INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

University of Alberta

Understanding Geological Hazards; Mercury and Earthquakes
GIS Applications

by

Daniel Glen Meldrum

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

Edmonton, Alberta

Spring, 1997

National Library
of Canada

Acquisitions and
Bibliographic Services

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale
du Canada

Acquisitions et
services bibliographiques

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence

Our file Notre référence

0-612-21192-4

Canada

University of Alberta

Library Release Form

Name of Author: Daniel Glen Meldrum

Title of Thesis: Understanding Geological Hazards; Mercury and Earthquakes, GIS Applications

Degree: Masters of Science

Year this degree granted: 1997

Daniel Glen Meldrum
#412 - 1020 Pembroke Street
Victoria, British Columbia
V8T 4Z6

Submitted to the Faculty of Graduate Studies and Research on April 18, 1997

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Understanding Geological Hazards; Mercury and Earthquakes: GIS Applications submitted by Daniel Glen Meldrum in partial fulfillment of the requirements for the degree of Master of Science

B.E.N. for

Dr. N. W. Rutter

Dr. B. Nesbitt

Dr. P. Crown

Dr. B. Rivard

Date approved by committee: April 16, 1997

Dedication

I would like to dedicate this work to my friends and colleagues at the B.C. Geological Survey, who have become like a family to me. I would especially like to thank F. Ferri for being a true friend and choosing me over a gopher, P. Bobrowsky for working me like a dog, M. Mihalynuk, for being an amazing mentor, a true lover of science, V. Vilkos, for keeping me amused with her unusual stories until midnight, and finally V. Levson, for his humanity, friendship, flexibility, fun, and being amazed at what I could do in five minutes, without Vic's encouragement this paper would not have happened.

I would also like to acknowledge some friends for their support and encouragement, in particular, J. Simpkins and E. Simpkins, who put a roof over my head when I had none, M. Gingras, for being a dear friend for 25 years, R. Gingras, for finally laughing at my jokes without promptings, S. Proceviat, for her undying faith in my abilities. Finally I would like to thank my future wife, A. Wong for her love and encouragement.

Abstract

The surficial geology of the Chilliwack area is dominated by gravelly to sandy alluvial deposits of a meandering to braided Fraser River. The earthquake hazards of a region depend on a number of factors, including the sediments in the upper 20 to 30 m . Therefore, in order to understand the earthquake hazards, researchers had to develop some method of determining the lithology below this blanket of material. A Geographic Information System (GIS) was used to help understand the three dimensional extents of subsurface Quaternary deposits.

Paleo ice-flow indicators, such as striae on bedrock, often suggest large variability in ice flow directions. A shape was constructed within a GIS that attempts to model the source area of a till sample site. This source area was subdivided both parallel and perpendicular to ice flow. Each subdivisions was given weights to attempt to accurately define the dispersal pattern of mercury, and subsequently model the variability in the ice flow direction. The dispersal train is modelled by: (1) determining the concentration of mercury in the bedrock, (2) multiplying by a factor that considers distance between source and deposition and (3) multiplying by a factor that considers the amount of mercury sourced at each angle. The glacial paleo-flow direction in the area was approximately 080^0. The best scenario was when 100% of the ice flowed within 5 degrees of the 080^0 direction

An apparent spatial correlation was observed between the concentration of mercury found in stream sediments and the trend of mapped faults on northern Vancouver Island, British Columbia. The apparent correlation was examined using a GIS. 912 stream sediment catchment basins were digitized. This catchment basin map was overlain onto a geological map. Next, a record of each fault orientation and a corresponding mercury concentration was produced. Statistical tests revealed that four populations of faults can be separated out based on their orientations, $0\text{-}25^0$, $25\text{-}95^0$, $95\text{-}155^0$ and $155\text{-}180^0$. The mean mercury concentrations for these groups are, 454, 229, 272, and 344 ppb, respectively. Each population is significantly different at a 95% confidence level.

Acknowledgments

I would like to thank several people who have helped me with various aspects of this paper. First I would like to than the members of my committee, Drs. B. Rivard, P. Crown, B. Nesbitt, and my Supervisor Dr. N.W. Rutter for reading and making suggestions on improving this paper. Vic Levson was very generous with his time and energy, helping with many editorial comments. I would also like to thank P. Monahan for his many insights and his editorial comments.

I would like to thank all the people who worked on the Chilliwack project including, V. Levson, P. Monahan, A. Sy, L. Yan, B. Watts, and R. Gerath. I would like to thank J. Hobday for her able and cheery assistance with data entry. A. Plouffe kindly allowed me to use his data for the Pinchi Mine study. S. Sibbick helped with the statistical analysis of the delineation of groups of faults and with editorial comments on the North Vancouver Island paper.

TABLE OF CONTENTS

CHAPTER 1 - Introduction

CHAPTER 2 - Earthquake Hazard Mapping in Southwestern British Columbia

CHAPTER 3 - Modelling glacial dispersal in a mercuriferous region

CHAPTER 4 - A Relationship between fault orientation and mercury concentration on Northern Vancouver Island, British Columbia.

CHAPTER 5 - Conclusions

List of Figures

List of Figures (cont ...)

List of Figures (cont ...)

List of Tables

List of Plates

List of Appendices

CHAPTER 1 - INTRODUCTION

This thesis presents three applications of using Geographic Information Systems (GIS) to assess geologic hazards. The three hazards that are considered are:

1) earthquake hazards in the lower mainland of British Columbia,

2) elevated mercury concentrations in soils near, Fort St. James, British Columbia,

3) elevated mercury concentrations in stream sediments on northern Vancouver Island, British Columbia.

In addition to a brief introduction to each of these subjects, an introduction to GIS is also included in this chapter.

EARTHQUAKE HAZARD MAPPING

Chapter 2 illustrates how a GIS was utilized to aid researchers in evaluating the earthquake hazards in a region known to be seismically active, the Lower Mainland of British Columbia. Earthquake hazard microzonation maps identify the relative potential for ground disturbance during an earthquake due to local ground conditions. A large amount of geological and geotechnical information is required to produce such a map. The data sets used in this study included; 1:20,000 chronostratigraphic surficial geology mapping, 700+ water wells, 1,700 geotechnical test holes as well as quantitative assessments of liquefaction and ground motion amplification hazards.

Earthquake hazards in a region depend on a number of factors, including the age and composition of the sediments in the upper 20 to 30 m (e.g. Finn, 1996, Idriss, 1991). Therefore an understanding of the surficial geology of the region is important. The surficial geology of the selected study area in the Chilliwack region is dominated by gravely to sandy alluvial deposits of a meandering to braided reach of the Fraser River (Levson *et al.*, 1996). Large portions of the area are capped with a few meters of silt that represent over bank deposits of the Fraser River. This thin blanket of material obscures much of the underlying surficial sediments. Therefore, in order to understand the earthquake hazards, a method of determining the lithology below this blanket of material had to be developed. A GIS was used to help understand the three dimensional extent of subsurface Quaternary deposits.

MERCURY IN THE ENVIRONMENT

The spatial distributions of natural mercury concentrations in relation to fault zones in two different geological settings are presented in chapters 3 and 4. Mercury is one of the most hazardous elements to occur in nature. It is toxic to plants and animals as a liquid, as a gas, and in nearly all of its compounds (Bailey *et al.*, 1973). In high concentrations, mercury can cause mental and physical disorders, and even death. Furthermore, it is bio-accumulative, and is readily stored in the tissues of plants and animals (Siegal *et al.*, 1985). Therefore, it is important to understand how and where mercury is concentrated. A significant amount of research has been directed towards anthropogenic enrichment of mercury, however, relatively little research has been conducted on the variability of naturally occurring mercury. Many factors, such as lithology, soil and climate, influence the amount of mercury found in the environment (Darnely, 1996). The average mercury concentration in rocks is approximately 80 ppb (Jonasson, 1970) but in certain geological environments it can be enriched to 1% (Bailey *et al.*, 1970). This magnitude of enrichment is often associated with large fault zones.

Modelling dispersal trains in a mercuriferous area

A mercury deposit located on a large fault zone in central British Columbia was selected as a study area for Chapter 3. Glacial ice-flow and subsequent dispersal of mercury was modelled using till geochemical data. A GIS was used to aid in evaluating the effects of glacial dispersal from an area of known mercury mineralization. The direction and relative amount of dispersal were modelled using a geometric shape and weighting functions. In glaciated areas, the last dominant paleo-flow direction of ice (and subglacial melt water) may be determined from large scale (tens of meters to a few kilometers) features such as flutings and drumlins on aerial photographs (e.g., Ryder, 1995). In many areas these landforms indicate a relatively simple ice-flow history. However, upon closer inspection smaller scale forms (a few centimetres to a few metres) such as striae and small crag and tails, will indicate more variable local ice flow directions. In addition, earlier phases in the ice flow history of an area are seldom preserved in the landform record. However, glacial flow directions are also recorded by dispersal of sediment eroded from distinctive rock types such as in highly mineralized areas. In some cases, this sedimentary record of glacial dispersal may provide more information on the ice flow history than can landforms.

Anomalous mercury concentrations in stream sediments

Chapter 4 presents how a GIS was utilized to an analysis of an apparent spatial correlation between the concentration of mercury found in stream sediments and the trend of mapped faults on northern Vancouver Island, British Columbia. The catchment basin for each of the stream sediment samples was determined, digitized and entered into a GIS. This catchment basin map was then digitally integrated with bedrock geology data for northern Vancouver Island. The amount of mercury in the stream sediment samples was then compared to the orientation of the fault segments within each catchment basin. This information was then statistically analyzed.

The study area is a remote, sparsely populated, island off the west coast of North America. It is isolated from any major industrial activity which could contribute mercury to the environment. Therefore, mercury in this area represents natural variation of mercury within the rocks.

This paper statistically validated the generally accepted correlation between faults and high metal concentrations (Armstrong, 1942; Bailey *et al.*, 1970, 1973; Ash, 1996). More importantly, it emphasizes the need to consider geological factors, such as faults, during environmental assessments.

CAPABILITIES OF GEOGRAPHIC INFORMATION SYSTEMS

A geographic information system is a computer system for managing spatial data (Bonham-Carter, 1994). Often a software package will be referred to as a GIS. This is, strictly speaking, incorrect, as GIS refers to both the hardware and software. GIS can usually be thought of as consisting of four main components: input, output, storage, and manipulation.

Introduction References

Armstrong, J.E. (1942):Geology of the Pinchi Lake Mercury Belt, British Columbia, The Canadian Institute of Mining and Metallurgy, Transactions 45: 311-323.

Ash, C.H. (1996) Silica -Carbonate Hg in Selected British Columbia Mineral Deposit Profiles, Volume 2 - Metallic Deposits, Lefebure, D.V and Hoy, T editors, Ministry of Employment and Investment, Open File 1996-13.

Bailey, E.H., Blake, M.C. and Jones, D.L. (1970): On-land Mesozoic oceanic crust in California. *In* Geological Survey Research 1970: U.S. Geol. Surv. Prof. Paper 700-C, p. 70-81.

Bailey, E.H., Clark, A.L., and Smith, R.M. (1973): Mercury. *In* Brobst, D. A., and Pratt, W.P. eds. U.S. Geol. Surv. Prof. Paper 820, p. 401-414.

Bonham-Carter, G.F. (1994): Geographic Information Systems for Geoscientist: Modelling with GIS. *In* Computer Methods in the Geosciences, 13: 398

Darnely, Arthur G. (1996): Mercury in the Environment. *In* International Council on Metals and the Environment Newsletter, 4: # 1: 1996.

Finn, L.W.D. (1996): Ground motion amplification factors for use in building codes; Proceedings, International Workshop on Site Response, Port and Harbor Research Institute, Japan, pages 105-117.

Idriss, I.M. (1991): Earthquake Ground Motions at Soft Soil Sites; Proceedings, Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Missouri, 1: 209-214.

Jonasson, I.R. (1970): Mercury in the natural environment: a review of recent work. Geological Survey of Canada, Paper 70-57, 39 p.

Levson, V. M., Gerath, R. F., Meldrum , D. G., Monahan, P. A. (1996): Surficial Geology of the Chilliwack area, NTS 92G/1 and H/4, B.C. Ministry of Employment and Investment Open File 1996-12.

Ryder, J.M. (1995): Recognition and Interpretation of Flow Direction Indicators for Former Glaciers and Meltwater Streams. *In* Drift Exploration in the Canadian Cordillera, (eds.) Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., British Columbia Ministry of Energy Mines and Petroleum Resources, Paper 1995-2, p. 165-166.

Siegel, S. M., Siegel, B. Z., Lipp, C., Kruckeberg, A., Towers, G. H. N. and Warren, H. (1985): Indicator plant-soil mercury patterns in a mercury-rich mining area of British Columbia; Water, Air, and Soil Pollution, 25: 73-85.

CHAPTER 2 - EARTHQUAKE HAZARD MAPPING IN SOUTHWESTERN BRITISH COLUMBIA: A GIS APPLICATION

INTRODUCTION

Earthquake hazard mapping involves the integration and manipulation of several large data sets of different types. In addition, the sciences of geotechnical engineering and earthquake hazard mapping are rapidly evolving. These two factors and the ability to display vast amounts of data in innovative ways, make a Geographic Information System, (GIS) an effective tool to aid researchers in producing, updating and refining earthquake hazard maps. This paper will present how a GIS (Terra Soft™) was utilized to enter and manipulate many different data sets to produce an earthquake hazard map. Earthquake hazard maps identify the relative potential for ground disturbance during an earthquake. The British Columbia Geological Survey conducted a pilot earthquake hazard mapping project in the Chilliwack region of southwestern British Columbia strting in 1996 (Levson *et al.*, 1996; Figure 2-1).

Earthquake hazard maps, identify the relative potential for ground disturbance during an earthquake (Levson *et al.*, 1996a). These maps are generally 1:20,000 to 1:50,000 scale maps, and usually cover urban areas. This paper will present the procedures used to produce a map that delineates areas that are susceptible to liquefaction and ground motion amplification. These maps are produced by gathering geologic and geotechnical data which characterize local site conditions. Site conditions, earthquake magnitude and source, are the major factors in potential ground disruption (Levson *et al.*, 1996a).

The lower mainland has been known to experience frequent small magnitude earthquakes (Rogers, 1992) and relatively infrequent large scale earthquakes (Clague *et al.*, 1992). Most of the larger earthquakes have hit the area before significant urbanization. The most recent, large earthquake to shake the area was in 1965, in the Seattle area.

Figure 2-1. Location of study area

The objectives of this paper is to determine the earthquake hazard of an area, by understanding the three dimensional extents of surficial sediments .

Purpose of earthquake hazard mapping

The purpose of earthquake hazard mapping is to provide information for:

1) land use planners to delineate regions appropriate for development
2) emergency planners to better understand the likelihood of damage to lifelines and transportation corridors;
3) engineers to better plan transportation and utility corridors
4) large public or private sector groups interested in priorizing seismic retrofitting
5) insurance companies to more accurately access property rates
6) general public to better understand the threat of seismic activity.

Limitations of earthquake hazard mapping

It is important to note the limitations of this kind of mapping. For instance, earthquake hazard maps can not be used to directly predict the amount of damage that will occur at any one site. Other factors such as building design, building height, and population density must be considered. It is also important to note that earthquake hazard maps do not replace site specific investigations. These maps are of a regional scale, and therefore are to be used only as a guide for comparing the hazard of one area to another area. If an area is designated as a low hazard area, it does not mean that there is no risk of damage. Conversely, if an area is designated as a high hazard area, it does not mean that damage is inevitable.

PREVIOUS WORK

The correlation between local ground conditions and the corresponding hazard due to a seismic event has been understood at some level since biblical times. However, the first modern microzonation map was not completed until 1946, in Tblisi, USSR, (Medvedev, 1965). This and most of the subsequent mapping was based almost entirely on surficial geology data.

Earthquake hazard mapping has been carried out in many countries of the world, most notably Japan, United States, Mexico, Brazil and Canada (Levson *et al.*, 1996a). Recently, hazard mapping has been aided by computer technology, and GIS. These new technologies have enabled researchers to quantify seismic risks. Examples of state of the art microzonation maps in the Pacific Northwest and the Lower mainland include (Grant *et al.* 1991; Mabey and Madin, 1993; Mabey *et al.*, 1994; Palmer *et al.*, 1994; B.C. Hydro, 1992; and Watts *et al.*, 1992). A more complete review of earth quake hazard mapping can be found in Tables 2-1 and 2-2. An example of an earthquake hazard map for the city of Victoria, B.C. is shown in Figure 2-2. Numerous studies by the Geological Survey of Canada have added to the understanding of earthquake hazards in the Lower Mainland (e.g., Clague *et al.*, 1992; Hunter *et al.*, 1993; Lutenauer *et al.*, 1994; Figure 2-3; Rogers, 1994).

The surficial geology of the Chilliwack study area was mapped by Armstrong (1980, 1984). Groundwater studies were performed by Halstead (1986) and Dakin (1994). Cameron (1989) completed a thesis on the area based partly on bore hole data. Lastly a soil survey was conducted in the area by Comar *et al.* (1962).

SURFICIAL GEOLOGY

Figure 2-4 is a chronostratigraphic surficial geology map of the study area, compiled at a 1:20 000 scale using existing information sources, aerial photographic mapping and field confirmation.

Table 2-1. Liquefaction Hazard Maps (After Youd, 1991)

COUNTRY	LOCALITY OR REGION	TECHNIQUES USED
Argentina	Valle de Tullum, San Juan Province	SUS : Geol., Geot OPP : M-a_{max}
	Mendoza Province	SUS : Geol., Geot. OPP : M-a_{max}
Canada	Offshore Regions	OPP : M-a_{max}
	Quebec City	SUS : Hist. Geol., Geot.
	Greater Vancouver	SUS : Geol. POT : Geol., Geot.
China	Tangshan Region	SUS : Hist., Geol., Geot.
Japan	Shimizu Prefecture	SUS : Geol., Geot.
	Tokyo Region	SUS : Hist., Geol., Other
	Tokyo Downtown	SUS : Geol., Geot.
	Tokyo Lowlands	SUS : Hist., Geol.
Greece	Thessaloniki	SUS : Geot.
Italy	Italy	SUS : Hist.
Puerto Rico	San Juan Area	SUS : Geol., Geot.
Yugoslavia	Monte Negro Region	SUS : Hist., Geol., Other
United States	Northern California	SUS : Hist.
	Southern S.F. Bay Area	SUS : Geol., Geot.
	San Francisco County	SUS : Geol., Geot. OPP : M-a_{max} , other
	San Mateo County	SUS : Geol., Geot.
	Santa Cruz County	SUS : Geol.
	Monterey County	SUS : Geol., Hist.
	Southern California	OPP : LSI
	Los Angeles City	SUS : Geol., Geot.
	Los Angeles County	SUS : Geol., Geot.
	San Fernando Valley	SUS : Geol., Geot. OPP : M-R

Table 2-1 (cont...) Liquefaction Hazard Maps (After Youd, 1991)

COUNTRY	LOCALITY OR REGION	TECHNIQUES USED
	Los Angeles Basin	SUS : Geol., Geot. OPP : M-R
	San Bernadino Valley	SUS : Geol., Geot.
	San Diego City	SUS : Geol., Geot. OPP : $M\text{-}a_{max}$
	Seattle, Washington	SUS : Geol., Geot.
	Utah	OPP : LSI
	Davis County, Utah	SUS : Geol., Geot. OPP : $M\text{-}a_{max}$
	Salt Lake County, Utah	SUS : Geol., Geot. OPP : $M\text{-}a_{max}$
	Utah County, Utah	SUS : Geol., Geot. OPP : $M\text{-}a_{max}$
	New Madrid Seismic Zone	SUS : Hist., Geol., Geot.
	St. Louis Missouri	SUS : Geol.
	Memphis, Tennesse	SUS: Geot.
	Charleston, N. Carolina	SUS : Geot. OPP : $M\text{-}a_{max}$
	New York - Manhattan & Buffallo	SUS : Geol., Geot.
	Fairbanks, Alaska	SUS : Geol.
	Portland, Oregon	SUS : Geol., Geot. DIS : Topo

Map Type: SUS = liquefaction susceptability
OPP = liquefaction oppotunity
POT = liquefaction potential
DIS = liquefaction induced displacements
SUS Technique: Geol. = Geological Mapping
Geot. = Geotechnical analysis
Hist. = Historical occurences
OPP Technique M_R = magnitude - distance relation ships
LSI = liquefaction severity index
$M\text{-}a_{max}$ = magnitude maximum acceleration relationship

Table 2-2. Ground Motion Amplification Maps (After Klohn - Crippen, 1994)

AUTHOR	REPORT/PAPER TITLE	YEAR	LOCATION	MAP LEVEL
Wuorinen	Seismic Microzonation of Victoria - A Social Response to Risk	1976	Victoria, British Columbia	I
Elton and Martin	Dynamic Site periods in Charelston, S.C.	1989	Charelston, South Carolina	III
Chagnon and Gilbert	Development of a Method of Seismic Microzonation Mapping Applicable to the Urban Areas of Canada	1990	Quebec City, Quebec	I

Hensolt and Brabb	Map showing elevation of bedrock and amplification for design of engineered structures to withstand earthquake shaking in San Mateo County, Calif.	1990	San Mateo County, California	I
DOGMI and Metro	Relative Earthquake Hazard Map of the Portland, Oregon 7 1/2 Minute Quadrangle	1993	Potland, Oregon	III

Level I mapping refers toprducing a GMA map from the distribution of soil type, soil thickness, and rock exposures. These distributions can then be compared to Finn (1996) or Seed and Idriss (1982) amplification chart.

Level II mapping incorporates shear wave velocity data from either downhole or surface measurements. Borcherdt et al. (1991) has shown the correlation between the shear wave velocity and areas of significant damage.

Level III mapping refers to the process of combining the information associated with level I and level II maps with SHAKE analysis.

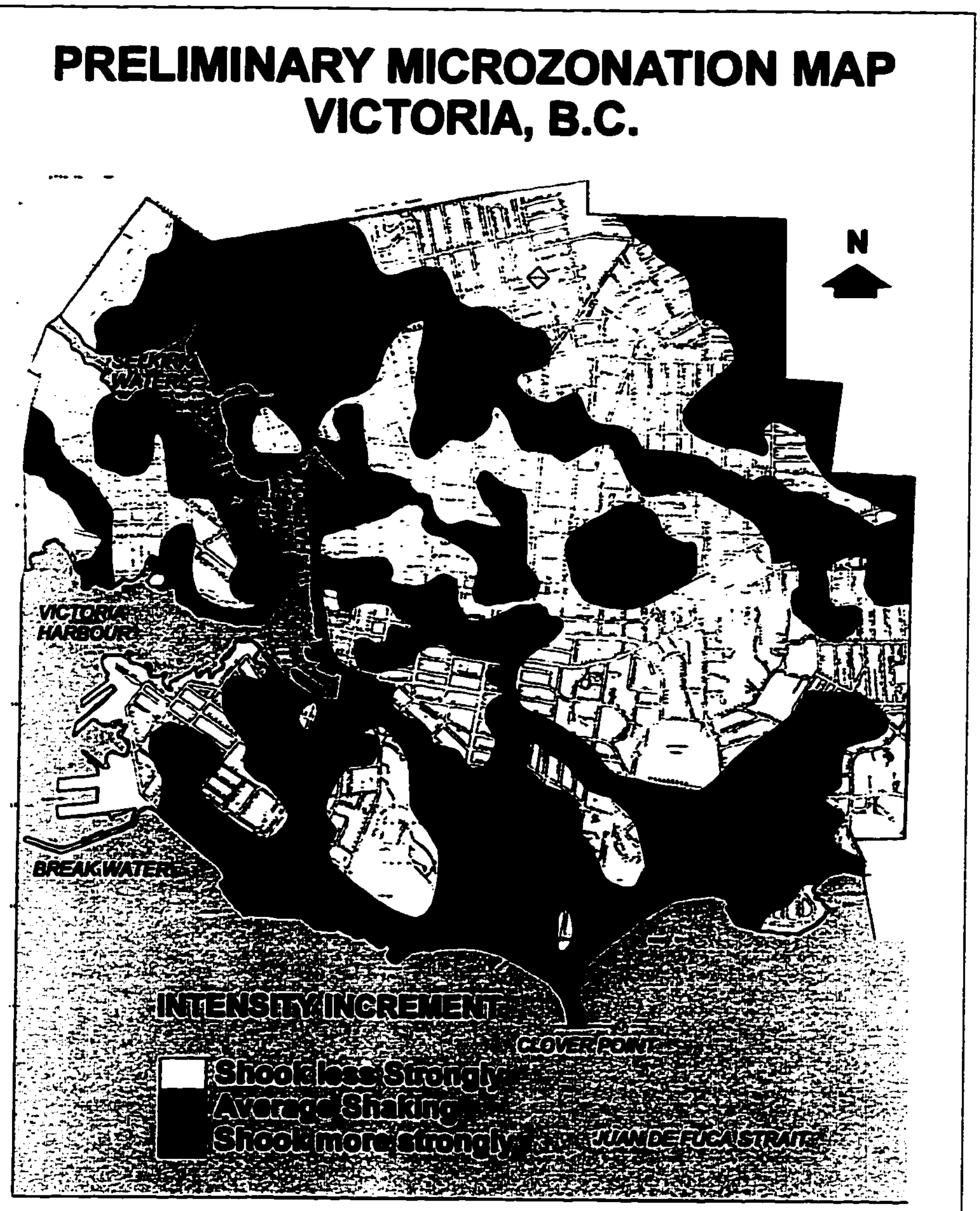


Fig. 2-2. Example of an earthquake hazard map showing areas that shook more or less strongly during the 1964 earthquake of central Vancouver Island (After Wuorinen, 1974).

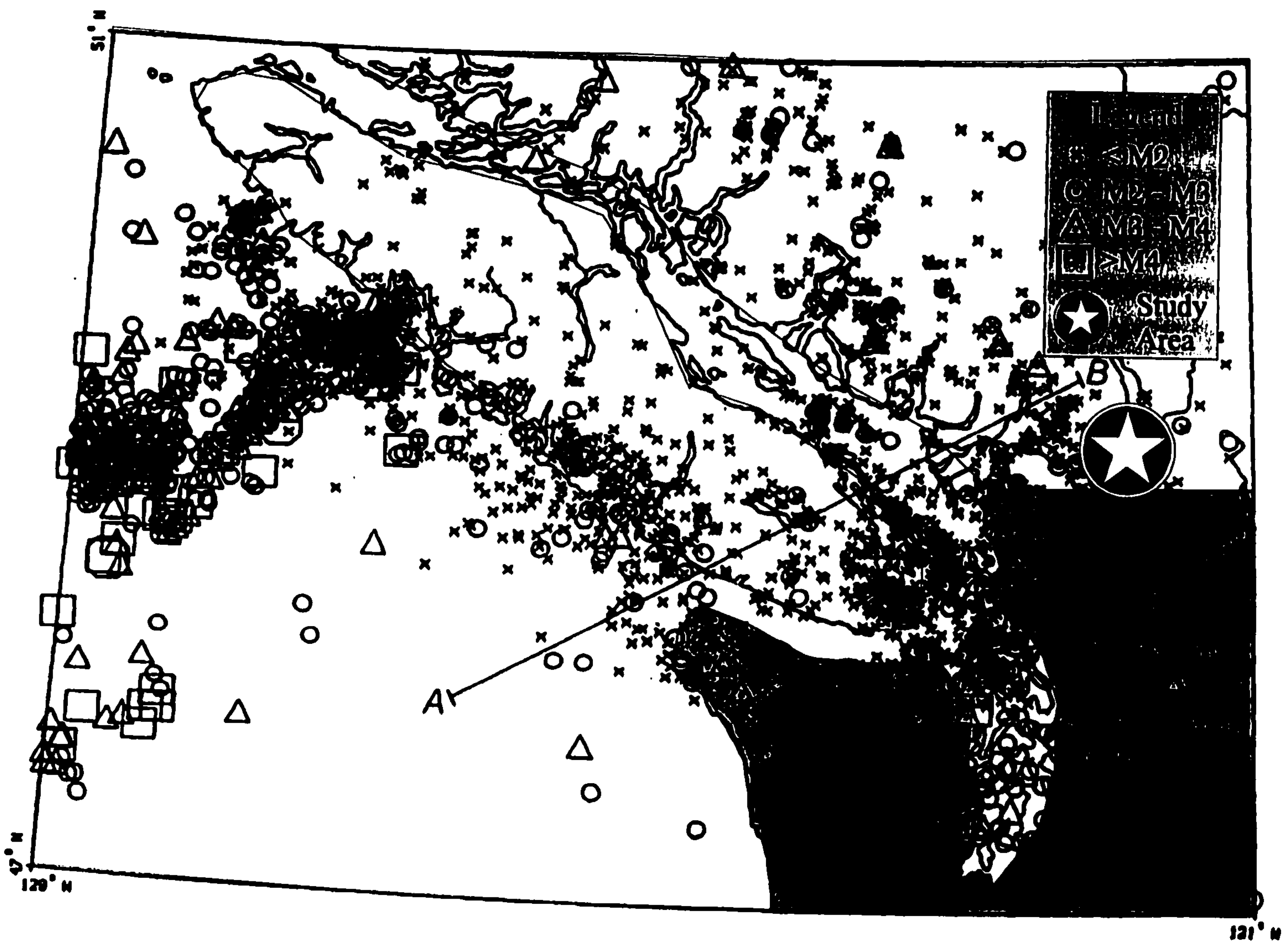


Fig. 2-3. Seismic activity in the Lower Mainland of British Columbia for a ten year period (After, Rogers, 1994).

The surficial geology of the area was described by Levson *et al.* (1996 a, b) and is summarized here. The Fraser River lowland is characterized by numerous semi-active channels and abandoned sloughs. Prior to diking of the river along the northern boundary of the study area, many of these channels were periodically occupied by flood waters. Elsewhere, Fraser River alluvium is dominated by denser gravels and sands with up to a few meters of overbank silts. The western edge of the study area is underlain by lacustrine silts, sands and clays (Figure 2-4). Immediately east of the lacustrine deposits, a large alluvial fan occurs, where the Chilliwack-Vedder River enters the Fraser River valley. The alluvial fan deposits become thinner and more sandy - less gravely toward the margins (Figure 2-5 points A to B).

Several smaller alluvial and colluvial fans and a large landslide deposit (known as the Cheam slide) extend out onto the Fraser Valley from the mountains to the southeast (Figure 2-4). This large area of landslide debris, overlies glaciogenic deposits and is capped by up to 10 meters of soft silt, peat and marl. Upland areas, such as the Ryder Lake upland, are mantled by glacial deposits and locally are capped by a few meters of loess. Several tens of meters of Pleistocene silt, sand and gravel underlie till, in the upland area southeast of Vedder Crossing. Several poorly drained areas with thick surface accumulations of silt, clay and organics are also present on the Fraser Lowland. These include an area southeast of Chilliwack, interpreted as a large paleochannel on a relatively old part of the Fraser River flood plain and an area northwest of the Vedder fan. The fluvial deposits of the Fraser River are underlain by early Holocene and/or earlier glaciomarine (?) silts, clays and sands that locally extend to depths of over 400 meters (Levson *et al.*, 1996a,b).

The surficial geology of the region is divided into 21 units (Figures 2-4 and 2-6). A concept known as an 'average sediment lithology column' (ASLC) is used here to illustrate the stratigraphy within each surficial geology unit. The ASLC uses a bar graph to show the proportion of each sediment type within each geological unit (Figure 2-7 to 2-20). The proportion of each sediment type is shown along the horizontal axis, and the depth is shown on the vertical axis. Consider the example of 10 drill holes being located within a surficial geology unit; in the first meter, 3 holes encountered gravel, 4

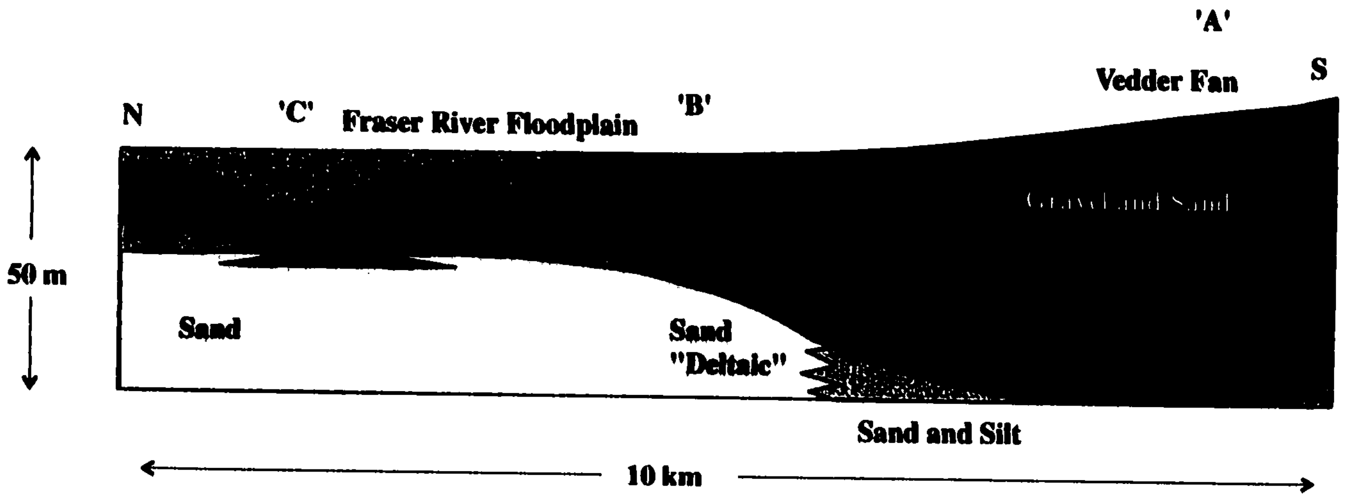


Fig. 2-5. North - south cross section of the Chilliwack area, showing the vertical distribution of surficial sediments (After, Levson et al., 1996a)

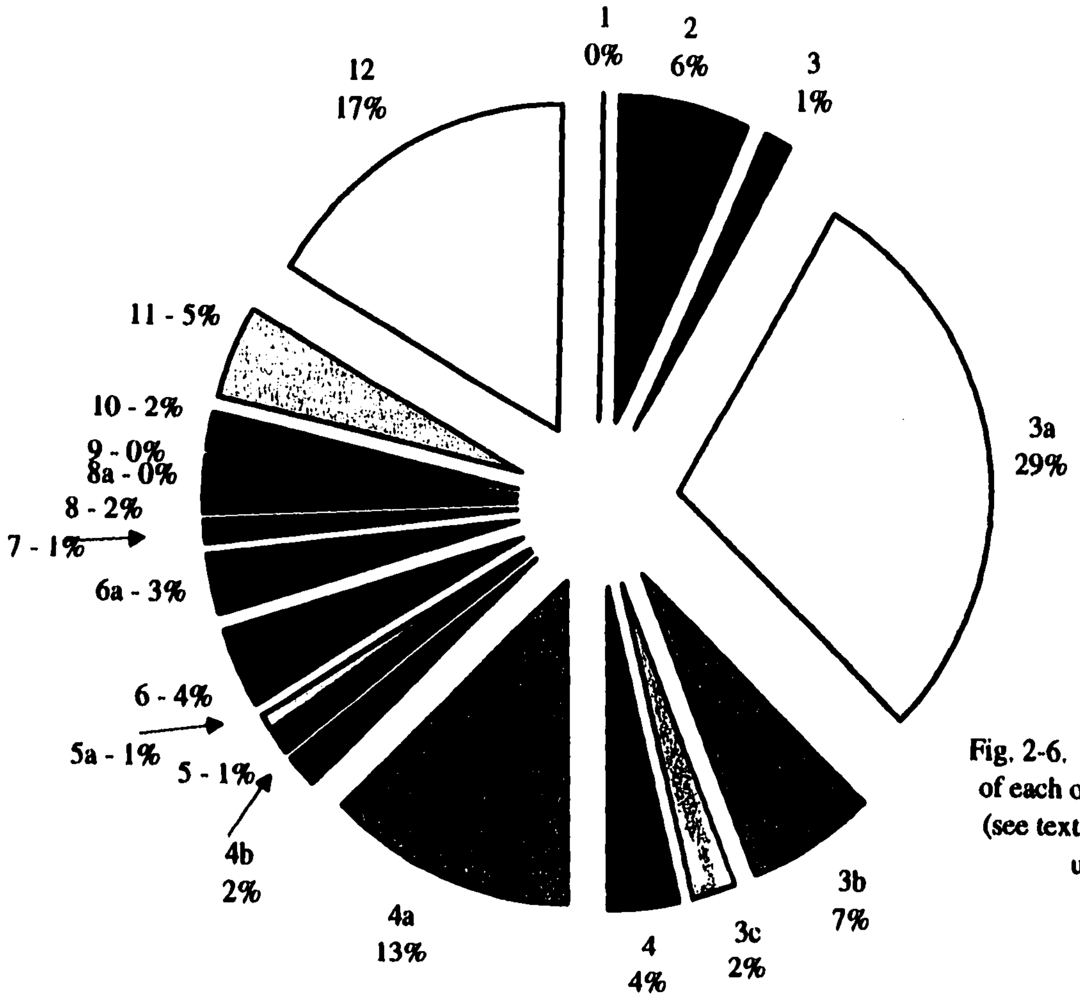


Fig. 2-6. Relative proportion of each of the surficial units (see text for explanation of unit names)

encountered sand, and 3 encountered clay. The ASLC would show the first meter as consisting of 30% gravel (red), 40% sand (yellow) and 30% clay (light blue).

One of the negative aspects of this method is that one loses information about the number of holes that contain information at any depth. In the Upper Fan, for example, only four holes extend below 18 m depth. Therefore, one unrepresentative hole can have a misleading effect on the ASLC. It is important to understand the limitations associated with any method of data portrayal.

In the following sections the geology of each of the main Quaternary units in the study area is described using the ASLC as an illustrative tool.

1) Anthropogenic deposits(<1% of area)

The only anthropogenic deposit depicted on the map is located in the northwestern corner of the area, on the south bank of the Fraser River. A logging operation filled part of the Fraser River with gravels and sands. Other anthropogenic deposits not delineated on the map, but worthy of discussion, are the dikes located on the banks of the Fraser, Chilliwack, and Vedder Rivers and the Vedder Canal. Due to the very high water table, probable looseness of the material, and lack of fines, they represent a significant liquefaction hazard. These deposits make up the highest dikes in western Canada. The dikes were engineered to withstand a seismic event, but at the time they were constructed, the true nature of the seismicity in the region was not fully realized.

2) Active River Alluvium (6% of area)

This unit is made up of the sediments underlying the Fraser, Vedder, and Chilliwack rivers and the Vedder Canal. The sediment in the Chilliwack and Vedder rivers tends to be relatively coarse gravel, due to the relatively high energy in these channels. Whereas the sediments underlying the Fraser River and Vedder Canal tend to be finer (sands and silts). The overall trend within this unit is fining downward (Figure 2-7). This is likely due to the meandering nature of the rivers. The holes are located within the presently active channels of these fluvial systems. The active channel is where the coarsest material is present. Peripheral to the active channel, one would find finer sediments

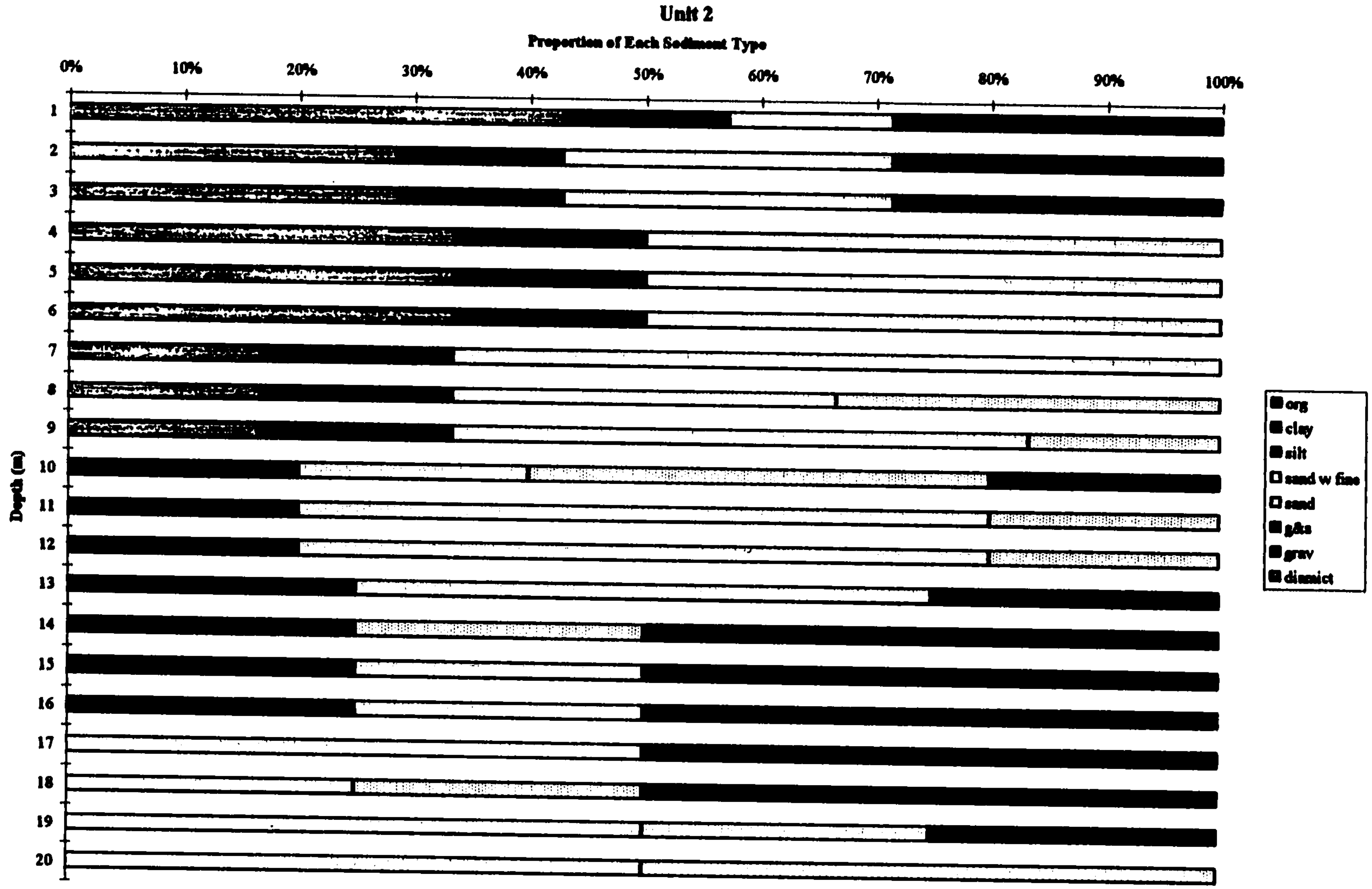


Fig. 2-7. Average sediment lithology column - Unit 2. Showing the depth on the vertical axis and the proportion of drill holes that intersected each sediment type on the horizontal axis.

representing overbank deposits. The material located below the present active channel would record a time when the active river was peripheral to it's present location. Therefore, the sediments below the active channel would represent overbank deposits of the channel.

3) Semi-active channels and sloughs (1% of area)

This unit makes up the relatively large channels that were active during high Fraser River water levels prior to the diking of the area. Located mostly in the northern half of the map, these areas are underlain by mostly gravel with sand, sand, and sand with fines (Figure 2-8). A few diamictons are present at the surface (i.e. in the upper 5 meters). These likely represent anthropogenic fill associated with bridge and overpass construction peripheral to the swamps/channels. Sandy sediments become more predominant at depth (i.e. below 15 meters).

3a) Fraser River alluvium with preserved channel and bar topography (29% of area)

This unit is underlain by a sequence of sediments that in the upper 20 meters roughly retains a bilateral symmetry on the ASLC (Figure 2-9). The upper 10 m of the area is a fining upwards sequence. At 10 m depth, sands with fines and finer sediments make up 30% of the sediments, this gradually increasing to approximately 80% at the surface. This sequence is likely due to sandy to silty overbank deposits of the Fraser River. The lower sequence is a coarsening upwards one, with 15% gravel at 20 m depth gradually increasing to 40% at 10 m depth. This is likely due to the lateral migration of the Fraser River.

3b) Fraser River Alluvium with thick overbank fines (7% of area)

This unit is characterized by several meters of silts, clays and organics at surface (Figure 2-10). Silts constitute a significant portion of the sediment underlying these areas to a depth of 13 m. Water well records were also analyzed for this unit because relatively few geotechnical holes penetrated below 15 m. A definite fining upwards trend was shown, with clays increasing from 0% at 20 m to 85% at surface. The areas

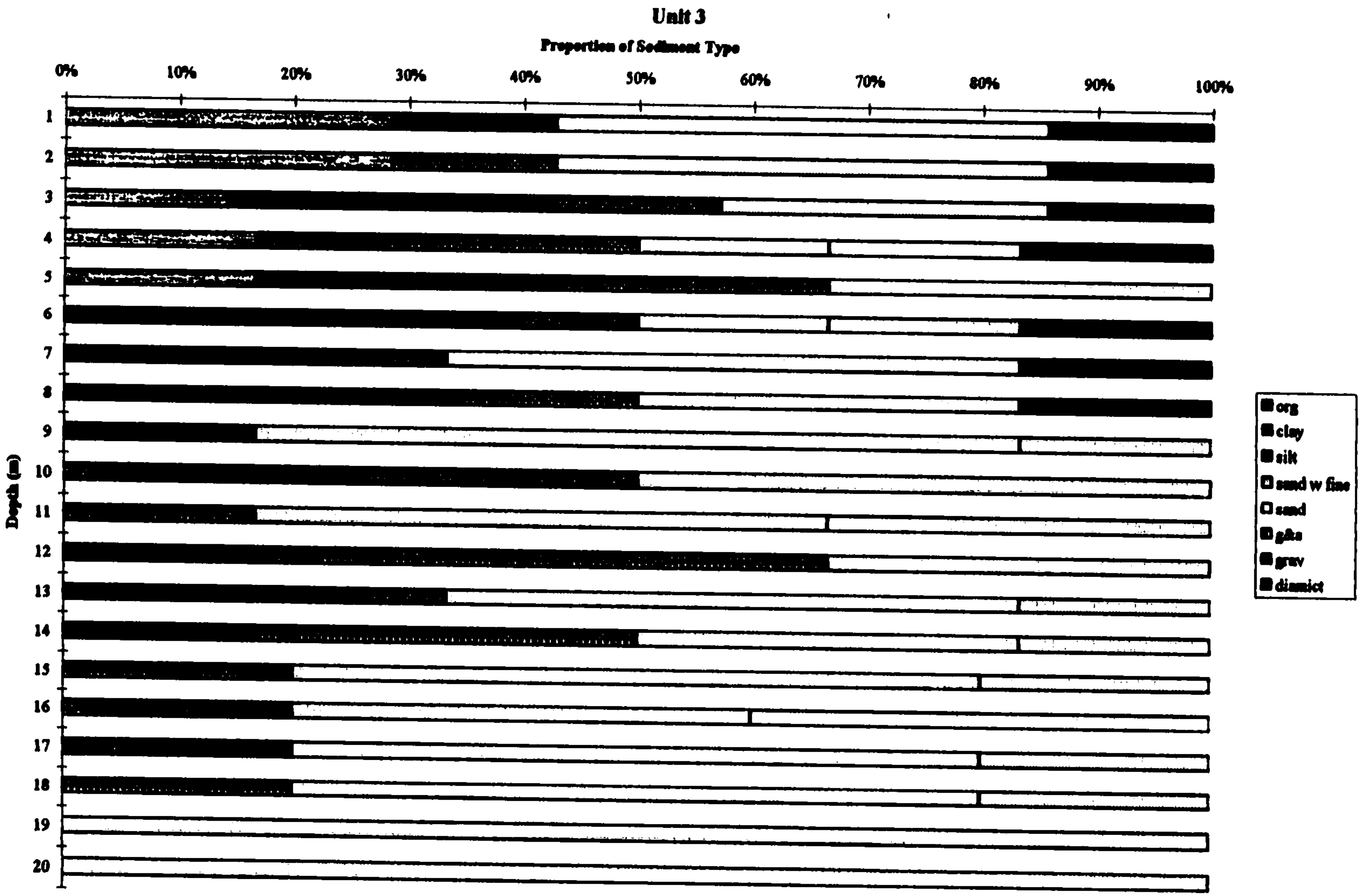


Fig. 2-8. Average sediment lithology column - Unit 3.

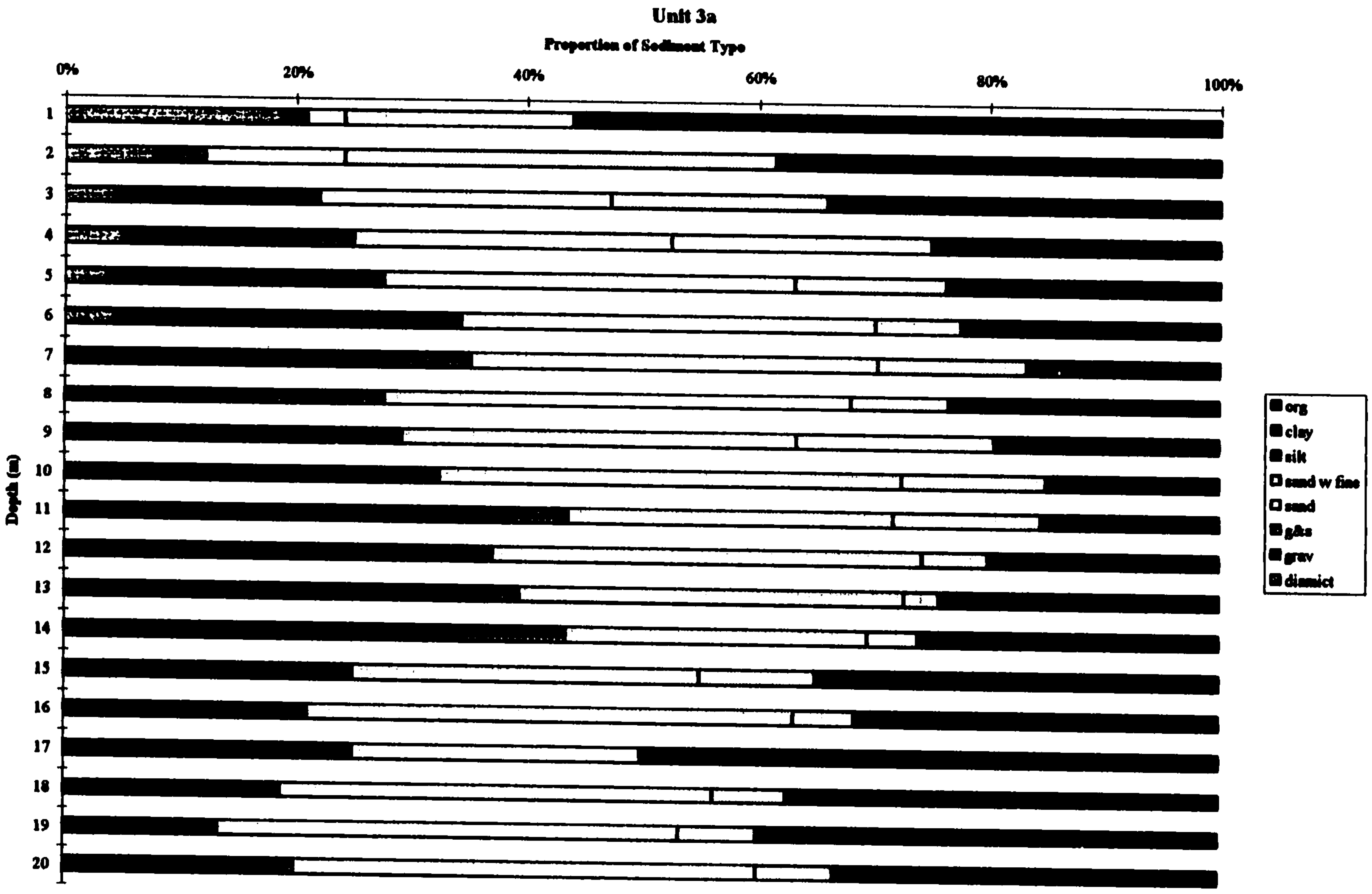


Fig. 2-9. Average sediment lithology column - Unit 3a.

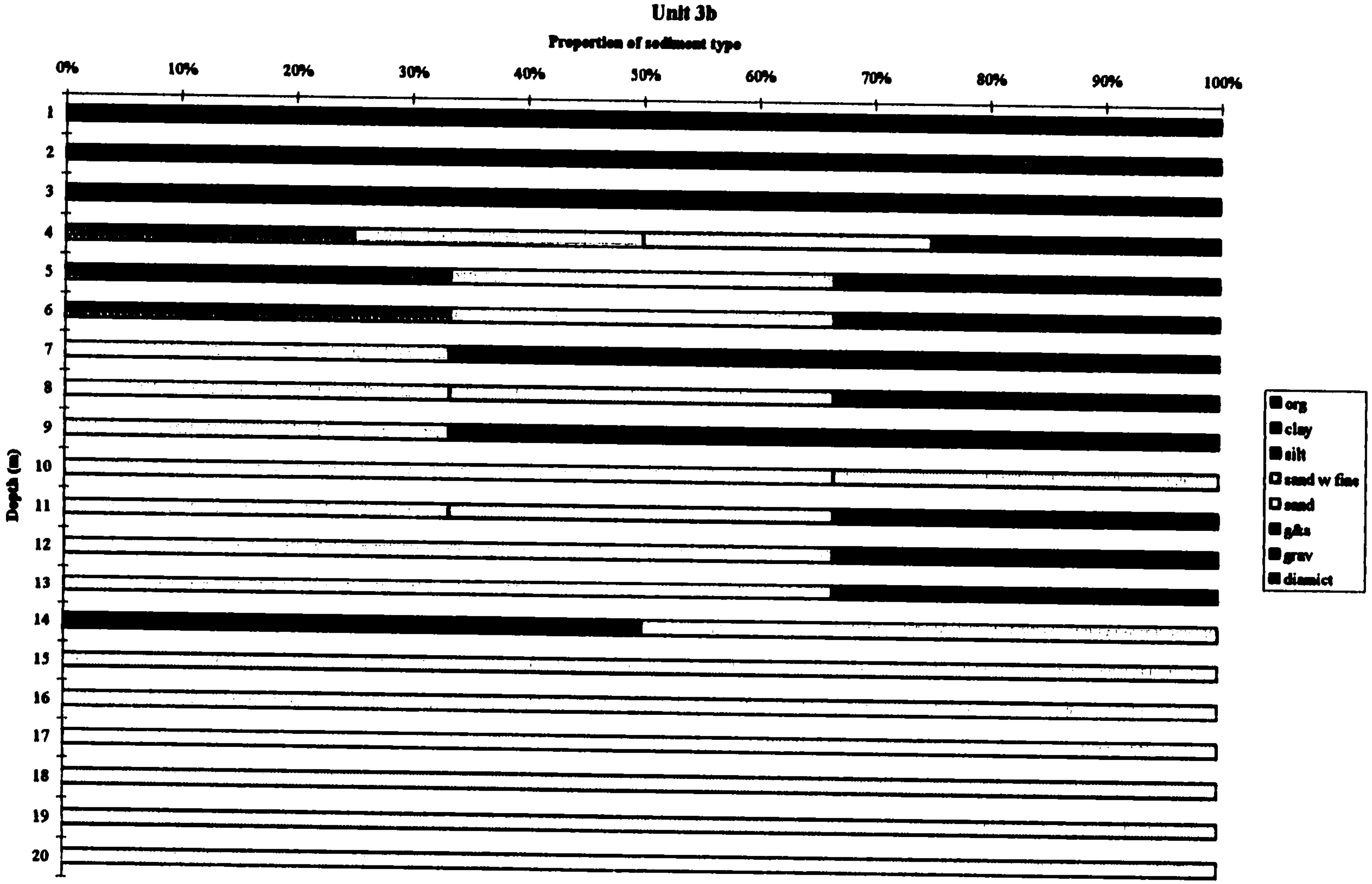


Fig. 2-10. Average sediment lithology column - Unit 3b.

within this unit formed low areas prone to flooding and prone to the accumulation of over bank silts.

3c) Abandoned creek channels and small sloughs (2% of area)

These features are located in most parts of the map area, except the south west corner. This unit is very similar to unit 3a, with the upper 5 meters being underlain with silts and organics, the rest of the succession is mostly gravel and sand (Figure 2-11). The surface diamicton again likely represents fill from bridge and road construction.

4) Proximal Vedder Fan (4% of area)

The upper Vedder fan is underlain predominantly by gravels (Figure 2-12). There are two sequences recognized within the fan stratigraphy, a coarsening-upwards sequence from 20 m to about 8m depth, and a fining upwards sequence from 8 m to surface. The upper sequence dominated by sands with silts, and silts with minor organics, likely represents overbank deposits of the Vedder - Chilliwack River. The coarsening-upwards sequence may be caused by some of the holes penetrating through the fan into the underlying lacustrine sediments.

4a) Distal Vedder Fan (16% of area)

The distal fan is underlain by a relatively chaotic assemblage of sediments. The upper 2 meters are relatively fine and again likely represent overbank deposits of the Chilliwack - Vedder River (Figure 2-13). At the base (17 - 20 m) the sediments are very fine, up to 50% clays, these are likely the lacustrine sediments below the fan. The lower fan is quite thin, from 0 m to about 10 m, and the varied stratigraphy of the sediments there is likely reflecting the many different sub fan units including, lacustrine sediments, gravely Fraser alluvium and sandy Fraser alluvium.

5) Upper colluvial / alluvial fans (1% of area)

The amount of subsurface information in this map unit is relatively sparse. The upper fans are located at the bottom of steep mountain fronts. The sediments deposited

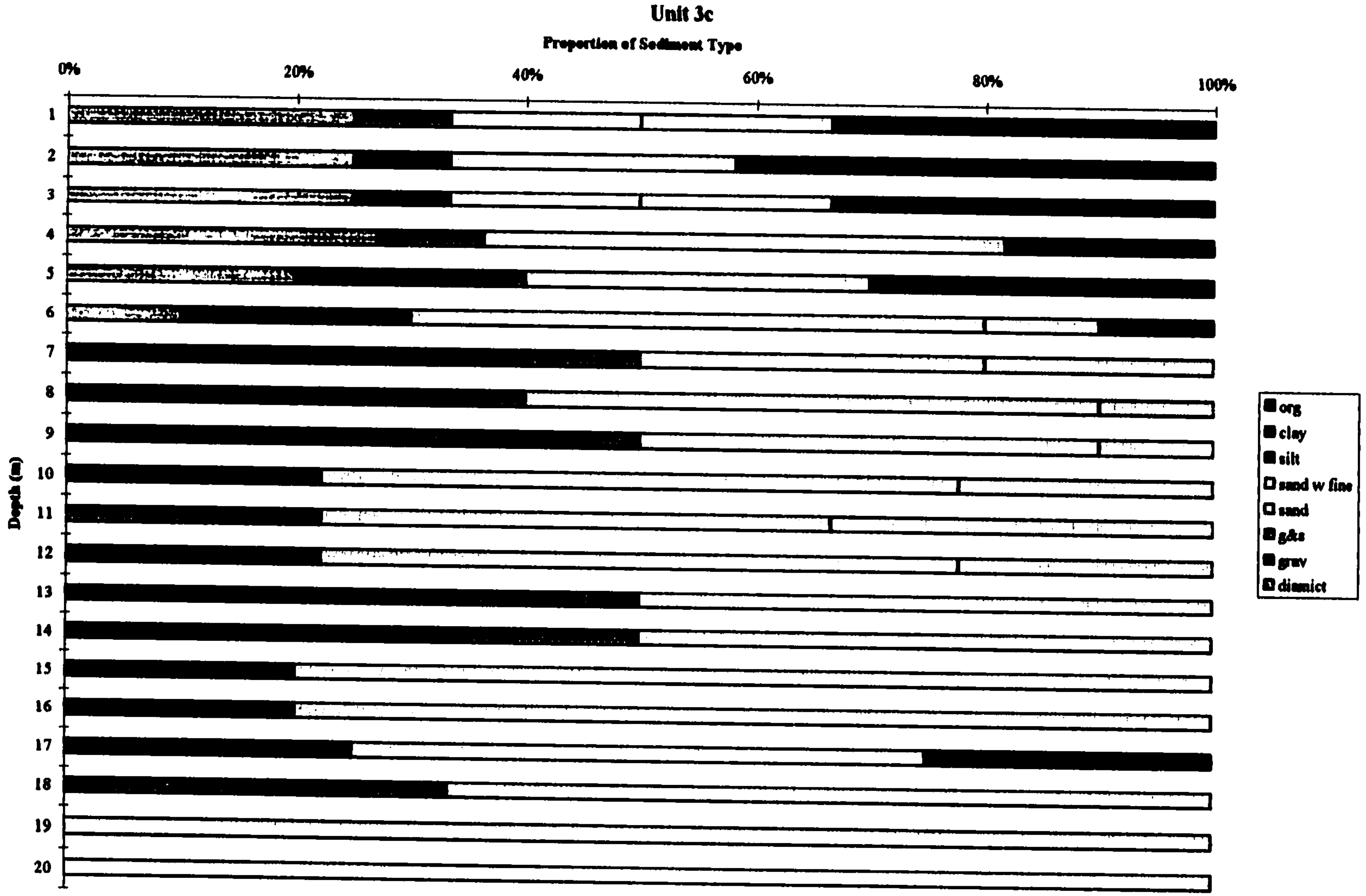


Fig. 2-11. Average sediment lithology column - Unit 3c.

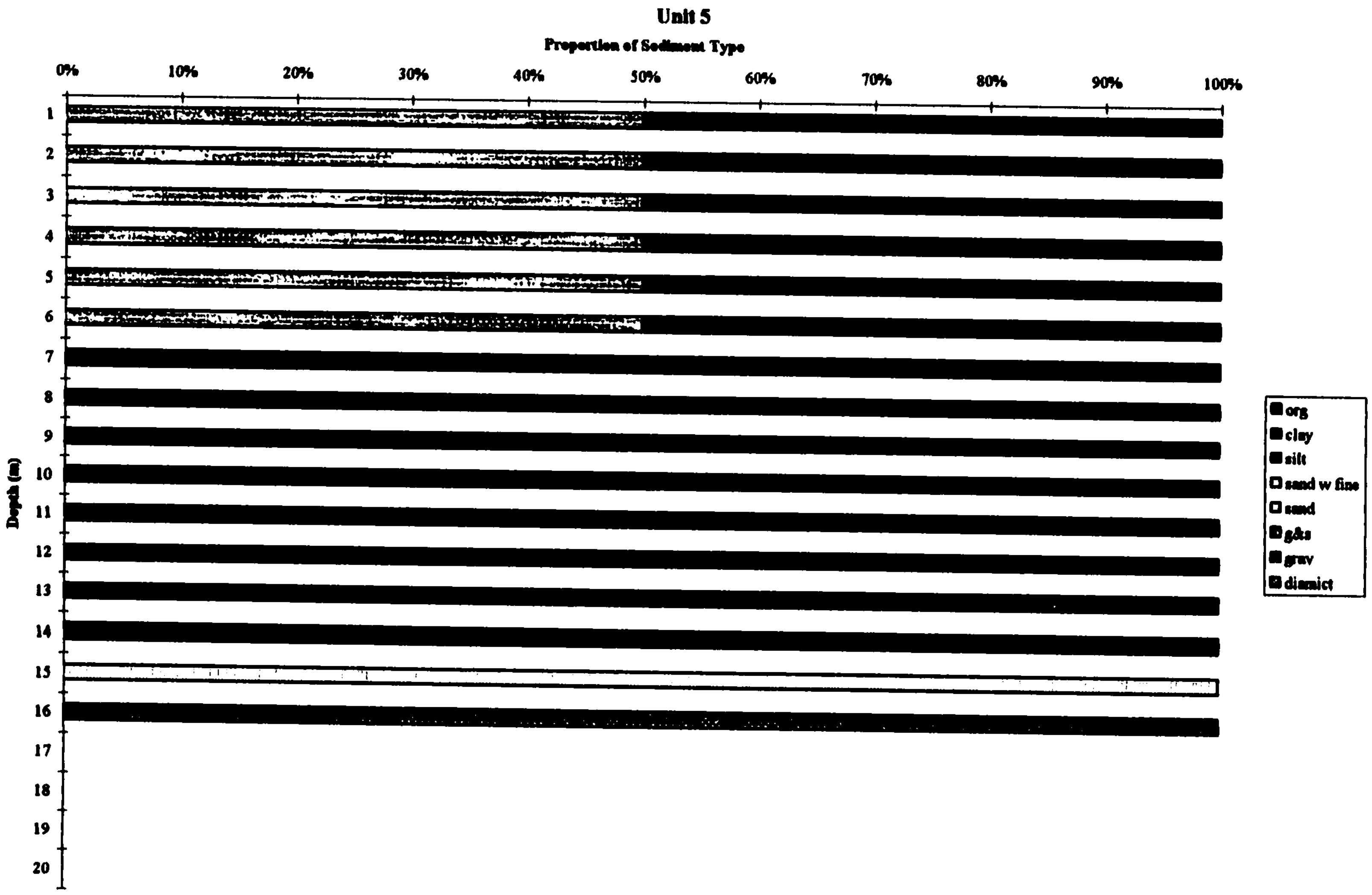


Fig. 2-14. Average sediment lithology column - Unit 5.

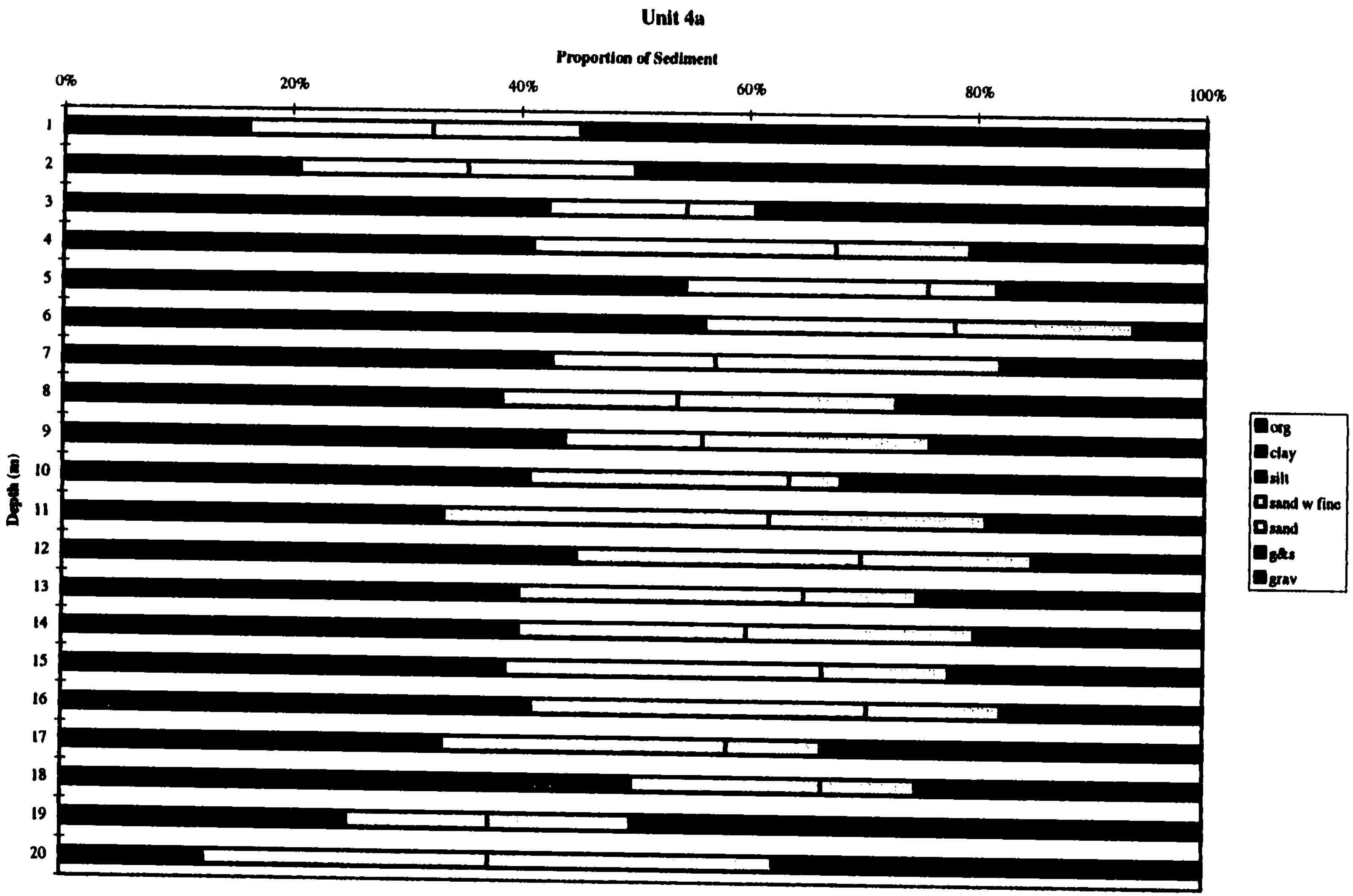


Fig. 2-13. Average sediment lithology column - Unit 4a.

at this kind of location are likely to be relatively coarse, mainly diamicton and coarse gravels. The drill hole data supports this interpretation (Figure 2-14).

5a) Lower colluvial / alluvial fans (1% of area)

Very little subsurface information is available for this unit. These are the distal equivalents of the upper fans. As such, it seems likely that they would be characterized by slightly finer grained material at surface than the upper fans. At depth one would expect gravels and diamictons. Again, the limited subsurface information seems to back up this hypothesis (Figure 2-15).

6) Flood plain swamps and bogs (4% of area)

This unit is characterized by deep (> 10 m) organics (Figure 2-16). Fine sediments (silts and clays) dominate the entire unit. The sands and gravels in the 4 - 12 m depth range likely represent channel deposits. The areas where this unit is present are considered to have an elevated ground motion amplification hazard.

6a) Thin organic deposits and undifferentiated alluvium (3% of area)

These areas, mostly in the south central map area, represent the transition between flood plain swamps / bogs and the Fraser River alluvium. As such, the organics are intermediate between the two, and only extend to a maximum depth of 6 m (Figure 2-17). The sands and gravels are not as prevalent as in the Fraser River unit likely due to the distance to the active channel.

7) Lacustrine sediments (1% of area)

Confined to the western edge of the map area, these sediments were deposited in Lake Sumas, before the lake was drained for agricultural purposes. The upper 7 m is dominated underlain (50-60% of the holes) by diamict (Figure 2-18). This represents the dikes that were built to keep the lake from reflooding. The rest of the unit is underlain by sands and silts with only minor variability.

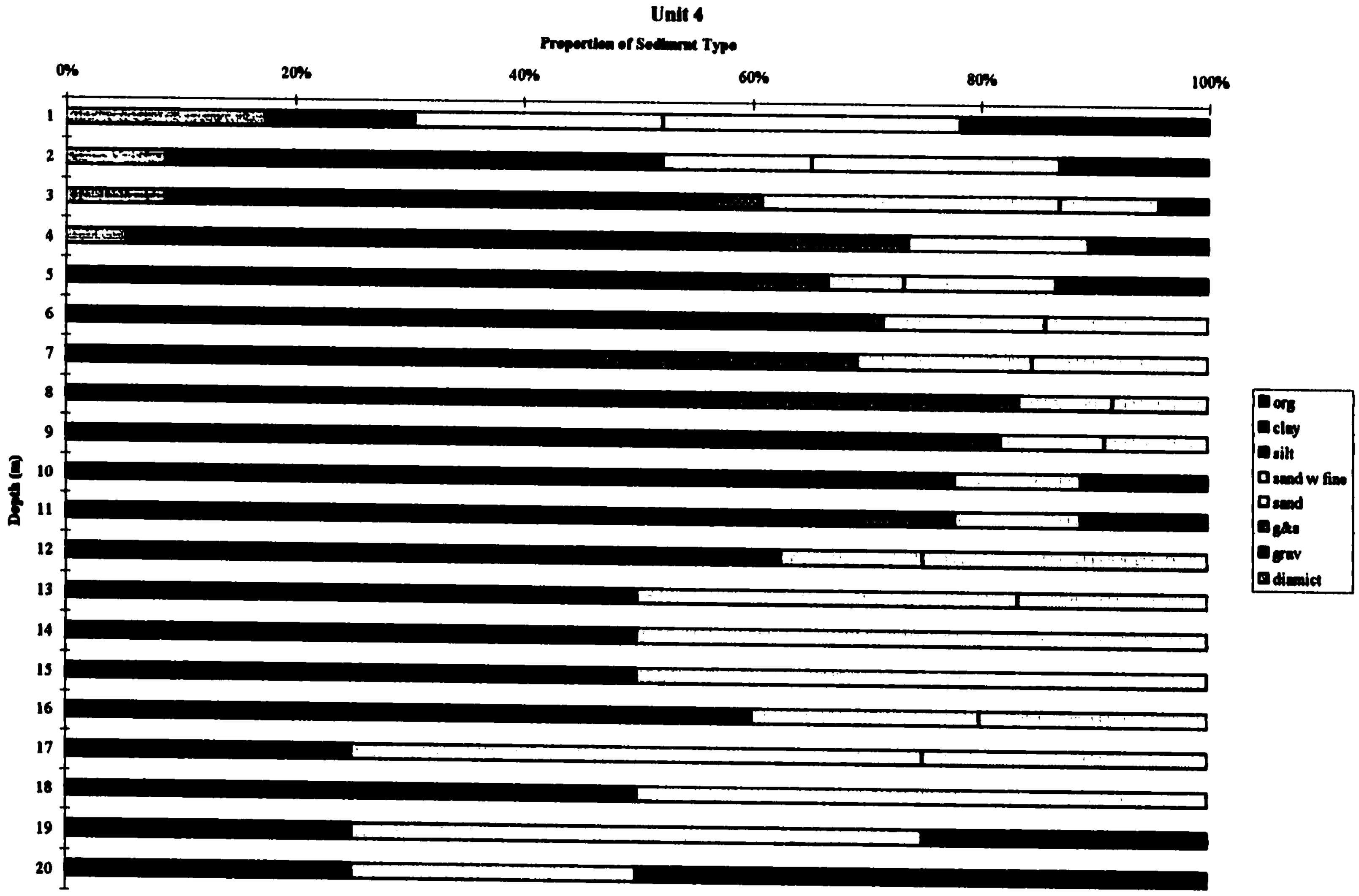


Fig. 2-12. Average sediment lithology column - Unit 4.

