

HYDROGEOLOGICAL AND GEOCHEMICAL CONTROLS
ON TRACE METAL CONCENTRATIONS IN
LAKE SEDIMENT IN THE HOLYROOD GRANITE

CENTRE FOR NEWFOUNDLAND STUDIES

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HYDROGEOLOGICAL AND GEOCHEMICAL CONTROLS ON TRACE METAL
CONCENTRATIONS IN LAKE SEDIMENT IN THE HOLYROOD GRANITE

BY

ROBERT MACLEOD

A thesis submitted to the School of Graduate
Studies in partial fulfilment of the
requirements for the degree of
Master of Science

Department of Earth Science
Memorial University of Newfoundland

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ABSTRACT

A regional lake/pond sediment survey over the Avalon Peninsula in 1976, by the Nfld. Department of Mines, showed a number of lakes with anomalous concentrations of uranium and other metals in the area of the Holyrood Pluton. These anomalies are not reflected in the average host granite rock geochemistry. The hydrogeological framework, including detailed analysis of the fracture systems as major groundwater conduits, has been studied in an attempt to determine the role of groundwaters in transporting and localizing concentrations of trace metals in lake sediment in four lakes in the area.

Groundwater discharge into the lakes was estimated to range from 20 to 35 percent of their water balances, based on characteristic chemical differences between groundwater and surface waters. Detailed sampling of lake sediment, on a grid pattern, showed a non-uniform areal distribution of metals in these lakes. This sampling also showed that peak concentrations were not restricted to the centres or deepest points in the lakes. The maximum concentration of uranium found in these lakes ranged from 69 to 309 ppm, which is higher than those recorded in the regional survey. In some cases, the elongated shape of the uranium-rich area of sediment is aligned with the orientation of one of the major

fracture sets in the study area. Sampling of vertical sediment profiles showed a considerable variation of metals in the sediment column. However there appeared to be no direct relationship between metal concentration in surface sediment and maximum concentrations at depth. Although concentrations of most metals in the sediment are near levels expected for a detrital granite-source origin, anomalous concentrations of uranium at depth in the cores appear to be associated with a rapid change in organic content. A mechanism is proposed whereby mobile dissolved uranium in oxidizing groundwaters is reduced to its tetravalent state when it encounters organic rich mud as it discharges into a lake. The magnitude of seepage flux values and uranium concentrations found in deep groundwaters in the granite suggest that groundwaters are a possible mechanism for the transport concentration of metals in these post-glacial lake sediments.

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I would like to extend a special thanks to John Gale who believed in giving a "local boy" a chance and to John Welhan who somehow managed to teach me something about geochemistry.

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Chapter 1 INTRODUCTION

1.1 Statement of Problem

A common preliminary step in the regional assessment of the mineral potential of an area is to conduct a geochemical survey to determine the metal concentrations in lake, pond and stream sediments. Such surveys are useful in identifying gross regional geochemical trends and anomalously high concentrations of trace metals may indicate local mineralization in the surficial materials or bedrock.

Regional lake geochemical surveys in Newfoundland have consisted of collecting one sample from a lake or pond every seven to eight four km² (Butler, 1980). This method of sampling assumes that within a given lake there is a systematic distribution of metals in the lake sediment, either areally uniform or related to depth. However, if the areal distribution of metal concentrations in the lake sediment varies non-systematically, it is possible that an anomalous concentration may be missed if it does not coincide with the chosen sampling point in the lake. In addition, samples in most lake sediment survey are collected using a torpedo-shaped sampler which may penetrate up to 1 m into the sediment. Therefore only the upper layers of lake sediment is sampled

and the depth of the sample is variable and unconstrained. Thus the sample provides data only on the most recent accumulations of sediment, which may be biased to identifying surface particulate and dissolved metal inputs, and provides no indication of the distribution of metals in the sediment with depth and possible non-surface metal inputs.

The vertical distribution of trace metals in the sediment column can provide additional data which may identify the processes or mechanisms by which trace metals are transported and concentrated in the sediment (Frape and Patterson, 1981). Metals can be transported to a lake as detrital matter by stream transport or glacial action or as dissolved solids in either surface water or groundwater. Understanding which processes have been responsible for transporting metals to a lake is essential in designing an effective exploration program for the source of metals found in lake sediments.

The processes by which trace metals are transported, as both particulate matter and dissolved constituents, and concentrated in lake and pond sediments, are well documented and have been summarized by Lush (1984). However, the role of groundwater in transporting and localizing concentrations of trace metals in lake sediment is often overlooked. It is known that groundwater can dissolve and transport metal

species as it moves through a rock mass. These dissolved metals could then be concentrated in lake sediment as groundwater discharges into a lake through its sediment (Figure 1.1). Therefore, in order to be able to properly interpret regional lake geochemical surveys, it is important to define the hydrogeological framework of the area surrounding a lake or pond and to identify regional/local recharge and discharge zones when attempting to determine the source(s) of trace metal concentrations in lake and pond sediment.

In Canada, and especially Newfoundland, there are many areas which are covered by only a thin layer of overburden material and are underlain by fractured bedrock. In regions underlain by metamorphic or granitic bedrock, which have low matrix permeability, fractures act as the main conduits for groundwater flow. If groundwater is an important agent for transporting dissolved metals in these areas it is necessary to conduct a detailed analysis of the fracture networks existing in the underlying rock mass. Given the heterogeneity imposed by the dispersed nature of fracture conduits, fracture controlled discharge to a lake may give rise to an uneven distribution of trace metal concentrations in the sediment. Thus, this study focuses on understanding the role of

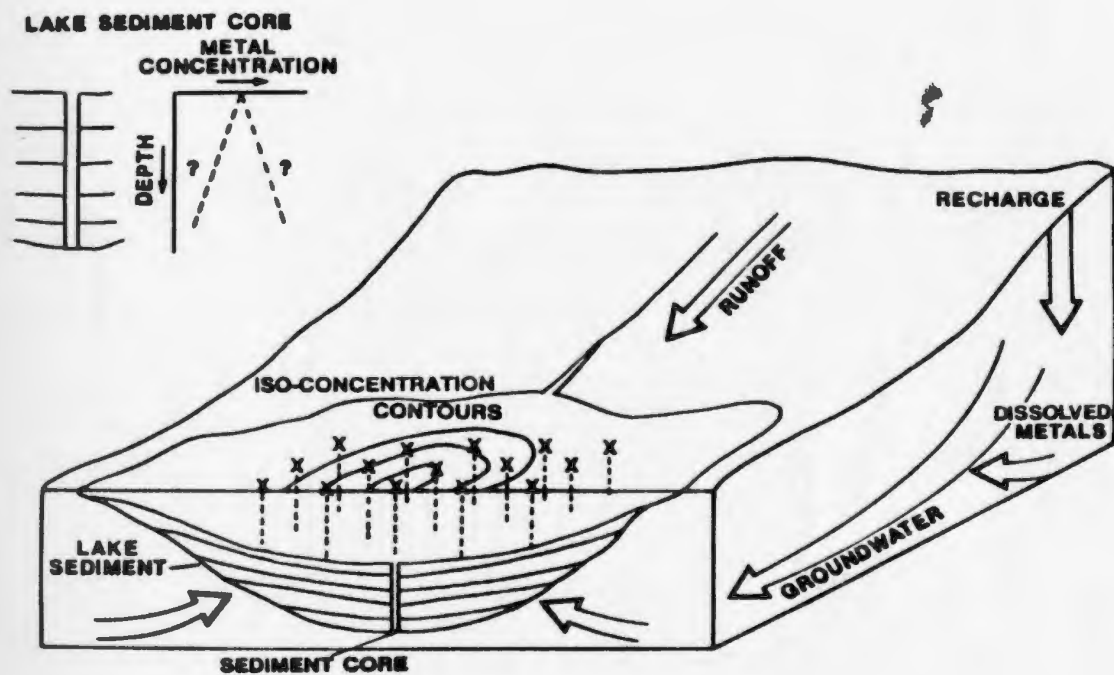


Figure 1.1 Schematic diagram of groundwater discharge into a lake giving rise to metal anomaly in the lake sediment. Sediment sampling points are indicated by X.

groundwater in transporting and localizing trace metals in the sediments of lakes underlain by fractured rock.

1.2 Objectives and Scope

The three main objectives of this field study were: 1) to determine the areal and vertical distribution of trace metal concentrations in the sediments of lakes underlain by fractured rock; 2) to determine the relationship between the concentrations of dissolved metal species found in groundwater and the concentrations observed in lake sediments; and 3) to determine if the hydrogeological framework of the study area is consistent with the distributions and measured concentrations of trace metals in lake sediments.

Four small lakes (locally referred to as ponds) underlain by the Holyrood granite were chosen for this study. Two of the small lakes, Gull Pond and Nut Brook Pond, showed anomalously high concentrations of uranium in a regional lake sediment survey (Davenport and Butler, 1976). The two other adjacent ponds, Pennys Pond and Rocky Pond, were not sampled in the regional survey. In order to establish the distribution of trace metals in the sediment of these lakes a sediment sampling program was undertaken. The first stage of the sampling program, which was carried out during the winter

months, consisted of collecting sediment from each lake on a detailed grid pattern marked on the frozen lake surface. The second stage involved coring and sampling vertical sections of lake sediment, in areas of the lakes known to contain anomalous or background concentrations of trace metals in the sediment.

The groundwater chemistry of the area was determined by evaluating existing regional groundwater chemical data as well as by sampling groundwater which was thought to be discharging into lakes. This was achieved by drilling a shallow borehole at the edge of one of the lakes to intersect discharging groundwater and by drilling through the sediment and into bedrock in another lake to sample groundwater discharging through the lake bottom.

Large scale lineaments and structural features were identified from aerial photographs in an attempt to define the hydrogeological framework of the underlying fractured granite bedrock. Further information on the fracture geometry was provided by an analysis of fracture orientations, trace lengths and spacings from data collected from bedrock outcrops.

Factors controlling the mobilization, transport and subsequent deposition of metal species in lake sediment, such as organic content and oxidation conditions, were also examined to define the relationship between discharging groundwaters and observed sediment anomalies.

1.3 Previous Work

A regional lake sediment survey carried out over the eastern portion of the Avalon Peninsula identified a group of lakes underlain by the Holyrood granite which contained high concentrations of uranium in the sediment, ranging up to 208 ppm (Davenport and Butler, 1976) (Figure 1.2). Some of these lakes also had correspondingly high concentrations of molybdenum and other metals. However, whole rock analyses of the granite, which would be a likely source for the metals, showed no corresponding anomalous concentrations of uranium (Davenport, 1978).

In an attempt to identify a possible source for the uranium, Houle (1985) collected samples of surface waters and shallow sediment from a small lake in the area on a regular grid pattern to determine the distribution of metals in the lake sediments. Results of the sediment sampling showed an uneven distribution of trace metals and localized areas of high

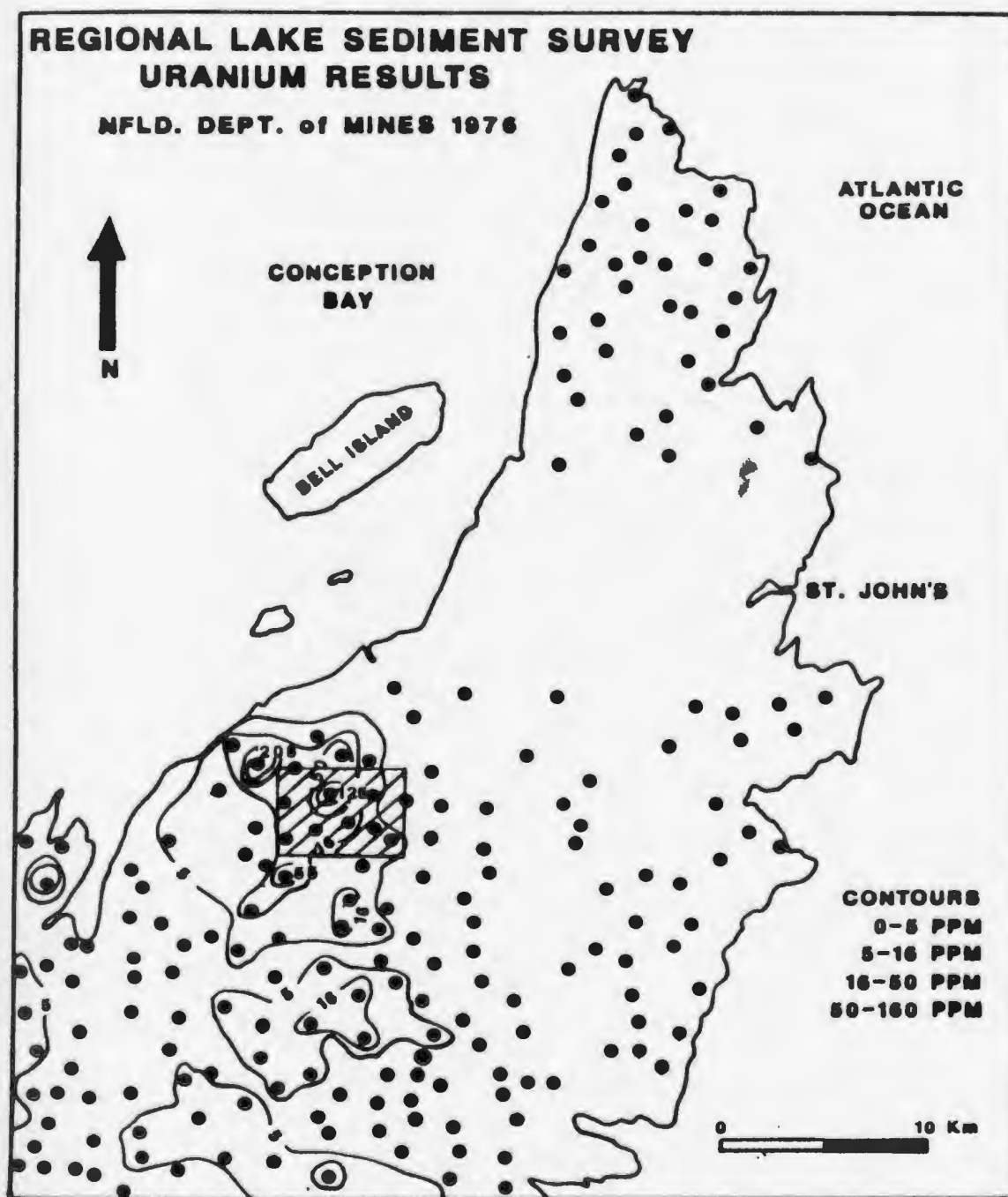


Figure 1.2 Results of uranium analysis from the regional lake sediment survey carried out by Newfoundland Department of Mines (Davenport and Butler, 1976). The cross-hatched rectangle indicates the location of the area described in this study.

concentrations within the lake. The concentrations of metals in the waters were relatively low and did not correlate very well with metal concentrations in the sediment. Since a source of the uranium could not be identified locally in the surrounding bedrock or surface waters it was suggested that groundwaters discharging into the lake may provide a means for transporting trace metals from a distant source.

Until recently, lakes were thought to be isolated from groundwater by the lake bottom sediments. However, detailed research by McBride and Pfannkuch (1975), Winter (1976, 1978) and Lee et al. (1980) which focused on groundwater-lake interactions has shown that lakes form an integral part of dynamic groundwater flow systems. Theoretical and field evidence suggests, that groundwater may discharge into a lake, be recharged from a lake, or both, depending on where the lake is situated relative to local and regional flow systems.

Frape and Patterson (1981) evaluated the distribution of dissolved constituents in groundwaters adjacent to a small lake and in interstitial waters in sediment cores, to define the pattern of groundwater seepage into the lake. The sediment cores, which were also analyzed for trace metals, showed increased concentrations of iron and manganese at particular levels. It was suggested that dissolved iron and

manganese transported by groundwater would precipitate upon encountering an oxygenated zone in the sediment, which could account for the observed metal concentrations in the sediment. A recent study of two lakes in Sweden (Sundblad et al., 1990) was carried out to determine how radionuclides, transported by groundwater, would be distributed in lake sediments. The sediments in these lakes were enriched in uranium in areas where groundwater was discharging into the lake and the uranium enrichment appeared to be associated with organic rich layers of sediment.

