0.09	13.62	0.00	0.08	9.98	95.09	M12639-1Bt3
4	37.57	5.07	12.65	0.01	14.37	0.11	14.47	0.00	0.09	9.86	94.19	M12639-1Bt4
24	38.33	5.22	12.87	0.00	14.40	0.10	14.60	0.04	0.11	9.95	95.61	M12639-5Bt1
25	37.96	5.82	12.86	0.03	14.85	0.05	14.00	0.05	0.11	9.95	95.66	M12639-5Bt2
26	38.06	5.82	12.95	0.00	14.92	0.05	13.92	0.04	0.09	10.14	95.99	M12639-5Bt3
27	38.46	5.25	12.81	0.00	14.33	0.07	14.46	0.07	0.09	10.08	95.62	M12639-5Bt4
Bt avg	37.98	5.52	12.73	0.01	14.73	0.08	14.14	0.03	0.09	10.02	95.33	
std dev	0.29	0.31	0.16	0.02	0.32	0.03	0.34	0.03	0.02	0.11	0.55	
36	36.22	5.64	15.07	0.04	17.67	0.02	10.58	0.02	0.06	10.07	95.37	M12640-1Bt1
37	36.38	6.26	14.59	0.05	18.50	0.06	10.22	0.00	0.04	10.08	96.17	M12640-1Bt2
38	36.15	5.63	15.18	0.01	18.04	0.03	10.55	0.01	0.11	10.00	95.72	M12640-1Bt3
39	36.57	5.38	15.08	0.06	18.18	0.05	10.84	0.02	0.04	9.96	96.17	M12640-1Bt4
47	36.09	5.57	14.77	0.04	19.46	0.06	10.39	0.01	0.04	9.98	96.40	M12640-3Bt1

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
48	36.84	5.36	14.91	0.00	19.88	0.08	10.37	0.02	0.08	9.96	97.49	M12640-3Bt2
49	36.37	5.33	14.85	0.01	19.52	0.03	10.61	0.00	0.05	9.91	96.68	M12640-3Bt3
50	36.36	5.71	14.82	0.07	19.50	0.06	10.43	0.00	0.04	10.06	97.03	M12640-3Bt4
55	36.41	5.53	14.90	0.02	19.69	0.07	9.92	0.07	0.07	9.60	96.27	M12640-5Bt1
56	35.27	5.49	14.12	0.02	19.75	0.07	10.08	0.08	0.10	9.52	94.49	M12640-5Bt2
57	35.43	5.34	14.09	0.05	19.90	0.04	9.69	0.06	0.06	9.42	94.07	M12640-5Bt3
58	35.77	5.34	14.32	0.00	19.71	0.05	10.26	0.05	0.05	9.70	95.25	M12640-5Bt4
Bt avg	36.15	5.55	14.73	0.03	19.15	0.05	10.33	0.03	0.06	9.85	95.93	
std dev	0.46	0.26	0.37	0.02	0.81	0.02	0.32	0.03	0.02	0.23	1.00	
108	35.21	5.35	13.30	0.00	21.77	0.09	8.82	0.08	0.10	9.37	94.08	M12643-5Bt
110	36.93	5.37	13.14	0.00	21.92	0.08	9.18	0.05	0.08	9.66	96.40	M12643-5Bt
111	36.24	4.92	13.53	0.01	22.24	0.10	9.40	0.11	0.12	9.09	95.75	M12643-6Bt
Bt avg	36.13	5.21	13.32	0.00	21.98	0.09	9.13	0.08	0.10	9.37	95.41	
std dev	0.87	0.25	0.20	0.00	0.24	0.01	0.29	0.03	0.02	0.29	1.20	
10	35.51	3.21	15.36	0.03	23.73	0.09	8.06	0.03	0.10	7.53	93.66	N05a-1Bt
11	36.08	3.32	15.35	0.01	23.20	0.13	8.22	0.07	0.06	7.74	94.18	N05a-1Bt
12	34.84	3.25	15.30	0.02	24.28	0.12	8.75	0.09	0.08	6.68	93.41	N05a-1Bt
16	37.45	3.28	15.12	0.00	21.17	0.10	8.28	0.00	0.11	9.61	95.13	N05a-2Bt
17	37.53	3.56	14.87	0.00	21.60	0.07	8.29	0.00	0.09	9.55	95.55	N05a-2Bt
18	36.27	3.24	15.13	0.01	21.55	0.09	8.41	0.04	0.14	9.26	94.15	N05a-2Bt
29	36.27	0.27	17.80	0.00	21.96	0.17	8.23	0.12	0.34	8.78	93.95	N05a-3Bt
30	35.78	0.35	17.36	0.00	23.34	0.19	7.72	0.11	0.32	9.03	94.18	N05a-3Bt
31	35.71	0.94	17.00	0.03	24.45	0.22	7.14	0.17	0.36	8.67	94.68	N05a-3Bt
38	36.88	3.71	14.81	0.00	21.29	0.15	8.25	0.09	0.12	9.45	94.73	N05a-5Bt
39	36.61	3.60	14.82	0.03	21.36	0.11	8.27	0.05	0.10	9.57	94.52	N05a-5Bt
40	37.45	3.34	15.18	0.00	20.95	0.08	8.63	0.02	0.08	9.80	95.52	N05a-5Bt
Bt avg	36.36	2.67	15.68	0.01	22.41	0.13	8.19	0.07	0.16	8.81	94.47	
std dev	0.85	1.32	1.06	0.01	1.30	0.05	0.42	0.05	0.11	0.99	0.68	
47	54.95	0.09	1.58	0.04	19.21	0.01	6.41	0.03	0.04	10.12	92.48	N05c-1Bt
48	54.52	0.09	1.42	0.06	19.20	0.00	6.34	0.05	0.02	10.43	92.11	N05c-1Bt
49	55.91	0.10	1.46	0.03	17.92	0.03	6.82	0.00	0.03	10.31	92.61	N05c-1Bt
68	56.31	0.08	3.20	0.04	16.27	0.00	7.33	0.01	0.04	10.20	93.45	N05c-3Bt
69	55.76	0.11	1.97	0.00	17.08	0.02	7.53	0.01	0.04	10.75	93.28	N05c-3Bt
70	56.18	0.08	2.36	0.00	16.81	0.03	7.37	0.05	0.02	10.55	93.44	N05c-3Bt
Bt avg	55.61	0.09	2.00	0.03	17.75	0.02	6.97	0.02	0.03	10.39	92.90	
std dev	0.71	0.01	0.69	0.02	1.25	0.01	0.52	0.02	0.01	0.24	0.57	
8	37.79	5.18	13.89	0.16	14.80	0.00	14.09	0.03	0.09	9.79	95.83	HW3521-1Bt1
9	37.74	5.15	14.18	0.11	13.82	0.05	14.56	0.01	0.11	10.02	95.75	HW3521-1Bt2
10	37.69	4.31	14.48	0.13	12.67	0.00	15.50	0.03	0.09	9.84	94.74	HW3521-1Bt3
17	37.54	5.49	13.67	0.14	14.82	0.01	13.54	0.02	0.11	10.22	95.57	HW3521-2Bt1
18	37.37	5.23	13.66	0.22	15.01	0.03	13.23	0.03	0.10	10.14	95.04	HW3521-2Bt2
19	37.14	5.65	13.68	0.26	15.22	0.01	12.98	0.05	0.10	9.97	95.06	HW3521-2Bt3
47	37.29	5.40	14.27	0.08	14.43	0.01	13.84	0.00	0.08	10.17	95.59	HW3521-5Bt1
48	36.85	5.86	14.18	0.15	14.79	0.05	12.76	0.03	0.08	10.07	94.81	HW3521-5Bt2
49	36.54	5.84	14.08	0.09	15.00	0.03	13.00	0.00	0.14	10.01	94.71	HW3521-5Bt3
Bt avg	37.33	5.35	14.01	0.15	14.51	0.02	13.72	0.02	0.10	10.03	95.23	
std dev	0.43	0.47	0.30	0.06	0.80	0.02	0.89	0.01	0.02	0.15	0.45	
62	38.42	3.30	13.22	0.01	14.07	0.02	15.56	0.01	0.04	10.12	94.77	HW3522-1Bt1
63	36.47	5.51	13.73	0.13	16.47	0.03	12.73	0.01	0.04	9.90	95.01	HW3522-1Bt2
64	36.65	5.93	13.81	0.07	16.13	0.06	12.50	0.01	0.08	10.04	95.25	HW3522-1Bt3
71	36.84	5.50	13.65	0.09	15.56	0.00	13.24	0.02	0.02	10.09	95.02	HW3522-2Bt1
72	37.11	5.56	13.95	0.07	15.72	0.03	13.07	0.02	0.07	10.06	95.66	HW3522-2Bt2
73	36.99	5.52	13.68	0.08	15.57	0.02	13.53	0.00	0.07	9.97	95.41	HW3522-2Bt3
Bt avg	37.08	5.22	13.67	0.08	15.59	0.03	13.44	0.01	0.05	10.03	95.19	
std dev	0.70	0.96	0.25	0.04	0.82	0.02	1.10	0.01	0.02	0.08	0.32	
98	37.33	4.79	14.19	0.15	13.45	0.03	14.63	0.05	0.15	9.85	94.62	HW3523-1Bt1
99	36.77	5.06	14.39	0.15	13.31	0.02	14.30	0.05	0.14	9.82	94.00	HW3523-1Bt2
113	37.65	4.51	15.35	0.08	13.05	0.05	15.10	0.06	0.10	9.91	95.87	HW3523-2Bt1
114	37.01	5.33	14.97	0.15	13.83	0.03	14.19	0.06	0.13	9.63	95.32	HW3523-2Bt2
115	37.09	5.13	14.96	0.16	13.42	0.03	14.43	0.03	0.06	9.77	95.09	HW3523-2Bt3
131	37.42	5.24	14.69	0.16	14.42	0.02	13.90	0.00	0.13	9.91	95.88	HW3523-4Bt1
133	37.55	4.87	14.39	0.16	14.29	0.03	14.38	0.00	0.10	9.99	95.77	HW3523-4Bt3
Bt avg	37.26	4.99	14.70	0.14	13.68	0.03	14.42	0.04	0.12	9.84	95.22	
std dev	0.32	0.28	0.41	0.03	0.52	0.01	0.38	0.03	0.03	0.12	0.71	
146	37.23	4.63	14.38	0.12	13.80	0.04	14.86	0.02	0.15	9.66	94.89	HW3524-3Bt1
147	37.33	4.33	14.40	0.11	13.48	0.04	15.14	0.04	0.14	9.61	94.62	HW3524-3Bt2
149	37.47	4.76	14.24	0.12	13.63	0.03	14.64	0.07	0.19	9.65	94.81	HW3524-3Bt4
Bt avg	37.34	4.58	14.34	0.12	13.64	0.04	14.88	0.04	0.16	9.64	94.77	
std dev	0.12	0.22	0.08	0.01	0.16	0.00	0.25	0.02	0.03	0.03	0.14	
245	38.38	4.25	13.55	0.01	11.35	0.06	16.82	0.02	0.08	10.17	94.68	HW3527-1Bt1
246	38.59	4.57	13.42	0.03	11.85	0.07	16.78	0.01	0.02	10.33	95.68	HW3527-1Bt2
247	38.46	4.59	13.16	0.00	12.09	0.05	16.83	0.01	0.02	10.17	95.38	HW3527-1Bt3

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
278	37.90	4.90	13.24	0.00	12.36	0.05	16.11	0.06	0.02	9.94	94.58	HW3527-3Bt1
279	38.15	5.29	13.21	0.10	12.57	0.08	15.62	0.04	0.04	9.95	95.05	HW3527-3Bt2
280	38.31	4.49	13.55	0.04	11.35	0.08	16.81	0.06	0.04	10.10	94.83	HW3527-3Bt3
Bt avg	38.30	4.68	13.36	0.03	11.93	0.06	16.49	0.03	0.04	10.11	95.03	
std dev	0.24	0.36	0.18	0.04	0.51	0.01	0.51	0.02	0.02	0.15	0.43	