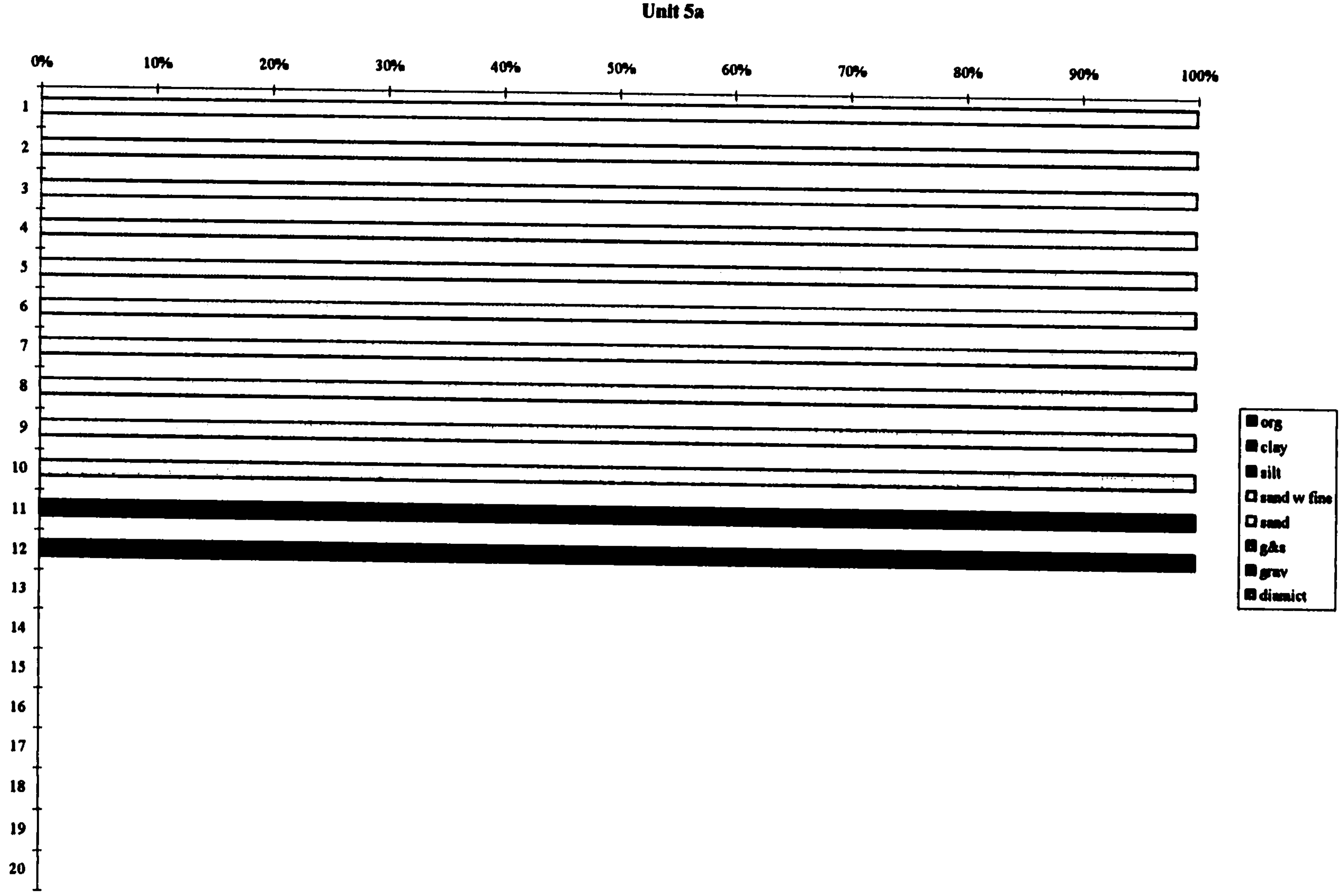


Fig. 2-15. Average sediment lithology column - Unit 5a.

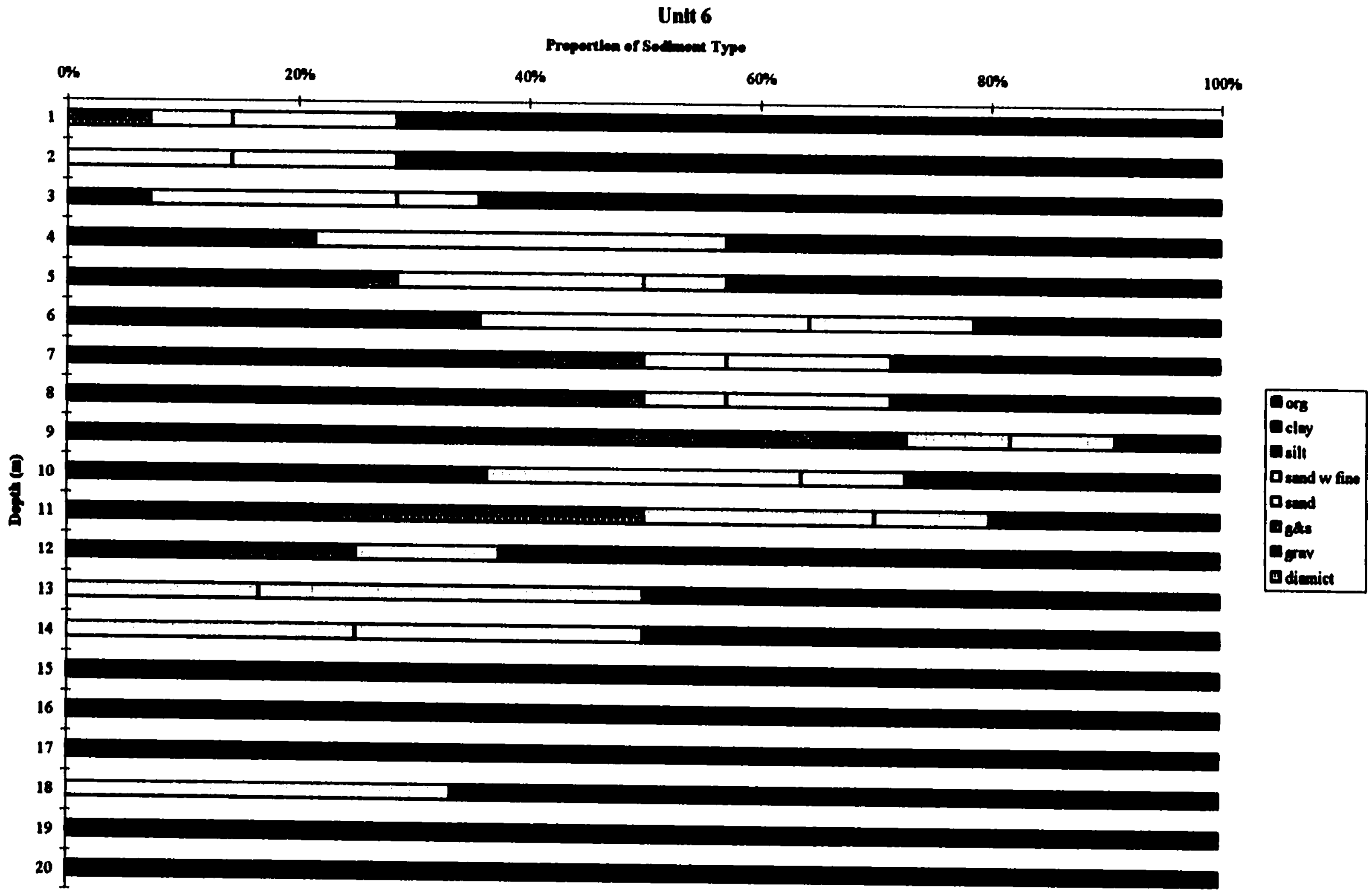


Fig. 2-16. Average sediment lithology column - Unit 6.

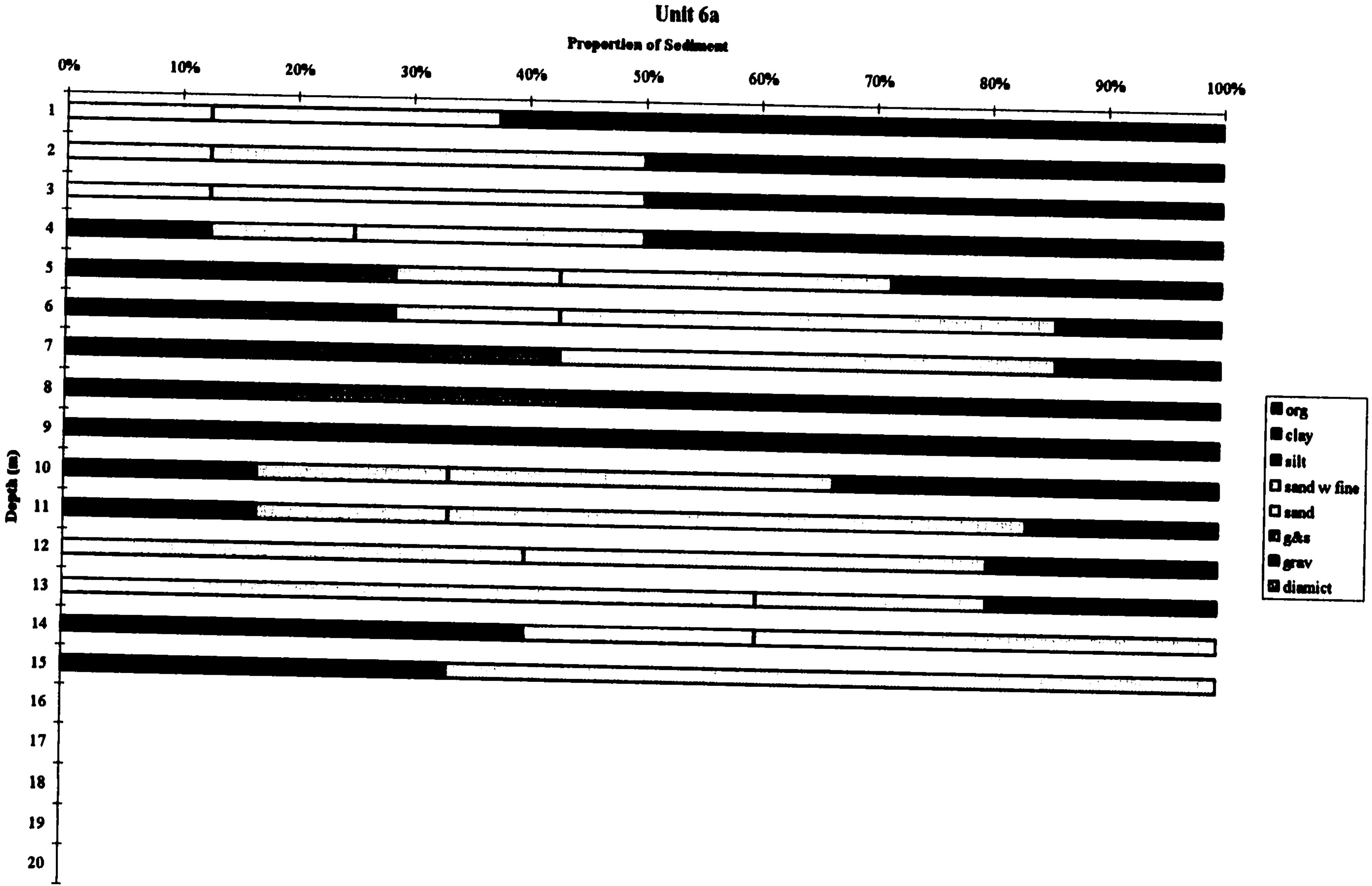


Fig. 2-17. Average sediment lithology column - Unit 6a.

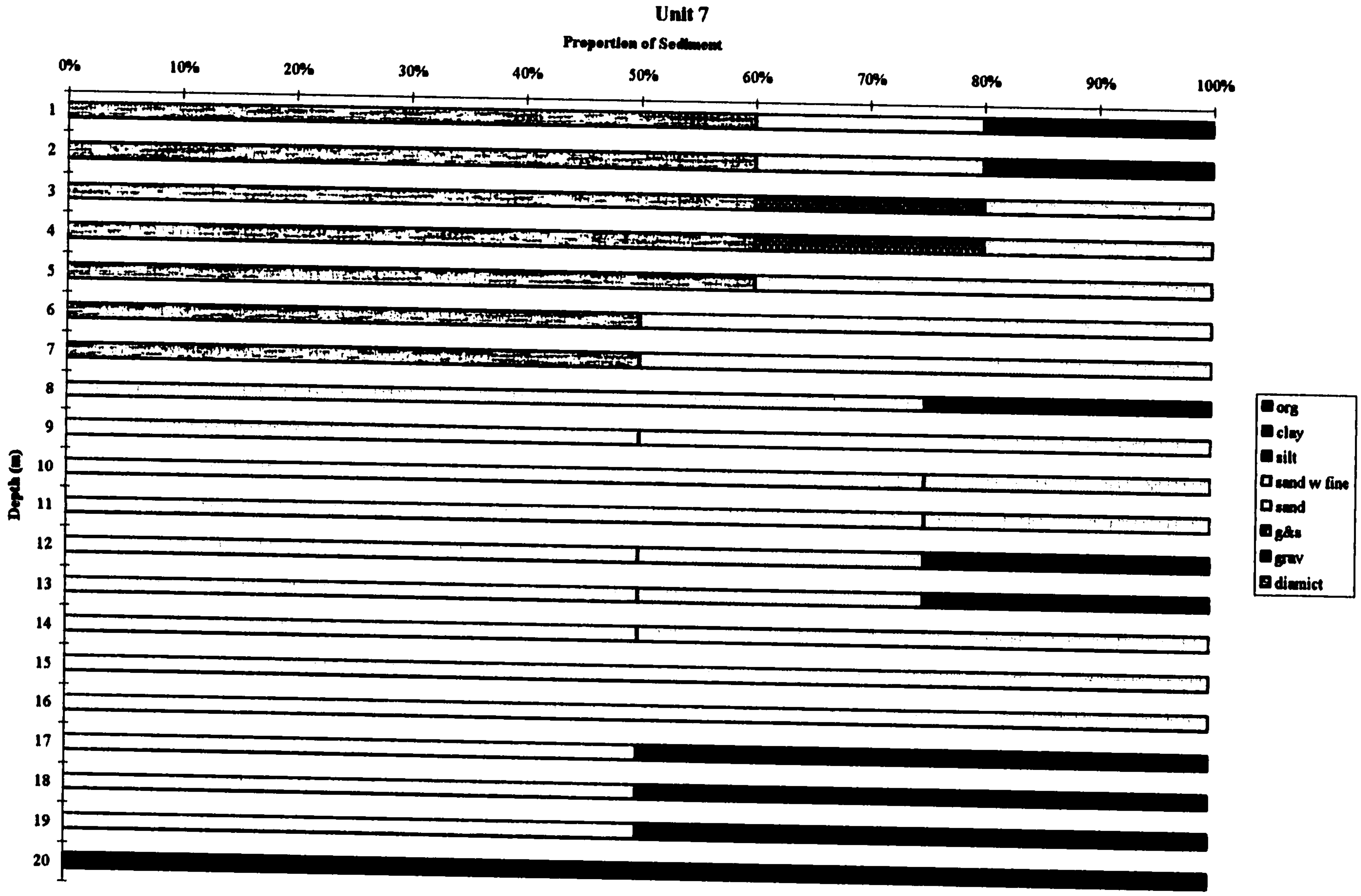


Fig. 2-18. Average sediment lithology column - Unit 7.

8) Cheam Landslide deposits (2% of area)

Located in the far eastern edge of the map, the Cheam slide deposits represent very coarse material (including boulders tens of meters in diameter) derived from the mountains to the south (Figure 2-19). The test holes within this unit are not diagnostic of the true nature of the materials that occur in low lying areas between landslide debris. Most geotechnical pits are not attempted in areas of very coarse material. Therefore, by choosing finer-grained areas for the test pits, the data has been skewed.

8a) Alluvial sand overlying slide debris (<1% of area)

This material is the same as above, but with a thin skiff (perhaps a few meters) of fluvial sands and gravels (Figure 2-20).

9) Loess (<1% of area)

No geotechnical data was obtained in these areas. The writer visited an area of loess exposure in the study area, and found thin (2-3 m), well sorted sand overlying bedrock. Due to the relatively thin nature and low water table, these deposits are not considered to pose a high liquefaction hazard.

10) Steeply eroded Pleistocene sediments (2% of area)

These deposits are confined to the southern edge of the map, peripheral to the mountain front. Most of these areas are underlain by sands, gravels and diamicton (Figure 2-21). The silts and organics at the surface are likely the result of some soil development. However, the finer sediments at depth are likely to be primary in origin.

11) Till and undifferentiated gravels and sands (5% of area)

Due to the coarse, compact, nature of these deposits, very low earthquake hazards are associated with these deposits. As such, no information was entered into the GIS.

12) Bedrock (17% of area)

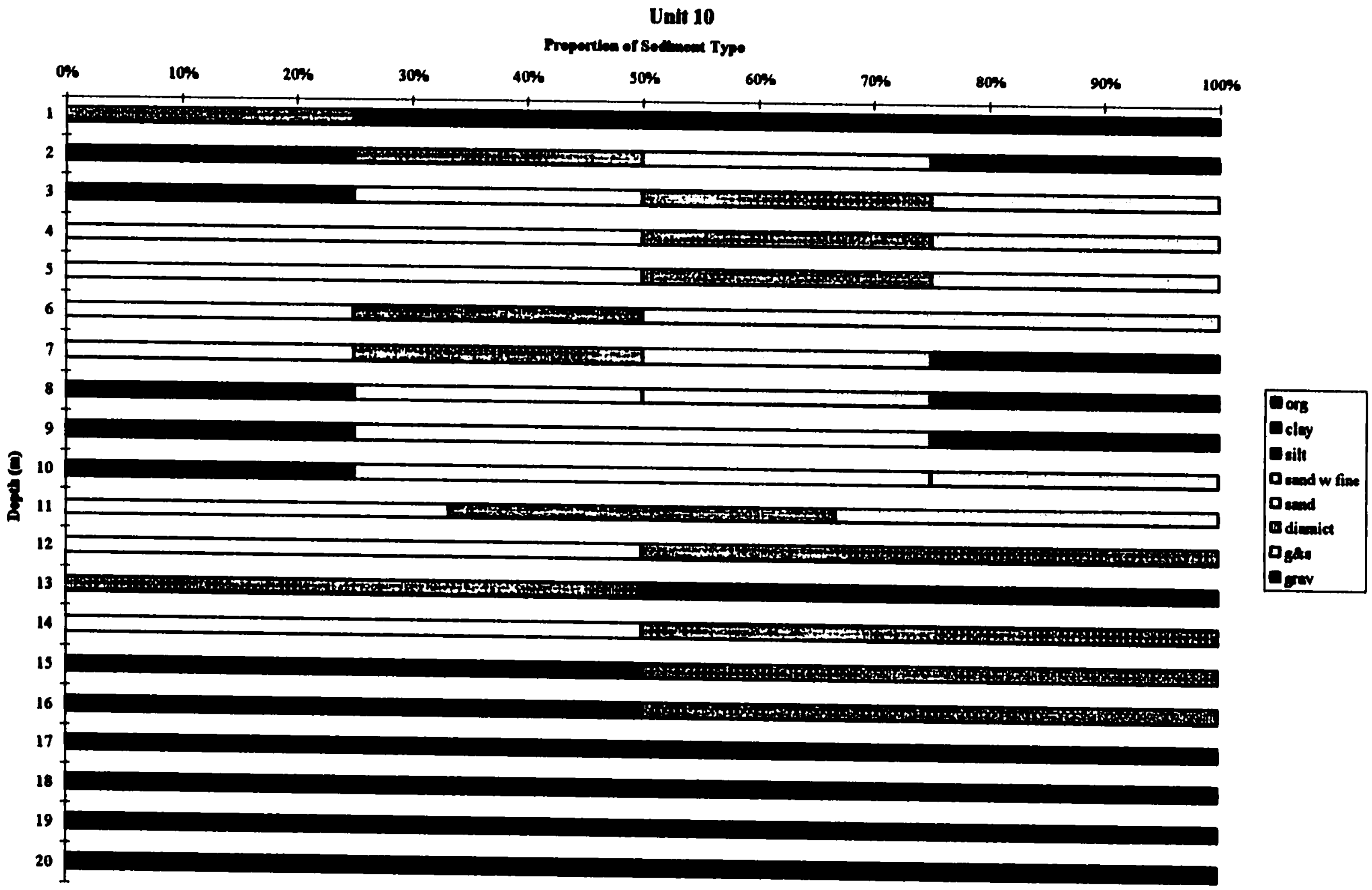


Fig. 2-20. Average sediment lithology column - Unit 10.

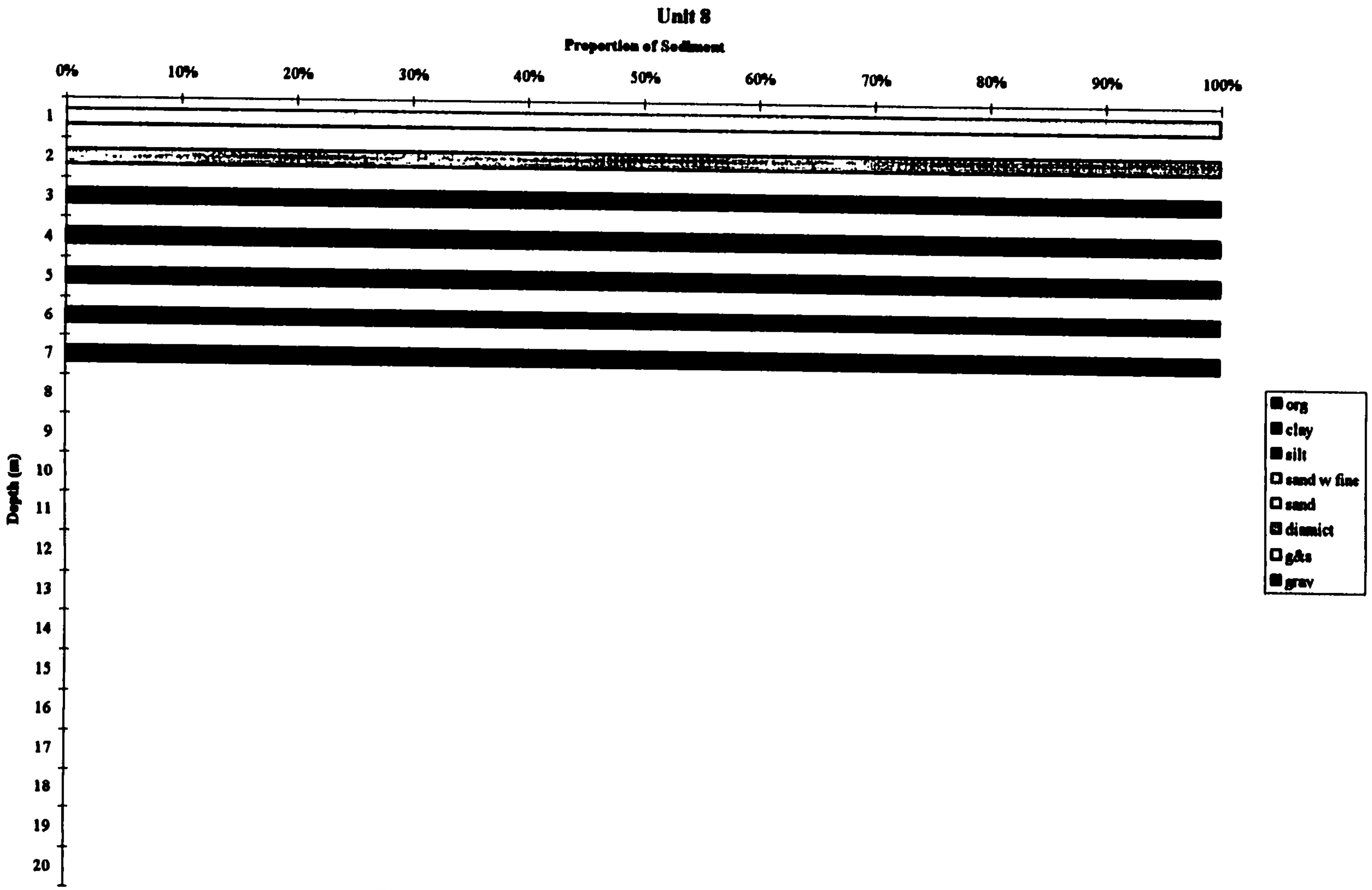


Fig. 2-19. Average sediment lithology column - Unit 8.

No geotechnical data was entered for this region. Bedrock is considered to have very low to nil liquefaction or ground motion amplification hazard.

LIQUEFACTION AND GROUND MOTION AMPLIFICATION

Qualitative liquefaction assessment

Liquefaction is the temporary conversion of unconsolidated soils (usually sands and silts) into a medium that behaves like a fluid. This occurs during high magnitude, long duration ground motion (Reiter, 1990). Water in the interstices of the sediment can not escape fast enough to permit compaction. The pore pressures are elevated such that the sediment becomes quicksand (EERI, 1984). The liquefaction susceptibility of a soil is dependent upon several factors including grain-size distribution and density. These factors can be estimated in a qualitative manner based on a basic understanding of sedimentology and surface processes. Once these factors are determined, the liquefaction susceptibility can then be evaluated (Table 2-3). Many liquefaction maps are based solely on this kind of information. Liquefaction maps based solely on soil classifications are referred to as 'Level One' liquefaction hazard maps (Klohn-Crippen, 1994).

Quantitative liquefaction assessment

To quantify liquefaction susceptibility, sophisticated computations are required. A software package, modified from a version of PROLIQ2 (Atkinson *et al.*, 1986) was used to evaluate the liquefaction potential at 25 sites using 65 high quality geotechnical drill holes. PROLIQ2 factors in the following parameters for each meter of sediment:

1) the density of the soil from a Standard Cone Penetration test (Seed, 1979)
2) the average depth of the water table

Table 2-3. Estimated Susceptibility of Sedimentary Deposits to Liquefaction During Strong Seismic Shaking (After Youd and Perkins, 1978)

Type of deposit	Gen. distributiuon of cohesionless sediments in deposits	Likelihood that cohesionless Sediments when saturated would be Susceptable to Liquefaction (by age of deposit)			
		<500 yrs	Holocene	Pleis tocene	Pre-Pleistocene
(a) Continental Deposits					
River Channel	Locally Variable	V. High	High	Low	V.Low
Flood plain	Locally variable	High	Mod.	Low	V. Low
Alluvial fan and plain	Widespread	Mod.	Low	Low	V. Low
Marine terraces and plains	Widespread	-	Low	V. Low	V. Low
Delta and Fan Delta	Widespread	High	Mod.	Low	V. Low
Lacustrine and Playa	Variable	High	Mod.	Low	V. Low
Colluvium	Variable	High	Mod.	Low	V. Low
Talus	Widespread	Low	Low	V. Low	V. Low
Dunes	Widespread	High	Mod.	Low	V. Low
Loess	Variable	High	High	High	?
Glacial Till	Variable	Low	Low	V. Low	V. Low
Tuff	Rare	Low	Low	V. Low	V. Low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	V. Low	V. Low
Sebka	Locally variable	High	Mod.	Low	V. Low

Table 2-3. (cont...) Estimated Susceptibility of Sedimentary Deposits to Liquefaction During Strong Seismic Shaking (After Youd and Perkins, 1978)

(b) Coastal Zone

Delta	Widespread	V. High	High	Low	V. Low
Esturine	Locally variable	High	Mod.	Low	V. Low
High energy					
Beach	Widespread	Mod.	Low	V. Low	V. Low
Low energy					
Beach	Widespread	High	Mod.	Low	V. Low
Lagoonal	Locally variable	High	Mod.	Low	V. Low
Fore shore	Locally variable	High	Mod.	Low	V. Low

(c) Artificial (fill)

Uncompacted	Variable	V. high	-	-	-
Compacted	Variable	Low	-	-	-

3) grain-size distribution

4) a probabilistic method of seismic risk assessment (Cornell, 1968).

5) National Building Code of Canada seismicity model

6) the mean attenuation curve of Hasegawa *et al.* (1981)

7) the ground amplification chart of Idriss (1991).

The value that is produced from PROLIQ2 gives the probability of liquefaction occurring in a 50-year period, at specified depths at a given site. These values were further manipulated to produce a 'liquefaction hazard index' (LHI) shown in equation 2-1:

$$\mathrm{LHI} = \frac{\Sigma\,(W_i\ H_i\ Pl_i)}{\Sigma\,(W_i\ H_i)} \qquad \text{Equation 2-1}$$

where:

Wi is the weighting factor (inversely proportional to depth of unit) starting at 0.1 at surface and decreasing linearly to 0 at 20 m depth

Hi is the thickness of unit (in meters)

Pli is the value calculated from PROLIQ2,

LHI is equal to the probability of the locality suffering liquefaction within the 50 year period (Figure 2-21; Levson *et al.*, 1996a).

The LHI value is used because the severity of surface disruption is proportional to how liquefiable a unit is, and to its thickness and depth. For example, a liquefiable unit 20 m thick represents a greater hazard than a liquefiable unit 1 m thick. Furthermore, a liquefiable sand layer 5 m thick at surface poses a greater hazard than would the same 5 m unit at 15 m depth.

Liquefaction hazard maps that include probabilistic liquefaction information are classified as 'Level two' hazard maps (Klohn-Crippen, 1994). Liquefaction lateral spreading maps (Youd, 1991) are given the 'Level three' rank. This level of mapping

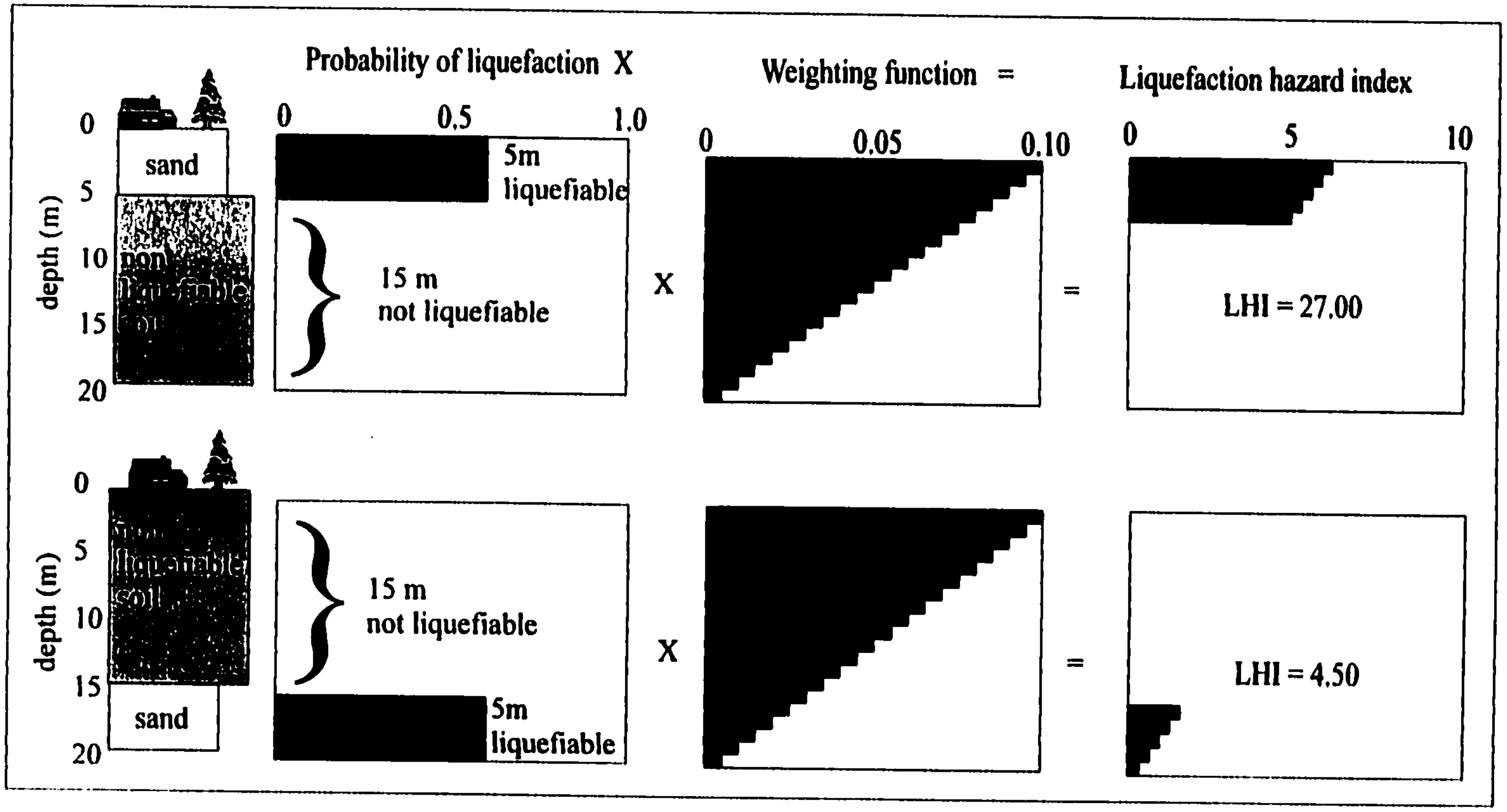


Fig. 2-21. Diagram showing a simplified LHI calculation. Note the same 5 m sand horizon at the surface results in a much larger LHI value than would the same horizon at 15 m depth. (After, Levson, 1995).

was not attempted in this project due to time and funding constraints. The lateral spreading map uses a digital elevation model (DEM) to determine the slopes of an area. Features such as free faces (escarpment) are noted and considered in this kind of mapping. Free faces, simply put, give liquefying sediments an escape route. This tends to cause an increase in the distance that liquefied sediments travel. The farther the sediment travels, the greater the risk to buildings and other features built on the soil. The expected travel distance of the sediments is overlain on the Level 2 map to produce a liquefaction lateral spreading map.

Qualitative assessment of ground motion amplification

Ground motion amplification is the capability of a site to amplify the seismic motions relative to motions on rock or firm ground at nearby sites (EERI, 1984). Ground motion amplification susceptibility can be crudely estimated by a soils map and an understanding of the geotechnical properties of these units. This level of mapping is referred to as level 1 ground motion amplification hazard mapping. Table 2-4 gives a general description of surficial and bedrock features and their susceptibility to amplification.

Quantitative assessment of ground motion amplification

Level 2 ground motion amplification mapping requires the addition of quantitative data. NEHRP site classes for amplification are based primarily on the average shear wave velocity in the upper 30 m (Vs_{30} ; Table 2-4). Vs_{30} values can be derived by two different field techniques.

In areas where soils are gravely or dense, shear wave velocities can be inferred from spectral analysis of surface waves (SASW; Stokoe *et al.*, 1994; Plate 2-1). This is a non-intrusive geophysical technique that uses the variation in the velocity of surface (Rayleigh) waves with depth to model the Vs profile of a site. Rayleigh waves were generated by hammer impacts on a metal or hard rubber plate. These waves were

Table 2.4 Categories for Soil Susceptibility to Amplification (Finn, 1996)

Class	General Description	Definition	Susceptibility
A	Hard rock	V_{s30}>1500 m/sec	Nil
B	Rock	760 < V_{s30} < 1500 m/sec	Very low
C	Very dense soil and soft rock	360 < V_{s30} < 760 m/sec, or N_{AVE} > 50 kPa or $S_{U/Ave.}$ > 100 kPa	Low
D	Stiff soils	180 < V_{s30} < 360 m/sec, or 15 kPa < N_{AVE} < 50 kPa, or 50 kPa < $S_{U/Ave.}$ < 100 KPa	Moderate
E	Stiff soils, or profile with >3 m soft silt & clay	V_{s30} <180 m/sec, or >3m silt and clay with plasticity index > 20%, moisture content > 40%, and undrained shear strength <25 kPa	High
F_1	Soils vulnerable to potential failure or collapse (e.g. liquefiable soils)		Very High
F2	Peats or highly organic clays	Peat thickness > 3m	Very high (?)
F3	Very high plasticity clays	Clays > 8 m thick & plasticity index > 75%	Very high
F4	Very thick soft/medium stiff clay	Clay thickness > 36 m	Very high

V_{s30} = average shear wave velocity in upper 30 m; N_{AVE} = average standard penetration resistance in upper 30 m
$S_{U/Ave}$ = average undrained shear strength in upper 30 m

Plate 2.1 SASW field technique

recorded by a pair of geophones spaced 1 to 10 m apart and located up to 20 m from the plate (Monahan and Levson, 1997).

The other field technique employs a seismic cone penetration test (SCPT's; Robertson *et al.*, 1992). A SCPT is performed by pushing an instumented cone tipped rod into the ground at a constant rate using a modified drill rig (Plate 2-2). The tip is studded with a battery of instruments including:

1) a load cell at the tip that records the resistance to penetration (tip resistance)
2) a friction sleeve above the tip that records the frictional resistance of the sediment
3) a pore pressure element that records the dynamic pore pressures during penetration
4) a geophone that is placed near the cone tip to record shear wave arrivals.

The first three instruments digitally record information every 5 cm. Shear wave measurements were recorded every meter. Shear waves were generated by using a sledge hammer to strike either a horizontal steel beam beneath the drill rig or an auger inserted into the ground.

Once the shear wave velocity has been determined by the aforementioned techniques, the amount of amplification can be estimated. The degree to which the soil will amplify ground motions is not only a function of the site conditions but also the strength of shaking that occurs. Table 2-5 lists the soil classification, strength of shaking, and the actual amplification factor.

As one might expect, certain ground conditions (e.g., soil class 'E') are far more hazardous than others (e.g., soil class 'A'). However, when shaking is quite intense (on firm ground) the soil type does not have as great of an effect as when ground motion is relatively weak. For example, consider soil class 'E' at 0.1g (relatively weak shaking) the amplification factor is 2.5 whereas at 0.4 g (relatively strong shaking) the amplification factor is 0.9 (i.e. deamplification actually occurs). This phenomenon greatly increases the complexity of mapping ground motion amplification hazards.

Table 2.5 Amplification Factors (Finn, 1996)

Site Class	Peak surface horizontal firm ground acceleration				
	0.1g	0.2g	0.3g	0.4g	0.5g
A	0.8	0.8	0.8	0.8	0.8
B	1	1	1	1	1
C	1.2	1.2	1.1	1	1
D	1.6	1.4	1.2	1.1	1
E	2.5	1.7	1.2	0.9	?

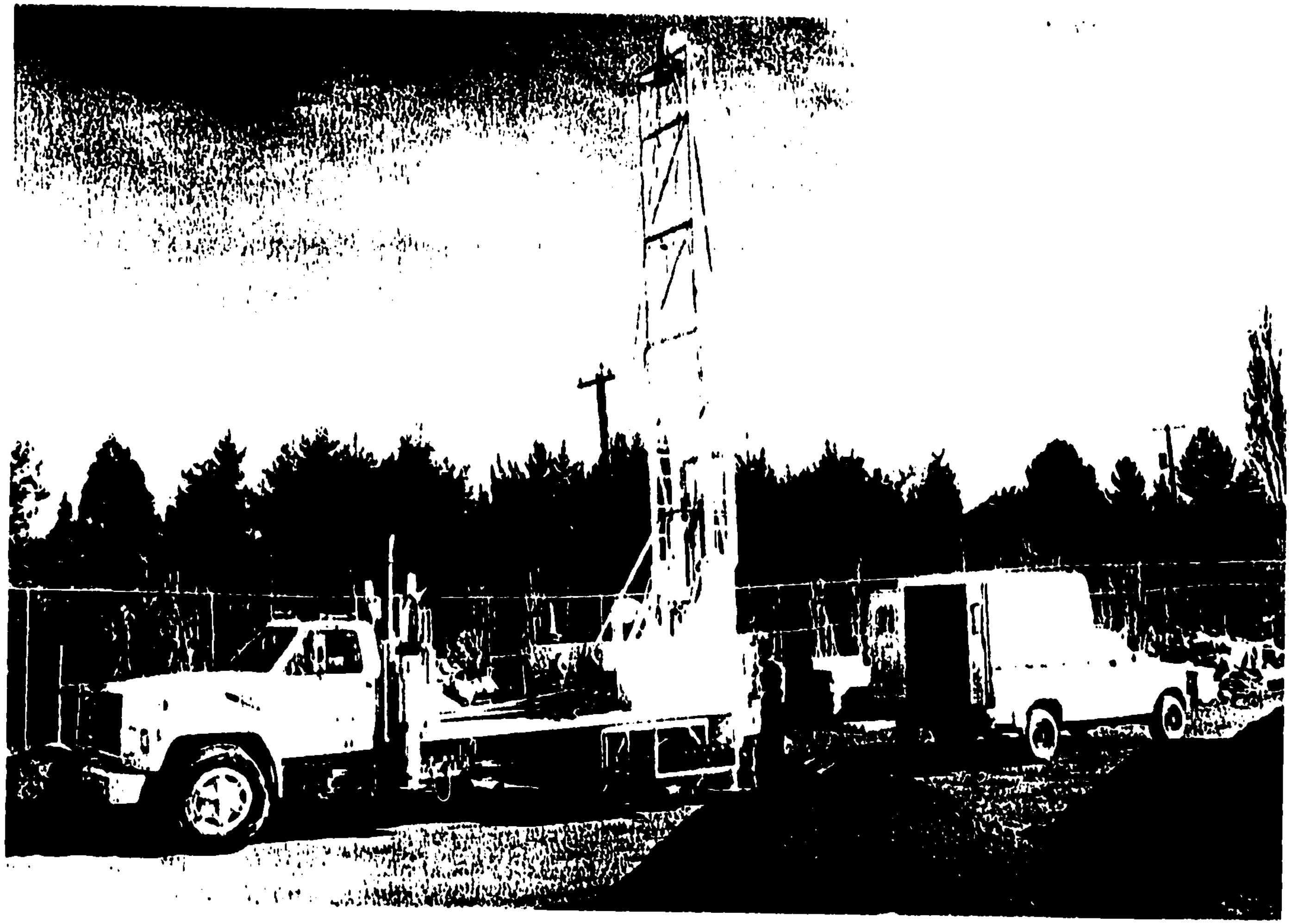


Plate 2.2 Seismic cone penetration test (SCPT) rig

To further complicate the quantification of amplification hazards, amplification of specific periods of ground motion due to resonance can be far greater than shown in Table 2-5. This resonance factor can be particularly damaging to structures whose natural periods match those of the site (Rial, 1992; Reiter, 1990). Finn (1994) calculates this natural site period by:

$$T = 4H / V$$

where: T = fundamental period of the site
H = thickness of the soil layer
V = average shear-wave velocity of the soil layer

The natural period of a building can be estimated by multiplying the number of stories by 0.1 second. Level 3 mapping includes this kind of analysis. A program called SHAKE (Schnabel, *et al.*, 1972) is the industry standard at the time of writing (Klohn-Crippen, 1994)

Finally, other factors which are very difficult to quantify can also affect amplification, these include; topographic features, and the geometry of bedrock basins filled by amplifiable sediments.

QUANTITATIVE LIQUEFACTION ASSESSMENT

Liquefaction hazard index

LHI values, determined using the method described above, are displayed as circles on Figure 2-22, with the size of the circle corresponding to the LHI value at that location. These values are coded by the surficial geology unit in which they occurred. The ranges of LHI values for each of these surficial units is then determined. An earlier attempt at assigning LHI values to surficial geology units was not satisfactory as it was found that a few flood plain units had LHI values ranging from very low to very high. Upon closer examination it was realized that LHI values occurring near

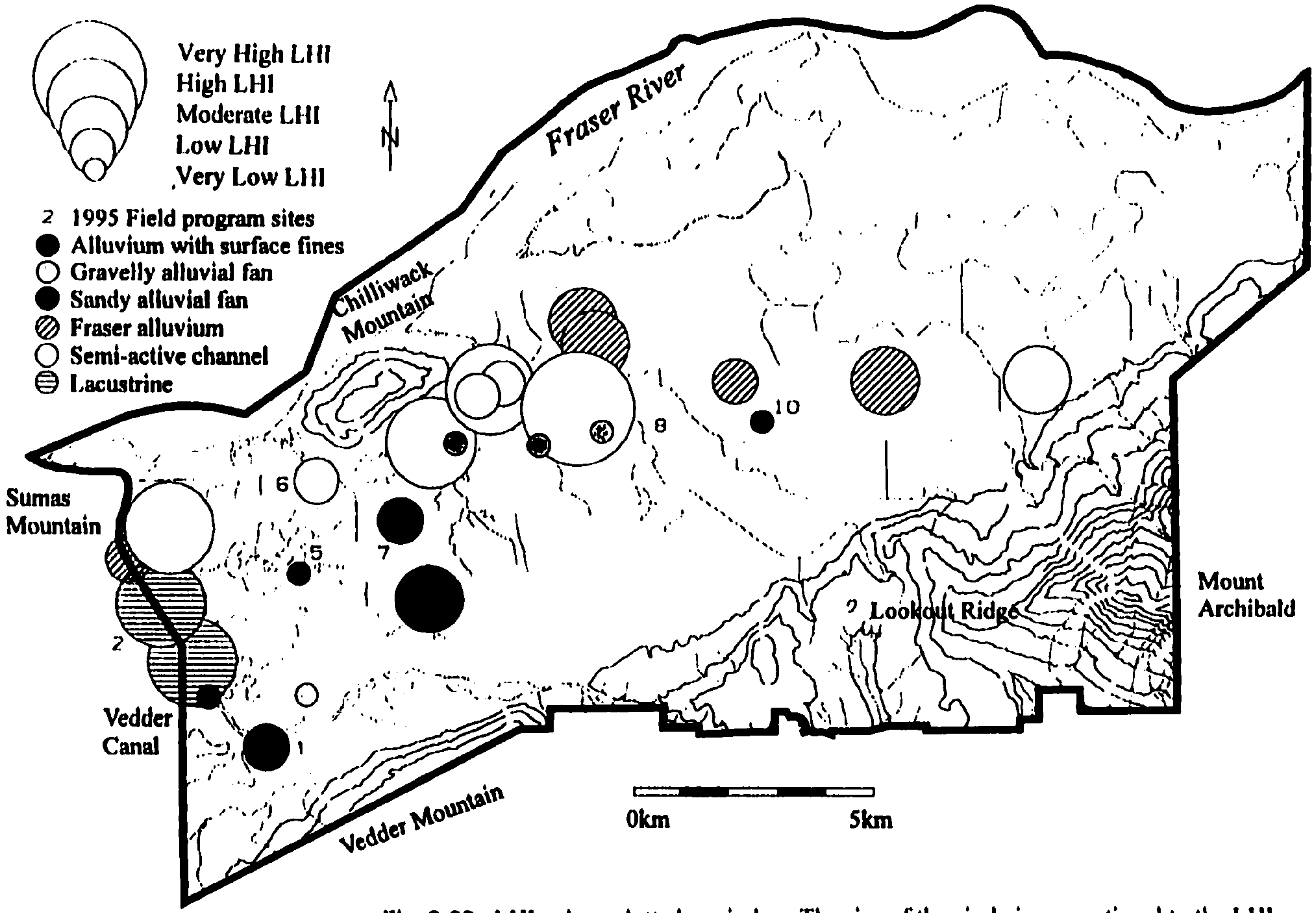


Fig. 2-22. LHI values plotted as circles. The size of the circle is proportional to the LHI value, the shading is related to the depositional environment (After, Levson et al., 1996a).

abandoned channels were much higher than those further away (Figure 2-23). To flag the areas peripheral to the channels, a GIS buffer function is used to construct a corridor 50 m either side of semi-active and abandoned channels.

There are three main reasons for the elevated liquefaction hazard along the abandoned channels. Firstly, the abandoned channels would often retain a free face, which facilitates lateral spread of material. Secondly, the water table around these features was often higher than the surrounding areas. Lastly, the abandoned channels deposited sandy to silty sediment in their point bars. The free face and the elevated water table were modelled by the buffer function fairly well. However the complex and often unpredictable deposition of the sandy point bars is not well described. This inadequacy must be noted in the text accompanying the maps. The buffer function was also to flag an area 200 m peripheral to the active Fraser River. This was done for similar reasons as above: the free face, and the elevated water table proximal to the active channel.

Subsurface Geology

An important factor that has to be carefully addressed in assessing the liquefaction hazard is the subsurface geology. For example, the Vedder fan is relatively thick at the mountain front ('A' on Figure 2-5), but gradually thins completely out near the edge ('B' on Figure 2-5). The ground conditions for areas that are located at the periphery of the Vedder Fan are more influenced by the underlying sediments than by the sediment type mapped at the surface. Other subsurface features, such as abandoned channels, are also very important, but may have little or no surface expression ('C' on Figure 2-5).

To address the problem of understanding subsurface sediments, each meter of 300 representative geotechnical test holes, and 400 water wells was recorded into a data base. The quality of the geotechnical test holes was generally quite high, but the quality of the water well data was sometimes suspect partly due to the expertise of the personnel logging the hole. Furthermore, the locational accuracy of the water wells was often suspect, due to changes in the reference grid system and re-plotting errors. For these reasons only geotechnical drill holes are considered in this paper.

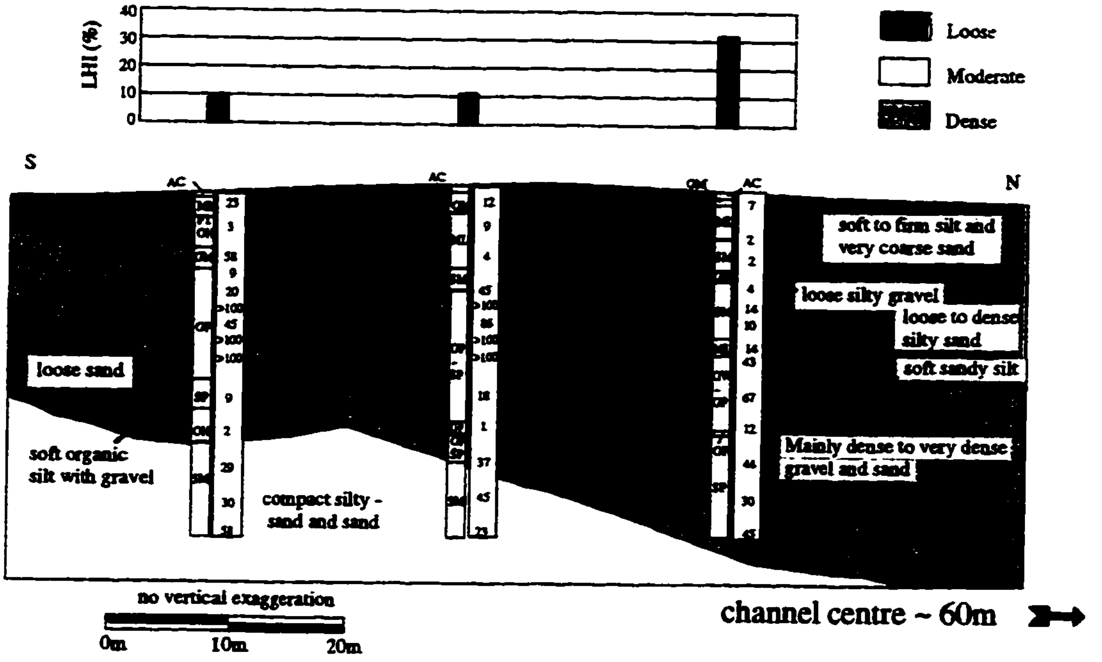


Fig. 2-23. Cross section peripheral top a semi-active channel. Note the increase of loose sediment and LHI values, closer to the channel. The cross section is located south-south-west of Rosedale at a road crossing for the Trans Canada Highway.

In the following sections the subsurface geology of the Vedder fan is discussed using different GIS tools to illustrate the types of evaluations that are required to assess the liquefaction hazard of any one geologic unit.

Georeferenced pie diagrams

Figure 2-24 is an example of a georeferenced pie diagram. It shows the type of sediment by color and the depth of the sediment by its position in the pie. For example, a sand unit that extends from surface to 5 m depth overlying a 10 m thick horizon of gravels would be displayed as a mid grey slice from 12 O'clock to 3 O'clock, and a black slice from 3 O'clock to 9 O'clock. The center of the pie is located at the geographic location of the test hole. Using this method the researcher can plot the pies on the same map as the surficial geology line work, and with a little practice visualize three dimensional geology on a two dimensional map. For example, trends such as the Vedder fan becoming sandier further away from the mountain front can be readily observed (Fig. 2-24). The extent of subsurface features such as buried channels, that have no surface expression can also be seen. Even small features such as the thick buried silts under downtown Chilliwack are easily spotted and their spatial extent can be defined using this map.

The geology of the Vedder fan is well illustrated by the georeferenced pie plot (Figure 2-24). Note the pies in the Upper fan are almost exclusively black (gravels) with lesser mid grey sections at the surface, likely representing overbank sand deposits. In contrast, the pies located in the lower fan are primarily mid to light grey (sand and silt), with a few gravely (black) horizons. This is because of the lower energy environment of the lower fan compared to the upper fan. This technique allows a researcher to evaluate and visualize a large amount of three dimensional data on a two dimensional map.

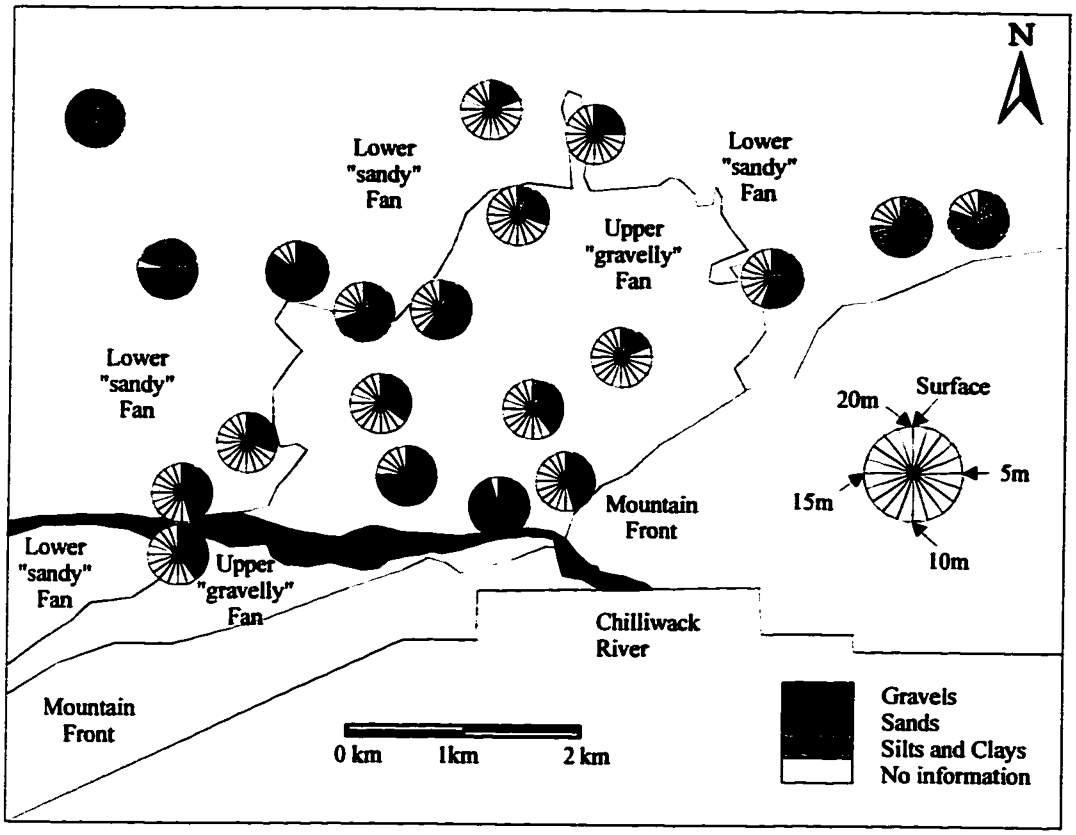


Fig. 2-28.
Georeferenced pie diagram of the Vedder Fan area, showing the sediment type as a shade of grey and its depth by the position in the pie. Using this diagram one can visualize the three dimensional extents of the sediments.

Non georeferenced pie diagrams

The geology of the Vedder fan can further be evaluated using a non-georeferenced pie diagram (Fig. 2-25). In this case the test hole information is sorted within the data base and given artificial geographical locations corresponding to columns and rows. The upper and lower fan units are separated on figure 2-25 and a stratigraphic differences between the two units is readily discernible. Geological variability within each unit can also be evaluated. For example, there is significant variability within the lower fan. The first pie (from the left) is almost entirely silt and clay down to 12 m depth, whereas the third pie is almost entirely sands to 12 m depth. The upper fan, however, has very little variation; almost all test holes are dominated by gravels.

Average sediment lithology column

The average sediment lithology column (ASLC) diagram in figures 2-12 and 2-13 illustrate the differences between the geological units in the Vedder fan. For example, a comparison of the amount of gravels within each unit shows that within the lower Vedder fan, gravels or diamictons generally occur in 20 to 40% of the holes. The upper fan, in comparison, is composed of gravel or diamicton in 40 to 60% of the holes except in the upper and lower few meters. Diagram of this type are useful to assess the average amount of any sediment type at any depth in any geological unit.

Quaternary sedimentary facies to 20 m

All of the subsurface data, displayed as pie diagrams, and surficial geology data were analyzed in a manner similar to that described above for the Vedder fan to produce, a Quaternary Sedimentary Facies map (Monahan and Levson, in press). This map delineates areas with similar three dimensional geology to a depth of twenty meters. Each area denoted by this map is assigned the appropriate ranges of liquefaction hazard (Figure 2-26; Inset 2, Levson *et al.*, 1996c).

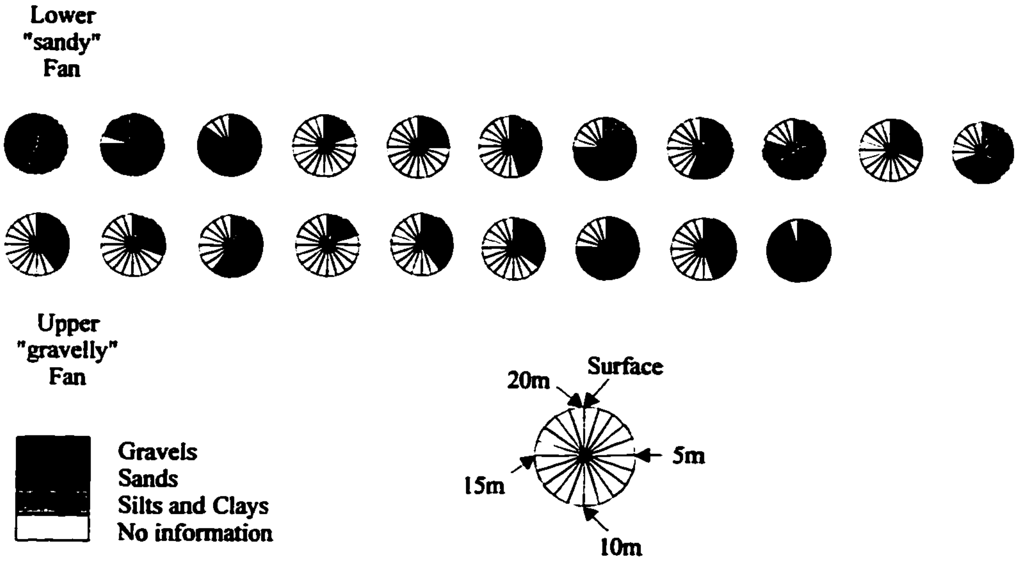


Fig. 2-29. Non-Georeferenced pie diagram of the Vedder Fan area, showing the sediment type as a shade of grey and its depth by the position in the pie. This diagram is useful for determining within unit homogeneity (e.g. the upper fan is fairly homogenous whereas the lower fan is relatively inhomogenous and perhaps should be split up).

GROUND MOTION AMPLIFICATION HAZARD MAP

Figure 2-26 (Inset 3) is a ground motion amplification hazard map of the study area. The map uses Finn's (1994, 1996) categories for soil susceptibility to amplification (Table 2-5). The characteristics of each map unit were compared to the table, and a range of amplification hazards was assigned. Unit assignments are corroborated by shear wave velocity data were measured or derived for eleven sites.

COMBINATION HAZARD MAP

The final step in the hazard evaluations is the production of a combination map, that factors in both liquefaction and amplification hazards (Fig. 2-26; Inset 1). This map was produced for the non - technical user, such as the land use planner. A straightforward, objective approach was taken in this process of combining the two aforementioned hazards. Areas where the liquefaction hazard span did not equal the amplification hazard span were given the upper hazard of the two rankings. For example, if a unit has a low to *moderate* hazard rating for amplification and a high to *very high* hazard rating for liquefaction, it would receive a *moderate* to *very high* combination rating. No attempt to add or average the two hazards was undertaken, as the two phenomenon are not additive (Levson *et al.*, 1996c).

SUMMARY

The lower mainland region of British Columbia is seismically active. The sediments that underlie the area are variably prone to liquefaction and ground motion amplification. The susceptibility to these phenomenon can be estimated by understanding the three dimensional distribution of Quaternary sediments in the area. A GIS is used to assist in modelling the distribution and characteristics of geological materials at depth. Geotechnical test hole data were entered and displayed on maps using GIS functions. Once the distribution of the surficial sediments and bedrock was ascertained, the relative or absolute hazard associated with each geological unit was determined to produce the final earthquake hazard map. A GIS was used at a number of stages throughout the hazard mapping process including:

1) evaluation of the 3-D geology using georeferenced and non georeferenced geotechnical data,

2) overlaying geological and geotechnical data,

3) evaluating within-unit and between-unit variability to identify subsurface features not recognizable on the surface geology map and to flag potentially erroneous data,

4) modifying and creating geologic unit boundaries with tools such as the buffer functions

5) spatially evaluating the liquefaction (LHI), and ground motion amplification hazards,

6) and combined the two hazards into a final composite map.

Earthquake Hazard Mapping References

Armstrong, J.E. (1984): Environmental and Engineering Applications of the Surficial Geology of the Fraser Lowland, British Columbia; Geological Survey of Canada, Paper 83-23.

Armstrong, J.E. (1980): Surficial Geology, Chilliwack (West Half), British Columbia. Geological Survey of Canada, Map 1487A.

Atkinson, G.M., Finn, W.D.L. and Charlwood, R.G. (1986): PROLIQ2 - A computer program for estimating the probability of seismic liquefaction including both aerial and fault sources; Depatment of Civil Engineering, University of British Columbia, Vancouver, British Columbia, 78 p.

B.C. Hydro (1992): Liquefaction Hazard Assessment for the Lower Mainland Region; Report No. H24747, includes 1:75 000 scale liquefaction hazard map.

Borcherdt, R.D. et al. (1991): Methodology for Predictive GIS Mapping of Special Study Zones for Strong Ground Shaking in the San Francisco Bay Region, California; Proceedings of the Fourth International Conference on Seismic Zonation, Stanford, California, pages 545-552.

Cameron, V. J. (1989): The Late Quaternary Geomorphic History of the Sumas Valley. unpublished M.A. thesis, Simon Fraser University, 154 pages.

Chagnon, J.Y. and Gilbert, F.D. (1990): Development of a Method of Seismic Microzonation Mapping Applicable to the Urban Areas of Canada; Report submitted to Emergency Preparedness Canada, Report GGL-90-02, Supply and Services Canada, January.

Clague, J.J., Naesgaard, E. and Sy, A. (1992): Liquefaction Features on the Fraser River Delta: Evidence for Prehistoric Earthquakes?; Canadian Journal of Earth Sciences, 29: 1734-1745.

Comar, V.K., Sprout, P.N., and Kelley, C.C. (1962): Soil Survey of the Chilliwack Map Area, lower Fraser Valley; B.C. Department of Agriculture, Preliminary Report 4.

Cornell, C.A. (1968): Engineering seismic risk analysis: Seismological Society of America, Bulletin 58: 1583-1606.

Dakin, R.A. (1994): Section 9.1.1 Fraser Lowland. *In* Groundwater Resources of British Columbia, B.C. Ministry of Environment, Lands and Parks and Environment Canada, pages 9.1-9.30.

Dragert H., Hyndman, R.D., Rogers, G.C., and Wang, K. (1994): Current deformation and the width of the seismogenic zone of the northern Cascadia subduction thrust; Journal of Geophysical Research, 99: 653-668.

Elton, D.J. and Martin, R.J. II (1989): Dynamic Site periods in Charelston, South Carolina; Earthquake Spectra, 5: No. 4.

Finn, L.W.D. (1996): Ground motion amplification factors for use in building codes; Proceedings, International Workshop on Site Response, Port and Harbor Research Institute, Japan, pages 105-117.

Finn, L.W.D. (1994) Geotechnical aspects of the estimation and mitigation of earthquake risk. *In* Tucker, B.E., Erdick, M., and Hwang, C.N., eds., Issues in Earthquake Risk: Kluwer Academic Publishers, p. 35-77.

Grant, W.P., Perkins, W. J. and Youd, T.L. (1991): Evaluation of Liquefaction Potential, Seattle, Washington; U.S. Geological Survey, Open File Report 91-441, 44 pages and map.

Halstead, E.C. (1986): Ground Water Supply - Fraser Lowland, British Columbia; Environment Canada, Inland Waters Directorate, NHRI Paper 26, IWD Scientific Series 145.

Hasegawa, H.S., Basham, P.W., and Berry, M.J. (1981): Attenuation relations for strong seismic ground motions in Canada: Seismological Society of America, Bulletin 71: 1943:1962.

Heaton, T.H. and Hartzell, S.H. (1987): Earthquake hazards on the Cascadia subduction zone; Science, 236: 162-168.

Hensolt, W.H. and Brabb, E.E. (1990): Map showing elevation of bedrock and amplification for design of engineered structures to withstand earthquake shaking in San Mateo County, California; United States Geological Survey, Open File Report 90-496.

Hunter, J.A., Woeller, D.J., Addo, K.O., Luternauer, J.L. and Pullan, S.E. (1993): Application of Shear-wave Seismic Techniques to Earthquake Hazard Mapping in the Fraser River Delta, British Columbia; Society of Exploration Geophysicists, 63rd Annual Meeting Abstracts, pages 501-503.

Idriss, I.M. (1991): Earthquake Ground Motions at Soft Soil Sites; Proceedings, Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Missouri, 1: 209-214.

Klohn-Crippen Consultants Ltd. (1994): Preliminary Seismic Microzonation Assessment for British Columbia; B.C. Resource Inventory Committee, Report 17, 108 pages.

Levson, V. M., Monahan, P.A., Meldrum , D.G., Matysek, P.F., Gerath, R.F., Watts, B.D., Sy, A., Yan, L. (1996a): Surficial Geology and Earthquake Hazard Mapping, Chilliwack, British Columbia (92G/1 and H/4) *In* Geological Fieldwork 1995, B.M. Grant, and J. M. Newell editors, B.C. Ministry of Employment and Investment Paper 1996-1, pp. 191-203.

Levson, V. M., Gerath, R. F., Meldrum , D. G., Monahan, P. A. (1996b): Surficial Geology of the Chilliwack area, NTS 92G/1 and H/4, B.C. Ministry of Employment and Investment Open File 1996-12.

Levson, V. M., Monahan, P.A., Meldrum , D.G., Matysek, P.F., Gerath, R.F., Watts, B.D., Sy, A., Yan, L. (1996c): Preliminary relative earthquake hazard map of the Chilliwack area showing areas of relative potential for liquefaction and/or amplification of ground motion (92G/1 and H/4), B.C. Ministry of Employment and Investment Open File 1996-25.

Luternauer, J.L. et al. (1994): Fraser River Delta: Geology, Geohazards and Human Impact; *In* Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia, J.W.H. Monger, Editor, Geological Survey of Canada, Bulletin 481, pp 197-220.

Mabey, M.A., Madin, I.P. and Palmer, S.P. (1994): Relative Earthquake Hazard Map for the Vancouver, Washington, Urban Region; Washington Division of Geology and Earth Resources, Geologic Map GM-42, 5 pages and 1:24 000 maps.

Mabey, M.A. and Madin, I.P. (1993): Relative Earthquake Hazard Map of the Portland, Oregon 7-1/2 Minute Quadrangle; Oregon Department of Geology and Mineral Industries and Metro, 10 pages and 1:24 000 map.

Mendvedev, S.V. (1965): Engineering Seismology, trans. Israel Program for Scientific Translation staff p. 87.

Monahan, P.A. and Levson, V. M. (in press): Quaternary geology map (Upper 20 meters) Chilliwack, British Columbia (92G/1 and H/4), B.C. Ministry of Employment and Investment Open File.

Monahan, P.A. and Levson, V.M. (1997): Earthquake hazard assessment in Greater Victoria, British Columbia: Development of a shear wave velocity model for the Quaternary deposits. (92B/6 and B/11) *In* Geological Fieldwork 1996, B.C. Ministry of Employment and Investment Paper 1997-1.

Mulder, T. L. and Rogers, G.C. (1993): Crustal earthquakes in southwestern British Columbia (abstract) EOS, Transactions, American Geophysical Union, 74: 201.

Oregon Department of Geology and Mineral Industries (DOGMI) and Metro (1993): Relative Earthquake Hazard Map of the Portland, Oregon 7 1/2 Minute Quadrangle; January.

Palmer, S.P., Schasse, H.W. and Norman, D.K. (1994): Liquefaction Susceptibility for the Des Moines and Renton 7.5-minute Quadrangles, Washington; Washington Division of Geology and Earth Resources, Geologic Map GM-41, 15 pages and 1:24,000 maps.

Reiter, L. (1990):Earthquake Hazard Analysis: Issues and Insights; Columbia University Press, New York, p 254.

Rial, J.A., Salzman, N.G., and Ling, H. (1992): Earthquake induced resonance in sedimentary basins; American Scientist, 80: 566-578.

Robertson, P.K., Woeller, D.J., and Finn, W.D.L. (1992): Seismic cone penetration test for evaluating liquefaction under seismic loading; Canadian Geotechnical Journal, 29: 686-695.

Rogers, G.C. (1994): Earthquakes in the Vancouver Area; *In* Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia, Monger, J.W.H., Editor, Geological Survey of Canada, Bulletin 481, pages 221-229.

Rogers, G.C. (1992): The Earthquake Threat in Southwest British Columbia; *In* Geotechnique and Natural Hazards, Vancouver Geotechnical Society and Canadian Geotechnical Society, Geohazards '92 Symposium Volume, BiTech Publishers Ltd., pages 63-69.

Rogers, G.C. (1988): An assessment of the mega-thrust earthquake potential of the Cascadia subduction zone; Canadian Journal of Earth Sciences, 24: 844-852.

Rogers, G.C. (1983): Seismotectonics of British Columbia; Ph.D. thesis, University of British Columbia, Vancouver, British Columbia, 247 p.

Schnabel, P.B. et al. (1972): SHAKE: A computer program for Earthquake Response Analysis of Horizontally Layered Sites; Report No. EERC 72-12, University of California, Berkeley, December.

Seed, H.B. (1979): Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground During Earthquakes; Journal of Geotechnical Engineering, 105: 201-255.

Stokoe, K.H., Wright, S.G., Bay, J.A., and Roesset, J.M. (1994): Characterization of geotechnical sites by SASW method; *In* Geotechnical Characterization of Sites, Woods, R.D. Editor, Volume prepared by ISSMFE Technical Committee #10, for XIII ICSMFE, Science Publisher, New York, pages 15-25.

Watts, B. D., Seyers, W.D. and Stewart, R.A. (1992): Liquefaction Susceptibility of Greater Vancouver Area Soils. *In* Geotechnique and Natural Hazards, Vancouver Geotechnical Society and Canadian Geotechnical Society, Geohazards '92 Symposium Volume, BiTech Publishers Ltd., pages 145-157.

Wuorinen, Vilho (1976): Seismic Microzonation of Victoria - A Social Response to Risk; Victoria Physical Environment and Development, Western Geographical Series, Vol. 12, University of Victoria.

Youd, T.L. (1991): Mapping of earthquake-induced liquefaction for seismic zonation. *In* Proceedings, Fourth International Conference on Seismic Zonation, Stanford

California, Volume 1: Oakland, California, Earthquake Engineering Research Institute, p. 111-147.

Youd, T.L., and Perkins, J.B. (1978): Mapping of liquefaction-induced ground failure potential: Journal of Geotechnical Engineering, ASCE 104 (GT4), p. 433-446.

CHAPTER 3 - MODELLING GLACIAL DISPERSAL IN A MERCURIFEROUS REGION: A GIS APPLICATION

INTRODUCTION

This chapter presents how paleo ice-flow direction in an area can be modelled using till geochemical data. A Geographic Information System (GIS) was used to quantify glacial dispersal using shapes and weighting functions that represent the direction and relative amount of dispersal. In glaciated areas, the last dominant paleo-flow direction of ice (and subglacial meltwater) may be determined from features such as flutings, drumlins, striae and crag and tails. These features will often be at some angle relative to each other, suggesting some variability in ice-flow direction. Furthermore, earlier phases in the ice flow history of an area are often obscured or completely eroded. However, glacial flow directions are also recorded by dispersal of sediment eroded from distinctive rock types such as in highly mineralized areas. In some cases, the sedimentary record of glacial dispersal may provide more information on the ice flow history than can landforms.

All of these features must be considered when trying to determine the paleo-flow direction history in an area. The researcher must decide what evidence is due to minor topographic effects and last stage melting phenomenon, and what evidence is important in determining variation in local ice-flow direction. Furthermore, if there was significant variability in ice-flow direction, one must determine how variable it was.

The study area is located in central British Columbia within NTS map sheet 93 K/9 at approximately latitude 54° 38' and longitude 124° 26' (Figure 3.1). The Pinchi Lake mercury deposit was discovered in 1937 by J.G. Gray of the Geological Survey of Canada (Gray, 1938). It is located on a prominent limestone hill on the north shore of Pinchi Lake, approximately 25 km from Fort St. James, British Columbia. Other mercury deposits (i.e. the Bralorne) were later discovered along the same fault zone. (Bailey and Jakobsen, 1989). The area was selected for this study for several reasons:

Fig. 3-1. Location of study area.