Chapter 2 GEOLOGICAL AND HYDROGEOLOGICAL FRAMEWORK

2.1 General Geology

The study area, located on the northeastern Avalon Peninsula, is underlain by granitic rocks of the Holyrood Pluton (Figure 2.1). The Holyrood Pluton intrudes a series of Pre-Cambrian volcanic rocks which make up the Harbour Main Group. The underlying volcanic rocks can be divided into three fault blocks separated by the Topsail - Frenchmans Cove Fault to the east and the South Arm Fault to the west (Hughes and Brueckner, 1971; Gale et al. 1984). The eastern block is dominated by pillow lavas and tuffs. The western block in the Avondale - Harbour Main area is characterized by ash flows mixed with fluvial and lacustrine sediments overlain by basalt flows. The central block, where the lakes in this study are located, consists of mafic and felsic flows, pyroclastics, and minor volcaniclastics which have been intruded by the Holyrood Pluton, a high level granite. The Holyrood Pluton consists mainly of pink, medium grained, biotite granite along with dioritic-gabbroic phases in isolated areas (Strong et al., 1974). The granite is unconformably overlain to the northwest along Conception Bay by shallow dipping marine sediments composed of black shales and green siltstones.

SIMPLIFIED GEOLOGY OF HOLYROOD GRANITE

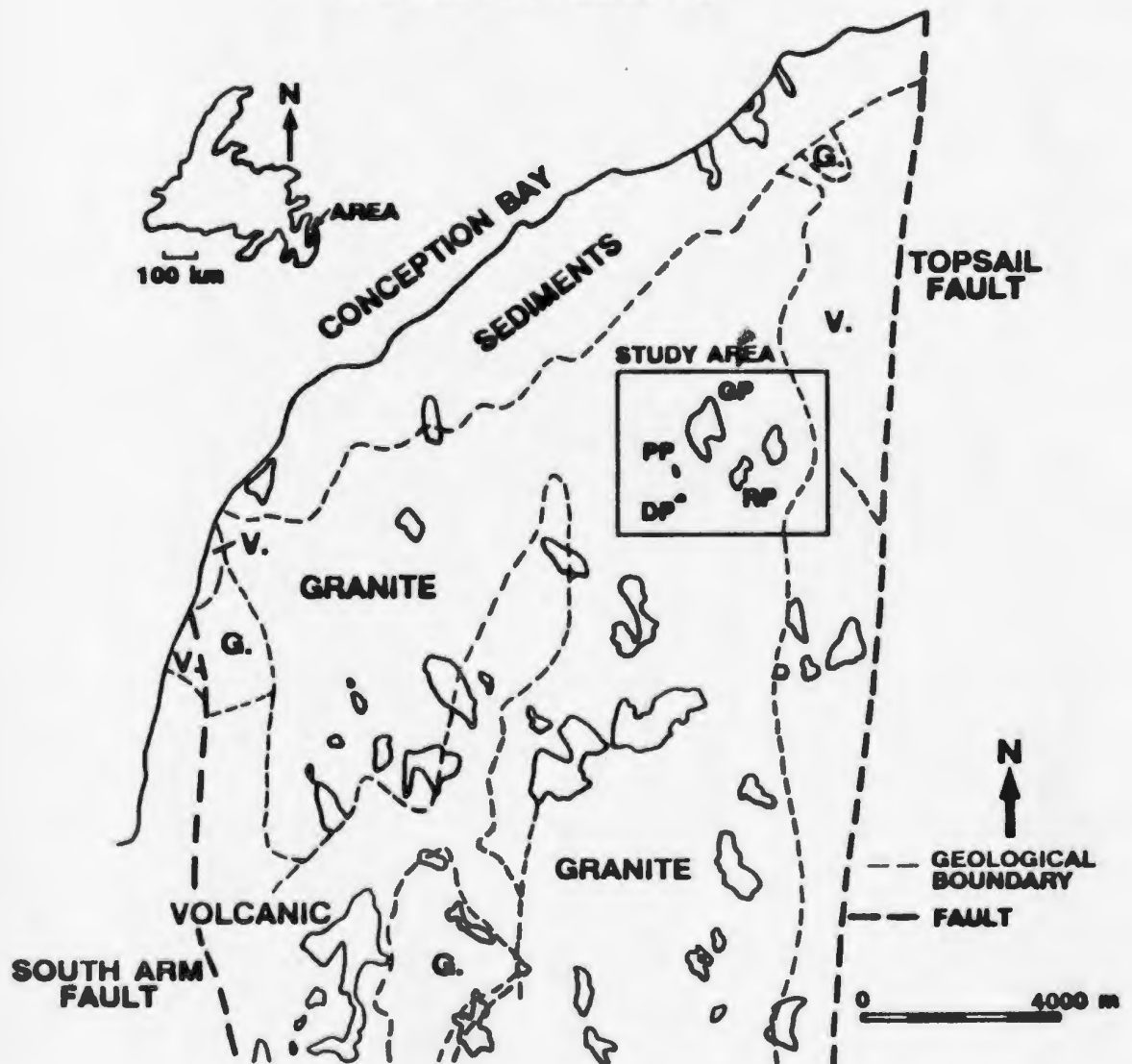


Figure 2.1 Simplified regional geology surrounding the study area (after King, 1984). The lakes sampled in this study are identified as GP = Gull Pond, PP = Pennys Pond, RP = Rocky Pond, and DP = Nut Brook Pond.

The major structural features surrounding the study area are the two north trending regional faults which bound the area. The Topsail fault zone is well exposed along the eastern side of Conception Bay, as evidenced at Topsail Head, and trends south, merging with the Frenchmen's Cove fault in the Fermeuse area. The South Arm fault to the west extends southward from the Holyrood area and intersects the Peter's River fault. Several other smaller scale faults and fracture zones as well as numerous joints and fractures have also been observed in the rocks in the study area.

2.2 Fracture Geometry

The bedrock underlying the study area is predominantly granite, which is considered to have characteristically low matrix porosity and permeability. Unlike a porous media system where fluids may easily move through the pore spaces, in a crystalline rock mass, discontinuities such as joints, fractures and shear zones are the major conduits for fluid movement. In a fractured rock system, the orientation, density and interconnectivity of fractures will largely influence the direction and rate of groundwater flow. Therefore, if groundwaters are to be considered a medium for the transport of dissolved metals in this study, it is

necessary to characterize the fracture network in the surrounding granitic rock mass.

On a regional scale, structural features and lineaments were identified from aerial photographs as indicated in Figure 2.2. Most of the lineaments, which were assumed to be sub-vertical features due to their lack of curvature, trend toward the northwest while a smaller group trend toward the northeast (Figure 2.3). The lineaments, that were identified, varied in trace length from 58 m to 1226 m, with a mean trace length of 252 m. Although the ends of some features may be covered by overburden and vegetation, from the aerial photographs the large scale structural features do not appear to be well connected. Hence, the small scale fractures (joints) will be essential to interconnect the large and small scale fracture systems and ensure that a pathway exists for fluids to move through the rock mass. The approach used to characterize the small scale fracture geometry in the study area consisted of collecting and analyzing data on fractures from nine different outcrops (Figure 2.2) surrounding the four lakes using a method of scanline mapping, based on the one used by La Pointe and Hudson (1985). A summary of the mapping approach and procedures along with the fracture data are presented in Appendix A.

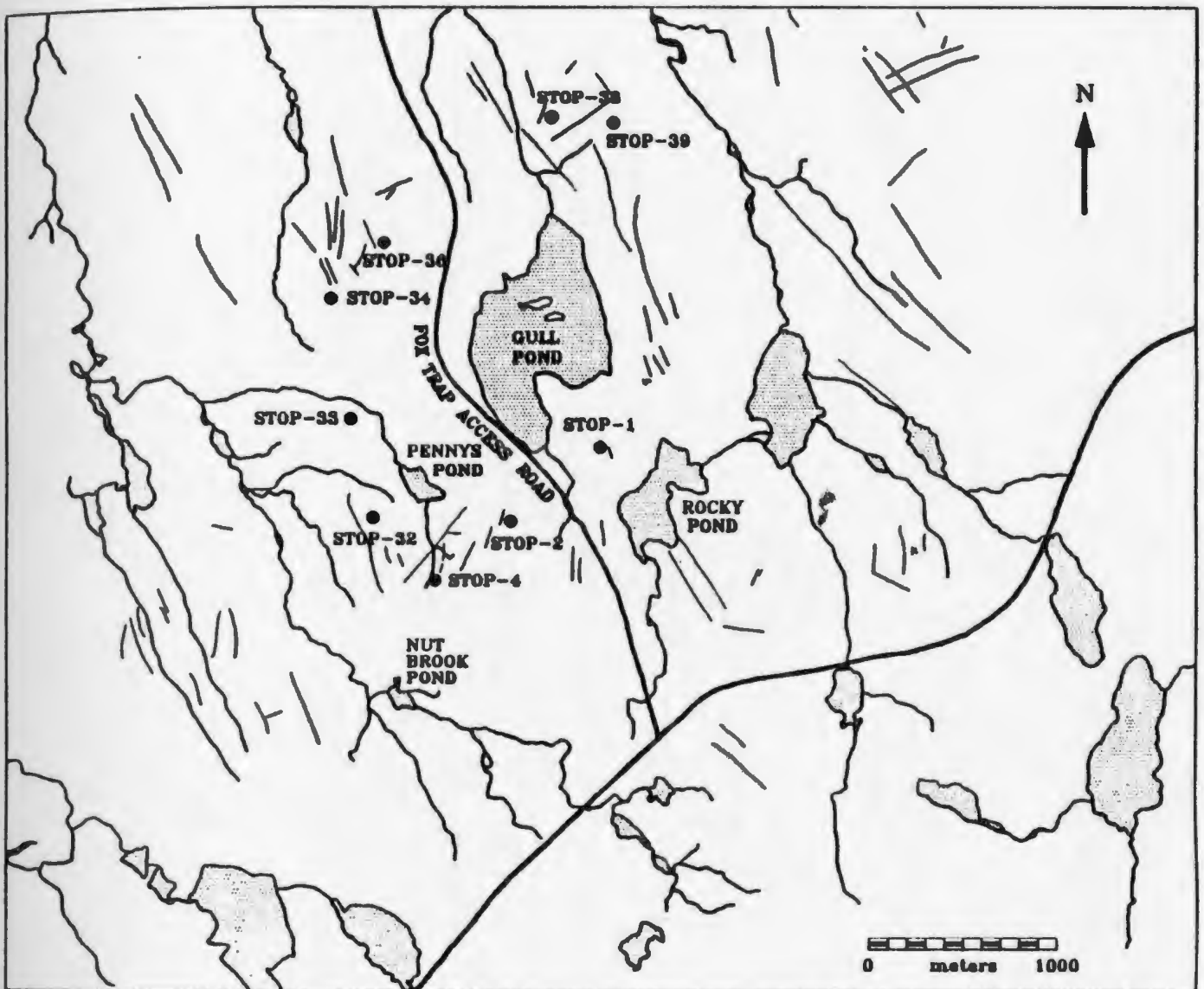


Figure 2.2 Lineaments and structural features observed from aerial photographs. The solid circles indicate the locations of detailed scanline fracture mapping.

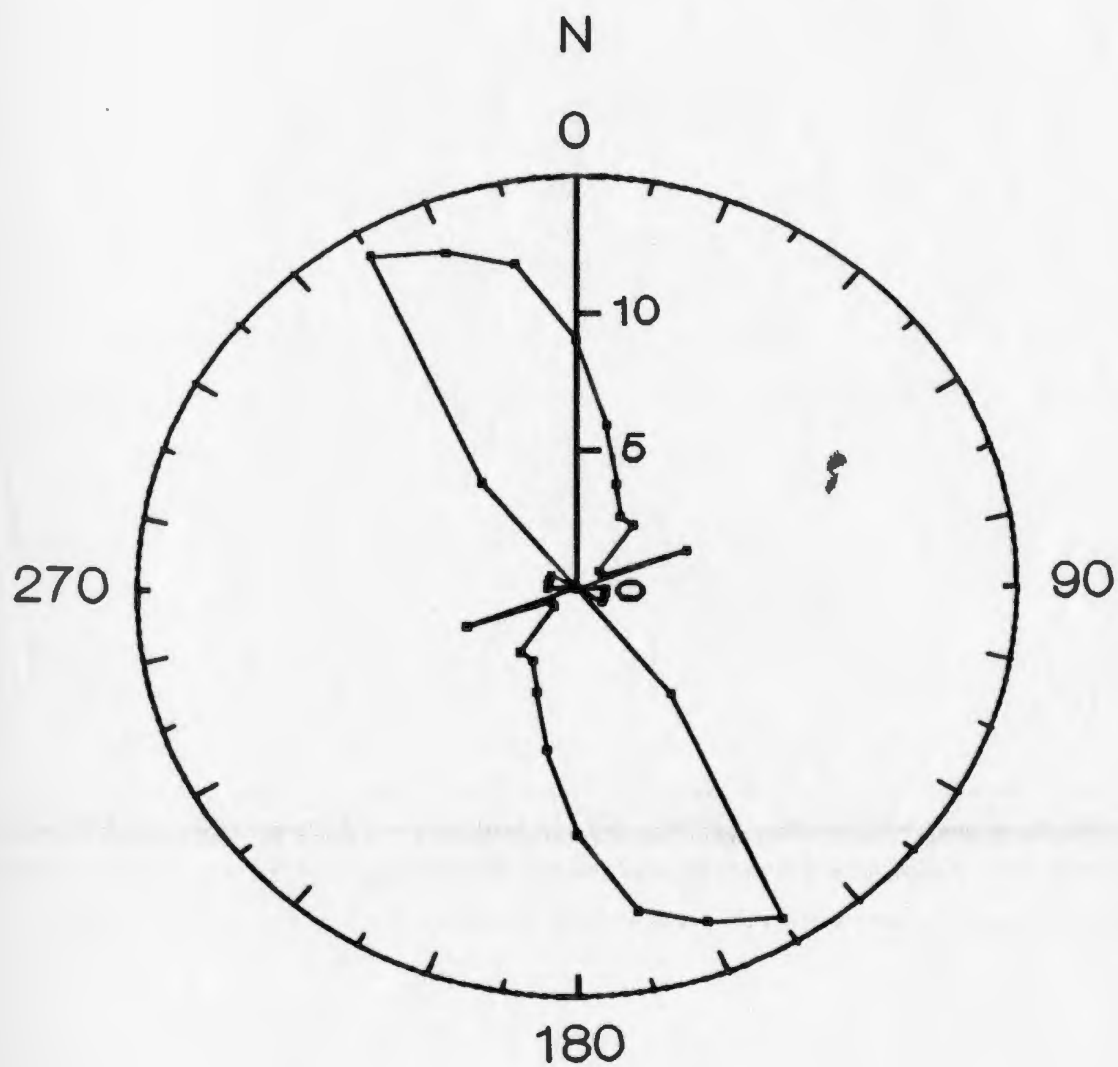


Figure 2.3 Rose diagram of large scale regional structural features and lineaments, showing the frequency of fractures by orientation

The distribution of fracture orientations in the rock mass in the study area was determined by plotting and contouring the poles to fracture planes from all the outcrops mapped on a lower hemisphere stereoplot (Figure 2.4). From Figure 2.4, two dominant sub-vertical sets appear to be present; one oriented northwest-southeast and the other oriented northeast-southwest. Since all the scanlines were laid out on horizontal outcrops, sub-horizontal fractures were less likely to be sampled, which may explain why sub-vertical fractures were dominant in the data set.

To avoid subjective bias introduced by delineating sets solely on the basis of observed peaks on contoured stereoplots, a computer program CLUSTAN (Gillet, 1987) was used to objectively define clusters and assign individual fractures to a set on a statistical basis. Cluster analysis of the fracture orientations indicated that there were two strong clusters which correlated with the density contours shown in the stereoplot (Figure 2.4). Cluster 1 contains 270 fractures and has a mean orientation of 69.5/82.5 (dip azimuth/dip) while cluster 2 contains 390 fractures and has a mean orientation of 158.4/73.4.