Ilmenite Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
199	0.04	50.98	0.05	0.03	50.36	0.47	0.76	0.02	0.05	0.00	102.76	M12350-4Ilm
200	0.04	49.77	0.05	0.10	51.16	0.46	0.68	0.00	0.00	0.01	102.26	M12350-4Ilm
201	0.07	49.46	0.06	0.04	51.60	0.43	0.47	0.01	0.03	0.00	102.16	M12350-4Ilm
202	0.06	50.20	0.05	0.04	50.66	0.49	0.61	0.00	0.01	0.01	102.12	M12350-4Ilm
203	0.03	51.05	0.05	0.09	49.62	0.90	0.70	0.00	0.02	0.00	102.46	M12350-4Ilm
Ilm avg	0.05	50.29	0.05	0.06	50.68	0.55	0.64	0.01	0.02	0.01	102.35	
Ilm norm	0.05	49.14	0.05	0.06	49.51	0.54	0.63	0.01	0.02	0.00	100.00	
std dev	0.02	0.71	0.01	0.03	0.76	0.20	0.11	0.01	0.02	0.00	0.26	
1	0.03	53.30	0.00	0.00	46.37	2.26	0.04	0.01	0.05	0.00	102.07	N05a-1Ilm
2	0.03	53.51	0.03	0.00	45.92	2.30	0.04	0.01	0.00	0.00	101.83	N05a-1Ilm
3	0.03	53.58	0.02	0.05	46.32	2.27	0.04	0.02	0.03	0.00	102.35	N05a-1Ilm
Ilm avg	0.03	53.46	0.02	0.02	46.20	2.28	0.04	0.01	0.03	0.00	102.08	
Ilm norm	0.03	52.37	0.02	0.02	45.26	2.23	0.04	0.01	0.03	0.00	100.00	
std dev	0.00	0.15	0.02	0.03	0.25	0.02	0.00	0.01	0.03	0.00	0.26	
165	0.06	47.52	0.09	0.02	48.99	0.36	1.22	0.02	0.02	0.01	98.29	HW3525-1Ilm1
166	0.06	47.82	0.06	0.01	48.47	0.38	1.24	0.01	0.06	0.01	98.11	HW3525-1Ilm2
167	0.07	47.85	0.05	0.00	48.76	0.37	1.16	0.01	0.02	0.01	98.30	HW3525-1Ilm3
186	0.02	48.37	0.04	0.09	48.97	0.29	1.37	0.00	0.05	0.00	99.21	HW3525-2Ilm1
187	0.02	49.82	0.08	0.05	47.78	0.34	1.35	0.00	0.00	0.00	99.43	HW3525-2Ilm2
196	0.03	48.48	0.03	0.05	48.86	0.52	0.78	0.00	0.04	0.00	98.78	HW3525-3Ilm2
197	0.02	48.00	0.06	0.05	49.26	0.52	0.71	0.00	0.00	0.00	98.63	HW3525-3Ilm3
Ilm avg	0.04	48.26	0.06	0.04	48.73	0.40	1.12	0.01	0.03	0.00	98.68	
Ilm norm	0.04	48.91	0.06	0.04	49.38	0.40	1.13	0.01	0.03	0.00	100.00	
std dev	0.02	0.76	0.02	0.03	0.48	0.09	0.26	0.01	0.02	0.00	0.49	
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**Comment**
207	0.04	47.99	0.08	0.05	49.45	0.31	1.21	0.00	0.05	0.00	99.18	HW3526-1Ilm1
208	0.04	48.84	0.08	0.00	48.27	0.22	1.23	0.03	0.06	0.01	98.76	HW3526-1Ilm2
209	0.03	48.37	0.09	0.05	48.45	0.28	1.25	0.00	0.01	0.00	98.52	HW3526-1Ilm3
Ilm avg	0.04	48.40	0.08	0.03	48.72	0.27	1.23	0.01	0.04	0.00	98.82	
Ilm norm	0.04	48.98	0.08	0.03	49.30	0.27	1.25	0.01	0.04	0.00	100.00	
std dev	0.00	0.42	0.01	0.03	0.64	0.05	0.02	0.01	0.03	0.00	0.33	
251	0.02	50.21	0.07	0.00	46.84	1.18	0.61	0.01	0.01	0.00	98.96	HW3527-1Ilm1
252	0.05	49.98	0.06	0.05	47.47	1.14	0.60	0.01	0.05	0.01	99.41	HW3527-1Ilm2
253	0.05	51.15	0.07	0.00	46.08	1.28	0.68	0.04	0.01	0.00	99.34	HW3527-1Ilm3
Ilm avg	0.04	50.45	0.06	0.02	46.80	1.20	0.63	0.02	0.02	0.00	99.23	
Ilm norm	0.04	50.84	0.06	0.02	47.16	1.21	0.63	0.02	0.02	0.00	100.00	
std dev	0.01	0.62	0.01	0.03	0.70	0.07	0.04	0.02	0.02	0.01	0.24	
296	0.03	47.44	0.07	0.01	48.35	1.22	0.89	0.02	0.03	0.00	98.07	HW3530-1Ilm1
297	0.04	47.82	0.06	0.00	48.45	1.24	0.87	0.03	0.05	0.00	98.57	HW3530-1Ilm2
298	0.01	49.08	0.07	0.00	47.13	1.25	0.84	0.02	0.01	0.02	98.43	HW3530-1Ilm3
Ilm avg	0.03	48.12	0.07	0.00	47.98	1.24	0.87	0.02	0.03	0.01	98.35	
Ilm norm	0.03	48.92	0.07	0.00	48.78	1.26	0.88	0.02	0.03	0.01	100.00	
std dev	0.01	0.86	0.01	0.01	0.73	0.02	0.02	0.00	0.02	0.01	0.26	
4	0.01	52.23	0.05	0.07	48.39	0.93	1.09	0.00	0.00	0.00	102.77	HW-1A-1Ilm
5	0.05	52.62	0.06	0.09	48.01	1.00	1.12	0.00	0.00	0.00	102.95	HW-1A-1Ilm
6	0.04	53.17	0.04	0.03	47.14	1.02	1.10	0.00	0.01	0.00	102.56	HW-1A-1Ilm
Ilm avg	0.03	52.67	0.05	0.06	47.85	0.99	1.10	0.00	0.00	0.00	102.76	
Ilm norm	0.03	51.26	0.05	0.06	46.56	0.96	1.07	0.00	0.00	0.00	100.00	
std dev	0.02	0.47	0.01	0.03	0.64	0.05	0.01	0.00	0.01	0.00	0.20	

Pseudorutile Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	Total	Comment
95	0.17	59.90	0.17	0.00	39.14	0.09	0.06	0.06	0.04	0.00	99.63	M3997-3P-rut
96	0.12	59.20	0.15	0.05	39.75	0.08	0.03	0.09	0.03	0.01	99.51	M3997-3P-rut
97	0.16	59.80	0.13	0.04	39.30	0.05	0.07	0.07	0.09	0.00	99.71	M3997-3P-rut
P-rut avg	0.15	59.63	0.15	0.03	39.40	0.07	0.05	0.07	0.05	0.00	99.60	
P-rut norm	0.15	59.87	0.15	0.03	39.56	0.07	0.05	0.07	0.05	0.00	100.00	
std dev	0.02	0.38	0.02	0.03	0.32	0.02	0.02	0.02	0.03	0.00	0.10	
123	0.10	58.96	0.12	0.07	37.72	2.12	0.04	0.03	0.03	0.00	99.19	M4002a-4P-rut
124	0.05	60.14	0.08	0.10	36.84	2.71	0.03	0.03	0.02	0.01	100.01	M4002a-4P-rut
125	0.13	60.58	0.09	0.09	37.72	1.97	0.06	0.02	0.03	0.02	100.71	M4002a-4P-rut
P-rut avg	0.10	59.90	0.09	0.09	37.42	2.27	0.04	0.03	0.03	0.01	99.98	
P-rut norm	0.10	59.91	0.09	0.09	37.43	2.27	0.04	0.03	0.03	0.01	100.00	
std dev	0.04	0.84	0.02	0.02	0.51	0.39	0.02	0.01	0.01	0.01	0.76	

No.	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	Total	Comment
347	0.89	52.95	0.80	0.00	36.66	1.07	0.17	0.04	0.01	0.07	92.66	M12352a-3P-rut
348	0.76	51.75	0.73	0.01	37.97	1.90	0.22	0.03	0.02	0.05	93.44	M12352a-3P-rut
349	0.20	51.40	0.16	0.04	41.03	0.92	0.18	0.01	0.04	0.02	94.00	M12352a-3P-rut
P-rut avg	0.62	52.03	0.56	0.02	38.55	1.30	0.19	0.03	0.02	0.05	93.37	
P-rut norm	0.66	55.73	0.60	0.02	41.29	1.39	0.20	0.03	0.02	0.05	100.00	
std dev	0.37	0.81	0.35	0.02	2.24	0.53	0.03	0.02	0.02	0.03	0.67	
138	0.16	61.39	0.17	0.05	35.12	0.13	0.09	0.08	0.11	0.01	97.31	M12638-2P-rut
139	0.21	60.52	0.18	0.01	36.06	0.84	0.10	0.06	0.04	0.01	98.03	M12638-2P-rut
140	0.08	60.67	0.07	0.00	35.11	0.58	0.08	0.02	0.04	0.00	96.65	M12638-2P-rut
P-rut avg	0.15	60.86	0.14	0.02	35.43	0.52	0.09	0.05	0.06	0.01	97.33	
P-rut norm	0.15	62.53	0.14	0.02	36.40	0.53	0.09	0.05	0.07	0.01	100.00	
std dev	0.07	0.47	0.06	0.03	0.55	0.36	0.01	0.03	0.04	0.01	0.69	
115	3.45	54.12	2.23	0.02	31.79	0.17	0.67	0.62	0.08	0.07	93.22	M12643-7P-rut
116	0.15	59.96	0.07	0.05	37.15	3.10	0.14	0.03	0.03	0.01	100.69	M12643-7P-rut
119	0.58	57.69	0.31	0.03	38.13	1.81	0.24	0.04	0.01	0.01	98.85	M12643-7P-rut
P-rut avg	1.39	57.26	0.87	0.03	35.69	1.69	0.35	0.23	0.04	0.03	97.59	
P-rut norm	1.43	58.67	0.89	0.03	36.57	1.74	0.36	0.24	0.04	0.03	100.00	
std dev	1.79	2.94	1.18	0.02	3.41	1.47	0.28	0.34	0.04	0.03	3.89	
19	0.04	59.90	0.06	0.00	39.22	1.73	0.05	0.02	0.00	0.00	101.02	N05a-2P-rut
20	0.08	59.14	0.06	0.01	39.47	2.42	0.13	0.00	0.00	0.00	101.31	N05a-2P-rut
21	0.20	58.52	0.14	0.00	38.02	2.05	0.05	0.01	0.00	0.02	99.01	N05a-2P-rut
P-rut avg	0.11	59.19	0.09	0.00	38.90	2.07	0.08	0.01	0.00	0.01	100.45	
P-rut norm	0.11	58.92	0.09	0.00	38.73	2.06	0.08	0.01	0.00	0.01	100.00	
std dev	0.08	0.69	0.05	0.01	0.78	0.35	0.05	0.01	0.00	0.01	1.25	
56	0.12	59.08	0.98	0.06	34.83	2.83	0.12	0.01	0.01	0.02	98.06	N05c-2P-rut
57	0.08	59.55	0.10	0.03	39.82	0.81	0.06	0.03	0.02	0.01	100.51	N05c-2P-rut
58	0.08	60.46	0.09	0.01	38.33	1.16	0.04	0.02	0.02	0.00	100.21	N05c-2P-rut
P-rut avg	0.09	59.70	0.39	0.03	37.66	1.60	0.07	0.02	0.02	0.01	99.59	
P-rut norm	0.09	59.94	0.39	0.03	37.81	1.61	0.07	0.02	0.02	0.01	100.00	
std dev	0.02	0.70	0.51	0.03	2.56	1.08	0.04	0.01	0.01	0.01	1.34	
89	0.44	64.97	0.37	0.00	31.44	0.03	0.15	0.22	0.06	0.01	97.69	HW-3A-4P-rut
90	0.51	66.39	0.45	0.06	29.13	0.00	0.10	0.22	0.09	0.01	96.96	HW-3A-4P-rut
91	0.46	67.40	0.40	0.02	28.08	0.02	0.17	0.23	0.03	0.00	96.81	HW-3A-4P-rut
P-rut avg	0.47	66.25	0.41	0.03	29.55	0.02	0.14	0.22	0.06	0.01	97.15	
P-rut norm	0.48	68.19	0.42	0.03	30.42	0.02	0.14	0.23	0.06	0.01	100.00	
std dev	0.04	1.22	0.04	0.03	1.72	0.02	0.04	0.01	0.03	0.01	0.47	

Rutile Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
47	0.58	103.18	0.23	0.00	0.29	0.02	0.04	0.14	0.07	0.01	104.56	M4002b-1Rt
48	0.27	103.51	0.15	0.12	0.36	0.00	0.00	0.07	0.00	0.00	104.48	M4002b-1Rt
49	0.21	102.62	0.21	0.00	0.81	0.05	0.02	0.12	0.02	0.01	104.07	M4002b-1Rt
69	0.54	99.33	0.44	0.01	0.90	0.05	0.25	0.04	0.02	0.03	101.61	M4002b-6Rt
70	0.46	100.17	0.19	0.02	0.43	0.00	0.05	0.15	0.07	0.06	101.60	M4002b-6Rt
71	2.21	95.04	1.35	0.02	2.14	0.05	0.67	0.12	0.04	0.07	101.70	M4002b-6Rt
Rt avg	0.71	100.64	0.43	0.03	0.82	0.03	0.17	0.11	0.04	0.03	103.00	
std dev	0.75	3.22	0.46	0.05	0.69	0.02	0.26	0.04	0.03	0.03	1.51	

Hematite Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
47	0.18	0.05	0.09	0.04	88.44	0.01	0.03	0.02	0.02	0.01	88.87	M3796-1Hm
49	0.07	0.04	0.09	0.00	88.31	0.09	0.07	0.01	0.07	0.01	88.75	M3796-1Hm
68	0.20	0.12	0.14	0.03	88.50	0.05	0.05	0.02	0.00	0.00	89.12	M3796-3Hm
69	0.12	0.11	0.06	0.00	88.53	0.04	0.03	0.02	0.02	0.02	88.95	M3796-3Hm
Hm avg	0.14	0.08	0.09	0.02	88.45	0.05	0.05	0.02	0.03	0.01	88.92	
std dev	0.06	0.04	0.03	0.02	0.10	0.04	0.02	0.00	0.03	0.01	0.16	
338	0.10	0.23	0.45	0.11	86.98	0.03	0.04	0.02	0.06	0.01	88.03	M12352a-2Hm1
339	0.29	0.15	0.54	0.12	86.94	0.00	0.05	0.02	0.08	0.04	88.23	M12352a-2Hm2
340	0.37	0.11	0.53	0.12	86.85	0.01	0.07	0.03	0.05	0.03	88.17	M12352a-2Hm3
Hm avg	0.25	0.16	0.51	0.12	86.92	0.01	0.05	0.02	0.07	0.03	88.14	
std dev	0.14	0.06	0.05	0.00	0.06	0.02	0.02	0.01	0.01	0.01	0.10	
50	0.31	0.03	0.47	0.10	88.87	0.04	0.03	0.09	0.06	0.00	89.98	M12549-1Hm
51	0.43	0.00	0.51	0.04	88.92	0.00	0.07	0.06	0.00	0.01	90.04	M12549-1Hm
52	0.42	0.00	0.50	0.08	88.19	0.00	0.01	0.01	0.05	0.01	89.28	M12549-1Hm
53	0.40	0.03	0.41	0.05	88.59	0.03	0.05	0.01	0.06	0.02	89.64	M12549-1Hm
54	0.21	0.04	0.42	0.04	88.83	0.03	0.04	0.01	0.03	0.01	89.67	M12549-1Hm
87	0.15	0.02	0.18	0.14	88.05	0.01	0.01	0.00	0.00	0.00	88.55	M12549-9Hm
88	0.11	0.00	0.25	0.12	88.34	0.03	0.06	0.00	0.08	0.00	88.99	M12549-9Hm
89	0.15	0.04	0.24	0.13	88.08	0.03	0.05	0.04	0.01	0.01	88.76	M12549-9Hm
90	0.17	0.06	0.22	0.14	87.40	0.04	0.06	0.01	0.03	0.00	88.12	M12549-9Hm
91	0.15	0.02	0.18	0.15	87.90	0.01	0.06	0.03	0.06	0.02	88.57	M12549-9Hm