1) A high quality till geochemical data base was available for the area (Plouffe, 1995a)

2) A well developed glacial dispersal train was noted from this data set

3) Distinctive mineralization that is useful for studying glacial dispersal is present. Furthermore, the zone of mineralization is relatively small and the surrounding country rock contains very little mineralization (i.e. the source of the distinctive mineralization can be considered as a point source or at least several distinct points). This makes modelling the dispersal pattern much easier and more accurate.

4) Most of this distinctive mineralization has most likely been discovered in the immediate area, as it has been extensively explored for 60 years.

In summary, the amount of mercury in the till is well known, a well defined dispersal train is discernible, an easily detectable, distinctive lithology (mercury mineralization) occurs in the area, and the amount and location of the mercury in the bedrock is well constrained.

OBJECTIVES

Paleo ice-flow indicators, such as striae on bedrock, often suggest large variability in ice-flow directions. Some of these striae may reflect important deviations in ice-flow direction due to events such as a deflection caused by another body of ice. However, the orientation of other striae may have been affected by relatively unimportant local topographical effects. The objective of this paper is to *quantify* the amount and relative importance of variability in paleo-ice flow direction. This method may be used to model glacial dispersal and ice dynamics in an area and also is of practical application to exploration companies interested in better understanding the likely source direction of mineralized clasts.

PINCHI LAKE MERCURY DEPOSIT

Brief mine history

Mineralization was first discovered in 1937. The land was subsequently staked the next year by A.J. Ostrem, and optioned to Consolidated mining and Smelting Company (now Cominco) that same year (Stevenson, 1940). In 1940 the mine went into production (Figure 3.2). The production continued to increase until 1944, at which time the mine closed due to soft mercury prices. The mine re-opened in 1968 and continued to produce mercury until 1975 when the mine again closed, due to high production costs and soft mercury prices. The total amount of ore mined was 2, 046, 460 tonnes, with a total amount of mercury recovered being 6, 116, 139 kg. The deposit has remaining reserves of 1.1 million tonnes at 3.2 % mercury (Bailey and Jakobsen, 1989). With lower cost mines with huge reserves in California and Spain it seems unlikely that the Pinchi mine will reopen in the near future.

Genetic Model

Ash (1996) identifies the Pinchi Deposit as a Silica Carbonate Mercury type deposit. Mineralization in this deposit type usually occurs at relatively shallow levels along major faults. Stevenson, (1940) noted the association of mercury, at the Pinchi deposit, with fault zones, stating that "structural conditions (faulting) permitted the passage of cinnabar bearing solutions under no great pressure, and, subsequently caused the trapping and deposition of the sulphides". These observations were made in the field by simply observing the relationships between mineralization and the fractures in the rock. Note on Figure 3.3 the spatial relationship between the faults and the cinnabar occurrences. It is widely believed that the fault acted as a conduit for mercury-laden hydrothermal fluids to migrate up from depth (e.g. Armstrong, 1942; Nesbitt *et al.*, 1989; Ash, 1996). As the water rose up the fault, it cooled, the pressure lessened, and finally the fluids may have been trapped in the low permeability fault gouge depositing the

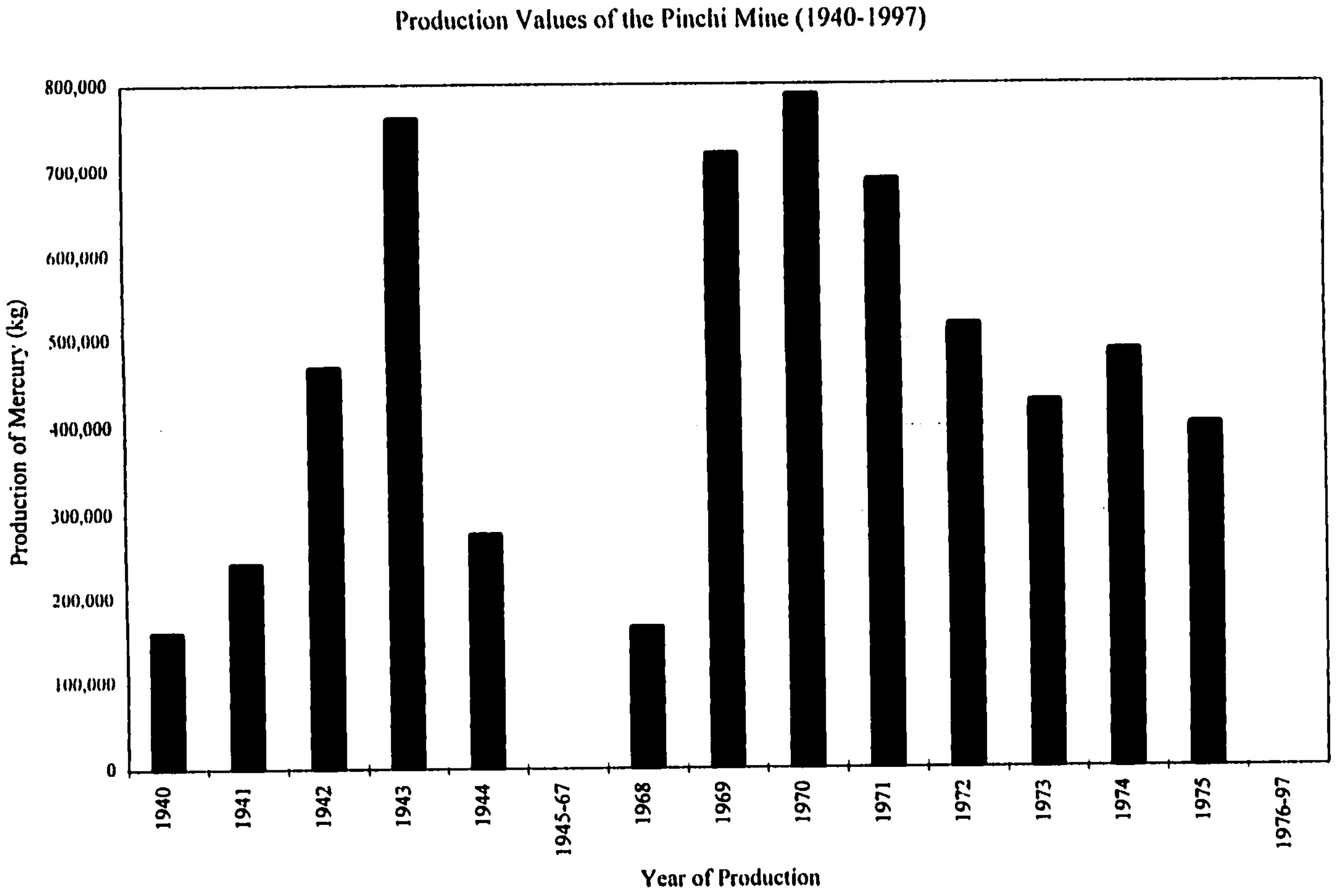


Fig. 3-2. Mercury production from the Pinchi Mine.

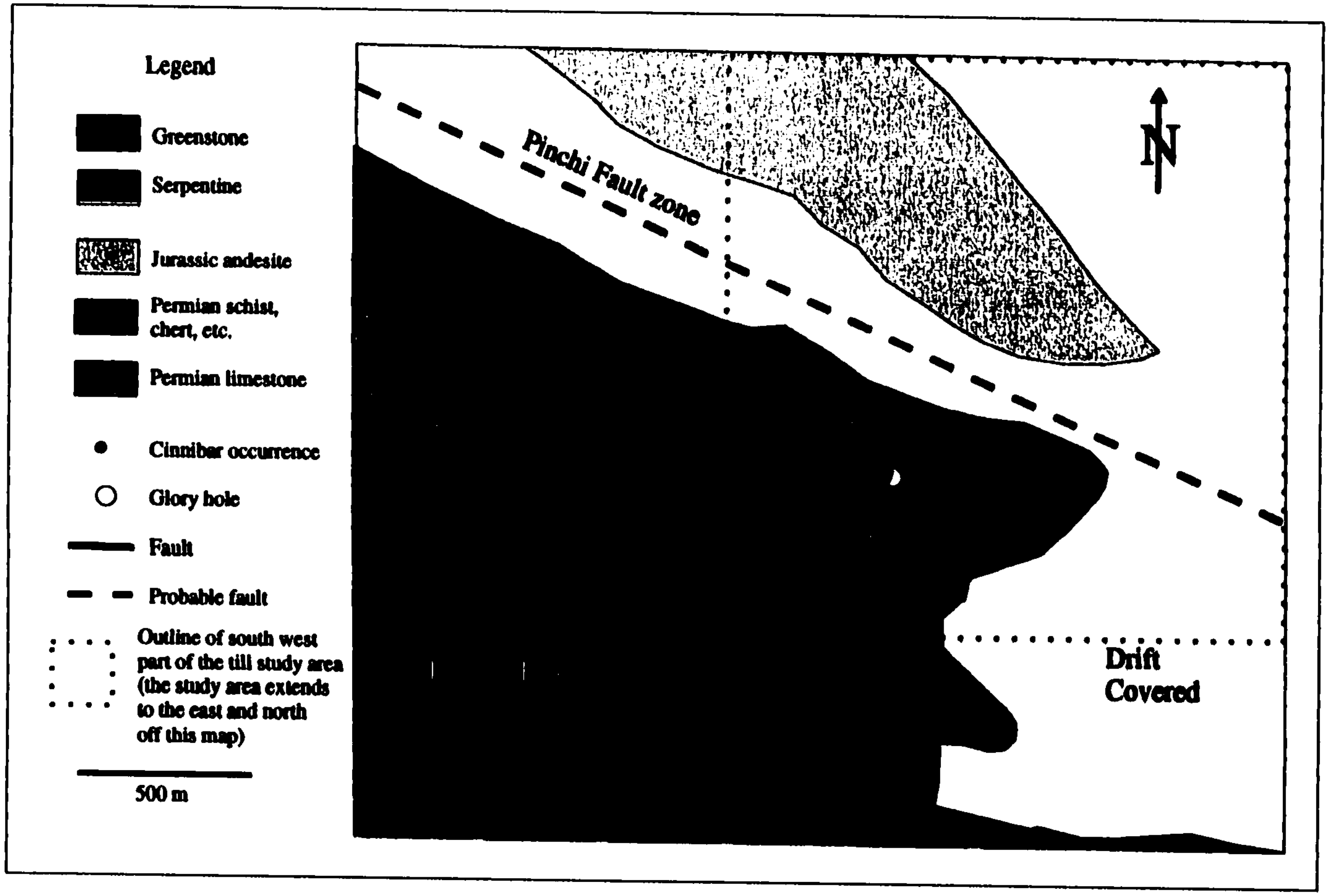


Fig. 3-3. Bedrock geology of area surrounding Pinchi Mine (After Armstrong, 1942)

cinnabar at or near the surface (Gray, 1938; Armstrong, 1942; Bailey *et al.* 1973; Ash, 1996).

Advances in thermo - barometry have allowed researchers to accurately determine the temperatures and pressures at which mercury is transported and subsequently deposited by hydrothermal solutions. It is now widely accepted that the solubility of elemental mercury ranges from ~0.5 ppm at 100^0 C to ~16 ppm at 200^0 C to ~400 ppm at 300^0 C (Sorokin, 1973, Khodakovskii et al., 1977; Nesbitt et al., 1989).

Local Geology

The Pinchi Lake deposit is associated with the Pinchi Fault zone which separates Carboniferous to Jurassic Cache Creek rocks from Upper Triassic to Jurassic Takla Group rocks. The 'mine hill' is underlain by Cache Creek ribbon chert, quartzite, schist, limestone, and minor greenstone. Small bodies of serpentine intrude the Cache Creek rocks. The rocks underlying the hill to the north of the mine are Takla Group rocks, which include green to greenish - grey andesites (Bailey and Jakobsen, 1989). These andesites are augite and plagioclase phyric.

Structural Geology

The mineralization occurs mainly along or near northwesterly trending faults cutting folded Permian limestones. The 'south fault', which hosts most of the mineralization, strikes approximately north 60 degrees west and dips approximately 60^0 to the west (Figure 3.3). The faulting style changes from one distinct fault surface near the 'glory hole' to a group of closely spaced faults 300 m to the northwest. The rocks in the area often have slickensides and are brecciated and silicified across a zone 1 to 10 m wide (Armstrong, 1942).

Mineralization

Mineralization is concentrated in these breccia zones along the faults as well as in strata cut by the faults. Most of the massive, red, cinnabar occurs as veinlets and blebs filling pre-existing openings such as solution cavities, interstices between grains, fissures, and breccia fragments. Stibnite is fairly abundant in the lower levels of the mine. Gangue minerals include, calcitic, ankeritic, and dolomitic carbonates; fine-grained quartz is abundant. Alunite also occurs locally in the mine (Armstrong, 1949).

QUATERNARY GEOLOGY

Previous Work

Surficial mapping in the surrounding area has been carried out by Plouffe (1994 a, b) and by Kerr (1991). Detailed (1:20,000) mapping was performed by Ryder (1993, 1994) in areas adjacent to the study area. Rutter (1977) mapped to the east in the Parsnip River Area (Figure 3.4) now underlain by Williston Lake. Other contributions to the understanding of the surficial geology of the region include work by Armstrong and Tipper (1948), Tipper (1971), Clague (1987, 1988), and Plouffe (1992). Plouffe (1995a) and Plouffe and Ballantyne (1993) performed till geochemistry and other related studies in the region. Quaternary geology mapping and till geochemistry studies have also been conducted west and south of the study area in the Babine Lake and southern Nechako regions, including studies by; Levson et al. (1994, 1997); Levson and Giles (1995); O'Brien et al. (1995); Huntley et al. (1996); and Stumpf et al. (1996, 1997).

A number of geochemical studies in the immediate area have been conducted on soils, gasses, vegetation, and lake sediments. Geochemical surveys on soils in the Pinchi Lake area have been conducted by Warren et al. (1966); Sutherland Brown (1967); Azzaria and Webber (1969) and John et al. (1975). Gasses within the soils were also found to be anomalous in mercury in work done by Seigal et al. (1985). Vegetation was

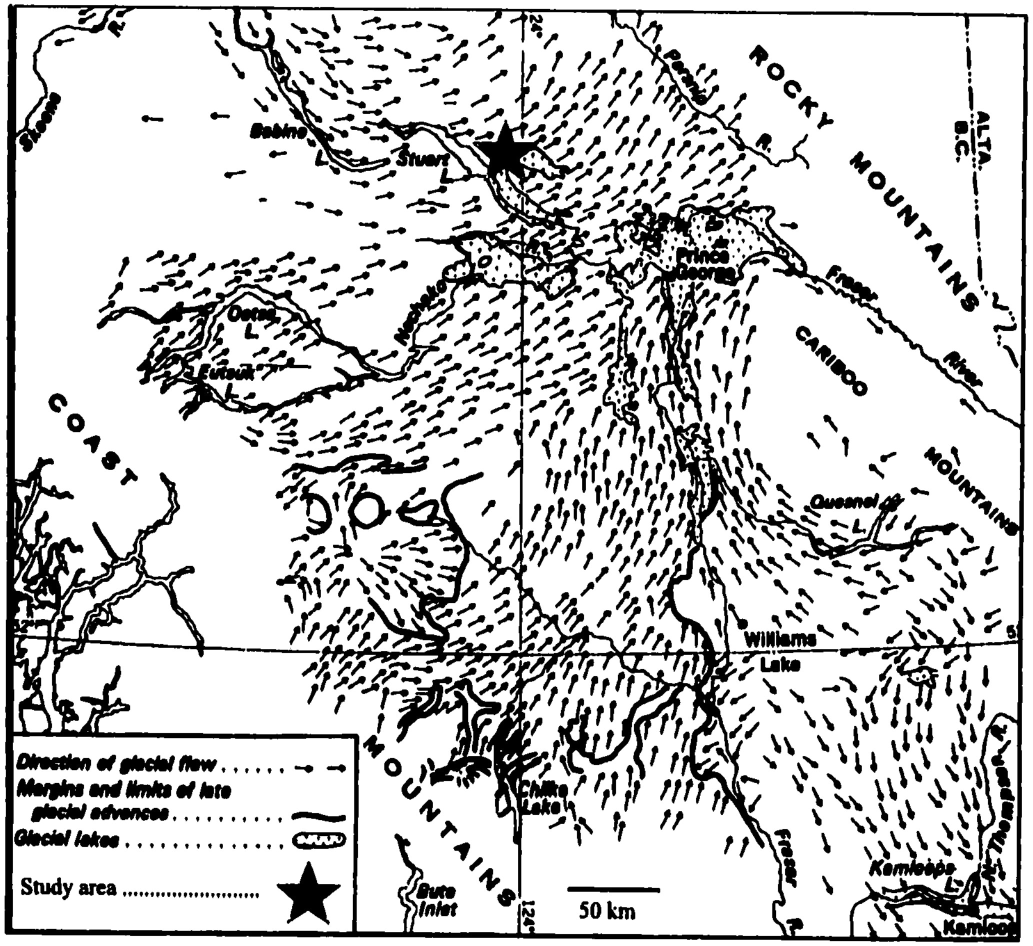


Fig. 3-4. Figure showing the ice flow directions in Central British Columbia. Note that the ice flow directions in the study are are approximately 80 degrees (After Tipper, 1971)

analyzed by Warren et al. (1983, 1984). Finally, Cook et al. (1996) analyzed lake sediments in Pinchi Lake adjacent to the mine site.

Glaciation

During the Late Wisconsinan glaciation, the Coast, Skeena and Cariboo mountains were the principle source areas for ice in the region (Figure 3.4; Armstrong and Tipper, 1948; Tipper, 1971; Plouffe, 1991; Plouffe, 1995a). Jackson and Clague (1991) report a maximum elevation of glaciation in this region to be approximately 2,000 m above sea level (an ice thickness of roughly 1,300 m). Harington et al., (1974) dated interglacial wood fragments, found in the Babine Lake area, at 42 900 +/- 1860 years B.P., and 43 800 +/- 1830 years B.P., and a mammoth bone at 34 000 +/- 690 years B.P.. Furthermore, Rutter (1976, 1977, 1980, 1984) dated plant matter, found under a till, at 25 940 +/- 380 years B.P. in the Finlay River area.

Ice flow direction

Ice flow direction, in the study area, was towards the east northeast (Figure 3.4) and reflects coalescence of glaciers from the west and south. Regional ice flow directions have been deduced by studying large scale glacial landforms and lithologic studies of pebbles in till (Tipper, 1971; Plouffe, 1995a). In the immediate area of the mine site, the ice flow direction was just north of east. This is believed to be caused by the deflection of easterly flowing ice by an ice lobe flowing north from the Cariboo mountains at about the glacial maximum (Tipper, 1971; Plouffe 1995a).

DRIFT PROSPECTING, GLACIAL TRANSPORT AND DEPOSITION

To understand why glaciogenic materials (i.e. mineralized boulders or till geochemical anomalies) occur where they do, a brief discussion of how material is eroded, transported and deposited by glaciers is required.

Glacial Transport

Four ways in which glaciers transport material are recognized by Dreimanis (1990; Figure 3.5):

Subsole drag - this process occurs under a glacier when water saturated, unconsolidated sediment or very soft bedrock is transported by drag forces at the base of the ice without directly being incorporated into the glacier.

Basal transport - just above the sole of the glacier is a zone of traction. This basal traction zone is responsible for most of the basally entrained glacial debris. In active glaciers this zone can vary from 90% debris (10% ice) to a fraction of a percent debris , but averages about 25% debris (Lawson, 1979; Pessl and Fredrick, 1981). Most of the erosion that is associated with glaciers takes place in this zone or along the glacier sole.

Englacial transport - the englacial transport zone directly overlies the basal transport zone. This debris poor area is often called 'amber ice'. In areas of strongly crevassed ice, supraglacial material may fall into this zone. There is negligible abrasion or crushing in the amber ice. Therefore, weak lithologies and soft sediment may be able to survive extended transport distances in this zone (Dreimanis, 1976).

Supraglacial transport - This transport mechanism is most important in mountain glaciation. Material from areas peripheral to the glacier tumble down and land on top of the glacier. These materials are transported either on top of the glacier, or covered by snow or firn. These materials can be transported very large distances with little to no evidence of glacial abrasion (i.e. striations).

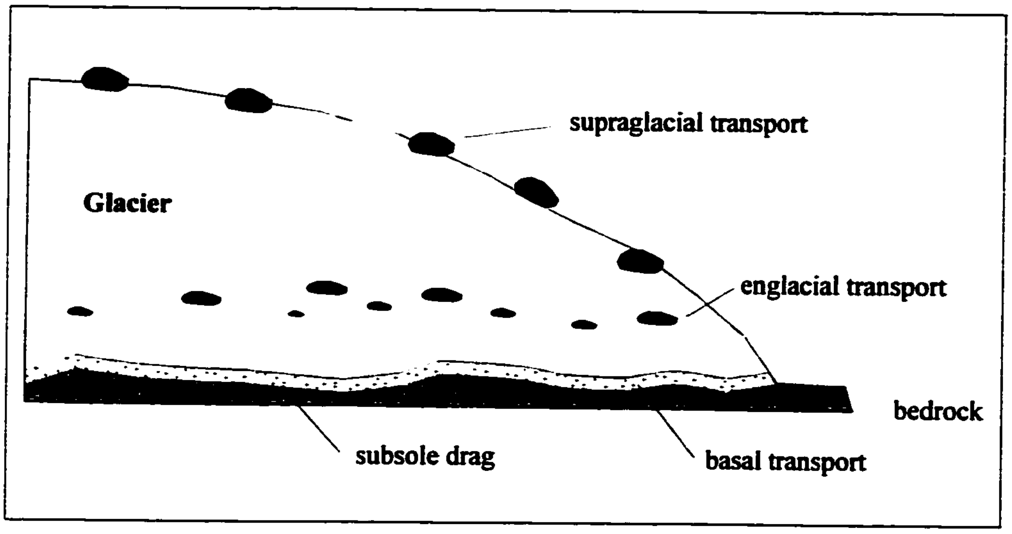


Fig. 3-5. Modes of glacial transport showing the various modes of sediment tansport (After Proudfoot *et al.*, 1995).

Glacial Deposition

Dreimanis (1990) divides the depositional processes that form till into two main groups; primary and secondary. The primary category is further subdivided into three groups, (1) melt out and sublimation, (2) lodgment and (3) stoppage of subsole drag. Secondary processes include mass movements and water movements. These processes may be argued to be non-till forming, in the strictest definition of till. Dreimanis argues that if the composition of the till is not changed significantly, they should be included in the till forming processes.

Melting out or melt-out and sublimation - melt out is the slow release of material from more or less stagnant ice (Shaw, 1985). In very cold and dry environments sublimation may effectively 'remove' the stagnant ice.

Lodgment - lodgment is the deposition of till at the base of the glacier. This can be accomplished in several different ways;

1) clast by clast released from the glacier's base

2) smearing thin sheets of basal melt out debris onto the underlying strata

3) plastering entire sheets of debris-rich basal ice (Dreimanis, 1990)

This method of deposition is arguably the most important primary depositional process although it is very difficult to accurately assess the mechanisms of lodgment due to the problems associated with directly observing the bottom of an active glacier (Dreimanis, 1989). Lodgment tills generally have relatively small transport distances, making them a preferred medium for drift prospecting (e.g. Proudfoot et al. 1995).

Stoppage of subsole drag - strongly deformed weak bedrock being transported by subsole drag will eventually be deposited. This process may be related to lodgment (Dreimanis, 1990).

Resedimentation by gravity - this is a secondary till forming process as previously discussed. There is a wide range of processes associated with secondary till deposition and classification schemes are somewhat controversial. For example, most researchers would accept that if a till slumped a horizontal distance of a meter or two under the influence of gravity, it would still be a till. However, if a till was to be transported 100's of meters down slope, and experienced some sorting, many workers would not consider the deposit to be a till. This debate extends past the scope of this paper, interested readers are encouraged to examine works by Lawson (1979) and Dreimanis (1987, 1989) for further insights.

Drift Prospecting

Drift prospecting has been successfully implemented since the 18th century (Tilas, 1740). Since that time significant refinements in drift prospecting techniques have been made. One of the reasons for the success of drift prospecting is that glacial dispersal trains can be 100's to 1000's of times larger than the original bedrock source. (Figure 3.6; Miller, 1984; DiLabio, 1990; Levson and Giles, 1995). Glaciers erode, transport, and deposit mineralized bedrock in either the gravel fraction of a till (as erratics) or in the matrix (clay to sand fractions). Dispersal trains have a characteristic elongate shape (Figure 3.6) in the direction of ice flow and often have clear lateral and vertical contacts with the surrounding till (DiLabio, 1990). The effect of the mineralized bedrock source becomes progressively less intense in the down-ice direction. At a certain point down-ice the effect of the bedrock mineralization drops to the background levels. Note that the location of the bedrock source is up-ice of the head of the dispersal train (Figure 3.6). The distance up-ice, 'C', depends on a number of factors, most importantly; (1) the angle of ascent 'α' (Figure 3.6) and (2) the thickness of the till (Miller, 1984; DiLabio, 1990; Bobrowsky, 1995). These factors can be assessed through subsurface sampling, trenching and drilling. A comprehensive outline of these techniques is discussed by Plouffe (1995b).

The complexity of the ice flow history of an area has a major influence on the ease of drift prospecting. The simplest case is one where there is a point source of mineralization eroded and deposited by a single, unidirectional glacier. This process will form a ribbon shaped dispersal train parallel to ice flow. A fan shaped dispersal pattern may result from a situation where ice flow was multi-directional. The dispersal pattern in

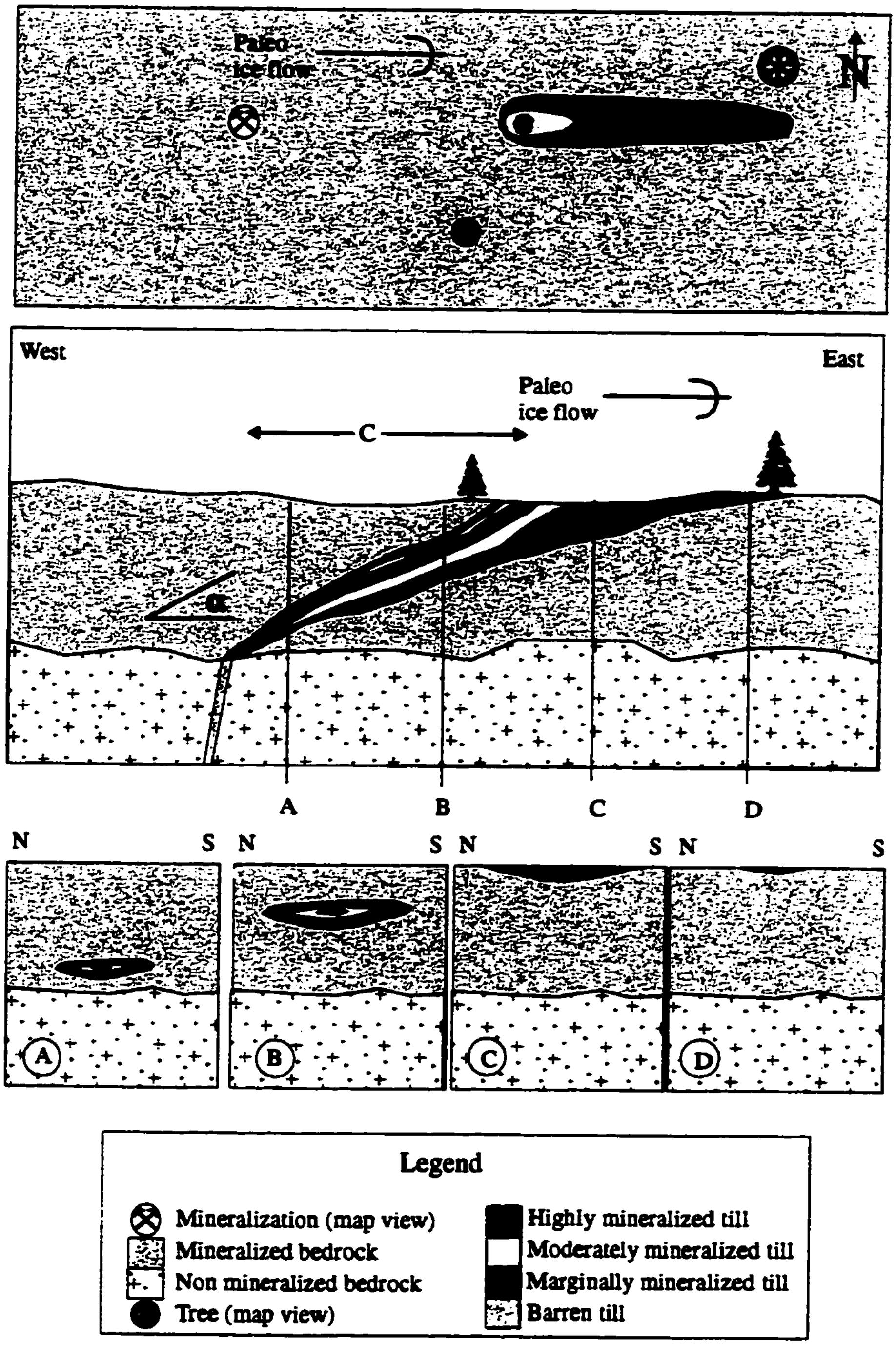


Fig. 3-6. Figure showing dispersal plume geometry, note that the geochemical anomaly is much larger than the original source area, also note that alpha is the angle of ascent and 'C' is the distance between the bedrock source and the first occurrence of mineralization in till at surface (After, Miller, 1984).

areas with multiple directions of ice flow can be diffuse and difficult to trace back to its source.

Data sets used

The location of till samples and the corresponding mercury concentrations for the clay size fraction (Plouffe, 1995a) in parts per billion were entered into a GIS (Appendix 3.1 - Figure 3.7). If more than one sample was taken at a geographical location the average mercury value was used for the site. Most of the multiple till samples (profile samples) were taken directly down ice of the mine, where the mercury concentrations were high. Averaging the multiple samples avoided biasing the statistics towards these higher mercury values. In general, the variability between samples taken from one site was not very large Appendix 3.1).

The locations of bedrock samples were then entered into the GIS (Figure 3.7). Most of the locational error (and therefore computational error) is likely to occur in this step. The map with the location of bedrock samples had very few landmarks by which to accurately georeference the sites. Mercury concentration in bedrock was then determined from a series of 39 chip samples taken by Stevenson (1940). The chip samples clustered about three main points, referred to in this paper as the north, central and south showings. The average mercury content for each site was calculated and then assigned to the appropriate location (Table 3.1). The chip sample data set was chosen over the mine site data because the mine would preferentially exploit the higher grade material. Furthermore, the grade of mercury at depth is likely to be different from the grades at surface. This brings up one source of possible error in this method; there is no way of knowing if the material that the glacier eroded was higher (or lower) grade than is presently at surface.

South Showing		Central Showing		North Showing	
Sample	mercury	Sample	mercury	Sample	mercury
#	ppm	#	ppm	#	ppm
1	4,000	19	7,500	34	11,300
2	12,700	20	1,100	35	16,900
3	4,500	21	1,200	36	21,800
4	150	22	1,100	37	5,600
5	2,200	23	250	38	29,600
6	800	24	70,200	39	900
7	1,100	25	22,000		
8	600	26	26,000	Average	**14,350**
9	800	27	30,300		
10	700	28	27,100		
11	550	29	7,500		
12	850	30	10,900		
13	650	31	14,300		
14	5,100	32	14,000		
15	5,600	33	4,500		
16	450				
17	1,000	Average	**15,863**		
18	450				
Average	**2,344**				
Location:		Location:		Location:	
Northing	6054529.7	Northing	6054658.6	Northing	6054954.7
Easting	407466.43	Easting	407332.06	Easting	407024.62

Table 3.1

Location of bedrock mineralization

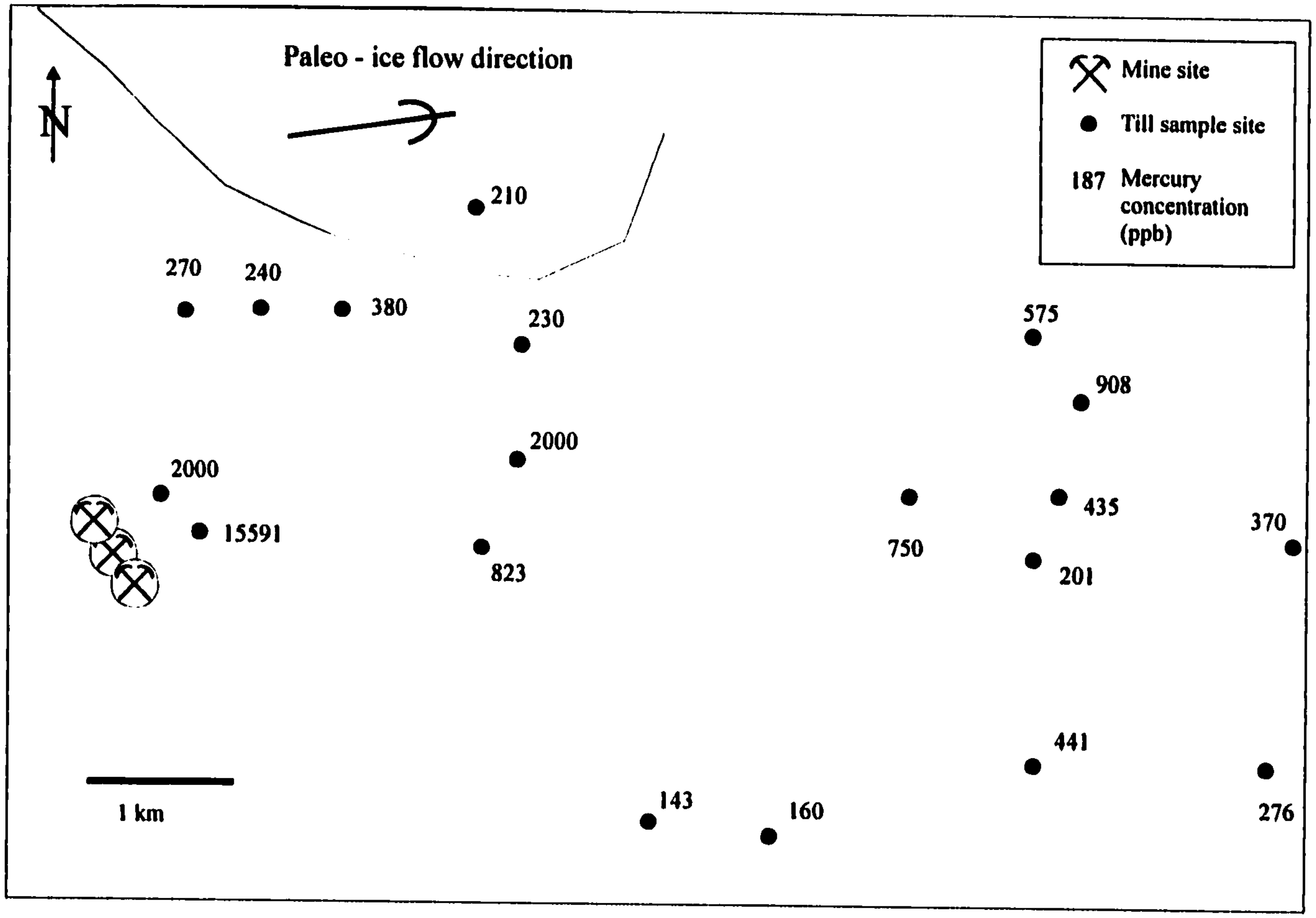


Fig. 3-7. Mercury concentrations in till samples in the area of the Pinchi Mine.

Till sample area of influence model

Once the till and bedrock data were plotted (Figure 3.7) local ice flow direction was determined to be towards 080 degrees by the shape and orientation of the dispersal train in relation to the known mercury mineralization in bedrock. This determination coincides well with Plouffe (1995a) who suggested that regional ice-flow was generally eastward with local deflections from northerly flowing ice from the Cariboo Mountains. The GIS was then used to model the area that would source the material found in a till site. The shape of the modelled source area resembles a distended triangle (Figure 3.8). As an analogy, this triangle is to a till sample, as a catchment basin is to a stream sediment sample. The triangle apex is placed on the till site and is rotated such that it is pointing directly opposite the local ice-flow direction (Figure 3.8).

The shape of the triangle was determined as follows:

1) the apex angle was based on the shape of the dispersal pattern, which was relatively narrow. Measurements on the width of the dispersal pattern suggested an angle of approximately 10 degrees. The source area triangle was constructed with a forty degree arc, to give an 300% margin of error. Furthermore, Hirvas and Nenonen (1990) report 'probability sectors' for tracing mineralized boulders to be on the order of 10, to 25 degrees. Lastly, figure 3.9 shows the shape inverted illustrating all of the anomalous mercury values found in till site could be modelled by a forty degree angle.

2) the overall length of the triangle (parallel to ice flow) was made from the mercury dispersal data. The mean mercury level in till sites east of the Pinchi fault is 220 ppb, excluding anomalous values associated with the mine site (Plouffe, 1995a). This mean was used to define background/anomalous threshold. The length of the dispersal train was determined by measuring the distance between the mine and the point at which the concentration of mercury dropped below 220 ppb (Figure 3.10). This same length was used for the source area triangle.

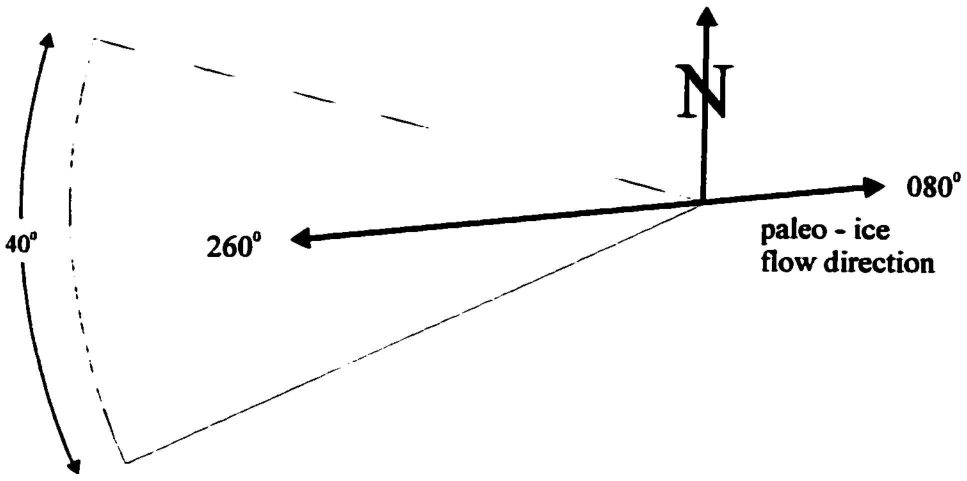


Fig. 3-8. Till sample source area shape. Oriented with apex angle pointing directly down ice (e.g. 080 degrees)

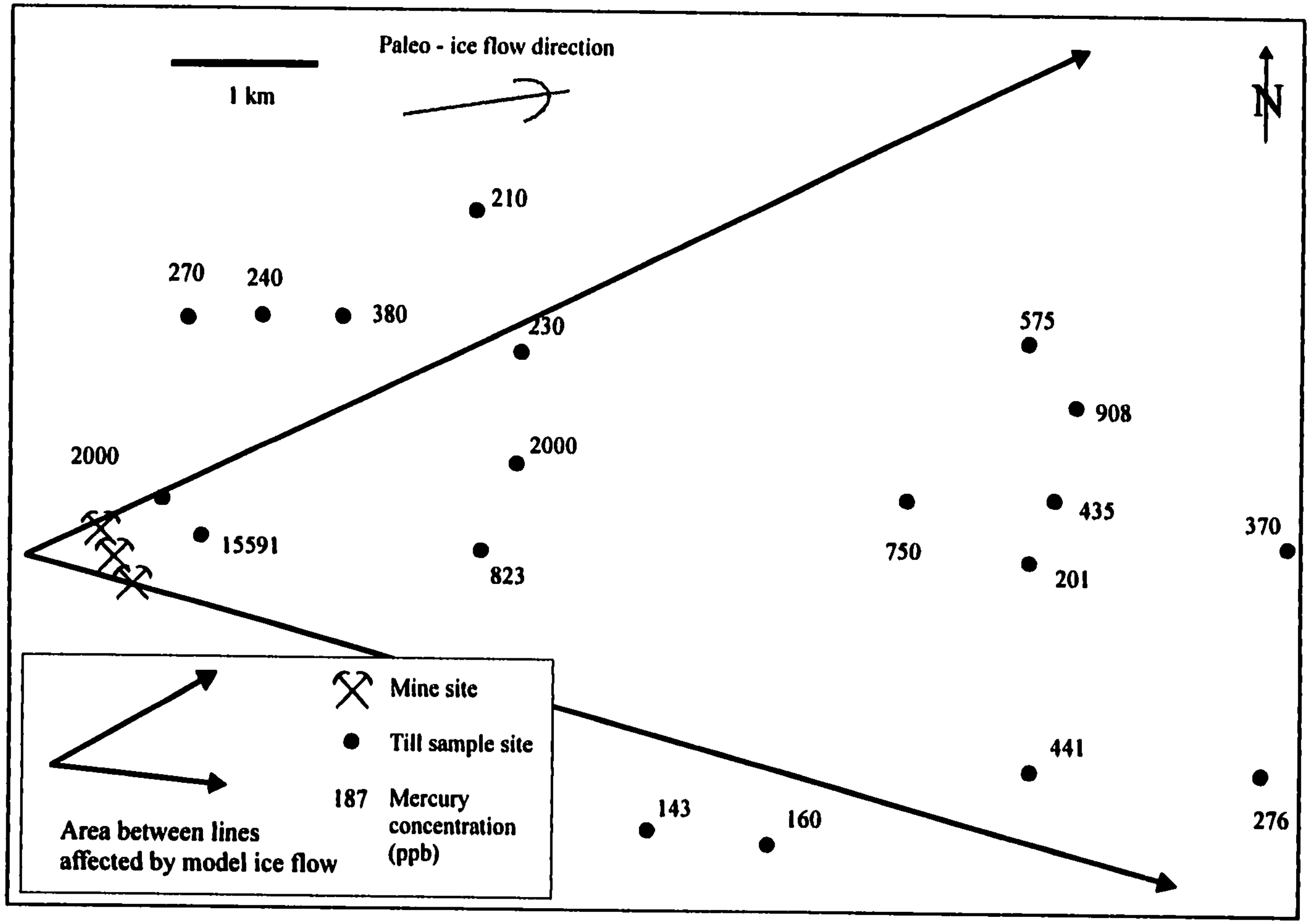


Fig. 3-9. Distribution of modeled mineralization dispersal, showing that all anomalous till sites are within 40 degree angle.

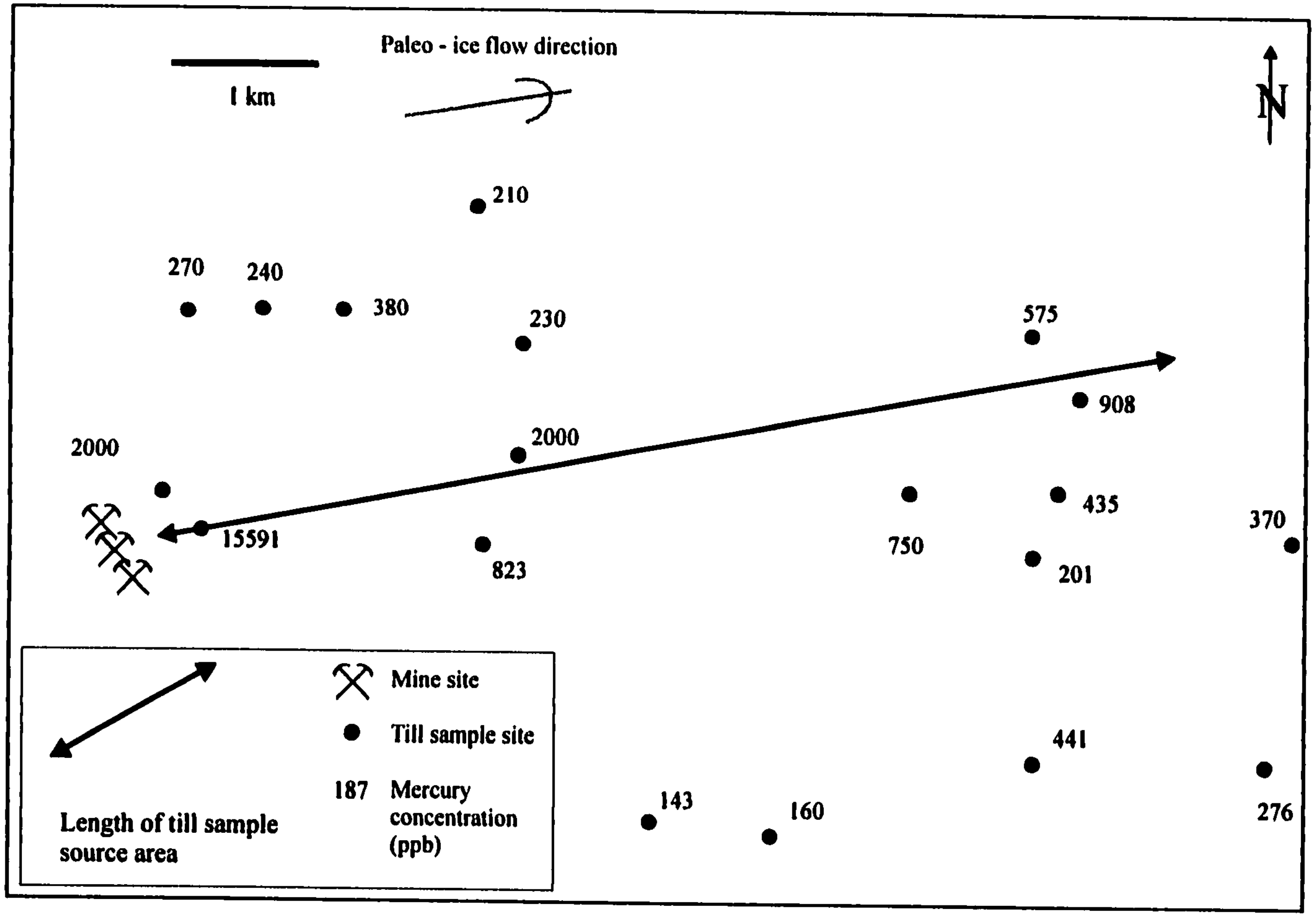


Fig. 3-10. Determination of till sample source area length. Distance from mineralization to background levels of mercury in till.

Refining the Source area triangle perpindicular to ice flow

To refine this dispersal model, a mercury concentration profile was drawn in a direction parallel to ice flow (Figure 3.11). The horizontal distance between the mineralization and the highest concentration of mercury in the till was determined to be 550 m. This distance (C) is intended to be used with concentration (or abundance) of a distinctive lithology in pebble counts (Miller, 1984; DiLabio, 1990; Bobrowsky, 1995) but in this example is used to describe concentration of mercury. The mercury concentration profile was then digitized and analyzed within the GIS. The lower cutoff was placed at 220 ppb (the mean mercury concentration for the study region). The area between the curve and the 220 ppb line was determined (Table 3.2). This area was divided into 550m increments ('C' distance). The portion of the area under each portion of the curve was then calculated (Table 3.2, the shaded areas were considered insignificant for this study). Figure 3.11 is a two dimensional model of how the glacier deposited till in this area. For example, it shows that most of the material (63%) was deposited within 1.65 km of where it was eroded. Therefore, to model how a till site is affected by up ice mineralization, this model is simply reversed. That is, most of the material that is deposited at a site, has been derived from within 1.65 km up-ice (Figure 3.12).

Refining the Source area triangle parallel to ice flow

To determine the variability of ice flow direction, the source area triangle was modified further. It was divided into a central zone of 10 degrees and was flanked by 3 additional zones of influence, each 5 degrees on either side (Figure 3.13). The final shape is shown with all its divisions in Figure 3.14. Each of these zones was later assigned relative weights. Each set of relative weights is called a weighting scenario. The best scenario was determined by evaluating how well each scenario modelled the bedrock data compared to the actual mercury concentration found in the tills.

	D	From	To	Area under curve	Area
	1/2	(km)	(km)	(mixed units)	proportion
Mine	1	0.00	0.55	0.09364	22.17%
	2	0.55	1.10	0.11261	26.66%
	3	1.10	1.65	0.06099	14.44%
	4	1.65	2.20	0.03530	8.36%
	5	2.20	2.75	0.02066	4.89%
	6	2.75	3.30	0.01732	4.10%
	7	3.30	3.85	0.01548	3.66%
	8	3.85	4.40	0.01386	3.28%
	9	4.40	4.95	0.01243	2.94%
	10	4.95	5.50	0.01089	2.58%
	11	5.50	6.05	0.00941	2.23%
	12	6.05	6.60	0.00756	1.79%
	13	6.60	7.15	0.00534	1.26%
	14	7.15	7.70	0.00328	0.78%
	15	7.70	8.25	0.00206	0.49%
	16	8.25	8.80	0.00120	0.28%
	17	8.80	9.35	0.00042	0.10%
Down ice	18	9.35	9.90	0.00000	0.00%
		Total		0.42245	100.00%

Table 3.2

Area under longitudinal profile curve

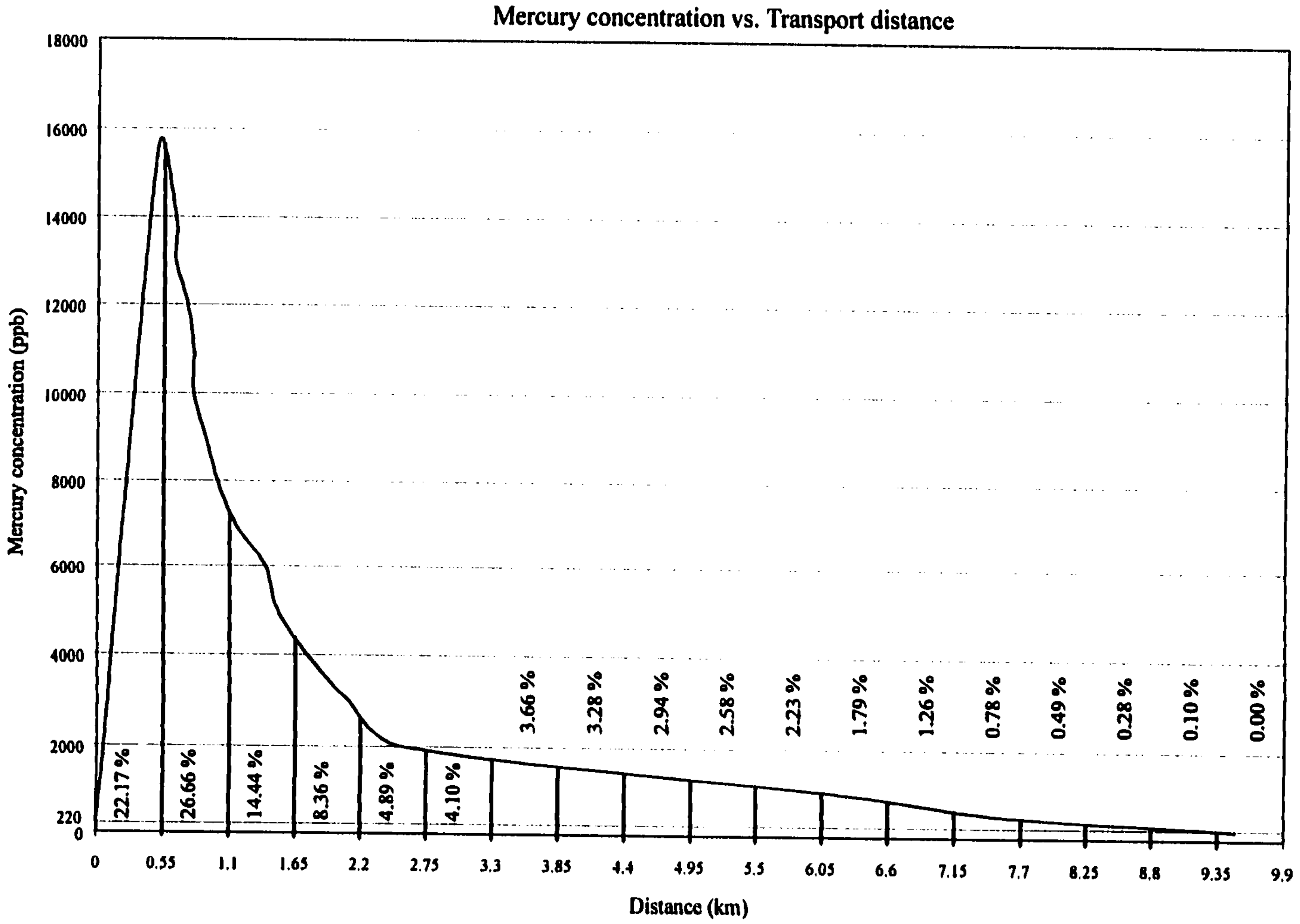


Fig. 3-11. Diagram showing the longitudinal profile of mercury concentration in tills down ice of the mine site.

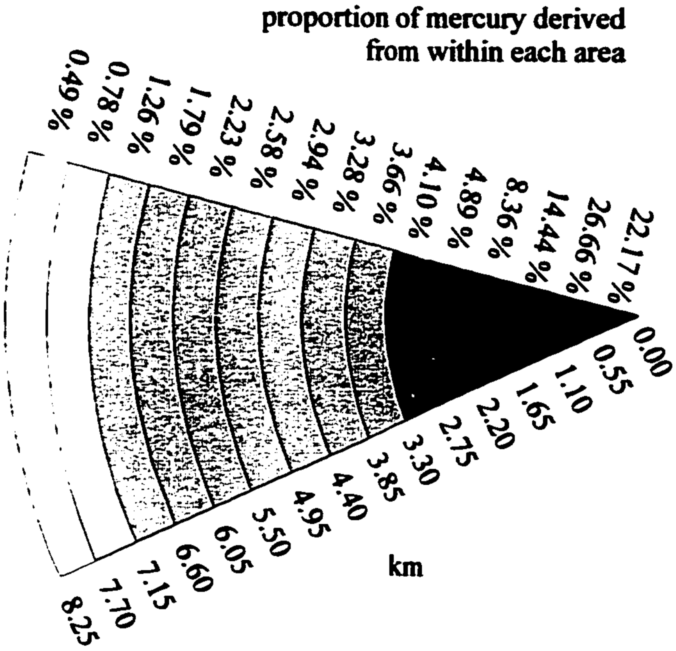


Fig. 3-12. Till sample source area subdivided perpindicular to ice-flow, proportions and distances refer to Figure 3-11.

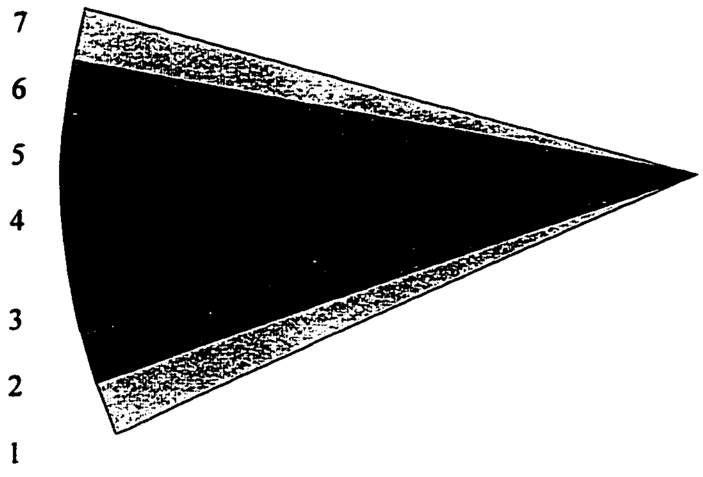


Fig. 3-13. Till sample source area subdivided parallel91 to ice-flow. Numbers refer to the portions of the shape they occur next to.

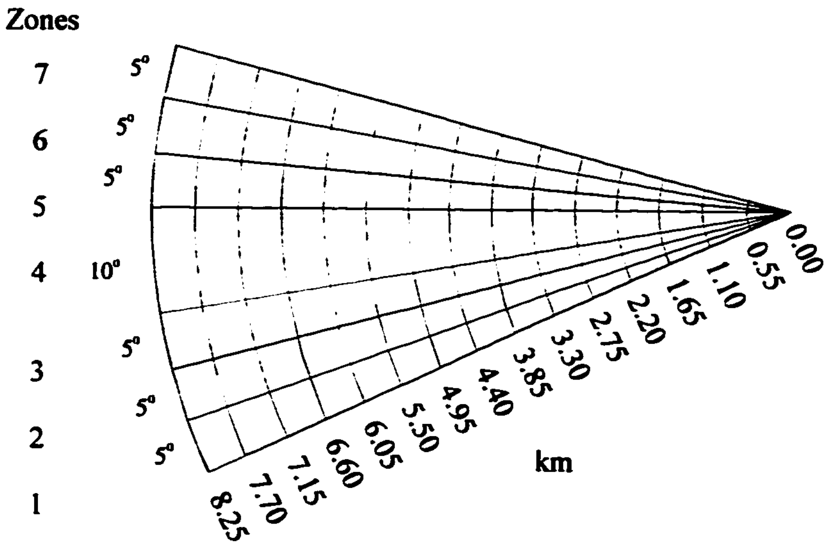


Fig. 3-14. Till sample source area subdivided perpendicular and parallel to ice-flow. The central zone is 10 degrees all others are 5 degrees.

Data manipulation

For all the till samples located down ice of the mine site, the apex of the source area triangle was positioned over the till sample site (Figure 3.15). The source area shape was then rotated to the correct orientation (i.e. directly opposite paleo ice-flow direction). The source area triangle was overlain onto the map with the location and grade of mercury mineralization in bedrock. The location of each point of mineralization within the triangle was recorded (i.e. in Figure 3.15 the mineralization would be located in Zone 3 at a distance weight of 2.23%). The calculations on Figure 3.15 show some of the calculations used. For instance, if the mineralization was located between 5.50 km and 6.05 km away from the till site, it would be given a distance weight of 2.23%. Furthermore, if it was located in Zone 3 it may receive an angle weight of 6.3% (a discussion of how these weights were chosen is upcoming). After these weights were applied, a final factor was required which is related to how easily the mineralization was eroded. This will be referred to as the erodability factor.

Therefore, the concentration of mercury in the till sample is modelled by determining:

1) the concentration of mercury in the bedrock
2) multiplied by a factor that considers distance between source and deposition
3) multiplied by a factor that considers the amount of mercury sourced at each angle

The till sites located directly down ice of the mineralization are listed in Table 3.3. The analysis of the data could begin once the relative location of each site of mineralization was determined for every till sample site. A spreadsheet was set up to evaluate the information. A portion of this spreadsheet is shown in Table 3.4. There are several aspects of this spread sheet that require explaining:

Column 1 contains the till sample labels (Plouffe, 1995a)

Columns 2, 5, and 8 contain the mean mercury concentrations found in bedrock at the north, central and south showings, respectively (Stevenson, 1940)

Till Sample	HG
93-PMA-504-1	15591
93-PMA-508-1	2000
91-PMA-098	2000
91-PMA-119	887
93-PMA-512-1	575
93-PMA-513-1	750
91-PMA-132	435
91-PMA-118	390
91-PMA-133	201
91-PMA-126	823
91-PMA-135	370
91-PMA-125	230
91-PMA-131	276

Table 3.3

Till sites down ice of mineralization

Till Sample	North Show ppm Hg	Distance Weight. Function	Angle Weight. Function	Central Show ppm Hg	Distance Weight. Function	Angle Weight. Function	South Show ppm Hg	Distance Weight. Function	Angle Weight. Function	Actual Conc. in Till	Total Weight. Conc.
93-PMA-504-1	14350	0.00%	0.00	15863	22.17%	0.25	2344	22.17%	0.13	15,591	1,164
93-PMA-508-1	14350	4.10%	0.25	15863	4.89%	0.25	2344	4.89%	0.13	2,000	575
91-PMA-098	14350	26.66%	0.25	15863	0.00%	0.00	2344	0.00%	0.00	2,000	1,176
91-PMA-119	14350	1.26%	0.25	15863	1.79%	0.25	2344	1.79%	0.25	887	347
93-PMA-512-1	14350	1.79%	0.25	15863	1.79%	0.25	2344	1.79%	0.13	575	360
93-PMA-513-1	14350	2.23%	0.13	15863	2.58%	0.25	2344	2.58%	0.25	750	377
91-PMA-132	14350	1.26%	0.13	15863	1.79%	0.25	2344	1.79%	0.25	435	324
91-PMA-118	14350	0.00%	0.00	15863	0.49%	0.25	2344	0.49%	0.25	390	242
91-PMA-133	14350	1.79%	0.13	15863	1.79%	0.13	2344	2.23%	0.13	201	294
91-PMA-126	14350	4.89%	0.13	15863	4.89%	0.13	2344	4.89%	0.25	823	433
91-PMA-135	14350	0.49%	0.13	15863	0.49%	0.13	2344	0.49%	0.13	370	240
91-PMA-125	14350	4.10%	0.13	15863	4.10%	0.13	2344	0.00%	0.00	230	375
91-PMA-131	14350	0.00%	0.00	15863	0.49%	0.13	2344	0.78%	0.13	276	232

Table 3.4

Spreadsheet used to determine best scenario

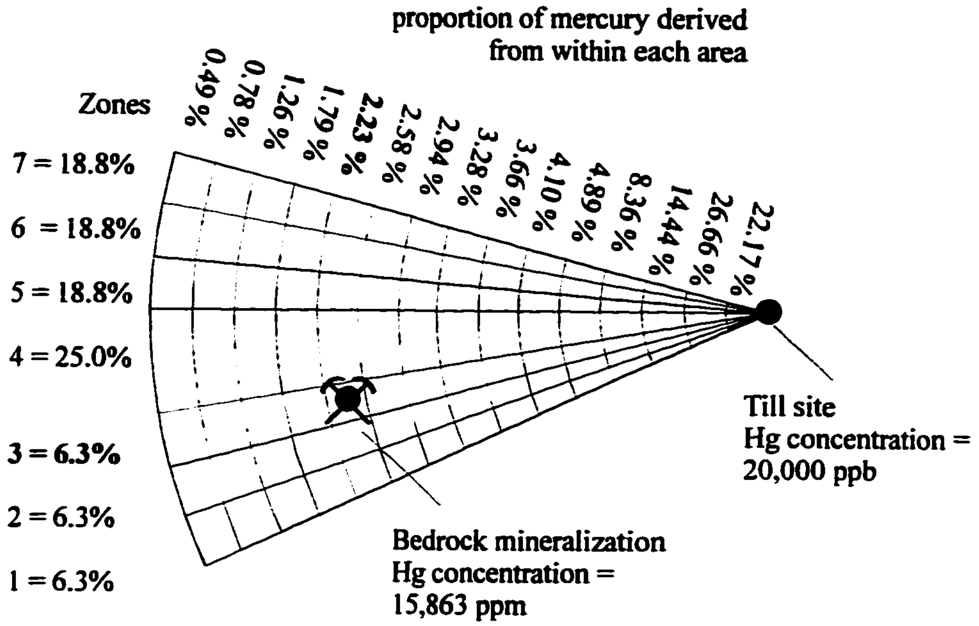


Fig. 3-15. Sample calculation for a till site. The amount of mercury in bedrock is multiplied by the angle weighting factor and the distance weighting factor and then compared to the amount of mercury in the till sample.

Bedrock Conc. (ppm)		Dist. Factor		Angle Factor		Total modeled Hg conc. (ppb)		Actual Hg conc. in till sample (ppb)
15,863	*	2.23%	*	6.3 %	=	22,985.5	~	20,000

Columns 3, 6, and 9 contain the value that factors in the distance between each till site and each bedrock source area.

Columns 4, 7, and 10 contain the value that factors in the relative amount of input from various angles to the till sample site. The values are shown in the upper right of the spreadsheet. These values model the variability in the ice flow direction (more discussion of the selection of these values to follow).

Column 11 contains the concentration of mercury in the till sample (if more than one sample was taken at one spot, the average of all the samples taken at the site was applied, Plouffe, 1995a).

Column 12 contains the sum of all the bedrock sites multiplied by the angle and distance factors for each till site.

Determining the best scenario

The weights for each of the seven zones were assigned in 12 different combinations referred to here as scenarios. Scenario B, for example was given weighting scenario such that one hundred percent of the weight was given to Zone 4 (the central zone) and weightings of zero percent were given to the other zones.

A statistic was set up to determine which scenario better models the glacial dispersion of mercury. A chi squared value was used to determine the amount of variability between the actual mercury concentrations in the till samples and the theoretical (or modelled) mercury concentration (Equation 3.1).

$$\textbf{chi square} = \textbf{sum} \left\{ \frac{(\textbf{t.v.} - \textbf{a.v.})^2}{\textbf{n}} \right\} \qquad \text{Equation 3.1}$$

where: t.v. = theoretical value

a.v. = actual value

n = number of samples

The chi squared value for each of the twelve scenarios was then compared to determine which scenario best modelled the glacial ice flow variability.

RESULTS

The glacial paleo-flow direction in the area was approximately 080^0 as indicated by the orientation of the geochemical dispersal train interpreted to be derived from the Pinchi Lake mercury deposit (Plouffe, 1995a). The relative amount of mercury deposited in till at various distances from mineralization is shown on Figures 3.7 and 3.10. A 'source area shape' was developed and then overlain onto the bedrock mineralization map. To determine the direction of dispersal, the source area was divided into seven zones of influence (Figure 3.12).

Weightings were assigned to each zone. The amount of mercury deposited at each till site was modelled using 12 iterative weighting scenarios. The resultant modelled mercury value was then compared to the actual mercury that was reported at the till sample. A chi squared statistic was used to determine how closely the modelled values were to the actual values. The chi squared values for each scenario were tabulated and ranked (Table 3-5). A comparison of the different scenarios indicate which one most closely approximates reality. The results and interpretation of each scenario are discussed below.

The scenario ranked as best in this paper can, inevitably, be improved upon. However, one can deduce by the trends in the chi squared value, that the weighting fairly closely approximates the true variability of the movement of ice (Table 3.5). The trend is qiute clear that the greater the weighting in the central zone the lower the Chi square value, and therefore the more closely the scenario resembles reality. The difference in Chi square values between scenarios that put more emphasis on the northern or southern zones (e.g. Scenarios H and K) was quite small. This suggests that flow in directions to the south or north of 80 degrees did not significantly impact the dispersal train.

Zone 1 weight	0.00%	1.59%	2.81%	3.92%	2.61%	10.83%	11.67%	12.50%	5.00%	8.34%	6.25%	15.00%
Zone 2 weight	0.00%	2.51%	4.70%	7.75%	4.22%	10.83%	11.67%	12.50%	10.00%	8.34%	6.25%	15.00%
Zone 3 weight	0.00%	6.31%	10.18%	21.56%	8.66%	10.83%	11.67%	12.50%	15.00%	8.34%	6.25%	20.00%
Zone 4 weight	100.00%	79.66%	64.98%	50.96%	50.96%	35.00%	30.00%	25.00%	25.00%	25.02%	25.00%	20.00%
Zone 5 weight	0.00%	6.31%	10.18%	8.66%	21.56%	10.83%	11.67%	12.50%	20.00%	16.68%	18.75%	10.00%
Zone 6 weight	0.00%	2.51%	4.70%	4.22%	7.75%	10.83%	11.67%	12.50%	15.00%	16.68%	18.75%	10.00%
Zone 7 weight	0.00%	1.59%	2.81%	2.61%	3.92%	10.83%	11.67%	12.50%	10.00%	16.68%	18.75%	10.00%
Total weight	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Scenario	B	J	I	H	K	F	C	L	A	E	D	G
Chi Value (000,000)	**11.17**	**12.31**	**13.25**	**14.23**	**14.26**	**15.45**	**15.86**	**16.27**	**16.30**	**16.32**	**16.34**	**16.69**
Rank (out of 12)	1	2	3	4	5	6	7	8	9	10	11	12
Till Sample	model	model	model	model	model	model	model	model	model	model	model	model
93-PMA-504-1	3,736	3,034	2,529	2,052	2,034	1,507	1,335	1,164	1,151	1,143	1,132	1,001
93-PMA-508-1	1,584	1,314	1,118	940	925	710	643	575	578	571	568	516
91-PMA-098	4,045	3,267	2,706	2,169	2,169	1,559	1,368	1,176	1,176	1,177	1,176	985
91-PMA-119	727	624	550	478	478	398	372	347	347	347	347	321
93-PMA-512-1	761	653	576	505	499	414	387	360	361	359	358	337
93-PMA-513-1	689	614	558	487	528	419	398	377	401	391	397	346
91-PMA-132	546	491	450	402	425	354	339	324	338	332	335	303
91-PMA-118	309	291	278	265	265	251	247	242	242	242	242	238
91-PMA-133	220	248	266	260	312	284	289	294	326	319	331	279
91-PMA-126	335	378	406	375	500	420	427	433	509	495	526	391
91-PMA-135	220	230	236	234	254	237	239	240	252	246	250	236
91-PMA-125	220	245	266	291	262	354	365	375	311	323	297	406
91-PMA-131	220	222	223	222	224	230	231	232	230	236	238	230

Table 3.5

Chi square values and characteristics of each scenario

Scenario 'B'

Figure 3.16

Rank 1 out of 12

Chi - squared value = 11,170,000

Weightings (1-7 in %) 0, 0, 0, **100**, 0, 0, 0

This model considers the scenario that no mercury is sourced from outside the central zone (4). The fact that this model performed better than all the others suggests that very little of the mercury was sourced from the peripheral zones.

Scenario 'J'

Figure 3.17

Rank 2 out of 12

Chi - squared value = 12,310,000

Weightings (1-7 in %) 1.6, 2.5, 6.3, **80.0**, 6.3, 2.5, 1.6

This model considers the scenario in which mercury is sourced primarily (80%) from the central zone (4). The amount that is sourced from the peripheral zones (20%) decreases outwardly by a square root function, i.e. 6.3% in zone 3, the square root of 6.3% (2.5%) in zone 2 and so on. This is the scenario with the second highest weighting in the central zone (4), and it also performed the second best. This scenario was tried to see how distributing the weightings out of the central zone would affect the Chi value.

Fig. 3-16
Scenario 'B'
Rank = 1 out of 12
Chi square = 11,170,000

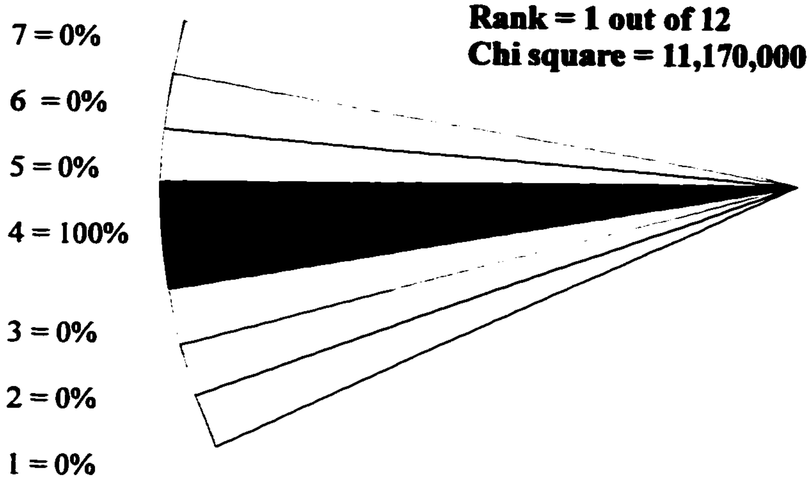
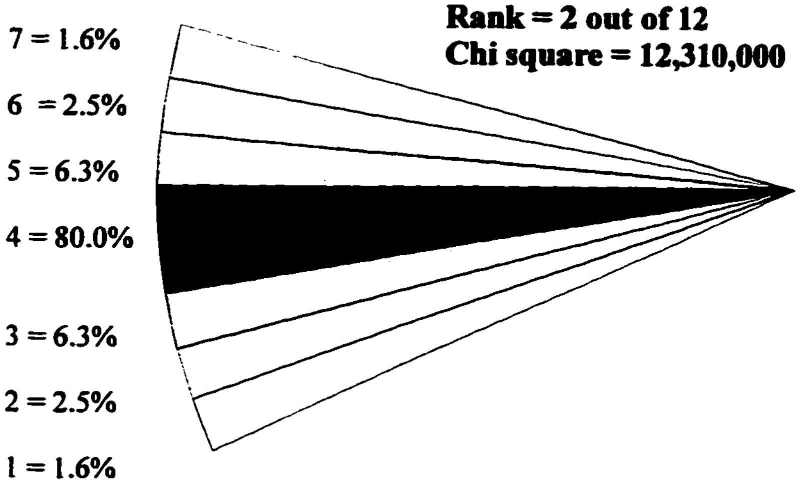


Fig. 3-17
Scenario 'J'
Rank = 2 out of 12
Chi square = 12,310,000



Scenario 'I'

Figure 3.18
Rank 3 out of 12
Chi - squared value = 13, 250, 000
Weightings (1-7 in %) 2.8, 4.7, 10.2, **65.0**, 10.2, 4.7, 2.8

This model considers the scenario in which mercury is sourced in a large part (65%) from the central zone (4). The amount that is sourced from the peripheral zones (35%) decreases outwardly by a power of -1.5 function, i.e. 2.8% in zone 1, $2.8\%^{1.5}$ (4.7%) in zone 2 and so on. The trend continues where lowering the weight on the central zone increases the Chi value.

Scenario 'H'

Figure 3.19
Rank 4 out of 12
Chi - squared value = 14, 230, 000
Weightings (1-7 in %) 3.9, 7.8, 21.6, **51**, 8.7, 4.2, 2.6

This model considers the scenario in which mercury is sourced mainly in the central zone (51%). The remainder was split such that weighting drops off at the power of 1.5 but with the southern zones receiving 1.5 times that of the northern zone. So if zone 7 receives 2.6% zone 1 receives 1.5 times that or 3.9%. The zones closer to the center receive the power of 1.5 more than these weights i.e. zone 2 receives $3.9\%^{1.5}$ or 7.8%. Again, as the central zone weighting is decreased the Chi value increased.