Since the hydraulic interconnectivity of fractures in a rock mass is influenced by the length of individual fractures, the

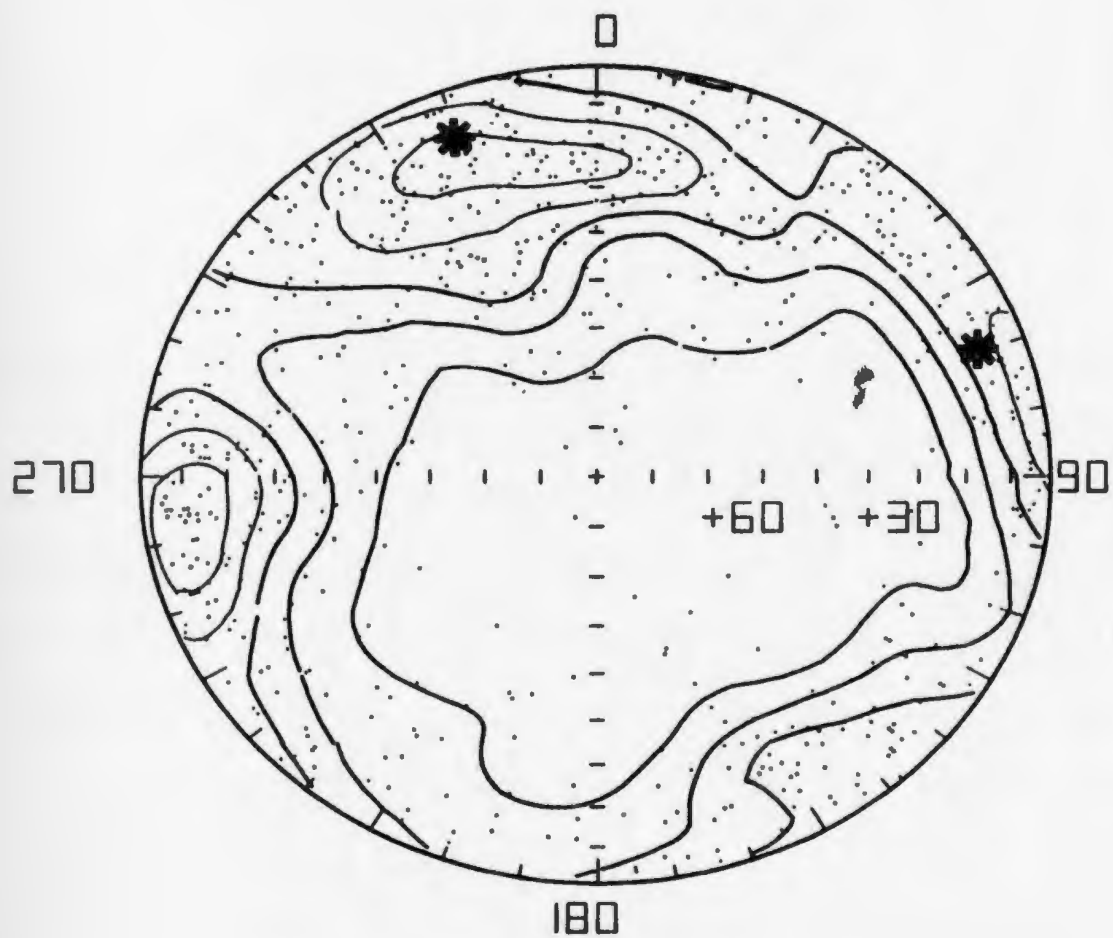


Figure 2.4 Contoured lower hemisphere stereoplots of poles to fracture planes for all fractures mapped in the study area. Mean cluster orientations are shown as solid circles, and individual fracture poles as small dots.

length of fracture traces intersecting the scanlines were measured. The actual length of a fracture trace may be longer than that measured since in the field one or both ends of a fracture trace may be censored, meaning a portion of the total fracture trace is hidden. Figure 2.5 shows the frequency histograms and basic trace length statistics for fractures of each cluster by degree of censoring. Although the distribution of trace lengths is skewed, the focus of this study is on recognizing long fractures which may have a role in forming conduits and accounting for the skewness of the distribution would result in small geometric means. Approximately 55% of fractures in cluster 1, which have a mean trace length of 3.96 m, are censored compared to 36% of fractures in cluster 2 which have a mean trace length of 2.57 m. Since fractures of cluster 1 have a larger mean trace length and are more highly censored than fractures of cluster 2, they are generally considered to be longer, and therefore may have a greater influence on the direction of groundwater movement.

The way in which fractures terminate against each other may also give some indication of ability of the fractures to act as a pathway for fluid movement. A fracture may intersect with another fracture at one end, both ends, or be free at both ends which is important when determining the

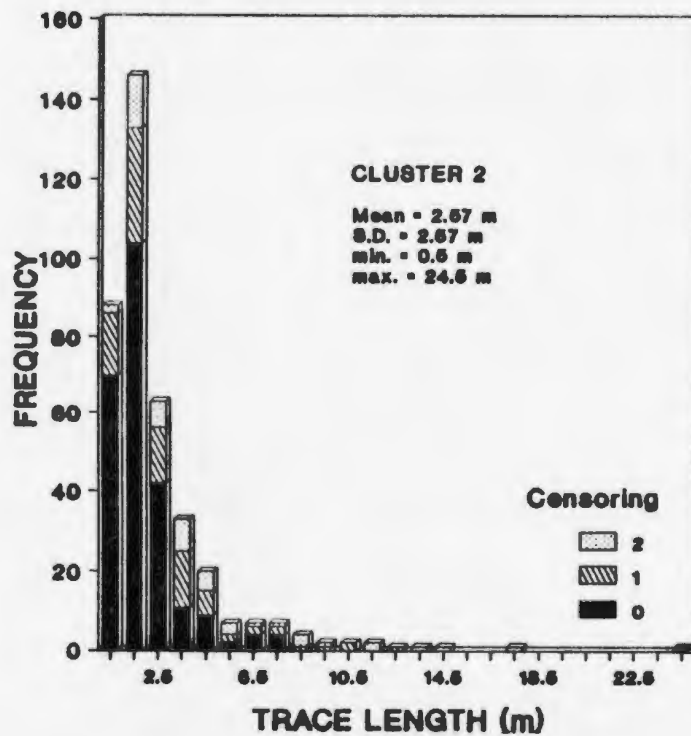
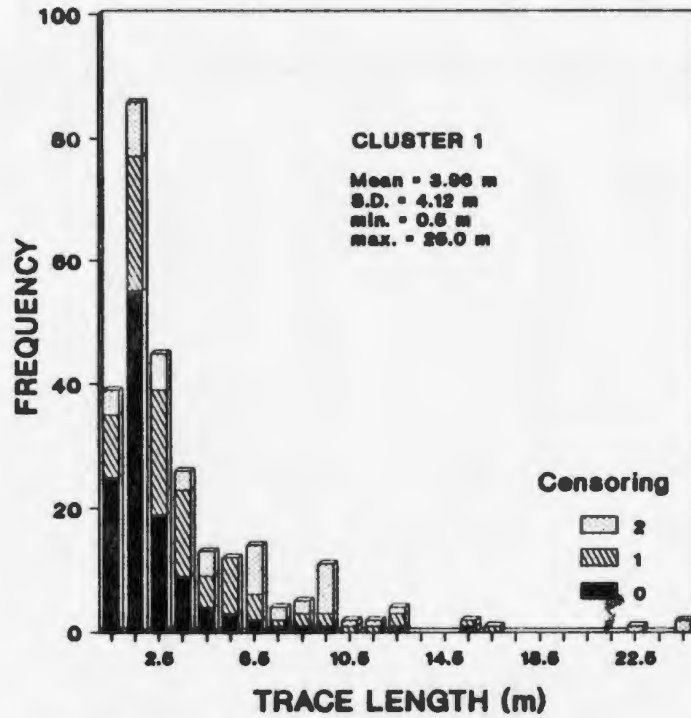


Figure 2.5 Frequency histograms of trace length by censoring (0=both ends exposed, 1=one end covered, 2 = both ends covered) for clusters 1 and 2.

interconnectivity of fractures. Figure 2.6 shows the frequency histograms of trace lengths by termination mode for each cluster. Of the fractures that are uncensored (ones in which the mode of termination can be determined) 55% of fractures in cluster 2 intersect other fractures while 40% of fractures in cluster 1 terminate against other fractures. This indicates a moderate degree of fracture interconnectivity in the rock mass which would allow fluids to easily move in preferred directions through the rock mass along fracture pathways.

The density of fractures in a rock mass can be estimated from fracture spacing which is defined in this study as the perpendicular distance between two fractures of the same set. Fracture spacing is computed from the measured distance between two fractures of the same set intersecting a scanline, and the angle measured between the mean normal of the fracture set and the scanline. Fracture density can then be expressed as the inverse of the fracture spacing.

Frequency histograms and statistics of fracture spacings for cluster 1 and 2 are shown in Figure 2.7. The spacing values vary from near zero to 6.11 m, with cluster 1 having a mean spacing value of 0.77 m compared to cluster 2 which has a mean spacing value of 0.57 m. This indicates that there is a

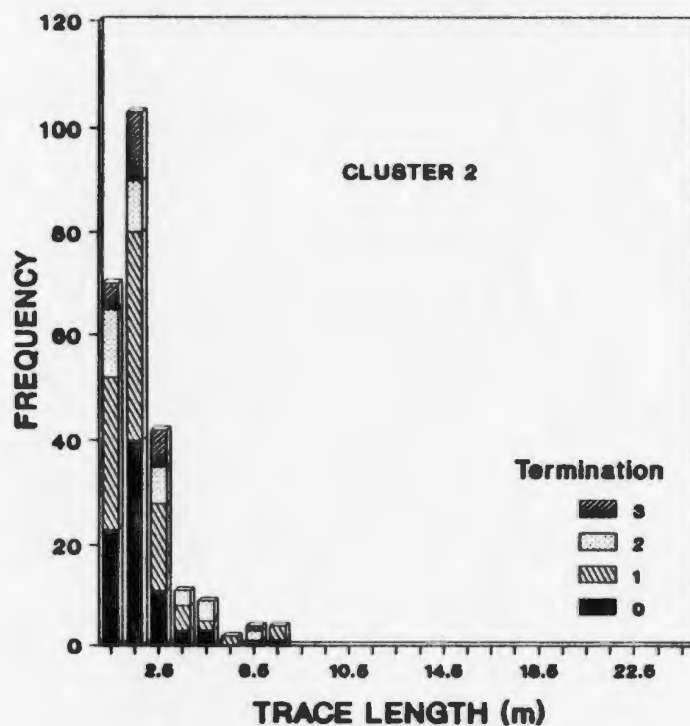
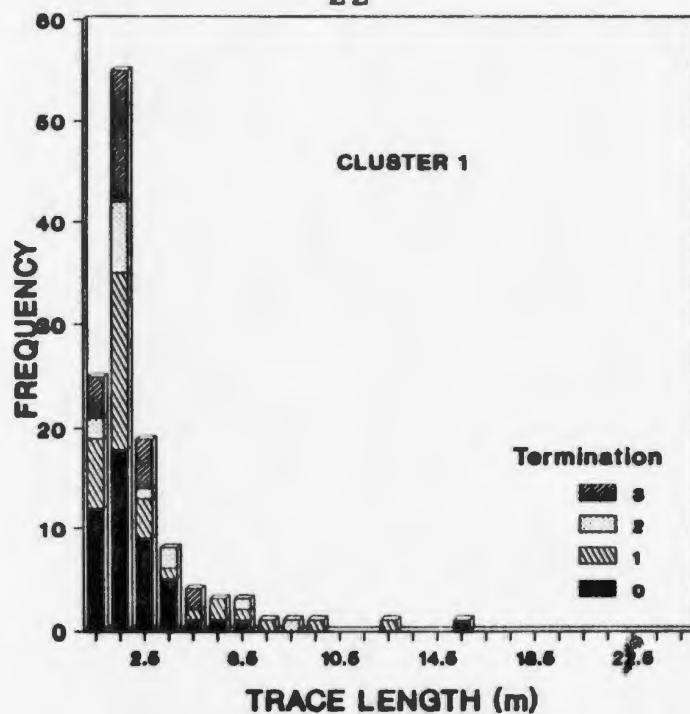


Figure 2.6 Frequency histograms of trace length by termination mode (0=both ends free, 1=one end free, 2=both against another, and 3=splays) for clusters 1 and 2.

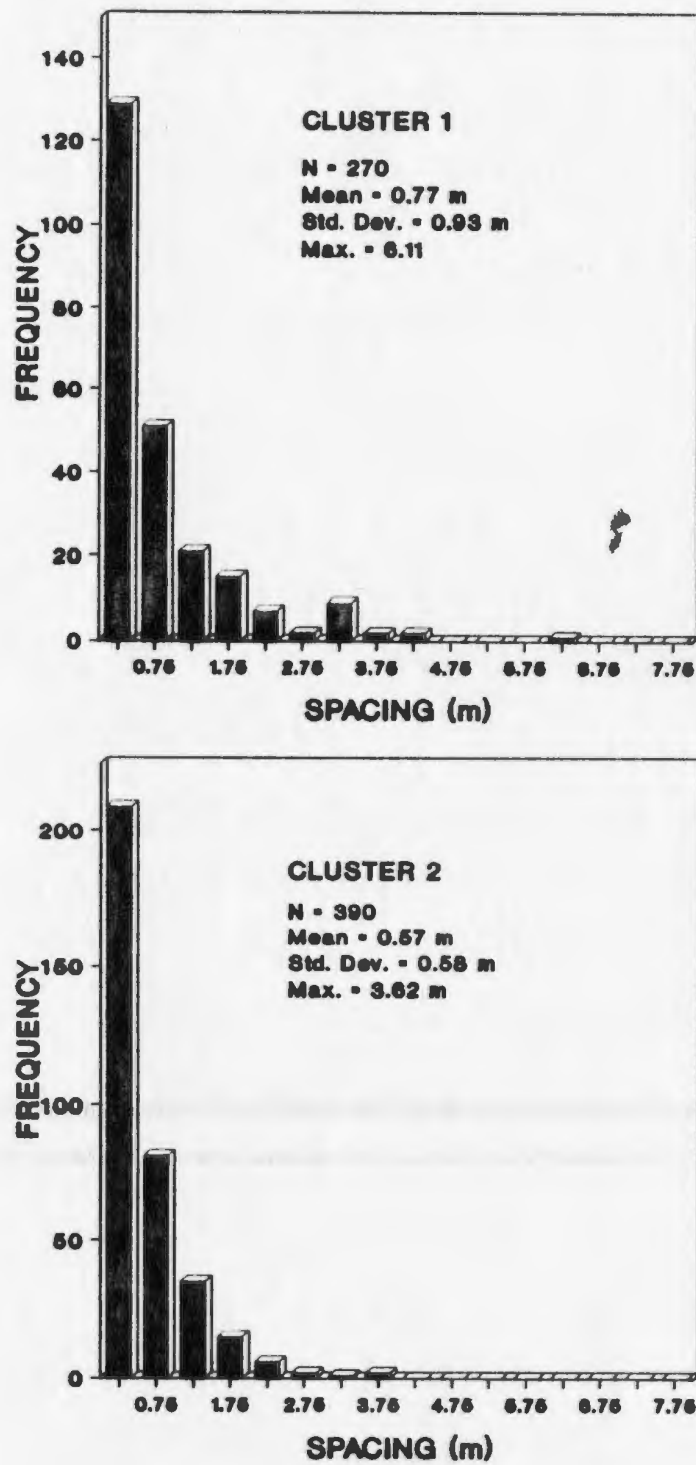


Figure 2.7 Frequency histograms of spacing for clusters 1 and 2.

greater degree of fracturing in the NE-SW direction (cluster 2), 1.75 fractures per metre estimated from the spacing calculation, than in the NW-SE direction (cluster 1), 1.29 fractures per metre. Since only fractures above a given trace length (truncation length equals 0.5 m) are mapped, fracture spacings will increase with increasing truncation bias.