No.	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	Total	Comment
Hm avg	0.25	0.02	0.34	0.10	88.32	0.02	0.04	0.03	0.04	0.01	89.16	
std dev	0.13	0.02	0.14	0.04	0.49	0.02	0.02	0.03	0.03	0.01	0.66	
132	0.18	0.10	0.38	0.00	87.84	0.02	0.03	0.01	0.09	0.00	88.66	M12638-1Hm
133	0.32	0.06	0.42	0.02	87.66	0.02	0.06	0.04	0.09	0.02	88.69	M12638-1Hm
134	0.44	0.06	0.62	0.00	87.04	0.00	0.09	0.03	0.00	0.03	88.31	M12638-1Hm
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**	**Comment**
141	0.19	0.03	0.39	0.10	87.56	0.01	0.08	0.03	0.07	0.02	88.47	M12638-2Hm
142	0.20	0.07	0.30	0.07	88.20	0.02	0.06	0.05	0.04	0.00	89.01	M12638-2Hm
143	0.51	0.34	0.45	0.13	86.73	0.06	0.04	0.03	0.07	0.04	88.39	M12638-2Hm
160	0.10	0.04	0.32	0.12	88.81	0.03	0.01	0.02	0.04	0.01	89.50	M12638-4Hm
161	0.23	0.05	0.39	0.10	87.75	0.05	0.04	0.01	0.02	0.02	88.65	M12638-4Hm
162	0.41	0.21	0.44	0.21	87.35	0.03	0.11	0.01	0.05	0.02	88.84	M12638-4Hm
Hm avg	0.28	0.11	0.41	0.08	87.66	0.03	0.06	0.03	0.05	0.02	88.72	
std dev	0.14	0.10	0.09	0.07	0.61	0.02	0.03	0.01	0.03	0.01	0.36	
130	0.09	0.10	0.34	0.05	87.95	0.03	0.04	0.01	0.01	0.00	88.62	N06c-3Hm
131	0.06	0.04	0.46	0.04	87.75	0.00	0.02	0.00	0.00	0.01	88.38	N06c-3Hm
132	0.07	0.04	0.49	0.01	87.55	0.05	0.05	0.00	0.05	0.01	88.32	N06c-3Hm
Hm avg	0.07	0.06	0.43	0.03	87.75	0.03	0.04	0.00	0.02	0.01	88.44	
std dev	0.02	0.03	0.08	0.02	0.20	0.03	0.02	0.01	0.03	0.00	0.16	
299	0.07	0.02	0.38	0.03	86.29	0.00	0.05	0.00	0.03	0.01	86.87	HW3530-1Hm
300	0.16	0.12	0.47	0.03	86.13	0.04	0.06	0.01	0.07	0.00	87.08	HW3530-1Hm
322	0.50	0.33	0.50	0.01	87.46	0.03	0.12	0.03	0.01	0.00	88.98	HW3530-4Hm
Hm avg	0.24	0.16	0.45	0.02	86.62	0.02	0.08	0.01	0.04	0.00	87.64	
std dev	0.23	0.16	0.06	0.01	0.72	0.02	0.04	0.01	0.03	0.00	1.16	
80	0.08	0.06	0.32	0.01	86.83	0.05	0.05	0.01	0.07	0.00	87.47	HW-3A-3Hm
81	0.08	0.09	0.41	0.04	87.66	0.04	0.05	0.01	0.01	0.01	88.40	HW-3A-3Hm
82	0.05	0.03	0.33	0.02	87.16	0.00	0.06	0.00	0.07	0.00	87.72	HW-3A-3Hm
92	0.21	0.00	0.30	0.10	85.94	0.02	0.08	0.03	0.07	0.00	86.75	HW-3A-4Hm
93	0.12	0.02	0.33	0.08	86.00	0.05	0.08	0.02	0.03	0.00	86.73	HW-3A-4Hm
94	0.13	0.10	0.31	0.10	85.86	0.03	0.03	0.01	0.06	0.00	86.63	HW-3A-4Hm
Hm avg	0.11	0.05	0.33	0.06	86.58	0.03	0.06	0.01	0.05	0.00	87.28	
std dev	0.06	0.04	0.04	0.04	0.75	0.02	0.02	0.01	0.03	0.00	0.71	

Magnetite Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total	Comment
48	0.04	0.02	0.07	0.01	92.13	0.06	0.03	0.01	0.00	0.00	92.36	M3796-1Mt
70	0.09	0.02	0.10	0.00	92.28	0.04	0.00	0.01	0.01	0.01	92.55	M3796-3Mt
Mt avg	0.06	0.02	0.09	0.00	92.21	0.05	0.02	0.01	0.00	0.00	92.45	
std dev	0.03	0.00	0.02	0.00	0.11	0.01	0.02	0.00	0.00	0.01	0.13	
184	0.09	13.39	0.18	0.33	77.91	0.11	0.25	0.01	0.01	0.01	92.30	M12350-tita-Mt
185	0.08	12.25	0.21	0.33	78.71	0.09	0.20	0.02	0.04	0.01	91.94	M12350-tita-Mt
186	0.08	14.11	0.19	0.33	77.74	0.11	0.25	0.01	0.03	0.00	92.84	M12350-tita-Mt
titanomagnetite avg	0.08	13.25	0.19	0.33	78.12	0.10	0.23	0.01	0.03	0.01	92.36	
std dev	0.01	0.94	0.01	0.00	0.52	0.01	0.03	0.01	0.01	0.01	0.46	
113	0.05	0.09	0.27	0.08	92.20	0.02	0.04	0.02	0.00	0.01	92.78	N06c-1Mt
114	0.08	0.00	0.23	0.09	92.29	0.02	0.03	0.00	0.05	0.00	92.77	N06c-1Mt
121	0.04	0.10	0.36	0.11	92.40	0.01	0.01	0.00	0.04	0.02	93.07	N06c-2Mt
122	0.08	0.12	0.44	0.09	92.43	0.01	0.04	0.00	0.03	0.00	93.23	N06c-2Mt
123	0.05	0.12	0.44	0.05	91.79	0.02	0.03	0.00	0.05	0.00	92.55	N06c-2Mt
Mt avg	0.06	0.08	0.35	0.08	92.22	0.02	0.03	0.00	0.03	0.00	92.88	
std dev	0.02	0.05	0.10	0.02	0.26	0.01	0.01	0.01	0.02	0.01	0.27	
254	0.05	0.07	0.35	0.52	91.90	0.01	0.06	0.01	0.00	0.01	92.97	HW3527-1Mt1
255	0.06	0.01	0.33	0.49	92.18	0.04	0.05	0.01	0.05	0.00	93.22	HW3527-1Mt2
256	0.05	0.09	0.35	0.52	91.21	0.02	0.04	0.02	0.00	0.00	92.30	HW3527-1Mt3
266	0.07	0.03	0.47	0.46	91.91	0.06	0.03	0.00	0.03	0.01	93.09	HW3527-2Mt1
267	0.08	0.05	0.48	0.57	91.57	0.00	0.08	0.00	0.02	0.01	92.84	HW3527-2Mt2
268	0.07	0.08	0.43	0.50	91.67	0.00	0.04	0.00	0.00	0.01	92.79	HW3527-2Mt3
281	0.13	0.03	0.25	0.44	91.61	0.02	0.02	0.01	0.04	0.00	92.54	HW3527-3Mt1
282	0.07	0.09	0.47	0.40	91.82	0.05	0.06	0.02	0.02	0.00	93.00	HW3527-3Mt2
283	0.06	0.08	1.80	0.44	89.95	0.03	0.23	0.03	0.03	0.00	92.66	HW3527-3Mt3
Mt avg	0.07	0.06	0.55	0.48	91.53	0.02	0.07	0.01	0.02	0.00	92.82	
std dev	0.02	0.03	0.48	0.05	0.65	0.02	0.06	0.01	0.02	0.01	0.29	
301	0.05	0.17	0.32	0.02	91.46	0.06	0.06	0.01	0.03	0.00	92.17	HW3530-1Mt3
320	0.08	0.40	0.35	0.10	92.32	0.05	0.09	0.01	0.02	0.00	93.41	HW3530-4Mt1
321	0.05	0.40	0.25	0.02	92.24	0.04	0.06	0.00	0.00	0.00	93.06	HW3530-4Mt2
Mt avg	0.06	0.32	0.30	0.05	92.01	0.05	0.07	0.01	0.02	0.00	92.88	
std dev	0.02	0.13	0.05	0.04	0.48	0.01	0.02	0.01	0.01	0.00	0.64	
1	0.04	0.03	0.33	0.16	91.45	0.07	0.08	0.00	0.04	0.01	92.20	HW-1A-1Mt
2	0.07	0.15	0.34	0.14	91.44	0.04	0.09	0.00	0.07	0.01	92.35	HW-1A-1Mt
3	0.06	0.03	0.19	0.15	91.37	0.01	0.01	0.00	0.01	0.00	91.84	HW-1A-1Mt

No.	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	Total	Comment
Mt avg	0.06	0.07	0.28	0.15	91.42	0.04	0.06	0.00	0.04	0.01	92.13	
std dev	0.02	0.07	0.08	0.01	0.05	0.03	0.04	0.00	0.03	0.00	0.26	
53	0.11	0.04	0.21	0.37	91.06	0.00	0.01	0.06	0.04	0.00	91.90	HW-2A-3Mt
54	0.29	0.09	0.41	0.39	90.69	0.00	0.01	0.01	0.00	0.01	91.89	HW-2A-3Mt
55	0.08	0.05	0.18	0.38	90.69	0.07	0.02	0.00	0.00	0.00	91.46	HW-2A-3Mt
Mt avg	0.16	0.06	0.27	0.38	90.81	0.02	0.01	0.02	0.01	0.00	91.75	
std dev	0.11	0.03	0.13	0.01	0.22	0.04	0.01	0.03	0.02	0.01	0.25	

Electron Microprobe Analyses for synthetic test mix

Potassium Feldspar Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
176	64.58	0.03	18.77	0.00	0.08	0.00	0.03	0.17	3.17	11.60	98.41
177	64.68	0.04	18.85	0.00	0.08	0.02	0.00	0.21	3.07	11.37	98.32
179	64.72	0.02	18.70	0.00	0.08	0.00	0.04	0.15	3.08	11.58	98.35
181	64.27	0.03	19.00	0.00	0.11	0.02	0.00	0.24	3.19	11.35	98.22
182	64.64	0.02	18.83	0.00	0.12	0.06	0.02	0.18	3.20	11.57	98.63
183	64.44	0.03	18.74	0.00	0.11	0.00	0.02	0.18	3.00	11.60	98.12
186	64.41	0.00	18.80	0.00	0.09	0.02	0.00	0.18	3.20	11.51	98.20
187	64.87	0.00	18.42	0.01	0.07	0.03	0.03	0.15	2.93	11.74	98.23
189	65.15	0.00	18.67	0.00	0.07	0.01	0.01	0.17	3.16	11.64	98.88
190	64.30	0.01	18.68	0.01	0.10	0.02	0.01	0.15	3.22	11.56	98.07
192	64.53	0.02	18.83	0.05	0.11	0.01	0.03	0.14	3.15	11.51	98.36
194	64.61	0.04	18.83	0.00	0.11	0.03	0.01	0.19	3.12	11.43	98.37
198	64.71	0.03	18.59	0.00	0.10	0.01	0.02	0.16	3.07	11.54	98.22
199	64.53	0.00	18.71	0.00	0.10	0.00	0.02	0.15	3.18	11.53	98.22
201	64.16	0.02	18.77	0.00	0.11	0.02	0.03	0.19	3.25	11.52	98.07
204	64.64	0.02	18.58	0.00	0.10	0.00	0.02	0.15	3.17	11.56	98.24
205	64.62	0.06	18.60	0.00	0.09	0.00	0.02	0.15	3.17	11.48	98.18
206	64.98	0.01	18.82	0.00	0.11	0.00	0.00	0.15	3.19	11.68	98.94
208	64.66	0.04	18.72	0.00	0.12	0.03	0.02	0.13	3.03	11.63	98.38
210	64.87	0.02	18.59	0.02	0.09	0.02	0.02	0.16	3.05	11.57	98.39
216	64.46	0.02	18.60	0.01	0.12	0.03	0.03	0.16	3.13	11.49	98.04
218	64.60	0.02	18.62	0.00	0.08	0.00	0.01	0.14	3.21	11.56	98.25
221	64.27	0.05	18.86	0.01	0.05	0.00	0.01	0.12	2.27	12.83	98.46
223	64.63	0.02	18.78	0.00	0.10	0.01	0.02	0.18	3.10	11.43	98.26
225	63.80	0.02	18.50	0.00	0.02	0.01	0.00	0.02	0.77	15.28	98.41
Kfs avg	64.56	0.02	18.71	0.00	0.09	0.01	0.02	0.16	3.00	11.74	98.33
std dev	0.28	0.01	0.13	0.01	0.02	0.01	0.01	0.04	0.50	0.79	0.22