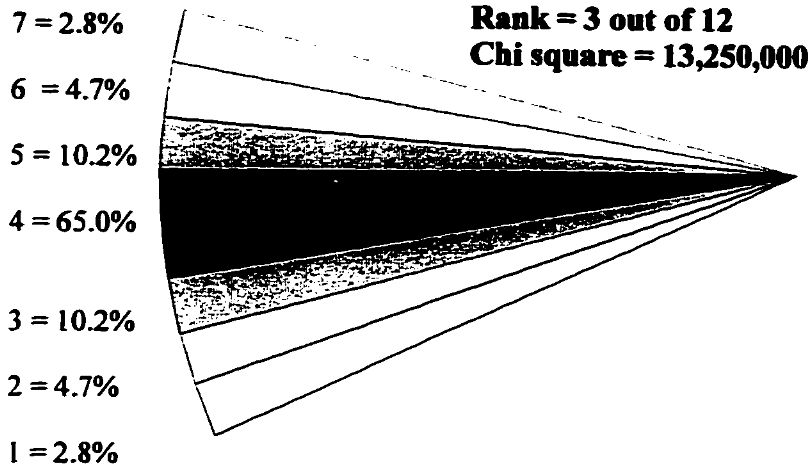


Fig. 3-18
Scenario 'I'
Rank = 3 out of 12
Chi square = 13,250,000

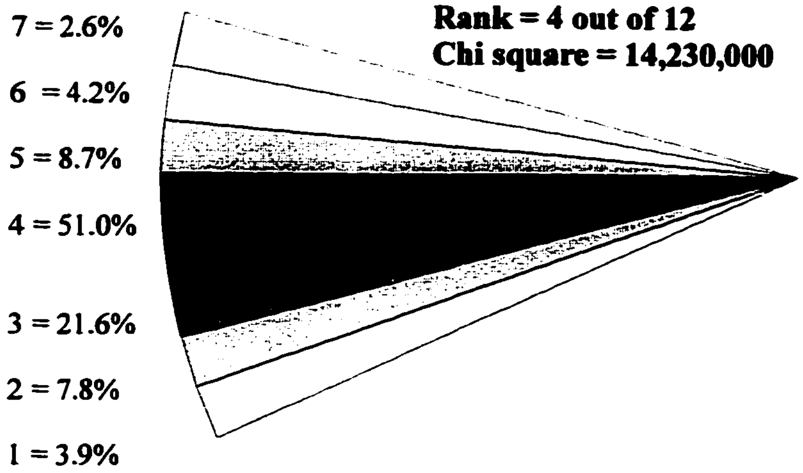


Fig. 3-19
Scenario 'H'
Rank = 4 out of 12
Chi square = 14,230,000

Scenario 'K'

Figure 3.20

Rank 5 out of 12

Chi - squared value = 14, 260, 000

Weightings (1-7 in %) 2.6, 4.2, 8.7, **51,** 21.6, 7.8, 3.9

This model is the same as described above with the exception that the northern zones are more heavily weighted than the southern zones. This score a higher Chi value than scenario 'H', however the difference between the scores is almost negligable. This suggests that the amount of dispersal varies little from north to south of the central zone.

Scenario 'F'

Figure 3.21

Rank 6 out of 12

Chi - squared value = 15, 450, 000

Weightings (1-7 in %) 10.8, 10.8, 10.8, **35,** 10.8, 10.8, 10.8

This model considers the scenario of approximately equal weighting in all the zones (the central zone is twice as wide as the other zones, therefore, 35% is only marginally higher per area than 10.8%). This model performed relatively poorly due to the low central weighting.

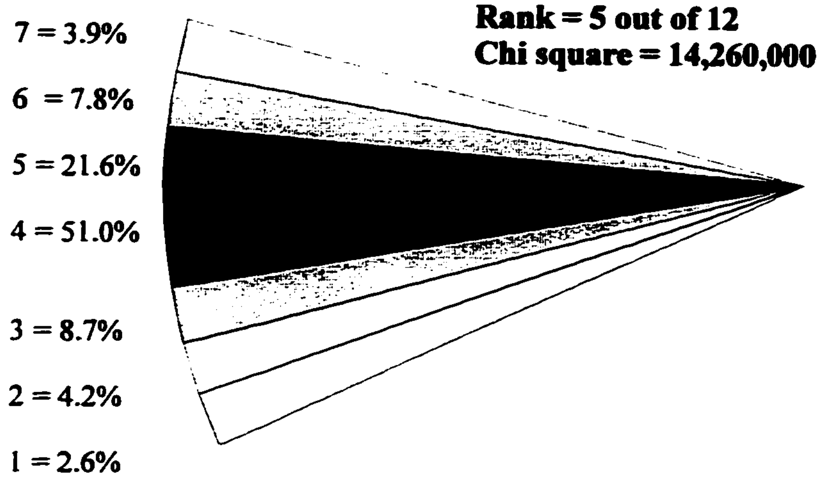


Fig. 3-20.
Scenario 'K'
Rank = 5 out of 12
Chi square = 14,260,000

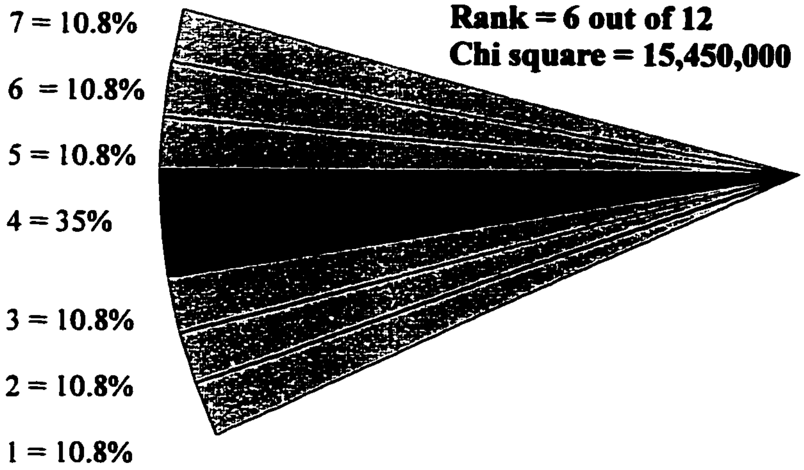


Fig. 3-21
Scenario 'F'
Rank = 6 out of 12
Chi square = 15,450,000

Scenario 'C'

Figure 3.22

Rank 7 out of 12

Chi - squared value = 15, 860, 000

Weightings (1-7 in %) 11.7, 11.7, 11.7, **30,** 11.7, 11.7, 11.7

This model considers the scenario of nearly equal weighting in all the zones, but with a slightly stronger weighting in the central area. Therefore, the model suggests that nearly the same amount of material was derived from one direction as any other direction within 20^0 either side of the up ice direction. However, slightly more was derived from the central zone, per area. The same trend continues with this scenario. The central zone recieved less weight and therefore the scenario performed more poorly than the other previous scenarios..

Scenario 'L'

Figure 3.23

Rank 8 out of 12

Chi - squared value = 16, 270, 000

Weightings (1-7 in %) 12.5, 12.5, 12.5, **25,** 12.5, 12.5, 12.5

This model considers the scenario of exactly equal weighting in all the zones (again zone 4 is twice as wide as the others). Therefore the model suggests that the same amount of material was derived from one direction as any other direction within 20^0 either side of the up ice direction. The fact that this scenario performed relatively poorly suggests that this scenario is not closely related to the way the glacier moved over the area.

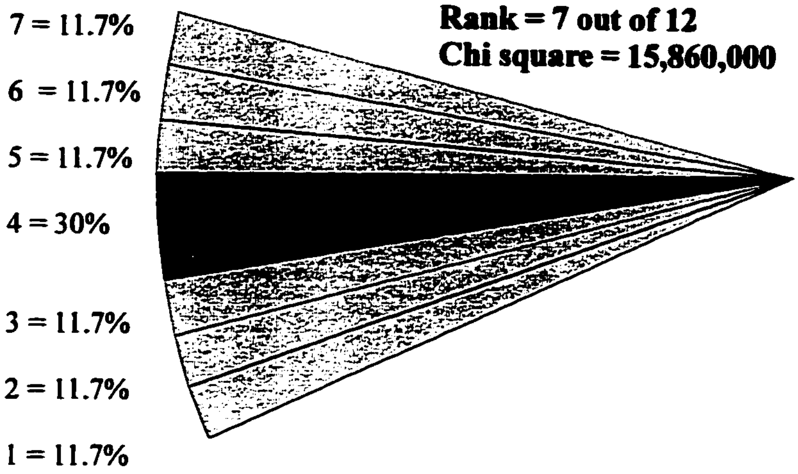


Fig. 3-22
Scenario 'C'
Rank = 7 out of 12
Chi square = 15,860,000

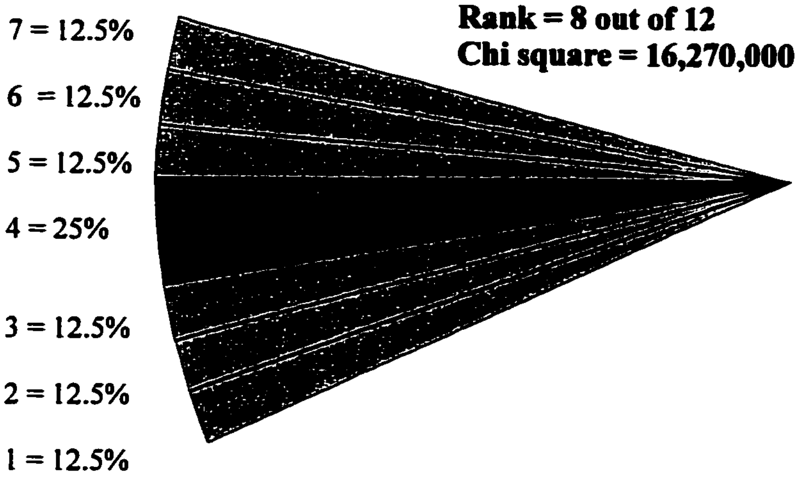


Fig 3-23.
Scenario 'L'
Rank = 8 out of 12
Chi square = 16,270,000

Scenario 'A'

Figure 3.24

Rank 9 out of 12

Chi - squared value = 16, 300, 000

Weightings (1-7 in %) 5, 10, 15, **25**, 20, 15, 10

This model considers the scenario of a moderate to strongly weighted northern zone, a moderately weighted central zone and a moderate to relatively weakly weighted southern zone. This model suggests that the central zones (3,4, and 5) were responsible for sourcing the material for the till sites. The zones further away from the central zones were responsible for less of the material and the zones furthest from the center sourced the least material. The northern zones were responsible for sourcing slightly more than the southern zones. Scenarios L, A, E and D all have central weighting of approximately 25%, even though the weighting of the outer zones differ in each scenario, the chi value is almost unchanged, again suggesting that the central zone is the most important.

Scenario 'E'

Figure 3.25

Rank 10 out of 12

Chi - squared value = 16, 320, 000

Weightings (1-7 in %) 8.3, 8.3, 8.3, **25**, 16.7, 16.7, 16.7

This model considers the scenario of a fairly strongly weighted northern zone, a moderately weighted central zone and a relatively weakly weighted southern zone. This model suggests that the northern zones were responsible for sourcing more of the till than were the southern zones. The central zone again seems to be the determining zone, as this scenario performed quite poorly relative to scenarios with higher central weightings.

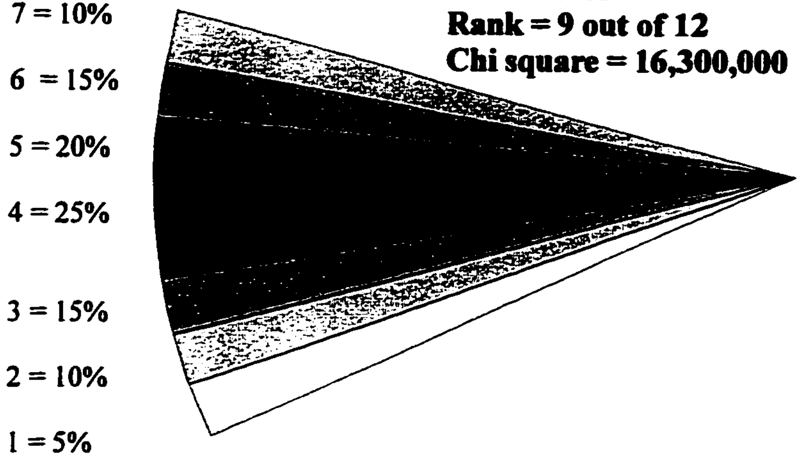


Fig. 3-24
Scenario 'A'
Rank = 9 out of 12
Chi square = 16,300,000

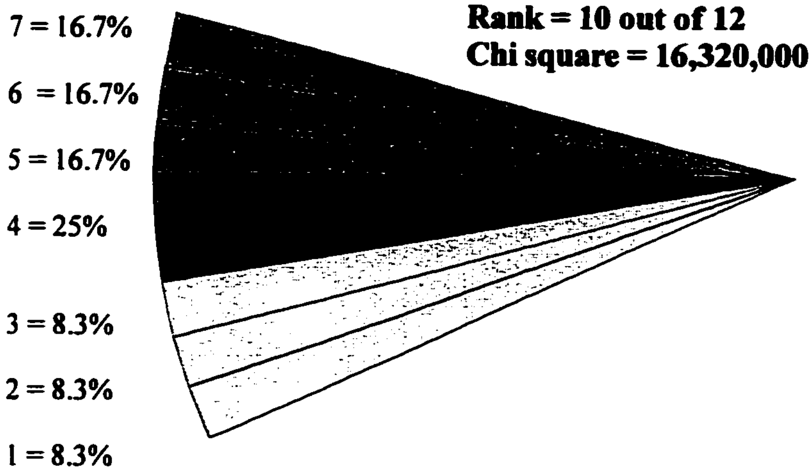


Fig. 3-25.
Scenario 'E'
Rank = 10 out of 12
Chi square = 16,320,000

Scenario 'D'

Figure 3.26

Rank 11 out of 12

Chi - squared value = 16, 340, 000

Weightings (1-7 in %) 6.3, 6.3, 6.3, **25**, 18.8, 18.8, 18.8

This model considers the scenario of a strongly weighted northern zone, a moderately weighted central zone and a weakly weighted southern zone. This model suggests that the northern zones were responsible for sourcing more of the till than were the southern zones. This scenario attained the second highest chi value suggesting that the southern zones were responsible for sourcing more till than the northern zones, but more importantly that the central zone is responsible for sourcing greater than 25% of the till. .

Scenario 'G'

Figure 3.27

Rank 12 out of 12

Chi - squared value = 16, 690, 000

Weightings (1-7 in %) 15, 15, 20, **20**, 10, 10, 10

This model considers the scenario in which mercury is sourced mainly in the southern zones (50%), moderately from the central zone (20%) and sparingly from the northern zones (30%). This model has the lowest central weighting of all the scenarios and it performed the most poorly. This further reinforces the trend expressed throughout this chapter.

Fig. 3-26.
Scenario 'D'
Rank = 11 out of 12
Chi square = 16,340,000

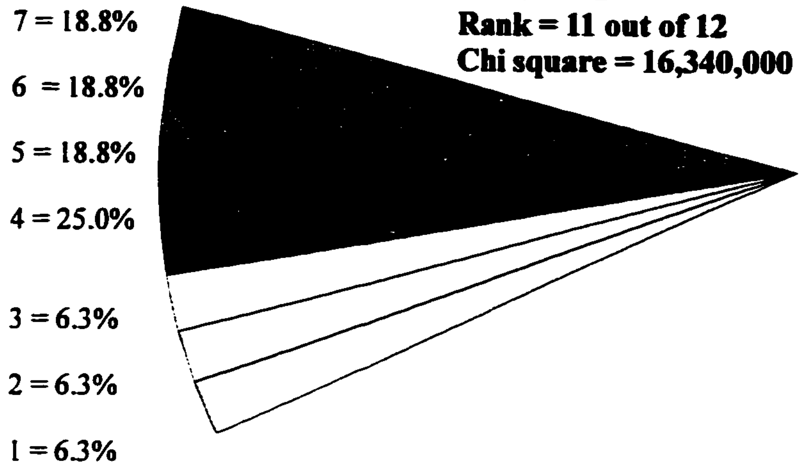
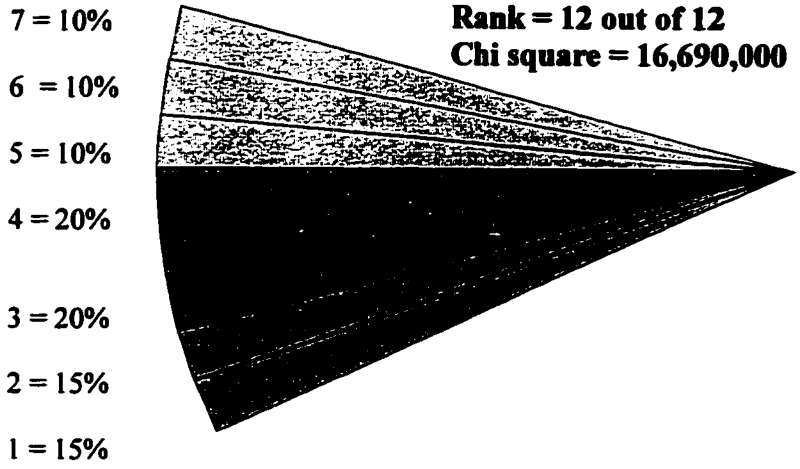


Fig. 3-27.
Scenario 'G'
Rank = 12 out of 12
Chi square = 16,690,000



CONCLUSIONS

The concentration of mercury found in the till east of the Pinchi mine site very closely approximates a classic example of glacial dispersal from a point source (Miller, 1984; Coker and DiLabio, 1989; Bobrowsky, 1995). Large scale features in the area suggest that the ice in this area flowed from the west towards the east (080^0). Small scale features such as striations on bedrock in the area confirmed a dominantly eastward paleo-ice flow direction. However, some striations were found at angles not parallel to 080^0. This paper has shown a method to quantify the significance of the variability in ice flow direction. A GIS was used to model ice flow direction in the area using glacial dispersal data. In this case study, it appears as though ice flow variability was relatively insignificant. As the scenario that performed the best had 100% of the material sourced from the narrow 10 degree central zone.

This method may be used by academics to better understand the importance of glacial flow variability in an area. It may also be applied by explorationists as a tool to help find the source of mineralized float or anomalous till samples.

Dispersal References

Armstrong, J. E. (1949): Fort St James Map-Area Cassiar and Coast District, British Columbia; Geological Survey of Canada, Memoir 252, 204 p.

Armstrong, J. E. and Tipper, H. W. (1948): Glaciation in north central British Columbia; American Journal of Science, 246: 283-310.

Armstrong, J.E. (1942) Geology of the Pinchi Lake Mercury Belt, British Columbia, The Canadian Institute of Mining and Metallurgy, Transactions, 45: 311-323.

Ash, C.H. (1996) Silica -Carbonate Hg in Selected British Columbia Mineral Deposit Profiles, Volume 2 - Metallic Deposits, Lefebure, D.V and Hoy, T editors, Ministry of Employment and Investment, Open File 1996-13.

Azzaria, L.M. and Webber (1969): Mercury Analysis in geochemical exploration. Canadian Institute of Mining and Metalurgy Transactions LXXII: 126-135.

Bailey, D.G. and Jacobsen, D.E. (1989) : MINFILE 093K, Fort Fraser Occurrence Map: B.C. Ministry of Energy, Mines and Petroleum Resources, MINFILE, released Sept. 1989.

Bailey, E.H., Clark, A.L., and Smith, R.M. (1973): Mercury, Brobst, D. A., and Pratt, W.P. eds. in U.S. Geol. Surv. Prof. Paper 820, pp. 401-414.

Bobrowsky, P.T. (1995): Lithological Analysis in Drift Prospecting Studies in Drift Exploration in the Canadian Cordillera, (eds.) Bobrowsky, P.T., Sibbick, S.J., Newell, J.M., and Matysek, P.F., British Columbia Ministry of Energy Mines and Petroleum Resources, Paper 1995-2, p. 113-120.

Clague, J.J. (1988); Quaternary stratigraphy and history, Williams Lake, British Columbia. Canadian Journal of Earth Sciences, 24: 147-158.

Clague, J.J. (1987); Quaternary stratigraphy and history, Quesnel, British Columbia. Geographie Physique et Quaternaire. 42: 279-288.

Coker, W. B. and DiLabio, R. N. W. (1989): Geochemical exploration in glaciated terrain: geochemical responses; in Proceedings of Exploration '87, (ed.) G. D. Garland, Ontario Geological Survey, Special Volume 3, p. 336-383.

Cook, S.J., Jackaman, W., McCurdy, M.W., Day, S.J. and Friske, P.W. (1996): Regional Lake Sediment and Water Geochemistry of Part of the Fort Fraser Map Area, British Columbia; B.C. Ministry of Employment and Investment, Open File 1996-15, 51 pages.

DiLabio, R.N.W. (1990) Glacial dispersal trains, in Glacial Indicator Tracing. eds: R. Kujansuu and M. Saarnisto, Rotterdam: Balkema, pp. 109-122.

Dreimanis, A (1990): Formation, deposition, and identification of subglacial and supraglacial tills in Glacial Indicator Tracing. eds: R. Kujansuu and M. Saarnisto, Rotterdam: Balkema, pp. 217-247.

Dreimanis, A (1989): Tills, their genetic terminology and classification. In R.P. Goldthwait and C.L. Matsch (eds.), Genetic Classification of Glaciogenic deposits: Rotterdam. Balkema, pp. 15-81.

Dreimanis, A (1987): Genetic complexity of a subaquatic till tongue at Port Talbot, Ontario, Canada. In R. Kujansuu and M. Saarnisto (eds.), INQUA Till Symposium, Finland, 1985. Geological Survey of Finland, Special Paper 3: 23-38.

Dreimanis, A (1976): Tills, their origin and properties. In R.F. Legget (ed.), Glacial Till. The Royal Society of Canada Special Publication 12: 11-49.

Gray, J.G. (1938): East Half, Fort Fraser Map Area, British Columbia, Geological Survey of Canada Paper 38-14, 1938.

Harington, C.R., Tipper, H.W. and Mott, R.J. (1974): Mammoth from Babine Lake, British Columbia; Canadian Journal of Earth Sciences, 11: 285-303.

Hirvas, H and Nenonen, K. (1990): Field Methods for Field Glacial indicator tracing in Glacial Indicator Tracing. eds: R. Kujansuu and M. Saarnisto, Roterdam: Balkema, pp. 217-247.

Huntley, D.H., Stumpf, A., Levson, V.M. and Broster, B.E. (1996): Babine Porphyry Belt Project: Quaternary Geology and Regional Till Geochemistry Sampling in the Old Fort Mountain (93M/01) and Fulton Lake (93L/16) Map Areas, British Columbia; in Geological Fieldwork 1995, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1996-1, pages 45-53.

Jackson, L.E. and Clague, J.J. (1991) The Cordilleran Ice Sheet; 150 years of Exploration, Geographie Physique et Quaternaire. 45: 269-280.

John, M.K., Van Laerhoven, C.J., Osborne, V.E. and Cotic, I. (1975): Mercury in soils of British Columbia, a mercuriferous region. Water, Air and Soil Pollution 5: 213-220.

Kerr, D. E. (1991): Surficial geology of the Mount Milligan area, NTS 93N/1A, 93O/4A; British Columbia Ministry of Energy, Mines and Petroleum Resources, Open File 1991-7.

Khodakovskii, I.L., Popova, M. Ya., and Ozerva, N.A. (1977) Forms of Mercury migration in hydrothermal solutions. In: Geochemical Processes of Migration of Metallic Elements, Khitarov, N.I., Ed., pp 86-118. Moscow: Nauka

Lawson, D.E. (1979): Sedimentological analysis of the western terminus region of the Mantanuska Glacier, Alaska. Cold Region Research and Engineering Laboratory Report 79-9.

Levson, V.M., Stumpf, A.J., Meldrum, D.G., O'Brien, E.K., and Broster, B.E. (1997): Quaternary geology and Ice Flow History of the Babine Lake Region: (NTS 93 L/16, M/1, M/8); in Geological Fieldwork 1996, Lefebure, D.V., McMillan, W.J. and McArthur, J.G, Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1997-1, 427-438.

Levson, V.M. and Giles, T.R. (1995): Glacial Dispersal Patterns of Mineralized Bedrock with Examples from the Nechako Plateau, Central British Columbia; in Drift Exploration, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-2, pages 67-76.

Levson, V.M., Giles, T.R., Cook, S.J. and Jackaman, W. (1994): Till Geochemistry of the Fawnie Creek Area (93F/03); B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1994-18, 34 pages with appendices.

Miller, J.K. (1984) Model for clastic indicator trains in Till. Prospecting in Areas of Glaciated Terrain - 1984. Institution of Mining and Metallurgy, London: 69-77.

Nesbitt, B.E., Muehlenbachs, K, and Muowchick, J.B. (1989) Genetic Implications of Stable Isotope Characteristics of Mesothermal Au Deposits and Related Sb and Hg Deposits in the Canadian Cordillera in Economic Geology, 84: 1489-1506.

O'Brien, E.K. Broster, B.E. Giles, T.R. and Levson, V.M. (1995): Till Geochemical Sampling: CH, Blackwater-Davidson, and Uduk Lake Properties, British Columbia: Report of Activities; in Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-1, pages 207-211.

Pessl, F. and Fedrick, J.E. (1981): Sediment source for melt-water deposits. Annals of Glaciology 2; pp 92-96.

Plouffe, A. (1995a): Geochemistry, lithology, mineralogy and visible gold content of the till in the Manson River and Fort Fraser map areas, central British Columbia (93K, 93N), Geological Survey of Canada, Open File 3194, 119 p.

Plouffe, A. (1995b): Drift Prospecting Sampling Techniques in Drift Exploration in the Canadian Cordillera, (eds.) Bobrowsky, P.T., Sibbick, S.J., Newell, J.M., and Matysek, P.F., British Columbia Ministry of Energy Mines and Petroleum Resources, Paper 1995-2, p. 43-52.

Plouffe, A. (1994a): Surficial geology, Chuchi Lake, British Columbia, (93N/SE); Geological Survey of Canada, Open File 2842, scale 1:100 000.

Plouffe, A. (1994b): Surficial geology, Tezzeron Lake, British Columbia (93K/NE); Geological Survey of Canada, Open File 2846, scale 1:100 000.

Plouffe, A. (1992): Quaternary stratigraphy and history of central British Columbia; in Current Research, Part A, Geological Survey of Canada, Paper 92-1A, p. 189-193.

Plouffe, A. (1991): Preliminary study of the Quaternary geology of the northern interior of British Columbia; in Current Research, Part A, Geological Survey of Canada, Paper 91-1A, p. 7-13.

Plouffe, A. and Ballantyne, S.B. (1993): Regional Till Geochemistry, Manson River and Fort Fraser Area, British Columbia (93K, 93N), Silt Plus Clay and Clay Size Fractions; Geological Survey of Canada, Open File 2593, 210 pages.

Proudfoot, D.N., Bobrowsky, P.T. and Meldrum, D.G. (1995): Drift Exploration potential maps derived from terrain geology maps in Drift Exploration in the Canadian Cordillera, (eds.) Bobrowsky, P.T., Sibbick, S.J., Newell, J.M., and Matysek, P.F., British Columbia Ministry of Energy Mines and Petroleum Resources, Paper 1995-2, p. 23-31.

Rutter, N.W. (1976): Multiple Glaciation in the Canadian Rocky Mountains with special reference on northeastern British Columbia. In: Mahaney, W.C. (ed.), Quaternary Stratigraphy of North America, pp. 409-440. Dowden, Hutchinson and Ross, Stroudsburg.

Rutter, N.W. (1977): Multiple Glaciation in the area of Williston Lake, British Columbia. Geological Survey of Canada, Bulletin 273, 31 p.

Rutter, N.W. (1980): Late Pleistocene history of the western Canadian ice-free corridor. Canadian Journal of Anthropology, 1: 49-56.

Rutter, N.W. (1984): Pleistocene history of the western Canadian ice-free corridor. In: Fulton, R.J. (ed.), Quaternary Stratigraphy of Canada - A Canadian contribution to IGCP Project 24. Geological Survey of Canada, Paper 84-10, pp. 49-56.

Ryder, J. M. (1994): Stuart-Takla watersheds: Terrain and sediment sources; Internal report, British Columbia Ministry of Forests, Prince George Forest Region, 26 p.

Ryder, J. M. (1993): Terrain Analysis for the Wolf-Capoose and AOK-Moondust Areas; Internal report - Mineral Deposit Research Unit, University of British Columbia, 24 p.

Shaw, J. (1985) Subglacial and ice marginal environments. In G.M. Ashley, J. Shaw, and H.D. Smith (eds.), Glacial Sedimentary Environments. SEPM Short Course 16. Tulsa: Society of Economic Paleontologists and Mineralogists: 7-84.

Siegel, S. M., Siegel, B. Z., Lipp, C., Kruckeberg, A., Towers, G. H. N. and Warren, H. (1985): Indicator plant-soil mercury patterns in a mercury-rich mining area of British Columbia; Water, Air, and Soil Pollution, 25: 73-85.

Sorokin, V. I. (1973) Solubility of Mercury in Water in the Temperature Interval of 300^0 C to 500^0 C and pressures of 500 to 1,000 atm. Akad. Nauk SSSR Dokldy. Chem. Sect. 213: 852-855.

Stevenson, J. S. (1940) Mercury Deposits in British Columbia, Bulletin No. 5. British Columbia Department of Mines.

Stumpf, A.J., Broster, B.E. and Levson, V.M. (1997): Evaluating the Use of Till Geochemistry to Define Buried Mineral Targets: A Case Study from the Bell Mine Property, (93 L/16, M/1) West-Central British Columbia; in Geological Fieldwork 1996, Lefebure, D.V., McMillan, W.J. and McArthur, J.G, Editors, B.C. Ministry of Employment and Investment, Paper 1997-1, 439-456.

Stumpf, A., Huntley, D.H., Broster, B.E. and Levson, V.M. (1996): Babine Porphyry Belt Project: Detailed Drift Exploration Studies in the Old Fort Mountain (93M/01) and Fulton Lake (93L/16) Map Areas, British Columbia; in Geological Fieldwork 1995, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1996-1, pages 37-44.

Sutherland Brown, A. (1967): Investigation of mercury dispersion haloes around mineral deposits in central British Columbia; in Proceedings, Symposium on Geochemical Prospecting, Geological Survey of Canada, Paper 66-54, p. 72-83.

Tilas, D. (1740): Tankar om malmletande I anledning af lose grastenar. Kongl. Svenska Vetenskaps-Akademiens Handlingar. I. 1939-1740: 190-193.

Tipper, H. W. (1971): Multiple glaciation in central British Columbia; Canadian Journal of Earth Sciences, 8: 743-752.

Warren, H. V., Horsky, S. J. and Lipp, C. (1984): Biogeochemistry indicates mineral anomalies along southern extensions of the Pinchi Fault; Western Miner, 57: 31-34.

Warren, H. V., Towers, G. H. N., Horsky, S. J., Kruckeberg, A. and Lipp, C. (1983): Mineral indications along the Pinchi Fault; Western Miner, 56: 25 - 28.

Warren, H. V., Delavault, R.E., and Barakso, J. (1966): Some observations on the geochemistry of mercury as applied to prospecting. Economic Geology 61: 1010-1028.

CHAPTER 4 - FAULT ORIENTATION AND ANOMALOUS MERCURY CONCENTRATIONS IN STREAM SEDIMENTS

INTRODUCTION

General

In this chapter, the relationship between fault orientations and mercury concentrations in stream sediment samples are statistically analyzed using a Geographic Information System (GIS). The orientation of mapped faults running through stream sediment catchment basins are first delineated. The concentration of mercury associated with each catchment basin is compared with the orientation of the fault segments. Statistical analysis on this data demonstrates a significant relationship between fault orientation and mercury concentration. The study area is located at the northern end of Vancouver Island which is located on the western edge of North America between latitudes 48^0 and 51^0, and between longitudes 123^0 and 129^0. It is a large island some 450 km long and 125 km wide, with an area of approximately 32,000 km^2 (Figure 4.1). The study area, selected to minimize the possibility of any anthropogenic enrichment of mercury, is a non - industrialized and sparsely populated.

A regional stream sediment geochemical survey was conducted on Vancouver Island in 1988 (Matysek *et al.*, 1989) and 2746 sites (1657 moss mats and 1089 stream sediments) were sampled at an average density of 1 per 10.9 km^2 (Gravel and Matysek, 1989). Primary and secondary streams with catchment basins of less than 10 km^2 were sampled. These sediments were analysed for 21 elements, including mercury, by cold vapour Atomic Absorption Spectroscopy (Gravel and Matysek, 1989; Appendix 4.1).

High rainfall in the study region flushes many streams of all material finer than medium sands. For this reason, moss mats were sampled instead of the customary stream sediments at most sites. Analytical results for 100 paired moss mat and stream sediment samples showed no significant differences in mercury concentration (Matysek and Day,

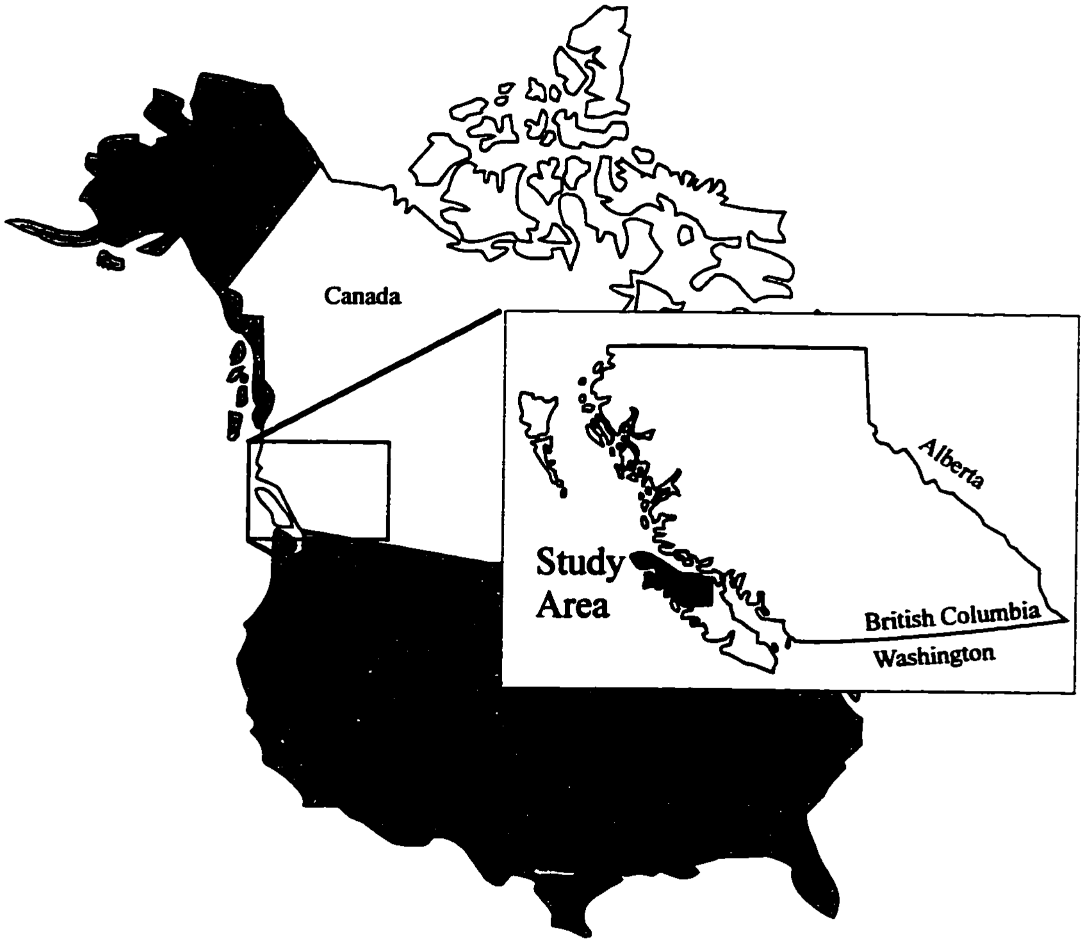


Fig. 4-1. Location of study area.

1988). To eliminate any possibility of data bias, only moss mat samples are used in this study. In this paper, the sediments taken from the moss mat samples will be refered to as stream sediments.

Results show a distinct pattern of elevated mercury concentrations along much of the western coast of the island. These high values are concentrated in the northern portion of the island in NTS map areas 92L and 102I. These high concentrations were investigated by Sibbick and Laurus (1995) who concluded that they were likely due to mercury derived from the numerous northwesterly and northeasterly trending faults in the area.

Based on this observation, this study was initiated to investigate the apparent spatial correlation between mercury concentrations found in stream sediments and the orientation of faults on northern Vancouver Island.

Objective

The purpose of this chapter is to evaluate the statistical relationship between mercury concentrations and the orientations of faults on northern Vancouver Island. The implications of this study are numerous. Most importantly, it stresses the need for further study of the natural distribution of deleterious metals in the environment. This is especially important for drafting legislation that determines if a site should be considered contaminated.

Description of the study area

Muller *et al.* (1974) describe the bedrock geology of the study area as dominatly by Jurassic and Upper Triassic Island Arc volcanics and minor associated sediments, with lesser amounts of Cretaceous sediments (Figure 4.2). These lithologies are intruded by granitic plutons. Nixon *et al.* (1993a,b, 1994), notes that the Tertiary, Alert Bay volcanics are more wide spread than previously mapped.

Yorath and Nasmith (1995) divide northern Vancouver Island into four physiographic regions: the Nahwhitti Plateau, the Suquash Basin, the North Vancouver Island Ranges and the West Vancouver Island Fiordland. The Nahwhitti Plateau is located at the northern tip of the island. This area is characterized by gently rolling hills mostly under 600 m elevation. The Suquash Basin is located in the Port Hardy area, it is characterized by gently rolling hills and level ground. Most of this area is under 300 m elevation. The North Vancouver Island Ranges form the central core of the island. They are characterized by rugged mountains dissected by deep valleys. The tallest peak in the study area is located within this region; Victoria Peak is the highest point in the map area at 2164 m elevation. The peaks in this region often have snow caps that last well into the summer. West Vancouver Island Fiordland is located on the westernmost edge of the study area. Moderately high mountains are dissected by steep-sided, deep inlets. These inlets generally cut into the mountains perpendicular to the coastline. Some of these inlets are 300 m deep (Yorath and Nasmith, 1995).

Northern Vancouver Island receives on the order of 300 cm of precipitation a year. The climate is relatively mild. Summer temperatures rarely exceed 30^0 C and winter temperatures rarely fall below freezing. The soil derived from the volcanic rock is quite fertile. The result of these factors is luxuriant, rain-forest like vegetation for most of the study area, except for the regions above tree-line.

PREVIOUS WORK

Previous Work (1885 - 1975)

G.M. Dawson (1887) with the Geological Survey of Canada was the first to investigate northern Vancouver Island. He investigated to Vancouver Island in 1885, in a schooner and surveyed parts of the coastline and adjacent islands. He noted the presence of coal-bearing beds in the Quatsino Sound area and published records of coal exploration holes. Furthermore, he mapped Vancouver Group volcanic rocks along most of the coast. Alunite and pyrophyllite-bearing rocks of Kyuquot Sound were examined by Clapp (1912). Dolmage (1919, 1921) performed fieldwork between Quatsino Sound and Barkley Sound in 1918 and 1920. He introduced the name "Quatsino Formation". Gunning (1930, 1932) visited the Quatsino and Nimpkish areas in 1929 and 1931, and the Zebalos region in 1932 (Gunning, 1933). His work contributed to the understanding of the stratigraphy of the Vancouver Group. Gunning was responsible for naming the Karmutsen Formation and Bonanza Group. Lastly, he worked on classifying and describing the mineral deposits of northern Vancouver Island. Hoadley (1953) continued the mapping of Zeballos map-area from 1947-1950. Jeletzky (1950, 1954a,b) investigated the coastline from Esperanza Inlet north into Quatsino Sound in the years 1949 to 1954. His extensive fossil collections established the basis for the Mesozoic stratigraphy in the area. Jeletzky has published extensively on the Mesozoic and Tertiary stratigraphy of the island (1969, 1970 a, b, 1973 a, b).

Northcote (1969, 1971) investigated a mineralized belt from Rupert Arm to west of Cape Scott, and studied the Island Copper deposit in detail. Carlisle of the University of California, and his students contributed important information on the Paleozoic and Triassic Formations of the area (Carlisle, 1963, 1972a, b; Carlisle and Susuki, 1965, Surdham, 1968).

Carson (1969, 1973; Carson *et al.*, 1971) completed a Ph.D. on the mineral deposits and granitic rocks of Vancouver Island. Carson also contributed to other Geological Survey of Canada papers (Muller and Carson, 1969).

Previous Work (1976 - 1996)

In 1971 Island Copper, a large copper mine on northern Vancouver Island began production (Yorath and Nasmith, 1995). When reserves at the mine ran low, the British Columbia Geological Survey was dispatched to promote exploration in the area in hopes of discovering another 'Island Copper'. Bedrock mapping was performed at a 1:50,000 scale by Massey and Melville, (1991) in the Quatsino Sound Area. Nixon et al. 1993, 1994, 1995 conducted mapping in the Mahatta Creek, Quatsino-Port McNeill, Quatsino - San Josef map areas respectively. This work refined Muller et al, (1974) in two ways;

first by mapping at a larger scale (1:50,000) than Muller, and secondly increased road access provided by logging activityin the area. Twenty years of mechanized logging in the area provided a plethora of new clear cuts and road networks. Which provided a great number of new rock outcroppings. Archibald et al., (1995) and Panteleyev, et al., (1995) added to the understanding of the ages of volcanic rocks and mineralization in the area respectively. Panteleyev and Koyanagi, (1993 and 1994), studied the advanced argillic alteration in Bonanza Volcanic rocks in the area, trying to uncover the chemistry of the solutions responsible for the alteration associated with the copper porphyry systems in the study area. In somewhat related studies Koyanagi and Panteleyev (1993 and 1994): measured the pH of the streams in the Mount McIntosh and Pemberton Hills areas. Panteleyev, et al, (1996) examined how this technique could be applied in other areas as a tool for exploration.

Another tool for exploration that was introduced into the area was drift prospecting. By sampling the glacial till and having it analysed for its content metals and other pathfinder elements, areas with anomalous concentrations of metals could be found. By understanding the glacial history of the area, especially the ice flow direction, the areas of elevated metals in till could be traced back to their bedrock source. A number of these studies were focused on northern Vancouver Island: Kerr and Sibbick (1992); Kerr, et al. (1992); Meldrum and Bobrowsky (1994a,b); Bobrowsky, et al., (1994a); Huntley and Bobrowsky (1995a, c); Bobrowsky et al., (1995); and Bobrowsky and Sibbick (1996).

The surficial sediments of the area has been studied, primarily by two agencies, the B.C. Ministry of Energy, Mines and Petroleum Resources and the B.C. Ministry of the Environment. The environment ministry performed terrain mapping at 1:50,000 scale that covers the entire area (see Bobrowsky et al., 1992 for a list of authors). Terrain mapping closely resembles surficial geology mapping but has no chronological order implied. Howes (1981a, b and 1983) studied the late Quaternary sediments, geomorphic history and geological hazards of northern Vancouver Island.

Surficial geological mapping was carried out in the areas underlain by rocks similar to those underlying the Island Copper deposit. This work was carried out by Bobrowsky and Meldrum (1994b, c): in the Port McNeill and Alice Lake areas; Huntley and Bobrowsky (1995b) in the Mahatta Creek Area; and by Kerr, (1992) in the Quatsino area. This mapping was performed primarily to understand the areal extent of materials appropriate for till sampling.

C. Stream sediment sampling

Stream sediment sampling studies within the study area include the regional sampling program conducted by Matysek et al. (1989). Sibbick (1994) used a GIS to overlay bedrock geology onto the catchment basins used in this study. Further studies by Sibbick and Laurus (1995) spurred this present study by introducing the apparent relationship between fault orientations and the level of mercury found in stream sediments.

GEOLOGY

A. Bedrock Geology

The map-area is underlain by the primarily volcanic Vancouver Group rocks located on the north eastern side of the map-area and Bonanza Group rocks located primarily on the south west side of the map-area . The Vancouver Group rocks consist of a basal Middle Triassic sediment-sill unit, a Triassic basaltic volcanics of the Karmutsen Formation, and the Upper Triassic carbonate, pelitic and volcanoclastic sediments of the Quatsino and Parson Bay formations. The Bonanza Group is comprised of a Lower Jurassic sequence of basaltic effusive and pyroclastic volcanics with minor intercalated sediments and the Lower Jurassic limestones of the Harbledown Formation.

The Vancouver Group is intruded by large and small bodies of Middle Jurassic Island intrusions. A Lower Cretaceous clastic wedge unconformably overlies the Vancouver

Group on the northwest edge of the island (Muller et al., 1974). The two oldest units in the area are the Sicker Group with Pennsylvanian and (?) Permian limestones and argillite, and probably the West coast Gneiss Complex of Brooks Peninsula (Muller et al., 1974). The youngest rocks in the area are the late Tertiary volcanic rocks of the Port McNeill area (Nixon et al., 1993a, b).

The region may be subdivided into several large structural blocks, separated mainly by important near vertical faults. These blocks are divided by the Brooks Fault Zone into southeastern and northwestern groups. The southeastern group contains the, White River block, Victoria Arch, Nimpkish block, Karmutsen Block, Kyuquot block and Kyuquot Swell. The northwestern group is composed of Nahwitti block, Quatsino block, Cape Scott block, and Brooks Peninsula block. The Suquash Basin lies peripheral to these blocks on the northeast. Finally, the Pacific Rim block forms the continental slope on the southwest (Muller et al., 1974).

B. Faults

Steep faults are the dominant structural discontinuities. These zones of shattered rock often wear down, and form large valleys and thus are obscured by surficial deposits and water. The best exposure of shatter zones are present along the west coast between Kyukuot and Quatsino Sound. Most of the faults in the area run approximately parallel to the coastline with steep northeast dips. Muller et al. (1974) was not been possible to determine a direction of movement in these complexly faulted rocks. However, the northerly faults are within the Karmutsen rocks and have right lateral separation, whereas, the westerly faults, predominantly in the granitic rocks show mostly left lateral separation.

C. Surficial Geology

Detailed work by Fyles (1963) and Halstead (1966, 1968) in Southern Vancouver Island has established the presence of two glacial tills on the east coast of Vancouver Island, separated by marine and fluvial Quadra Sediments, ranging in age from 25,000 to 36,000 years. The younger Vashon Till is thought to represent the classical Wisconsin Glaciation in the region (Fyles 1963). Kerr and Sibbick (1992) supported the two till hypothesis. During the climax of that episode, probably about 15,000 years ago (Armstrong et al., 1965), most of Vancouver Island was covered by an ice sheet, continuos with that of the mainland and flowing southward across the island (Muller et al., 1974). This notion is backed up by exotic granitic clasts found in till by Bobrowsky and Meldrum (1994).

METHODS

The method used in this chapter was relatively straightforward. Stream sediment sample data set was available in point form (Matysek *et al.,* 1989). The catchment basin for each sample was delineated and digitized. This catchment basin was then overlain onto the map containing the surface traces of the faults in the study area. Each fault segment was assigned the mercury concentration of the sample site (i.e. catchment basin). From this point a data base was produced that listed each segment of fault along with its orientation and the concentration of mercury associated with the catchment basin. This data base was then exported into a statistics package for further analysis (see Results).

A. Catchment Basin Delineation

Catchment basins for 912 stream sediment samples were delineated (Figure 4.3; Appendix 4.2). The stream sediment sample points were first plotted on the mylar

1:50,000 scale topography map with 100 foot (~30m) contours. The areas that would drain into each sample site were determined by a geologist. The catchment basins drawn on the mylar were digitized within AutoCAD and brought into a GIS. Each catchment basin was then assigned the same identification number as the sample associated with it. In this way, the geochemical results for the sample site could be displayed and analysed as an area, as opposed to a point. For this study the catchment basin was given the mercury value associated with the stream sediment sample (Figure 4.4).

B. Overlay on Fault Map

A 1:250,000 digital map of the bedrock geology of northern Vancouver Island (Massey et al, 1994) was brought into the GIS. The catchment basin map was then overlain onto this map. Where the fault lines intersected the catchment basin lines, the lines were split (Figure 4.5). The problem of different scales of the two maps is not too problematic. Most of the 1:250,000 bedrock geology map was digitized at 1:50,000 scale (Massey, personal comm., 1996), however, the difference in accuracy of the two maps should be noted.

C. Mercury concentration transfer from basin to fault segment

Each fault segment was then assigned the mercury value associated with the intersected catchment basin (Figure 4.6; Appendix 4.3). Any fault segments lying outside of the catchment basins were eliminated from this study. If more than one fault passed through the basin, each segment was assigned the mercury value for the basin. The orientation of each fault segment was determined. A database that consists of an entry for each fault segment was produced along with its geographic location, angle of rotation, and the appropriate concentration of mercury.

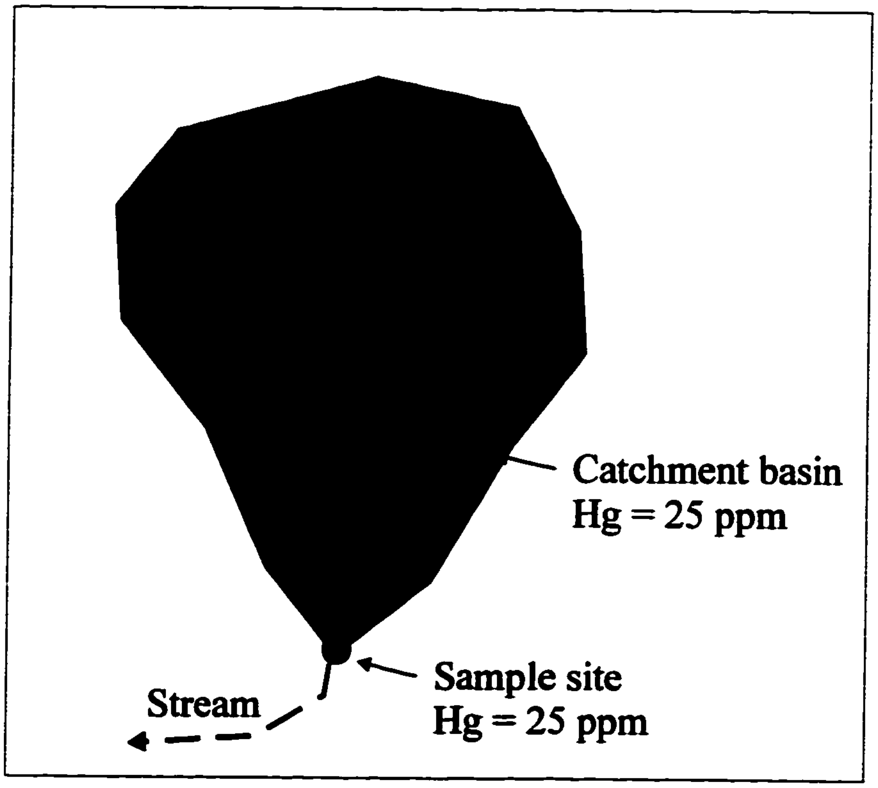


Fig. 4-4. Figure showing the catchment basin being given the value associated with the sample site.

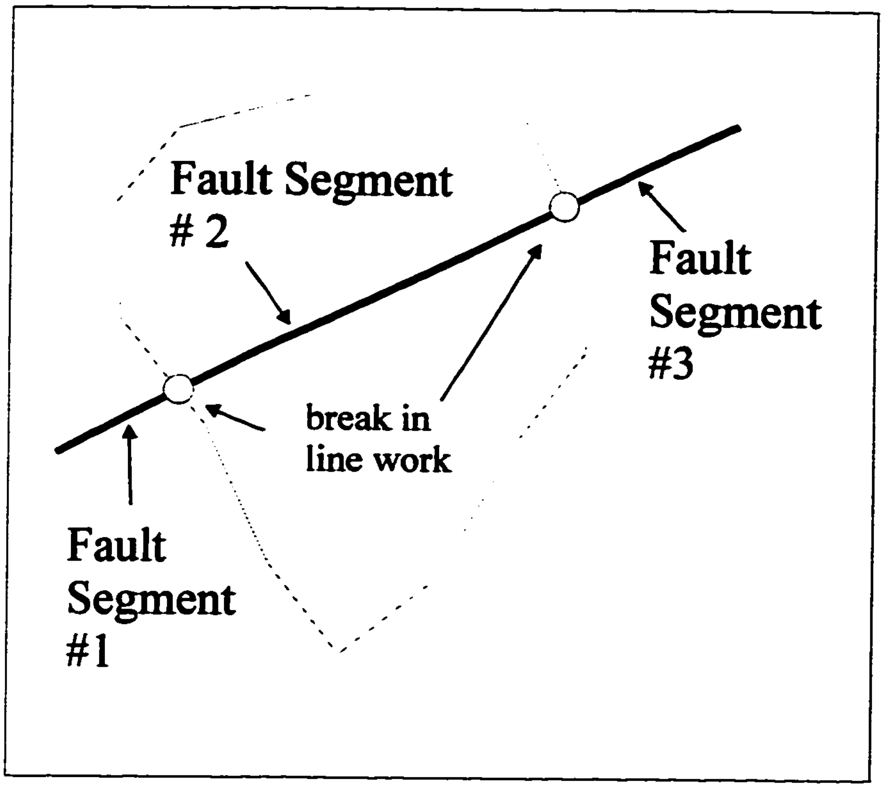


Fig. 4-5. Figure showing the fault segments being broken by the catchment basin line work. The orientation of each fault segment within the catchment basin is determined and stored within the GIS.

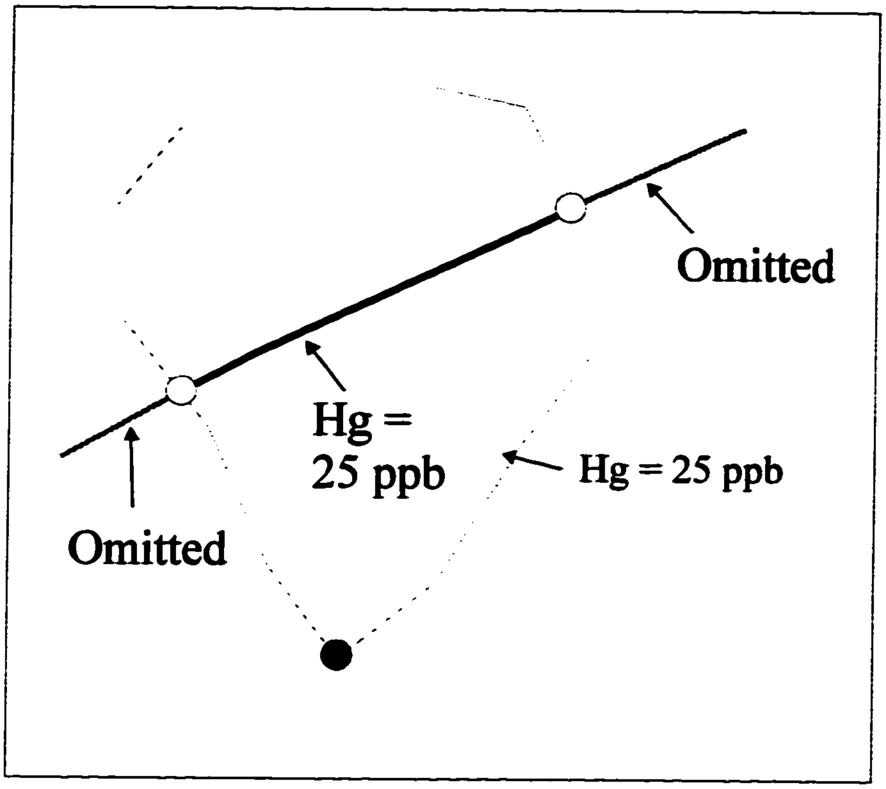


Fig. 4-6. Figure showing the fault segments inside the catchment basin being assigned the mercury concentration associated with the catchment basin. All fault segments outside the catchment basins were omitted from this study.

RESULTS

Mercury concentrations on northern Vancouver Island associated with the faults varied from 30 ppb to 6,200 ppb with a mean of 276 ppb (Figure 4.7). Table 4.1 lists some standard statistics for the mercury concentrations associated with all catchment basins on northern Vancouver Island.

Populations of faults were picked from inflection points on probability plots (Figure 4.8). A program developed at the University of British Colmbia called PROB-PLOT was used to determine these inflection points. This is a sophisticated statistical package that is used by geochemists to delineate population clusters. Four populations of fault orientations are selected, 0-25 degrees, 25-95 degrees, 95-155 degrees, and 155-180 degrees. Figure 4.9 shows the proportions of different orientations of fault segments that have passed through catchment basins. Note that the number of faults within population one is quite small. The variability of stream sediment data is quite large. These two factors cause the variation within any population to be quite large, this is especially true for population one. The statistical validity of this selection may be questionable, however, in an attempt to remain impartial to the data, the author decided to use the populations that were picked using PROB-PLOT. Orientations of fault segments were measured from 0^0 - 180^0 due to a software convention. To represent the data in a circular manner, the data were simply repeated, this gives a mirror image effect.

Table 4.1 Summary statistics for fault segments

n	1138
Min	30 ppb
Mean	320 ppb
Max	20,000 ppb
Stand. Dev.	712

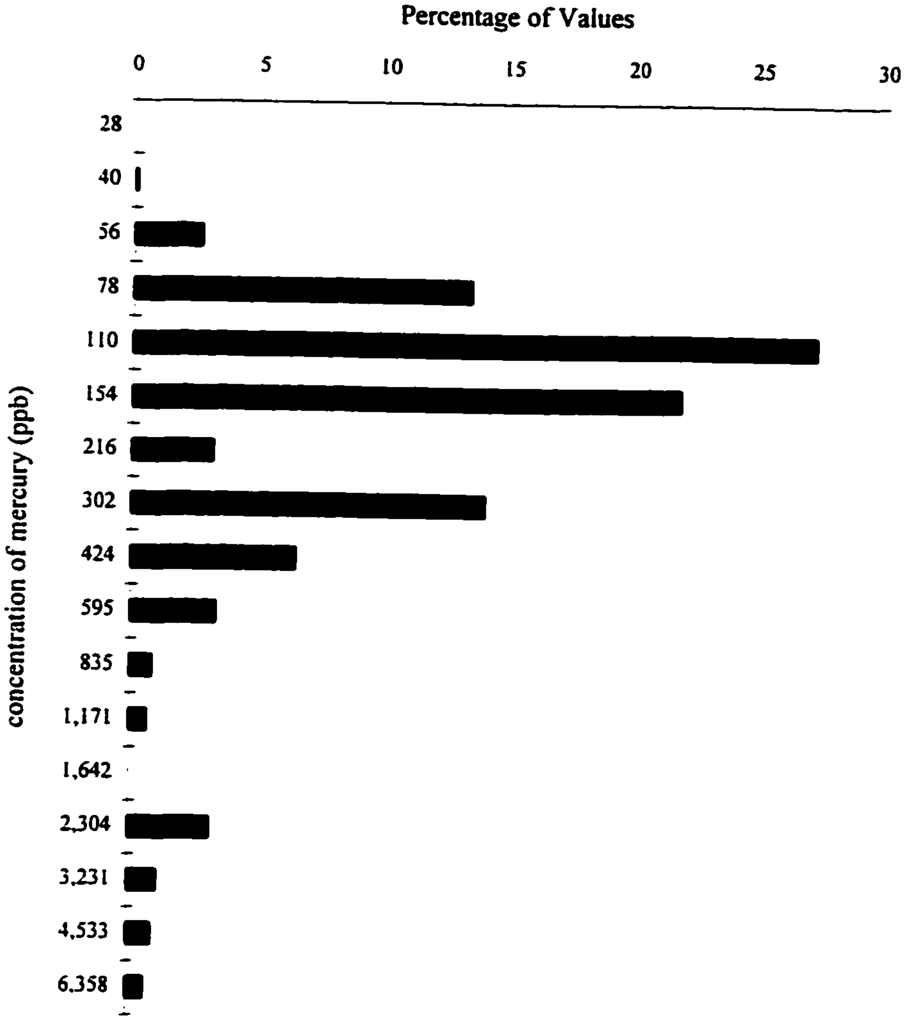


Fig. 4.7

Bar chart showing the distribution of Mercury in the study area

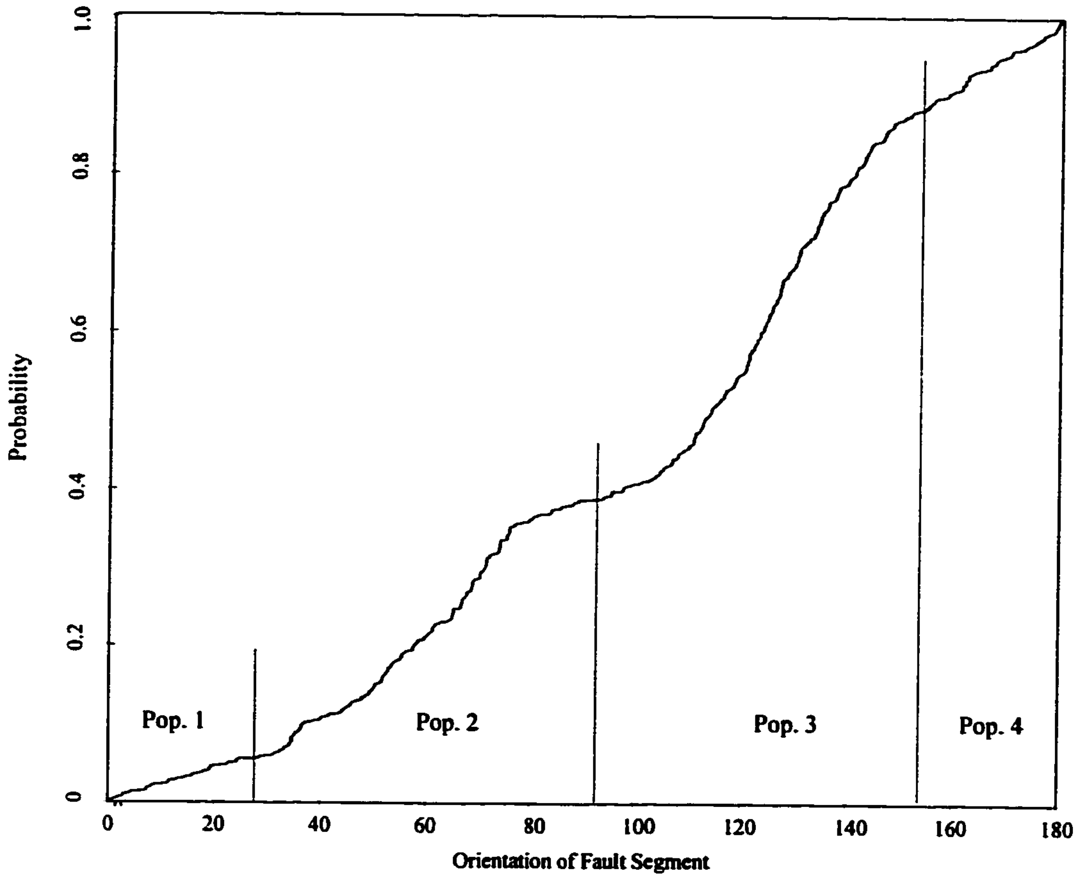


Fig. 4-8. Probability plot showing populations. The populations were picked using the progam PROB-PLOT, which uses maximum liklihood optimization proceedures.

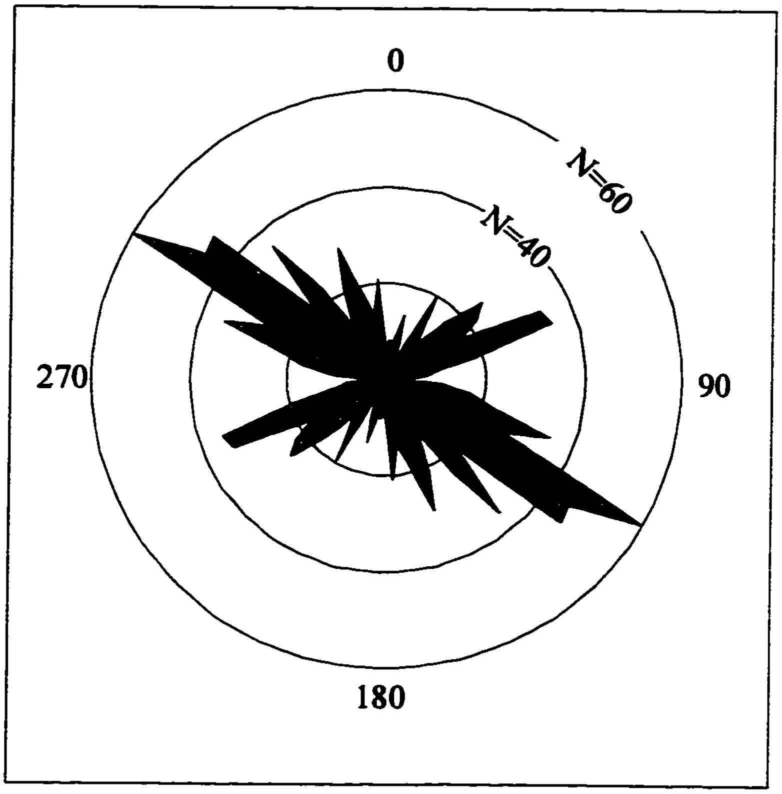


Fig. 4-9. Rose diagram showing the distribution of fault orientations (5 degree increments)

A second rose diagram was produced showing the mean mercury concentrations for each of the populations (Figure 4.10). A box and whisker plot (Figure 4.11) shows the spread of values within each group. Summary statistics for each population are shown in Table 4.2.

Table 4.2. Summary statistics for each population.

Pop.	n	Mean (ppb)	Min. (ppb)	Max. (ppb)	Standard Deviation
1	64	453.8	60	6200	579
2	381	228.6	60	2000	157
3	568	271.9	40	3600	269
4	125	343.5	30	6200	373

There is a correlation between mercury concentrations and fault orientations. The average concentration of mercury associated with faults of Population 1 is approximately twice that of faults the average concentration of mercury associated with faults in populations 2 and 3 (Table 4.2). To statistically prove that the populations are significantly different ANOVA, f-test, and t-tests were conducted, all at the 95% confidence limit on log-normal mercury concentrations. Each test concluded that there is a significant difference between the populations (Tables 4.3, 4.4, 4.5). The ANOVA test shows that at least one of the means is statistically different than the others (Table 4.3). The F-test shows that nearly all the variances between samples are unlikely to have come from the same population (Table 4.4). The t-test shows that the remaining pairs that passed the F-test are unlikely to have means that have come from the same population (Table 4.5).

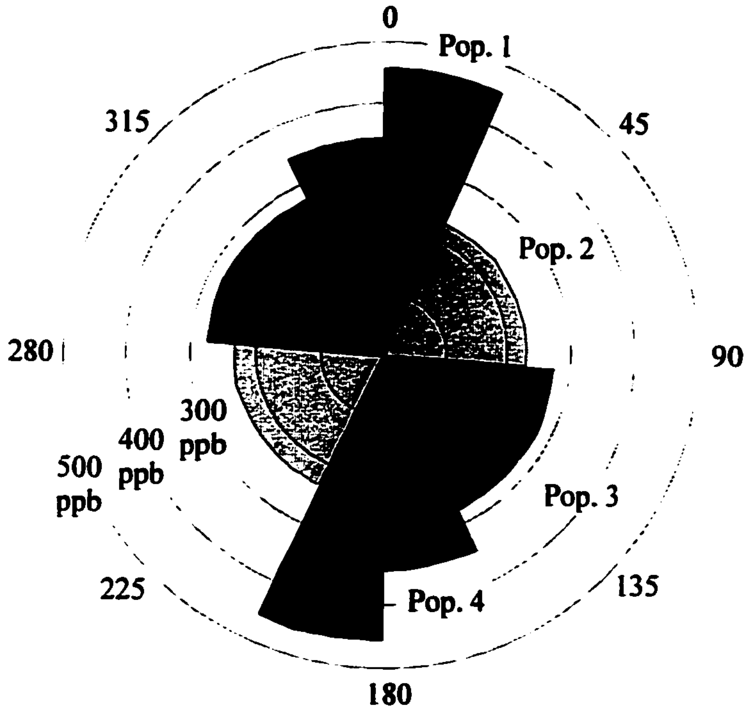


Fig. 4-10. Rose diagram showing the mean concentration of mercury of each population. The orientation of the fault segments were merged with the mercury concentration information to produce a file with both fault segment orientation and mercury concentration.

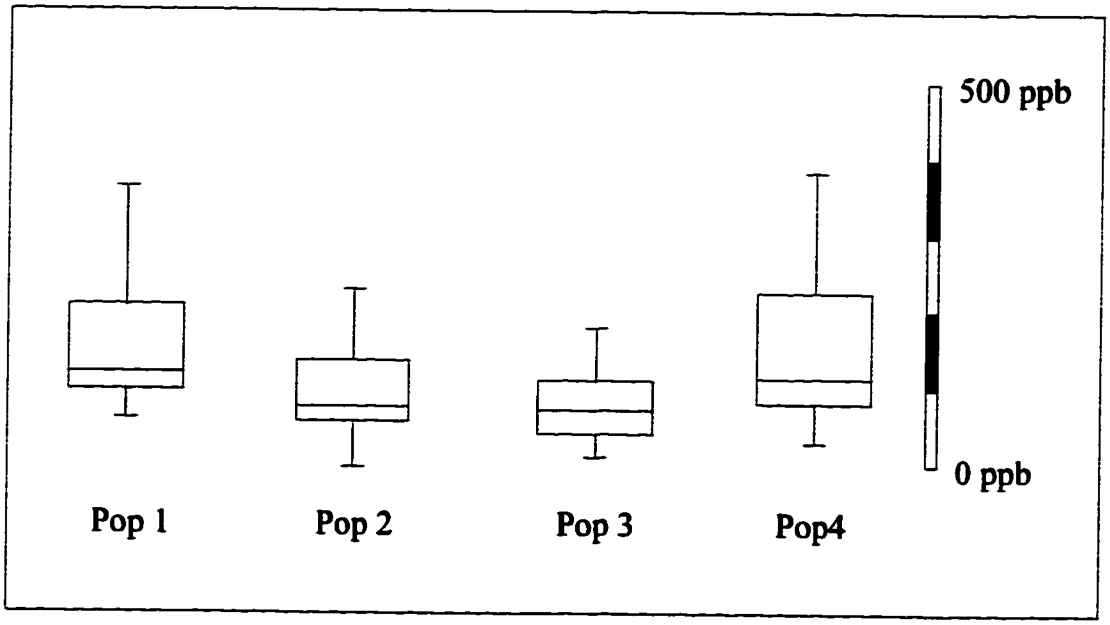


Fig. 4-11. Box and whisker plot of mercury concentrations of the four populations

Table 4.3. ANOVA test (95% confidence)

	Sum	d.f.	Mean	F-test
SSa	1082	3	360.9	**-457**
SSw	-895	1134	-0.8	
SSt	187	1137		

d.f. = degrees of freedom, SSa = sum of squares, SSw = sum of squares within, SSt = sum of squares total

bold type indicates significant difference: normal type indicates no significant difference

Table 4.4. F-test (95% confidence level)

	Pop. 2	Pop. 3	Pop. 4
Pop. 1	**1.54**	**21.17**	1.42
Pop. 2	**32.67**	1.08	
Pop. 3	**30.12**		

bold type indicates significant difference: normal type indicates no significant difference

Table 4.5. One tailed t-test (95% confidence level)

	Pop. 2	Pop. 3	Pop. 4
Pop. 1	0.58	0.30	**2.07**
Pop. 2	0.99	**2.61**	
Pop. 3	1.10		

bold type indicates significant difference: normal type indicates no significant difference

DISCUSSION

Mercury concentrations in stream sediments associated with faults trending north-north-east have higher mercury concentrations than do sediments from streams associated with other orientations of faults. The reason for this relationship is not well understood. The most likely explanation is that the hydrothermal fluids associated with the N-N-E trending faults were enriched in mercury. Other factors that could be considered in future studies of this area might include spatial associations with gold mineralization and bedrock geology.

A. Relationship between mercury and faults

Different materials on the surface of the earth contain different concentrations of mercury. The average amount of mercury in the crust of the earth is approximately 80 ppb (Jonasson, 1970). Bailey et al.(1973) tabulated the mean concentrations of mercury in common earth materials, such as: igneous rocks (5-100 ppb), sandstone (20-75 ppb), coal (10-1,000 ppb), shale (100-1,000 ppb) mercury ore (3,000,000+ ppb) (Bailey et al., 1970, Figure 4.12).

The most common way for mercury to be enriched to economic levels occurs by hydrothermal activity associated with fault zones and hot springs (Stevenson, 1940; Bailey, 1959; White, 1967; Dickson and Tunnel, 1968; Henderson, 1969; Sorokin, 1973; Khodakovskii et al., 1977; Studemeister, 1983; Nesbitt et al., 1989; and Peters, 1991). Furthermore, nearly all the mercury production in North America is associated with large fault zones (Armstrong, 1942; Bailey et al., 1970; Studemeister, 1983; and Sherlock, 1992).

The spatial association between fault zones and mercury deposits was understood prior to the 1940's (e.g. Stevenson, 1940). Furthermore, Bailey (1959) noted that the distribution of mercury deposits about the world is restricted to the volcanic and tectonic belts capable of generating the heated solutions that deposit mercury.