The degree of fracture interconnectivity indicated by the termination mode of individual fractures along with fracture density estimated from fracture spacings indicate that the granitic rock mass is relatively permeable and will allow moderate groundwater movement. The fracture density and trace length calculated for clusters 1 and 2 indicate there is a degree of heterogeneity in the rock mass and that there may be a preferred direction for groundwater movement. On a regional scale the general direction of the hydraulic gradient in the study area is from the southeast towards the northwest. Therefore fractures of cluster 1, which are oriented slightly west of north, subvertical and have longer traces, are most likely to dominate the direction of groundwater flow. This is consistent with the trend of the regional lineaments observed from the aerial photographs. However, since a greater percentage of fractures belong to cluster 2, which are more closely spaced, on a local scale the dominant flow direction may be towards the northeast depending on the hydraulic

gradients. Although sub-horizontal fractures, such as sheeting fractures, do not appear to be very dominant based on the analysis of the fracture data collected, they do exist in the rock mass and will provide a pathway for sub-horizontal groundwater flow.

2.3 Hydrogeology

The preglacial landscape of the study area is characterized by an upland area typical of the Lawrence Peneplain, (Twenhofel and MacClintock, 1940) with gently rolling relief rising up from the coast toward the southeast to an elevation of about 300 m. The main drainage divide in the region is defined by a northeast trending ridge which directs surface water flow toward the coast of Conception Bay along several narrow, northwest-oriented sub-basins. Regional drainage generally follows preglacial patterns which are largely influenced by bedrock structures and joint features.

Most of the lakes and ponds in the area formed in basins in the granitic bedrock, either excavated by ice or dammed by glacial debris (Henderson, 1972). Sediments in the lakes are comprised of a layer of silty clay, probably deposited from glacial outwash, overlain by up to 400 mm of mineral sediment,

followed by organic sediment accumulations (MacPherson, 1982). These sediments have developed over the past 7000 to 9300 years and organic sediments are estimated to have accumulated at an average rate of approximately 0.6 mm per year, based on dating from pollen analysis.

Hills or topographic highs in the area are characterized by well exposed outcrops while lower areas tend to be filled with thin deposits of glacial material. Glacial drift is relatively thin and discontinuous averaging less than 5 meters in thickness. The lack of overburden material suggests that sub-surface flow in the area is mainly through the granite bedrock where fractures and discontinuities in the rock mass are the major conduits for groundwater movement. Groundwater recharge is expected to occur in topographic highs, although the amount of actual infiltration may be low due to surface run-off over areas of exposed bedrock. Similarly groundwater discharge would occur in topographically low areas. The presence of several small lakes and swamps on aerial photographs and topographic maps of the area suggests that the water table in these areas is close to ground surface and closely reflects the topography of the area. The lakes and ponds in the area are thought to be points of local and/or regional discharge, and have an important role in controlling the groundwater flow system (Gale et al., 1984).

All of the four lakes in this study are contained in individual sub-basins and each lake has only one stream flowing into it which derives its head waters from within close proximity of each lake (Figure 2.8). Although the lakes are not connected by streams, due to differences in lake elevations (Figure 2.8), there may be some sub-surface flow between local drainage basins, particularly through fracture channels.

The four lakes are located in the mid to upper portion of the regional flow system and therefore groundwater discharging into these lakes would be mainly from local flow systems in their vicinity. For example, Pennys Pond at an elevation of 154 m, is located at the base of Pennys Hill which rises to an elevation of 210 m. The lake has very little stream inflow but has a sizeable outflow, and has a marshy area surrounding the lake which suggests that Pennys Pond is being fed by local groundwater.

Although pole plots of fractures recorded from outcrops surrounding the lake indicate that the dominant orientation of fracturing is toward the northeast (Figure 2.9.), there is also another set of fractures present which are oriented slightly west of north. Given the hydraulic gradient toward the lake imposed by Pennys Hill, along with the abundance of

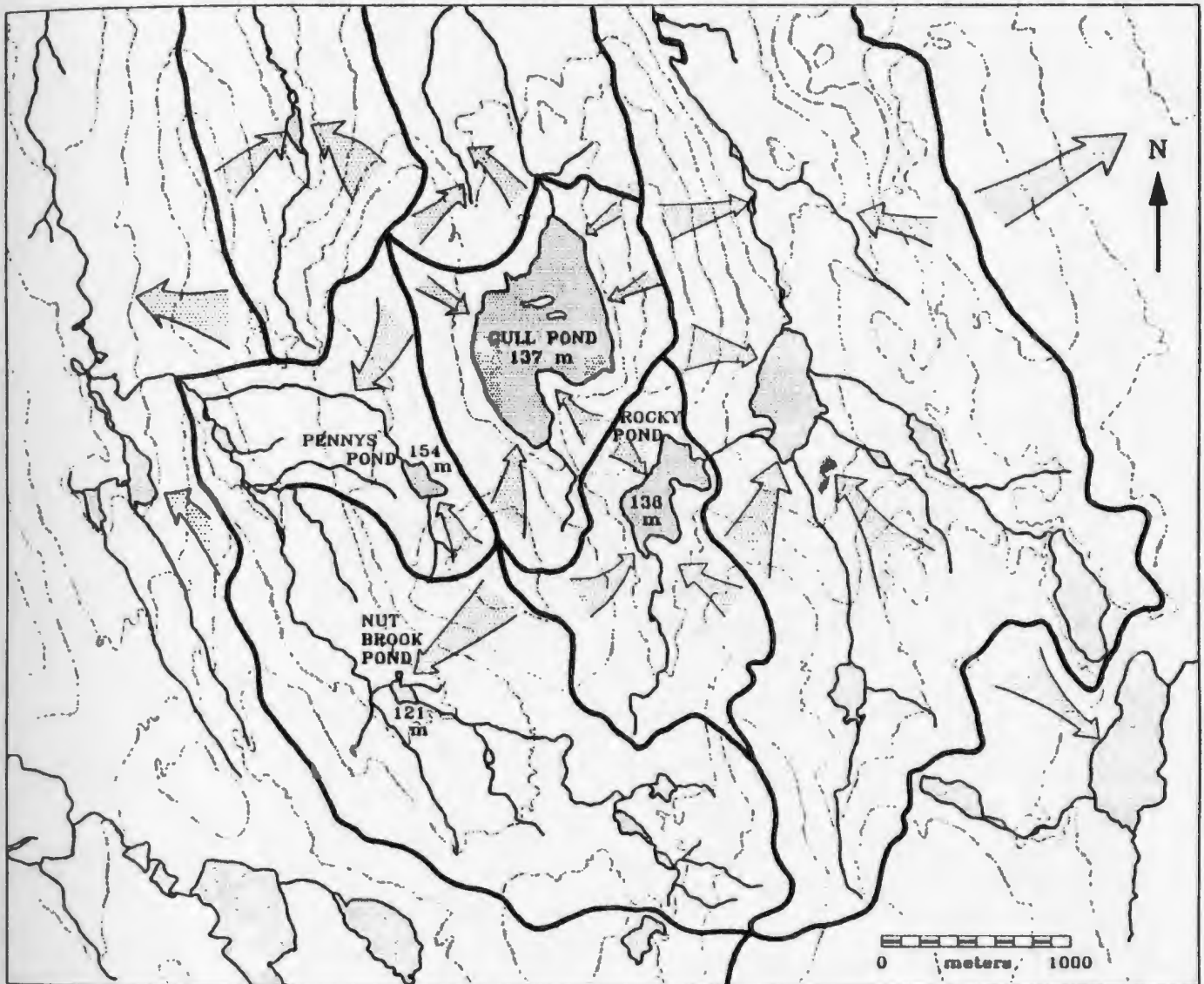


Figure 2.8 Map showing drainage and lake outlines, topographic contours (faint lines), drainage basin divides (thick lines), and inferred direction of groundwater movement (arrows) in the study area. The water level elevation for each lake in the study is given in meters.

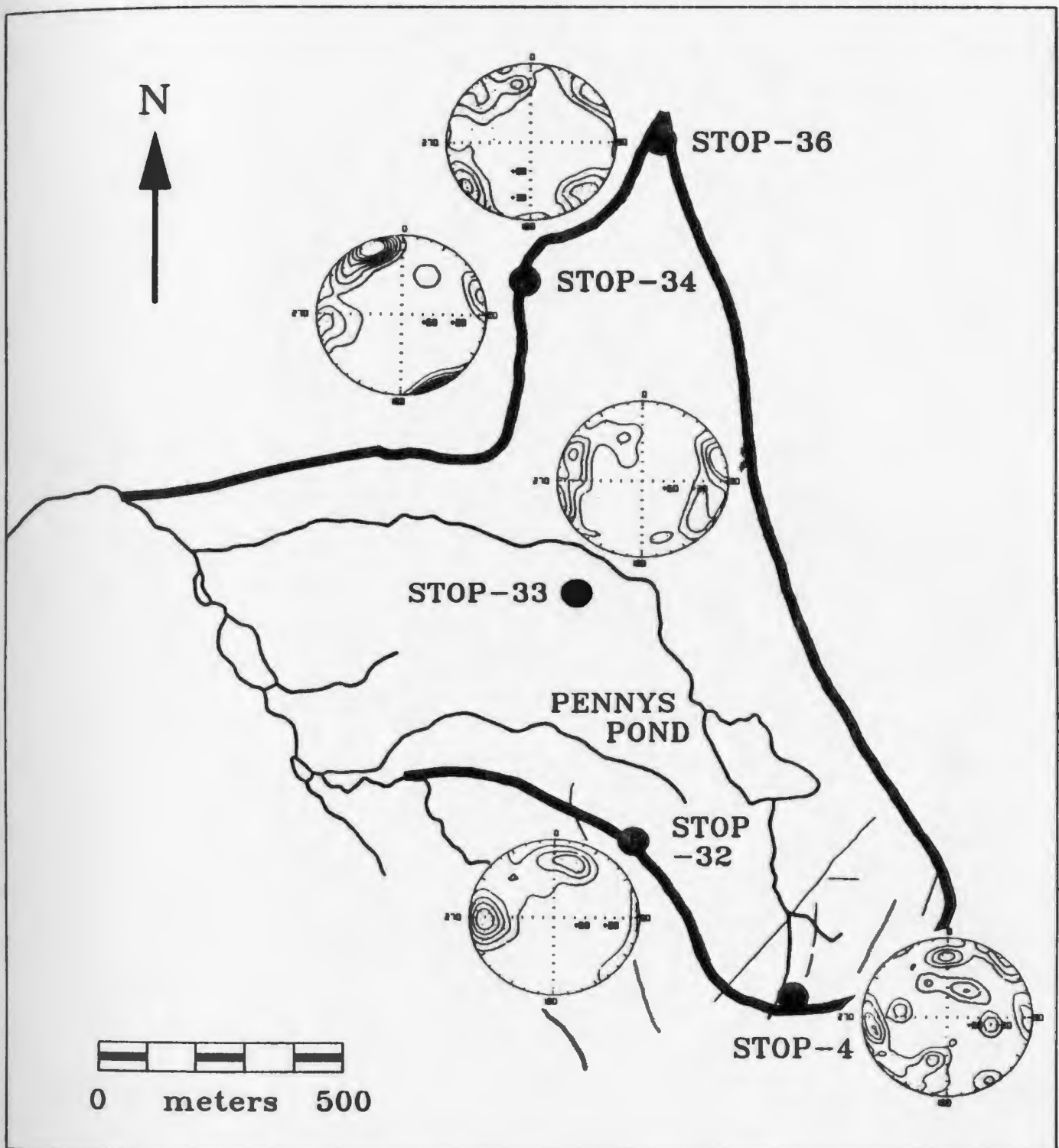


Figure 2.9 Map showing large scale structural features and contoured lower hemisphere stereoplots of fractures identified from scanline mapping of outcrops in the vicinity of Pennys Pond.

large scale features in the area oriented toward the northwest it is likely that groundwater would be directed toward the lake along northwest trending features.

Figures 2.10 and 2.11 show the pattern of fracturing surrounding Gull Pond and Rocky Pond. As in the case with Pennys Pond, the direction of groundwater movement into these lakes will be influenced by local gradients and the orientation of the two major fracture sets that are present. Gull Pond is surrounded by a ridge on three sides which funnels groundwater into the lake. Gull Pond and Rocky Pond are at approximately the same elevation, 137 m and 138 m respectively, but are separated by a ridge which acts as a basin divide between the two lakes. Although Rocky Pond has a common point of recharge with Gull Pond it also derives waters from an area to the southwest.

Nut Brook Pond to the southwest is the smallest lake included in this study and is at the lowest elevation, 121 m. Pennys Hill is to the northeast of Nut Brook Pond which serves as a substantial driving force for the local groundwater recharge toward the lake. The area surrounding the lake is extremely wet and boggy indicating that the water table is quite high and that groundwater is discharging in the area.

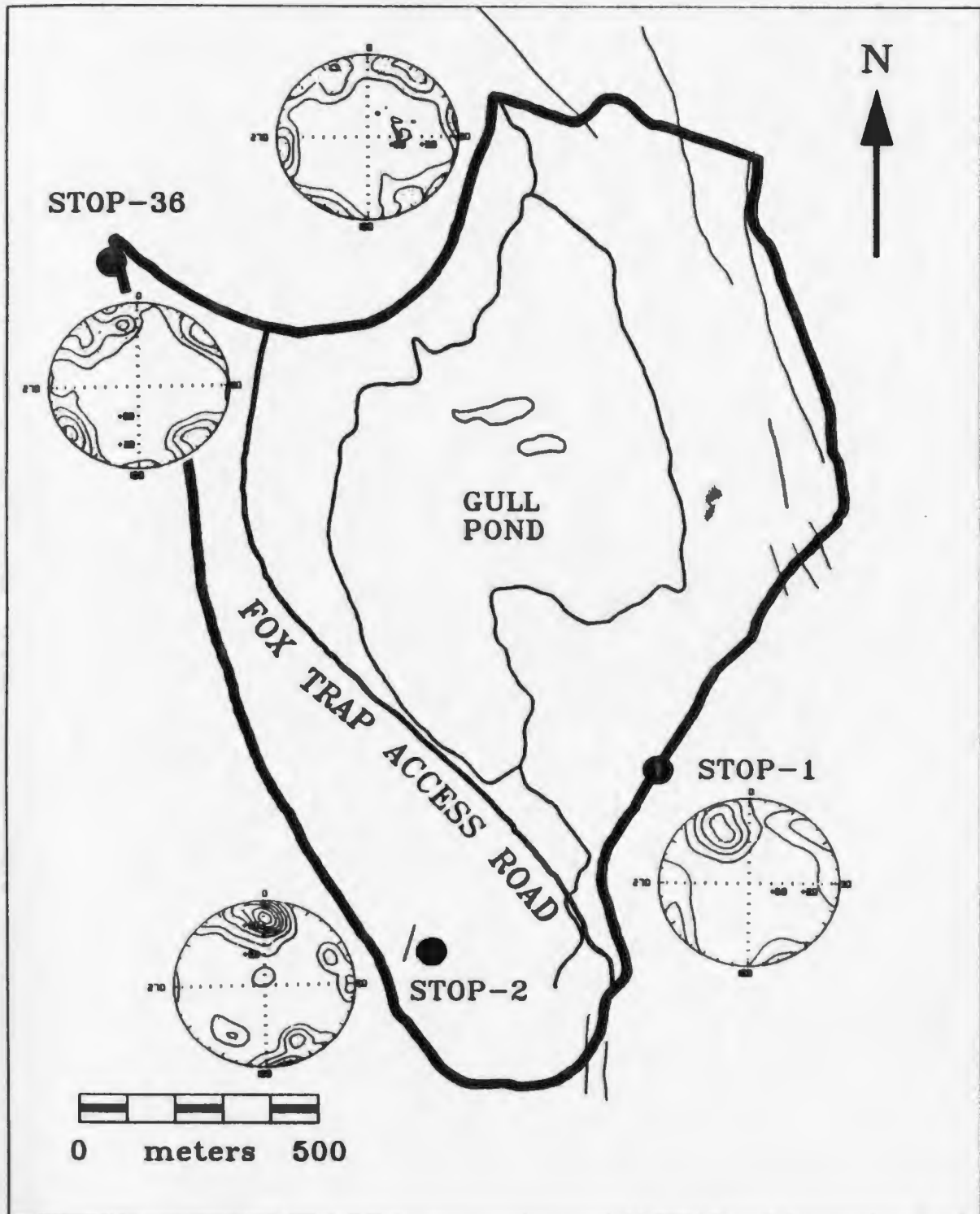


Figure 2.10 Map showing large scale structural features and contoured lower hemisphere stereoplots of fractures identified from scanline mapping of outcrops in the vicinity of Gull Pond.