Plagioclase Feldspar Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
226	64.89	0.01	21.35	0.04	0.11	0.00	0.01	2.33	9.77	0.44	98.96
227	64.91	0.00	21.26	0.00	0.05	0.00	0.04	2.40	9.75	0.43	98.83
228	65.11	0.00	21.47	0.00	0.10	0.00	0.03	2.34	10.03	0.42	99.51
229	65.24	0.01	21.46	0.01	0.10	0.00	0.02	2.36	9.96	0.43	99.60
230	64.90	0.00	21.48	0.00	0.07	0.01	0.02	2.34	9.89	0.46	99.17
231	65.00	0.00	21.45	0.01	0.12	0.01	0.00	2.33	9.87	0.42	99.21
232	65.18	0.00	21.37	0.00	0.10	0.02	0.03	2.35	10.02	0.43	99.50
233	65.15	0.00	21.51	0.04	0.08	0.01	0.01	2.36	9.96	0.44	99.57
234	64.82	0.03	21.36	0.03	0.07	0.04	0.02	2.35	9.81	0.42	98.94
235	65.82	0.01	21.26	0.00	0.01	0.01	0.02	2.22	10.13	0.18	99.66
236	65.02	0.00	21.50	0.00	0.13	0.00	0.01	2.32	10.00	0.45	99.43
237	65.28	0.00	21.49	0.02	0.13	0.00	0.00	2.31	9.89	0.43	99.56
238	65.10	0.01	21.24	0.00	0.07	0.00	0.01	2.36	9.96	0.42	99.16
239	65.25	0.02	21.63	0.00	0.07	0.01	0.01	2.34	9.96	0.44	99.72
240	65.19	0.00	21.48	0.02	0.09	0.02	0.02	2.33	9.90	0.46	99.50
241	65.00	0.04	21.38	0.02	0.10	0.03	0.01	2.32	9.96	0.41	99.26
242	65.05	0.01	21.33	0.00	0.09	0.01	0.00	2.32	10.04	0.46	99.31
243	65.12	0.00	21.39	0.03	0.08	0.00	0.04	2.34	10.03	0.45	99.46
244	65.27	0.04	21.45	0.00	0.10	0.02	0.00	2.39	9.92	0.45	99.63
245	64.84	0.01	21.25	0.01	0.09	0.00	0.01	2.35	9.87	0.45	98.87
246	65.16	0.01	21.39	0.03	0.08	0.00	0.02	2.36	9.89	0.41	99.34
247	64.83	0.00	21.48	0.00	0.08	0.00	0.00	2.34	9.91	0.44	99.07
248	65.24	0.00	21.37	0.00	0.11	0.00	0.01	2.35	9.88	0.45	99.41
249	64.96	0.01	21.45	0.00	0.06	0.01	0.02	2.38	9.98	0.43	99.30
250	64.84	0.00	21.30	0.01	0.08	0.01	0.02	2.29	9.98	0.43	98.95
252	64.97	0.01	21.49	0.00	0.14	0.02	0.01	2.31	9.88	0.43	99.26
253	65.17	0.07	21.60	0.00	0.07	0.02	0.01	2.32	9.97	0.43	99.67
254	64.78	0.03	21.48	0.00	0.09	0.00	0.00	2.40	9.97	0.42	99.17
255	65.01	0.01	21.53	0.07	0.10	0.01	0.01	2.31	9.83	0.42	99.31
256	65.02	0.00	21.56	0.00	0.11	0.03	0.00	2.35	9.93	0.41	99.39
257	65.02	0.00	21.39	0.00	0.09	0.00	0.02	2.38	9.90	0.44	99.23
258	65.15	0.05	21.33	0.01	0.11	0.00	0.02	2.34	9.97	0.45	99.44
259	65.08	0.00	21.39	0.00	0.06	0.00	0.01	2.29	9.93	0.39	99.16
260	64.95	0.00	21.45	0.00	0.08	0.03	0.02	2.36	9.92	0.46	99.26
261	65.03	0.02	21.45	0.00	0.09	0.00	0.01	2.35	9.83	0.46	99.24
262	65.03	0.05	21.40	0.06	0.08	0.03	0.01	2.31	9.82	0.44	99.22
263	64.93	0.03	21.31	0.00	0.09	0.00	0.01	2.33	9.81	0.42	98.93
264	64.89	0.01	21.25	0.00	0.10	0.00	0.00	2.32	9.87	0.47	98.89

No.	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	Total
265	65.21	0.05	21.35	0.02	0.09	0.00	0.01	2.37	9.94	0.45	99.49
266	64.80	0.00	21.44	0.00	0.08	0.01	0.01	2.35	9.78	0.40	98.87
267	64.93	0.02	21.42	0.01	0.08	0.00	0.01	2.30	9.93	0.44	99.13
268	65.36	0.00	21.39	0.00	0.10	0.03	0.02	2.34	9.96	0.45	99.64
269	65.33	0.02	21.48	0.05	0.08	0.03	0.02	2.35	10.07	0.43	99.84
270	65.15	0.01	21.40	0.00	0.11	0.00	0.01	2.30	9.92	0.43	99.31
271	65.19	0.02	21.30	0.00	0.11	0.03	0.00	2.33	9.99	0.44	99.41
272	64.98	0.02	21.35	0.00	0.07	0.03	0.01	2.38	9.85	0.41	99.10
No.	**SiO2**	**TiO2**	**Al2O3**	**Cr2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
273	65.46	0.03	21.67	0.04	0.06	0.02	0.02	2.31	10.09	0.34	100.03
274	65.07	0.01	21.46	0.00	0.10	0.00	0.03	2.33	9.88	0.42	99.30
275	64.75	0.00	21.35	0.00	0.09	0.00	0.02	2.34	9.91	0.45	98.91
avg	65.07	0.01	21.41	0.01	0.09	0.01	0.01	2.34	9.92	0.43	99.31
std dev	0.20	0.02	0.10	0.02	0.02	0.01	0.01	0.03	0.08	0.04	0.27

Phlogopite Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
276	39.00	2.91	14.51	0.00	3.64	0.02	21.76	0.00	0.16	10.14	92.12
277	39.98	0.79	14.73	0.00	3.62	0.05	22.48	0.03	0.11	10.44	92.24
278	39.81	0.73	14.74	0.00	3.65	0.05	22.48	0.01	0.14	10.36	91.96
279	39.41	0.80	14.58	0.00	4.25	0.05	22.13	0.00	0.14	10.25	91.59
280	39.91	0.78	14.99	0.00	3.64	0.04	22.08	0.00	0.15	10.31	91.89
281	39.92	0.88	14.77	0.00	3.68	0.06	22.33	0.00	0.18	10.38	92.20
282	39.69	0.69	14.84	0.04	3.66	0.08	22.31	0.00	0.13	10.46	91.89
283	38.27	3.99	14.20	0.07	3.58	0.02	21.93	0.01	0.12	10.02	92.21
284	39.31	2.11	14.46	0.00	3.65	0.02	22.13	0.00	0.14	10.33	92.15
285	39.88	0.76	14.83	0.07	3.62	0.06	22.27	0.00	0.18	10.35	92.01
286	39.68	0.75	14.78	0.00	3.67	0.05	22.24	0.00	0.16	10.36	91.70
287	39.79	0.78	14.80	0.01	3.69	0.02	22.06	0.02	0.17	10.35	91.67
288	40.01	0.83	14.70	0.00	3.70	0.02	22.50	0.00	0.14	10.31	92.21
289	39.89	0.74	14.66	0.01	3.68	0.04	22.47	0.00	0.14	10.33	91.96
290	39.32	0.78	14.70	0.00	3.63	0.06	21.84	0.00	0.18	10.13	90.64
291	40.11	0.75	14.83	0.00	3.74	0.05	22.48	0.02	0.17	10.34	92.48
292	39.40	1.59	14.48	0.00	3.61	0.06	22.37	0.00	0.25	10.32	92.07
293	39.78	0.78	14.80	0.00	3.72	0.03	22.20	0.02	0.30	10.39	92.01
294	39.69	0.71	14.78	0.02	3.71	0.03	22.40	0.04	0.31	10.37	92.06
295	40.00	0.82	14.94	0.00	3.56	0.09	22.55	0.01	0.16	10.42	92.54
296	39.77	0.78	14.79	0.00	3.61	0.04	22.31	0.02	0.15	10.42	91.89
297	39.73	0.80	14.94	0.00	3.68	0.08	22.36	0.07	0.17	10.38	92.20
298	39.94	0.84	14.81	0.00	3.67	0.04	22.40	0.00	0.15	10.40	92.25
299	39.85	0.73	14.42	0.00	3.64	0.07	22.59	0.01	0.46	10.52	92.28
300	39.78	1.94	14.63	0.00	3.60	0.04	22.21	0.02	0.16	10.35	92.73
301	39.96	0.80	14.82	0.00	3.73	0.05	22.30	0.00	0.13	10.52	92.30
302	39.94	0.75	14.86	0.00	3.59	0.01	22.40	0.00	0.11	10.43	92.09
303	40.02	0.74	14.69	0.00	3.65	0.01	22.52	0.00	0.16	10.50	92.29
304	39.97	0.77	14.70	0.00	3.69	0.06	22.41	0.00	0.14	10.42	92.17
305	39.97	0.72	14.68	0.00	3.62	0.03	22.55	0.00	0.14	10.41	92.12
306	40.18	0.75	14.83	0.00	3.58	0.07	22.47	0.00	0.13	10.38	92.38
309	39.99	0.69	14.72	0.00	3.70	0.05	22.56	0.00	0.14	10.37	92.21
310	39.44	1.75	14.55	0.00	3.74	0.09	22.38	0.02	0.16	10.04	92.16
311	39.93	0.72	14.67	0.01	3.66	0.04	22.53	0.00	0.14	10.44	92.13
312	39.81	0.79	14.87	0.00	3.73	0.00	22.30	0.01	0.17	10.46	92.13
313	39.30	0.78	14.79	0.04	3.70	0.06	21.63	0.00	0.15	10.22	90.66
314	39.96	0.73	14.81	0.00	3.63	0.05	22.55	0.01	0.14	10.51	92.38
315	39.95	0.73	14.88	0.05	3.74	0.04	22.22	0.00	0.16	10.38	92.14
avg	39.75	1.02	14.73	0.01	3.67	0.05	22.31	0.01	0.17	10.35	92.06
std dev	0.36	0.69	0.16	0.02	0.11	0.02	0.23	0.01	0.06	0.12	0.40

Ilmenite Compositions

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
126	0.02	59.20	0.05	0.00	40.96	0.92	0.01	0.00	0.00	0.00	101.16
127	0.03	54.65	0.05	0.00	47.12	0.98	0.02	0.01	0.05	0.00	102.91
128	0.02	54.32	0.03	0.01	47.30	1.09	0.07	0.01	0.02	0.00	102.87
129	0.03	54.24	0.00	0.01	47.09	1.11	0.03	0.00	0.04	0.00	102.54
130	0.04	54.07	0.02	0.00	47.03	1.07	0.04	0.00	0.04	0.00	102.31
131	0.04	54.42	0.02	0.08	46.92	1.12	0.05	0.01	0.01	0.01	102.68
132	0.03	54.14	0.03	0.01	46.14	1.25	0.04	0.02	0.03	0.00	101.68
133	0.01	54.10	0.05	0.00	46.65	1.04	0.02	0.00	0.03	0.00	101.89
134	0.01	53.90	0.01	0.00	47.11	1.08	0.03	0.01	0.00	0.00	102.15
135	0.05	54.32	0.03	0.00	47.26	1.08	0.06	0.00	0.04	0.00	102.83
136	0.05	62.08	0.05	0.00	37.20	0.84	0.04	0.01	0.02	0.00	100.29
137	0.03	53.76	0.01	0.00	46.93	1.12	0.07	0.03	0.00	0.01	101.95
138	0.05	54.09	0.02	0.00	47.06	1.03	0.05	0.02	0.04	0.00	102.36
139	0.02	53.98	0.02	0.04	46.92	1.07	0.06	0.01	0.03	0.00	102.14
140	0.07	54.28	0.04	0.00	47.13	1.10	0.05	0.00	0.01	0.00	102.67
141	0.03	54.27	0.02	0.03	46.59	1.08	0.07	0.02	0.06	0.00	102.16
142	0.02	54.54	0.04	0.02	46.72	1.26	0.05	0.00	0.01	0.00	102.66
143	0.03	54.17	0.01	0.06	46.76	1.30	0.06	0.00	0.00	0.00	102.38
144	0.02	54.17	0.01	0.00	46.70	1.47	0.01	0.01	0.00	0.00	102.37
145	0.06	54.32	0.02	0.02	47.06	1.08	0.04	0.01	0.02	0.00	102.63

No.	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	Total
146	0.03	53.94	0.02	0.00	46.66	1.15	0.03	0.00	0.05	0.00	101.87
147	0.02	54.01	0.02	0.00	46.93	1.04	0.05	0.02	0.00	0.00	102.08
148	0.04	54.64	0.00	0.00	47.05	1.04	0.04	0.00	0.02	0.00	102.84
149	0.01	54.89	0.01	0.00	46.41	1.14	0.04	0.00	0.02	0.02	102.53
150	0.04	60.74	0.05	0.05	39.55	0.92	0.04	0.02	0.01	0.01	101.42
151	0.07	54.89	0.02	0.00	46.75	1.13	0.04	0.02	0.03	0.00	102.92
152	0.01	46.36	0.02	0.00	53.62	1.05	0.04	0.01	0.03	0.00	101.12
153	0.06	54.82	0.00	0.00	46.53	1.41	0.03	0.02	0.05	0.00	102.92
154	0.03	55.02	0.00	0.00	46.07	1.25	0.04	0.01	0.01	0.00	102.42

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
155	0.02	54.60	0.02	0.02	46.99	1.14	0.06	0.01	0.00	0.00	102.86
156	0.02	54.33	0.00	0.00	46.78	1.18	0.01	0.00	0.00	0.00	102.32
157	0.05	58.59	0.06	0.02	41.44	0.98	0.02	0.01	0.03	0.00	101.20
158	0.03	54.45	0.02	0.00	46.86	1.11	0.06	0.01	0.02	0.00	102.56
160	0.05	54.89	0.03	0.00	46.75	1.18	0.05	0.00	0.00	0.00	102.96
161	0.02	54.24	0.01	0.00	46.66	1.06	0.05	0.01	0.00	0.00	102.05
162	0.04	54.76	0.03	0.00	46.73	1.07	0.03	0.00	0.04	0.00	102.70
163	0.03	54.74	0.01	0.03	47.03	1.13	0.02	0.00	0.04	0.00	103.03
164	0.03	54.72	0.00	0.03	46.93	1.11	0.06	0.02	0.00	0.00	102.90
165	0.02	54.83	0.03	0.01	47.15	1.05	0.04	0.01	0.07	0.00	103.19
166	0.02	54.88	0.02	0.00	47.04	1.04	0.07	0.00	0.04	0.00	103.10
167	0.02	53.85	0.04	0.00	46.27	1.80	0.04	0.01	0.00	0.01	102.04
168	0.00	54.76	0.04	0.01	47.30	1.09	0.06	0.00	0.03	0.00	103.29
169	0.04	54.45	0.01	0.00	46.95	1.06	0.03	0.01	0.00	0.00	102.55
170	0.02	54.72	0.01	0.00	47.24	1.01	0.06	0.03	0.03	0.00	103.11
172	0.03	53.81	0.01	0.00	47.47	1.03	0.08	0.00	0.00	0.00	102.44
173	0.03	54.63	0.00	0.04	47.06	1.11	0.07	0.00	0.00	0.00	102.94
174	0.04	54.61	0.02	0.01	46.78	1.07	0.06	0.00	0.00	0.00	102.58
175	0.03	55.00	0.03	0.06	46.89	1.12	0.08	0.00	0.07	0.00	103.28
Ilm avg	0.03	54.73	0.02	0.01	46.43	1.11	0.04	0.01	0.02	0.00	102.41
Ilm norm	0.03	55.73	0.02	0.01	47.27	1.14	0.04	0.01	0.02	0.00	104.27
std dev	0.02	2.09	0.02	0.02	2.31	0.15	0.02	0.01	0.02	0.00	0.63