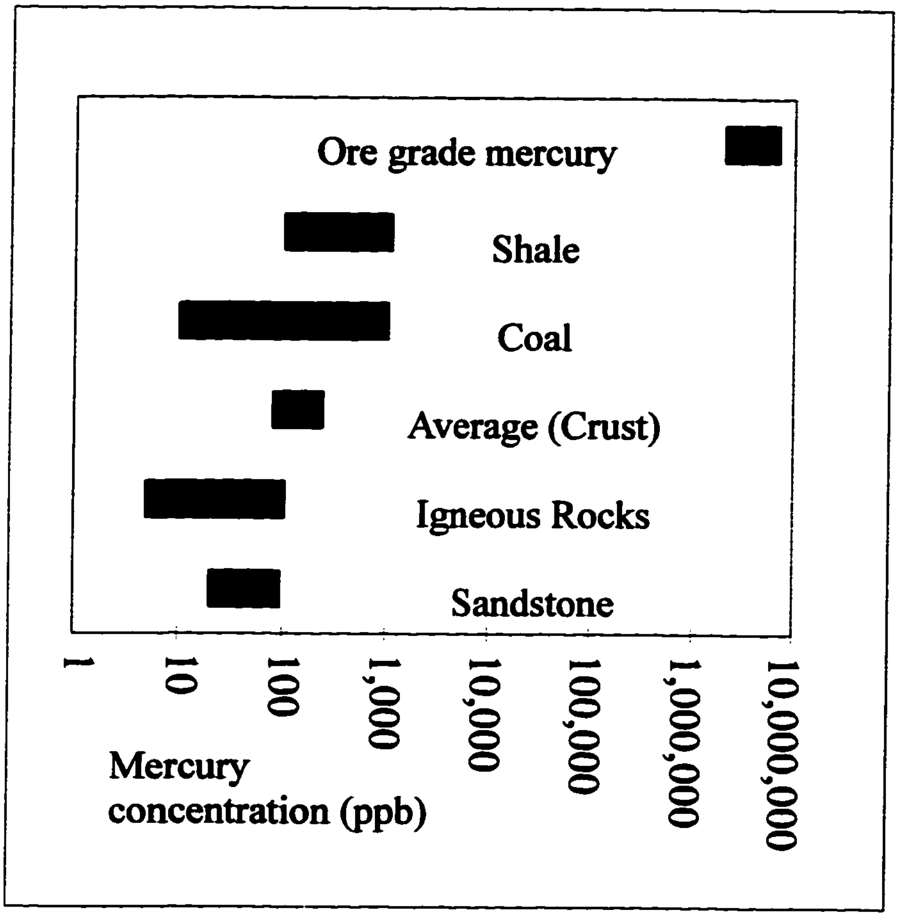


Fig. 4-12. Bar chart showing mercury concentrations of earth materials (note log scale).

Advances in experimental geochemistry have allowed researchers to accurately determine the temperatures and pressures at which mercury is transported by hydrothermal solutions. It is now widely accepted that the solubility of elemental mercury ranges from ~0.5 ppm at 100 ^{0}C to ~16 ppm at 200 ^{0}C to ~400 ppm at 300 ^{0}C (Sorokin, 1973, Khodakovskii et al., 1977; Nesbitt et al., 1989).

Most mercury is deposited relatively close to surface, between 1 and 7 km (Nesbitt et al., 1989). Bailey (1962) points out that all deposits (in the Coast Ranges) that can be accurately dated are Pliocene (5.2 Million Years) or younger. This is because areas associated with hot spring activity (i.e., mercury mineralization) are often uplifted and eroded quite quickly.

B. Possibility of mercury from anthropogenic sources

All reasonable sources of anthropogenic mercury were considered, communities, mining, local industrial sources, and distant industrial sources.

Communities:

There are eleven communities in the study area, all with populations of less than 6,000 persons (Stats Canada, 1996). It seems unlikely that these communities of this size could significantly affect mercury concentrations in the study area. Furthermore, the two largest communities are located on the eastern edge of the map area, down wind of the anomalous drainage basins.

Local industries:

There are four main industries in the area: mining, fishing, tourism, and logging (Stats, B.C., 1996). Denisiger (pers. commun., 1996) was unable to cite an instance of any mercury enrichment due to these activities in the area. Of these four industries, mining seemed to be the most likely to contribute mercury into the environment. As such, it was investigated thoroughly.

Mining:

Three hundred and fifty three mineral occurrences have been discovered within the study area. Only one has been documented to contain any mercury mineralogy. This site has not been developed or explored in any significant manner. No mercury or mercury related minerals have ever been mined in the area (Vanderpoll et al., 1989).

Placer gold mining can contribute mercury to the environment if conducted carelessly. Placer miners sometimes use native mercury to refine the gold ore. If a spill was to occur, stream sediments could become enriched in mercury. Only one placer mine has operated in the study area, Amos Creek (Vanderpoll et al., 1989). The area in which it was located, the southwestern coast of Brooks Peninsula, is not anomalous in mercury.

Remote industrial sources:

Mercury is a liquid at room temperature, and elemental mercury can exist as a gas. Therefore, mercury can be transported by wind currents. However, northern Vancouver Island is located on the westernmost edge of North America. Prevailing wind flow is from the west (Canadian Hydrographic Service, 1990). Therefore, the closest possible industrial source of airborne mercury is Japan or Russia (~6,000 km to the west). In a study of mercury transported by wind, Henderson and McMartin (1995) report marginal mercury enrichment in soils 40 km downwind of a smelter. However, 80 km downwind of the smelter, soils were found to contain background levels of mercury. Therefore, it seems very unlikely that a significant amount of mercury could travel 6,000 km.

C. Possibility of mercury from faults

Northern Vancouver Island has all of the features that are associated with the enrichment of mercury as described above.

Tectonics and young faults:

The presence of Tertiary age faults within the study area has been well established (Massey, 1994; Nixon et al., 1994). The present tectonic activity off the coast of

Vancouver Island is well understood, Vancouver Island rests above an active subduction zone (Rogers, 1983, 1988, 1992, 1994; Heaton and Hartzell, 1987; Mulder and Rogers, 1993; and Dragert et al., 1994).

Hydrothermal activity:

Volcanism is also well documented just inland of the study area. Part of the heat associated with this tectonic activity manifests itself, via hot springs. Only one hot springs (measured at 32^0 C) has been reported in the area (Coombs, personal communication, 1996) several are located less than 80 km to the south at Knight Inlet, Flores Island, and Hot Springs Cove. Blackwell and Steele (1992) have documented high heat flow in the rocks of northern Vancouver Island (60-70 mWm^2 compared to 30-40 mWm^2 on southern Vancouver Island) suggesting the potential for more undiscovered hot springs. Tertiary dike swarms dated at, 32.3 million years provide further evidence that there is high heat flow in the region (Nixon et al., 1994). Quaternary volcanoes are present to the east of the study area.

Nearby mercury deposits:

Several mercury deposits are known to occur along strike of the study area, on southern Vancouver Island (Vanderpoll et al., 1989). Stevenson (1940) describes one occurrence on the north shore of Barclay Sound (~200 km south east of the map-area). No production was reported from the site, but mercury globules were reported and samples contained up to 1.6% (16 million ppb) mercury.

Summary:

In summary; elevated mercury concentrations are associated with recent tectonic activity and are spatially associated with hot spring activity and fault zones. Northern Vancouver Island rests on an active subduction zone. Tertiary intrusive dyke swarms, and high crustal heat flow have been reported in the region. Hot spring activity occurs within and immediately to the south of the study area. Faults are present and have been mapped by several researchers (e.g. Muller et al., 1974; Nixon et al, 1994, 1995). Mercury deposits are located south of the study area (Stevenson, 1940).

CONCLUSIONS

Drainage basins that have north to northeasterly trending faults within them have significantly higher mercury concentrations in them than do drainage basins with other fault orientations. Four populations of faults were separated out, based on their orientations, 0-25^0, 25-95^0, 95-155^0 and 155-180^0. The mean mercury concentrations for these groups are, 454, 229, 272, and 344 ppb, respectively. Each population is significantly different (at a 95% confidence level).

There is a well known corelation between mercury enrichment and faults (e.g. Armstrong, 1942; Bailey et al., 1970; Studemeister, 1983; and Sherlock, 1992). Northern Vancouver Island is a remote non-indusrialized island on the west coast of North America. The chance of anthropogenic mercury enrichment is very small. Therefore, the evidence suggests that the anomalous mercury concentrations in the stream sediment samples are associated with natural variables, such as faulting.

The implications of this study are two fold. Firstly, mercury levels can vary significantly due to geological features such as faults. Secondly, geological factors should be considered during an environmental assessment of an area.

North Vancouver Island References

Archibald, D.A. and Nixon, G.T. (1995): ^{40}Ar/^{39}Ar Geochronometry of Igneous Rocks in the Quatsino - Port McNeill Map Area, Northern Vancouver Island (92L/12,11); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-1, pp 49-59.

Armstrong, J.E., Crandel, D.R., Easterbrook. D.J. and Noble, J.B. (1965): Late Pleistocene stratigraphy and chronology in southwestern British Columbia and northwestern Washington; Geological Society of America., Bulletin 72: 321-330.

Armstrong, J.E. (1942):Geology of the Pinchi Lake Mercury Belt, British Columbia, The Canadian Institute of Mining and Metallurgy, Transactions 45: 311-323.

Bailey, E.H. (1962):Mercury in the United States. United States Geological Survey Min. Res. Map 30., 8 pages.

Bailey, E.H. (1959):Resources, chapter 3 of Pennington, J.W., Mercury - a materials survey: United States Bureau of Mines Information Circular 7941, p. 11-27.

Bailey, E.H., Clark, A.L., and Smith, R.M. (1973):Mercury, Brobst, D. A., and Pratt, W.P. eds. in U.S. Geol. Surv. Prof. Paper 820, pp. 401-414.

Bailey, E.H., Blake, M.C., and Jones, D.L. (1970): On-land Mesozoic oceanic crust in California, in Geological Survey research 1970: U.S. Geol. Surv. Prof. Paper 700-C, pp. C70-C81.

Blackwell, D.D., and Steele, J.L. (1992):Geothermal Map of North America, Geological Society of America

Bobrowsky, P.T. and Sibbick, S.J. (1996): Till Geochemistry of Northern Vancouver Island Area (92L/5, 6W, 11W and 12); B.C. Ministry of Employment and Investment, Open File 1996-7.

Bobrowsky, P.T., Best, M., Dunn, C.E., Huntley, D.H., Lowe, C., Roberts, M., Seeman, D.A., and Sibbick, S.J.N. (1995): Integrated Drift Exploration Studies on Northern Vancouver Island (92L); *in* Geological Fieldwork, 1994, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-1, pp 23-33.

Bobrowsky, P.T. and Meldrum, D. (1994a): Preliminary Drift Exploration Studies, Northern Vancouver Island (92L/6, 92L/11); *in* Geological Fieldwork, 1993, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1994-1, pp 87-99.

Bobrowsky, P.T. and Meldrum, D.G. (1994b): Surficial Geology of the Port McNeill Area (NTS 92L/11); B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50 000, Open File 1994-4.

Bobrowsky, P.T. and Meldrum, D.G. (1994c): Surficial Geology of the Alice Lake Area (NTS 92L/6); B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50 000, Open File 1994-5.

Bobrowsky, P.T., Giles, T., and Jackaman, W. (1992): Surficial Geology Map Index of British Columbia; B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1992-13.

Canadian Hydrographic Service (1990):Sailing Directions, British Columbia Coast (South Portion) Vol. 1, 15th Edition, Department of Fisheries and Oceans, pp 47.

Carlisle, D. (1972a):Butte Inlet map-area, Vancouver Island, British Columbia; in Report of Activities, April to October, 1971, Geological Survey of Canada, Paper 1972-1A, pp. 21-23.

Carlisle, D. (1972b): Late Paleozoic to mid-Triassic sedimentary volcanic sequence of north eastern Vancouver Island; in Report of Activities, November, 1971 to March, 1972, Geological Survey of Canada, Paper 1972-1B, pp. 24-30.

Carlisle, D. (1963):Pillow breccias and their aquagene tuffs, Quadra Island, British Columbia; Journal of Geology, 71: 48-71.

Carlisle, D. and Susuki, T. (1965):Structure, stratigraphy and paleontology of an Upper Triassic section on the west coast of British Columbia; Canadian Journal of Earth Science, 2: 442-484.

Carson, D.J.T. (1973):Petrography, chemistry, age and emplacement of the plutonic rocks of Vancouver Island; Geological Survey of Canada, Paper 72-44.

Carson, D.J.T. (1969):Tertiary mineral deposits of Vancouver Island, British Columbia; Bulletin of Canadian Institute of Mining and Metallurgy, 72: 116-125.

Carson, D.J.T., Muller, J.E., Wanless, R.H., and Stevens, R.D. (1971):Age of the contact metasomatic copper and iron deposits, Vancouver and Texada Islands, British Columbia; Geological Survey of Canada Paper 71-36.

Clapp, C.H. (1912):Notes on the geology of the geology of the Comox and Suquash Coal fields; Geological Survey of Canada, Sum. Report. 1911, p. 105-107.

Coombs, B. (1996):Ministry of Environment, personal communication

Dawson, G.M. (1887):Report on a Geological Examination of the northern part of Vancouver Island and adjacent coasts; Geological Survey of Canada, Annual Report. 1886, 2: pt. B: 1-107.

Denisiger, J. (1996):Ministry of Environment, personal communication

Dickson, F.W., and Tunnel, G. (1968):Mercury and Antimony deposits associated with active hot springs in the western United States, 1933-1967; AIME Graton Sales, Vol II, J.D. Ridge, Ed. pp. 1675-1701.

Dolmage, V. (1921):West coast of Vancouver Island between Barkley and Quatsino Sounds; Geological Survey of Canada, Summary Report. 1920, pt. A, p. 12-22.

Dolmage, V. (1919):Quatsino Sound and certain mineral deposits of the west coast of Vancouver Island, British Columbia; Geological Survey of Canada, Summarry Report. 1918.

Dragert H., Hyndman, R.D., Rogers, G.C., and Wang, K. (1994): Current deformation and the width of the seismogenic zone of the northern Cascadia subduction thrust; Journal of Geophysical Research, 99: 653-668.

Fyles, J.G. (1963):Surficial Geology of Home Lake and Parksville map areas, Vancouver Island, British Columbia; Geological Survey of Canada, Memoir 318.

Gravel, J.L. and Matysek, P.F. (1989): 1988 Regional Geochemical Survey, Northern Vancouver Island and Adjacent Mainland (92E, 92K, 92L, 102I); *in* Geological Fieldwork 1988, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1989-1, pages 585-592.

Gunning, H.C. (1933):Zebalos River area, Vancouver Island, British Columbia; Geological Survey of Canada, Summary Report. 1932, pt. A2, p. 29-50.

Gunning, H.C. (1932):Preliminary Report on the Nimpkish Lake Quadrangle, Vancouver Island, British Columbia; Geological Survey of Canada, Summary Report. 1931, pt. A, p. 22-35.

Gunning, H.C. (1930):Geology and Mineral Deposits of the Quatsino - Nimpkish Areas, Vancouver Island; Geological Survey of Canada, Summary Report. 1929, pt. A, p. 94-143

Halstead, E.C. (1968): The Cowichan ice tongue; Canadian Journal of Earth Sciences, 5: 1409-1415.

Halstead, E.C. (1966): Surficial geology of Duncan and Shawnigan map area, British Columbia; Geological Survey of Canada, Paper 65-24.

Heaton, T.H. and Hartzell, S.H. (1987): Earthquake hazards on the Cascadia subduction zone; Science, 236: 162-168.

Henderson, F.B. (1969):Hydrothermal Alteration and Ore Deposition in Serpentenite-Type Mercury Deposits, in Economic Geology, 64: 489-499.

Henderson, P. and McMartin, I. (1995):Mercury distribution in humus and surficial sediments, Flin Flon, Manitoba, Canada, Water, Air and Soil Pollution 80: 1043-1046.

Hoadley, J.W. (1953): Geology and Mineral Deposits of the Zeballos-Nimpkish Area, Vancouver Island, British Columbia, Geological Survey of Canada Memoir 272, 82 pages.

Howes, D.E. (1983): Late Quaternary Sediments and Geomorphic History of Northern Vancouver Island, British Columbia; Canadian Journal of Earth Sciences, 20:57-65.

Howes, D.E. (1981a): Terrain Inventory and Geological Hazards: Northern Vancouver Island; B.C. Ministry of Environment, Lands and Parks, APD Bulletin 5.

Howes, D.E. (1981b): Late Quaternary sediments and geomorphic history of north-central Vancouver Island; Canadian Journal of Earth Sciences, 18: 1-12.

Huntley, D.H. and Bobrowsky, P.T. (1995a): Surficial Geology and Drift Exploration: Mahatta Creek Map Area (92L/5); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-1, pages 35-48.

Huntley, D.H. and Bobrowsky, P.T. (1995b):Surficial Geology of the Mahatta Creek Area (NTS 92L/5); B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50 000, Open File 1995-11.

Huntley, D.H. and Bobrowsky, P.T. (1995c):Drift Applicability of the Mahatta Creek Area (NTS 92L/5), B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50 000, Open File 1995-18.

Jeletzky, J.A. (1973a):Cretaceous and Jurassic Stratigraphy of northern Vancouver Island (102I) and Manning Park area (92H, E/2 and W/2),British Columbia; Geological Survey of Canada, Paper 73-1A, p. 259-262.

Jeletzky, J.A. (1973b):Mesozoic and Tertiary rocks of Quatsino Sound, Vancouver Island; Geological Survey of Canada, Open File 148.

Jeletzky, J.A. (1970a):Mesozoic stratigraphy of northern and eastern parts of Vancouver Island; in Report on Activities, April to October 1969, Geological Survey of Canada, Paper 70-1a, p. 209-214.

Jeletzky, J.A. (1970b):Some salient features of early Mesozoic history of insular tectonic belt, western British Columbia; Geological Survey of Canada, Paper 69-14.

Jeletzky, J.A. (1969):Mesozoic and Tertiary stratigraphy of northern Vancouver Island; in Report on Activities, April to October 1968, Geological Survey of Canada, Paper 69-1a, p. 126-134.

Jeletzky, J.A. (1954a):Tertiary rocks of the Hesquiat-Nootka area, west coast of Vancouver Island, British Columbia; Geological Survey of Canada, Paper 54-37.

Jeletzky, J.A. (1954b):Geological History of the west coast of Vancouver Island (abstract); Bulletin of the Geological Society of America, 65: 1269.

Jeletzky, J.A. (1950):Stratigraphy of the west coast of Vancouver Island between Kyuquot Sound and Esperenza Inlet, British Columbia; Geological Survey of Canada, Paper 50-57.

Jonasson, I.R. (1970): Mercury in the natural environment: a review of recent work. Paper 70-57 Geological Survey of Canada 39 pp.

Kerr, D.E. (1992): Surficial Geology of the Quatsino Area, NTS 92L/12; B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50,000, Open File 1992-6.

Kerr, D.E. and Sibbick, S.J. (1992): Preliminary Results of Drift Exploration Studies in the Quatsino (92L/12) and the Mount Milligan (93N/1E, 93O/4W) Areas; *in* Geological Fieldwork 1991, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1992-1, pages 341-347.

Kerr, D.E., Sibbick, S.J. and Jackaman, W. (1992): Till Geochemistry of the Quatsino Map Area (92L/12); B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1992-21.

Khodakovskii, I.L., Popova, M. Ya., and Ozerva, N.A. (1977):Forms of Mercury migration in hydrothermal solutions. In: Geochemical Processes of Migration of Metallic Elements, Khitarov, N.I., Ed., pp 86-118. Moscow: Nauka

Koyanagi, V.M. and Panteleyev, A. (1994): Natural Acid Rock-Drainage in the Red Dog - Hushamu - Pemberton Hills Area, Northern Vancouver Island (92L/12); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1994-1, pages 119-125.

Koyanagi, V.M. and Panteleyev, A. (1993): Natural Acid-Drainage in the Mount McIntosh/Pemberton Hills Area, Northern Vancouver Island (92L/12); *in* Geological Fieldwork 1992, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1993-1, pages 445-450.

Massey, N.W.D., Desjardins, P.J., and Grunsky, E.C. (1994):Geological Compilation, Vancouver Island, British Columbia (NTS 92B,C,E,F,G,K,L,102I), B.C. Ministry of Energy, Mines and Petroleum Resources, Open File1994-6, 5 digital files, legend,1:250,000 scale.

Massey, N.W.D. and Melville, D.M. (1991): Quatsino Sound Project; *in* Geological Fieldwork 1992, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1991-1, pages 85-88.

Matysek, P.F., Gravel, J.L., and Jackaman, W. (1989):1988 Regional Geochemical Survey, Stream Sediment and Water Geochemical Data, NTS 92L/102I - Alert Bay Cape Scott; B.C. Ministry of Energy, Mines and Petroleum Resources, RGS 23.

Matysek, P.F. and Day, S.J. (1988): Geochemical Orientation Surveys: Northern Vancouver Island, in Fieldwork and Preliminary Results. B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1987, Paper 88-1, pp. 493-502.

Meldrum, D.G. and Bobrowsky, P.T. (1994a): Drift Exploration Potential of the Port McNeill Area (NTS 92L/11); B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50 000, Open File 1994-11.

Meldrum, D.G. and Bobrowsky, P.T. (1994b): Drift Exploration Potential of the Alice Lake Area (NTS 92L/6); B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50 000, Open File 1994-12.

Mulder, T. L. and Rogers, G.C. (1993): Crustal earthquakes in southwestern British Columbia (abstract) EOS, Transactions, American Geophysical Union, 74: 201.

Muller, J.E., Northcote, K.E. and Carlisle, D. (1974):Geology and Mineral Deposits of Alert - Cape Scott map-area, Vancouver Island, British Columbia. Geological Survey of Canada , Paper 74-8.

Muller, J.E. and Carson, D.J.T. (1969):Geology and Mineral Deposits of Alberni map-area, British Columbia (92F); Geological Survey of Canada, Paper 68-50.

Nesbitt, B.E., Muehlenbachs, K, and Muowchick, J.B. (1989):Genetic Implications of Stable Isotope Characteristics of Mesothermal Au Deposits and Related Sb and Hg Deposits in the Canadian Corillera in Economic Geology, 84: 1489-1506.

Nixon, G.T., Hammack, J.L., Payie, G.J., Snyder, L.D., Archibald, D.A. and Barron, D.J. (1995): Quatsino - San Josef Map Area, Northern Vancouver Island: Geological Overview (92L/12W, 102I/8, 9); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-1, pages 9-21.

Nixon, G.T., Hammack, J.L., Koyanagi, V.M., Payie, G.J., Panteleyev, A., Massey, N.W.D., Hamilton, J.V. and Haggart, J.W. (1994): Preliminary Geology of the Quatsino-Port McNeill Map Areas, Northern Vancouver Island (92L/12, 11); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1994-1, pages 63-85.

Nixon, G.T., Hammack, J.L., Hamilton, J.V. and Jennings, H. (1993a): Geology of the Mahatta Creek Map Area, NTS 92L/5; B.C. Ministry of Energy, Mines and Petroleum Resources, scale 1:50 000, Open File 1993-10.

Nixon, G.T., Hammack, J.L., Hamilton, J.V. and Jennings, H. (1993b): Preliminary Geology of the Mahatta Creek Area, Northern Vancouver Island (92L/5); *in* Geological Fieldwork 1992, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1993-1, pages 17-35.

Northcote, K.E. (1971):Rupert Inlet-Cape Scott map-area; B.C. Ministry of Mines and Petroleum Resources, Geology, Exploration and Mining in British Columbia, 1970, p. 254-278.

Northcote, K.E. (1969):Geology of the Port Hardy-Coal Harbor area; B.C. Ministry of Mines, Annual Report, 1968, pp. 84-87.

Panteleyev, A., Sibbick, S.J. and Koyanagi, V.M. (1996): Natural Acidic Drainage in Northern Vancouver Island - Its Place in Geoenvironmental Ore Deposit Models; *in* Geological Fieldwork 1995, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1996-1, pages 61-66.

Panteleyev, A., Reynolds, P.H. and Koyanagi, V.M. (1995): ^{40}Ar/^{39}Ar ages of Hydrothermal Minerals in Acid Sulphate - Altered Bonanza Volcanics, Northern Vancouver Island (NTS 92L/12); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-1, pages 61-65.

Panteleyev, A. and Koyanagi, V.M. (1994): Advanced Argillic Alteration in Bonanza Volcanic Rocks, Northern Vancouver Island - Lithologic and Permeability Controls; *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1994-1, pages 101-110.

Panteleyev, A. and Koyanagi, V.M. (1993): Advanced Argillic Alteration in Bonanza Volcanic Rocks, Northern Vancouver Island - Transitions Between Porphyry Copper and Epithermal Environments (92L/12); *in* Geological Fieldwork 1992, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1993-1, pages 287-293.

Peters, E. K. (1991):Gold-Bearing Hot Spring Systems of the Northern Coast Ranges, California, in Economic Geology 86: 1519-1528.

Rogers, G.C. (1994): Earthquakes in the Vancouver Area; *in* Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia, Monger, J.W.H., Editor, Geological Survey of Canada, Bulletin 481, pp. 221-229.

Rogers, G.C. (1992): The Earthquake Threat in Southwest British Columbia; *in* Geotechnique and Natural Hazards, Vancouver Geotechnical Society and Canadian Geotechnical Society, Geohazards '92 Symposium Volume, BiTech Publishers Ltd., pages 63-69.

Rogers, G.C. (1988): An assessment of the mega - thrust earthquake potential of the Cascadia subduction zone; Canadian Journal of Earth Sciences, 24: 844-852.

Rogers, G.C. (1983):Seismotectonics of British Columbia; Ph.D. thesis, University of British Columbia, Vancouver, British Columbia, 247 p.

Sibbick, S.J. (1994): Preliminary Report on the Application of Catchment Basin Analysis to Regional Geochemical Survey Data, Northern Vancouver Island (92L/03, 04, 04 and 06); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1994-1, pages 111-117.

Sibbick, S.J. and Laurus, K. (1995): Investigation of a Natural Acid Rock Drainage and an Anomalous Mercury-bearing stream, Northern Vancouver Island (92L/12, 102I/9); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1995-1, pages 67-70.

Sorokin, V. I. (1973):Solubility of Mercury in Water in the Tempperature Interval of 300^0 C to 500^0 C and pressures of 500 to 1,000 atm. Akad. Nauk SSSR Dokldy. Chem. Sect. 213: 852-855.

Sherlock, R.L., (1992):The Empirical Relationship between Gold - Mercury Mineralization and Hydrocarbons, in the Northern Coast Ranges, California, in Program with Abstracts, Geological Association of Canada, Mineralogical Association of Canada. Volume 8.

Stats Canada, (1996):

Stats, British Columbia (1996):

Stevenson, J.S. (1940):Mercury Deposits in British Columbia, Bulletin No. 5. British Columbia Department of Mines.

Studemeister, P.A. (1983):The Origin of Mercury Deposits in the California Coast Ranges, in Program with Abstracts, Geological Association of Canada, Mineralogical Association of Canada, Volume 8.

Surdam, R.C. (1968):The stratigraphy and volcanic history of the Karmutsen Group, Vancouver Island, British Columbia; Univ. Wyoming, Contrib. Geology, 7: 15-26.

Vanderpoll, W., Hulme, N., Duffett, L. (1989): MINFILE, 92L and 102I Northern Vancouver Island Mineral Occurrence Map; B.C. Ministry of Energy, Mines and Petroleum Resources, MINFILE, released Sept. 1989.

White, D.E. (1967):Mercury and base metal deposits with associated thermal and mineral waters; in Barnes, Hugh L., 1967: Geochemistry of Hydrothermal Ore Deposits; New York, Holt, Reinhart, and Winston, Inc., pub., pp. 575-631.

Yorath, C.J. and Nasmith, H.W. (1995):The Geology of Southern Vancouver Island: A Field Guide, Orca Book Publishers, 172 pp.

CHAPTER 5 - CONCLUSIONS

Geographic information systems can be used as a tool to aid researchers in solving spatially oriented geological problems. GIS may be useful when large or numerous data sets are involved. Computers have the ability to solve geometrical, numerical, and statistical problems quickly and efficiently. User-friendly software has allowed earth scientists, to use GIS in their research more efficaciously. This paper has presented three applications for the use of a GIS in understanding geological hazards. Each application was significantly different in its method and scope.

In the first application, the earthquake hazard mapping program, the GISwas used to display a large amount of data in innovative ways. The surficial geology of the study area is rather complex, with alluvial sediments from a large river system, a large alluvial fan, several small alluvial/colluvial fans, landslide deposits, lacustrine deposits and semi-active channels. Several methods of presenting lithological information were introduced. Geo-referenced pie chart showing the type of sediment at each meter within a drill hole was helpful to the researchers in determining the extents of subsurface geological features. Average sediment lithology charts and non geo-referenced pie plots were also helpful. The GIS was also utilized to perform other functions including buffering, dynamic labeling, query functions, as well as producing the final publication quality map. Earthquake hazard mapping has many uses including, emergency planning, seismic upgrade priorization, land use planning, insurance premium decision making and site location for future development.

In the ice-flow modelling project, the GIS was used to produce a model for dispersal. Paleo ice-flow indicators such as stria and crag and tails often show a range of possible directions. Indicators formed from early phases of ice movement may be eroded by later phases. Other indicators may have been influenced by late stage melting phenomenon or local topographic effects. Dispersal of indicator clasts (such as mercury mineralization) may be used to help understand the movement of ice in an area. The location and mean mercury content of bedrock mineralization were overlain by a shape created within the GIS. This shape was developed to model the way a glacier would deposit eroded material from a bedrock source. The apex of the shape was placed on each till site down ice of the mine site. The amount and location of mineralization within the shape were determined by the GIS. Once this information was collected a spreadsheet was set up to perform the numerical and statistical calculations.

This technique may be useful to academics interested in determining the variability in ice-flow direction. It may also be used by explorationists to determine the most likely distance and direction of mineralized bedrock from mineralized float or anomalous till samples.

In Chapter 4, the catchment basins were assigned the amount of mercury collected in stream sediments. Each fault segment within this catchment basin was subsequently assigned the mercury value associated with the catchment basin. These fault segments were then grouped by their orientation. The amount of mercury associated with the four groups was then analyzed statistically. The amount of mercury in each population was significantly different from the others.

The association between faults and mercury deposits is well understood (e.g. Gray, 1938; Armstrong, 1942; Bailey *et al.* 1973; Ash, 1996). However, some researchers will attempt to attribute mercury anomalies to anthropogenic sources if no mercury mineralization is recognized. This paper demonstrates a statistical method to show the correlation between fault orientation and the amount of mercury within stream sediments in an area of no known mercury mineralization. Faults of different orientations often occur at different times. The geochemistry of the fluids migrating through these faults at the time of activation may be the reason for the relationship between mercury and fault orientation.

The implications of this study are two fold. Firstly, mercury levels can vary significantly due to geological features such as faults, even if no mercury mineralization is recognized. Secondly, geological factors should be considered during an environmental assessment of an area.

Appendix 2-1

Active River Alluvium

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
180	2	ml	ml	ml	sp	sp	sp	sp	sp	sp	sp	sp	sw	sw	ml	ml	ml	ml	ml	sp	sp
179	2	fill	fill	fill	fill	fill	fill	fill	fill	fill	ml	sp	sp	ml	sm	sp	ml	ml	ml	ml	sm
8	2	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
94	2	sp	sp	sp	gp	gp	gp	gp	gp	gp	gp	gp	gp	gp	gp	gp	gp	sp	sm	sm	sm
202	2	fill	silt	silt	sp	sp	sp	sp	sm	sm	sm	sm	sm	sp	silt	silt	sp	sp	sp	sp	sp
17	2	fill	fill	fill	fill	fill	fill	sp	sp	sp	sm	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
25	2	ml	sw	sw	sw	sand	sand	sand	sm	sand	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
	grav	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
	g&s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	diamict	3	2	2	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
	sand	1	2	2	3	3	3	4	2	3	1	3	3	2	0	1	1	2	1	2	2
	sand w fine	0	0	0	0	0	0	0	2	1	2	1	1	0	1	0	0	0	1	1	2
	silt	2	2	2	0	0	0	0	0	0	1	0	0	1	2	2	2	2	2	1	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	1	1	1	1	1	1	2	2	2	3	3	3	3	3	3	3	3
		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Semi-active channels

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
194	3	ml	ml	ml	ml	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sm	sp	sp	sp
197	3	gp	sm	gp	sm	sp	gm	sp	gm	sm	gm	sm	gm	sp	sm	sp	sm	sp	sp	sp	sp
198	3	sm	sm	sm	gm	gm	gm	gm	gp	sp	gm	sm	gm	sm	gm	sm	sm	sp	sm	sp	sp
6	3	fill	fill	sm	sp	gp	gp	gp	gp	sp	sp	sp	gp	gp	gp	sp	sp	sp	sp	sp	sp
117	3	sm	sg	sg	sg	sg	sm	sp	sw	gw	sg	sg	sg	sg	sg	sg	sg	sg	sg	eoh	eoh
211	3	fill	fill	fill	fill	fill	ml	ml	ml	sw	sw	sw	sw	sw	sp	eoh	eoh	eoh	eoh	eoh	eoh
64	3	sm	sm	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
	grav	1	0	2	0	1	1	1	2	1	0	0	1	1	1	0	0	0	0	0	0
	g&s	0	1	1	2	2	2	1	1	0	3	1	3	1	2	1	1	1	1	0	0
	diamict	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	0	0	0	1	2	1	3	2	4	3	3	2	3	2	3	2	3	3	4	4
	sand w fine	3	3	2	1	0	1	0	0	1	0	2	0	1	1	1	2	1	1	0	0
	silt	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3
		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
61	3a	fill	clay	clay	silt	clay	silt	sm	clay	sm	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
186	3a	gp	ol	ol	sp	sp	sm	sm	ml	sm	sm	sm	sm	ml	ml	ml	ml	ml	ml	ml	ml
27	3a	ml	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
28	3a	sm	sm	sm	sm	sm	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
227	3a	sm	sm	sp	sp	sp	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
216	3a	ml	sg	sg	sg	sg	sg	sg	sg	sw	sm	sm	sm	sm	sw	sm	sm	sw	sg	sg	sg
47	3a	silt	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
226	3a	ml	sw	sw	sw	sw	sw	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
71	3a	ml	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
82	3a	fill	cl	sm	ml	ml	ml	ml	ml	ml	ml	ml	ml	ml	eoh	eoh	eoh	eoh	eoh	eoh	eoh
191	3a	fill	ol	ol	ol	gp	gp	gp	gp	gp	gp	gp	sp	gp	gp	gp	sp	gp	sp	gp	gp
173	3a	ml	sm	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
174	3a	sm	sm	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
171	3a	sand	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
112	3a	ml	ml	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
30	3a	ml	sw	sw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
224	3a	ml	sm	sm	sm	sm	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
43	3a	ml	sp	sp	sp	sp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
42	3a	ml	sm	sm	gw	sp	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
70	3a	ml	sm	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
195	3a	sm	sm	sm	sm	sm	sp	gp	sp	gp	sp	gp	sp	sp	gp	cl	cl	sp	sp	cl	cl
44	3a	fill	ml	sm	sm	gm	gm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
65	3a	ol	ml	sw	sw	sw	sw	sw	sw	grav	sw	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
111	3a	ml	sm	sg	sg	sg	sw	sw	sw	sw	sw	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
37	3a	fill	sm	sp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
67	3a	sm	sm	gp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
196	3a	sm	sm	sm	sm	sp	sw	gw	gw	gw	gm	gw	gw	silt	clay	org	silt	clay	org	silt	clay
49	3a	fill	sp	sp	sp	sp	gm	gm	gm	gm	gm	gm	gm	gm	gm	gm	gm	eoh	eoh	eoh	eoh
167	3a	cl	cl	sm	sp	sp	sp	sp	sp	gp	gp	gp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh
176	3a	fill	ml	ml	sand	sand	sand	sg	sand	grav	grav	grav	grav	sg	sg	cl	sw	cl	cl	cl	cl
12	3a	ml	ml	ml	sm	sm	sg	sg	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
41	3a	fill	ml	ml	sw	sw	sw	sw	sw	sw	grav	sw	sw	sw	eoh	eoh	eoh	eoh	eoh	eoh	eoh
46	3a	fill	sm	sw	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
115	3a	fill	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
76	3a	silt	silt	sm	sm	gw	gw	sw	gw	sw	gw	gw	gw	gw	gw	sw	sw	silt	silt	sw	sw
116	3a	silt	sm	sp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
120	3a	oh	oh	oh	pt	cl	cl	sp	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh
119	3a	cl	cl	ch	ch	pt	ch	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
189	3a	fill	fill	cl	cl	ml	cl	cl	ml	ml	ml	ml	ml	cl	cl	sm	sp	ml	sp	sp	sp
123	3a	ch	ch	pt	cl	cl	cl	ml	ml	ml	ml	ml	ml	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh
190	3a	CLAY	CLAY	CLAY	silt	silt	silt	silt	silt	silt	silt	silt	silt	silt	sm	silt	silt	silt	silt	sand	sand
124	3a	ml	ml	cl	cl	cl	ml	ml	ml	ml	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
125	3a	clay	clay	ch	ch	cl	cl	cl	cl	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh

127	3a	ch	ch	ch	ch	pt	pt	pt	cl	cl	cl	ml	ml	ml	ml	sp	sp	gp	gp	eoh	eoh
128	3a	ol	of	oh	oh	ml	sm	sm	pt	sm	sp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh
129	3a	ch	ch	ml	sm	sm	sp	sp	sp	sp	sp	sp	sp	sp	gp	gp	eoh	eoh	eoh	eoh	eoh
130	3a	mh	mh	ml	ml	sp	sp	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
131	3a	ch	ch	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
188	1a	ml	ml	ml	ml	sm	ml	sm	sp	sp	sp	cl	ml	ml	ml	ml	ml	sp	sp	sm	sm
77	3a	silt	sm	silt	sm	sw	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
132	3a	pt	sm	ol	sc	sp	diam	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
135	3a	pt	pt	OL.	cl	cl	ol	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
136	3a	cl	sm	sm	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
29	3a	sm	sm	sm	sm	sp	sp	gm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
217	3a	ml	sp	sp	sp	sp	grav	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
193	3a	sm	sm	gm	gm	gm	gm	sp	sp	sp	sp	gp	gp	gp	gp	gp	gp	gp	sp	sp	sp
192	3a	sc	sc	gp	gp	sp	sp	gp	gp	gp	gp	gp	gp	sp	sp	sp	sp	sp	sp	ml	ml
62	3a	sm	sm	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
225	3a	ml	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
39	3a	pt	sp	sp	sw	sw	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
38	3a	gp	gp	gp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
40	3a	sm	sm	gp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
36	3a	ol	cl	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
168	3a	cl	sm	sw	sw	sw	sg	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
122	3a	ml	ol	ch	sm	sm	sw	sw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
214	1a	ml	ml	sp	sp	sp	sp	sp	sp	sp	sp	sp	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh
22	3a	ml	sp	sp	sp	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
20	3a	fill	fill	fill	fill	ml	sp	sp	sp	gp	gp	sp	sp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh
223	3a	ml	sm	sm	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
60	1a	sm	sm	silt	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed	bed
213	3a	fill	fill	fill	fill	fill	fill	sg	sg	sg	sg	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
63	3a	ml	ml	ml	sm	sw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
214	3a	fill	fill	fill	fill	fill	ml	sm	sm	sm	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
21	3a	ml	ml	sw	sm	sm	sand	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
220	3a	sm	sm	sw	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
219	3a	sm	sm	grav	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
9	3a	sp	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
218	3a	silt	ml	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
101	1a	sp	sp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
170	3a	fill	fill	fill	fill	fill	fill	sm	sp	sp	gp	gp	gp	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh
221	3a	fill	fill	ml	ml	ml	sg	sg	sg	grav	grav	grav	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh
222	3a	sm	sm	sg	sand	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
229	3a	sm	ml	ml	sp	ml	ml	ml	sm	ml	sp	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh
24	3a	ml	ml	ml	sw	sw	sw	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
166	3a	sm	sm	ml	ml	ml	ml	ml	sm	sm	sp	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh
240	3a	ml	sm	sp	sp	sp	sp	sp	sp	sw	sw	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh
181	3a	cl	cl	cl	sm	sp	sp	sp	sp	sp	sp	sp	sp	sw	sw	sw	gp	cl	cl	cl	sw

228	3a	ml	sm	sm	sm	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
187	3a	fill	fill	ml	ml	ml	sm	gm	gm	sm	gp	gp	gp	gp	gp	gp	gp	gp	gw	sp	gp
156	3a	sm	sm	sm	ml	ml	sand	sand	ml	ml	ml	grav	sand	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh
185	3a	clay	clay	silt	silt	sm	sm	sm	sm	sm	sp	sm	silt	silt	silt	silt	silt	silt	sm	sp	sp
			•																		
	grav	2	2	9	12	11	11	9	6	9	10	15	11	11	8	4	3	4	2	1	2
	g&s	0	2	7	4	7	9	10	7	3	3	2	2	2	2	1	1	0	1	1	1
	diamict	17	7	4	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	3	11	23	22	27	24	19	19	14	16	11	13	11	6	6	8	4	6	6	6
	sand w fine	18	34	17	18	10	5	7	4	7	5	5	2	1	1	2	1	0	1	1	1
	silt	32	16	15	10	10	8	6	7	7	5	5	7	7	4	4	5	5	3	3	2
	clay	12	13	9	7	6	5	2	3	1	1	1	0	1	2	2	1	3	2	3	3
	org	7	6	7	3	2	2	1	1	0	0	0	0	0	0	1	0	0	1	0	0
	bedrock	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	eoh	0	0	0	10	14	23	36	43	49	50	51	55	57	67	70	71	74	74	75	75
		91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91

Fraser River Alluvium with surface fines

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
66	3b	ml	ml	sg	sg	sg	sg	cl	mi	mi	sw	ml	ml	ml	eoh	eoh	eoh	eoh	eoh	eoh	eoh
138	3b	ml	ml	ml	sand	sand	sand	sand	sm	ml	sm	sm	sand	sand	grav	eoh	eoh	eoh	eoh	eoh	eoh
48	3b	ol	ol	ol	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
182	3b	clay	silt	clay	clay	clay	clay	silt	sp	sp	sp	sp	sp	sp	sp	sm	sm	sp	sm	sm	sm
	grav	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	g&s	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	diamict	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	0	0	0	1	1	1	1	1	1	2	1	2	2	1	0	0	1	0	0	0
	sand w fine	0	0	0	1	0	0	0	1	0	1	1	0	0	0	1	1	0	1	1	1
	silt	2	3	1	0	0	0	1	1	2	0	1	1	1	0	0	0	0	0	0	0
	clay	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	0	1	1	1	1	1	1	1	1	1	2	3	3	3	3	3	3
		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
177	3c	sp	sp	ml	ml	ml	ml	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
161	3c	sg	sg	sg	sg	sg	sg	sg	sg	sg	sg	sg	sg	sg	grav	grav	grav	eoh	eoh	eoh	eoh
172	3c	sm	sp	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
199	3c	silt	silt	sm	sp	silt	sp	sm	sp	sm	sp	sm	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh
45	3c	sm	sw	sw	sw	sg	sg	sg	sg	sg	sg	sg	sg	sg	sg	sw	sw	sg	sg	sw	sw
50	3c	fill	fill	fill	fill	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	ml	sp	sp	eoh
118	3c	pt	pt	pt	mh	ol	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	eoh	eoh
235	3c	ml	ml	sw	sp	sp	sp	sp	sp	gp	sp	sp	sp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh
212	3c	fill	fill	fill	fill	fill	sm	gw	gw	gw	sm	sm	sm	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh
215	3c	fill	fill	fill	fill	fill	fill	sm	sm	sw	sm	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
239	3c	ml	ml	ml	sp	sp	sp	gw	sp	sp	sp	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh
231	3c	sand	ml	ml	sand	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
	grav	0	0	0	0	0	0	3	2	3	0	0	0	2	2	1	1	0	0	0	0
	g&s	1	1	1	1	2	2	2	2	2	2	2	2	2	1	0	0	1	1	0	0
	diamict	3	3	3	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	2	3	2	5	3	5	3	5	4	5	4	5	4	3	4	4	2	2	2	1
	sand w fine	2	0	2	0	0	1	2	1	1	2	3	2	0	0	0	0	0	0	0	0
	silt	3	4	3	2	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	1	2	2	2	2	2	3	3	3	4	6	7	7	8	9	10	11
		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12

Upper Vedder Fan

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
58	4	sp	sp	sp	sm	sm	gp	gp	gp	gp	gp	gp	sm	sp	sp	sp	sp	sp	sp	sp	ch
13	4	ml	ml	sp	ml	ml	sm	sm	sw	sw	ml	ml	sw	sw	sw	sw	sm	sm	sw	ml	ml
205	4	gw	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
10	4	silt	sp	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
91	4	sw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh
86	4	sm	gp	sp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
79	4	fill	fill	fill	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
80	4	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	sw
145	4	sm	sm	grav	grav	grav	sg	sg	sg	sg	sg	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
81	4	sp	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
92	4	pt	gp	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
88	4	gp	gp	gp	gp	gp	sw	sw	gp	gp	gp	gp	gp	gp	gp	gp	gp	eoh	eoh	eoh	eoh
89	4	sp	gw	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
54	4	sm	sm	sm	sm	sm	sm	sm	sm	sm	sm	sm	sm	sm	sw	sw	gw	sw	gw	sw	gw
93	4	fill	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
84	4	sm	sm	sw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
55	4	fill	fill	fill	fill	sw	gw	sw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
85	4	silt	silt	gm	gm	gm	gm	gm	gm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
87	4	fill	sm	gw	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
83	4	sp	gp	sm	sm	gp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
90	4	sm	gw	gw	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
75	4	sm	sm	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
146	4	ml	ml	ml	ml	ml	sand	sg	sg	sg	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
	grav	3	10	11	11	9	8	6	7	7	5	6	5	3	3	3	3	1	2	1	1
	g&s	0	0	1	2	1	2	3	3	2	2	1	0	0	0	0	0	0	0	0	0
	diamict	4	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	5	3	6	0	1	2	2	1	1	0	0	1	2	3	3	1	2	2	2	1
	sand w fine	6	5	2	3	2	2	2	1	1	1	1	2	1	0	0	1	1	0	0	0
	silt	4	3	1	2	2	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	org	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	4	8	9	10	11	12	14	14	15	17	17	17	18	19	19	19	19
		23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23

Distal Vedder Fan

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
144	4a	ml	ml	ml	grav	grav	grav	sm	sm	sg	sg	sg	sg	silt	sand	sand	sand	eoh	eoh	eoh	eoh
56	4a	sp	sm	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
73	4a	sm	sm	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
78	4a	fill	silt	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
72	4a	sw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
98	4a	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl
99	4a	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw
233	4a	sw	sw	gw	gw	gw	gw	sp	sp	sp	sp	sp	sp	sp	gw	sg	sg	sg	sg	sp	sp
121	4a	sm	sm	sm	sp	sp	sp	sp	sp	gp	gp	gp	gp	gp	gp	gp	gp	gp	gp	eoh	eoh
147	4a	ml	ml	ml	ml	sand	sand	ml	ml	ml	sg	sg	sg	sg	ml	ml	ml	eoh	eoh	eoh	eoh
148	4a	sm.	sm	sand	ml	ml	sm	sm	sand	sm	sm	sm	sm	sm	sm	grav	sm	eoh	eoh	eoh	eoh
209	4a	ml	ml	ml	sw	sw	sw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
200	4a	silt	clay	clay	sm	sm	sm	sm	sm	sm	sp	sm	sm	sm	sm	sm	sp	sm	sm	sm	sm
242	4a	fill	sp	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh
108	4a	fill	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
208	4a	ol	sw	gw	sw	sw	sw	sw	ml	sw	sw	sw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
163	4a	cl	cl	cl	cl	grav	sm	sm	sm	cl	cl	cl	cl	cl	cl	sp	cl	cl	cl	cl	cl
14	4a	fill	fill	fill	fill	sp	sp	sp	sp	sp	sw	sw	sw	sw	sw	sw	sw	sw	sw	eoh	eoh
241	4a	fill	fill	fill	sp	gp	gp	gp	gp	gp	sw	sw	sw	sw	sw	sw	sw	sw	sw	eoh	eoh
204	4a	ml	ml	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
34	4a	mh	mh	mh	sw	gw	gw	gw	gw	gw	gw	mh	mh	mh	mh	mh	gw	gw	gw	eoh	eoh
33	4a	ml	ml	gw	sw	ml	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
59	4a	gw	gp	gw	silt	clay	gw	gp	silt	sm	clay	sm	gw	clay	sm	clay	gp	clay	silt	clay	sm
139	4a	ml	ml	ml	sm	sand	sand	sm	ml	ml	ml	sand	sand	sand	sm	sm	sm	eoh	eoh	eoh	eoh
140	4a	ml	ml	ml	sand	sand	sand	ml	ml	ml	ml	sand	sand	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh
232	4a	sm	sg	sg	sg	sg	sm	sm	sm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
35	4a	sp	sp	ml	ml	ml	ml	ml	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
203	4a	gw	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
141	4a	ml	ml	ml	sg	sg	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
32	4a	ml	ml	ml	ml	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh
183	4a	silt	silt	silt	sm	sm	sm	silt	silt	silt	silt	sm	sm	sp	sp	sp	sp	sp	gw	gw	sp
142	4a	ml	ml	sand	sand	sg	sg	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
162	4a	grav	grav	grav	grav	cl	sg	sg	sg	sg	sg	sg	sg	sg	sg	sg	sg	cl	sg	cl	cl
11	4a	gw	ml	sp	gw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
74	4a	sw	gw	gw	gw	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
143	4a	ml	sm	sm	sm	sg	sg	sm	sm	sm	ml	ml	sg	sg	sg	grav	grav	eoh	eoh	eoh	eoh
	grav	5	6	13	12	14	14	9	8	9	6	4	5	5	6	5	5	3	4	2	1
	g&s	0	1	1	2	4	4	3	2	2	3	3	4	3	2	2	2	1	2	0	0
	diamict	5	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	5	5	4	9	7	7	4	4	3	5	6	5	5	4	5	5	3	2	1	2
	sand w fine	4	5	2	4	2	5	7	5	5	1	4	3	2	4	2	2	1	1	1	2
	silt	14	14	10	5	3	1	4	6	4	4	2	1	2	2	2	1	0	1	0	0

Distal Vedder Fan

	clay	2	3	3	2	3	1	1	1	2	3	2	2	3	2	2	2	4	2	4	3
	org	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	1	1	3	4	8	10	11	14	15	16	16	16	18	19	24	24	28	28
		36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36

Upper colluvial / alluvial fan

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
109	5	gc	gc	gc	gc	gc	gc	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
4	5	ml	ml	ml	ml	ml	ml	ml	gp	gp	gp	gp	gp	gp	gp	sm	gm	eoh	eoh	eoh	eoh
	grav	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
	g&s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	diamict	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand w fine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	silt	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2

Lower Colluvial / Alluvial Fans

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
157	5a	sm	sm	sm	sm	sm	sand	sand	sand	sand	sand	grav	grav	coh	coh	coh	coh	coh	coh	coh	coh
	grav	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
	g&s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	diamict	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
	sand w fine	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	silt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	coh	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Upper Colluvial / Alluvial Fans

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
109	5	gc	gc	gc	gc	gc	gc	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
4	5	ml	ml	ml	ml	ml	ml	ml	gp	gp	gp	gp	gp	gp	gp	sm	gm	eoh	eoh	eoh	eoh
	grav	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
	g&s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	diamict	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand w fine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	silt	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2
		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
26	6	ml	ml	ml	ml	ml	sw	sm	sm	grav	sand	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
11	6	sm	sm	gp	gp	sm	sm	sm	sm	gm	gm	gm	gm	silt	silt	silt	silt	silt	sw	silt	silt
184	6	sm	sm	sm	gm	gm	gm	gp	gp	gp	gw	gm	cl	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh
169	6	pt	pt	pt	pt	pt	pt	pt	pt	sm	sm	sm	cl	cl	cl	cl	cl	cl	cl	cl	cl
152	6	ml	ml	sand	sand	ml	sand	sg	sg	sg	ml	ml	ml	sm	sm	ml	eoh	eoh	eoh	eoh	eoh
153	6	ml	ml	ml	sand	sand	sg	sg	sg	sg	sg	sg	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
154	6	ml	ml	sand	sand	grav	grav	grav	grav	grav	sand	sand	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
155	6	silt	sand	sand	sand	grav	grav	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
137	6	sp	sp	ml	ml	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	ml	ml	ml	ml	ml	ml
1	6	pt	ch	oh	oh	ml	ml	ml	ml	pt	ml	ml	ml	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
2	6	oh	pt	oh	gm	gm	gm	gm	gm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
3	6	gm	oh	pt	ml	ml	oh	oh	ml	gp	oh	gp	ch	ml	eoh	eoh	eoh	eoh	eoh	eoh	eoh
160	6	ml	ml	ml	sand	sand	sand	grav	grav	grav	grav	grav	grav	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
113	6	silt	org	s fines	s fines	s fines	sm	silt	silt	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
	grav	0	0	1	1	2	2	4	4	5	2	2	1	0	0	0	0	0	0	0	0
	g&s	1	0	0	2	2	3	3	3	3	2	3	1	0	0	0	0	0	0	0	0
	diamict	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	1	2	3	5	3	4	1	1	1	3	2	1	1	1	0	0	0	1	0	0
	sand w fine	2	2	1	0	1	2	2	2	1	1	1	0	2	1	0	0	0	0	0	0
	silt	7	5	4	3	4	1	2	3	0	2	2	2	2	1	3	2	2	1	2	2
	clay	0	1	1	1	1	0	0	0	0	0	0	3	1	1	1	1	1	1	1	1
	org	3	4	4	2	1	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	0	0	0	0	0	3	3	4	6	8	10	10	11	11	11	11	11
		14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Lacustrine sediments

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
210	7	ml	sp	sp	sp	sp	sp	sm	sm	sm	sm	sm	sm	sm	sm	sp	sp	ml	ml	ml	ml
230	7	sand	silt	sg	sg	sand	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
178	7	fill	fill	fill	fill	fill	fill	fill	ml	sp	sw	sw	sp	sp	eoh	eoh	eoh	eoh	eoh	eoh	eoh
236	7	fill	fill	fill	fill	fill	fill	fill	sm	sm	sp	sw	ml	ml	eoh	eoh	eoh	eoh	eoh	eoh	eoh
15	7	fill	fill	fill	fill	fill	sw	sm	sm	sw	sw	sw	sw	sp	sp	sp	sp	sp	sp	sp	eoh
	grav	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	g&s	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	diamict	3	3	3	3	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	1	1	1	1	2	2	0	0	2	3	3	2	2	1	2	2	1	1	1	0
	sand w fine	0	0	0	0	0	0	2	3	2	1	1	1	1	1	0	0	0	0	0	0
	silt	1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	1	1	1
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	0	0	1	1	1	1	1	1	1	1	3	3	3	3	3	3	4
		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Cheam Landslide deposits

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
102	8	sp	gc	gp	gp	gp	gw	gw	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
	grav	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	g&s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	diamict	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand w fine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	silt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
164	10	till	till	till	till	till	till	till	grav	grav	sg	till	till	till	till	till	till	grav	grav	grav	coh
106	10	pt	sm	gm	gm	gm	gm	gm	gm	gm	gm	coh	coh	coh	coh	coh	coh	coh	coh	coh	coh
105	10	ml	gp	gp	gm	gm	sp	sp	sp	gm	gp	gm	gm	ml	gm	gw	gw	gp	gw	gp	gp
104	10	ol	ol	sp	sp	sp	sp	ol	ml	ml	sp	sp	coh	coh	coh	coh	coh	coh	coh	coh	coh
	grav	0	1	1	0	0	0	0	1	1	1	0	0	0	0	1	1	2	2	2	1
	g&s	0	0	1	2	2	1	1	1	2	2	1	1	0	1	0	0	0	0	0	0
	diamict	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	0
	sand	0	0	1	1	1	2	1	1	0	1	1	0	0	0	0	0	0	0	0	0
	sand w fine	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	silt	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0
	clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	coh	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2	2	2	3
		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Bedrock

ID	LABEL	Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	Z19
107	12	ml	sw	sw	cl	gm	ml	gm	sm	gm	sm	gm	sm	eoh	eoh	eoh	eoh	eoh	eoh	eoh	eoh
	grav	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	g&s	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
	diamict	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	sand w fine	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0
	silt	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	clay	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	org	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	eoh	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Appendix 3-1

ID	East	North	Hg	ID	East	North	Hg
94-PMA-067-4	317125	6053150	140	92-PMA-115	390118	6182849	260
94-PMA-067-3	317125	6053150	130	92-PMA-109	383799	6174366	200
94-PMA-067-2	317125	6053150	120	92-PMA-108	383799	6174366	190
94-PMA-067-1	317125	6053150	80	92-PMA-104-7	396524	6172053	70
94-PMA-064	324625	6025225	100	92-PMA-104-6	396524	6172053	100
94-PMA-052	318050	5992950	120	92-PMA-104-5	396524	6172053	70
94-PMA-051	320550	5993675	100	92-PMA-104-4	396524	6172053	200
94-PMA-049-2	320350	6009900	230	92-PMA-104-3	396524	6172053	160
94-PMA-049-1	320350	6009900	70	92-PMA-104-2	396524	6172053	150
94-PMA-047-6	314150	6003300	80	92-PMA-104-1	396524	6172053	120
94-PMA-047-5	314150	6003300	50	92-PMA-103	404435	6170819	170
94-PMA-047-4	314150	6003300	70	92-PMA-102	404435	6170819	180
94-PMA-047-3	314150	6003300	10	92-PMA-098	398470	6175752	350
94-PMA-047-2	314150	6003300	40	92-PMA-097-4	398470	6175752	350
94-PMA-047-1	314150	6003300	40	92-PMA-097-3	398470	6175752	320
94-PMA-040-3	692600	6016125	100	92-PMA-097-2	398470	6175752	310
94-PMA-040-2	692600	6016125	60	92-PMA-097-1	398470	6175752	310
94-PMA-040-1	692600	6016125	30	92-PMA-094	397233	6176443	210
94-PMA-035-3	309050	6018950	130	92-PMA-093-4	397233	6176443	200
94-PMA-035-2	309050	6018950	120	92-PMA-093-3	397233	6176443	210
94-PMA-035-1	309050	6018950	150	92-PMA-093-2	397233	6176443	190
94-PMA-029-9	395800	6176600	230	92-PMA-093-1	397233	6176443	160
94-PMA-029-8	395800	6176600	200	92-PMA-091-3	395310	6179375	160
94-PMA-029-7	395800	6176600	220	92-PMA-091-2	395310	6179375	190
94-PMA-029-6	395800	6176600	230	92-PMA-091-1	395310	6179375	180
94-PMA-029-5	395800	6176600	260	92-PMA-089-5	394553	6181184	270
94-PMA-029-4	395800	6176600	240	92-PMA-089-4	394553	6181184	160
94-PMA-029-3	395800	6176600	240	92-PMA-089-3	394553	6181184	170
94-PMA-029-2	395800	6176600	270	92-PMA-089-2	394553	6181184	260
94-PMA-029-17	395800	6176600	190	92-PMA-089-1	394553	6181184	300
94-PMA-029-16	395800	6176600	160	92-PMA-086	350234	6122904	40
94-PMA-029-15	395800	6176600	220	92-PMA-084	356738	6124713	190
94-PMA-029-10	395800	6176600	220	92-PMA-081-2	355308	6122845	100
94-PMA-029-1	395800	6176600	280	92-PMA-081-1	355308	6122845	110
94-PMA-025	395450	6052450	100	92-PMA-080-2	380360	6126584	280
94-PMA-024	398975	6049050	120	92-PMA-080-1	380360	6126584	170
94-PMA-023	400400	6047850	30	92-PMA-079	380558	6125570	190
94-PMA-022	403800	6048450	120	92-PMA-078-4	387699	6119727	90
94-PMA-021	407200	6046075	90	92-PMA-078-3	387699	6119727	100
94-PMA-019-5	416625	6044600	310	92-PMA-078-2	387699	6119727	90
94-PMA-019-4	416625	6044600	140	92-PMA-078-1	387699	6119727	110
94-PMA-019-3	416625	6044600	190	92-PMA-074	388805	6059789	180
94-PMA-019-2	416625	6044600	160	92-PMA-071-2	391802	6055798	130
94-PMA-019-1	416625	6044600	350	92-PMA-071-1	391802	6055798	110
94-PMA-017	417225	6043550	130	92-PMA-067-7	395029	6180582	160
94-PMA-016	431200	6021075	90	92-PMA-067-6	395029	6180582	220
94-PMA-013-3	430550	6021750	90	92-PMA-067-5	395029	6180582	170
94-PMA-013-2	430550	6021750	110	92-PMA-067-4	395029	6180582	180
94-PMA-009-6	403300	6050150	70	92-PMA-067-3	395029	6180582	250
94-PMA-009-5	403300	6050150	60	92-PMA-067-2	395029	6180582	250
94-PMA-009-4	403300	6050150	90	92-PMA-067-1	395029	6180582	330
94-PMA-009-3	403300	6050150	70	92-PMA-066-7	395100	6180332	200
94-PMA-009-2	403300	6050150	320	92-PMA-066-6	395100	6180332	230

94-PMA-009-1	403300	6050150	160	92-PMA-066-5	395100	6180332	310
94-PMA-006-5	429850	6022725	110	92-PMA-066-4	395100	6180332	360
94-PMA-006-4	429850	6022725	120	92-PMA-066-3	395100	6180332	190
94-PMA-006-2	429850	6022725	110	92-PMA-066-2	395100	6180332	200
94-PMA-006-1	429850	6022725	70	92-PMA-066-1	395100	6180332	200
94-PMA-005-3	419525	6011050	80	92-PMA-065-2	393846	6182047	410
94-PMA-005-2	419525	6011050	50	92-PMA-065-1	393846	6182047	200
94-PMA-005-1	419525	6011050	100	92-PMA-062-3	367826	6187773	110
94-PMA-004-3	421350	6006100	50	92-PMA-062-2	367826	6187773	130
94-PMA-004-2	421350	6006100	80	92-PMA-062-1	367826	6187773	110
94-PMA-004-1	421350	6006100	90	92-PMA-059	364511	6196437	460
93-PMA-737	314502	6039638	140	92-PMA-058	362648	6208257	600
93-PMA-735	337631	5996868	170	92-PMA-057	365987	6205321	550
93-PMA-733	335296	5999010	70	92-PMA-056	365080	6204224	170
93-PMA-732	343418	5997126	160	92-PMA-055	363546	6204744	200
93-PMA-731	340640	6006520	100	92-PMA-054	363546	6204744	190
93-PMA-730	341200	6006850	70	92-PMA-051	358617	6197024	90
93-PMA-729	341200	6007100	80	92-PMA-050	358617	6197024	100
93-PMA-728	341089	6007851	70	92-PMA-049	358766	6193579	70
93-PMA-727	342592	6020304	60	92-PMA-048	363535	6194495	100
93-PMA-726	347757	6017131	60	92-PMA-047	363535	6194495	110
93-PMA-725	339522	6022154	60	92-PMA-046	361716	6189436	100
93-PMA-724	343777	6021688	110	92-PMA-044	366793	6187300	490
93-PMA-723	343625	6028155	140	92-PMA-042	372947	6186055	180
93-PMA-722	347750	6024707	130	92-PMA-041	378647	6187723	180
93-PMA-721	339261	6032399	60	92-PMA-032-3	403452	6197119	120
93-PMA-720	337944	6029366	50	92-PMA-032-2	403452	6197119	110
93-PMA-719	336565	6022086	80	92-PMA-032-1	403452	6197119	130
93-PMA-718	330995	6028358	80	92-PMA-028-7	402128	6188605	1700
93-PMA-717	328000	6023730	110	92-PMA-028-6	402128	6188605	200
93-PMA-716	331096	6038774	140	92-PMA-028-5	402128	6188605	140
93-PMA-715	315284	6053637	120	92-PMA-028-4	402128	6188605	150
93-PMA-713-2	318907	6050231	110	92-PMA-028-3	402128	6188605	150
93-PMA-713-1	318907	6050231	110	92-PMA-028-2	402128	6188605	160
93-PMA-712	318910	6048598	90	92-PMA-028-1	402128	6188605	280
93-PMA-711	314124	6048847	90	92-PMA-019	390088	6199765	430
93-PMA-710	306919	6051043	110	92-PMA-016-4	385550	6188977	130
93-PMA-709	317833	6044167	280	92-PMA-016-3	385550	6188977	140
93-PMA-708	323438	6044974	50	92-PMA-016-2	385550	6188977	120
93-PMA-707	325201	6038353	90	92-PMA-016-1	385550	6188977	160
93-PMA-706	313100	6027450	120	92-PMA-014	390812	6186367	620
93-PMA-705	317637	6026033	120	92-PMA-011	408902	6056145	380
93-PMA-703-2	316779	6027896	90	92-PMA-010	407840	6056221	270
93-PMA-703-1	316779	6027896	80	92-PMA-009-2	406528	6056549	330
93-PMA-700	319800	6031550	130	92-PMA-009-1	406528	6056549	270
93-PMA-698	313900	6033300	170	92-PMA-008	404997	6056721	370
93-PMA-697	310270	6031643	150	92-PMA-007-3	403902	6056749	280
93-PMA-695	312748	6016599	140	92-PMA-007-2	403902	6056749	330
93-PMA-694-4	311906	6021172	230	92-PMA-007-1	403902	6056749	320
93-PMA-694-3	311906	6021172	320	92-PMA-006	402368	6056997	370
93-PMA-694-2	311906	6021172	200	92-PMA-005-3	401661	6057565	260
93-PMA-694-1	311906	6021172	150	92-PMA-005-2	401661	6057565	380
93-PMA-693	692900	6009900	170	92-PMA-005-1	401661	6057565	360
93-PMA-692	306625	6001769	60	92-PMA-004-2	403282	6050089	100

93-PMA-691	306625	6001769	80	92-PMA-004-1	403282	6050089	360
93-PMA-690-3	306443	5996684	310	92-PMA-002-3	406255	6046674	200
93-PMA-690-2	306443	5996684	270	92-PMA-002-2	406255	6046674	180
93-PMA-690-1	306443	5996684	250	92-PMA-002-1	406255	6046674	150
93-PMA-689	312431	5997295	60	92-PMA-001	414230	6040708	310
93-PMA-687	311618	6004482	70	91-PMA-431-6	375281	6147910	61
93-PMA-686-1	307900	6008600	80	91-PMA-431-5	375281	6147910	133
93-PMA-685	695300	6012200	90	91-PMA-431-4	375281	6147910	94
93-PMA-684	695050	6020100	130	91-PMA-431-3	375281	6147910	100
93-PMA-682	310124	6018671	50	91-PMA-431-2	375281	6147910	128
93-PMA-681	307943	6023210	210	91-PMA-431-1	375281	6147910	144
93-PMA-680	355282	6017650	90	91-PMA-430-4	374924	6148250	72
93-PMA-679	358659	6020759	60	91-PMA-430-3	374924	6148250	117
93-PMA-678	355492	6022555	70	91-PMA-430-2	374924	6148250	100
93-PMA-677	363276	6026983	80	91-PMA-430-1	374924	6148250	100
93-PMA-676	364738	6024160	60	91-PMA-429-6	374851	6148148	61
93-PMA-673	363540	6020300	60	91-PMA-429-5	374851	6148148	44
93-PMA-670-2	359365	6017275	100	91-PMA-429-4	374851	6148148	111
93-PMA-670-1	359365	6017275	90	91-PMA-429-3	374851	6148148	39
93-PMA-669	367770	6019321	80	91-PMA-429-2	374851	6148148	39
93-PMA-668	362351	6014470	60	91-PMA-429-1	374851	6148148	70
93-PMA-667	367870	6014670	50	91-PMA-427-1	370303	6151227	248
93-PMA-666	355818	6012148	130	91-PMA-426-3	368969	6151512	135
93-PMA-664-2	358262	6010807	60	91-PMA-426-2	368969	6151512	203
93-PMA-664-1	358262	6010807	80	91-PMA-426-1	368969	6151512	194
93-PMA-663	378432	6019263	70	91-PMA-425-4	368872	6151661	194
93-PMA-662	372581	6022338	70	91-PMA-425-3	368872	6151661	208
93-PMA-661	377561	6022416	70	91-PMA-425-2	368872	6151661	219
93-PMA-660	381891	6013651	80	91-PMA-425-1	368872	6151661	216
93-PMA-659	376400	6016400	110	91-PMA-424	366932	6153461	227
93-PMA-658	373963	6000059	110	91-PMA-423	367138	6153082	161
93-PMA-657	370901	6001249	80	91-PMA-422-4	374578	6148472	228
93-PMA-656	368396	6000257	100	91-PMA-422-3	374578	6148472	239
93-PMA-655-2	364462	5999316	70	91-PMA-422-2	374578	6148472	111
93-PMA-655-1	364462	5999316	110	91-PMA-422-1	374578	6148472	144
93-PMA-654	369506	5995421	190	91-PMA-421	374488	6148715	89
93-PMA-653	368330	5995385	340	91-PMA-420-6	374483	6148607	150
93-PMA-652	422172	6198106	110	91-PMA-420-5	374483	6148607	111
93-PMA-651	427233	6198853	110	91-PMA-420-4	374483	6148607	105
93-PMA-650	429992	6196304	170	91-PMA-420-3	374483	6148607	67
93-PMA-647	355173	6117455	80	91-PMA-420-2	374483	6148607	111
93-PMA-646	369529	6115094	60	91-PMA-420-1	374483	6148607	194
93-PMA-645	355453	6108002	80	91-PMA-419	374417	6148755	139
93-PMA-644-2	379043	6090769	280	91-PMA-418-4	374359	6148832	72
93-PMA-644-1	379043	6090769	200	91-PMA-418-2	374359	6148832	161
93-PMA-643	372065	6096404	570	91-PMA-418-1	374359	6148832	133
93-PMA-638	348930	6133902	120	91-PMA-417-3	373716	6148614	72
93-PMA-635	369827	6121230	380	91-PMA-417-2	373716	6148614	94
93-PMA-633	364786	6123266	800	91-PMA-417-1	373716	6148614	121
93-PMA-632	360484	6127665	1500	91-PMA-412-2	402924	6112315	383
93-PMA-631	360484	6127665	1150	91-PMA-412-1	402924	6112315	66
93-PMA-628-2	310724	6120198	100	91-PMA-411-8	402453	6110910	294
93-PMA-628-1	310724	6120198	110	91-PMA-411-7	402453	6110910	222
93-PMA-627	311707	6115783	140	91-PMA-411-6	402453	6110910	289

93-PMA-626	315104	6113566	120	91-PMA-411-5	402453	6110910	250
93-PMA-624	320496	6113044	90	91-PMA-411-4	402453	6110910	278
93-PMA-623	324109	6113572	100	91-PMA-411-3	402453	6110910	289
93-PMA-622	319167	6107805	160	91-PMA-411-2	402453	6110910	283
93-PMA-621	323138	6107232	190	91-PMA-411-1	402453	6110910	261
93-PMA-619	328119	6107748	170	91-PMA-410-3	403121	6110950	155
93-PMA-617	323744	6111337	190	91-PMA-410-2	403121	6110950	294
93-PMA-615	329257	6110213	110	91-PMA-410-1	403121	6110950	239
93-PMA-614	332180	6107421	520	91-PMA-409	402370	6110683	174
93-PMA-611	334529	6103576	130	91-PMA-408-4	402487	6110710	254
93-PMA-607	393182	6093549	750	91-PMA-408-3	402487	6110710	97
93-PMA-605	389488	6095875	950	91-PMA-408-2	402487	6110710	139
93-PMA-604	389488	6095875	950	91-PMA-408-1	402487	6110710	240
93-PMA-603	392911	6098331	1000	91-PMA-407	402487	6110710	134
93-PMA-601	387355	6100097	750	91-PMA-406-3	402477	6110655	300
93-PMA-599	383352	6098362	1200	91-PMA-406-2	402477	6110655	282
93-PMA-597	384695	6101999	700	91-PMA-406-1	402477	6110655	236
93-PMA-595	378429	6099545	2550	91-PMA-405-2	402426	6110619	337
93-PMA-593	376230	6096115	650	91-PMA-405-1	402426	6110619	129
93-PMA-592	374336	6101730	800	91-PMA-404	427432	6161007	23
93-PMA-590-2	338734	6108676	140	91-PMA-403	424716	6159267	162
93-PMA-590-1	338734	6108676	100	91-PMA-402	422421	6163382	37
93-PMA-587	342642	6112529	100	91-PMA-401	420425	6166323	60
93-PMA-586	349049	6112673	70	91-PMA-400	420425	6166323	55
93-PMA-584	345883	6115671	60	91-PMA-399	416600	6168756	27
93-PMA-583	350231	6115660	60	91-PMA-398	425373	6163318	22
93-PMA-580	346607	6118624	110	91-PMA-395-2	433078	6165999	86
93-PMA-578	353255	6122936	150	91-PMA-395-1	433078	6165999	43
93-PMA-576-3	355796	6121945	100	91-PMA-394	433018	6162529	62
93-PMA-573	352833	6114709	70	91-PMA-393	431294	6162290	111
93-PMA-572	352833	6114709	80	91-PMA-392	431294	6162290	111
93-PMA-570	355451	6116774	60	91-PMA-384	436211	6159071	106
93-PMA-569	358787	6117726	140	91-PMA-383	436211	6159071	111
93-PMA-567	360826	6114931	130	91-PMA-378	430803	6147054	268
93-PMA-564	369128	6115093	600	91-PMA-377	428929	6149065	860
93-PMA-562	365688	6112124	1050	91-PMA-376	429047	6151802	300
93-PMA-557	351654	6107329	90	91-PMA-375-2	429047	6151802	369
93-PMA-556	347170	6108490	90	91-PMA-375-1	429047	6151802	245
93-PMA-555	347170	6108490	100	91-PMA-374	419911	6102627	152
93-PMA-549	352923	6105342	110	91-PMA-373	421123	6102709	393
93-PMA-548	352923	6105342	130	91-PMA-372	420691	6101406	291
93-PMA-544	359481	6100365	150	91-PMA-371	434035	6148207	296
93-PMA-543	359481	6100365	170	91-PMA-370-3	432370	6152552	161
93-PMA-541	363266	6098327	110	91-PMA-370-2	432370	6152552	152
93-PMA-540	363266	6098327	120	91-PMA-370-1	432370	6152552	365
93-PMA-537	362180	6099054	180	91-PMA-368	435828	6152981	54
93-PMA-536	362180	6099054	190	91-PMA-367-2	435828	6152981	81
93-PMA-535	366691	6106859	390	91-PMA-367-1	435828	6152981	62
93-PMA-534	361829	6111528	110	91-PMA-366	402020	6174091	257
93-PMA-532	356173	6108111	80	91-PMA-365	402020	6174091	281
93-PMA-531-2	358189	6104445	150	91-PMA-364	403969	6174170	173
93-PMA-531-1	358189	6104445	60	91-PMA-363	406865	6173284	216
93-PMA-530-2	365186	6102551	850	91-PMA-362	406865	6173284	275
93-PMA-530-1	365186	6102551	420	91-PMA-359	412383	6170153	154