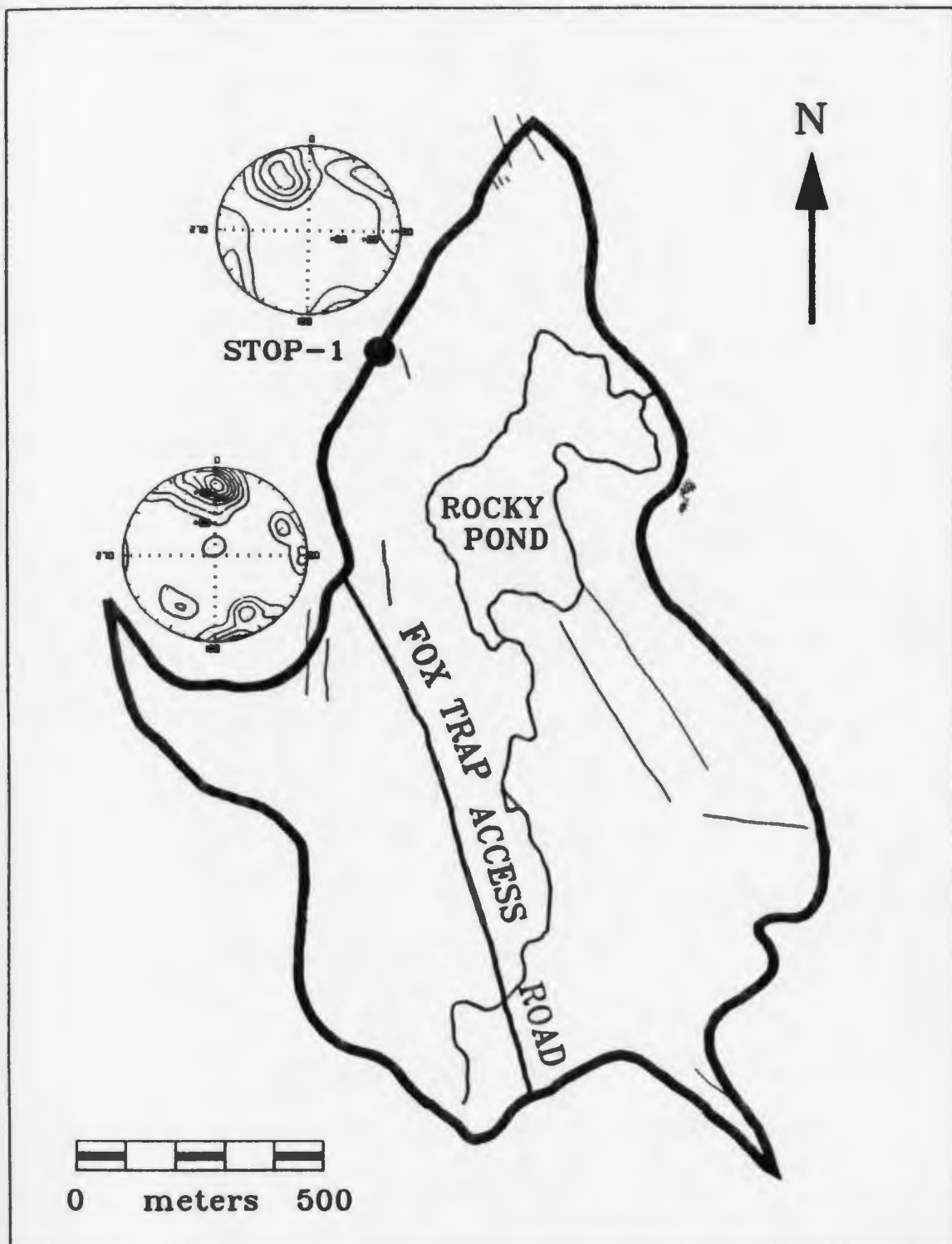


Figure 2.11 Map showing large scale structural features and contoured lower hemisphere stereoplots of fractures identified from scanline mapping of outcrops in the vicinity of Rocky Pond.

Chapter 3 LAKE SEDIMENT AND GROUNDWATER SAMPLING PROCEDURES

3.1 Lake Sediment Sampling and Analysis

The spatial distribution of metal concentrations within the sediments of the four lakes in this study were determined by collecting samples of sediment on a grid pattern marked on the ice surface of each lake. In the first phase of sampling, carried out during the winter of 1986, lake sediment samples were collected from Gull Pond (8980 m²) and Rocky Pond (2320 m²) using a 100 m grid pattern, while Nut Brook Pond (280 m²) which was smaller in size, was sampled at 25 metre intervals. Pennys Pond (490 m²) was sampled in 1985 using a 25 metre grid (Howle, 1985). A second phase of sampling was carried out over parts of Gull Pond and Rocky Pond during the winter of 1987, using a 50 metre grid, to more completely define the metal anomalies identified by the 1986 sampling.

Sediment samples were collected from the lake bottom using a weighted pipe torpedo-type sampler similar to the one described by Hornbrook et al. (1975). Holes were augured through the ice at the grid points and the sampler dropped through the hole allowing it to penetrate up to 1 metre into the lake sediment. After a sample was retrieved it was described in terms of colour, texture, and content and the

water depth at the grid location recorded. Each sample was then dried and crushed, and the crushed material sieved through 180 μm mesh screens to remove large bits of organic matter. One gram of each sample was digested in a 6 ml solution of 4M HNO_3 - 1M HCl at 90° C for two hours. The solution was then made up to 20 ml and analyzed by atomic absorption spectrophotometry for Cu, Pb, Zn, Fe, Mn, Cd and Mo. Neutron activation was used to determine uranium concentrations. An estimate of organic content was determined by measuring the percent weight of sample lost by ignition of 0.5 grams of sample at 500° C for four hours.

In addition to the samples of surface sediment collected from the lake bottom a total of eleven sediment cores were taken from Gull Pond, Rocky Pond, and Nut Brook Pond during the winter of 1987, in areas of anomalous and background metal concentrations as identified by the grid sampling, to define the vertical distribution of trace metals in the lake sediment. Continuous core samples were taken using a 0.5 m long half core sampler in water up to 16 m in depth. The core sampler was lowered on steel pipe through a 100 mm diameter ABS guide pipe which extended from the water surface to the lake sediment, allowing re-entry into the same hole each time to maintain a continuous sampling sequence. The cored sections of sediment ranged from 0.5 to over 3.0 metres. The

Nut Brook Pond cores were split into 50 mm sections for analysis. However, this did not always provide enough sample for a complete analysis. Hence, the cores from Gull Pond and Rocky Pond were divided into 100 mm sections. Analysis of the sediment core samples followed the same techniques as described above.

3.2 Groundwater Sampling and Analysis

The groundwater chemistry and hydraulic gradients beneath and adjacent to two of the study lakes were determined in order to establish the relationship between metal concentrations in lake sediment and groundwaters. A shallow 44 mm diameter borehole was drilled on an exposed outcrop at the edge of Pennys Pond to a depth of 12 m to intercept and sample discharging groundwaters (Figure 3.1). Permeable zones in the borehole were identified by performing fixed interval falling head permeability tests over the entire length of the borehole. After the borehole testing was completed, a multilevel piezometer modelled after those designed by Cherry and Johnson (1984), using chemical sealant packers, was installed in the borehole. Double packer assemblies were used to increase the length of the seal between sampling intervals to 600 mm and to minimize the possibility of short-circuiting

**MULTILEVEL PIEZOMETER INSTALLED
AT EDGE OF LAKE TO
SAMPLE DISCHARGING GROUNDWATERS**

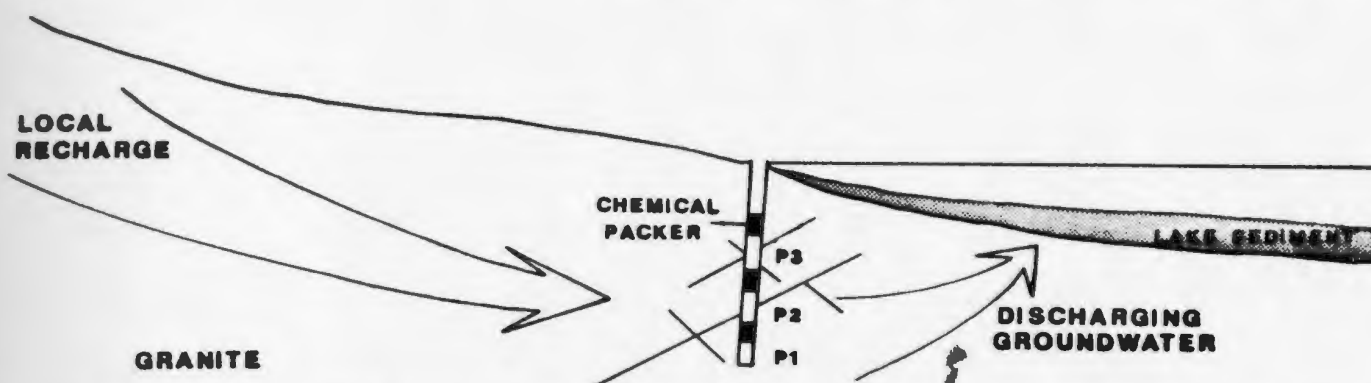


Figure 3.1 Schematic of multilevel piezometer installed on the shore of Pennys Pond.

PIEZOMETER INSTALLED IN BEDROCK UNDERLYING LAKE

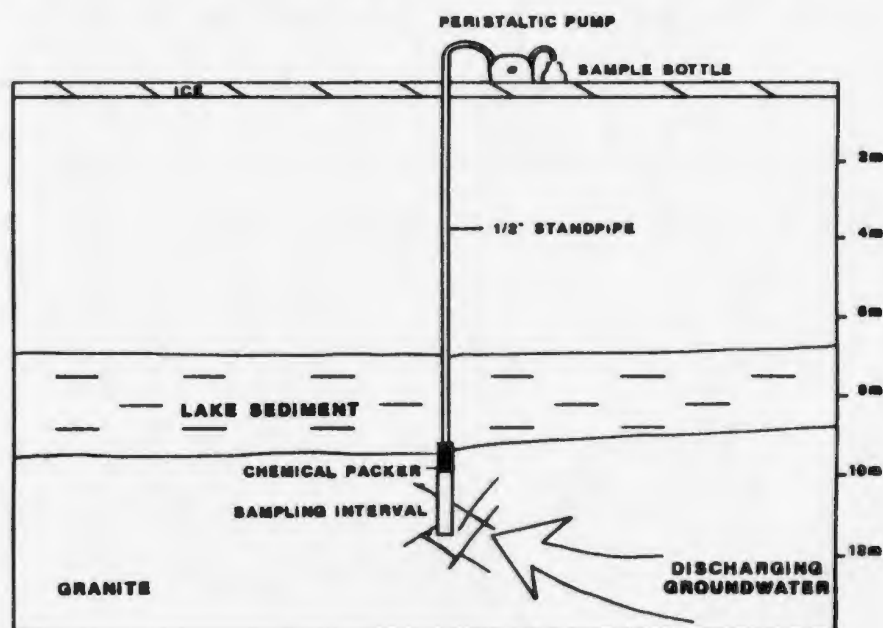


Figure 3.2 Schematic of piezometer installed through the lake sediment and into bedrock in Gull Pond.

between sampling intervals by connected fractures. This multilevel piezometer configuration provided three ports for the measurement of hydraulic gradients in the borehole and water sampling.

A second borehole was drilled from the ice surface, during the winter of 1988, in an area of Gull Pond which was identified as having anomalously high concentrations of uranium in the sediment in the previous grid sampling. The borehole penetrated the lake sediments and continued approximately two metres into granite bedrock. The bottom of the borehole provided a sampling interval which was sealed with a chemical packer (Figure 3.2). A 1/2 inch diameter polyethylene tube attached to the chemical packer was brought to the surface through the ice cover which allowed the hydraulic head in the isolated interval to be measured and groundwater samples to be collected directly at the bedrock/sediment interface.

Groundwater samples were extracted from all of the sampling intervals using a peristaltic pump. Measurements of pH and total conductivity were taken in the field at regular intervals during pumping. After stable readings were observed, two 125 ml polyethylene bottles of groundwater were collected. Two 125 ml bottles of lake water were also collected at the same time. Within four hours, each sample

was passed through a 0.45 μm filter and half the sample acidified with 1 ml of 16M nitric acid. Alkalinity was determined by acid titration of a portion of unacidified, unfiltered sample and reported as mg/l of equivalent bicarbonate. Analysis of major cations was done by atomic absorption spectrophotometry and trace metal concentrations were determined by inductively coupled plasma mass spectrometry (ICP/MS). Since bicarbonate was the dominant anion only semi-quantitative measurements of chloride and total sulphur were done by ICP/MS which gave values with a precision of $\pm 15\%$.

Chapter 4 GEOCHEMICAL AND ISOTOPIC FRAMEWORK

4.1 Regional Water Geochemistry

A hydrogeochemical data base for the Foxtrap - Holyrood area has been compiled as part of a regional groundwater flow system study (Gale et al., 1987). A survey of thirty one lakes and ponds in the area was carried out during May and June, 1985, to collect lake water samples for chemical analysis. The basic environmental parameters of pH, Eh, electrical conductivity and dissolved oxygen were measured at the time the water samples were collected. The water samples were analyzed for major anions and cations as well as trace metals. Groundwater samples were collected throughout the area from domestic water wells as well as from a series of research boreholes. Analytical results of the water samples collected are presented in Appendix B.