Hornblende Composition

No.	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
avg	40.84	0.77	10.78	0.01	23.61	1.05	6.79	10.55	1.95	1.60	97.95

APPENDIX E - Sample Plagioclase K values

Sample	Plagioclase Anorthite Content (%)	K (W/ m K)
M0034	0.20	2.01
M3796	0.15	2.03
M3997	0.38	1.91
M4002A	0.38	1.89
M4002B	0.03	2.10
M4015A	0.23	1.98
M4015B	0.38	1.89
M4017	0.15	2.04
M12350	0.44	1.82
M12351	0.30	1.93
M12352A	0.33	1.92
M12352B	0.30	1.94
M12354	0.30	1.94
M12549	0.34	1.91
M12636	0.39	1.88
M12637	0.39	1.88
M12638	0.33	1.92
M12639	0.30	1.94
M12640	0.32	1.93
M12643	0.27	1.95
N01A	0.42	1.87
N04	0.03	2.09
N05	0.30	1.94
N06	0.23	1.98
HW3521	0.33	1.92
HW3522	0.33	1.92
HW3523	0.33	1.92
HW3524	0.30	1.94
HW3525	0.27	1.95
HW3526	0.25	1.97
HW3527	0.25	1.97
HW3530	0.25	1.97
HW1	0.27	1.96
HW2	0.27	1.95
HW3	0.27	1.95

Equation to determine K value (y)
from anorthite content (x)
$y = 0.0064x + 1.4954$

APPENDIX F – Petrographic Descriptions

M0034

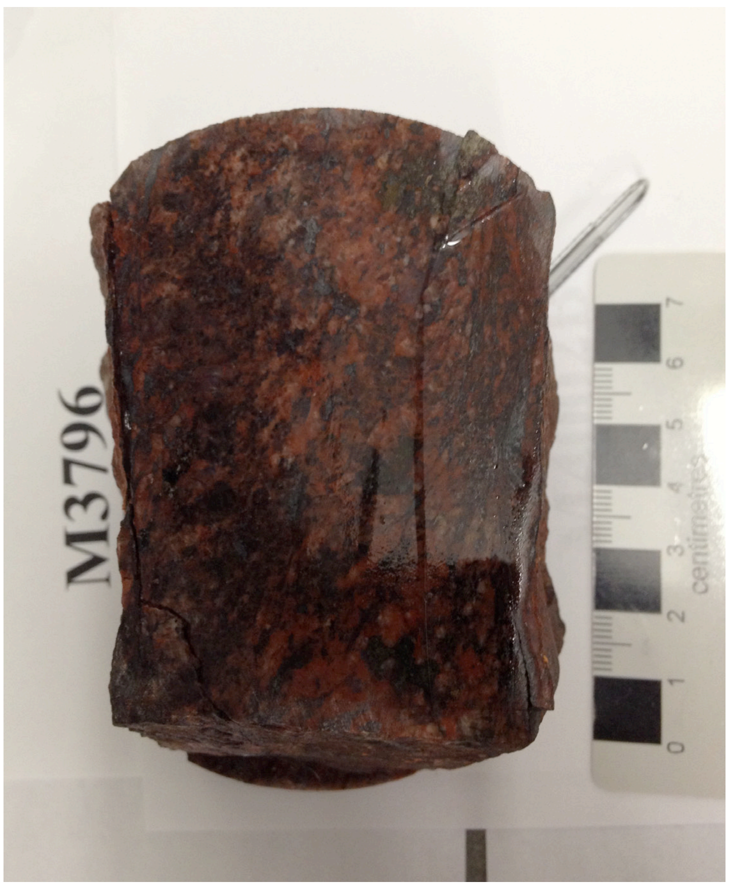
Minerals	Modal abundance (%)
K-spar	43.8
Quartz	32.4
Plagioclase	17.3
Biotite	4.7
Chlorite	*trace*
Opaques	*trace*

Quartz is observed as 2-5 mm grains, anhedral to subhedral, and displaying undulatory extinction. Feldspar crystals are 1-7 mm across, anhedral, with plagioclase crystals showing simple twinning and antiperithitic textures. Myrmekitic textures are seen at plagioclase grain boundaries. Inclusions of quartz and biotite are observed within the feldspars. Biotite appears as 1-2 mm anhedral grains that have undergone partial alteration to chlorite. The opaque minerals are anhedral and <1 mm in diameter.

M3796

Minerals	Modal abundance (%)
K-spar	29.1
Plagioclase	27.1
Quartz	19.5
Biotite	9.7
Hematite	12.5
Chlorite	*trace*

K-spar occurs as 0.5-2 mm anhedral grains with perithitic texture. Several large grains have undergone extensive secondary alteration. Plagioclase crystals are 0.5-4 mm, anhedral, with myrmekite textures at grain boundaries. Quartz crystals are 0.5-2 mm, anhedral, and show undulatory extinction. Biotite grains are 0.5 mm in diameter and have undergone chlorite alteration along grain rims. Opaque minerals are <1 mm in diameter and occupy spaces between feldspar and quartz grains.



M3997

Minerals	Modal abundance (%)
K-spar	34.8
Plagioclase	32.7
Quartz	29.2
Pseudorutile	1.8
Chlorite	*trace*

Potassium feldspar crystals are anhedral, 0.5-9 mm in length with some present as phenocrysts. They display both tartan twinning and sericitic alteration. The contact between plagioclase and alkali feldspars is often displaying myrmekitic alteration. Plagioclase grains are 2-3 mm in diameter, anhedral, and display secondary alteration. Opaque grains are 0.3-2 mm in diameter and anhedral. Biotite is seen in trace amounts and is often altered to chlorite.

M4002A

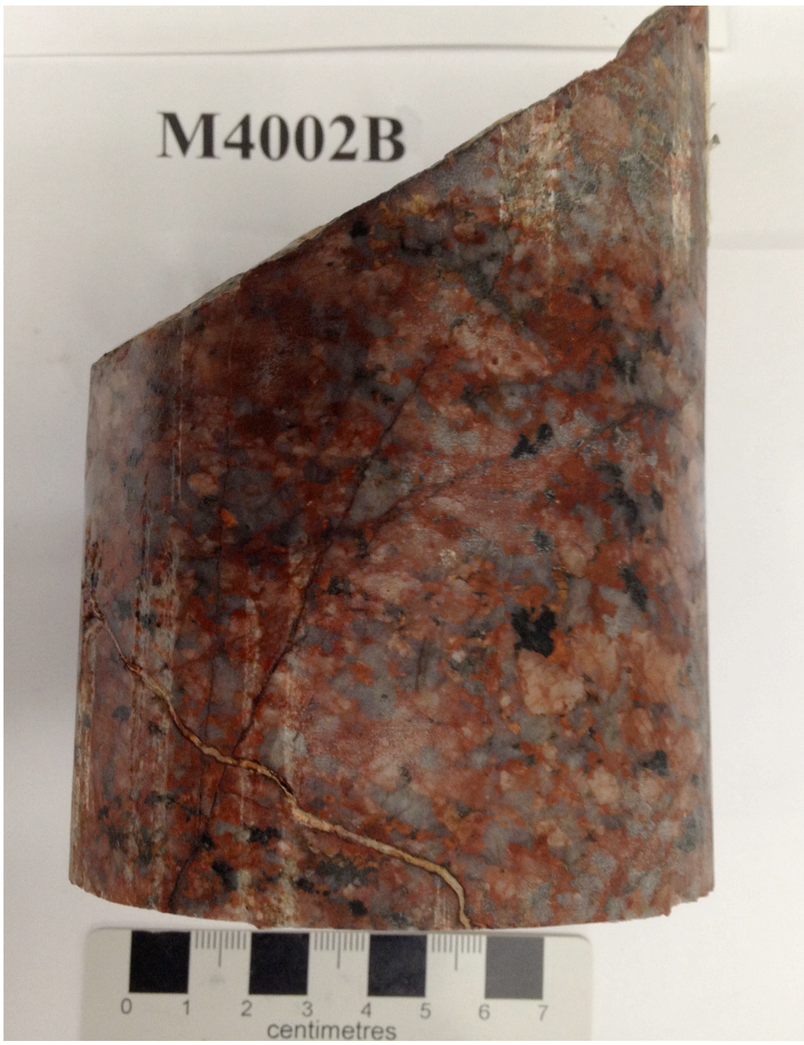
Minerals	Modal abundance (%)
K-spar	46.6
Quartz	37.8
Plagioclase	9.4
Biotite	4.9
Pseudorutile	0.1
Chlorite	*trace*

Feldspar grains are 3-7 in diameter, subhedral to anhedral in form, and have undergone extensive sericitic alteration. Quartz crystals are subhedral to anhedral, 1-7 mm in length, and have inclusions of feldspar and zircon. Biotite grains have mostly all been altered to chlorite and are 2-5 mm in diameter. Opaque minerals in this sample are 0.5-1 mm in diameter.

M4002B

Minerals	Modal abundance (%)
K-spar	46.2
Quartz	36.9
Plagioclase	10.1
Biotite	5.5
Rutile	0.2
Chlorite	*trace*

Same description as M4002A



M4015A

Minerals	Modal abundance (%)
K-spar	33.0
Quartz	32.3
Plagioclase	32.2
Biotite	2.5

Potassium feldspar grains are 4-5 mm in diameter and contain inclusions of quartz. Many grains show strong sericitic alteration. Plagioclase grains are 2-6 mm in diameter, anhedral, and display antiperithitic textures. Quartz is 2-7 mm in diameter, subhedral to anhedral, and shows minimal fracturing. Biotite exists in minor quantities in this sample, as 0.5-1 mm grains with subhedral to euhedral habit, and brown to light brown pleochroism.

M4015B

Minerals	Modal abundance (%)
Plagioclase	59.2
Hornblende	21.8
Opx	13.9
Quartz	3.7
Biotite	*trace*

Plagioclase crystals are 1-2 mm in diameter, anhedral to subhedral, and display deformed albite twinning. Hornblende crystals are 0.5-3 mm in diameter, subhedral, and display brown to green pleochroism. Orthopyroxene grains are similar size and habit to hornblende grains but display only brown pleochroism. Quartz is present in minor quantities as grains 1-2 mm in diameter and anhedral form. Biotite is found only in trace amounts.

M4017

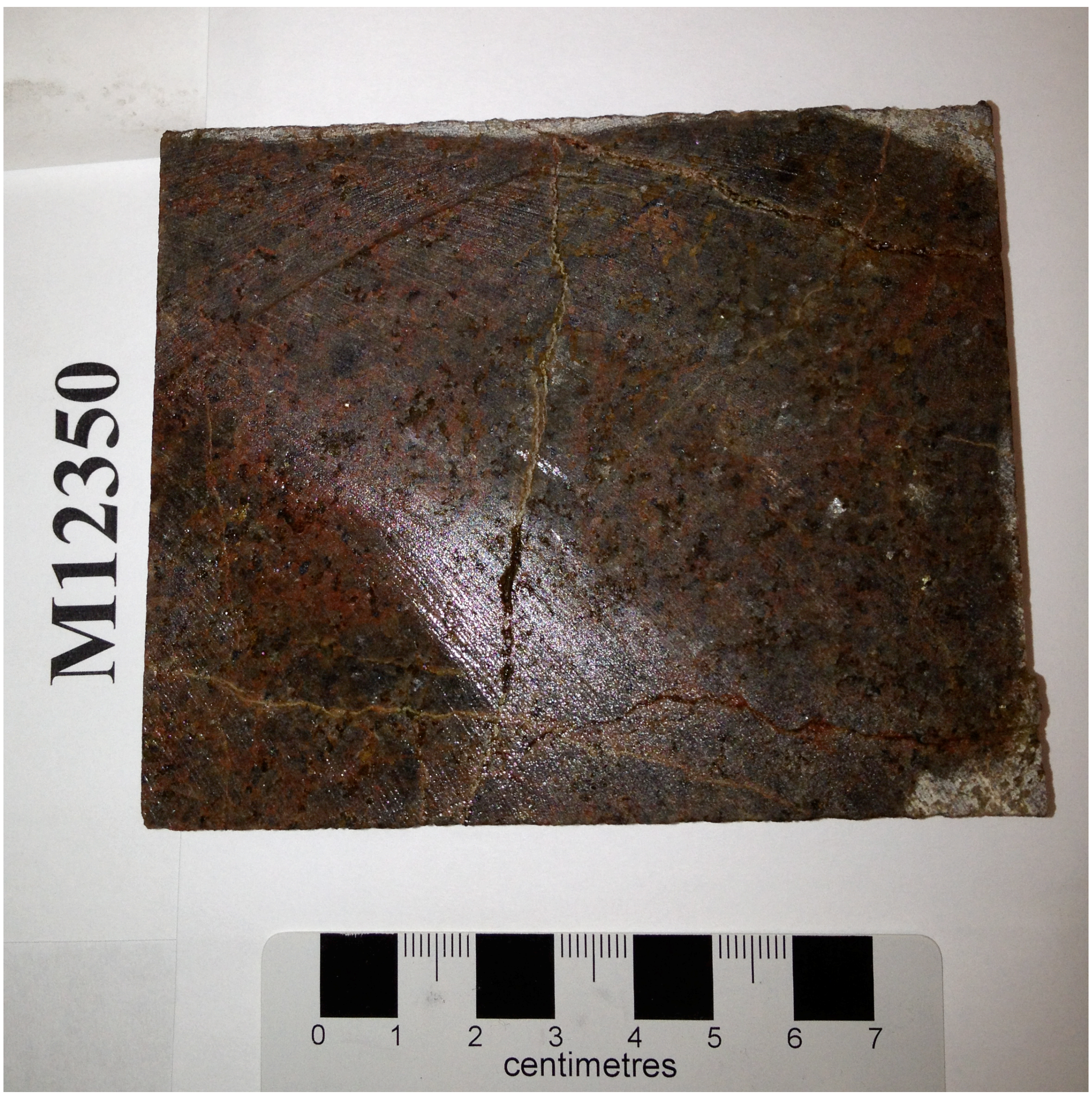
Minerals	Modal abundance (%)
Plagioclase	33.4
Quartz	30.5
K-spar	29.4
Biotite	6.6

Plagioclase grains are 1-2 mm in diameter, anhedral, and many display antiperithitic textures. Quartz grains are 2-5 mm in diameter, anhedral, with many grains strongly fractured. Potassium feldspar grains are 1-5 mm in diameter, anhedral, and have many quartz inclusions. They display simple and tartan twinning as well as myrmekitic textures at some grain boundaries. Both feldspars have been deformed and have an elongated shape. Biotite grains are 0.3-0.5 mm in length and have a preferred alignment in the sample due to deformation. They are often altered to chlorite.