93-PMA-528	365889	6106288	800	91-PMA-358	412383	6170153	170
93-PMA-526	367285	6104179	400	91-PMA-356-9	402443	6110772	203
93-PMA-525-3	379568	6072809	170	91-PMA-356-8	402443	6110772	296
93-PMA-525-2	379568	6072809	190	91-PMA-356-7	402443	6110772	157
93-PMA-525-1	379568	6072809	150	91-PMA-356-6	402443	6110772	291
93-PMA-524-1	405230	6049260	210	91-PMA-356-5	402443	6110772	131
93-PMA-523-4	404850	6050317	270	91-PMA-356-4	402443	6110772	252
93-PMA-523-3	404850	6050317	280	91-PMA-356-3	402443	6110772	246
93-PMA-523-2	404850	6050317	270	91-PMA-356-20	402443	6110772	173
93-PMA-523-1	404850	6050317	250	91-PMA-356-2	402443	6110772	135
93-PMA-521-3	425865	6053708	180	91-PMA-356-19	402443	6110772	165
93-PMA-521-2	425865	6053708	250	91-PMA-356-18	402443	6110772	57
93-PMA-521-1	425865	6053708	200	91-PMA-356-17	402443	6110772	38
93-PMA-520-3	426114	6052796	300	91-PMA-356-16	402443	6110772	78
93-PMA-520-2	426114	6052796	250	91-PMA-356-15	402443	6110772	227
93-PMA-520-1	426114	6052796	200	91-PMA-356-14	402443	6110772	208
93-PMA-519-1	419783	6052734	500	91-PMA-356-13	402443	6110772	171
93-PMA-518-1	420436	6053394	600	91-PMA-356-12	402443	6110772	222
93-PMA-516-1	418519	6053545	850	91-PMA-356-11	402443	6110772	143
93-PMA-515-1	418061	6053036	340	91-PMA-356-10	402443	6110772	171
93-PMA-513-1	412637	6054748	750	91-PMA-356-1	402443	6110772	170
93-PMA-512-2	413574	6055751	550	91-PMA-355	433152	6155236	176
93-PMA-512-1	413574	6055751	600	91-PMA-354	433152	6155236	184
93-PMA-511-2	413880	6055320	800	91-PMA-353	429012	6158277	43
93-PMA-511-1	413880	6055320	1100	91-PMA-352	429012	6158277	49
93-PMA-510-1	417054	6054518	650	91-PMA-349-3	425638	6153185	245
93-PMA-509-1	417610	6054526	850	91-PMA-349-2	425638	6153185	305
93-PMA-508-1	410025	6055130	2000	91-PMA-349-1	425638	6153185	356
93-PMA-507-3	408289	6056229	280	91-PMA-348-6	424932	6157242	162
93-PMA-507-2	408289	6056229	270	91-PMA-348-5	424932	6157242	152
93-PMA-507-1	408289	6056229	170	91-PMA-348-4	424932	6157242	120
93-PMA-505-9	407833	6054661	21500	91-PMA-348-3	424932	6157242	116
93-PMA-505-8	407833	6054661	21500	91-PMA-348-2	424932	6157242	152
93-PMA-505-7	407833	6054661	13500	91-PMA-348-1	424932	6157242	152
93-PMA-505-6	407833	6054661	13500	91-PMA-347	414972	6163813	231
93-PMA-505-5	407833	6054661	17500	91-PMA-346-2	414972	6163813	180
93-PMA-505-10	407833	6054661	11500	91-PMA-346-1	414972	6163813	231
93-PMA-504-5	407833	6054661	14500	91-PMA-345	417047	6161159	125
93-PMA-504-4	407833	6054661	19500	91-PMA-344-3	417047	6161159	116
93-PMA-504-3	407833	6054661	11500	91-PMA-344-2	417047	6161159	120
93-PMA-504-2	407833	6054661	14000	91-PMA-344-1	417047	6161159	111
93-PMA-504-1	407833	6054661	13000	91-PMA-342	418675	6159934	393
93-PMA-296	388550	6123450	350	91-PMA-341	427009	6157040	244
93-PMA-295	388000	6123750	50	91-PMA-340	422060	6155738	314
93-PMA-294	417705	6098867	190	91-PMA-339	425425	6153025	370
93-PMA-292	426190	6134534	380	91-PMA-338	425425	6153025	370
93-PMA-291	424237	6136222	120	91-PMA-333-2	429076	6143794	176
93-PMA-290-2	424237	6136222	140	91-PMA-333-1	429076	6143794	152
93-PMA-290-1	424237	6136222	120	91-PMA-332	430970	6141502	180
93-PMA-289	425329	6135404	110	91-PMA-331-2	430970	6141502	148
93-PMA-288	425329	6135404	150	91-PMA-331-1	430970	6141502	143
93-PMA-287-1	425329	6135404	240	91-PMA-330-2	386652	6123430	181
93-PMA-286	425329	6135404	220	91-PMA-330-1	386652	6123430	281
93-PMA-285	425329	6135404	200	91-PMA-329-3	384583	6135080	76

93-PMA-284	425333	6135385	220	91-PMA-329-2	384583	6135080	62
93-PMA-283	407350	6090200	290	91-PMA-329-1	384583	6135080	46
93-PMA-282	407350	6090200	280	91-PMA-328-4	386199	6127626	180
93-PMA-278-3	404748	6054914	60	91-PMA-328-3	386199	6127626	166
93-PMA-278-2	404748	6054914	120	91-PMA-328-2	386199	6127626	148
93-PMA-278-1	404748	6054914	290	91-PMA-328-1	386199	6127626	116
93-PMA-256	360112	5998213	80	91-PMA-327	432752	6138658	217
93-PMA-255	359728	6002578	60	91-PMA-326	429142	6138164	79
93-PMA-253-3	355462	6004754	90	91-PMA-325	429142	6138164	74
93-PMA-253-2	355462	6004754	100	91-PMA-324	434529	6135984	167
93-PMA-253-1	355462	6004754	90	91-PMA-323-2	436143	6135601	227
93-PMA-252-2	359667	6004194	100	91-PMA-323-1	436143	6135601	192
93-PMA-252-1	359667	6004194	60	91-PMA-322	425329	6135404	143
93-PMA-251-2	360900	6009680	90	91-PMA-321	421928	6136744	46
93-PMA-251-1	360900	6009680	80	91-PMA-320	419691	6140441	68
93-PMA-245	404188	6005785	110	91-PMA-319	419691	6140441	102
93-PMA-243	398098	6005847	80	91-PMA-316	416649	6138171	152
93-PMA-242	398098	6005847	60	91-PMA-315	389558	6121168	259
93-PMA-241	401712	5999167	50	91-PMA-314-3	414629	6112179	213
93-PMA-240	422050	6002249	100	91-PMA-314-2	414629	6112179	213
93-PMA-239	418431	6002715	70	91-PMA-314-1	414629	6112179	300
93-PMA-238	430408	6003119	220	91-PMA-312	407245	6118807	184
93-PMA-237	428700	5999500	100	91-PMA-311	402932	6124022	213
93-PMA-233	397591	6003134	80	91-PMA-310	402932	6124022	202
93-PMA-228	430424	6187531	60	91-PMA-309	402496	6125542	59
93-PMA-227	429640	6182188	30	91-PMA-308	401007	6126098	111
93-PMA-226-3	429119	6183468	60	91-PMA-307	401007	6126098	78
93-PMA-226-2	429119	6183468	20	91-PMA-306-3	383135	6071529	68
93-PMA-226-1	429119	6183468	40	91-PMA-299	429035	6134347	176
93-PMA-225	430319	6193069	60	91-PMA-298-2	432993	6132676	153
93-PMA-224	426004	6192300	60	91-PMA-298-1	432993	6132676	236
93-PMA-223	426004	6192300	70	91-PMA-297	432385	6128950	208
93-PMA-222	433330	6184157	100	91-PMA-296	432385	6128950	222
93-PMA-217	359956	6164097	360	91-PMA-295	429724	6125965	250
93-PMA-216	359956	6164097	130	91-PMA-281	420760	6117718	121
93-PMA-214	355364	6159584	1100	91-PMA-280-2	418492	6116890	297
93-PMA-213	355364	6159584	1050	91-PMA-280-1	418492	6116890	186
93-PMA-211-2	352526	6154010	420	91-PMA-278	416751	6116262	1176
93-PMA-211-1	352526	6154010	350	91-PMA-277-3	416751	6116262	1764
93-PMA-210-5	351220	6156087	1050	91-PMA-277-1	416751	6116262	1000
93-PMA-210-4	351220	6156087	700	91-PMA-276-2	427389	6124371	153
93-PMA-210-3	351220	6156087	750	91-PMA-276-1	427389	6124371	166
93-PMA-210-2	351220	6156087	650	91-PMA-275	424563	6121320	236
93-PMA-210-1	351220	6156087	650	91-PMA-274	422875	6125655	333
93-PMA-209	350374	6158728	3200	91-PMA-273	422875	6125655	328
93-PMA-208	350374	6158728	2450	91-PMA-272	419006	6125611	356
93-PMA-207	348583	6158642	1250	91-PMA-271	415714	6125960	116
93-PMA-206	344143	6157977	290	91-PMA-270	415714	6125960	97
93-PMA-205	334985	6150556	180	91-PMA-269	422014	6124342	358
93-PMA-204	330381	6150693	120	91-PMA-266-5	416518	6116482	653
93-PMA-202-2	324125	6151609	230	91-PMA-266-4	416518	6116482	345
93-PMA-202-1	324125	6151609	110	91-PMA-266-3	416518	6116482	390
93-PMA-201	317355	6154583	100	91-PMA-266-2	416518	6116482	229
93-PMA-199	313266	6158060	90	91-PMA-266-1	416518	6116482	289

93-PMA-198-2	313266	6158060	80	91-PMA-265-2	386899	6122797	161
93-PMA-198-1	313266	6158060	90	91-PMA-265-1	386899	6122797	241
93-PMA-195	317241	6153654	90	91-PMA-264-3	412307	6116652	165
93-PMA-194-3	315451	6152848	170	91-PMA-264-2	412307	6116652	306
93-PMA-194-2	315451	6152848	240	91-PMA-264-1	412307	6116652	273
93-PMA-194-1	315451	6152848	180	91-PMA-262	395139	6116877	257
93-PMA-189	338392	6153234	260	91-PMA-261	392065	6118630	133
93-PMA-187	340759	6155755	380	91-PMA-260	401320	6116054	148
93-PMA-185	361278	6168511	100	91-PMA-259	403199	6117609	281
93-PMA-183-2	404449	6169501	140	91-PMA-256	404429	6119160	161
93-PMA-183-1	404449	6169501	160	91-PMA-253	403333	6120257	205
93-PMA-181-6	404172	6168975	150	91-PMA-252	403333	6120257	157
93-PMA-181-5	404172	6168975	120	91-PMA-250	404154	6122016	164
93-PMA-181-4	404172	6168975	140	91-PMA-249	403024	6123221	173
93-PMA-181-3	404172	6168975	70	91-PMA-245	407865	6120531	135
93-PMA-181-2	404172	6168975	150	91-PMA-242	414502	6120122	108
93-PMA-181-1	404172	6168975	140	91-PMA-241	415811	6120332	327
93-PMA-180-4	404380	6169187	100	91-PMA-240	411870	6120404	230
93-PMA-180-3	404380	6169187	150	91-PMA-239-4	411870	6120404	324
93-PMA-180-2	404380	6169187	170	91-PMA-239-3	411870	6120404	262
93-PMA-180-1	404380	6169187	150	91-PMA-239-2	411870	6120404	149
93-PMA-179-2	404100	6168643	130	91-PMA-239-1	411870	6120404	162
93-PMA-179-1	404100	6168643	140	91-PMA-238	411307	6120512	111
93-PMA-178-2	405049	6171041	270	91-PMA-235	412311	6122303	122
93-PMA-178-1	405049	6171041	170	91-PMA-233	408535	6123750	86
93-PMA-174	406908	6158592	90	91-PMA-232	413762	6122053	306
93-PMA-173	401746	6147118	50	91-PMA-231	414834	6122015	366
93-PMA-169-3	399901	6136680	60	91-PMA-230	419075	6121789	125
93-PMA-169-2	399901	6136680	60	91-PMA-229	419075	6121789	88
93-PMA-167-3	382211	6121618	160	91-PMA-228	411640	6124727	84
93-PMA-167-2	382211	6121618	160	91-PMA-224	420910	6119542	225
93-PMA-167-1	382211	6121618	170	91-PMA-218	421187	6114649	316
93-PMA-166	371255	6171190	300	91-PMA-217	422511	6110810	533
93-PMA-165	368625	6171276	280	91-PMA-215	422406	6106719	310
93-PMA-164	366856	6168490	130	91-PMA-214	422389	6104436	310
93-PMA-163	363431	6164157	380	91-PMA-212	419091	6098142	76
93-PMA-162	364411	6164883	570	91-PMA-210-3	416494	6099583	261
93-PMA-161	364907	6165476	330	91-PMA-210-2	416494	6099583	265
93-PMA-159	375377	6171654	350	91-PMA-210-1	416494	6099583	245
93-PMA-158	375377	6171654	330	91-PMA-209	413559	6101144	185
93-PMA-157	404269	6170440	150	91-PMA-208	418834	6093770	241
93-PMA-156	404269	6170440	150	91-PMA-207	418834	6093770	273
93-PMA-155	425915	6182014	70	91-PMA-206	422527	6088884	185
93-PMA-154	430099	6179890	90	91-PMA-205-3	428101	6089221	267
93-PMA-152	430763	6177824	40	91-PMA-205-2	428101	6089221	297
93-PMA-151	432919	6175474	50	91-PMA-205-1	428101	6089221	246
93-PMA-149-3	434123	6178907	60	91-PMA-202	432241	6092391	313
93-PMA-149-2	434123	6178907	50	91-PMA-201	431669	6089866	248
93-PMA-149-1	434123	6178907	50	91-PMA-200	433439	6088899	140
93-PMA-148	435137	6177929	90	91-PMA-199	425489	6091940	149
93-PMA-145-4	356247	6185771	160	91-PMA-198	425652	6085964	253
93-PMA-145-3	356247	6185771	60	91-PMA-197	422020	6083630	350
93-PMA-145-2	356247	6185771	60	91-PMA-196	420640	6079527	241
93-PMA-139	341051	6111095	80	91-PMA-195	420640	6079527	233

93-PMA-135	354205	6122810	80	91-PMA-194	416685	6082185	348
93-PMA-134	349542	6103685	140	91-PMA-192	417801	6086976	201
93-PMA-133	362905	6111512	120	91-PMA-191	416409	6088579	544
93-PMA-132	364468	6102358	160	91-PMA-190	418040	6083422	448
93-PMA-129	389240	6097896	900	91-PMA-189	415948	6083738	294
93-PMA-128	372634	6100818	950	91-PMA-188	411792	6086372	882
93-PMA-127-3	347967	6081668	80	91-PMA-186	408254	6089635	338
93-PMA-127-2	347967	6081668	70	91-PMA-185	408254	6089635	313
93-PMA-127-1	347967	6081668	80	91-PMA-183	402366	6090676	370
93-PMA-126-3	350522	6082130	110	91-PMA-182	428028	6081495	201
93-PMA-126-2	350522	6082130	100	91-PMA-181	429923	6081288	253
93-PMA-126-1	350522	6082130	100	91-PMA-180	432325	6079829	189
93-PMA-124	353613	6084034	120	91-PMA-179	432325	6079829	189
93-PMA-121	356755	6086864	180	91-PMA-178	432474	6081232	245
93-PMA-119	351747	6090509	90	91-PMA-176	428983	6078023	273
93-PMA-118-2	351747	6090509	90	91-PMA-175	425189	6078285	241
93-PMA-118-1	351747	6090509	90	91-PMA-174-2	425189	6078285	273
93-PMA-113	340868	6107132	90	91-PMA-174-1	425189	6078285	225
93-PMA-1100	410868	6170668	360	91-PMA-173	412512	6070824	326
93-PMA-1098	422426	6159171	410	91-PMA-172	405971	6077643	318
93-PMA-1097	423463	6154137	900	91-PMA-167	424483	6072769	305
93-PMA-1096	425368	6154458	320	91-PMA-166	427707	6074447	329
93-PMA-1095-2	432966	6165680	80	91-PMA-165	427707	6074447	302
93-PMA-1095-1	432966	6165680	80	91-PMA-164	433100	6073815	334
93-PMA-1093-2	412350	6169892	210	91-PMA-162	435921	6072035	261
93-PMA-1093-1	412350	6169892	230	91-PMA-161	430936	6069946	277
93-PMA-1092-2	412338	6170035	200	91-PMA-160	405769	6072505	370
93-PMA-1092-1	412338	6170035	180	91-PMA-159	402511	6074745	382
93-PMA-1090-4	412528	6170349	70	91-PMA-158	411817	6070896	189
93-PMA-1090-3	412528	6170349	170	91-PMA-157	411817	6070896	201
93-PMA-1090-2	412528	6170349	170	91-PMA-156	416697	6069315	285
93-PMA-1090-1	412528	6170349	240	91-PMA-154	414936	6064636	446
93-PMA-1089	412711	6170412	130	91-PMA-153	417493	6073815	249
93-PMA-1087	420036	6166374	50	91-PMA-150-5	421895	6069957	261
93-PMA-1085	417397	6167913	30	91-PMA-150-4	421895	6069957	226
93-PMA-1084	416966	6168294	50	91-PMA-150-3	421895	6069957	264
93-PMA-1083-2	416574	6168604	80	91-PMA-150-2	421895	6069957	235
93-PMA-1083-1	416574	6168604	40	91-PMA-150-1	421895	6069957	221
93-PMA-1082	416157	6168914	60	91-PMA-149	422530	6070023	187
93-PMA-1081	415780	6169256	90	91-PMA-148	425744	6068459	267
93-PMA-1080	415497	6169603	60	91-PMA-147	425744	6068459	255
93-PMA-108-3	339183	6105858	100	91-PMA-144	431621	6052647	348
93-PMA-108-2	339183	6105858	110	91-PMA-140	402222	6062736	138
93-PMA-108-1	339183	6105858	110	91-PMA-139	402222	6062736	132
93-PMA-1079	415251	6169870	50	91-PMA-138	404285	6059403	245
93-PMA-1078	415014	6170288	60	91-PMA-137	404285	6059403	221
93-PMA-1077	420977	6165328	100	91-PMA-135	415254	6054300	370
93-PMA-1076	422134	6163851	190	91-PMA-133	413499	6054273	201
93-PMA-1075	423796	6163638	30	91-PMA-132	413713	6054719	435
93-PMA-1074	423207	6162064	130	91-PMA-131	414955	6052804	276
93-PMA-1072	427660	6163637	100	91-PMA-129	413394	6052877	441
93-PMA-1071	427070	6161830	40	91-PMA-128	410801	6052696	143
93-PMA-1070	425944	6160545	100	91-PMA-126	409740	6054573	823
93-PMA-107-3	339917	6104871	90	91-PMA-125	410129	6055860	230

93-PMA-107-2	339917	6104871	90	91-PMA-123	424559	6033122	248
93-PMA-107-1	339917	6104871	90	91-PMA-121	409826	6056791	210
93-PMA-1069	424515	6158056	140	91-PMA-119	413880	6055320	823
93-PMA-1068	412979	6171017	100	91-PMA-118	415481	6054897	390
93-PMA-1067-2	413450	6171525	200	91-PMA-117	415829	6054343	620
93-PMA-1067-1	413450	6171525	210	91-PMA-115	419659	6051979	187
93-PMA-1066	435182	6147919	220	91-PMA-112	429608	6040103	207
93-PMA-1065	432992	6149324	440	91-PMA-110	433465	6033405	227
93-PMA-1064	435301	6162073	140	91-PMA-108	434987	6030129	175
93-PMA-1063	435380	6163362	100	91-PMA-107	428745	6027647	227
93-PMA-1061	436847	6162785	110	91-PMA-106	405261	6030766	175
93-PMA-1060	438200	6162000	90	91-PMA-105	403889	6030606	132
93-PMA-1059	437200	6161600	90	91-PMA-104	403389	6032244	92
93-PMA-1058	437900	6159025	50	91-PMA-103-2	403389	6032244	83
93-PMA-1057	436404	6159564	110	91-PMA-103-1	403389	6032244	89
93-PMA-1055	435797	6160983	160	91-PMA-098	407594	6054998	2000
93-PMA-1052	435352	6160378	200	91-PMA-097	404546	6029812	97
93-PMA-1049	427233	6156782	150	91-PMA-096	429515	6036588	92
93-PMA-1048	427233	6156782	150	91-PMA-094-1	429847	6022731	95
93-PMA-1047-2	427233	6156782	110	91-PMA-093	433843	6014633	86
93-PMA-1047-1	429948	6155404	90	91-PMA-092	431176	6016528	89
93-PMA-1046-2	432053	6156014	250	91-PMA-090	337747	6054117	118
93-PMA-1046-1	432053	6156014	130	91-PMA-089	335237	6058072	123
93-PMA-1045-1	440625	6167300	130	91-PMA-086	340047	6051330	149
93-PMA-1044	440800	6164950	80	91-PMA-085-2	345255	6049331	72
93-PMA-1043	443200	6167400	90	91-PMA-085-1	345255	6049331	86
93-PMA-1041	438900	6165700	110	91-PMA-083-2	350514	6048834	129
93-PMA-1040	437825	6165300	150	91-PMA-083-1	350514	6048834	92
93-PMA-1039-2	438400	6167325	270	91-PMA-082-2	359133	6047257	98
93-PMA-1039-1	438400	6167325	130	91-PMA-082-1	359133	6047257	60
93-PMA-1038	436556	6166928	110	91-PMA-081	359883	6047325	92
93-PMA-1037	432732	6163574	40	91-PMA-080	364189	6052021	89
93-PMA-1034	431751	6152878	60	91-PMA-079	362147	6043376	123
93-PMA-1033	428370	6153107	110	91-PMA-075	369144	6046903	172
93-PMA-1032	430520	6151822	600	91-PMA-074	369222	6042906	118
93-PMA-1031	430984	6147210	600	91-PMA-073-4	374034	6042982	118
93-PMA-1030	434286	6146767	140	91-PMA-073-3	374034	6042982	103
93-PMA-1029	434286	6146767	130	91-PMA-073-2	374034	6042982	106
93-PMA-1028	432848	6146939	800	91-PMA-073-1	374034	6042982	106
93-PMA-1027	432053	6148137	650	91-PMA-071	379643	6043044	184
93-PMA-1026	431238	6149404	800	91-PMA-070	377044	6053150	95
93-PMA-1024	430887	6150941	850	91-PMA-069-2	379353	6049882	144
93-PMA-1023	434133	6149760	130	91-PMA-069-1	379353	6049882	118
93-PMA-1022-2	433590	6151460	310	91-PMA-068	380643	6049042	106
93-PMA-1022-1	433590	6151460	230	91-PMA-065	386658	6047393	118
93-PMA-1021	432166	6151023	270	91-PMA-064	391570	6034598	77
93-PMA-1020-5	433002	6153194	180	91-PMA-063	385017	6042493	109
93-PMA-1020-4	433002	6153194	200	91-PMA-060	390413	6039078	112
93-PMA-1020-3	433002	6153194	170	91-PMA-059	393540	6032872	100
93-PMA-1020-2	433002	6153194	170	91-PMA-058	393540	6032872	98
93-PMA-1020-1	433002	6153194	150	91-PMA-054	391371	6020134	192
93-PMA-1019	433138	6154165	140	91-PMA-053	395267	6021199	106
93-PMA-1017	441450	6150800	90	91-PMA-049	419960	6034819	86
93-PMA-1012	438830	6152000	90	91-PMA-046	428080	6025343	92

93-PMA-1011	437290	6151790	270	91-PMA-042	404161	6003001	35
93-PMA-101-2	349078	6103872	160	91-PMA-041	405838	6008140	119
93-PMA-101-1	349078	6103872	150	91-PMA-040	408365	6004567	81
93-PMA-1009	437680	6153970	110	91-PMA-038	414216	6001823	77
93-PMA-1006-2	436815	6154673	70	91-PMA-031	418693	5998558	46
93-PMA-1006-1	436815	6154673	60	91-PMA-028	404139	6009935	40
93-PMA-1005	436631	6153805	110	91-PMA-027	403131	6015002	60
93-PMA-1004	435150	6153412	80	91-PMA-026	403131	6015002	69
93-PMA-1003-4	433800	6154182	110	91-PMA-023	399676	6012594	181
93-PMA-1003-3	433800	6154182	230	91-PMA-019	408947	6014149	115
93-PMA-1003-2	433800	6154182	140	91-PMA-017	412910	6012375	118
93-PMA-1003-1	433800	6154182	190	91-PMA-016	414998	6007847	98
93-PMA-1002	435169	6155598	110	91-PMA-009	426654	6008581	164
93-PMA-1001-2	434021	6155265	300	91-PMA-007	423255	6009706	210
93-PMA-1001-1	434021	6155265	150	91-PMA-003	418764	6017013	224
93-PMA-098	358348	6107790	130	90-PMA-229	411595	6045244	350
93-PMA-097	358348	6107790	120	90-PMA-226	418481	6042324	157
93-PMA-093-8	363974	6088057	80	90-PMA-224	425931	6063602	126
93-PMA-093-7	363974	6088057	80	90-PMA-223	426099	6057358	134
93-PMA-093-6	363974	6088057	80	90-PMA-220	426347	6051879	177
93-PMA-093-5	363974	6088057	80	90-PMA-218	411593	6052565	160
93-PMA-093-4	363974	6088057	120	90-PMA-215	419282	6051878	590
93-PMA-093-3	363974	6088057	140	90-PMA-210	428986	6039610	258
93-PMA-093-2	363974	6088057	110	90-PMA-206	422457	6037393	126
93-PMA-093-1	363974	6088057	60	90-PMA-204	399267	6029508	100
93-PMA-091	352094	6100722	130	90-PMA-198	401699	6023768	89
93-PMA-089	343666	6101951	160	90-PMA-195	406135	6025722	83
93-PMA-088	348308	6097640	210	90-PMA-189	418159	6014636	132
93-PMA-086	352188	6094257	320	90-PMA-188	421398	6006753	86
93-PMA-085	357162	6091354	230	90-PMA-186	424050	6000750	77
93-PMA-083	361153	6089737	170	90-PMA-182-2	302323	6016268	74
93-PMA-082	356667	6097568	140	90-PMA-182-1	302323	6016268	51
93-PMA-079	369514	6093566	170	90-PMA-178	302890	6023166	149
93-PMA-077	364286	6095544	200	90-PMA-176	309028	6025827	89
93-PMA-075	362334	6094595	150	90-PMA-175	317223	6009549	97
93-PMA-074	365012	6088473	150	90-PMA-172	336525	6013558	43
93-PMA-073	365012	6088473	140	90-PMA-171	331487	6016336	49
93-PMA-072	366422	6090049	120	90-PMA-169	340660	6013629	29
93-PMA-071	366422	6090049	120	90-PMA-165	322690	6011262	134
93-PMA-069	365970	6092243	150	90-PMA-161	338492	6018818	40
93-PMA-068	365970	6092243	170	90-PMA-160	340513	6026351	80
93-PMA-066-2	370938	6090792	170	90-PMA-159	342202	6031156	57
93-PMA-066-1	370938	6090792	160	90-PMA-153	334841	6025220	54
93-PMA-065-2	370938	6090792	260	90-PMA-150	306116	5992863	89
93-PMA-065-1	370938	6090792	260	90-PMA-146-2	322057	5997154	77
93-PMA-059-4	389570	6072684	290	90-PMA-144	328307	5998420	43
93-PMA-059-3	389570	6072684	250	90-PMA-142	319257	6039920	69
93-PMA-059-2	389570	6072684	290	90-PMA-141	325614	6042079	80
93-PMA-058-2	390021	6073112	90	90-PMA-139	325976	6034357	94
93-PMA-058-1	390021	6073112	120	90-PMA-136	326862	6028407	60
93-PMA-055	365828	6084144	110	90-PMA-135	321324	6020981	83
93-PMA-054	371355	6085097	260	90-PMA-133	307369	6030624	97
93-PMA-053	374389	6083345	290	90-PMA-131	313781	6023678	117
93-PMA-052	375211	6088139	160	90-PMA-127	358613	6014104	49

93-PMA-051	381009	6087550	250	90-PMA-125	352538	6010334	19
93-PMA-049	386473	6086490	540	90-PMA-123	347967	6007612	37
93-PMA-047	384641	6083742	220	90-PMA-122	340902	6006695	56
93-PMA-046	383961	6078861	170	90-PMA-118	321550	6008225	114
93-PMA-044	388219	6078657	280	90-PMA-117	322470	6002347	101
93-PMA-043	384105	6075455	150	90-PMA-115	329126	6001882	53
93-PMA-039	386450	6073900	110	90-PMA-107	372741	6024112	29
93-PMA-037-5	389800	6073050	120	90-PMA-105	381610	6019759	101
93-PMA-037-4	389800	6073050	80	90-PMA-103	381915	6012881	141
93-PMA-037-3	389800	6073050	70	90-PMA-101	334583	5999953	37
93-PMA-037-2	389800	6073050	80	90-PMA-099	335667	5991943	90
93-PMA-037-1	389800	6073050	80	90-PMA-098	343335	5991272	98
93-PMA-036	391032	6073878	190	90-PMA-097	341103	5992346	210
93-PMA-034	389490	6070216	110	90-PMA-095	347014	5998248	98
93-PMA-033	394043	6070540	170	90-PMA-089	374822	6000867	43
93-PMA-030	392463	6065312	250	90-PMA-088	378698	6005187	27
93-PMA-026	394631	6061039	110	90-PMA-086	371597	5998522	96
93-PMA-024	367608	6075389	100	90-PMA-081	371702	5987831	88
93-PMA-022	372925	6074494	120	90-PMA-078	367833	5986316	80
93-PMA-019	370120	6072262	120	90-PMA-077	425154	5996460	59
93-PMA-017	372782	6066902	110	90-PMA-073-1	432309	5993763	120
93-PMA-016	376901	6064176	140	90-PMA-068	413805	5985039	61
93-PMA-011	377554	6070561	120	90-PMA-065	406964	5996222	48
93-PMA-005	380474	6066045	270	90-PMA-063	389181	6006489	56
93-PMA-003	423361	6009667	200	90-PMA-062	389099	6008437	90
93-PMA-002	423361	6009667	220	90-PMA-057	392384	6004880	69
93-PMA-001	418466	6017032	290	90-PMA-055	395462	6000553	48
92-PMA-119	386054	6185143	380	90-PMA-052	391664	5996019	59
92-PMA-118	386054	6185143	320	90-PMA-050	366571	5990468	29
92-PMA-117	386195	6184917	720	90-PMA-036	396999	5988985	74
92-PMA-116	390118	6182849	230	90-PMA-035	393900	5987800	88
				90-PMA-028-2	395586	5993929	80
				90-PMA-028-1	395586	5993929	64
				90-PMA-026	389266	5991212	67
				90-PMA-020	383163	5990997	72
				90-PMA-009	383240	5995101	61

Appendix 4-1

1988 British Columbia Regional Geochemical Survey
NTS 92L/102I - Bute Inlet/Cape Scott

British Columbia Regional Geochemical Survey RGS-23.
Geological Survey of Canada Open File 2040.

INTRODUCTION

The 1988 reconnaissance survey was undertaken by the Geological Survey Branch of the British Columbia Ministry of Energy, Mines and Petroleum Resources with funding supplied in part under the Canada - British Columbia Mineral Development Agreement (1985 - 1989).

Open file package BC RGS 23 (Alert Bay/Cape Scott - NTS 92L/102I) is one of three regional geochemical open files covering northern Vancouver Island and the adjacent mainland which were sampled in 1988. Moss-mat sediment samples were collected on Vancouver Island, while stream sediments were collected on the mainland. Computer files contained on this floppy diskette present results of moss mat sediment, stream sediment and stream water analyses for 22 elements

Contracts were let to the following companies on a technically acceptable competitive bid basis and were managed by the staff of the Applied Geochemistry Subsection:

COLLECTION - McElhanney Engineering Services Limited, Vancouver, B.C.

PREPARATION - Kamloops Research and Assay Ltd, Surrey, B.C.

ANALYSES - Chemex Laboratories, North Vancouver, B.C. (sediments)
- Barringer Magenta Labs, Calgary, Alta (waters)

SAMPLE COLLECTION

In total 1140 sites were sampled for water and sediment at a density averaging 1 site per 10.5 sq km. Moss-mat sediment was collected at 73 sites on 102I and 911 sites on 92L. Stream sediments were taken from 156 sites on 92L. Seventy eight percent were collected by truck and boat; the remaining 22% by helicopter. Moss-mat sediment samples weighing 1-2 kilograms were scraped from boulders and logs found within the active stream channel and placed in large kraft-paper sample bags. Stream sediment samples ideally comprise 2-4 kg of sand size and finer inorganic material collected from low energy sites within the stream. Due to the rapid paced style of RGS sampling, large kraft-paper sample bags were used to ensure sufficient fines were collected. Water samples were collected in 250 ml nalgene bottles. Observations regarding sample material. sample site and the surrounding area were recorded in the field. To aid in follow up, aluminum identification tags inscribed with an RGS sample number were used to mark every sample site. Numerous field checks were conducted by staff geochemists to monitor, control and assess sample collection procedures.

SAMPLE PREPARATION

Field processing of the sediment samples was completed at a central depot located in Campbell River. Sediment samples were air-dried, first on open air racks, and then within a heated (<50C) drying shed. Moss-trapped sediment was liberated from plant fibres by pounding dried samples with a wooden mallet. All samples were then sieved to minus 18 mesh (approximately 1 mm) to reduce sample weight and to determine the fines content. Sample quality checks were run by routinely sieving to minus 80 mesh (<177 microns) 1 sample in each block of 20, plus any samples suspected of low fines content. Samples found to be deficient in fines (<40 gm) were resampled. Field prepared samples were then shipped to the contracted sample preparation laboratory for further sieving to minus 80 mesh (<177 microns). At this time, control reference samples and blind duplicate samples were inserted into each block of twenty sediment samples. For water samples, only control reference samples were inserted into the block.

SAMPLE ANALYSIS

Element	Units	Detection Limits	Sample Weight	Digestion Technique	Determination Method
Mercury	ppb	10 ppb	0.5 gm	20 ml HNO3 & 1 ml HCl	10% stannous sulphate added to evolve mercury vapour Atomic Absorption Spectrometer determination (after Jonasson et al.. 1973)

Appendix 4-2

P_LABEL	BASIN	Rot (degrees)	HG (ppb)	P_LABEL	BASIN	Rot (degree	HG (ppb)
4888	889024	138.39	6200	4990	889018	140.42	110
4962	889024	0.56	6200	4868	889018	139.74	110
4853	889024	0.49	6200	3007	883240	134.47	110
583	883265	165.53	4800	205	881120	134	110
1892	883265	137.63	4800	2021	883240	133.54	110
1910	883265	137.63	4800	2023	883240	133.54	110
3932	883265	136.89	4800	3255	881245	130.31	110
1909	883265	133.71	4800	4225	883288	127.38	110
1911	883266	131.72	4100	2886	883288	127.38	110
2962	883266	131.72	4100	444	881196	127.34	110
2950	883266	128.6	4100	3247	881196	127.32	110
2961	883266	128.6	4100	505	881245	125.42	110
585	883266	127.3	4100	3630	881245	125.41	110
2196	883266	104.53	4100	3048	881154	124.95	110
3940	883266	104.5	4100	3031	881154	124.94	110
2951	883266	104.5	4100	2571	883056	124.79	110
2197	883266	97.55	4100	4898	889018	122.34	110
2198	883266	97.34	4100	1862	883288	116.57	110
523	881091	55.02	3600	1887	883056	115.43	110
4891	889026	180	2800	2885	883288	112.48	110
4995	889026	178.29	2800	1710	883288	112.48	110
4871	889026	137.26	2800	2111	883288	111.9	110
1065	889026	128.32	2800	531	883288	111.9	110
4875	889026	123.81	2800	3411	883137	105.54	110
1069	889026	0.8	2800	3004	883240	99.35	110
1071	889026	0.23	2800	3537	883240	99.34	110
4870	889026	0.2	2800	815	883012	79.71	110
3701	881092	134.97	2600	5036	883012	79.71	110
4367	881092	57.43	2600	701	883012	76.7	110
3703	881092	57.41	2600	2051	883056	71.42	110
3705	881092	55.03	2600	4290	883056	71.42	110
2099	881092	55.02	2600	4303	883056	68.61	110
438	881053	116.99	2300	1951	883056	67.68	110
3207	881053	116.98	2300	4301	883056	67.48	110
4861	889008	133.98	2100	4293	883056	67.41	110
3993	883093	150.36	2000	415	883056	67.14	110
3994	883093	143.35	2000	4295	883056	67.09	110
5020	883093	143.23	2000	4302	883056	65.27	110
2044	883093	117.57	2000	412	883056	65.22	110
3997	883093	83.52	2000	3083	883056	65.22	110
2243	883093	67.9	2000	3071	883056	65.15	110
2242	883093	64.88	2000	1957	883056	65.15	110
2246	883093	45	2000	643	883056	64.98	110
4475	883193	164.52	1900	2926	883056	64.27	110
3923	883263	142.77	1900	4299	883056	64.27	110
2205	883263	142.77	1900	1956	883056	62.77	110
2955	883263	142.66	1900	62	883056	62.63	110
3944	883263	142.66	1900	2567	883056	60.95	110

2956	883263	141.23	1900	3539	883240	60.48	110
2949	883263	141.15	1900	3022	883240	59.59	110
1186	883263	141.15	1900	3548	883240	59.59	110
2966	883263	133.99	1900	1469	883240	59.04	110
3953	883263	133.84	1900	3442	883240	58.46	110
1907	883263	133.84	1900	3005	883240	57.64	110
1893	883263	130.85	1900	422	883240	57.54	110
3952	883263	130.83	1900	1975	881196	51.2	110
2200	883263	109.28	1900	1934	883240	50.35	110
2959	883263	104.64	1900	3006	883240	50.35	110
3955	883263	97.55	1900	96	881196	47.89	110
2202	883263	97.53	1900	1976	881196	47.89	110
3956	883263	87.02	1900	568	883218	44.1	110
3946	883263	60.26	1900	1094	883218	44.09	110
3924	883263	60.26	1900	3434	883240	41.17	110
4157	883263	59.57	1900	3024	883240	40.12	110
2187	883263	59.57	1900	1468	883240	40.1	110
461	881393	45.75	1900	3001	883240	34.61	110
459	881393	45.75	1900	142	883240	34.61	110
458	881393	44.09	1900	1471	883240	34.61	110
4519	883246	157.69	1100	4297	883056	29.74	110
2721	883246	147.58	1100	408	881154	8.87	110
624	883246	141.51	1100	725	881328	4.07	110
657	883246	141.44	1100	4544	883208	178.83	100
4716	883019	74.19	1000	510	881051	174.77	100
4885	888013	139.23	930	4143	883085	174.41	100
4851	889036	134.87	900	385	883080	168.26	100
4876	889036	45.27	900	3740	883080	167.98	100
3451	881157	56.07	720	265	883080	167.98	100
3452	881157	56.07	720	853	881342	167.6	100
2090	881157	48.57	720	301	883305	161.36	100
3685	881157	48.53	720	679	883305	160.88	100
5001	889006	139.9	710	672	883305	159.33	100
2483	889004	128.21	670	339	883215	159.03	100
4998	889004	121.24	670	4965	883068	152.91	100
3621	881230	28.56	600	3610	883186	148.71	100
2101	881230	28.56	600	480	881269	147.08	100
4423	881076	50.56	590	2072	883186	146.44	100
653	883211	155.77	580	3609	883186	146.44	100
4751	883211	155.77	580	2915	883293	143.73	100
4164	883211	149.87	580	2878	883293	143.73	100
4750	883211	120.96	580	4884	888008	143.7	100
4748	883211	120.94	580	381	883080	143.17	100
4501	881072	107.98	560	4561	881140	142.65	100
2708	881072	107.97	560	4863	888008	139.81	100
2709	881072	106.99	560	4562	881140	137.83	100
567	881072	106.99	560	581	883071	134.58	100
2681	881078	148.01	520	4601	883436	130.9	100
1515	881078	66.87	520	446	883165	129.45	100

1516	881078	66.87	520	692	881177	126.68	100
2067	881078	66.87	520	3608	883186	125.42	100
2	881078	66.87	520	818	881028	124.98	100
3614	881078	66.85	520	12	881028	124.98	100
3613	881078	66.85	520	15	881028	124.98	100
825	881107	170.22	510	295	881028	124.98	100
10	881107	170.22	510	2843	883072	124:5	100
3637	883188	161.81	500	530	883071	124.43	100
3616	881074	64.89	500	4803	881177	124.32	100
2763	881074	51.43	500	2479	881177	124.31	100
741	883236	130.35	480	447	883186	121.17	100
4214	883236	130.34	480	3047	883186	120.61	100
4217	883236	130.33	480	704	883284	112.49	100
3055	883236	105.12	480	4555	881144	111.17	100
3511	883236	105.09	480	4556	881144	111.17	100
3053	883236	105.09	480	1039	883055	110.98	100
2944	883236	103.26	480	751	883055	110.31	100
2511	883236	103.26	480	3735	883284	107.67	100
3056	883236	72.58	480	240	883055	106.88	100
3961	883236	70.59	480	387	883055	106.85	100
1209	883236	70.35	480	1040	883055	106.85	100
896	883236	53.36	480	4584	883136	106.58	100
4670	883158	143.5	460	2877	883293	106.02	100
2330	883158	143.47	460	308	883304	104.39	100
2136	883237	172.9	450	499	883304	102.7	100
589	883237	167.35	450	708	883304	102.65	100
771	881160	55.81	420	2876	883080	85.8	100
3707	881160	52.47	420	1127	883205	80.55	100
5021	883092	173.27	400	4533	883205	80.52	100
5019	883092	170.64	400	4551	883205	77.08	100
3468	883060	129.14	380	19	883205	75.39	100
4076	883060	128.3	380	2743	883205	75.33	100
2294	883060	128.3	380	4534	883205	75.31	100
3475	883060	126.44	380	938	883205	75.31	100
4265	883060	126.29	380	2746	883205	75.31	100
1428	883060	126.29	380	899	883128	73.91	100
4266	883060	126.29	380	1212	883057	73.91	100
545	883060	126.25	380	3062	883128	73.81	100
3525	883060	125.77	380	3067	883127	73.61	100
1889	883060	125.55	380	4285	883127	72.98	100
144	883060	125.54	380	4284	883127	71.57	100
4077	883060	125.54	380	3066	883128	71.27	100
145	883060	106.49	380	3061	883057	71.14	100
4055	883060	78.5	380	3065	883127	71.13	100
4051	883060	75.94	380	1946	883128	71.05	100
4079	883060	72.21	380	481	883272	70.89	100
2319	883060	72.13	380	1932	883272	70.87	100
1215	883060	72.04	380	4709	883203	70.31	100
2035	883060	72.04	380	2747	883205	70.31	100

4049	883060	71.42	380	1033	883205	70.31	100
604	883060	71.39	380	4159	883208	69.26	100
4264	883060	69.82	380	4543	883208	69.26	100
3080	883060	61.59	380	4537	883208	68.91	100
484	883060	61.53	380	4161	883208	68.91	100
2314	883060	61.51	380	1129	883208	68.86	100
3465	883060	58.01	380	2791	883208	68.86	100
1433	883060	58.01	380	454	883208	68.84	100
2317	883060	57.48	380	2792	883208	68.84	100
2320	883060	57.45	380	1211	883057	68.84	100
2292	883060	55.56	380	3068	883057	68.66	100
1016	883060	55.48	380	2563	883057	68.62	100
4081	883060	47.66	380	2052	883057	68.58	100
2121	883289	133.86	370	4535	883203	66.59	100
1551	883289	133.86	370	2788	883203	66.47	100
3756	883289	123.12	370	47	883085	65	100
3972	883289	123.1	370	3058	883057	64.07	100
2223	883289	116.47	370	4538	883208	62.57	100
3751	883289	116.46	370	2427	881204	61.18	100
2112	883289	114.18	370	2426	881204	61.18	100
3757	883289	114.18	370	2046	881204	60.41	100
2222	883289	114.02	370	814	883208	53.86	100
1550	883289	110	370	2365	883085	53.73	100
3749	883289	109.96	370	5014	883085	53.73	100
4413	883196	134.6	360	766	881204	52.7	100
779	883196	134.59	360	4685	881204	52.7	100
777	883196	129.62	360	4338	881204	51.94	100
1122	883196	129.6	360	2047	881204	51.86	100
517	883196	16.38	360	2048	881204	51.86	100
432	883096	142.82	350	1348	883208	49.99	100
4018	881158	122.54	340	1130	883208	49.85	100
4017	881158	122.54	340	655	883208	49.85	100
3043	881158	38.69	340	4878	889037	43.75	100
1877	883292	179.06	320	1783	881204	41.65	100
3315	883248	175.8	320	493	881204	41.65	100
2468	883248	175.8	320	4339	881204	41.6	100
3485	881159	169.21	320	4916	889039	38.63	100
487	881159	158.23	320	4917	889039	35.84	100
4935	881256	122.74	320	13	881030	24.73	100
2492	881256	122.74	320	822	881014	24.38	100
2261	881159	119.33	320	14	881030	22.78	100
2260	881159	118.4	320	294	881030	22.78	100
2228	883292	110	320	291	881030	19.38	100
895	881159	37.63	320	340	881030	19.38	100
3046	881159	31.12	320	1128	883205	11.59	100
1205	881159	31.07	320	2744	883205	11.42	100
4013	881159	27.62	320	4536	883205	11.39	100
2225	883292	7.05	320	1985	883205	11.39	100
2900	883292	4.32	320	9	881325	7.44	100

2227	883292	4.32	320	3306	883205	7.41	100
3970	883292	4.14	320	112	883205	7.34	100
4931	888037	132.1	300	3304	883205	7.34	100
826	883222	138.34	290	4545	883208	2.82	100
455	883222	129.97	290	286	883205	2.82	100
3412	883298	105.54	280	4162	883208	2.82	100
2964	883235	130.52	270	2446	883209	178.54	90
393	883235	114.78	270	2447	883209	178.5	90
2057	883235	114.75	270	5027	883209	178.5	90
4659	881207	53.3	270	2994	883118	177.17	90
602	881207	53.28	270	1917	883118	177.11	90
4657	881207	46.9	270	3016	883118	176.27	90
4658	881207	46.9	270	1242	883118	176.27	90
1903	883235	36.7	270	4141	883038	174.41	90
2963	883235	32.3	270	1848	883020	161.17	90
985	881184	135	260	2717	883020	161.14	90
3700	881184	134.97	260	4522	883020	161.14	90
2321	881184	127.75	260	4521	883020	161.11	90
4089	881184	127.72	260	560	881045	159.61	90
4037	883058	116.58	250	2332	883197	155.56	90
3456	883058	100.81	250	2724	883020	148.17	90
434	883058	53.36	250	1638	883020	148.17	90
3453	883058	50.26	250	807	883020	146.68	90
2564	883058	45.9	250	1847	883020	146.68	90
4855	888020	135.35	240	805	883020	146.68	90
2905	883035	34.13	240	4525	883020	144.23	90
4620	883035	24.37	240	2785	883197	143.91	90
4621	883035	24.36	240	3118	883232	142.83	90
4624	883035	8.4	240	3712	883232	142.77	90
4623	883035	8.4	240	4752	883209	141.47	90
4942	888026	145.74	230	2380	883209	141.45	90
4950	888026	140.98	230	4939	883046	135.22	90
1568	888026	140.98	230	4992	889014	130.91	90
1076	888026	140.98	230	4914	889035	130.67	90
185	888026	140.98	230	354	885002	130.44	90
4953	888026	140.98	230	2992	883118	126.98	90
1699	888026	140.93	230	2997	883118	126.98	90
3733	888026	139.87	230	2996	883118	126.98	90
1570	888026	137.46	230	555	883384	126.87	90
4948	888026	137.45	230	2675	883384	123.33	90
1569	888026	137.37	230	4450	883384	123.33	90
2882	888026	137.36	230	2480	883384	123.33	90
1694	888026	136.01	230	2102	881239	123.32	90
4943	888026	135.7	230	620	881239	123.32	90
4866	888017	133.66	230	4825	883384	122.7	90
4954	888026	127.49	230	1688	883384	122.7	90
2114	888026	127.37	230	1096	883384	122.7	90
259	888026	124.04	230	1690	883384	122.66	90
260	888026	124.04	230	2978	883118	122.22	90

4945	888026	123.98	230	1243	883118	122.19	90
4952	888026	123.98	230	627	883213	122.12	90
4838	888026	123.98	230	1131	883213	122.12	90
4919	888026	118.47	230	287	883213	122.1	90
4856	888026	118.4	230	4831	883043	121.22	90
4946	888026	114.49	230	4826	883043	121.22	90
1567	888026	114.45	230	733	883043	121.17	90
3720	883065	134.4	220	2517	883043	121.17	90
3964	883065	134.38	220	1641	883209	120.94	90
2108	883065	134.38	220	4753	883209	120.94	90
2179	883065	134.36	220	4747	883209	120.94	90
3919	883065	111.93	220	377	883073	119.2	90
3909	883065	103.5	220	3015	883118	114.03	90
710	883432	100.6	220	2999	883118	113.92	90
2908	883032	179.21	210	2995	883118	113.9	90
3879	883032	179.2	210	2823	881147	113.08	90
2523	883032	177.36	210	4827	883043	112.64	90
4611	883032	175.06	210	1193	883118	112.19	90
3777	883032	146.63	210	271	883132	110.98	90
2528	883032	144.4	210	1161	883132	110.98	90
4961	889031	136.64	210	639	883438	110.83	90
436	883059	128.3	210	3742	883438	110.83	90
2032	883059	127.28	210	2119	883438	110.81	90
491	883059	127.28	210	3743	883438	110.81	90
1757	883059	127.2	210	4393	883118	110.54	90
3084	883059	127.2	210	4590	883118	109.44	90
2087	883059	70.3	210	2441	883029	106.92	90
4310	883059	70.21	210	4704	883029	95.62	90
1758	883059	70.21	210	2442	883029	95.62	90
4311	883059	70.21	210	792	883029	95.6	90
2086	883059	66.66	210	4703	883029	95.6	90
898	883059	53.46	210	2145	881127	94.3	90
4608	883032	1.88	210	1994	881127	89.25	90
1881	883032	1.86	210	1995	881127	89.25	90
3262	881047	168.43	200	4824	883384	88.49	90
5010	883179	160.79	200	1689	883384	88.49	90
4407	883198	147.09	200	2674	883384	88.39	90
874	883198	147.06	200	2146	881127	88.11	90
2333	883198	147.05	200	3870	881124	84.75	90
3668	883151	140.5	200	1993	881124	81.31	90
4098	883151	139.56	200	1992	881124	81.31	90
1796	883151	139.56	200	4149	883020	80.29	90
66	883151	139.53	200	2890	883132	75.96	90
4988	889033	137.98	200	1741	883132	75.96	90
1522	883151	137.66	200	3771	883132	75.84	90
1984	883151	137.64	200	3770	883132	75.78	90
3719	883151	137.6	200	2405	883132	75.78	90
3884	881206	135	200	2991	883118	75.5	90
2782	883198	134.64	200	1928	883118	75.47	90

2641	883198	134.61	200	2990	883118	75.47	90
4405	883198	134.59	200	3772	883132	71.41	90
961	881206	130.68	200	2889	883132	71.41	90
2258	881206	130.38	200	755	883132	71.4	90
2254	881206	130.33	200	2888	883132	70.14	90
4012	881206	130.01	200	4147	883020	67.72	90
59	881206	127.28	200	4504	883038	65	90
3667	883151	125.65	200	2711	883038	65	90
4398	883151	125.59	200	2368	883038	64.89	90
1983	883151	124.71	200	4330	883232	55.36	90
1015	881206	119.07	200	762	883232	55.36	90
5040	881206	116.46	200	2634	883118	37.04	90
4003	881206	116.46	200	338	881033	22.55	90
2257	881206	116.36	200	5029	883213	21.35	90
1733	881206	115.85	200	1095	883213	19.15	90
2255	881206	115.85	200	1093	883213	19.15	90
3889	881206	115.85	200	1132	883213	19.08	90
4256	881206	115.85	200	4165	883213	7.79	90
4007	881206	115.54	200	3133	883118	1.16	90
4009	881206	115.54	200	131	883228	179.37	80
3885	881206	115.2	200	547	881326	170.56	80
2256	881206	113.56	200	549	881326	169.86	80
2253	881206	113.56	200	329	881189	166.49	80
1537	883151	113.06	200	349	881380	163.6	80
3496	881206	111.8	200	2841	883287	156.34	80
3495	881206	28.8	200	857	881337	155.22	80
3656	883179	19.91	200	854	881338	155.22	80
558	881043	159.61	190	550	881333	154.64	80
4044	881205	128.87	190	3003	883228	154.28	80
4045	881205	128.87	190	1936	883228	154.28	80
49	883067	127.01	190	2064	881189	154.07	80
4206	883067	127.01	190	4109	881189	154.07	80
2489	883067	126.95	190	677	881087	151.48	80
3526	881205	120.96	190	2063	881189	150.29	80
3087	881205	120.71	190	1863	883079	149.06	80
3086	881205	120.71	190	4252	883079	143.17	80
1765	881205	120.65	190	361	885042	137.75	80
156	881205	120.65	190	4929	888042	134.45	80
63	881205	120.65	190	4906	888042	134.08	80
1018	881205	120.63	190	4585	883135	130.21	80
1970	883185	120.6	190	2833	883287	124.43	80
4313	881205	120.38	190	2015	883287	124.43	80
787	883030	110.6	190	2406	883135	124.14	80
4040	881205	48.62	190	758	883135	124.14	80
4033	881205	44.71	190	695	883026	123.32	80
2277	881205	44.66	190	819	881029	122.12	80
4030	881205	44.63	190	4829	883045	121.2	80
4029	881205	43.3	190	3635	881188	121.17	80
2285	881205	40.4	190	3636	881189	121.17	80

2284	881205	40.4	190	4819	883026	120.32	80
3695	881205	34.93	190	2008	881263	118.79	80
521	881205	32.62	190	379	883287	118.5	80
2653	883184	156.11	180	2837	883287	118.5	80
1969	883184	156.11	180	552	881305	118.26	80
1954	883126	68.73	180	5023	881305	118.25	80
1753	883126	68.73	180	3414	883287	118	80
1754	883126	68.67	180	2838	883287	115.1	80
3076	883126	66.54	180	2842	883287	115.09	80
1948	883126	66.54	180	673	883308	113.77	80
3013	883126	66.5	180	2010	881263	112.28	80
1882	883033	33.27	180	2585	883135	111.15	80
2909	883033	33.26	180	4587	883135	110.86	80
4613	883033	33.26	180	4586	883135	110.83	80
3776	883033	33.23	180	2337	881189	110.78	80
527	883145	146.29	170	3335	881138	110.76	80
2106	883145	146.29	170	4933	881263	108.73	80
4349	883145	142.58	170	3983	883287	108.49	80
4893	889034	135.74	170	2856	883287	108.46	80
4858	889034	135.7	170	4106	881189	107.88	80
1075	889034	131.53	170	858	881423	107.73	80
441	881244	129.84	170	570	881142	103.82	80
1084	889034	126.68	170	3334	881138	103.73	80
4941	889034	125.66	170	316	881423	101.18	80
540	883106	98.73	170	616	881423	98.13	80
647	881162	50.02	170	356	883343	97.9	80
4915	889034	49.41	170	4820	883026	92.56	80
513	881077	49.19	170	3328	881123	89.26	80
333	881077	49.19	170	263	883079	85.82	80
1081	889034	40.07	170	2879	883079	85.8	80
204	881089	11.58	170	4247	883079	85.79	80
1467	883245	173.33	160	666	883014	79.71	80
4634	883238	137.87	160	664	883014	79.71	80
3438	881152	136.07	160	533	883286	65.24	80
3437	881152	136.07	160	44	883287	59.81	80
2137	883238	136.07	160	2840	883287	58.42	80
4882	889028	117.51	160	2233	883287	58.35	80
4741	883004	116.88	160	2834	883287	58.35	80
4739	883004	116.86	160	4532	881242	51.2	80
2025	881152	108.07	160	610	883194	45.14	80
1858	883004	77.14	160	724	881326	2.96	80
2432	881152	54.37	160	662	883017	175.82	70
4693	881152	54.37	160	4144	883091	172.91	70
765	881152	52.7	160	5018	883091	169.17	70
2431	881152	52.7	160	430	881375	165.5	70
2430	881152	52.7	160	431	881375	163.2	70
4688	881152	52.68	160	369	881349	162.26	70
4238	883040	18.18	160	847	881349	162.26	70
5015	883040	18.14	160	228	881349	162.26	70

3303	883206	17.73	160	850	881349	162.26	70
3141	883239	179.37	150	851	881349	162.26	70
3647	881050	178.07	150	34	881349	162.26	70
2583	883117	143.03	150	33	881349	162.26	70
4322	883117	143.01	150	717	881348	161.73	70
30	881366	140.15	150	856	881335	154.64	70
687	881366	135.36	150	768	883143	148.89	70
635	881366	131.53	150	2780	881273	147.81	70
2895	883117	104.12	150	3422	883142	146.44	70
3617	881050	64.89	150	1513	881190	143.63	70
2558	881163	57.85	150	508	881190	143.63	70
4653	881163	57.83	150	3423	883143	140.4	70
2421	881163	56.53	150	2150	883142	140.01	70
334	881315	46.03	150	3589	883234	139.02	70
451	881315	46.03	150	3587	883234	138.07	70
429	881392	45.75	150	772	883230	138	70
296	881315	43.62	150	2975	883230	137.98	70
4633	883239	35.26	150	2918	883143	137.36	70
388	883117	35.07	150	3108	883234	136.05	70
1162	883117	35.07	150	3711	883234	135.99	70
3352	883117	34.38	150	2737	883171	132.83	70
48	883117	34.38	150	4930	888034	132.5	70
4321	883117	34.19	150	5042	888032	132.5	70
4665	883117	34.19	150	3586	883234	132.35	70
644	883117	34.19	150	4932	888032	132.1	70
4664	883117	33.48	150	2398	883047	131.12	70
722	881300	8.12	150	731	883047	131.11	70
3002	883239	1.16	150	3834	883163	129.9	70
4925	883053	161.15	140	3252	883163	129.9	70
612	881073	147.92	140	3253	883164	129.89	70
4130	881073	142.26	140	843	883383	129.13	70
2352	881073	142.25	140	4860	889011	128.61	70
872	881073	84.04	140	4733	883171	126.38	70
1111	881073	83.96	140	2790	883170	124.74	70
5	881073	83.96	140	2789	883170	121.63	70
281	881073	83.96	140	4938	883052	121.27	70
279	881073	83.96	140	4926	883052	121.27	70
2770	881073	83.86	140	4936	883047	121.22	70
562	883055	75.84	140	2738	883171	118.73	70
1922	883229	75.76	140	4570	883042	112.79	70
5008	881073	74.09	140	1661	883042	112.79	70
1114	881073	73.95	140	642	883042	112.65	70
2647	881073	73.95	140	4567	883042	112.64	70
1115	881073	73.95	140	4568	883042	112.51	70
2646	881073	73.95	140	4569	883042	108.92	70
7	881073	73.95	140	51	883042	107.88	70
5009	881073	73.9	140	615	883497	106.79	70
5034	883015	73.6	140	3020	883275	97.71	70
1935	883229	66.7	140	4447	883275	97.71	70

623	883182	55.26	140	227	881349	93.89	70
2654	883182	55.26	140	3869	881122	88.1	70
3625	881073	52.07	140	848	881349	81.11	70
4496	881073	51.71	140	4785	883017	74.19	70
1512	881073	51.66	140	3120	883230	71.5	70
1116	881073	51.66	140	3119	883230	71.42	70
4131	881073	51.6	140	3250	883170	70.21	70
2773	881073	51.49	140	1923	883230	69.12	70
4133	881073	49.33	140	495	883230	69.12	70
2356	881073	49.19	140	4732	883170	66.59	70
3654	881073	49.17	140	3408	883302	65.14	70
4907	889003	178.78	130	304	883302	65.14	70
3014	883123	153.05	130	500	881190	61.83	70
3012	883123	151.77	130	2694	881190	61.83	70
2420	883123	151.77	130	4343	883144	61.32	70
3122	883119	142.34	130	2917	883144	61.26	70
3115	883119	142.34	130	4344	883144	61.26	70
3114	883119	131.88	130	2695	881190	60.11	70
4900	888007	126.81	130	337	881293	13.94	70
633	888007	126.79	130	862	881293	10.83	70
3033	881202	124.94	130	456	881400	176.42	60
3903	883172	124.74	130	578	883324	176.42	60
1079	888007	120.28	130	359	881299	170.56	60
4873	889003	119.95	130	723	881299	170.45	60
2328	881186	114.32	130	38	881344	170.4	60
4097	881186	114.29	130	229	881344	170.4	60
4864	888007	111.3	130	720	881344	167.49	60
608	881186	107.87	130	320	881344	167.49	60
4708	883199	103.7	130	321	881344	167.49	60
1121	883199	95.43	130	35	881344	167.49	60
4707	883199	95.43	130	671	883306	164.15	60
2419	883123	80.31	130	861	881344	161.73	60
2027	883123	75.77	130	318	881344	161.73	60
2418	883123	75.77	130	36	881344	161.73	60
4368	881202	57.43	130	39	881344	161.73	60
3447	883123	55.32	130	368	881344	161.73	60
4669	883159	54.06	130	322	881344	158.52	60
2613	881202	52.32	130	323	881344	158.52	60
1222	881202	52.32	130	317	881344	158.52	60
3099	881202	52.32	130	37	881344	158.52	60
402	881202	50.28	130	1865	883077	151.34	60
1427	883123	36.25	130	1864	883077	151.34	60
1966	883123	35.25	130	237	881280	151.33	60
3449	883123	35.25	130	2382	881280	149.86	60
4093	881186	16.73	130	2845	883077	148.24	60
3052	881186	15.9	130	2007	881268	146.43	60
1942	881186	15.89	130	698	883412	145.99	60
4094	881186	15.85	130	2120	883474	144.84	60
1713	883063	180	120	4360	883146	142.58	60

1888	883063	179.02	120	904	883146	142.13	60
2903	883063	179.02	120	1118	881247	136.08	60
2904	883063	179	120	3633	881247	133.91	60
813	883210	178.56	120	1119	881247	133.91	60
4756	883210	178.56	120	214	881258	133.38	60
1712	883063	175.5	120	2493	881258	133.35	60
2530	883034	175.05	120	640	881258	133.35	60
747	883034	175.05	120	4589	881254	133.32	60
4434	881183	166.52	120	4934	881254	133.32	60
4435	881183	166.52	120	2422	881212	132.62	60
330	881183	166.49	120	353	883277	130.64	60
1105	881183	166.49	120	830	883277	130.64	60
2756	881183	166.43	120	26	883277	130.64	60
3966	883064	146.71	120	305	883277	130.64	60
2127	883064	146.19	120	1981	881246	130.3	60
3780	883064	146.06	120	689	881164	130.2	60
4507	883037	144.23	120	690	881164	126.97	60
2960	883271	134.47	120	1049	881164	126.27	60
4881	889012	128.61	120	4445	883277	125.58	60
989	883066	126.05	120	303	883277	125.58	60
1151	883066	126	120	3339	881146	122.29	60
4192	883066	125.12	120	2828	881265	118.8	60
817	883011	123.58	120	2006	881265	118.8	60
4755	883210	121.62	120	466	883003	116.85	60
809	883018	121.6	120	1857	883003	116.85	60
4717	883018	121.6	120	2009	881265	113.07	60
477	883138	112.96	120	2819	881146	106.63	60
2487	883066	112.91	120	5041	883146	75.96	60
189	881116	112.2	120	3570	883146	74.14	60
293	881116	112.2	120	2608	883146	74.03	60
4189	883066	109.94	120	3841	883146	74.03	60
2149	883138	109.63	120	1614	883146	74.03	60
3907	883066	104.95	120	2606	883146	73.99	60
3123	883154	104.45	120	2982	883146	73.98	60
374	881116	102.84	120	3839	883146	71.53	60
4391	883154	95.4	120	4357	883146	71.53	60
1996	881126	94.13	120	4358	883146	71.5	60
3332	881126	94.12	120	2080	883176	51.64	60
2829	883011	76.7	120	804	883176	50.21	60
700	883011	76.7	120	4397	883152	37.04	60
2714	883037	67.81	120	1613	883146	32.5	60
4510	883037	67.72	120	2105	883146	32.49	60
4622	883037	67.71	120	4364	883146	31.55	60
4506	883037	67.71	120	528	883146	31.52	60
764	881156	61.18	120	619	881311	24.38	60
4683	881156	61.17	120	2381	881284	22.55	60
833	881274	47.79	120	427	883216	18.79	60
669	881274	47.79	120	683	883549	176.42	50
2173	883066	36.61	120	838	883319	155.81	50

2859	883066	36.61	120	714	881414	155.15	50
2171	883066	36.47	120	681	883319	154.71	50
3905	883066	36.47	120	370	881360	144.2	50
3754	883066	36.43	120	324	881369	140.98	50
2172	883066	36.43	120	372	881345	135.96	50
4195	883066	36.16	120	712	881412	135.64	50
3914	883066	36.14	120	866	881171	132.62	50
3755	883066	35.99	120	713	881412	129.38	50
182	883066	35.99	120	4802	881166	126.97	50
1152	883066	34.62	120	4801	881166	126.97	50
2860	883066	34.59	120	355	881411	126.76	50
4202	883066	34.59	120	716	881345	123.95	50
3904	883066	34.59	120	2775	881200	123.38	50
2501	883066	34.59	120	343	881199	123.38	50
820	883214	19.38	120	800	883025	120.32	50
2906	883034	14.76	120	2776	881200	119.74	50
2632	883154	14.65	120	367	881345	118.99	50
3963	883064	12.97	120	2735	881200	118.73	50
3967	883064	12.97	120	4540	881200	118.69	50
3009	883240	179.37	110	165	883022	117.93	50
341	883218	172.84	110	2383	881148	114.24	50
350	881373	163.2	110	734	881148	114.24	50
711	881373	162.86	110	4554	881148	111.17	50
1470	883240	161.96	110	364	881414	101.18	50
2469	883255	161.14	110	232	883279	173.58	40
810	883255	157.68	110	705	883279	172.33	40
834	881036	151.85	110	796	881248	139.73	40
1473	883240	150.43	110	630	883279	78.24	40
1472	883240	150.41	110	465	881415	154.64	30
4100	883156	148.23	110				
4401	881270	148.23	110				
345	883156	143.91	110				
3130	883156	143.86	110				

Appendix 4-3

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
TSITIKA	GR	DS							Producer	09	689182	5572917
BENSON LAKE	LS								Producer	09	624279	5582494
TAGORE	AU	AG	CU	ZN	PB				Past Producer	09	654304	5541251
WHITE STAR	AU	AG	CU	PB	ZN				Past Producer	09	657091	5543341
MOUNT ZEBALLOS	AU	AG	CU	PB	ZN				Past Producer	09	657028	5542103
ROPER	AU	AG	CU	PB	ZN				Past Producer	09	658093	5542443
KING MIDAS NO. 1 VEIN	AU	AG	CU	ZN	PB				Past Producer	09	658086	5547388
GOLD FIELD (L.1020)	AU	AG	CU	PB	ZN				Past Producer	09	658062	5540804
PRIVATEER (L.1040)	AU	AG	PB	CU	ZN				Past Producer	09	656312	5544091
LONE STAR (L.1052)	AU	AG	PB	ZN	CU				Past Producer	09	658086	5543370
RIMY 1-8	AU	AG	PB	ZN					Past Producer	09	658580	5543477
GOLDEN HORN	AU	AG	PB	CU	AS				Past Producer	09	660397	5542666
NUGENT QUEEN	AU	AG	PB	ZN	CU				Past Producer	09	625348	5650383
CENTRAL ZEBALLOS	AU	AG	PB	CU	ZN				Past Producer	09	658840	5544783
PRIDENT	AU	AG	ZN	PB	CU				Past Producer	09	657181	5543653
GOLDEN PEAK (L.1035)	AU	AG							Past Producer	09	657400	5542979
GOLDEN GATE	AU	CU	PB	ZN	AG				Past Producer	09	655467	5540975
NORTH STAR (L.1716)	AU	PB	ZN						Past Producer	09	659216	5542198
VAN ISLE (L.1744)	AU	PB	ZN						Past Producer	09	655444	5543138
CORDOVA NO.1	AU								Past Producer	09	655725	5545804
HADDINGTON ISLAND	BS	DS							Past Producer	09	640303	5607002
SUQUASH	CL								Past Producer	09	623762	5610294
KOSKEEMO	CL								Past Producer	09	600252	5606516
YREKA	CU	AG	AU						Past Producer	09	601707	5590199
PRINCESS	CU	AG							Past Producer	09	661738	5602827
MAJOR	CU	AU							Past Producer	09	661833	5544564
STEELE CREEK	CU	MA	AG	AU	ZN				Past Producer	09	659859	5575105
BENSON LAKE	CU	MA	FE	AU	AG				Past Producer	09	625869	5579596
ISLAND COPPER	CU	MO	AG	AU	RE	ZN	PB		Past Producer	09	608045	5606238
IRON CROWN (L.126)	FE	MA	CU	ZN	AU				Past Producer	09	652661	5569329
OLD SPORT	FE	MA	CU	AG	AU				Past Producer	09	625416	5582057
FORD	FE	MA							Past Producer	09	655120	5546065

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
BONANZA LAKE EAST	LS	MB	BS						Past Producer	09	655911	5586794
BEAVER COVE	LS	MB	BS						Past Producer	09	649471	5597982
JEUNE LANDING (L.1582)	LS								Past Producer	09	605133	5590514
PORT McNEILL	LS								Past Producer	09	637342	5602133
CLUXEWE RIVER	LS								Past Producer	09	631359	5601269
MARBLE RIVER	LS								Past Producer	09	613916	5588441
MERRY WIDOW 5	MA	FE	CU	AU	ZN	CO	LS		Past Producer	09	624352	5579406
RAVEN (L.1542)	MA	FE	CU	AU	AG	ZN			Past Producer	09	624346	5579653
KINGFISHER (L.1532)	MA	FE							Past Producer	09	624643	5579629
MORRIS (L.988)	PL	AI							Past Producer	09	621711	5554810
AT MONTEITH (L.826)	PL	AI							Past Producer	09	622706	5553875
MAQUINNA	AU	PB	ZN						Dev. Prospect	09	655358	5544743
EXTENSION 10 (L.1712)	CU	AU	AG	MA					Dev. Prospect	09	658905	5544631
RED DOG	CU	AU	MO	AG					Dev. Prospect	09	572690	5617950
HUSHAMU	CU	AU	MO						Dev. Prospect	09	580800	5614150
NIMPKISH COPPER	CU	AU	ZN	MO	CD	MA	FE		Dev. Prospect	09	653215	5577567
IDAHO FR (L.1481)	CU	MA	FE						Dev. Prospect	09	625405	5582521
HEP	CU	MO							Dev. Prospect	09	578350	5616175
HAZEL 7 (NIMPKISH CU)	CU	ZN							Dev. Prospect	09	652368	5577449
FERN HILL (L.1063)	CU								Dev. Prospect	09	656765	5544259
LITTLE LAKE	FE	MA	CU						Dev. Prospect	09	609382	5566222
CHURCHILL MAGNETITE	FE	MA							Dev. Prospect	09	655245	5548634
RIDGE	FE	MA							Dev. Prospect	09	654325	5546042
KASHUTL INLET	LS	MB	BS						Dev. Prospect	09	620328	5557158
FOX	LS								Dev. Prospect	09	575390	5607910
ARTLISH 3-6	MA	FE	CU						Dev. Prospect	09	654201	5550334
SHAMROCK (L.1492)	MA	FE							Dev. Prospect	09	624147	5581410
HILLER 4-5	MA	FE							Dev. Prospect	09	652827	5551099
HILLER 8-12	MA	FE							Dev. Prospect	09	651754	5552459
LEO D'OR	MB	DS	BS						Dev. Prospect	09	656466	5584709
HOLBERG	SI								Dev. Prospect	09	593250	5607300