Results of the major ion analysis of samples collected from wells and lakes located in granitic bedrock have been plotted on a Piper diagram (Figure 4.1) to compare the chemical composition of groundwaters and surface waters. Surface waters (plotted as *) fall mainly in the Na-Cl field of the plot while groundwaters (plotted as x) range from Ca-HCO₃ to Ca-Na-HCO₃ or Ca-Na-Cl. All groundwaters have a greater

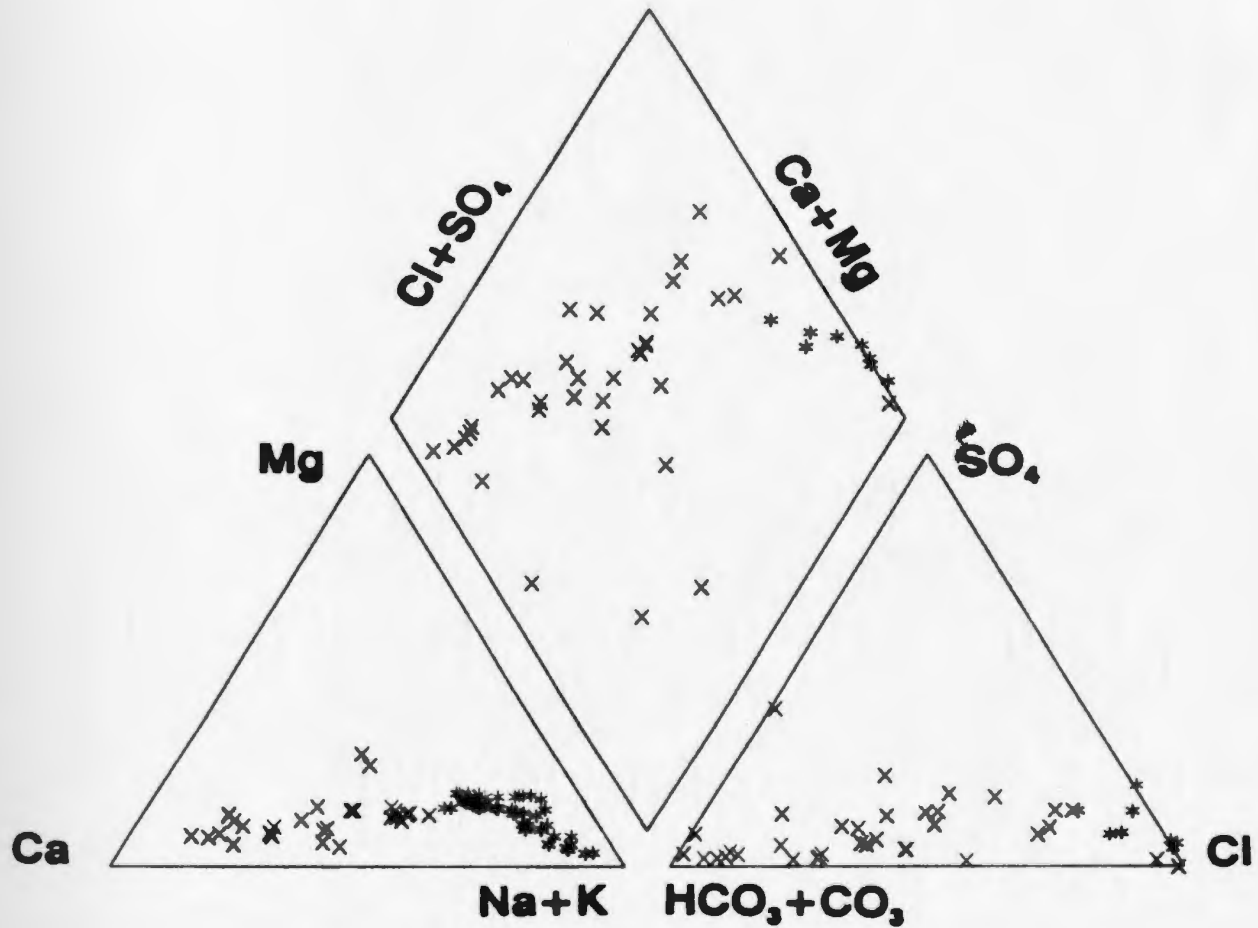


Figure 4.1 Piper plot for groundwater (x) and surface water (*) samples collected in Holyrood - Foxtrap area, May-June 1985, March 1987, and March 1989.

proportion of calcium than surface waters, and most have a higher proportion of bicarbonate, which is consistent for waters evolving in carbonate or plagioclase rich terrains. In general, surface waters have a Na/Ca ratio greater than 1.5 to 1, while groundwaters have Na/Ca ratios less than 1.5 to 1. This difference in sodium and calcium content can be used to differentiate between surface waters and shallow groundwaters.

Waters from most of the lakes in the study area have relatively low pH (less than 7) with several having pH values as low as 4.5. The Na-Cl character of surface waters is most likely related to the close proximity of the lakes to the coast and, in a few cases, road salt contamination introduced from the main highway and secondary roads which run through the head waters of the study area. Generally, the surface waters tend to be low in total dissolved solids compared to groundwater as approximately 80% of the lakes sampled had less than 10 ppm Na and less than 2 ppm Ca, while about 80% of the groundwater sampled contained greater than 10 ppm Ca. Concentrations of trace metals, with the exception of iron, also tend to be higher in groundwaters than in lake waters. The ratio of metal concentrations in groundwater to metals found in surface waters is in the range of 3 to 1, to 20 to 1, with the exception of uranium which is almost 1000 times greater in groundwater than in surface waters (Table 4.1).

Table 4.1 Comparison of the average trace metal concentrations found in groundwaters with the average concentrations found in surface waters.

	Cu ppb	Pb ppb	Zn ppb	Mn ppb	Fe ppm	Mo ppb	U ppb
Average Surface Water	9.7	2.0	22.8	31.5	140.7	0.1	0.1
Average Groundwater	35.9	10.2	70.9	408.3	43.9	1.7	89.4
Ratio GW/SW	3.7	5.1	3.1	12.9	0.3	17.0	894.0

Groundwater samples from deeper research boreholes (25 to 60 metres) along the Seal Cove River Valley to the west of the study area indicate that pH and dissolved solids generally increase with depth. The groundwaters from these boreholes are characteristically Ca-HCO₃ with slightly higher relative Na content in shallower intervals. Although dissolved solids in groundwater generally increase with depth, the groundwaters show no systematic increase of trace metal concentrations with depth. The exception to this is uranium which was found in concentrations up to 350 ppb in the deepest intervals sampled. This is consistent with relatively high Eh values observed in these intervals, which indicate that uranium should exist in its hexavalent state and would therefore be soluble at these depths. Domestic wells sampled in the lower part of the regional flow system and completed in the Holyrood granite

have similar water chemistry but generally lower pH, total dissolved solids, and uranium content. This may be due to dilution and mixing with shallow groundwaters, induced by long term pumping.

A number of samples collected from the research boreholes over a period of several days, as the boreholes were being pumped, were analyzed for stable isotopes. The $\delta^{18}\text{O}$ values determined for these boreholes ranged from -8.5 to -9.0 per mil vs SMOW (Standard Mean Ocean Water) and as high as -8.3 in the deepest borehole. Analysis of precipitation in 1985/86 indicated $\delta^{18}\text{O}$ mean annual values of -8.0 to -10.0 per mil for meteoric waters in the area (Welhan, pers. comm., 1987). Therefore it is difficult to differentiate between shallow and deep groundwaters using oxygen isotopes due to the similarity in ranges of $\delta^{18}\text{O}$ values.

An attempt was made to use differences in water chemistry from the regional lake survey as an indicator of lakes which are fed by groundwater. Lakes located in the lower portion of the regional groundwater flow system, and therefore likely to have a large component of groundwater discharging into them showed no apparent difference in water chemistry compared to other lakes in the area. The only lakes sampled which showed an enrichment in calcium and other dissolved solids were part of

the Yelligrews River system. These lakes were located downstream from a local dump which is a likely source for the observed increase in dissolved solids (Griffen, 1988). Oxygen isotopes proved to be inconclusive in distinguishing the component of groundwater discharge into a lake due to the lack of contrast in the isotopic composition of groundwaters and lake waters.

Samples of lake water taken in Gull Pond, Pennys Pond, Rocky Pond and Nut Brook Pond through the ice in the winter had higher concentrations of Ca than in samples collected in the spring (Table 4.2). Although there were corresponding increases in concentrations of Na in three of the four lakes they were not as significant as the increases in the concentrations of Ca indicating a possible enrichment by Ca - rich groundwater.

An estimate was made of the proportion of groundwater that would be necessary to enter each lake to produce the observed increase in calcium concentrations. It was assumed that the concentrations of Na and Ca observed in the samples of lake water taken in the spring were representative of normal surface waters conditions. It was also assumed that the concentrations of Na and Ca observed in lake water samples taken in the winter were indicative of surface water mixed

Table 4.2 Comparison of Ca and Na concentrations (ppm) in lake waters in Spring and Winter

		Spring	Winter	% change	Proportion of Groundwater
Gull Pond	Ca	1.5	2.2	46	23%
	Na	9.2	11.4	24	
Rocky Pond	Ca	2.7	4.6	70	29%
	Na	31.9	40.8	28	
Pennys Pond	Ca	0.7	0.9	28	20%
	Na	5.0	5.3	6	
Nut Brook Pond	Ca	11.1	15.2	37	35%
	Na	173.6	163.2	-6	
Average Groundwater	Ca	22.4			
	Na	13.2			

with a higher proportion of shallow groundwater during a period of no evaporation and little surface water input. The proportion of groundwater required to produce the concentrations observed in the mixed waters were calculated based on the minimum ratio of Na to Ca for shallow groundwater in the area of 1.5 to 1, determined from Figure 4.1.

These calculations indicate that groundwater contribute in the range of 20 to 35 percent of the total water recharging the lakes over the winter period. These estimates are probably low since during the winter period there is minimal surface run-off to the lakes and the greater percentage of water discharging into the lakes should be derived from groundwater.

In addition, the maximum Na/Ca ratio for groundwater was used in the calculations which maximizes the estimate of the proportion of groundwater entering each lake. These estimates are very approximate since Ca balance depends on the size, volume and flushing rate of the lake as well as the actual proportion of the lake's water balance that is comprised of groundwater. However, they do suggest that groundwater is discharging into these lakes.

4.2 Local Groundwater Geochemistry

Analytical results for water samples taken from Pennys Pond and Gull Pond and from boreholes drilled at both lakes are given in Table 4.3 while analytical results from other selected boreholes, are given in Table 4.4 for comparison. Samples PP-1, PP-2 and PP-3 were taken from three intervals of the multilevel piezometer installed in a 12 m borehole at the edge of Pennys Pond. Sample GPGW is from a borehole drilled through the bottom of Gull Pond. Sample NS7 is from a water well adjacent to Nut Brook Pond and H285B6 and H3951 are from two research boreholes located in the Seal Cove River Valley adjacent to the study area. The samples taken from the boreholes are typical of the groundwaters in the area since the dominant ions in these samples are calcium and bicarbonate.

Table 4.3 Analytical results of water samples collected from Pennys Pond and Gull Pond and from boreholes drilled at both lakes.

sample		PPLAKE	PP-P1	PP-P2	PP-P3	GPGW	GPLAKE
depth (m)		NA	7.92	6.10	3.35	NA	NA
pH		4.64	7.21	7.44	7.20	6.66	6.04
cond		39	195	375	200	190	105
Ca ²⁺	mg/l	0.9	43.2	46.4	41.5	11.8	3.0
Mg ²⁺	mg/l	1.1	2.7	3.0	2.6	2.9	1.4
K ⁺	mg/l	0.2	0.2	3.3	0.5	1.0	0.4
Na ⁺	mg/l	5.3	7.0	40.2	9.1	16.2	14.5
Fe ²⁺	mg/l	0.0	0.5	0.6	0.6	14.4	0.0
SiO ₂	mg/l	0.8	4.8	4.4	4.0	6.4	0.9
HCO ₃ ⁻	mg/l	3.9	123.4	138.9	123.4	46.3	7.8
Cl ⁻	ppm	0.5*	0.4*	0.7*	0.4*	1.5*	1.3*
SO ₄ ²⁻	ppm	2.4*	4.1*	73.1*	9.4*	1.2*	2.6*
Cu	ppb	2.7	1.7	5.8	2.7	1.7	2.8
Pb	ppb	1.7	0.8	16.0	1.6	0.7	1.6
Zn	ppb	15.0	11.0	18.0	8.5	13.0	11.0
Co	ppb	0.1	0.1	1.2	0.0	0.1	0.1
Ni	ppb	2.6	0.4	8.0	1.4	0.1	0.3
Mn	ppb	15.9	469.6	539.0	392.6	566.9	4.7
Fe	ppb	181.4	590.8	609.1	716.4	18813.0	9.8
Mo	ppb	0.1	14.6	31.2	9.6	1.4	0.1
U	ppb	0.1	81.6	133.8	61.5	0.6	0.1
Charge balance	%	±48.8	±11.9	±7.0	±9.5	±30.8	±61.5
δ ¹⁸ O		-8.35	-7.69	NA	NA	-7.77	-6.06

* = ICP/MS analysis ± 15%

NA - not available

The multilevel piezometer installed in the Pennys Pond borehole sampled three distinct intervals. The interval depths were P3, from 2.85 m to 4.85 m, P2, from 5.65 m to 7.65 m, and P1, from 8.50 m to the bottom of the hole which was

Table 4.4 Analytical results of water samples taken from selected boreholes in the study area.

sample		H285B6	H3851	NS7
depth (m)		62.80	24.86	90.0
pH		NA	NA	7.26
cond		NA	NA	470
Ca ²⁺	mg/l	17.9	32.5	54.6
Mg ²⁺	mg/l	1.4	3.7	4.7
K ⁺	mg/l	1.0	0.7	5.9
Na ⁺	mg/l	8.1	8.3	43.6
Fe ²⁺	mg/l	0.4	0.0	NA
SiO ₂	mg/l	NA	6.0	NA
HCO ₃	mg/l	NA	127.5	152.5
Cl	ppm	4.4	8.0	67.3*
SO ₄ ²⁻	ppm	2.6	3.8	15.8*
Cu	ppb	8.8	4.6	8.6
Pb	ppb	1.1	1.5	134.9
Zn	ppb	6.0	78.7	230.0
Co	ppb	0.9	0.1	NA
Ni	ppb	13.7	5.2	3.0
Mn	ppb	972.3	78.5	1030.5
Fe	ppb	41.5	21.2	77.6
Mo	ppb	0.4	0.5	1.5
U	ppb	213.3	357.5	99.0
Charge % balance		NA	±1.7	±4.5
δ ¹⁸ O		-6.06	-8.45	-8.00

* - ICP/MS analysis ± 15%

NA - not available

approximately 11.25 m. Based on the fracture frequency observed in the drill core and from permeabilities calculated from falling head tests, the size and location of the intervals were chosen to include zones which had the

highest rate of flow into the borehole. Hydraulic heads measured in the three piezometers were approximately 10 mm above the water level of the lake. There was a 2 to 3 mm increase in the interval heads with depth interval indicating that an upward gradient existed over the length of the borehole and that groundwater was discharging into the lake at that point.

Water samples taken from the three intervals had characteristically higher pH, conductivity, alkalinity and trace metal concentrations than the lake waters. Like other groundwater samples in the area, samples from the Pennys Pond borehole were found to have high concentrations of uranium ranging from 61 to 134 ppb uranium which were significantly higher than the lake waters. No other trace metals showed significant differences between lake water and groundwaters. The ratio of Na to Ca for groundwaters extracted from these three intervals were 0.14, 0.75 and 0.19 for P1, P2, and P3 respectively which, along with the relatively high measured concentrations of bicarbonate, indicates that the groundwaters are from part of the local flow system around the lake. Although the three samples were similar in composition, the middle interval (P2) was found to have higher concentrations of most dissolved constituents. This suggests that the groundwater extracted from this interval has possibly

travelled more slowly, and has been in contact with the rock mass for a longer period of time. This is consistent with the permeability calculated for the P2 interval which was approximately an order of magnitude lower than the other two intervals.

The borehole drilled through the lake bottom and into bedrock in Gull Pond was drilled approximately two metres into granite bedrock through a bouldery rubble zone below the organic sediments. The frequency of fractures in the interval was relatively low with only a few fractures being observed in the core that was recovered. A chemical packer was placed at the first contact with intact bedrock to provide a distinct sampling interval in the bottom section of the borehole. The hydraulic head measured in this interval was approximately 10 mm above the water level in the lake indicating a positive upward gradient suggesting that groundwater was discharging into the lake through the lake sediments. Also, when water was being pumped from the interval during sampling, there was very little drawdown of the water level in the piezometer suggesting that water was recharging into the interval.

It is important to note that when this borehole was first sampled the pH and specific conductivity were 7.27 and 395 $\mu\text{S}/\text{cm}$ respectively, but after a minute of pumping these

readings had changed to approximately 6.50 and 190 $\mu\text{S}/\text{cm}$. One possible explanation for the rapid change in pH and conductivity is that the initial values represented groundwater, but as the interval was pumped, lake water was drawn down into the sampling interval and mixed with discharging groundwater. The concentrations of both major ions and trace metals in the water sample (Table 4.3) suggest that it is neither a typical groundwater nor surface water compared with others waters in the study area. For example, values of alkalinity and calcium measured for the water sample are not as high as those found in most groundwaters but are higher than values found in surface waters. The ratio of Na to Ca for the sample is approximately 1.2 : 1 which suggests that the sample is composed of shallow groundwater that has been mixed with surface water. The lack of uranium in the water suggests that it is more typical of surface water.