M12350

Minerals	Modal abundance (%)
Plagioclase	65.4
Quartz	15.8
Biotite	10.5
Magnetite	3.9

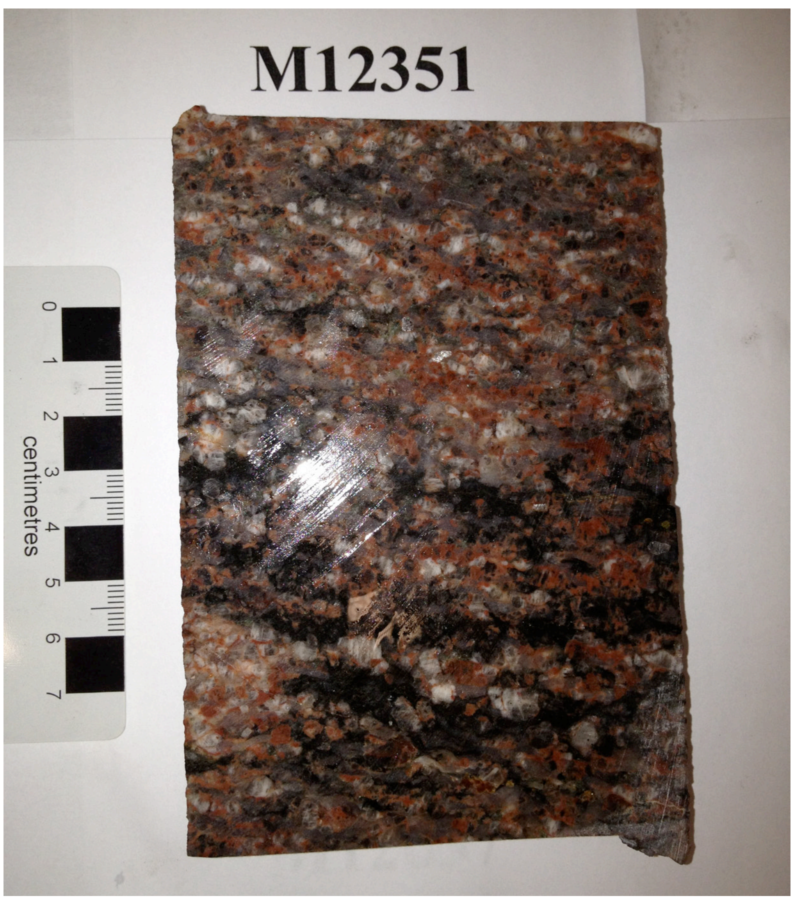
Plagioclase grains are typically 1-4 mm in diameter with anhedral form and inclusions of quartz. Antiperithitic textures are visible within the grains. Quartz grains are 1-2 mm in diameter, anhedral, and often mantled by an opaque alteration mineral. Biotite crystals are typically <1 mm in length and subhedral to euhedral. The opaque minerals are 0.5-3 mm in diameter.



M12351

Minerals	Modal abundance (%)
Quartz	33.7
K-spar	30.8
Plagioclase	27.3
Biotite	8.0
Opaques	*trace*
calcite	*trace*

Quartz crystals are 2-7 mm in diameter, anhedral to subhedral, and display strong undulatory extinction. They also contain numerous inclusions of potassium feldspar as well as zircons. Potassium feldspar grains are 1-6 mm in diameter, anhedral, and have extensive sericite alteration. Plagioclase grains are 2-4 mm in diameter and subhedral. Feldspars in this sample have been deformed to a more elongated shape. Biotite grains are typically <1 mm in length, range from anhedral to euhedral, are preferentially aligned in the same direction as the feldspar elongations. Opaque minerals and calcite are present only in traces and are <1 mm in diameter.



M12352A

Minerals	Modal abundance (%)
Quartz	38.7
K-spar	28.5
Plagioclase	23.1
Biotite	5.8
Hematite	2.4
Pseudorutile	*0.3*
Chlorite	*trace*

Quartz crystals are 2-4 mm in diameter, anhedral, display undulatory extinction, and are minimally fractured. Feldspar grains are 2-5 mm in diameter, anhedral, with the plagioclase grains displaying antiperithite exsolution lamellae. Biotite grains are <1 mm in length, subhedral to anhedral, and show some preferred orientation in one direction. Biotite grains are often altered to chlorite. Opaque minerals are often located in clumps with biotite grains and are typically <1 mm in diameter and anhedral.

M12352B

Minerals	Modal abundance (%)
Quartz	41.3
K-spar	21.0
Plagioclase	19.7
Biotite	10.4
Garnet	5.0
Chlorite	*trace*
Opaques	*trace*

Quartz crystals are 1-4 mm in diameter, anhedral, and show undulatory extinction. Feldspar grains are 1-2 mm in diameter, anhedral, with plagioclase crystals displaying antiperithitic exsolution. Biotite grains are <1 mm in length, subhedral to anhedral, and often have a preferred orientation in one direction. Many biotite grains have altered to chlorite. Garnet crystals are 1-4 mm in diameter, subhedral, and are found in clusters with biotite and opaque minerals. The garnets are poikiloblastic with inclusions of feldspar, biotite, and zircon. Opaque minerals occur in trace quantities as anhedral grains found near biotite crystals.

M12354

Minerals	Modal abundance (%)
K-spar	39.8
Plagioclase	29.1
Quartz	16.3

Potassium feldspar grains are 2-5 mm in diameter, anhedral, and have sericitic alteration. Plagioclase grains are 2-5 mm in diameter, anhedral, display albite twinning. Plagioclase grains also show antiperithitic exsolution lamellae. Myrmekitic textures are seen at many contacts between feldspars. Quartz grains range in size from 2-5 mm but most are >4 mm in diameter. They are anhedral, minimally fractured, and display strong undulatory extinction. Chlorite grains are quite small (<1 mm) and appear as alteration products with the opaque minerals.

M12549

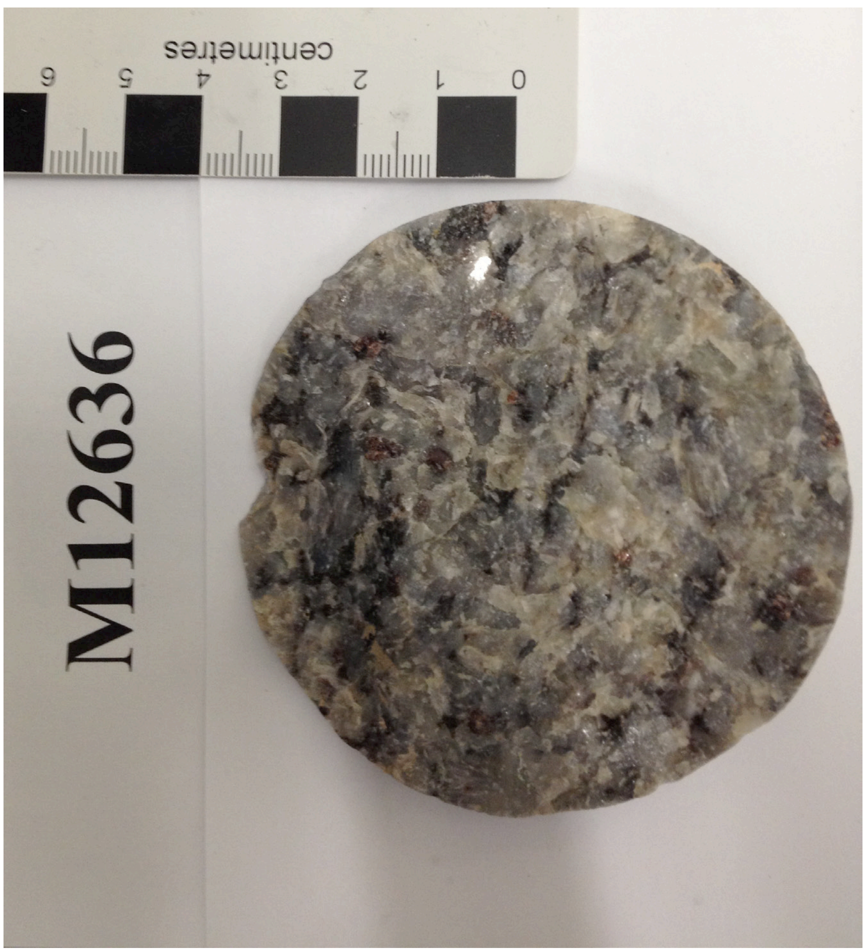
Minerals	Modal abundance (%)
K-spar	35.9
Quartz	34.6
Plagioclase	25.0
Biotite	3.1
Hematite	1.4

Potassium feldspar grains are 3-5 mm in diameter, anhedral, and have undergone some sericite alteration. Tartan twinning is seen as well. Quartz grains are 1-5 mm in diameter, anhedral, and fractured in some places. Undulatory extinction can be seen in all quartz grains. Plagioclase grains are 1-2 mm in diameter, anhedral, and display antiperithetic textures on some grains. Biotite grains are 1-2 mm in diameter, subhedral to anhedral, and show some alteration to chlorite. Opaque minerals are quite small (<1 mm), anhedral, and often forming near biotite grains.

M12636

Minerals	Modal abundance (%)
K-spar	44.0
Quartz	31.1
Plagioclase	18.8
Garnet	5.5
Biotite	0.5

Potassium feldspar grains are 2-3 mm in diameter, anhedral, and display some sericitic alteration. Quartz grains are 3-5 mm in diameter, anhedral, and have strong undulatory extinction. There are also inclusions of biotite and zircon within the quartz grains. Plagioclase grains are 2-4 mm in diameter, anhedral, and show some antiperithite exsolution lamellae. Garnet crystals are 2-5 mm in diameter, subhedral, and contain many inclusions of quartz, biotite, zircon and monazite. Biotite grains are <1 mm, anhedral, and often clumped to garnet crystals.



M12637

Minerals	Modal abundance (%)
K-spar	55.7
Quartz	27.7
Plagioclase	8.6
Biotite	6.1

Potassium feldspar grains are 2-15 mm in diameter, anhedral, and have inclusions of quartz, biotite, and zircon. Quartz grains are 4-10 mm in diameter, anhedral, and show undulatory extinction. Plagioclase grains are 1-3 mm in diameter, display albite twinning, and have antiperithite exsolution lamellae. Biotite grains are quite small (<1 mm) and often filling spaces between other large crystals.

M12638

Minerals	Modal abundance (%)
K-spar	47.8
Quartz	25.1
Plagioclase	22.2
Hematite	2.4
Pseudorutile	0.4
Calcite	*trace*
Biotite	*trace*

Potassium feldspar grains are 2-7 mm in diameter, subhedral, and elongated due to deformation. They also contain inclusions of quartz, opaques, and zircon. Also present in potassium feldspar are myrmekitic textures of quartz. Quartz is strongly deformed and granulated which has reduced grain size considerably. Plagioclase grains are 2-5 mm in diameter, anhedral, and display a antiperithitic texture. Opaque minerals are typically <1 mm in diameter and anhedral. Biotite grains are relativity minor, and occur in groups of lines wrapping around feldspar grains from deformation. Calcite is found only in trace amounts, as an alteration product in fractures.