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
MONTEITH BAY	SI								Dev. Prospect	09	622350	5554400
PILGRIM (L.2035)	ZN	AG	AU	PB	CD				Dev. Prospect	09	614035	5587516
CALEDONIA (L.1294)	ZN	AG	CU	PB	AU				Dev. Prospect	09	598775	5611000
SMITH COPPER (MAIN)	ZN	CU	PB	AG					Dev. Prospect	09	648173	5581008
HPH 1	AG	PB	ZN	CU	AU	MA	FE		Prospect	09	585180	5616380
SOUTH SHORE	AG	PB	ZN	CU					Prospect	09	581000	5616975
MO	AG	PB	ZN	MA					Prospect	09	575670	5618760
SOUTH SHORE (HSW 3)	AG	ZN	PB	CU					Prospect	09	581400	5616840
BRITANNIA M	AU	AG	AS						Prospect	09	658023	5542132
NORTH FORK	AU	AG	CU	ZN					Prospect	09	657425	5548883
BRITANNIA B-5	AU	AG	CU	ZN	PB				Prospect	09	657511	5544620
ALICE LAKE	AU	AG	PB	ZN					Prospect	09	612033	5588864
IXL (L.1054)	AU	AG	PB	ZN					Prospect	09	657469	5543352
KYU	AU	AG	PB	ZN	CU				Prospect	09	617062	5557610
PRIVATEER PE	AU	AG	PB						Prospect	09	656782	5543672
PRIVATEER P4A	AU	AG	PB	CU	ZN				Prospect	09	655784	5543766
SCRUTOR GOLD	AU	CU	AG						Prospect	09	641030	5555873
KING MIDAS LYNCH	AU	CU	AG	ZN					Prospect	09	657822	5547597
ELECTRUM	AU	CU	PB	ZN	AG				Prospect	09	614876	5557717
BARNACLE	AU	CU							Prospect	09	655396	5546846
A25	AU	CU							Prospect	09	650627	5553663
DORLON	AU	ZN	AG	CU	PB	CD	MA		Prospect	09	587880	5615800
PATMORE	AU	ZN	CU						Prospect	09	635941	5541217
BARNACLE (L.2011)	AU								Prospect	09	655409	5546382
BARNACLE (3060 ADIT)	AU								Prospect	09	655401	5546691
BAY 21	CU	AG	AU						Prospect	09	605425	5607425
ADAM WEST	CU	AG	AU						Prospect	09	709229	5575123
CRANBERRY	CU	AG	AU						Prospect	09	607938	5610469
SOUTH	CU	AG	AU	MA	FE				Prospect	09	608302	5609951
IRON COP	CU	CO	AG	AU	FE				Prospect	09	599969	5569404
BP	CU	FE	MA						Prospect	09	615893	5561138
BOB 17	CU	MA	FE	AU	AG				Prospect	09	660217	5574374

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
WHITE FANG	CU	MA							Prospect	09	660944	5573901
ROAD	CU	MO	FE						Prospect	09	608916	5605947
BAY 56	CU	MO							Prospect	09	604675	5609650
RUPERT	CU	MO							Prospect	09	614088	5605068
RAINBOW 1-4	CU	ZN	AG	PB	AU	MA			Prospect	09	607615	5609937
SWAMP	CU	ZN	AG	PB	AU				Prospect	09	606861	5610292
BLUEBIRD 1	CU	ZN	AU	CO					Prospect	09	624600	5579000
BLUEBIRD 2	CU	ZN	AU	CO					Prospect	09	624600	5579250
SNOWLINE 2	CU	ZN	AU						Prospect	09	624240	5579200
RUPERT (DEM)	CU								Prospect	09	605045	5602840
BOYES 3	CU								Prospect	09	710058	5573703
PRIVATEER P3D	CU								Prospect	09	656567	5544222
KEN	CU								Prospect	09	609064	5608268
BLUE BIRD - INGERSOL	FE	AU	MA	CU					Prospect	09	594807	5592233
JUNE (L.180)	FE	CU	AU	AG	SU	ZN	PB		Prospect	09	612938	5588049
BAY 4	FE	CU	AU	TI					Prospect	09	605650	5607710
YANKEE GIRL	FE	CU							Prospect	09	609417	5605494
BAY 29	FE	CU							Prospect	09	609409	5605865
POWER	FE	MA							Prospect	09	605898	5568036
BONANZA LAKE	LS	MB	BS						Prospect	09	655343	5585294
HARBLEDOWN ISL. LMSTN.	LS								Prospect	09	675991	5604213
SMITH COPPER	MA	FE	CU	ZN	PB	AG			Prospect	09	648632	5580867
MAGNET	MA	FE	CU						Prospect	09	644957	5585802
BLACKBIRD	MA	FE	CU						Prospect	09	655323	5544556
BON 22,24	MA	FE	CU						Prospect	09	665010	5569884
BLACKJACK (L.1498)	MA	FE							Prospect	09	624454	5580953
ISLAND CU PYROPHYLLITE	PL	AI							Prospect	09	608222	5606242
H & W	SI								Prospect	09	592100	5607290
MICA	SK	MI	SI						Prospect	09	635764	5546620
SOUTH SHORE (RAS 4)	ZN	AG	CU	PB	CD				Prospect	09	580540	5616986
MINERVA FR. (L.171,183)	ZN	CU	FE	MA					Prospect	09	612437	5588409
A	ZN	CU	PB	AG	AU				Prospect	09	591850	5613850

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
BIG ZINC	ZN								Prospect	09	611293	5588385
BOWERMAN	AG	PB	ZN	CU	AU				Showing	09	591700	5611260
HPH 2	AG	PB	ZN	CU	AU				Showing	09	585470	5616330
HPH 3	AG	PB	ZN	CU	AU	MA			Showing	09	584800	5616520
GOLDSPRING (L.1940)	AU	AG	CU	ZN	PB				Showing	09	657262	5547673
RED ROCK	AU	AG	CU	ZN					Showing	09	606310	5583987
CHURCHILL	AU	AG	PB	ZN	CU				Showing	09	655545	5548550
BOBMAC 6	AU	AG	PB	ZN					Showing	09	625710	5650100
ESPERANZA	AU	AG							Showing	09	651322	5553683
PEERLESS	AU	CU	ZN						Showing	09	654243	5545421
EAST HAZEL (NIMPKISH CU)	AU	CU	ZN	MO	CD				Showing	09	652924	5577373
BONANZA	AU	CU	ZN	PB					Showing	09	632194	5647339
LUCKY STRIKE	AU	CU							Showing	09	654285	5547432
MONITOR	AU	CU							Showing	09	661687	5542798
KING MIDAS CONTACT	AU	CU							Showing	09	658008	5548035
BRITANNIA DYKE	AU	MO	CU						Showing	09	657623	5543542
OMEGA	AU	PB	ZN	CU					Showing	09	654899	5545440
BODEN	AU	ZN							Showing	09	654463	5544686
BROWN BOMBER	AU	ZN							Showing	09	657669	5542647
PANDORA	AU								Showing	09	655843	5545159
IXL FRACTION (L.1694)	AU								Showing	09	658680	5542800
ECLIPSE	AU								Showing	09	636955	5540470
ACORN	AU								Showing	09	575426	5575702
AMOS CREEK	AU								Showing	09	584849	5551501
QUATSINO SOUND	CL								Showing	09	582190	5595945
HALLIDIE	CL								Showing	09	600269	5605620
DRY HILL (L.1548)	CO	CU							Showing	09	625679	5579283
CLIMAX	CU	AG	AU						Showing	09	600961	5590030
MARBLE CREEK	CU	AG	AU						Showing	09	609657	5598732
TIDEWATER (MAIN)	CU	AG	AU						Showing	09	673568	5602432
KING	CU	AG	AU						Showing	09	661040	5545776

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
CAM - DOC	CU	AG	AU						Showing	09	710903	5570396
DAVIS	CU	AG	AU	AS					Showing	09	705845	5556590
WEST	CU	AG	AU						Showing	09	607261	5609930
MILLINGTON	CU	AG	AU						Showing	09	567641	5612049
KNOB HILL	CU	AG	ZN						Showing	09	566878	5624087
COPPER KING	CU	AG							Showing	09	600691	5595896
TIDEWATER	CU	AG							Showing	09	674508	5602618
WALDER	CU	AG							Showing	09	672771	5602715
EDISON (L.244)	CU	AG							Showing	09	601484	5590504
PABLO 24-2	CU	AG							Showing	09	589892	5568112
BLUEGROUSE (YREKA)	CU	AG							Showing	09	602440	5590059
SCOTT	CU	AG							Showing	09	552399	5624231
MARTEN	CU	AU	AG	AS					Showing	09	624517	5579101
QUATSINO KING (L.676)	CU	AU	AG	ZN					Showing	09	606342	5582412
WOSS LAKE NO.2	CU	AU	AG						Showing	09	674614	5554394
LUCKY JIM	CU	AU	AG						Showing	09	705629	5564220
NOOTKA	CU	AU	AG						Showing	09	661412	5545324
GEORGE 5	CU	AU	AG						Showing	09	710597	5573105
EXTENSION 5 (L.1048)	CU	AU	AG	MA					Showing	09	658338	5544923
MARINO	CU	AU	AG	ZN	MO				Showing	09	639637	5589831
SILVER QUEEN 2 (L.1451)	CU	AU	AG						Showing	09	659439	5541401
KW	CU	CL							Showing	09	584360	5608425
EAGLE (L.1154)	CU	CO							Showing	09	624029	5578008
NORTH NOTCH	CU	CO							Showing	09	624800	5579900
WANOKANA	CU	FE	MA						Showing	09	594350	5613204
HEART	CU	FE							Showing	09	605109	5569874
ECILA	CU	MA	FE						Showing	09	616487	5592668
BERG 16	CU	MA	FE						Showing	09	573150	5621070
HAPPY JACK (L.1495)	CU	MA	FE						Showing	09	625727	5581447
STRANBY	CU	MA	FE						Showing	09	559455	5632493
ED CREEK	CU	MA	FE						Showing	09	560580	5629942
BOB 21	CU	MA							Showing	09	659384	5576389

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
HAB 11	CU	MA							Showing	09	660801	5576679
KLOOTCH	CU	MA							Showing	09	594856	5589485
CU	CU	MO	MA						Showing	09	630893	5560250
KEOGH	CU	MO	NI						Showing	09	629197	5597075
CLEAGH	CU	MO	ZN						Showing	09	590537	5588296
LOIS 1-36	CU	MO	ZN	PB	AU	AG	CO		Showing	09	597519	5568030
SCORPIO (L.1703)	CU	MO							Showing	09	656265	5544337
TIE	CU	MO							Showing	09	620341	5605208
RH 1-24	CU	MO							Showing	09	605171	5571729
MARIO	CU	MO							Showing	09	705367	5564829
STAR 24	CU	MO							Showing	09	605351	5584555
RUF 41	CU	MO							Showing	09	590703	5572852
TENT	CU	MO							Showing	09	600561	5574760
SINKER	CU	NI	CO	MO					Showing	09	588897	5574304
BROOKS	CU	PB	ZN						Showing	09	591204	5566682
LARSON 2	CU	PB							Showing	09	649839	5585011
CLIMAX (L.1874)	CU	SB							Showing	09	659527	5545113
PABLO 22	CU	ZN	AG	FE					Showing	09	589604	5567582
PAYSTREAK	CU	ZN	AU	AG					Showing	09	606414	5583711
FRANCES	CU	ZN	FE						Showing	09	609618	5609979
COPPER CREEK 18	CU	ZN	MO						Showing	09	653625	5577084
TONY	CU	ZN	PB						Showing	09	644198	5548139
RANIER	CU	ZN							Showing	09	624160	5576620
BLUE OX	CU	ZN							Showing	09	625895	5576043
AMAZON	CU	ZN							Showing	09	611386	5610016
KIMO	CU	ZN							Showing	09	583217	5589566
ENGL	CU	ZN							Showing	09	654821	5573410
LEMARE 1	CU	ZN							Showing	09	578305	5585629
PROSPERITY (L.1801)	CU								Showing	09	655739	5541911
WOSS LAKE NO.4	CU								Showing	09	674539	5554855
JR	CU								Showing	09	600050	5618580
SEAL	CU								Showing	09	575442	5609004

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
STUART	CU								Showing	09	571050	5619000
VULCAN (L.132)	CU								Showing	09	651135	5570738
DEMERARA	CU								Showing	09	650842	5605131
CRACROFT	CU								Showing	09	672676	5599620
LONE STAR	CU								Showing	09	676504	5602994
DEB	CU								Showing	09	603850	5616300
WALT	CU								Showing	09	626373	5599787
HAW 26	CU								Showing	09	590920	5618820
HAW 44	CU								Showing	09	587100	5618360
RAM	CU								Showing	09	598400	5618050
BON 15	CU								Showing	09	664672	5570554
BILLY 19	CU								Showing	09	703743	5581249
GEORGE	CU								Showing	09	710598	5574590
KEVIN 25	CU								Showing	09	711204	5572789
KETA	CU								Showing	09	711188	5575696
ROONEY 1-4	CU								Showing	09	703133	5581690
M	CU								Showing	09	595840	5615600
HAR	CU								Showing	09	612594	5603182
SAUCE	CU								Showing	09	613711	5609757
BRAD	CU								Showing	09	595112	5575247
RADIO (L.1627)	CU								Showing	09	625100	5578300
JARR	CU								Showing	09	592961	5573818
MOR	CU								Showing	09	589650	5616600
HAW 12	CU								Showing	09	589900	5618570
HAW 15	CU								Showing	09	589600	5617950
HAW 14,6	CU								Showing	09	589950	5617120
HAW 34	CU								Showing	09	587230	5617540
WIT 21	CU								Showing	09	587250	5617800
MARK	CU								Showing	09	636798	5546647
EASY	CU								Showing	09	617842	5558246
BW	CU								Showing	09	621007	5549974

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
AAA 48	CU								Showing	09	566101	5617436
AAA 6	CU								Showing	09	568076	5616380
KAINS	CU								Showing	09	568023	5590121
GILFORD ISLAND	CY								Showing	09	677528	5614622
ZEBALLOS DOLOMITE	DO	LS	MB	BS					Showing	09	658524	5545392
CALEDONIA (KAS) -	FE	CU	MN						Showing	09	618912	5563646
CALEDONIA	FE	CU	ZN	PB	MA				Showing	09	598983	5611250
CORDOVA	FE	MA							Showing	09	656114	5546094
CAVALIER 4 (L.1967)	FE	MA							Showing	09	656034	5547482
WOSS LAKE NO.1	FE	MA							Showing	09	675003	5555242
QUATSINO IRON ORE	FE								Showing	09	592027	5607972
PRINCE'S	FE								Showing	09	588182	5608647
SUNRISE (L.271)	FE								Showing	09	588750	5608600
KAOUK PYTT	FE								Showing	09	644101	5551010
HARBLEDOWN ISLAND	GT								Showing	09	668238	5602815
REALGAR	**HG**	**AS**	**GS**						**Showing**	**09**	**564806**	**5611086**
NIMPKISH LAKE LMSTN.	LS								Showing	09	645318	5587049
HANKIN POINT	LS								Showing	09	602532	5604521
QUATSE LAKE	LS								Showing	09	603560	5610650
KAINS LAKE	LS								Showing	09	594250	5617070
VAR	LS								Showing	09	605000	5602000
SUN	MA	FE	CU	ZN	PB				Showing	09	583720	5615850
MAGNET (L.129)	MA	FE	CU	ZN					Showing	09	651713	5569920
KLAANCH (L.128)	MA	FE	CU	ZN					Showing	09	652054	5569775
CONTACT	MA	FE	CU						Showing	09	657104	5546277
LONDON 1	MA	FE	CU	ZN					Showing	09	602249	5569293
PATCH	MA	FE	CU						Showing	09	600343	5571636
BON 20	MA	FE	PB						Showing	09	665564	5569901
AJAX (L.1502)	MA	FE							Showing	09	624820	5580498
SUMMIT (L.1554)	MA	FE							Showing	09	624765	5580343
WHISKEY JACK (L.1529)	MA	FE							Showing	09	624578	5579875
RAMBLER (L.1537)	MA	FE							Showing	09	625016	5579730

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
KEYSTONE (L.1534)	MA	FE							Showing	09	625086	5579269
IRON QUEEN	MA	FE							Showing	09	596790	5586245
SNOWBIRD (L.1586-1588)	MA	FE							Showing	09	622543	5582392
ALPHA 5 (NIMPKISH CU)	MA	FE							Showing	09	654244	5577566
WOLF	MA	FE							Showing	09	650034	5581617
MARTHA 4	MA	FE							Showing	09	648496	5582192
BON 24	MA	FE							Showing	09	664226	5570231
HILLER 1	MA	FE							Showing	09	654860	5549550
KAOUK	MA	FE							Showing	09	646861	5549695
KAOUK MAG	MA	FE							Showing	09	644803	5552266
SNOWLINE (L.1535)	MA								Showing	09	624298	5579157
MAC	MA								Showing	09	652465	5578905
BAY 49	MN	RO	BA	PB	AG	ZN	GS		Showing	09	607099	5608227
ARTLISH MO	MO								Showing	09	644980	5553043
BERG 87	MO								Showing	09	569365	5622730
ROSSLAND	PB	CU							Showing	09	603412	5585752
JACKIE	PB	ZN	AG	AU	CU	CD	MO	•	Showing	09	703018	5543061
LORENA 2	PB	ZN							Showing	09	648604	5597278
HUSHAMU	PL	CU							Showing	09	581862	5613179
SOCKEYE (L.528)	PL	KK	PO						Showing	09	622128	5553089
SIN 4,6	PL	TC							Showing	09	616467	5555743
PEMBERTON	PL								Showing	09	587425	5609250
SOUTH KNOB	PL								Showing	09	568244	5618544
SIC (L.528,529)	SI								Showing	09	622532	5552789
RAIN	ZN	AG	CU						Showing	09	587540	5615780
ON	ZN	AU							Showing	09	618824	5554251
ORI	ZN	CU	MA	FE	MO				Showing	09	562432	5632188
TUSCARORA (L.84)	ZN	CU	PB						Showing	09	601833	5590820
ALPHA 4 (NIMPKISH CU)	ZN	CU							Showing	09	654196	5577873
HAW 24	ZN	CU							Showing	09	590960	5618440
DIA	ZN	CU							Showing	09	648227	5570594

NAME	C1	C2	C3	C4	C5	C6	C7	C8	STATUS	ZONE	EAST	NORTH
NORTH SHORE	ZN	PB	AG	CU	MA				Showing	09	580040	5618030
ABAN	ZN	PB	AG						Showing	09	577070	5618220
HPH BLUFF	ZN	PB	CU						Showing	09	584800	5615950
JEAN (NORTH SHORE)	ZN	PB							Showing	09	581240	5617820
BOZO 2	ZN								Showing	09	599942	5570856

MINFILE COMMODITY CODES

Commodity (Index)	Code	Code (Index)	Commodity
Agate	AE	**	Unknown
Aggregate	AT	AB	Asbestos
Aluminum	AL	AD	Andalusite
Alunite	AI	AE	Agate
Amber	AM	AG	Silver
Andalusite	AD	AI	Alunite
Anhydrite	AN	AL	Aluminum
Antimony	SB	AM	Amber
Apatite	AP	AN	Anhydrite
Argillite	AR	AP	Apatite
Arsenic	AS	AR	Argillite
Asbestos	AB	AS	Arsenic
Barite	BA	AT	Aggregate
Bentonite	BN	AU	Gold
Beryl	BY	BA	Barite
Beryllium	BE	BE	Beryllium
Bismuth	BI	BI	Bismuth
Bitumen	BM	BM	Bitumen
Building Stone	BS	BN	Bentonite
Cadmium	CD	BS	Building Stone
Celestite	CI	BY	Beryl
Ceramic Clay	CC	CC	Ceramic Clay
Cerium	CE	CD	Cadmium
Cesium	CS	CE	Cerium
Chromium	CR	CH	Chrysotile
Chrysotile	CH	CI	Celestite
Clay	CY	CL	Coal
Coal	CL	CM	Corundum
Cobalt	CO	CO	Cobalt
Copper	CU	CR	Chromium
Corundum	CM	CS	Cesium
Diamond	DI	CU	Copper
Diatomite	DE	CY	Clay
Dimension Stone	DS	DE	Diatomite
Dolomite	DO	DI	Diamond
Dysprosium	DY	DO	Dolomite
Erbium	ER	DS	Dimension Stone
Europium	EU	DY	Dysprosium
Evaporites	EV	ER	Erbium
Expanding Shale	ES	ES	Expanding Shale
Feldspar	FD	EU	Europium
Fireclay	FC	EV	Evaporites
Flagstone	FS	FC	Fireclay
Fluorite	FL	FD	Feldspar
Fullers Earth	FR	FE	Iron
Gadolinium	GD	FL	Fluorite
Gallium	GA	FR	Fullers Earth
Garnet	GN	FS	Flagstone
Gemstones	GS	GA	Gallium
Germanium	GE	GD	Gadolinium
Gold	AU	GE	Germanium
Granite	GR	GN	Garnet
Graphite	GT	GR	Granite
Gravel	GV	GS	Gemstones
Gypsum	GY	GT	Graphite
Hafnium	HF	GV	Gravel
Hotspring	HS	GY	Gypsum
Hydromagnesite	HM	HF	Hafnium
Indium	IN	HG	Mercury
Iridium	IR	HM	Hydromagnesite
Iron	FE	HS	Hotspring

MINFILE COMMODITY CODES

Commodity (Index)	Code
Jade/Nephrite	JD
Kaolinite	KA
Kyanite	KY
Lanthanum	LA
Lead	PB
Limestone	LS
Lithium	LI
Lutetium	LU
Magnesite	MT
Magnesium	MG
Magnesium Sulphate	MS
Magnetite	MA
Manganese	MN
Marble	MB
Marl	MR
Mercury	HG
Mica	MI
Molybdenum	MO
Neodymium	ND
Nepheline Syenite	NS
Nickel	NI
Niobium	NB
Ochre	OC
Olivine	OL
Osmium	OS
Palladium	PD
Peat	PA
Perlite	PE
Phosphate	PP
Phosphorus	PH
Platinum	PT
Potash	PO
Potassium	KK
Potassium Nitrate	KN
Pozzolan	PZ
Praseodymium	PR
Pumice	PU
Pyrochlore	PY
Pyrophyllite	PL
Radioactive Material	RD
Radium	RA
Radon	RN
Railroad Ballast	RB
Rare Earths	RS
Rhenium	RE
Rhodium	RH
Rhodonite	RO
Ruby	RY
Ruthenium	RU
Samarium	SM
Sand	SD
Sandstone	SV
Scandium	SC
Selenium	SE
Sericite	SK
Shale	SH
Silica	SI
Sillimanite	SL
Silver	AG
Slate	ST
Soapstone	SZ

Code (Index)	Commodity
IN	Indium
IR	Iridium
JD	Jade/Nephrite
KA	Kaolinite
KK	Potassium
KN	Potassium Nitrate
KY	Kyanite
LA	Lanthanum
LI	Lithium
LS	Limestone
LU	Lutetium
MA	Magnetite
MB	Marble
MG	Magnesium
MI	Mica
MN	Manganese
MO	Molybdenum
MR	Marl
MS	Magnesium Sulphate
MT	Magnesite
NA	Sodium
NB	Niobium
NC	Sodium Chloride
ND	Neodymium
NI	Nickel
NS	Nepheline Syenite
OC	Ochre
OL	Olivine
OS	Osmium
PA	Peat
PB	Lead
PD	Palladium
PE	Perlite
PH	Phosphorus
PL	Pyrophyllite
PO	Potash
PP	Phosphate
PR	Praseodymium
PT	Platinum
PU	Pumice
PY	Pyrochlore
PZ	Pozzolan
RA	Radium
RB	Railroad Ballast
RD	Radioactive Material
RE	Rhenium
RH	Rhodium
RN	Radon
RO	Rhodonite
RS	Rare Earths
RU	Ruthenium
RY	Ruby
SB	Antimony
SC	Scandium
SD	Sand
SE	Selenium
SH	Shale
SI	Silica
SK	Sericite
SL	Sillimanite
SM	Samarium

MINFILE COMMODITY CODES

Commodity (Index)	Code
Sodalite	SX
Sodium	NA
Sodium Carbonate	SO
Sodium Chloride	NC
Sodium Sulphate	SS
Strontium	SR
Sulphur	SU
Talc	TC
Tantalum	TA
Tellurium	TE
Terbium	TB
Thallium	TL
Thorium	TH
Thulium	TM
Tin	SN
Titanium	TI
Travertine	TR
Tremolite	TT
Tungsten	WO
Unknown	**
Uranium	UR
Vanadium	VA
Vermiculite	VM
Volcanic Ash	VL
Volcanic Glass	VG
Wollastonite	WL
Ytterbium	YB
Yttrium	YR
Zeolite	ZE
Zinc	ZN
Zirconium	ZR

Code (Index)	Commodity
SN	Tin
SO	Sodium Carbonate
SR	Strontium
SS	Sodium Sulphate
ST	Slate
SU	Sulphur
SV	Sandstone
SX	Sodalite
SZ	Soapstone
TA	Tantalum
TB	Terbium
TC	Talc
TE	Tellurium
TH	Thorium
TI	Titanium
TL	Thallium
TM	Thulium
TR	Travertine
TT	Tremolite
UR	Uranium
VA	Vanadium
VG	Volcanic Glass
VL	Volcanic Ash
VM	Vermiculite
WL	Wollastonite
WO	Tungsten
YB	Ytterbium
YR	Yttrium
ZE	Zeolite
ZN	Zinc
ZR	Zirconium

Record count: *153*
Date: *11/01/96*
File name: *e19.dbf*

▩ Active river alluvium
Semi-active channels and l
Fraser River alluvium with
▩ Fraser River alluvium with
■ Abandoned creek channels a
■ Proximal Vedder Fan
▩ Distal Vedder Fan
▦ Vedder Fan channels
▓ Upper colluvial / alluvial
░ Lower colluvial / alluvial
■ Floodplain swamps and bogs
▩ Thin organic deposits and
■ Lacustrine sediments
▩ Cheam Landslide deposits
▩ Alluvial sand overlying sl
■ Loess
Steeply eroded Pleistocene
Till and undifferentiated
■ Bedrock
☐ Anthropogenic

and large sloughs

with preserved channel and bar

with thick overbank fines

els and small sloughs

uvial fan

uvial fan and slope base deposit

bogs

and undifferentiated alluvium

its

ng slide debris

ocene sediments

ated gravels and sands

graphy


CNR

Till and undifferentiated gr

■ Bedrock

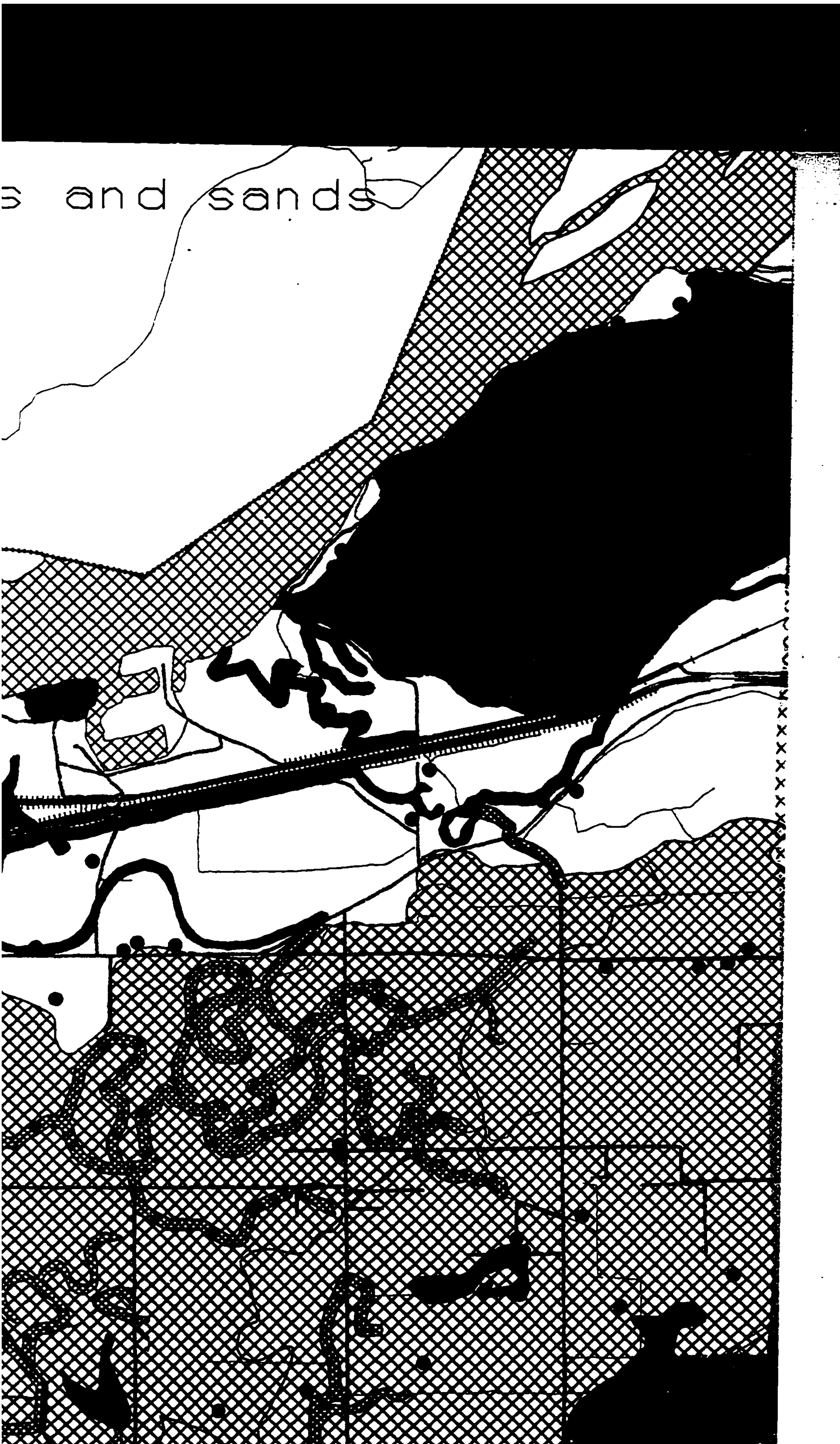
☐ Anthropogenic

Apparent landslide scarp

● Subsurface data

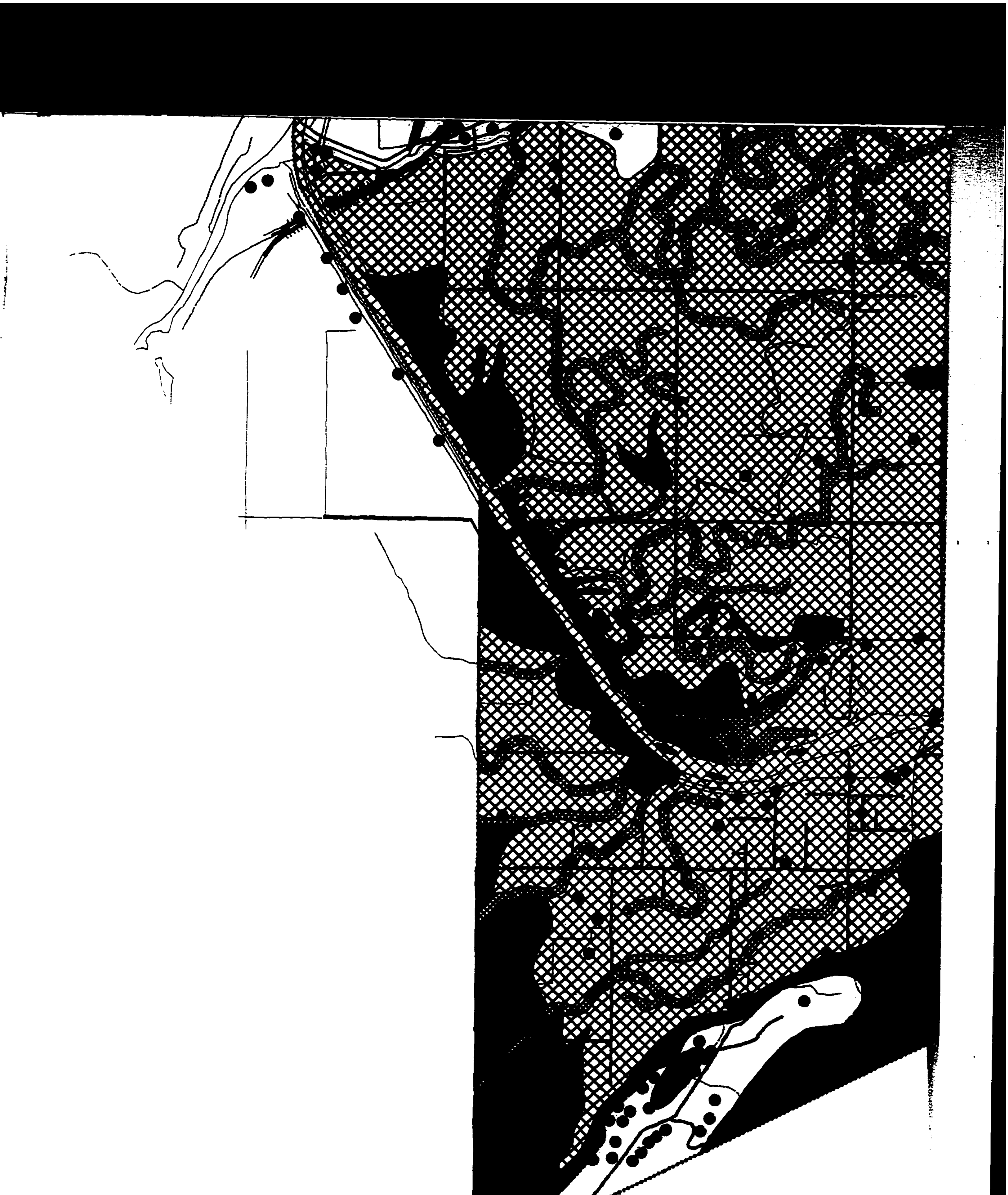
20m contour

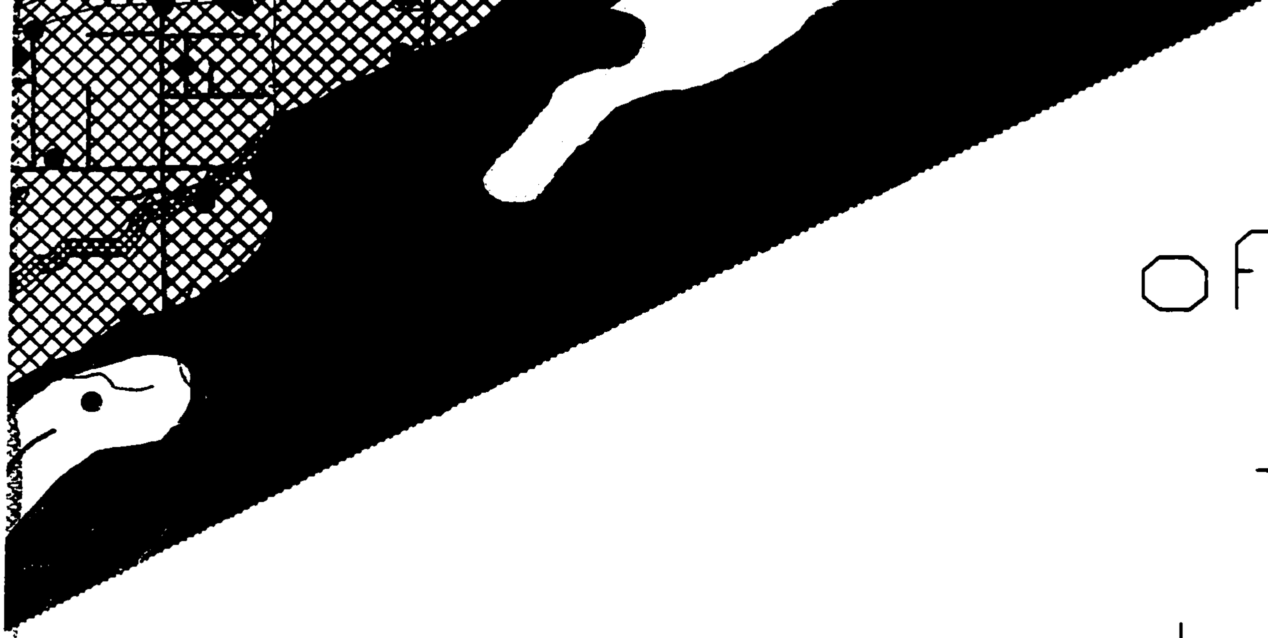
100m contour



and sands


CNR

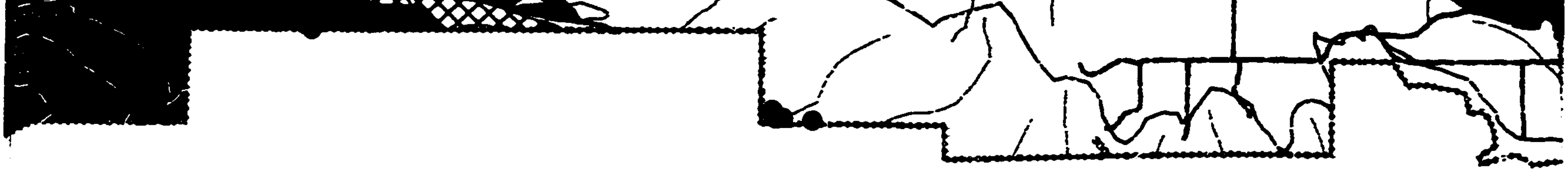




of the

To acc

by V.M.

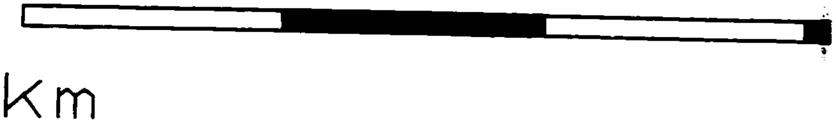


Surficial

the Chilliwack Are

accompany B.C. Geologi

V.M. Levson, R.F. Gerat

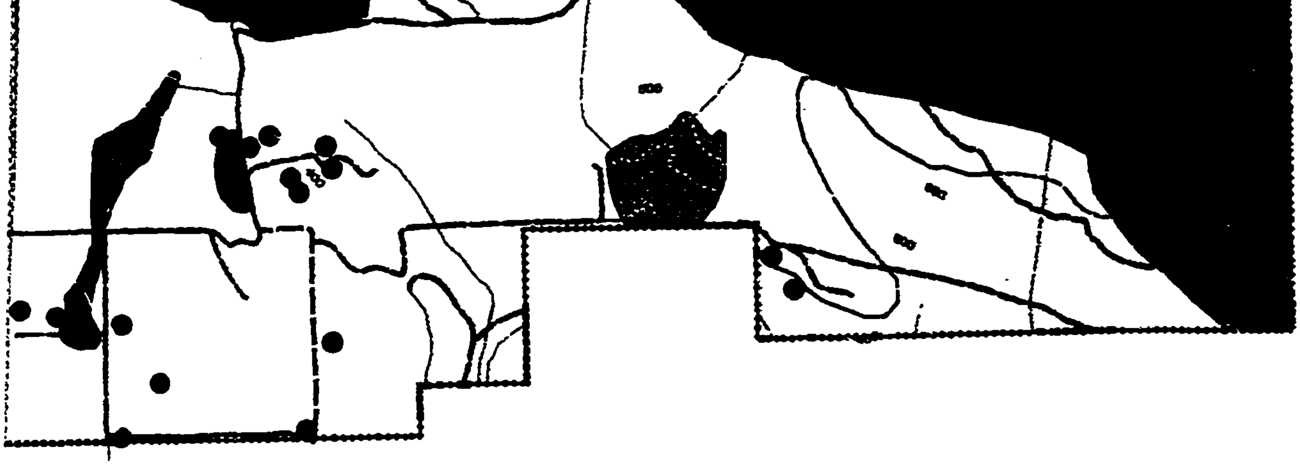


al Geology Map

Area (NTS 92G/1E &

logical Survey OPEN FIL

ierath, D.G. Meldrum & P

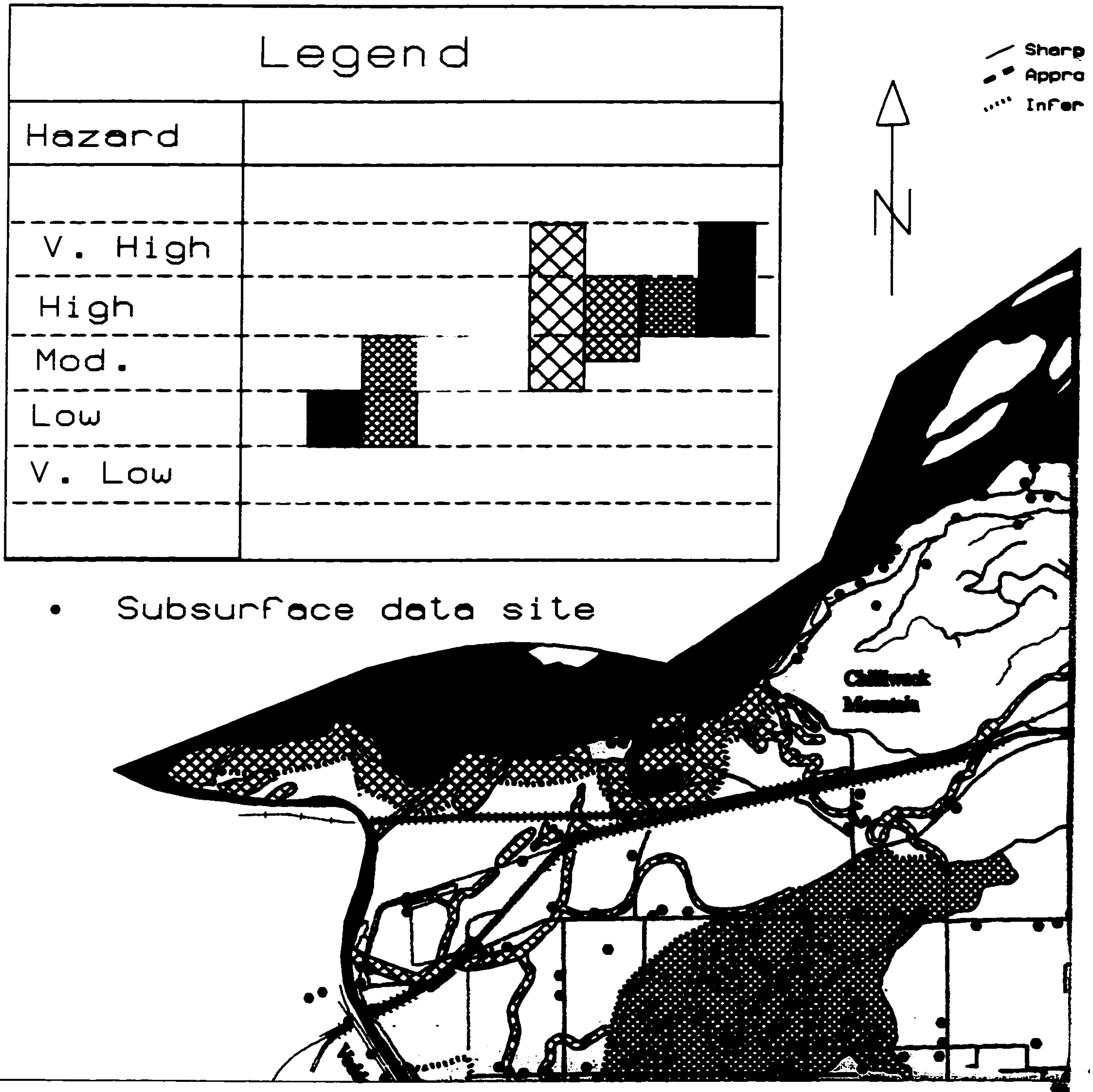


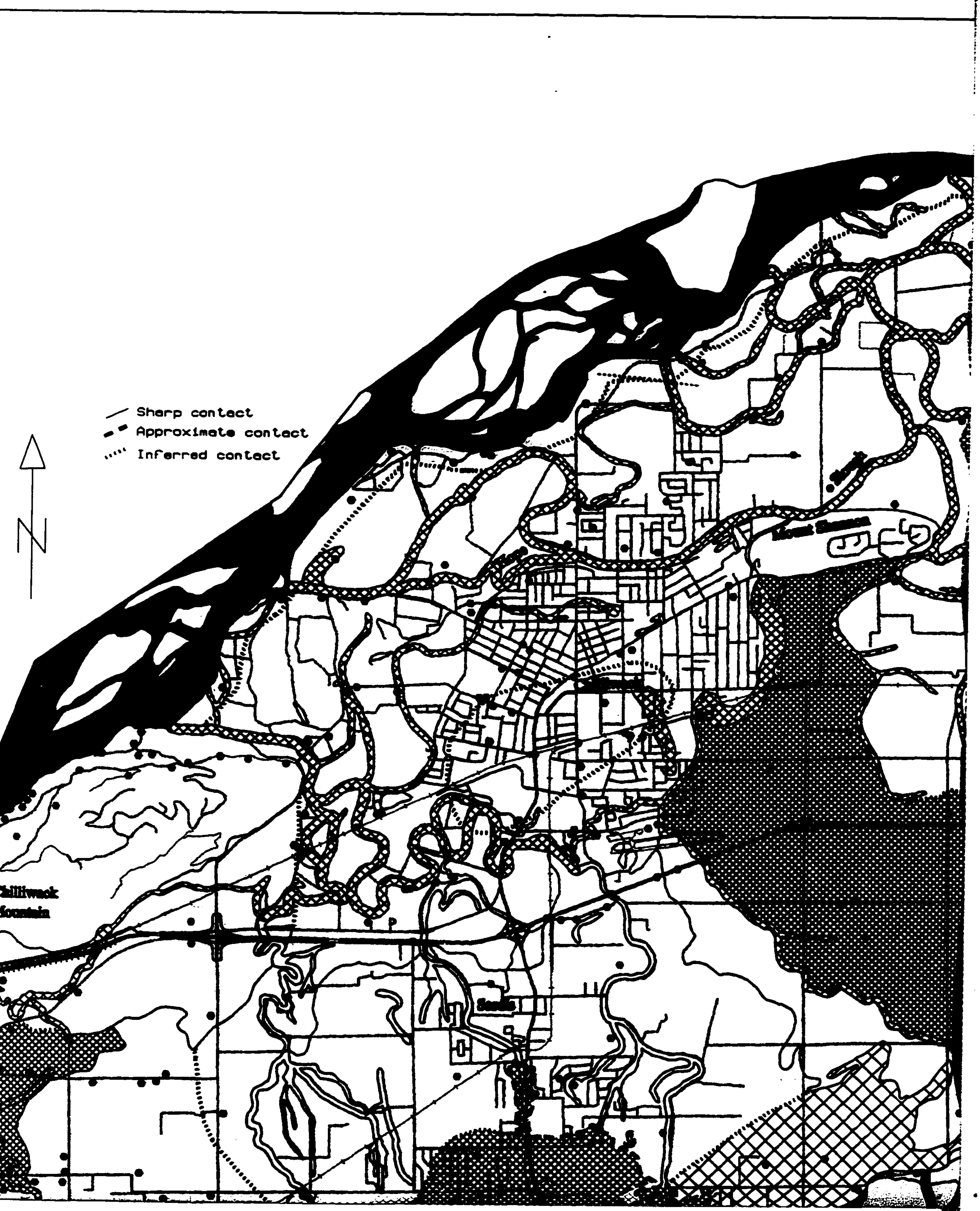
Map

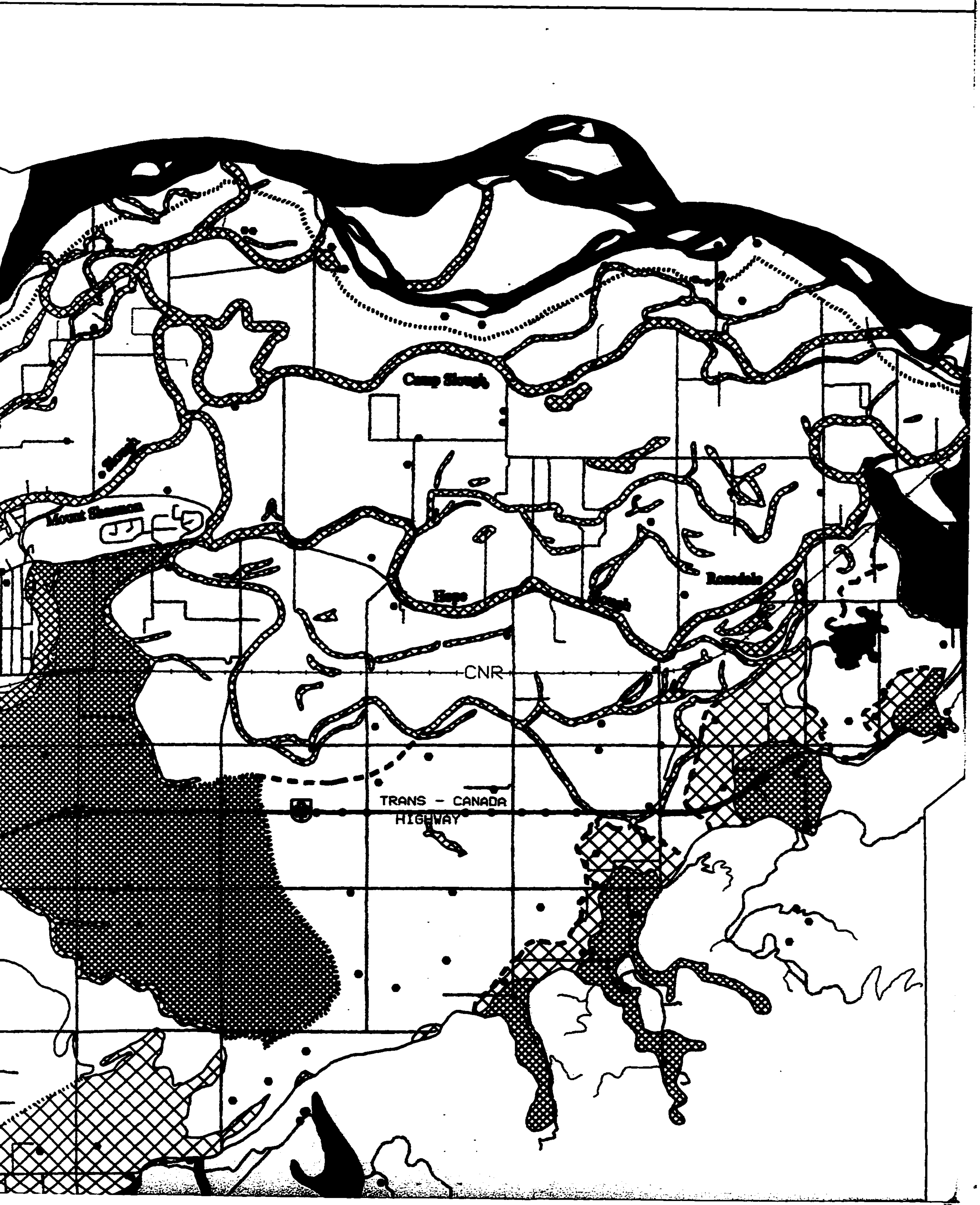
92G/1E & 92H/4W)

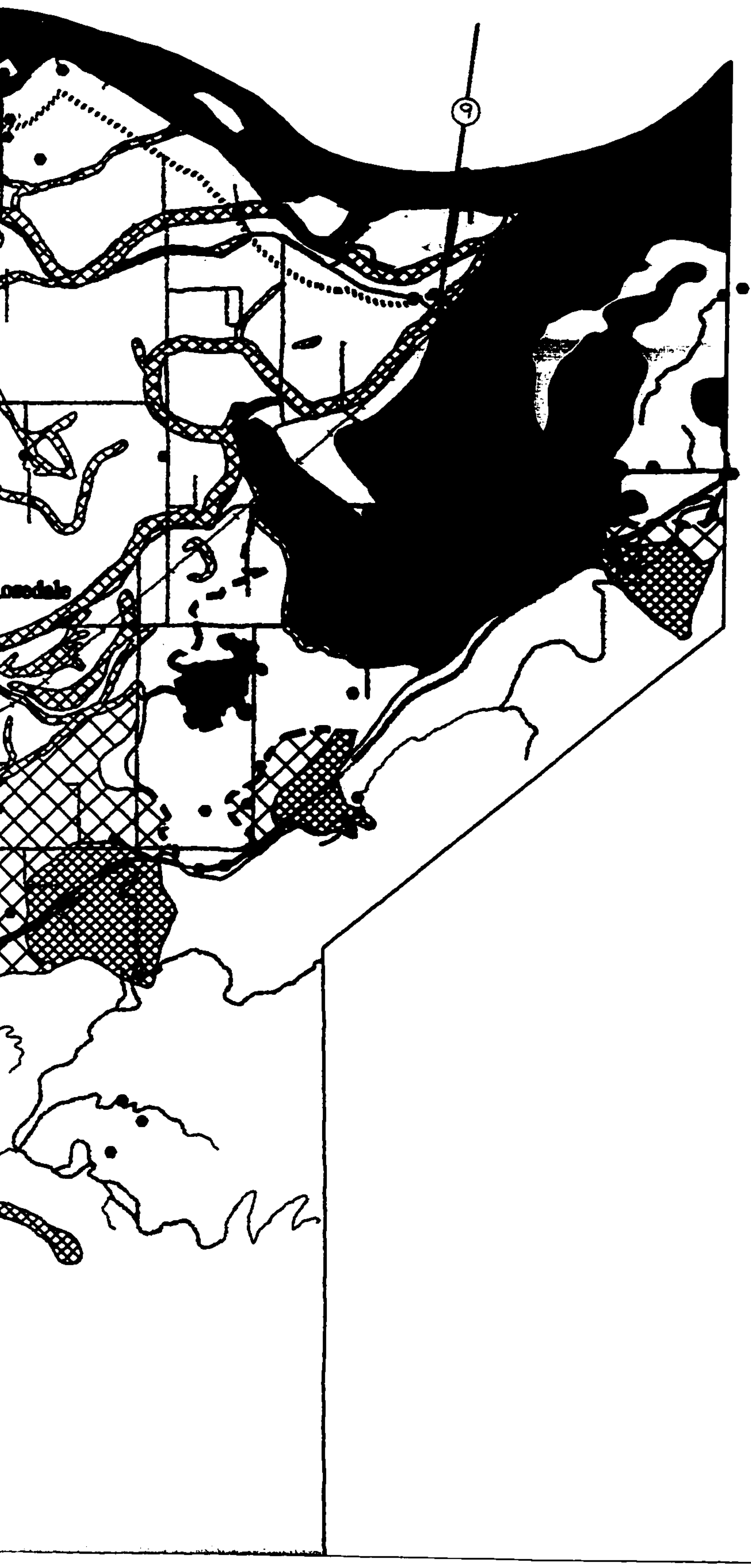
y OPEN FILE 1996-12

eldrum & P.A. Monahan


Legend
Hazard
V. High
High
Mod.
Low
V. Low
• Subsurface data site
Sharp
Appro
Infer
N
Chilliwack Mountain

Sharp contact
Approximate contact
Inferred contact
N
Mount Shannon
hilliwack
ountain
Sardis


Camp Slough
Slough
Mount Shannon
Hope
Slough
Rosedale
CNR
TRANS - CANADA
HIGHWAY



BRITISH COLU
Ministry of Employment and

PRELIMIN
OF TH
RELATI
A

Robert

INTRODUCTION

Earthquake hazard maps identify the
map (MAP 1) shows areas where the
firm or nonliquefiable soils. Altho
potential surface damage are large
be used for mitigative planning
Chilliwack region. *The map is int*
hazard evaluations. Although this
geologically vulnerable areas and
geotechnical studies prior to new
need for these studies, especially
only liquefaction and amplification
are not included on this map. In ad
high, but no area on the map is
levels of certainty, with the
(Klohn-Crippen, 1994). For example
potential (level 2) and liquefacti
could be augmented (at greater cost

DEFINITIONS

Liquefaction refers to the transfo
and behave like a liquid. The susc
and water table depth. Recently
liquefaction. When a soil liquefie
the ground slope and the distance o

Liquefaction susceptibility is de

ITISH COLUMBIA
f Employment and Investment

Geological Survey Branch

OPEN FILE 1996-25

(Sheet 1 of 1)

ELIMINARY RELATIVE EARTHQUAKE HAZARD MAP
)F THE CHILLIWACK AREA SHOWING AREAS OF
ELATIVE POTENTIAL FOR LIQUEFACTION AND/OR
AMPLIFICATION OF GROUND MOTION

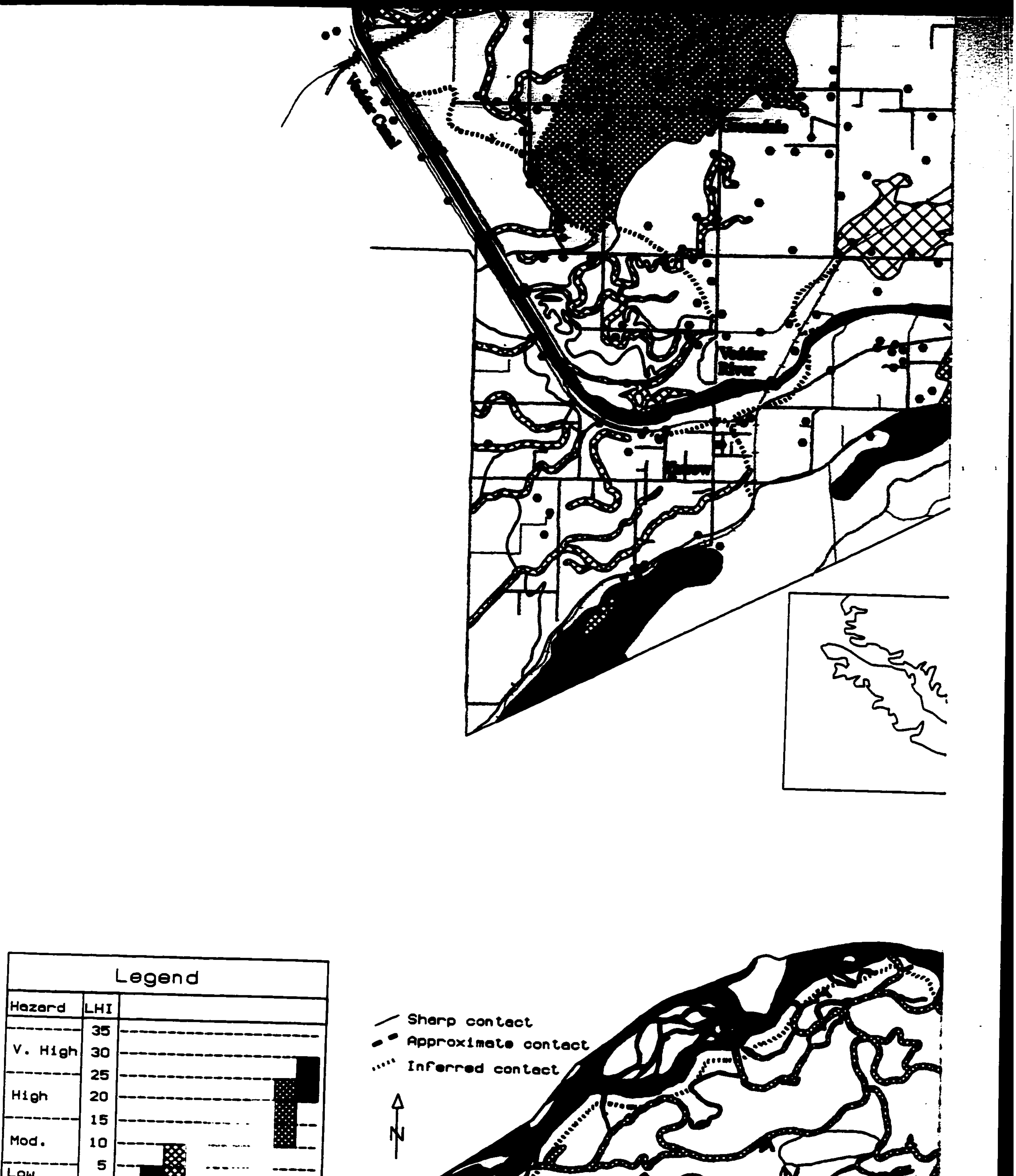
NTS 92G/1 and H/4

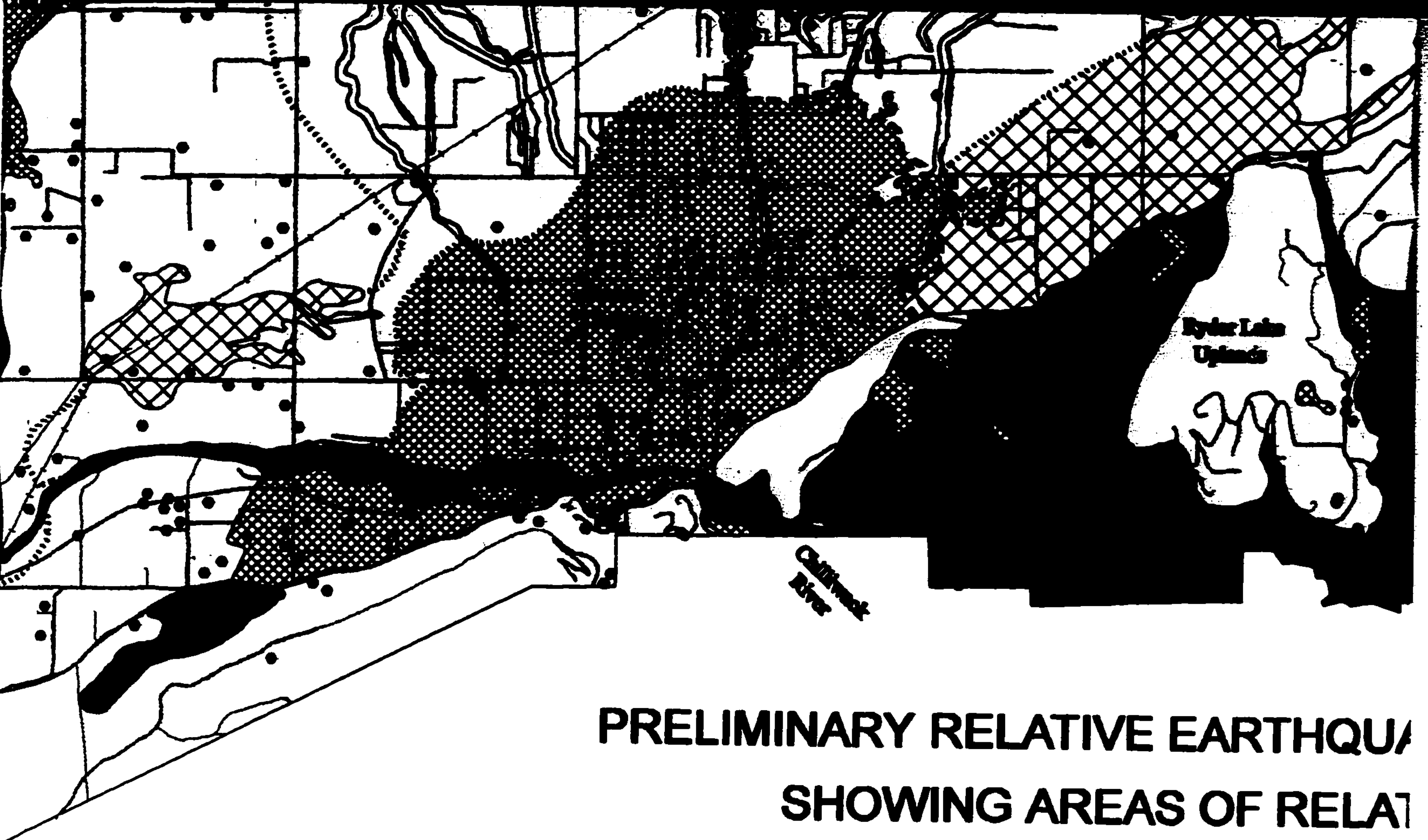
Victor M. Levson, Patrick A. Monahan, Daniel G. Meldrum,
British Columbia Geological Survey
Alex Sy, Li Yan, Bryan Watts, Klohn-Crippen Consultants Ltd.
Robert F. Gerath, Thurber Engineering Ltd. (Presently with Terratech Consulting Ltd.)

**entify the relative potential for ground disturbance during an earthquake due to local geologic conditions. This
vhere the presence of soft or liquefiable soils may result in an increased hazard, compared to other areas with
ils. Although the source and magnitude of earthquakes are difficult to predict, variations in soil behavior and
are largely controlled by mappable geologic and geotechnical conditions. Earthquake hazard maps, therefore can
planning in seismically active regions. This map results from a geological and geotechnical study of the
ap is intended for regional purposes only, such as landuse and emergency planning and not for site specific
ugh this map can be used with other criteria to help planners select potential areas for development, avoid
areas and prioritize seismic upgrading programs, *the map in no way replaces the need for site-specific*
r to new construction or upgrading of buildings and other facilities such as bridges. The map highlights the
especially in areas of high hazard. Although one or more hazards may be included in an earthquake hazard map,
lification of ground motion hazards are evaluated here. *Other hazards, such as earthquake-triggered landslides,*
map. In addition, the map shows where liquefaction or amplification hazards are expected to be relatively low or
map is entirely free from earthquake-induced ground shaking. Earthquake hazards can be mapped at different
th the amount, quality and cost of information required, generally increasing with each mapping level
r example, liquefaction hazard maps can be grouped into liquefaction susceptibility (level 1), liquefaction
iquefaction-induced ground displacement (level 3) maps. This map combines level 1 and level 2 procedures and
eater cost and effort) by level 3 hazard assessments.**

**e transformation that occurs when earthquake shaking (or other disturbances) cause a soil to lose its strength
The susceptibility of a soil to liquefaction is dependent on factors such as grain size, density, deposit age
Recently deposited, loosely packed, wet granular soils (such as sands) tend to be most susceptible to
liquefies, the amount of surface disturbance depends on the depth and thickness of the liquefiable layer(s),
listance of the site from a free-face such as river bank, toward which the soil may move.**

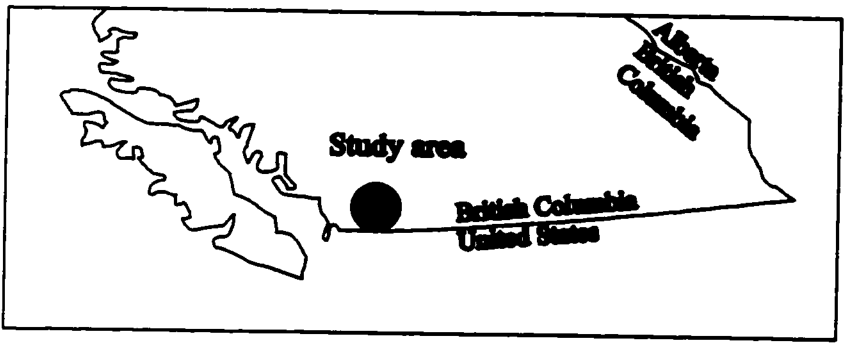
is dependent on the physical characteristics of the soil and does not account for variations in regional


Vedder Canal
Vedder River
Legend
Hazard
LHI
35
V. High
30
25
High
20
15
Mod.
10
5
Low
Sharp contact
Approximate contact
Inferred contact
N



PRELIMINARY RELATIVE EARTHQUA
SHOWING AREAS OF RELAT
AND/OR AMPLIF

(Inset M



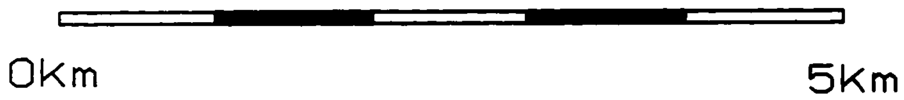
0Km

Legend

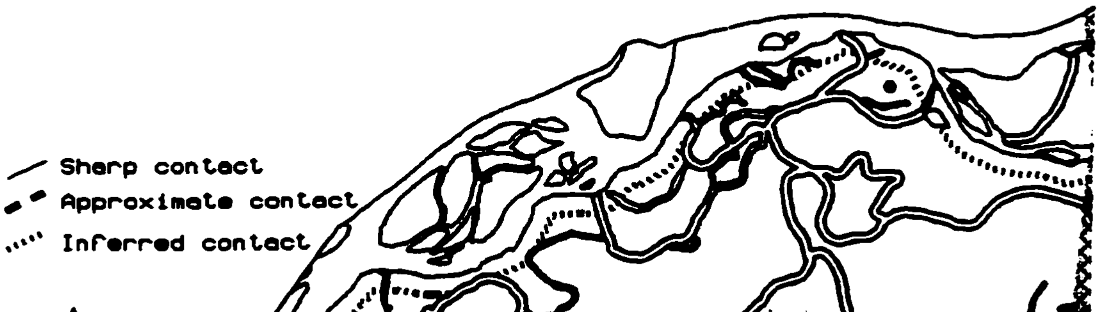
Hazard	NEHRP soil class	
V. High	F	
High	F	

LATIVE EARTHQUAKE HAZARD MAP OF THE CHILLIWACK ARE
AREAS OF RELATIVE POTENTIAL FOR LIQUEFACTION
AND/OR AMPLIFICATION OF GROUND MOTION

(Inset Map 1)



Legend		
Hazard	NEHRP soil class	
V. High	F	▩



ILLIWACK AREA
ACTION
N

could be augmented (at greater cost an

DEFINITIONS

Liquefaction refers to the transformat
and behave like a liquid. The suscepti
and water table depth. Recently de
liquefaction. When a soil liquefies,
the ground slope and the distance of t

Liquefaction *susceptibility* is depend
seismicity. However, liquefaction *pot*
for the expected intensity of seismic

Amplification of ground motion refer
example, thick, soft soil deposits
resonance, which can increase the inte

METHODOLOGY

The methodology used included: 1) col
shown on MAP 1 as dots); 2) 1:20,00
Information System (Meldrum et al., i
the upper 20 m; Monahan and Levson, i
ground motion amplification hazards
methods used generally follow those r
have been provided by Levson et al.
hazard mapping in the region are prov
are only summarised briefly here. Refe

LIQUEFACTION HAZARD MAPPING (INSET MAP

Liquefaction susceptibility of each un
and liquefaction. Liquefaction potent
density of liquefiable layers and the
were expressed as a Liquefaction Haz
was assigned to each map unit. For m
slopes and towards free-faces such as
near the banks of active and semi-act

GROUND MOTION AMPLIFICATION HAZARD MA

Potential ground motion amplification
with soil classes adopted by the U.
expressed as a range to reflect geol
amplification varies with the inten
accelerations in the San Francisco Ba
more than 0.25 g (Clough et al., 199
been observed that at very high acce
Chilliwack region, the peak horizonta
acceleration has a 10% chance of exce
the upper 30 metres. The effects of d
amplification, have not been consider
considered. However, in general, intensified shaking for l
for tall buildings could occur where depth to bedrock is d

COMBINING LIQUEFACTION AND GROUND MOTION

A simple, objective approach is used he
by planners. The approach is conservat
liquefaction and amplification hazard
with a low to high liquefaction hazard
(i.e. the composite rating reflects the
liquefaction hazard at the top end).
because the two types of hazards are di
of hazard will result in an overall
significant damage may result from one
that minor liquefaction will occur i
considered in the assessment of li
amplification hazard.