Chapter 5 RESULTS AND DISCUSSION OF SEDIMENT GEOCHEMISTRY

5.1 Results of Surface Sediment Sampling

A total of 143 surface sediment samples were collected, using a regularly spaced grid, from the four lakes; 63 from Gull Pond, 36 from Rocky Pond, 28 from Pennys Pond and 16 from Nut Brook Pond. Sample coverage was fairly complete except in some near-shore or shallow areas where there was insufficient sediment to collect a sample. The surface sediment samples consisted mainly of black brown silty organic ooze. A summary of the sediment analyses for the lakes sampled in this study are given in Table 5.1, while a complete list of analyses is given in Appendix C.

Frequency histograms and statistics of metal concentrations found in the sediment of each lake sampled (Figure 5.1) show that trace metals are not evenly distributed throughout the sediment in these lakes. Most of the concentration values for each element are close to or slightly less than the mean, but values range up to several standard deviations above the mean value. For example, Gull Pond has an average concentration of 31.2 ppm uranium in surface sediment but a localized area of the lake has a much higher concentration of 159 ppm uranium. Peak concentrations in the sediment vary from lake to lake,

Table 5.1 Summary of trace metal analyses of surface sediment samples (avg.= mean, std.= standard deviation).

		Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	U ppm	LOI %
Gull Pond	avg.	18.4	18.7	107.3	2680.7	3.2	10.7	31.2	32.0
	std.	7.4	6.1	28.7	5066.8	1.9	4.4	25.5	9.8
	min.	7.0	12.0	45.0	159.0	0.5	3.0	13.4	2.8
	max.	52.0	54.0	185.0	28600.0	7.1	30.0	159.0	44.2
	#	63	63	63	63	63	63	63	63
Rocky Pond	avg.	12.1	13.8	46.7	4127.9	3.8	9.3	14.2	29.8
	std.	2.8	4.8	18.1	9284.4	2.8	10.3	12.2	8.6
	min.	8.0	8.0	23.0	355.0	1.1	3.0	6.2	10.8
	max.	24.0	29.0	98.0	50600.0	11.7	68.0	69.0	40.3
	#	36	36	36	36	36	36	36	36
Pennys Pond	avg.	6.0	17.5	9.6	50.3	0.8	4.5	46.3	15.8
	std.	4.9	7.6	7.1	41.6	0.5	1.5	59.2	5.8
	min.	3.0	10.0	4.0	2.0	0.2	3.0	15.9	1.1
	max.	29.0	47.0	33.0	194.0	2.5	10.0	309.0	37.1
	#	28	28	28	28	28	28	28	28
Nut Brook Pond	avg.	13.9	38.9	26.4	190.6	0.7	7.6	92.0	28.9
	std.	3.4	10.9	29.6	140.5	0.4	3.1	66.5	6.4
	min.	9.0	23.0	3.0	34.0	0.3	3.0	30.8	15.0
	max.	21.0	60.0	124.0	536.0	1.5	13.0	250.0	40.6
	#	16	16	16	16	16	16	16	16
All Ponds	avg.	13.9	19.5	63.9	2251.4	2.6	8.8	36.7	27.9
	std.	7.3	9.9	46.8	5950.2	2.3	6.5	44.8	10.4
	min.	3.0	8.0	3.0	2.0	0.2	3.0	6.2	1.1
	max.	52.0	60.0	185.0	50600.0	11.7	68.0	309.0	44.2
	#	143	143	143	143	143	143	143	143

Table 5.2 Results of regional survey for Gull Pond and Nut Brook Pond (Davenport and Butler, 1976), based on a single sediment sample from each lake.

	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	U ppm	LOI %
Gull Pond	42	15	108	923	2.9	23	125	26.8
Nut Brook Pond	7	37	32	448	1.1	10	189	33.6

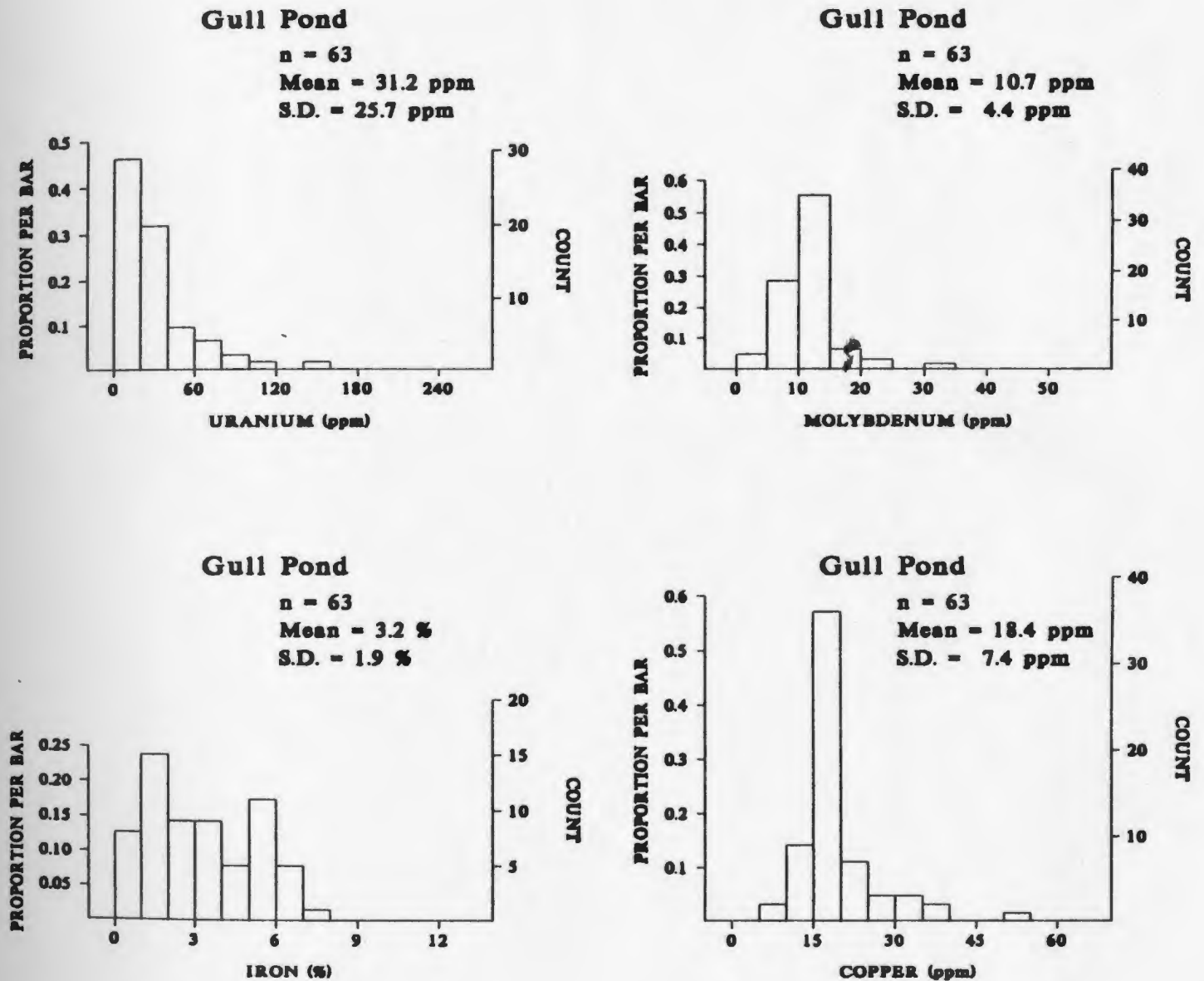


Figure 5.1 Frequency histograms showing the distribution of selected metals in the sediment in a) Gull Pond, b) Rocky Pond, c) Pennys Pond and d) Nut Brook Pond.

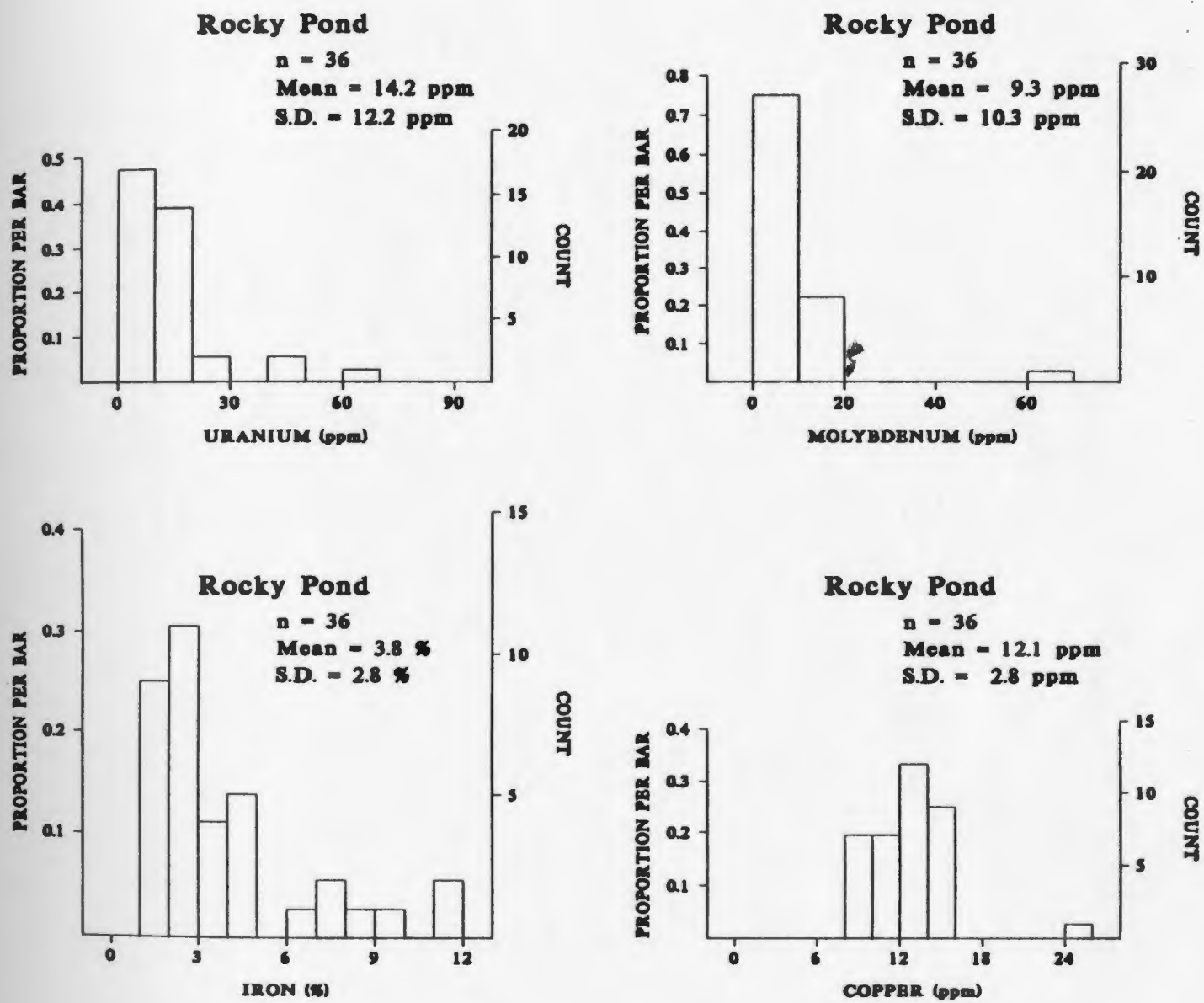


Figure 5.1 (cont'd)

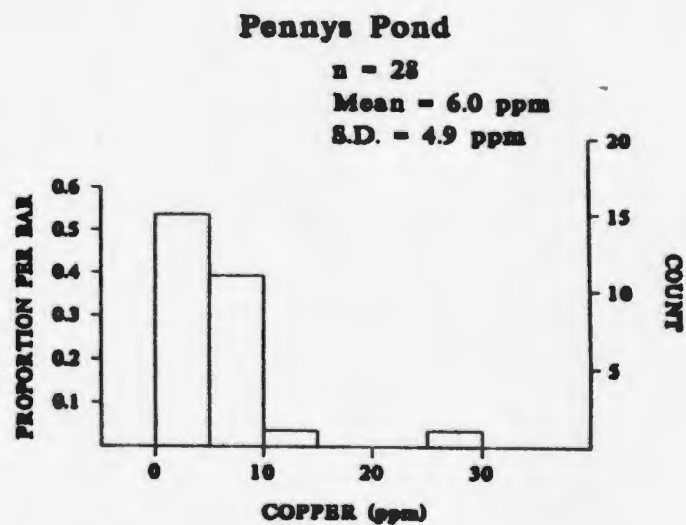
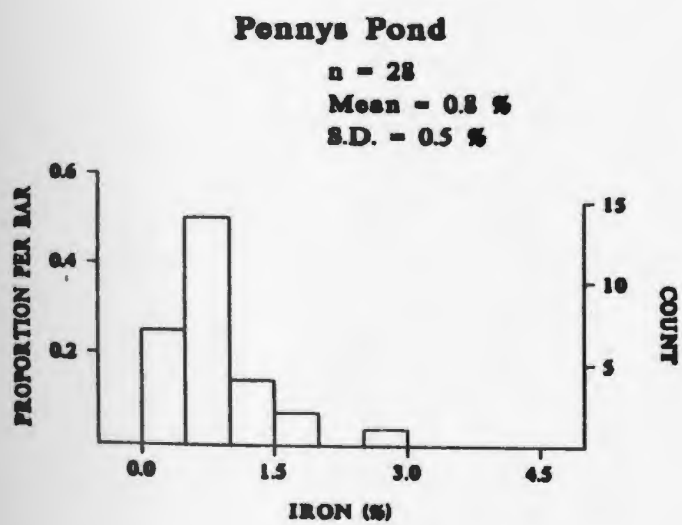
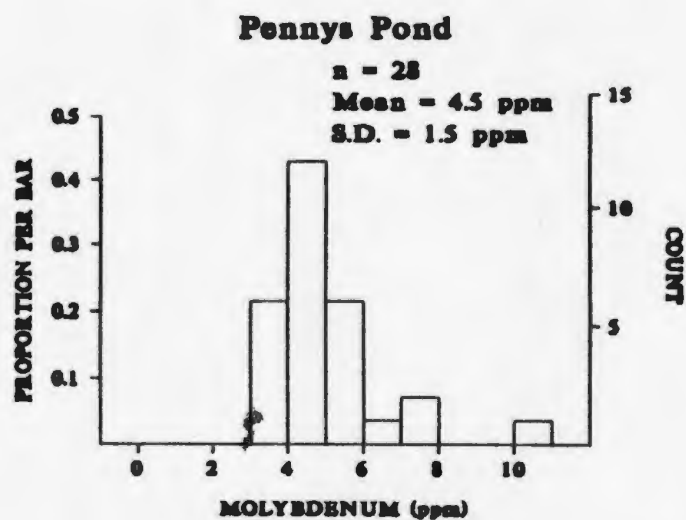
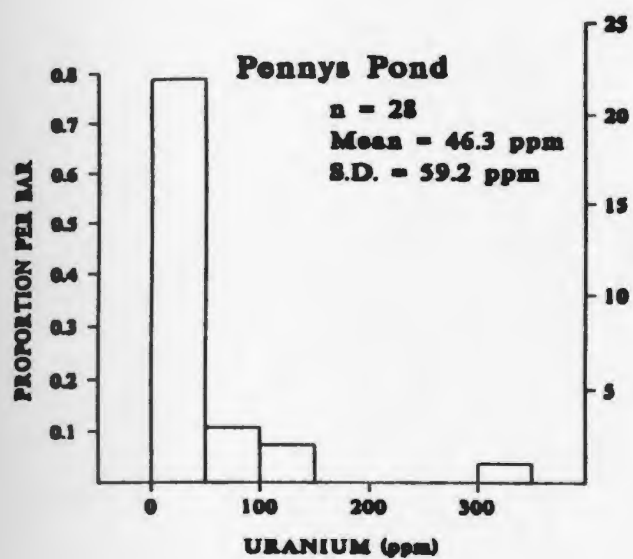