M12639

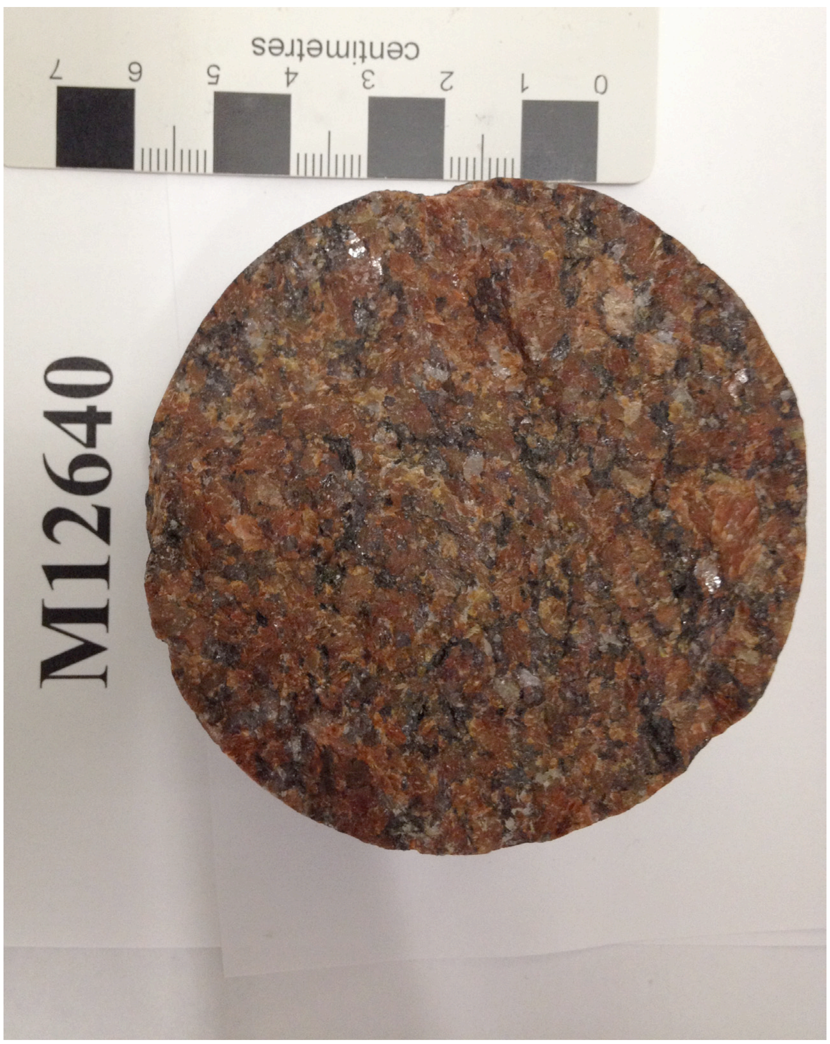
Minerals	Modal abundance (%)
Plagioclase	39.7
Quartz	26.4
K-spar	15.1
Biotite	18.6
Chlorite	*trace*
Opaques	*trace*

Plagioclase grains are 2-4 mm in diameter, anhedral, and display antiperithitic exsolution lamellae. They contain numerous inclusions of quartz and biotite. Quartz grains are 1-6 mm in diameter, anhedral, and have myrmekitic textures located at some grain contacts. Potassium feldspar grains are typically 2 mm in diameter, anhedral, and have some sericitic alteration. Biotite grains are anhedral and have some grains having undergone alteration to chlorite. Opaque minerals are typically 1-2 mm in diameter, anhedral, and often forming with biotite.

M12640

Minerals	Modal abundance (%)
K-spar	52.4
Quartz	23.0
Plagioclase	10.3
Biotite	13.6
Chlorite	*trace*

Potassium feldspar grains are 5-7 mm in diameter and have inclusions of plagioclase, biotite, and zircon. They have also have a significant amount of sericitic alteration. Quartz crystals are 1-4 mm in diameter, anhedral, and have inclusions of biotite. Quartz displays strong undulatory extinction. Plagioclase grains are typically 3 mm in diameter, subhedral, and display albite twinning. Biotite grains are small (<1 mm), anhedral, and often fill spaces between larger feldspar and quartz grains.



M12643

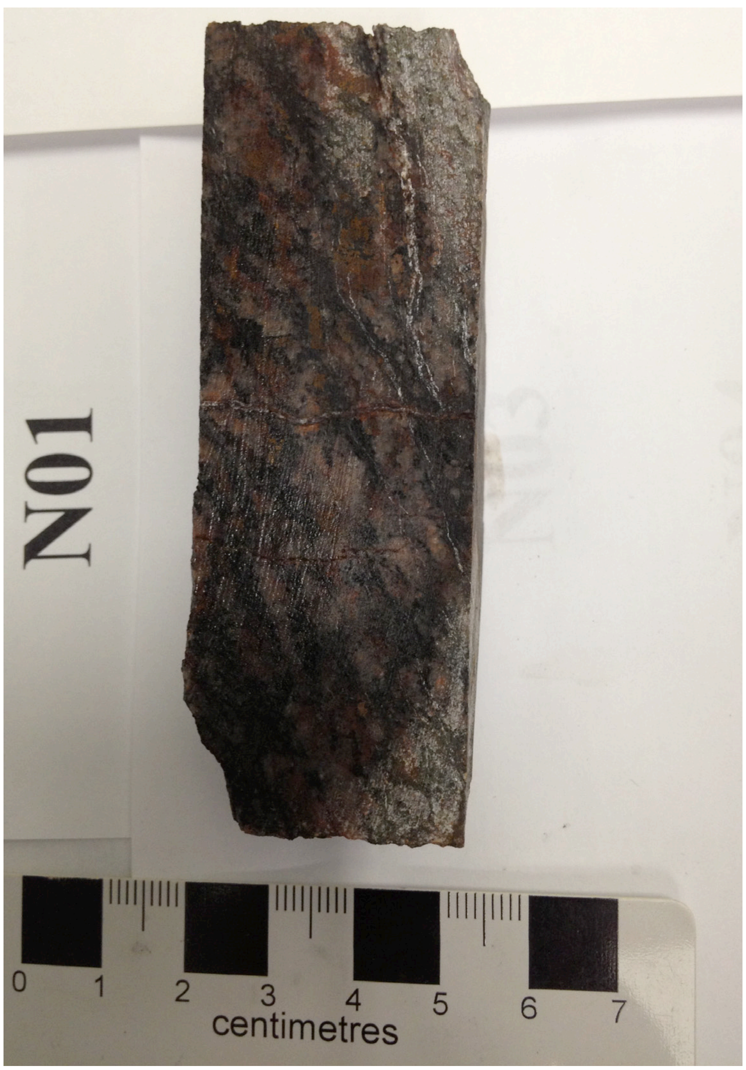
Minerals	Modal abundance (%)
K-spar	38.7
Quartz	33.7
Plagioclase	16.3
Biotite	9.8
Opaques	*trace*

Potassium feldspar grains are 2-4 mm in diameter, anhedral, and display weakly developed tartan twinning. Quartz grains are 1-7 mm in diameter, anhedral, contain inclusions of biotite and zircon, and display undulatory extinction. Plagioclase feldspar grains are 2-5 mm in diameter, anhedral, and show antiperithitic exsolution. Myrmekitic textures are visible at plagioclase grain boundaries. Biotite grains are subhedral to anhedral and <0.5mm in diameter. Opaque minerals are typically <1 mm in diameter and anhedral.

N01A

Minerals	Modal abundance (%)
Hornblende	45.5
Plagioclase	40.0
Quartz	9.7
Opaques	*trace*

Hornblende crystals are 0.5-2 mm in diameter, subhedral, display brown to green pleochroism, and contain inclusions of quartz. Some hornblende crystals have undergone alteration to a second phase. Plagioclase crystals are 0.5-3 mm in diameter, anhedral to subhedral, and display albite twinning. Quartz is present in minor quantities as grains 1-2 mm in diameter and anhedral form. Opaques are seen, but only in trace amounts as <0.5 mm grains.



N02B

Minerals	Modal abundance (%)
Quartz	35
Plagioclase	35
K-spar	30
Biotite	5
Opaques	*trace*

Quartz grains are 0.5-3 mm in diameter, anhedral, and show strong undulatory extinction. Feldspar grains are 1-2 mm in diameter, anhedral, with plagioclase grains displaying antiperithitic textures. Biotite is present as small (<0.5 mm) grains with some having undergone alteration to a secondary phase. Gneissic bands are visible with biotite and opaques located in type of band, and quartz and feldspar grains located in the other banding type.

N03

Minerals	Modal abundance (%)
Altered phase	45
Quartz	20
K-spar	20
Plagioclase	15
Biotite	*trace*
Opaques	*trace*

This sample is dominated by a secondary alteration phase, which occupies almost half of the granitic sample. The second half contains a more pristine assemblage of granitic minerals. Quartz is the most common with grains 1-3 mm in diameter, subhedral habit, and undulatory extinction. Feldspars are smaller (0.5-2 mm), and show evidence of secondary alteration. Biotite and opaque minerals are very small (<0.5 mm) and anhedral.

N04

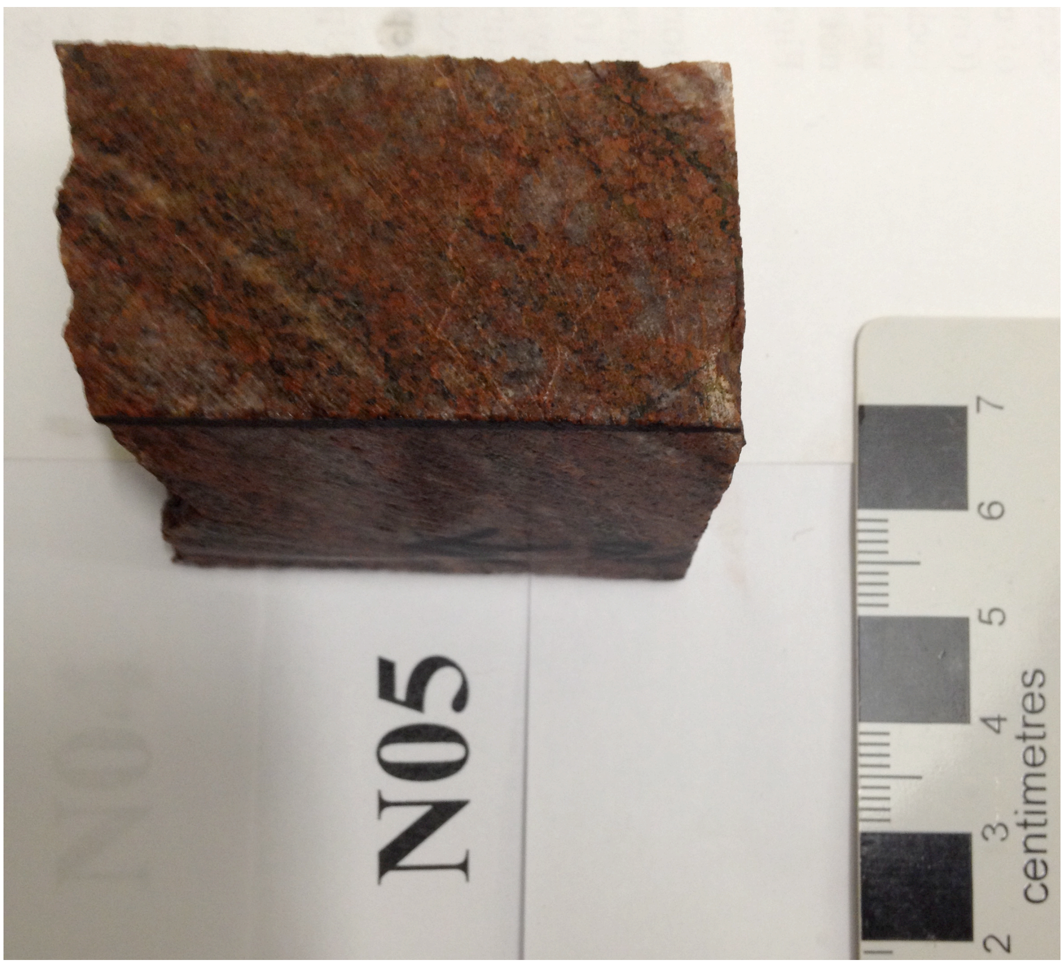
Minerals	Modal abundance (%)
Plagioclase	34.2
K-spar	33.5
Quartz	30.1

Plagioclase grains are 1-5 mm in diameter, anhedral, and have antiperithitic textures. Potassium feldspar grains are 1-4 mm in diameter and display tartan twinning. Quartz grains are 2-5 mm in diameter and show undulatory extinction. There are no minor phases present in this sample.

N05

Minerals	Modal abundance (%)
K-spar	36.8
Plagioclase	35.5
Biotite	18.7
Quartz	7.4
Pseudorutile	1.4

Potassium feldspar grains are 0.5-3 mm in diameter, anhedral, and have inclusions of quartz. Plagioclase grains are 0.5-2 mm in diameter and display albite twinning. Quartz grains are 0.3-3 mm in diameter, have undulatory extinction, and are anhedral. There is a relict mineral also present that is ~5 mm in diameter and anhedral that has altered to calcite and possibly chlorite. Opaque phases are visible in trace quantities as 0.25-0.5 mm sized minerals.



N06

Minerals	Modal abundance (%)
K-spar	33.6
Plagioclase	32.1
Quartz	28.0
Hematite	3.4
Biotite	*trace*

Potassium feldspar grains are 0.5-2 mm in diameter, anhedral, and display tartan twinning. Plagioclase grains are also 0.5-2 mm diameter and anhedral but show albite twinning. Quartz is 1-2 mm in diameter and displays undulatory extinction. Biotite and opaque minerals are present in trace amounts and are typically <1 mm.

HW3521

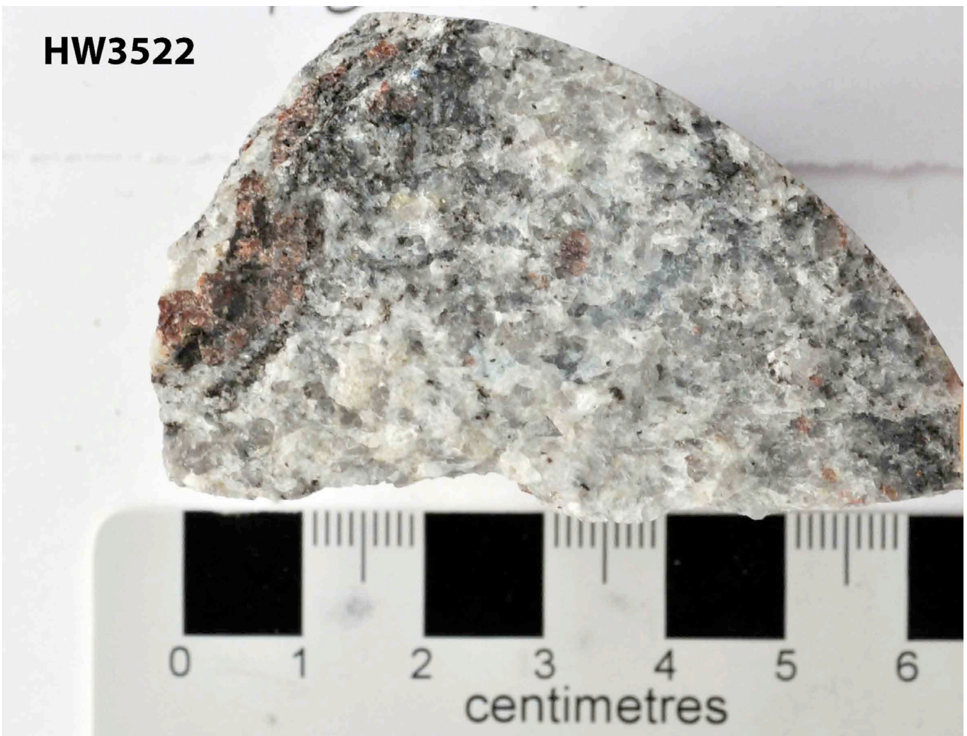
Minerals	Modal abundance (%)
Quartz	45.9
Plagioclase	18.1
K-spar	15.6
Garnet	15.2
Biotite	5.2
Opx	*trace*
Opaques	*trace*
Spinel	*trace*

Quartz is present in significant quantities in this sample with grains 2-7 mm in diameter and displaying undulatory extinction. Plagioclase grains are 1-4 mm, anhedral, and display albite twins. Potassium feldspar grains are of similar size and shape to plagioclase grains. Garnet grains are 1-10 mm in diameter, well fractured, and contain many inclusions. Biotite grains are typically <1 mm in diameter and anhedral. Orthopyroxene grains are 1-5 mm in diameter, display minor alteration, and have undergone deformation as seen by contorted cleavage planes. Spinel and opaque minerals are small (<1 mm), subhedral, and often included in garnet crystals.