The approach used here has the adva
incorporated. The merits of a non-avera
not be reduced to reflect a low lique
destroyed by a landslide, for example,

LIMITATIONS ON MAP USE

This map is regional in scope and ind
unit boundaries are based on geologic
approximate and may change with addit
variations within map units, gradati
earthquake, ground shaking will occur

induced ground displacement (level 3) maps. This map combines level 1 and level 2 procedures and
greater cost and effort) by level 3 hazard assessments.

the transformation that occurs when earthquake shaking (or other disturbances) cause a soil to lose its strength
id. The susceptibility of a soil to liquefaction is dependent on factors such as grain size, density, deposit age
h. Recently deposited, loosely packed, wet granular soils (such as sands) tend to be most susceptible to
oil liquefies, the amount of surface disturbance depends on the depth and thickness of the liquefiable layer(s),
he distance of the site from a free-face such as river bank, toward which the soil may move.

ility is dependent on the physical characteristics of the soil and does not account for variations in regional
iquefaction *potential* includes an assessment of the probability of liquefaction actually occurring by accounting
sity of seismic shaking (based on past records of earthquakes) as well as soil conditions.

d motion refers to an increase in the intensity of ground shaking at a site due to the soil conditions. For
soil deposits often amplify ground motions over and above the seismic motions on firm ground. The effects of
crease the intensity of shaking in buildings of different heights, are not considered in this evaluation.

ncluded: 1) collection of mainly existing geotechnical test hole and water well data (> 2400 logs from 390 sites,
s); 2) 1:20,000-scale surficial geology mapping (Levson et *al.*, 1996b); 3) integration of data in a Geographic
ldrum *et al.*, in press); 4) subsurface geological modeling; 5) production of a Quaternary geology map (reflecting
n and Levson, in press); 6) assessment of liquefaction susceptibility and liquefaction potential (INSET MAP 2) and
ation hazards (INSET MAP 3); and 7) development of a combined liquefaction and amplification hazard map. The
follow those recommended by the Seismic Microzonation Task Group (Klohn-Crippen, 1994). Summaries of the program
Levson et *al.* (1995, 1996a). The details of the methodologies and references for liquefaction and amplification
region are provided by Levson et *al.* (in press) and Monahan et *al. (in press), respectively. These methodologies
efly here. Reference should be made to these publications for a complete understanding of the procedures used.*

PING (INSET MAP 2)

*lity of each unit on the Quaternary geology map was estimated based on established correlations between soil types
efaction potential was then quantitatively assessed using a method that accounts for the depth, thickness and
layers and the seismic hazard, based on the National Building Code of Canada (NBCC) seismic model. The results
quefaction Hazard Index (LHI) and were determined for 59 test holes at 27 different sites. A range of LHI values
p unit. For more details see Levson et al. (in press). LHI does not account for lateral ground displacement on
-faces such as a river banks. However, lateral movements are qualitatively considered in this evaluation as areas
e and semi-active channels, are given a relatively high hazard rating.*

TION HAZARD MAPPING (INSET MAP 3)

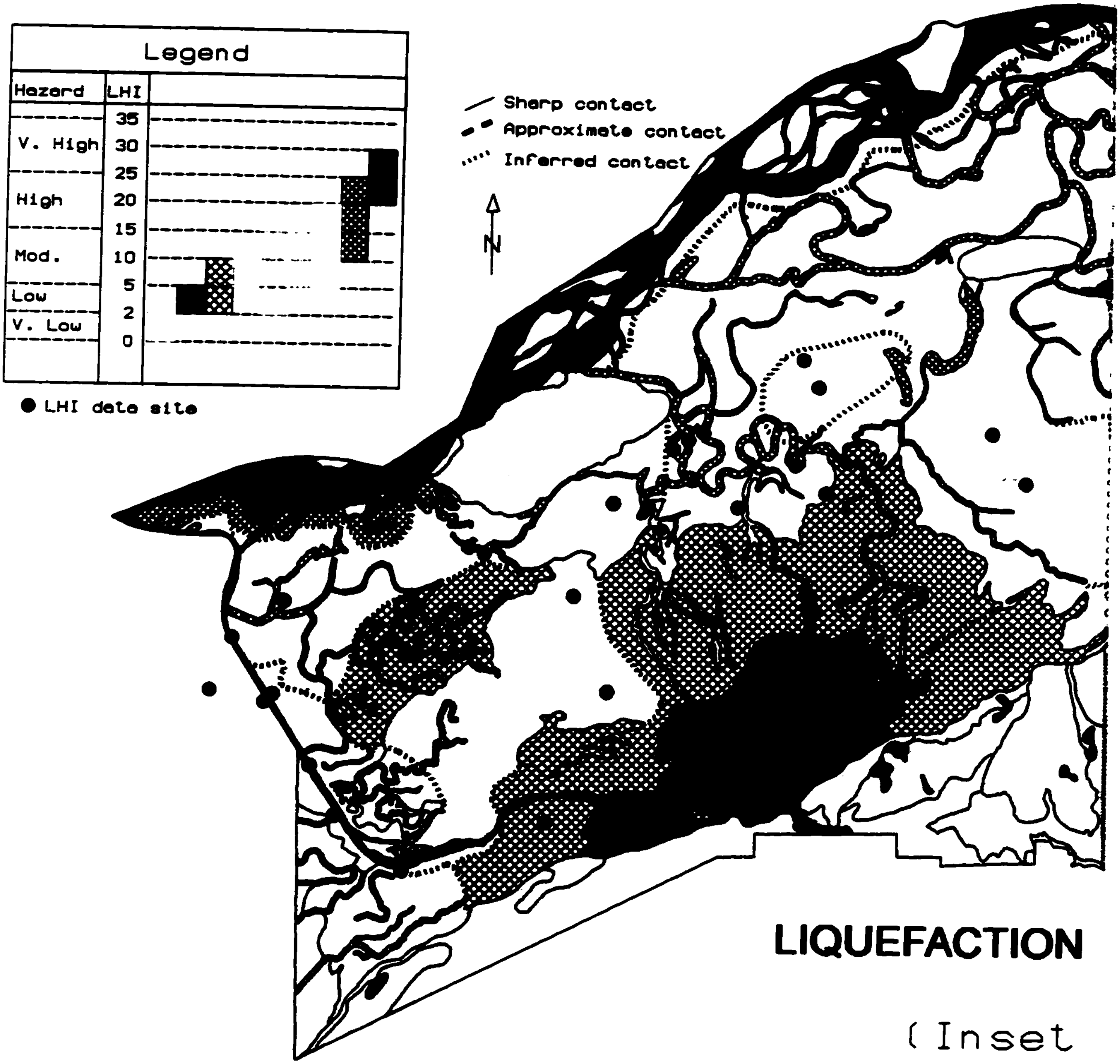
*amplification has been estimated by comparison of the characteristics of each unit on the Quaternary geology map
ted by the U.S. National Earthquake Hazards Reduction Program (Finn, 1996). The hazard for each map unit is
reflect geological variation. For more details see Monahan et al., (in press). The magnitude of ground motion
ith the intensity of firm ground acceleration. For example, in the 1989 Loma Prieta earthquake, firm ground
Francisco Bay area were less than 0.1 g, but at nearby sites on soft soils these accelerations were amplified to
h et al., 1994). Consequently, the greatest damage occurred in areas underlain by soft soils. However, it has
ery high accelerations (such as 0.5 g) on firm ground, amplification at soft soil sites is negligible. In the
peak horizontal, firm-ground acceleration used for design, as required by the NBCC, is approximately 0.2 g. This
chance of exceedance in 50 years, or a 475 year return period. The amplification map is based on soils data from
effects of deeper soils that are present in the area but are poorly understood, and the effects of topography on
been considered. As noted above, the effects of resonance, which can greatly increase the intensity of shaking for buildings of different heights have not been
sified shaking for low buildings could be anticipated where the depth to bedrock is relatively shallow, such as very close to the mountain front. Similarly, intensified shaking
depth to bedrock is deeper.*

D GROUND MOTION AMPLIFICATION HAZARDS

*ch is used here to combine earthquake-induced liquefaction and ground-motion amplification hazards into one map usable
is conservative in that it reflects the highest rating from either of the two types of hazards. For map units with
ation hazard ratings that span different ranges, the higher ends of the ranges are selected. For example, a map unit
action hazard rating and a moderate amplification rating would be presented on this map as a moderate to high hazard
reflects the highest bounding values, in this case the moderate amplification hazard at the bottom end and the high
e top end). No attempt is made to add and/or average the two hazards to develop a combined relative hazard rating
azards are distinct and are not simply additive. The basic premise behind the map is that a high rating in either type
an overall high earthquake hazard even though the rating in the other type of hazard may be lower. Therefore, if
ult from one type of hazard, such as high amplification of ground motion, this will not be minimized by the possibility
ill occur in the area. Although ground motion amplification may increase the liquefaction hazard, this has been
ment of liquefaction potential. Furthermore, an increased liquefaction hazard generally does not increase the*

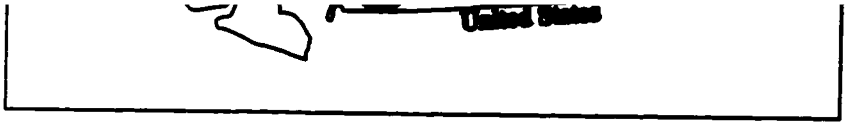
*has the advantage that other types of earthquake hazards, such as seismically-induced landslides, can also be
f a non-averaging conservative approach are more obvious in this example. A high landslide hazard rating clearly should
a low liquefaction or amplification rating in the same area, as it will matter little to a resident whose house is
for example, that the liquefaction hazard on the property was low!*

*cope and indicates general areas where materials susceptible to liquefaction or amplification are likely present. Map
on geological criteria and on limited borehole information only and, as such, the boundaries between map units are
with additional data. The earthquake hazard at any one site may be higher or lower than shown due to geological
ts, gradational and approximate map unit boundaries and the regional scale of this map. Furthermore, during an
will occur throughout the map area*

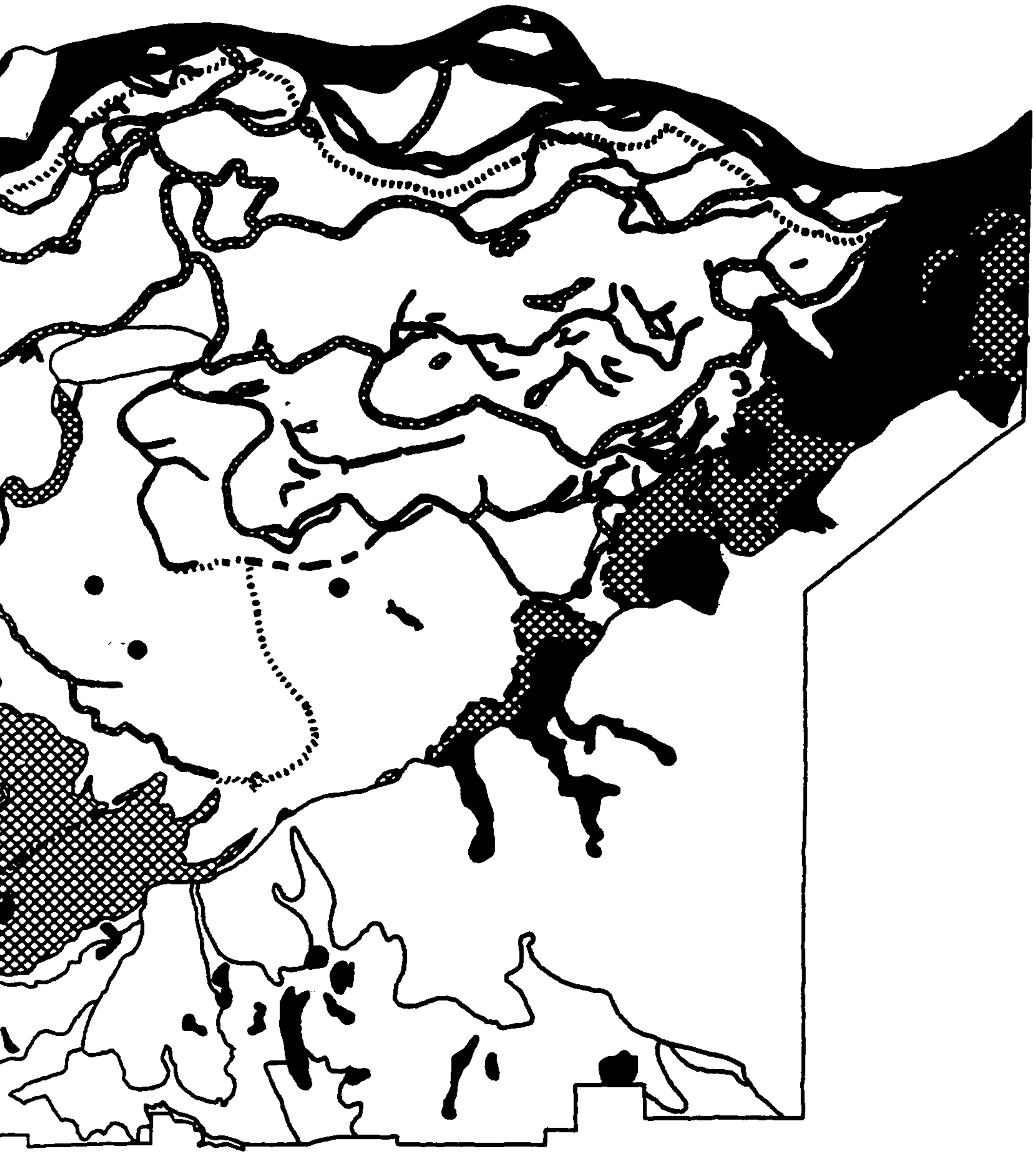


LIQUEFACTION

(Inset



0Km



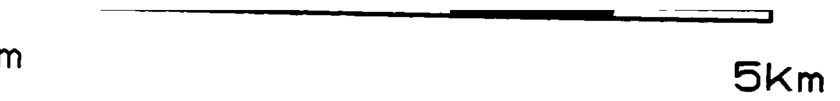
Hazard	NEHRP soil class
V. High	F
High	E
Mod.	D
Low	C
V. Low	B
– Nil	A

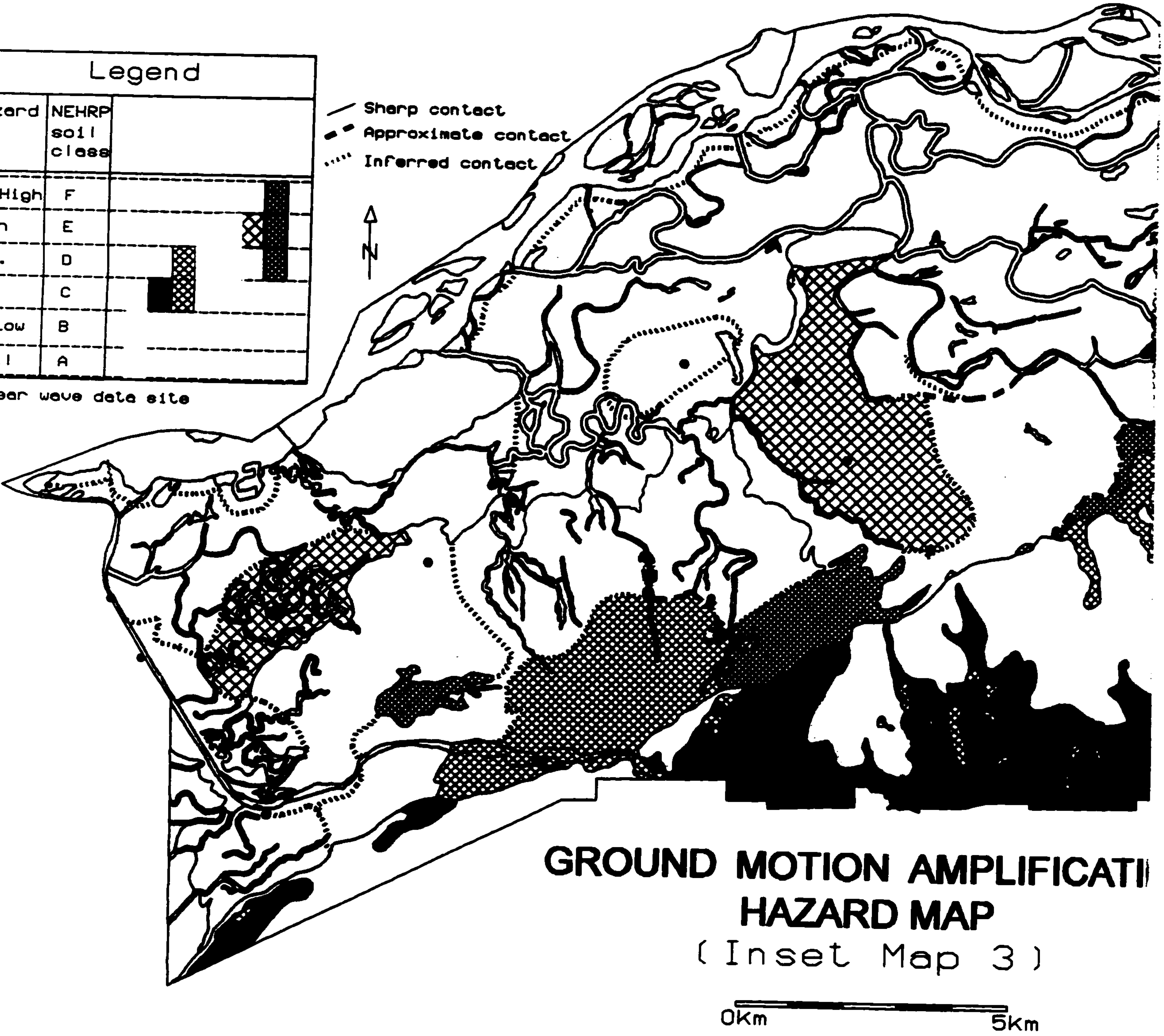
● Shear wave data site

FACTION HAZARD MAP

Inset Map 2)

0Km 5Km





GROUND MOTION AMPLIFICATI
HAZARD MAP
(Inset Map 3)

AMPLIFICATION
MAP
ap 3)

5Km

been observed that at very high accelerations (such
Chilliwack region, the peak horizontal, firm-ground
acceleration has a 10% chance of exceedance in 50 ye
the upper 30 metres. The effects of deeper soils that
amplification, have not been considered. As noted above, t
considered. However, in general, intensified shaking for low buildings could be a
for tall buildings could occur where depth to bedrock is deeper.

COMBINING LIQUEFACTION AND GROUND MOTION AMPLIFICATION H

A simple, objective approach is used here to combine ea
by planners. The approach is conservative in that it r
liquefaction and amplification hazard ratings that span
with a low to high liquefaction hazard rating and a mo
(i.e. the composite rating reflects the highest boundin
liquefaction hazard at the top end). No attempt is ma
because the two types of hazards are distinct and are n
of hazard will result in an overall high earthquake h
significant damage may result from one type of hazard,
that minor liquefaction will occur in the area. Alth
considered in the assessment of liquefaction potent
amplification hazard.

The approach used here has the advantage that othe
incorporated. The merits of a non-averaging conservative
not be reduced to reflect a low liquefaction or amplif
destroyed by a landslide, for example, that the liquefac

LIMITATIONS ON MAP USE

This map is regional in scope and indicates general a
unit boundaries are based on geological criteria and
approximate and may change with additional data. The
variations within map units, gradational and approxi
earthquake, ground shaking will occur throughout the m
generally not be increased due to liquefaction or ampli
freedom from earthquake hazards. For more information
area, reference should be made to the technical maps fr

The map is intended for regional purposes only, such as
are evaluated here. Potential effects from other hazar
evaluation of earthquake hazards in this area for landu

Earthquake hazard maps can not be used to directly pre
as building design or building height must be consid
controls. Likewise, earthquake hazard maps can not be
people present in the area at any one time and the type
a farmer's field, the risk of damage is obviously low,

REFERENCES

Clough, G.W., Martin, J.R. and Chameau, J.L. (1994):
Academy Press, pp. 29-67.
Finn, L.W.D. (1996): Ground Motion Amplification Factor
and Harbour Research Institute, Japan. Volume 2, pages
Klohn-Crippen Consultants Ltd. (1994): Preliminary Seis
Report 17, 108 pages.
Levson, V.M., Monahan, P.A., Meldrum, D.G., Matysek, P.
British Columbia: A Pilot Project. Canadian Geotechnic
927-936.
Levson, V.M., Monahan, P.A., Meldrum, D.G., Matysek, P.
Hazard Mapping, Chilliwack, British Columbia (92G/1
Columbia Ministry of Employment and Investment, Paper 1996-
Levson, V.M., Gerath, R.F., Meldrum, D.G. and Monaha
Columbia Ministry of Employment and Investment, Open File
Levson, V.M., Monahan, P.A., Meldrum, D.G., Sy, A.,
Liquefaction Potential Hazard Map, Chilliwack, Briti
File.
Meldrum, D.G., Monahan, P.A. and Levson, V.M. (in pres
British Columbia (92G/1 and H/4). British Columbia Mi
Monahan, P.A., Levson, V.M., Meldrum, D.G., Sy, A.,
British Columbia (92G/1 and H/4). British Columbia Min
Monahan, P.A. and Levson, V.M. (in press): Quaternar
Columbia Ministry of Employment and Investment, Open File.

for example, that the liquefaction hazard on the property was low.

ope and indicates general areas where materials susceptible to liquefaction or amplification are likely present. Map
on geological criteria and on limited borehole information only and, as such, the boundaries between map units are
with additional data. The earthquake hazard at any one site may be higher or lower than shown due to geological
ts, gradational and approximate map unit boundaries and the regional scale of this map. Furthermore, during an
will occur throughout the map area, even in areas of lower hazard rating, but the hazard in the latter areas will
due to liquefaction or amplification. For these reasons, a low hazard rating on this map should not be interpreted as
zards. For more information on the technical aspects and limitations of earthquake hazard mapping in the Chilliwack
ade to the technical maps from which this composite map was made (Levson et al., in press; Monahan, et al., in press).

gional purposes only, such as landuse and emergency planning. In addition, only liquefaction and amplification hazards
ial effects from other hazards such as earthquake-induced landslides should also be considered in any comprehensive
zards in this area for landuse or emergency planning or any other purpose.

not be used to directly predict the amount of damage that will occur at any one site because many other factors such
lding height must be considered. However, the maps can be used to estimate the relative hazard due to geological
uake hazard maps can not be used to estimate risk as this is dependent on many other factors such as the number of
at any one time and the types of facilities that are there. For example, although the earthquake hazard may be high in
of damage is obviously low, compared to the same level of hazard in a developed area of a city.

and Chameau, J.L. (1994): The Geotechnical Aspects; in Practical lessons from the Loma Prieta Earthquake, National

d Motion Amplification Factors for Use in Building Codes; in Proceedings, International Workshop on Site response, Port
itute, Japan. Volume 2, pages 105-117.
Ltd. (1994): Preliminary Seismic Microzonation Assessment for British Columbia; B.C. Resource Inventory Committee,

., Meldrum, D.G., Matysek, P.F., Watts, B.D., Yan, L. and Sy, A. (1995): Seismic Microzonation Mapping in Southwestern
Project. Canadian Geotechnical Society, Trends in Geotechnique, 48th Canadian Geotechnical Conference, Volume 2, pages

., Meldrum, D.G., Matysek, P.F., Gerath, R.F., Watts, B.D., Sy, A. and Yan, L.(1996a): Surficial Geology and Earthquake
ck, British Columbia (92G/1 and H/4). in Geological Fieldwork 1995, B.M. Grant and J.M. Newell, Editors, British
yment and Investment, Paper 1996-1, pages 191-203.
., Meldrum, D.G. and Monahan, P.A.(1996b): Surficial Geology of the Chilliwack Area, NTS 92G/1E and H/4W. British
yment and Investment, Open File Map 1996-12.
.A., Meldrum, D.G., Sy, A., Yan, L., Watts, B.D. and Gerath, R.F. (in press): Liquefaction Susceptibility and
azard Map, Chilliwack, British Columbia (92G/1 and H/4). British Columbia Ministry of Employment and Investment, Open

A. and Levson, V.M. (in press): Lithological data from geotechnical test holes and water wells in the Chilliwack Area,
nd H/4). British Columbia Ministry of Employment and Investment, Open File.
M., Meldrum, D.G., Sy, A., Yan, L. and Watts, B.D., (in press): Ground Motion Amplification Hazard Map, Chilliwack,
nd H/4). British Columbia Ministry of Employment and Investment, Open File.
V.M. (in press): Quaternary Geology Map (Upper 20 Metres), Chilliwack, British Columbia (92G/1 and H/4). British
yment and Investment, Open File.

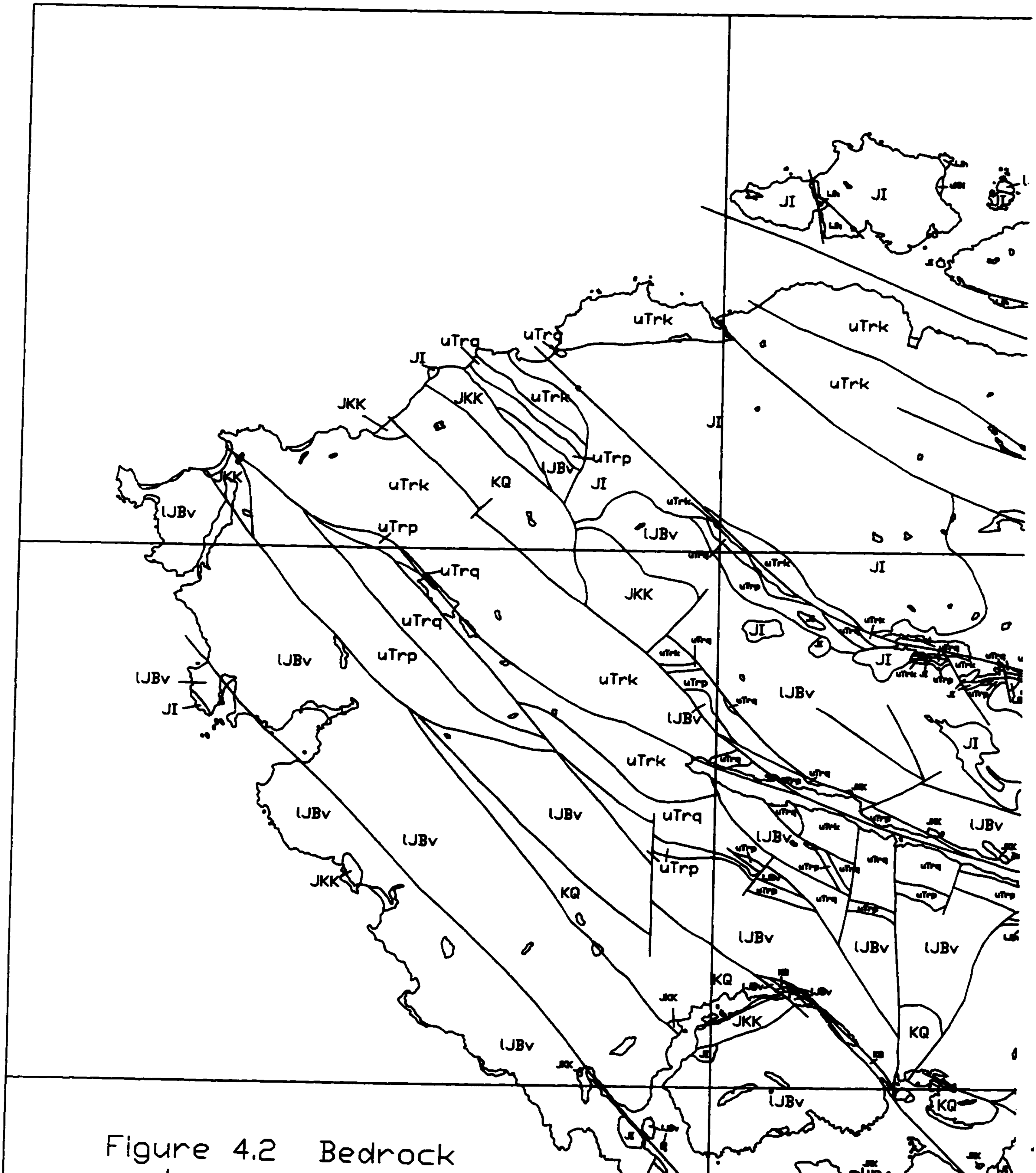
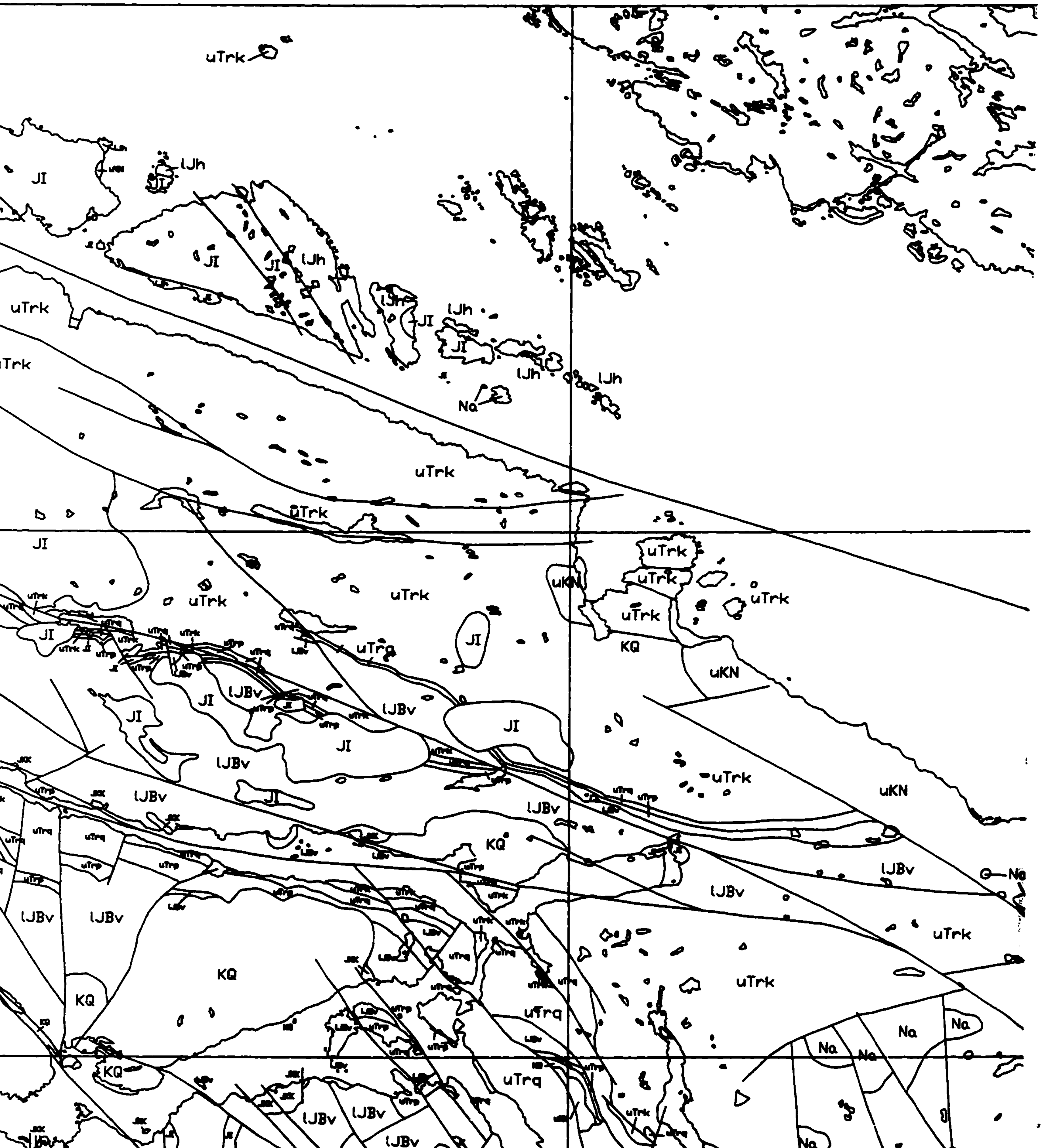
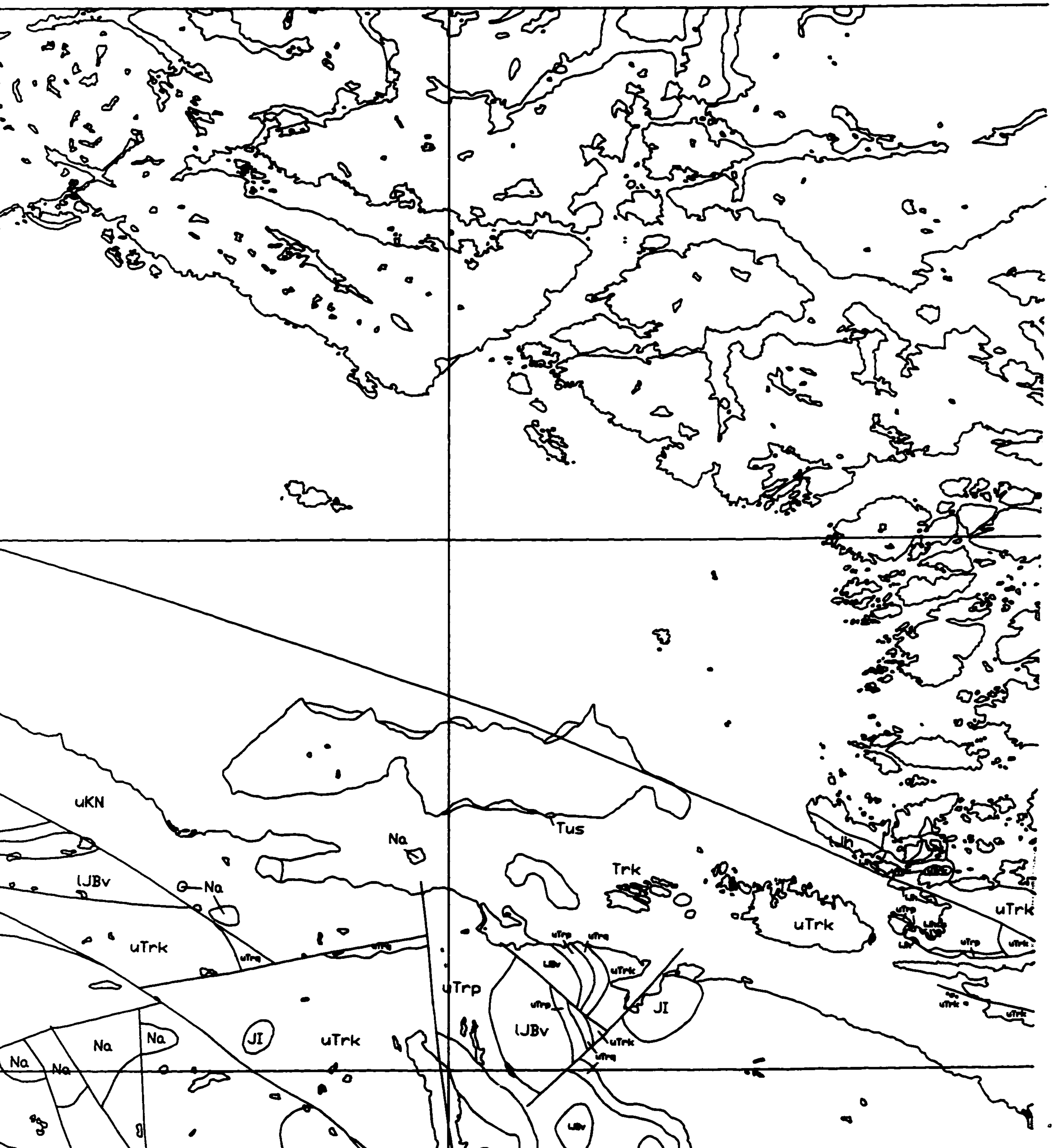
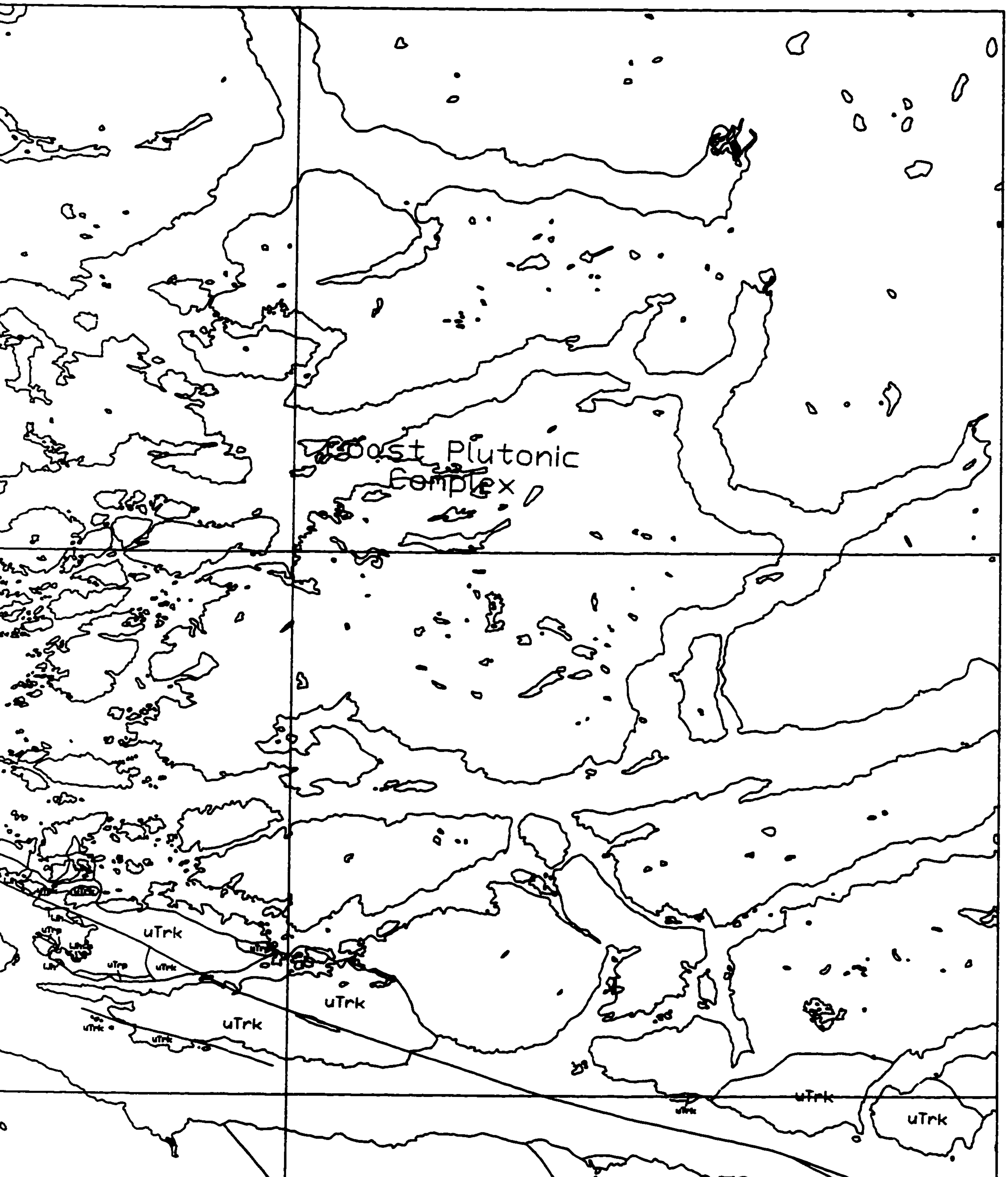


Figure 4.2 Bedrock



uTrk
Jl
lJh
Jl
Jl
Jl
lJh
uTrk
lJh
Jl
lJh
Jl
uTrk
lJh
lJh
Na
uTrk
uTrk
Jl
uTrk
uTrk
uTrk
uKN
uTrk
uTrk
Jl
uTrq
Jl
KQ
uKN
lJBv
Jl
lJBv
Jl
Jl
Jl
lJBv
uTrk
uKN
lJBv
Jl
lJBv
KQ
lJBv
Na
lJBv
lJBv
lJBv
uTrk
KQ
uTrk
KQ
uTrq
Na
Na
Na
Na
KQ
uTrq
lJBv
lJBv
lJBv
Na


uKN
Tus
Na
lJBv
Na
Trk
uTrk
uTrk
lJh
uTrk
uTrq
uTrp
uTrq
uTrp
uTrq
lJBv
uTrk
uTrp
lJBv
Jl
Jl
uTrk
uTrk
uTrq
Na
Na
Na
Na
uTrp
uTrk
uTrk
lJBv


Coast Plutonic Complex
uTrk
uTrp
uTrp
uTrk
uTrk
uTrk
uTrk
uTrk
uTrk
uTrk
uTrk

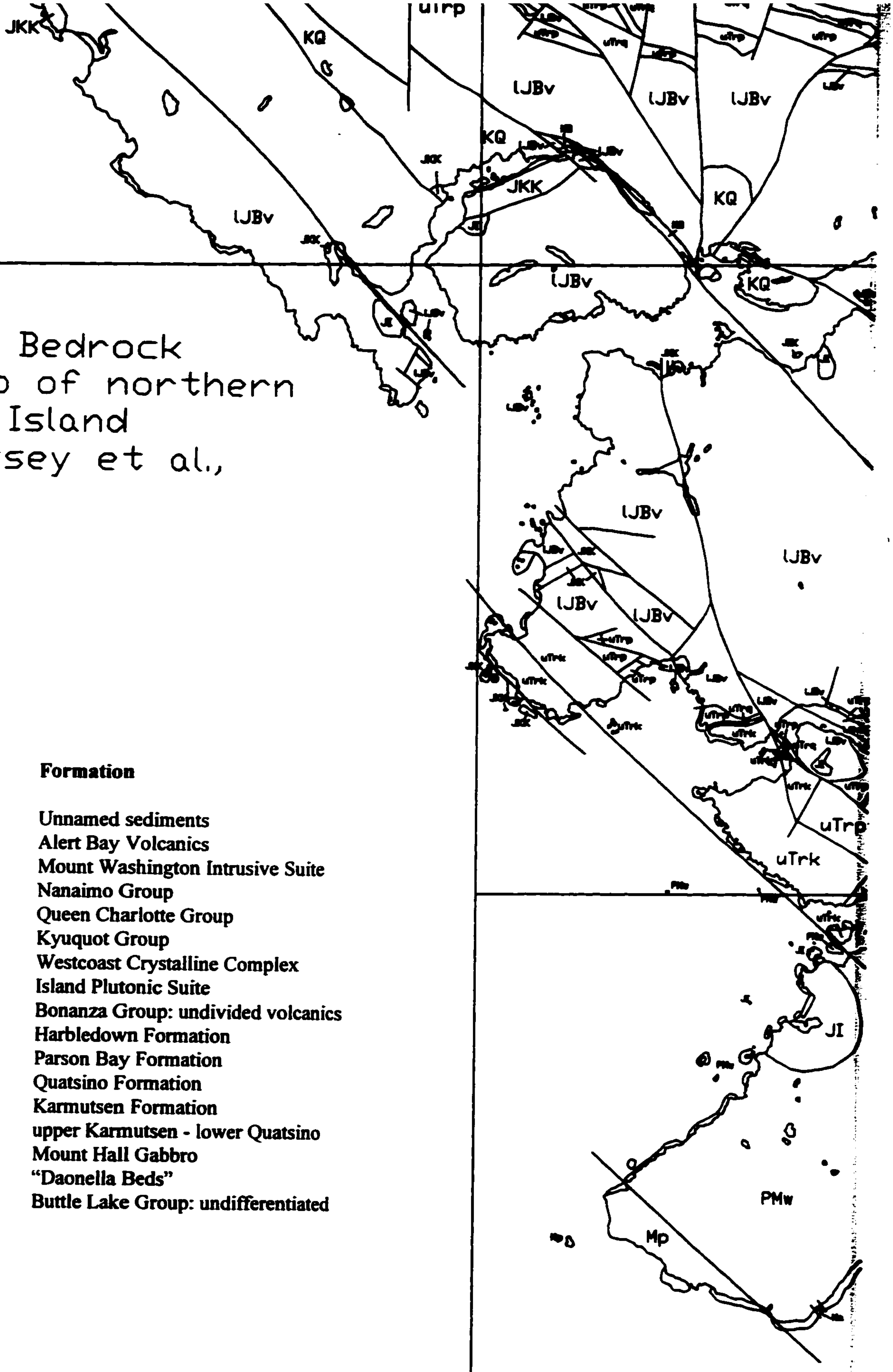
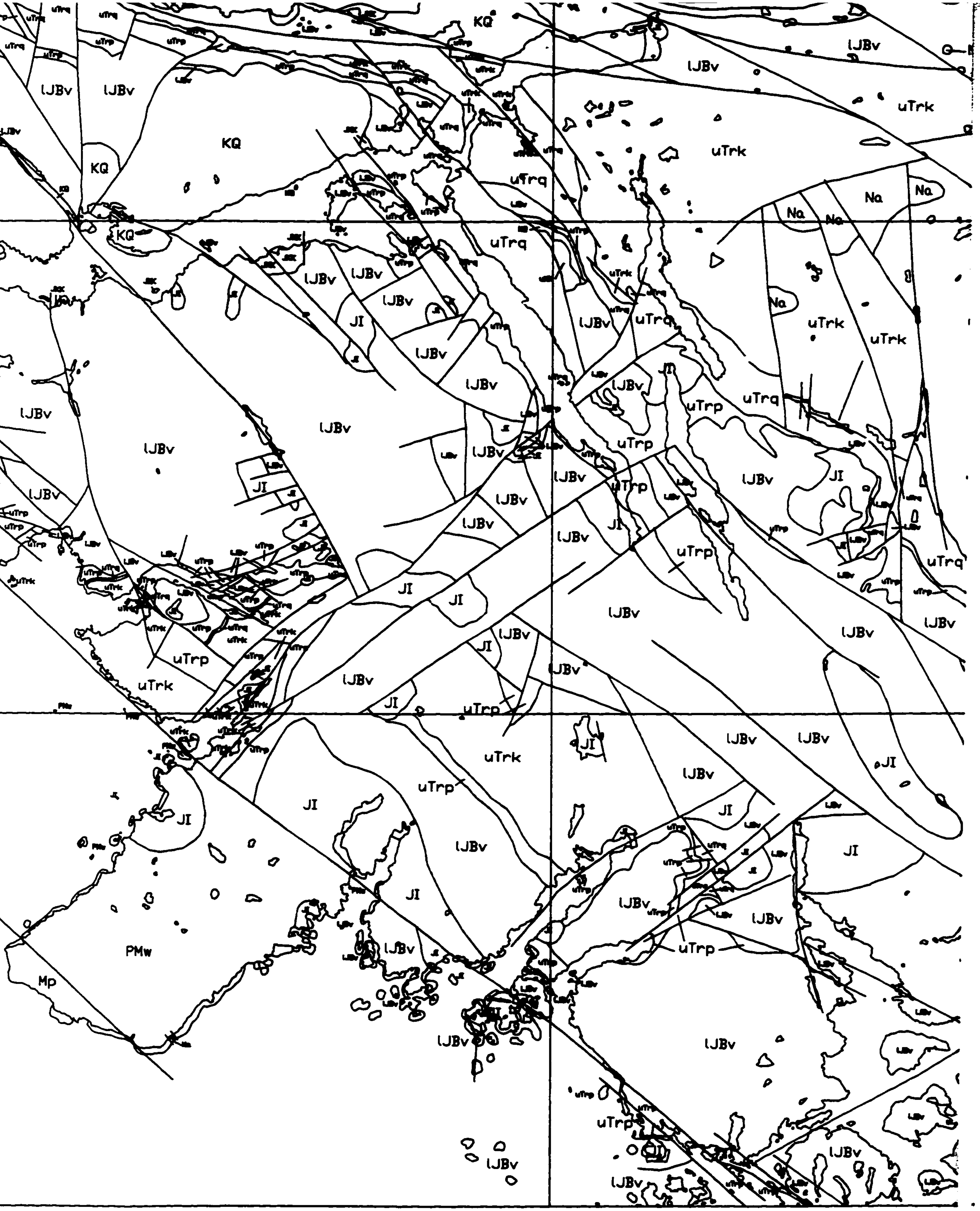
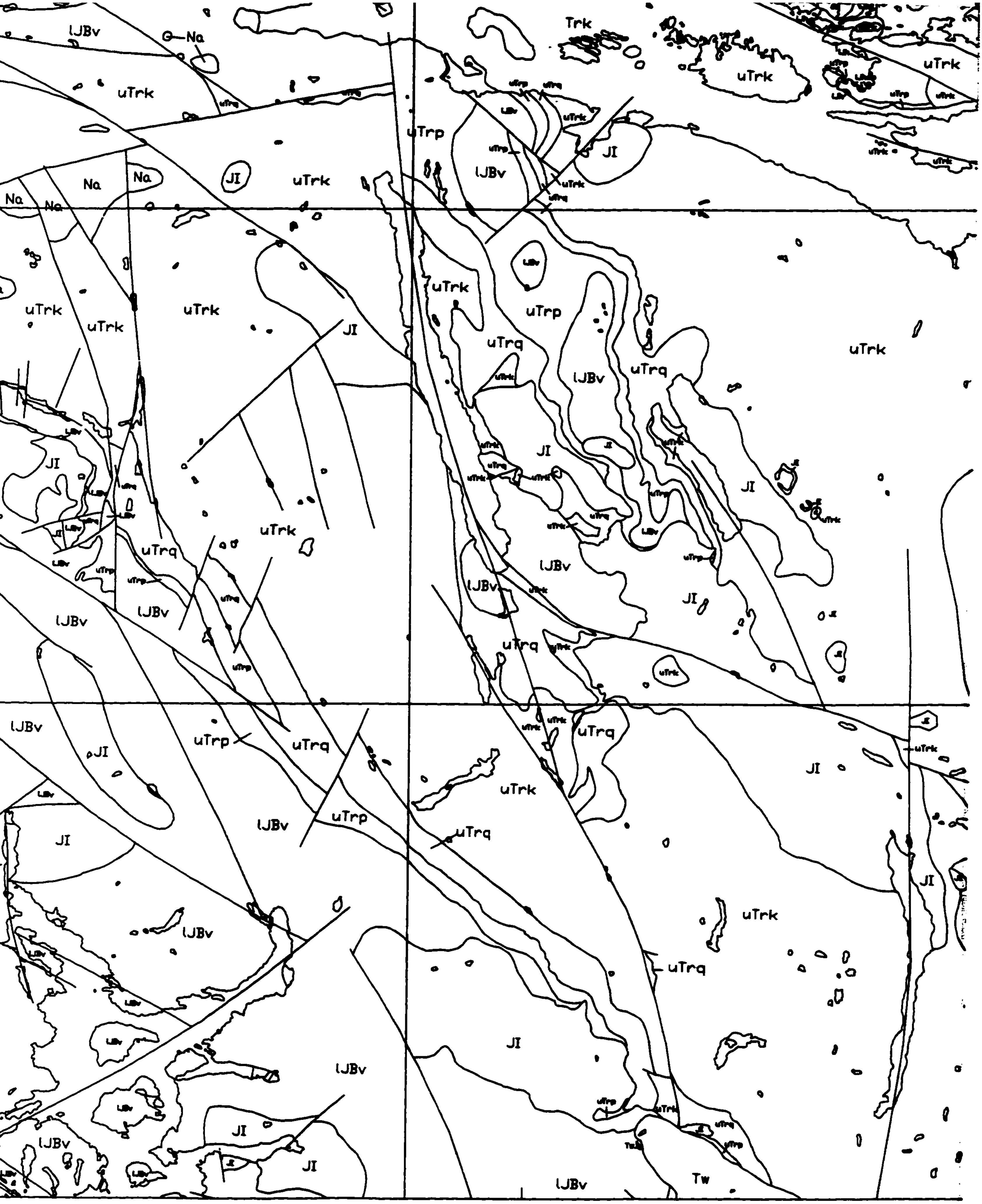


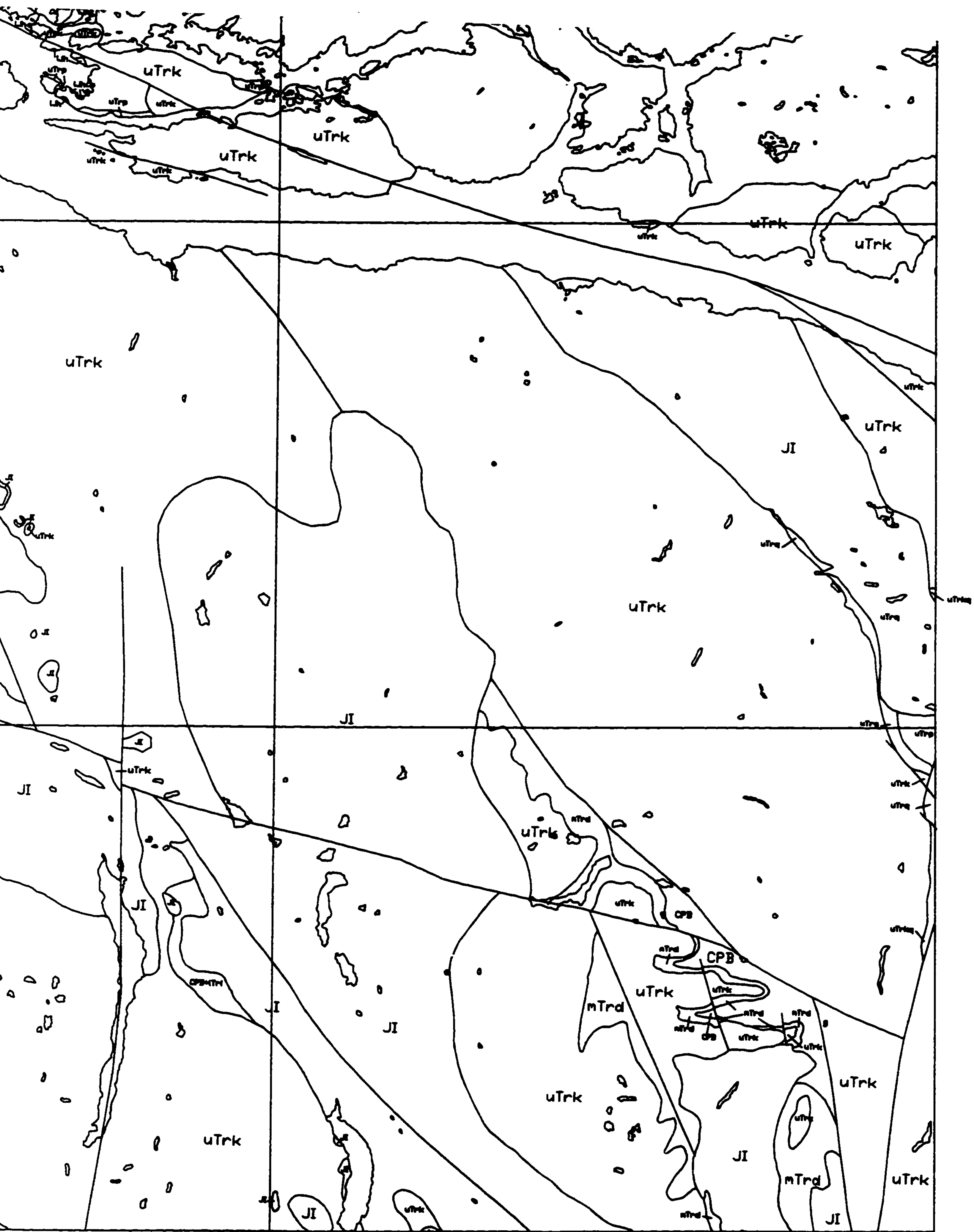
Figure 4.2 Bedrock geology map of northern Vancouver Island (After, Massey et al., 1994)

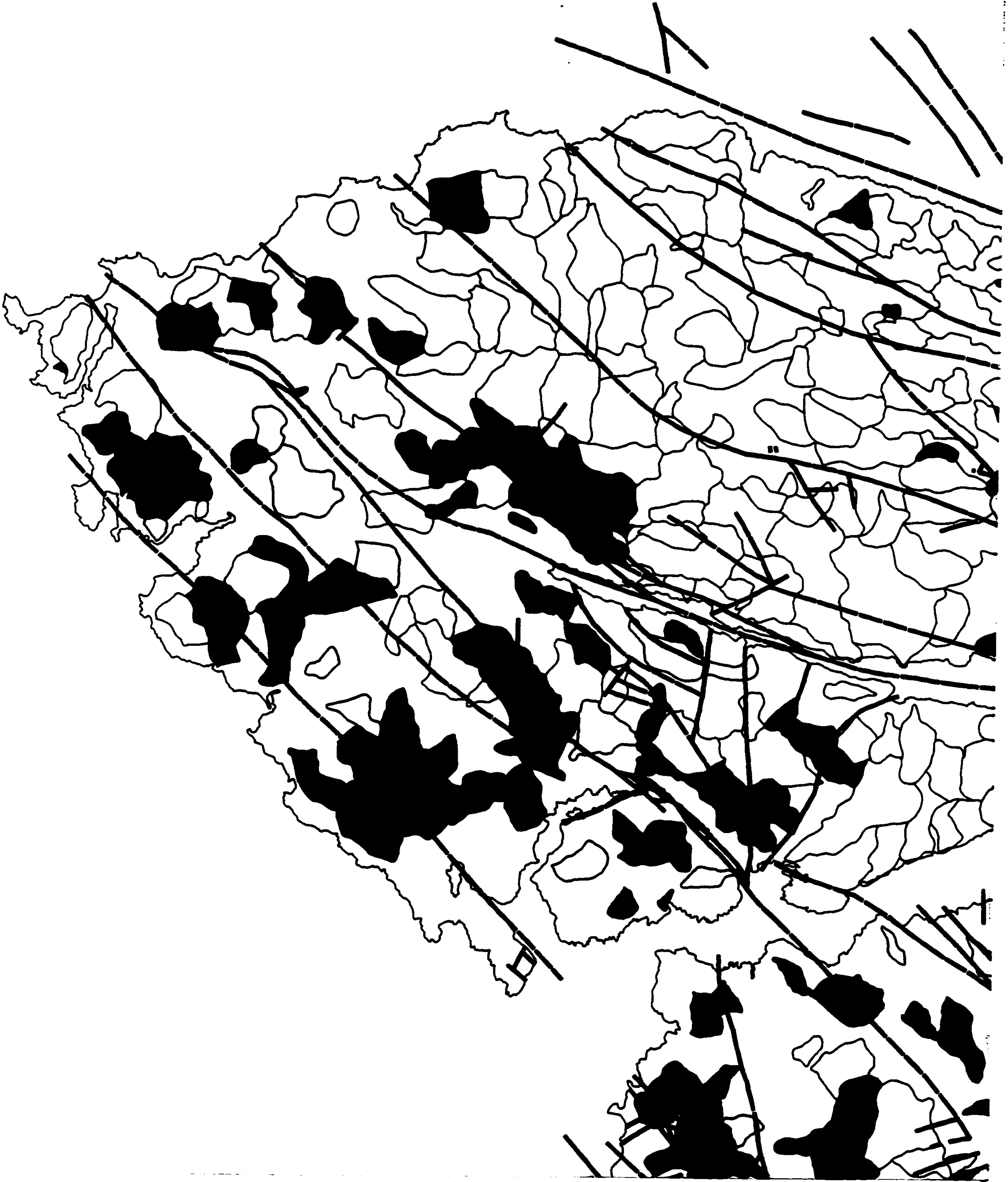
Code	Ma	Ma	Formation
Tus	120	120	Unnamed sediments
NA	122	121	Alert Bay Volcanics
Tw	124	123	Mount Washington Intrusive Suite
uKN	211	211	Nanaimo Group
KQ	214	214	Queen Charlotte Group
JKK	224	217	Kyuquot Group
PMw	344	224	Westcoast Crystalline Complex
JI	227	224	Island Plutonic Suite
lJBv	227	227	Bonanza Group: undivided volcanics
lJh	227	227	Harbledown Formation
uTrp	231	231	Parson Bay Formation
uTrq	231	231	Quatsino Formation
uTrk	231	231	Karmutsen Formation
uTrkq	231	231	upper Karmutsen - lower Quatsino
lTri	231	231	Mount Hall Gabbro
mTrd	234	234	"Daonella Beds"
CPB	337	317	Buttle Lake Group: undifferentiated

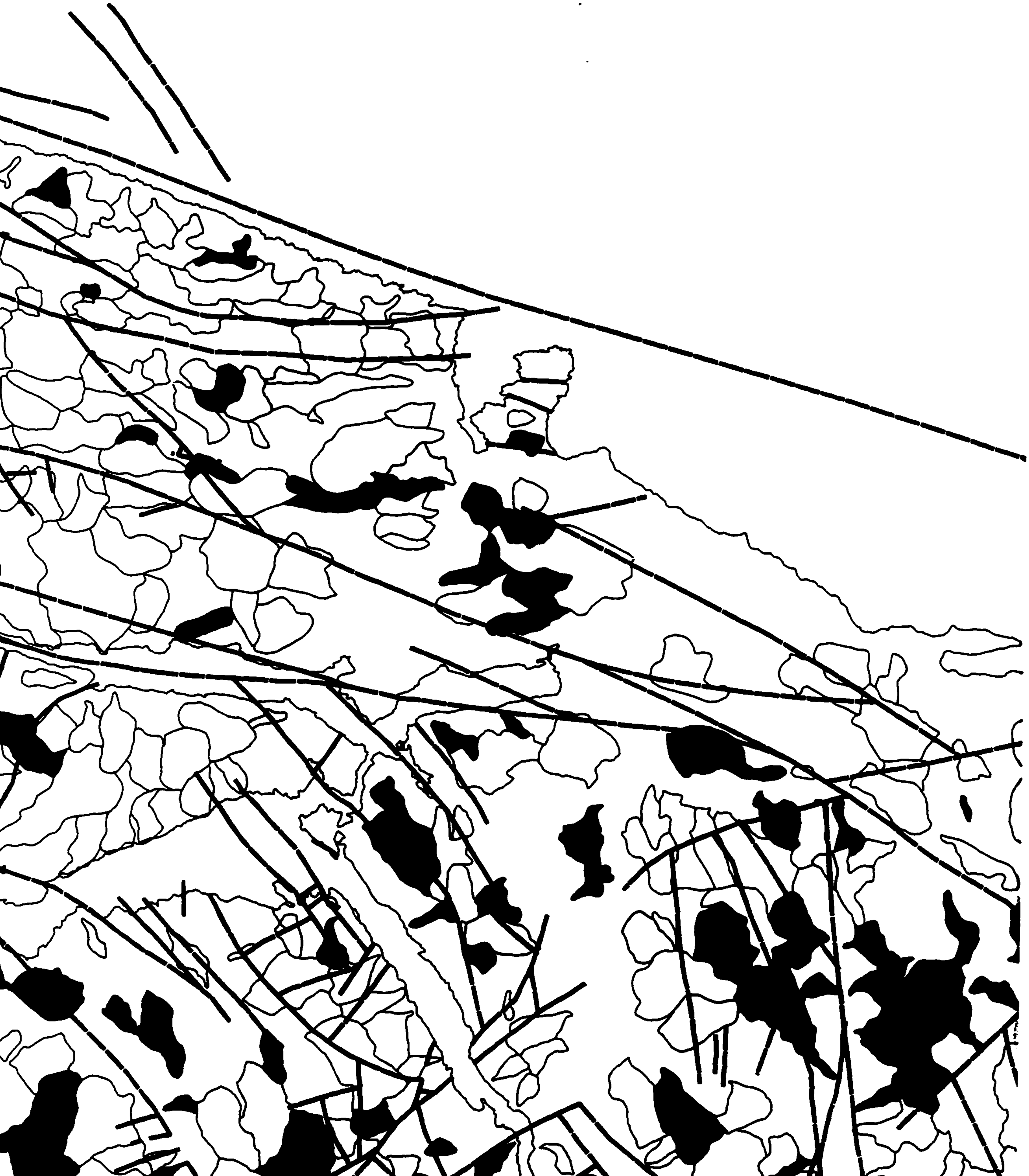

KQ
lJBv
lJBv
lJBv
uTrk
lJBv
KQ
KQ
uTrk
uTrq
Na
Na
Na
Na
KQ
uTrq
lJBv
lJBv
lJBv
Na
JI
uTrk
uTrk
lJBv
uTrq
lJBv
lJBv
JI
lJBv
uTrp
uTrq
lJBv
lJBv
uTrp
lJBv
lJBv
lJBv
lJBv
lJBv
JI
JI
uTrp
lJBv
JI
lJBv
JI
uTrp
uTrq
JI
lJBv
lJBv
lJBv
JI
lJBv
uTrp
uTrk
lJBv
JI
uTrp
JI
uTrk
lJBv
lJBv
lJBv
JI
uTrp
lJBv
JI
JI
lJBv
JI
JI
lJBv
lJBv
PMw
Mp
uTrp
lJBv
lJBv
lJBv
uTrp
lJBv
lJBv
lJBv

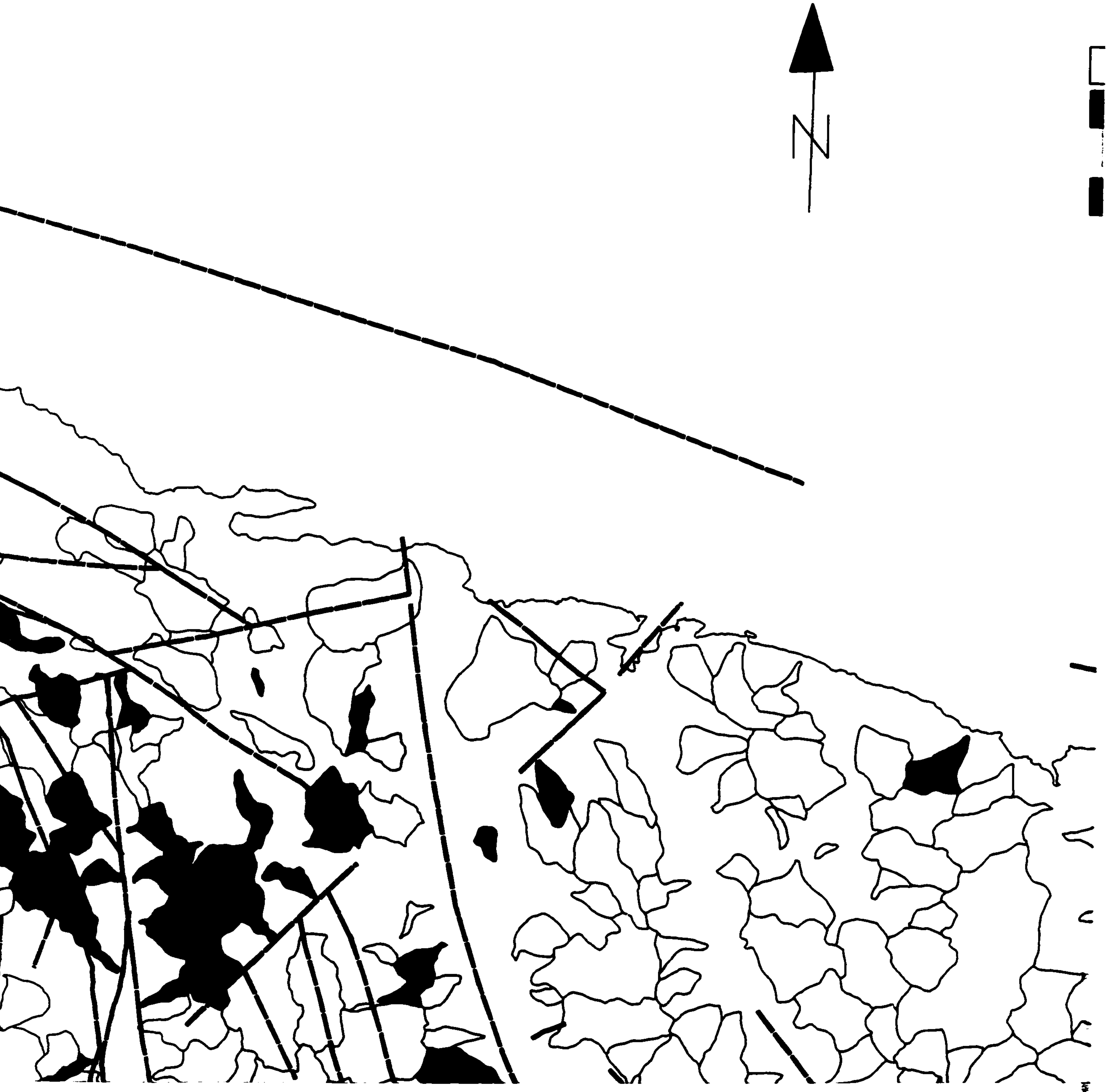


lJBv
Na
uTrk
uTrq
Trk
uTrk
uTrk
uTrp
uTrp
uTrq
uTrk
Jl
lJBv
Na
Jl
uTrk
Na
Na
Na
uTrk
uTrk
uTrk
uTrk
uTrp
Jl
uTrq
uTrk
lJBv
uTrq
Jl
Jl
uTrk
uTrq
uTrp
uTrk
lJBv
uTrq
uTrp
lJBv
lJBv
lJBv
uTrq
uTrk
Jl
lJBv
uTrp
uTrq
uTrk
lJBv
uTrp
uTrq
Jl
uTrk
uTrq
Jl
uTrk
lJBv
uTrp
lJBv
Jl
uTrk
uTrq
lJBv
Jl
lJBv
Jl
Jl
lJBv
uTrp
uTrk
uTrq
uTrp
Tw
lJBv
Tw


uTrk
uTrk
uTrk
uTrk
uTrk
uTrk
uTrk
JI
uTrk
JI
JI
uTrk
mTrd
uTrk
CPB
CPB
uTrk
mTrd
JI
JI
uTrk
uTrk
uTrk
uTrk
JI
mTrd
uTrk
JI
JI
uTrq
uTrq
uTrkq
uTrq
CPB+uTrl






N

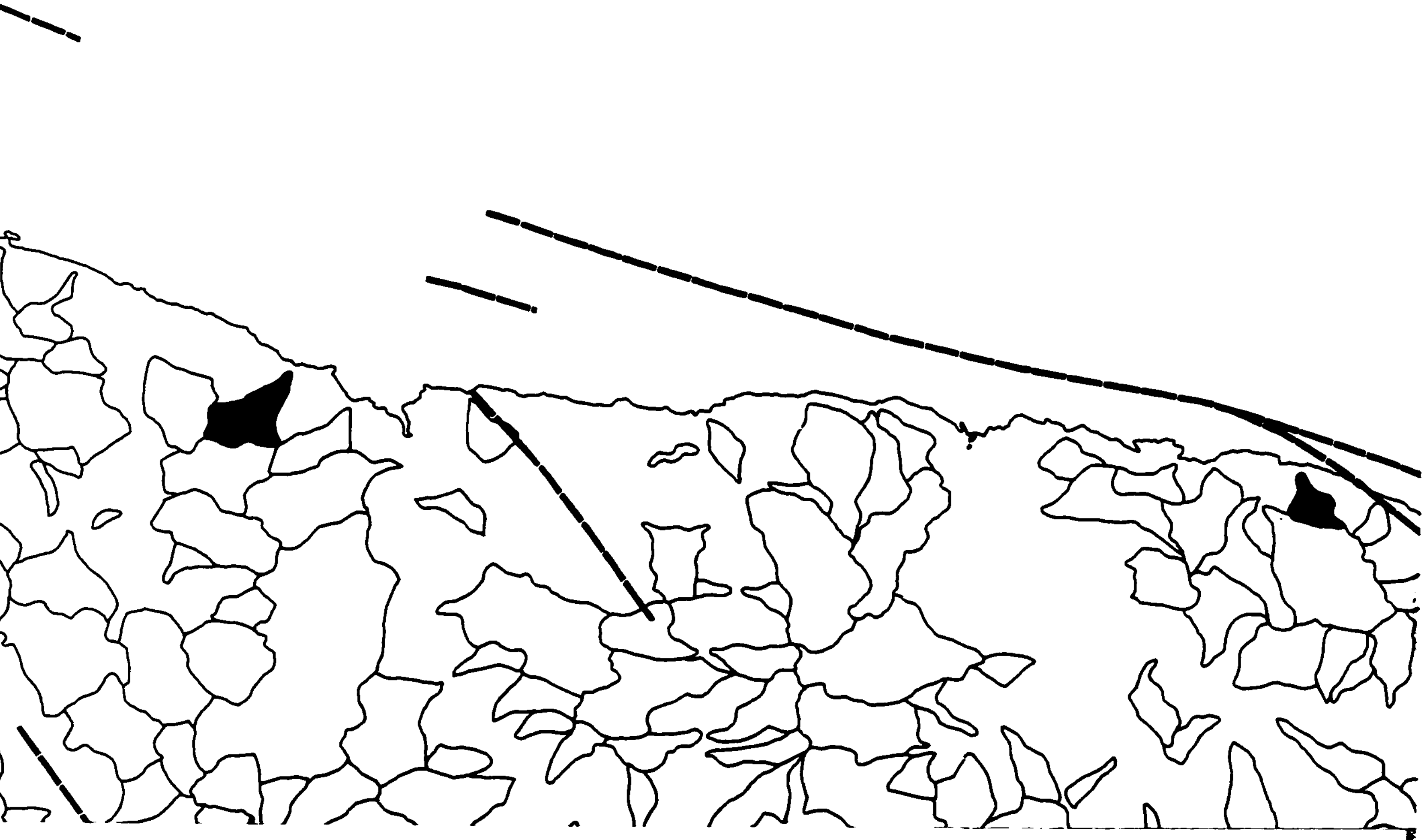


Figure 4.3

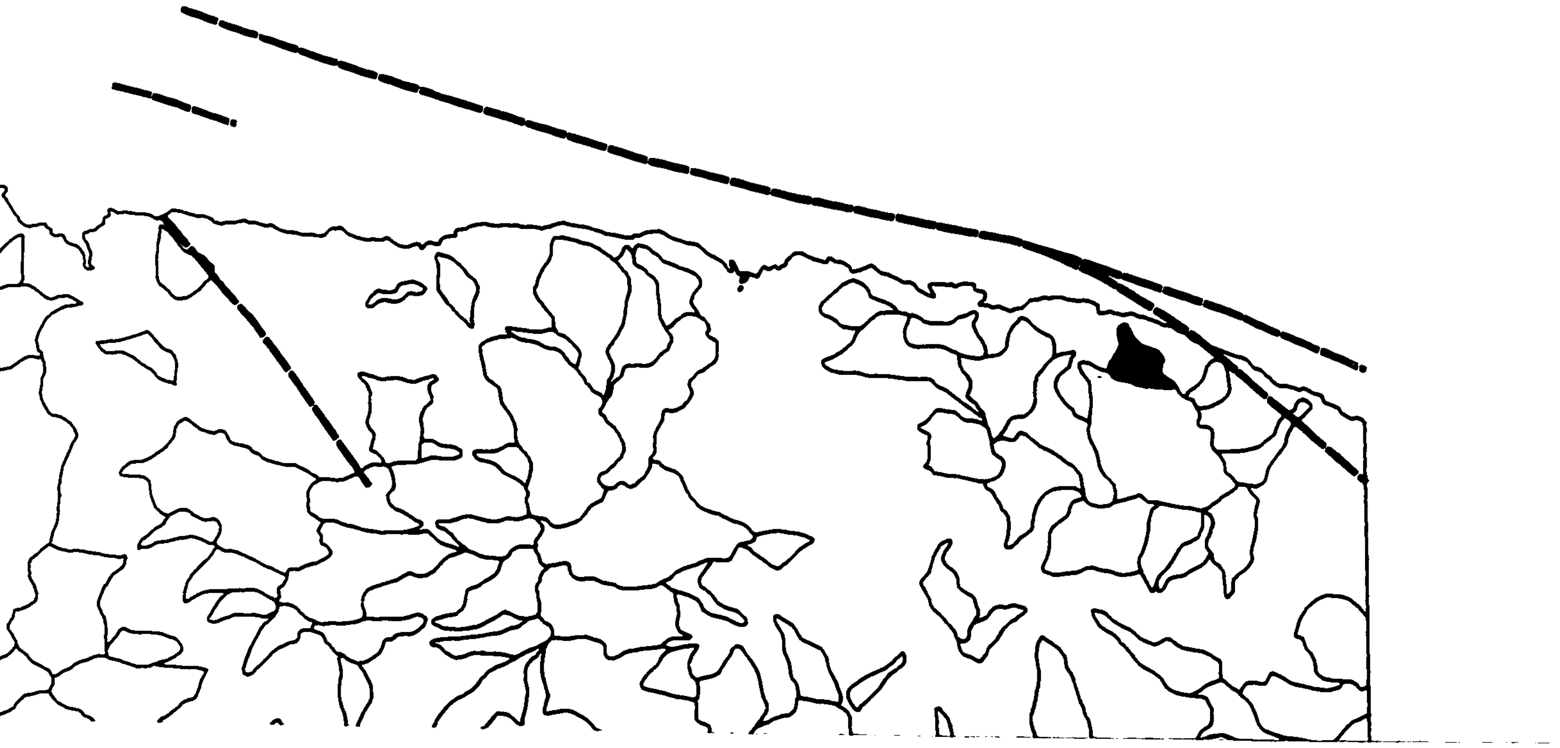
Catchment basins for 912 stream sediment samples on northern Vancouver Isl
92L and 102I). The basins are coded by mercury concentrations. Faults are sh
heavy black lines, the coastline and catchment basins are in thin black lines.

Mercury

☐ 0-75%tile
■ 75-90%tile
90-95%tile
■ 95-100%tile

Figure 4.3

Catchment basins for 912 stream sediment samples on northern Vancouver Island (NTS 92L and 102I). The basins are coded by mercury concentrations. Faults are shown in heavy black lines, the coastline and catchment basins are in thin black lines.




0 Km
25 Km