HW3522

Minerals	Modal abundance (%)
Quartz	51.5
Plagioclase	31.5
Garnet	6.3
Biotite	5.9
K-spar	4.2
Opaques	*trace*

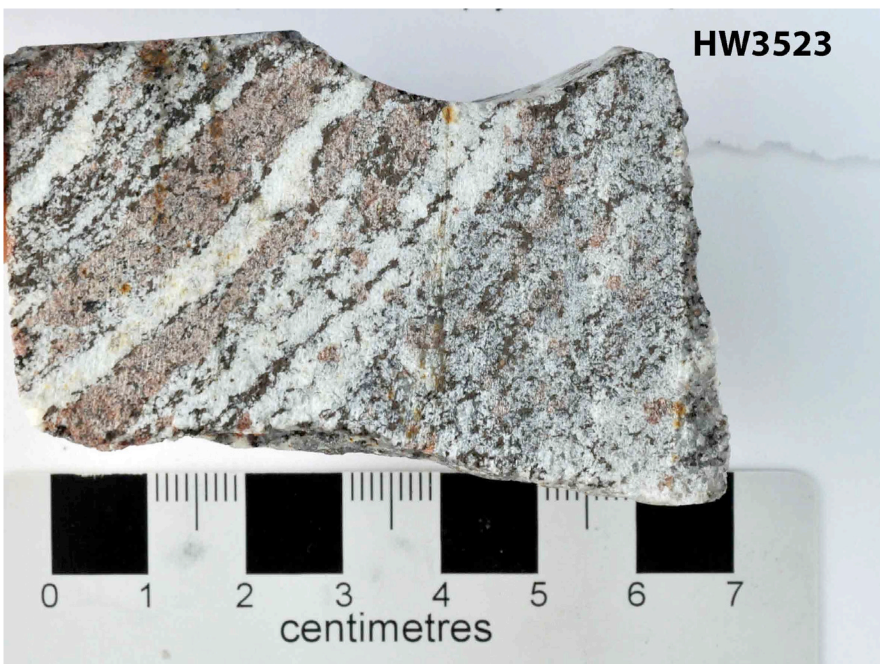
Quartz is very abundant in this sample with grains 1-4 mm in diameter, anhedral, and displaying undulatory extinction. Plagioclase grains are subhedral, 1-3 mm, and display antiperithitic exsolution lamellae. Garnets are 1-7 mm in diameter, fractured, and have biotite inclusions. Potassium feldspar and opaques are present only in minor quantities. Garnet and quartz form gneissic bands visible in hand sample.



HW3523

Minerals	Modal abundance (%)
Garnet	28.0
Plagioclase	24.1
Quartz	17.4
K-spar	16.9
Biotite	10.8
Spinel	*trace*
Opaques	*trace*

Garnet grains are 1-15 mm in diameter, subhedral, and fractured. Garnet is present as gneissic bands in this sample. Feldspar grains are 1-4 mm in diameter, subhedral to anhedral, and have sericitic alteration. Quartz is 1-3 mm in diameter, anhedral, and displays undulatory extinction. Biotite grains form gneissic bands in the sample and are 1-2 mm and euhedral. Spinel is present as a trace phase included in garnets. Opaque minerals are small (<1 mm) and included in garnets and present elsewhere in the sample.



HW3524

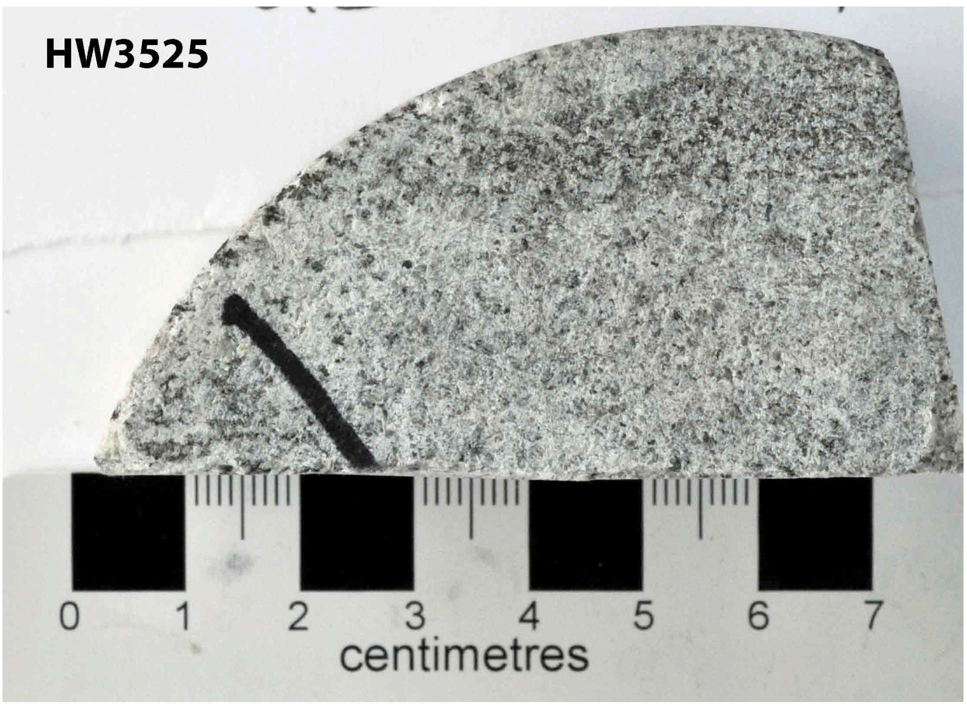
Minerals	Modal abundance (%)
Garnet	43.6
K-spar	19.5
Biotite	11.9
Quartz	11.7
Plagioclase	9.8
Spinel	*trace*
Opaques	*trace*

Garnet grains are 1-15 mm in diameter, subhedral, and fractured. Garnet is present as gneissic bands in this sample. Potassium feldspar grains are 1-4 mm in diameter, subhedral, and display sericitic alteration. Biotite grains are 1-2 mm in diameter, euhedral, and are commonly included in the garnet grains. Quartz and plagioclase grains are 2-4 mm in diameter, anhedral, with quartz displaying undulatory extinction and plagioclase displaying albite twinning. Spinel is present as elongated bands included inside the garnet grains. Opaque minerals are typically <1 mm in diameter, anhedral, and present both as inclusions inside the garnets and elsewhere in the sample.

HW3525

Minerals	Modal abundance (%)
Plagioclase	53.1
Quartz	24.6
K-spar	13.1
Opx	6.5
Ilmenite	1.0

Feldspar grains are 1-3 mm, anhedral, with plagioclase grains displaying antiperithitic textures. Quartz grains are 1-2 mm in diameter, anhedral, and display undulatory extinction. Orthopyroxene and opaque grains are 1-2 mm in diameter and subhedral to anhedral.



HW3526

Minerals	Modal abundance (%)
Plagioclase	52.9
K-spar	21.7
Quartz	10.7
Opx	10.5
Ilmenite	2.1

Plagioclase grains are 1-4 mm in diameter, anhedral, and display antiperithitic exsolution lamellae. Potassium feldspar grains are 1-3 mm in diameter and anhedral. Quartz grains 1-3 mm in diameter and show undulatory extinction. Orthopyroxene and opaque grains are <2 mm in diameter and subhedral to anhedral.

HW3527

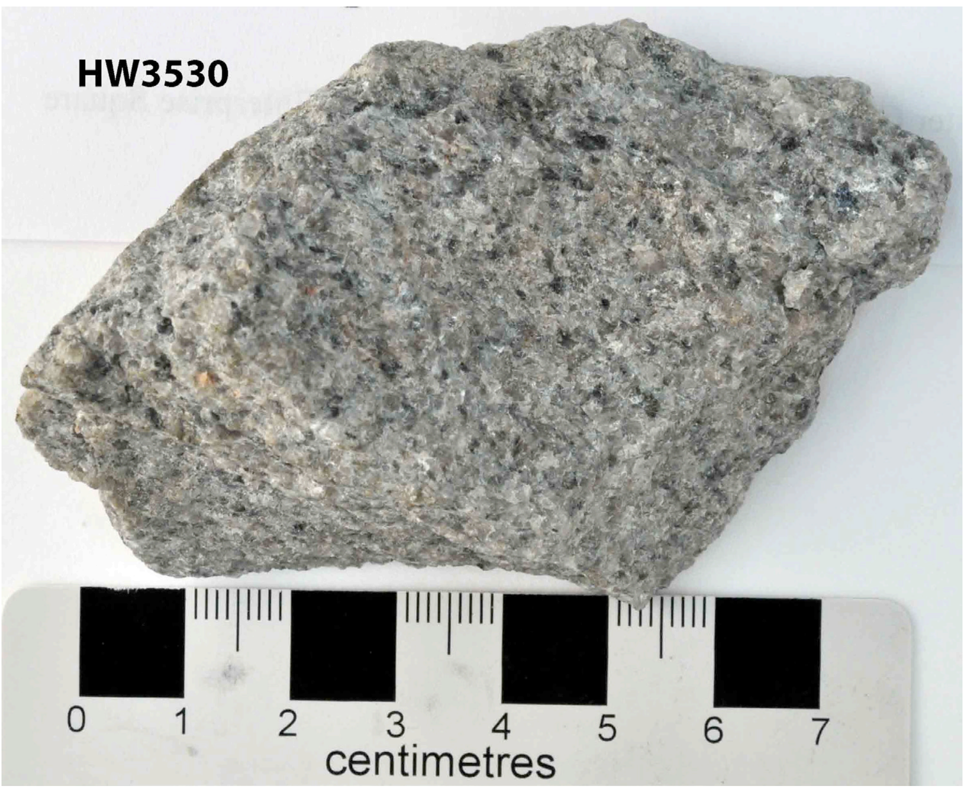
Minerals	Modal abundance (%)
Plagioclase	40.5
Quartz	28.9
K-spar	24.5
Biotite	4.5
Magnetite	1.5
Opx	*trace*

Plagioclase grains are 1-3 mm in diameter, anhedral, and have antiperithitic exsolution lamellae present. Quartz grains are 1-2 mm in diameter, anhedral, and show undulatory extinction. Potassium feldspar grains are 1-2 mm in diameter and are anhedral. Biotite grains are <2 mm in length and euhedral to subhedral. Opx and opaques occur in trace quantities as <1 mm grains.

HW3530

Minerals	Modal abundance (%)
K-spar	34.8
Quartz	34.5
Plagioclase	29.2
Hematite	0.8
Ilmenite	0.1

Potassium feldspar grains are 1-3 mm in diameter, anhedral, and display tartan twinning. Quartz grains are also 1-3 mm in diameter, anhedral, and display undulatory extinction and fracturing. Plagioclase grains are 2-4 mm in diameter, anhedral, and have antiperithitic exsolution lamellae. Opaque minerals are euhedral to anhedral and <1 mm in diameter.



HW1A

Minerals	Modal abundance (%)
Plagioclase	57.0
Quartz	19.6
K-spar	7.5
Cpx	7.1
Opx	5.6
Ilmenite	2.1

Plagioclase feldspar grains are 2-4 mm in diameter, anhedral, and display a strong antiperithitic texture. Grains show evidence of deformation. Quartz grains are 1-3 mm in diameter, anhedral, and display undulatory extinction. Potassium feldspar grains are 1-2 mm in diameter, anhedral, contain inclusions of quartz, and display tartan twins. Both feldspars display evidence of deformation. Pyroxene is present as both cpx and opx with grains up to 2 mm in diameter and often filling the interstities between other minerals. Biotite and opaque minerals are anhedral and included in plagioclase grains. Calcite is present as a trace phase, filling preexisting fractures.

HW2A

Minerals	Modal abundance (%)
Plagioclase	56.1
Quartz	29.9
K-spar	5.9
Opx	5.0
Magnetite	1.4
Ilmenite	0.9
Calcite	*trace*
Biotite	*trace*

Plagioclase feldspar grains are 1-3 mm in diameter, anhedral, and display an antiperithitic texture. Quartz grains are 1-3 mm, anhedral to subhedral, and have some fractures occupied by calcite. Potassium feldspar is relatively minor, with grains typically 1 mm in diameter. Both feldspars display evidence of deformation. Orthopyroxene grains are typically 2 mm in diameter and subhedral. Opaque minerals are minor, 0.5 to 1 mm in diameter, and anhedral.

HW3A

Minerals	Modal abundance (%)
Quartz	48.6
Plagioclase	43.3
K-spar	4.3
Pseudorutile	0.9
Calcite	*trace*

Plagioclase grains are 1-4 mm in diameter, anhedral to subhedral, and contain inclusions of quartz. Plagioclase grains also display an antiperithitic texture. Quartz grains are 1-3 mm in diameter and anhedral. Potassium feldspar grains are minor, 1-2 mm in diameter, and anhedral. Opaques are typically <1 mm in diameter and anhedral. Calcite is a trace