Figure 5.1 (cont'd)

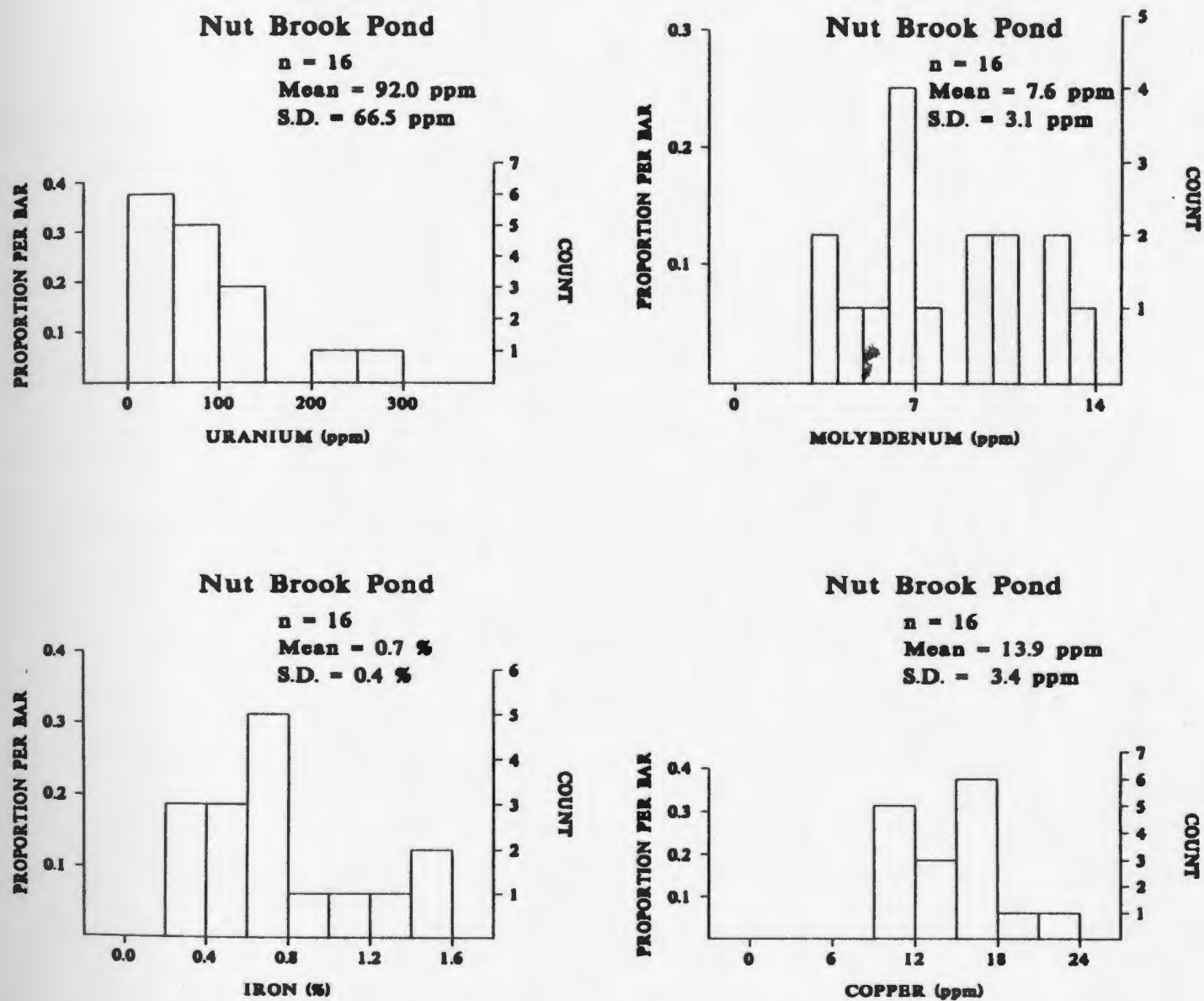


Figure 5.1 (cont'd)

but are generally 2 to 3 times the average value for that lake. In each lake there is a location within the lake which had an anomalously high concentration for a particular metal in the sediment. However, the peak concentrations for different metals were not always found at the same location within a lake.

The results of the detailed sampling showed that there were locations sampled in Gull Pond and Nut Brook Pond that contained metal concentrations that exceeded the values recorded in the regional survey (Table 5.2). The regional survey reported values of 125 ppm and 189 ppm U versus maximum values of 159 ppm and 250 ppm in the detailed sampling for Gull Pond and Nut Brook Pond, respectively. Pennys Pond which reported the highest concentration of uranium, 309 ppm U, in the detailed sampling was not sampled in the regional survey.

The contoured plots of uranium concentration for each lake (Figure 5.2) show that the anomalous areas are not found at any particular location in each lake, with respect to the lake morphology or inflow and outflow streams. The uranium anomaly in Nut Brook Pond is near a source of surface water input but is in a relatively central area in Pennys Pond and Gull Pond, and near a stream outflow in Rocky Pond. The extent and shape of the uranium anomalies were also different in each lake.

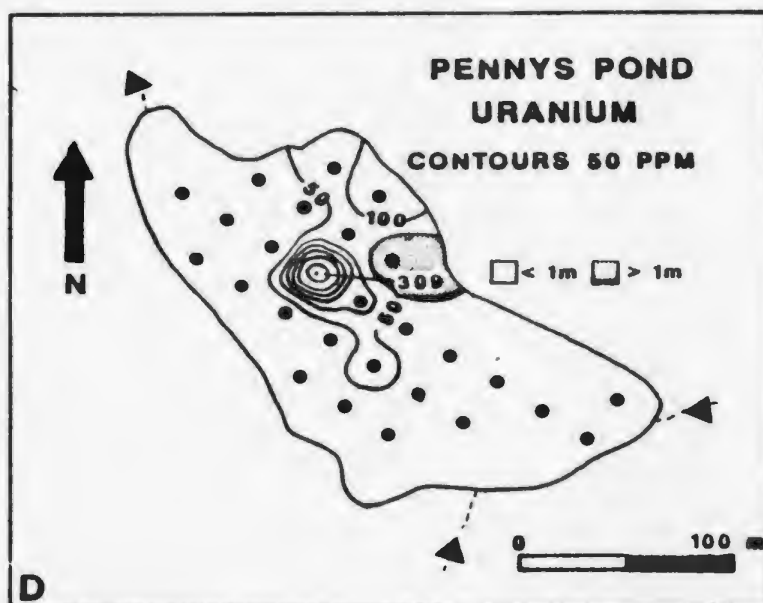
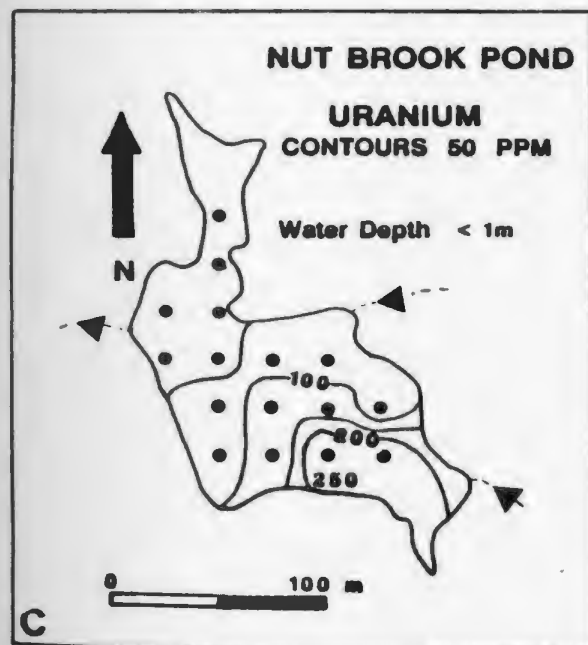
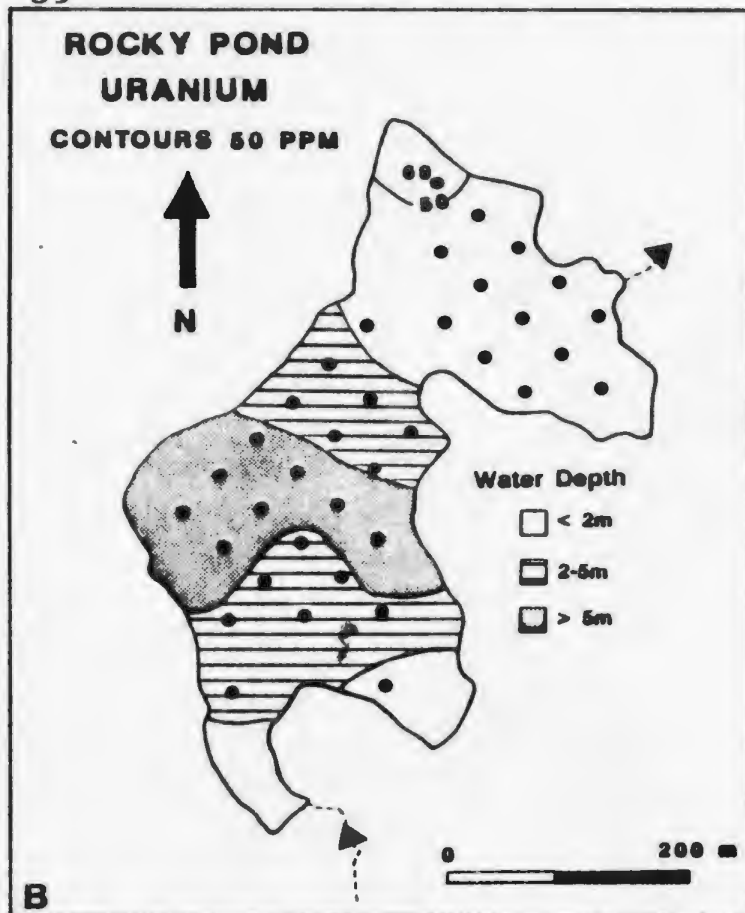
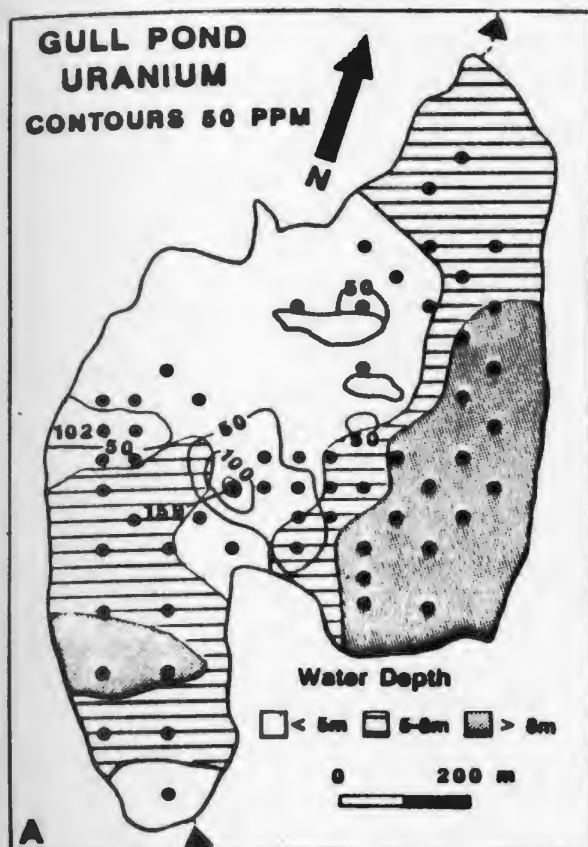


Figure 5.2 Contour plots showing the distribution of uranium concentrations in lake sediment as well as the distribution of water depth in a) Gull Pond, b) Rocky Pond, c) Nut Brook Pond and d) Pennys Pond. Arrows indicate direction of streamflow.

For example, in Pennys Pond the anomaly was somewhat elongated, peaking in a circular "bull's eye" type of pattern located in the centre of the lake. The uranium anomaly in Gull Pond showed a similar pattern to Pennys Pond, with the peak of the anomaly located in the middle portion of the lake, where the water depth at that point was only 2 to 3 metres. In Nut Brook Pond the uranium anomaly formed a frontal pattern which decreased outward into the lake away from its peak point near a stream inlet. Finally in Rocky Pond, which had the lowest concentrations of uranium relative to the other lakes, only one sampling point showed concentrations above 50 ppm.

5.2 Discussion of Surface Sediment Sampling

The detailed sediment sampling carried out in this study has shown that there is variability in the intensity of metal concentrations in lake sediments and that anomalous areas are not always located in the centre or deepest part of a lake (Figure 5.2). Lake centres are normally sampled in regional geochemical lake sediment surveys because they are thought to be the most likely location to find concentrations of metals in the sediment and for consistency between lakes (Hornbrook et al. 1975a). The centre or deepest part of a lake is usually sampled because this is where the fine size particles are most likely to be found. The finer particles have a

greater exposed surface area and are therefore better able to absorb and retain metal species as they settle in the water column. However, there are many factors which can influence where metals will be concentrated in the lake sediment, such as the size, depth and morphology of the lake and particulate size. The circulation patterns and the degree of mixing of waters within a lake will also affect where metals are concentrated in the lake sediment. Therefore, in a regional survey, a representative sample of metal concentrations may not always be obtained by only sampling sediment from the deepest or most central part of a lake.

A comparison was made between the concentrations of metals found in the sediment and those found in the granitic bedrock to determine if the concentration of metals found in the sediment was a result of detrital input into the lake from the granitic bedrock or other processes. Samples of the granitic bedrock from the northeastern portion of the Holyrood Granite near alteration zones were collected and analyzed for trace metals as part of a study by Hayes (1989). Data from the freshest and least altered samples were used to determine the average concentrations for Cu, Pb, Zn, Fe, Mn and Mo in the granite. The average uranium concentration was calculated by Davenport (1978) from samples collected by Strong et al. (1974). Average concentrations of metals in lake sediment

were determined from lake sediment samples collected in the regional sediment survey (Davenport and Butler, 1976); only those lakes located in granite catchment basins were averaged. The average concentrations for each metal in both the rock and lake sediment, as well as the ratio of concentrations in the sediment to the concentrations in the rock are given in Table 5.3.

The ratios of Cu, Pb, Zn and Fe concentrations in sediment to rock were close to 1:1, which would suggest that trace metals in the sediment were transported as detrital material with only minor secondary enrichment. The sediment to rock ratio for molybdenum is slightly higher at 2.8, while the ratios for uranium and manganese are approximately an order of magnitude higher than the others. The high manganese ratio can possibly be accounted for by the way in which Mn in a mineral phase in the granite would be liberated as Mn^{2+} , and would later oxidize and precipitate as it is transported by surface drainage to the sediment. Manganese may exist in the mobile Mn^{2+} state longer than iron, since the phase boundary between Fe^{2+} and oxidized iron occurs at a lower oxidation potential than for Mn.

Davenport (1978) suggests that the difference in the average concentration factor of uranium in lake sediment relative to

Table 5.3 Comparison of average trace metal concentrations found in Holyrood Granite and in lake sediments found in the granite catchment basins (Davenport, 1978 and Hayes, 1989).

		Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	U ppm
Granite	Mean	13.5	24.9	40.3	539	2.5	5.2	2.4
	S.D.	11.4	26.2	22.2	308	1.5	6.3	0.8
	n	15	15	15	15	15	15	15
Sediment	Mean	11.4	39.5	71.4	10150	5.0	14.4	28.7
	S.D.	9.1	36.2	45.3	18178	2.8	14.4	44.4
	n	21	21	21	21	21	21	21
Sed/Rock		0.9	1.6	1.8	18.8	2.0	2.8	12.1

bedrock is a result of either the under sampling of late phase aplites and pegmatites in the granite where uranium may be enriched, or the depletion of uranium in the granite by weathering of minerals such as uraninite. The comparison of metal concentrations in the sediment with bedrock concentrations indicates that most metals in the sediment represent detrital concentrations. However, the elevated levels of uranium in the sediment compared to concentrations found in the underlying granitic bedrock suggest that uranium is being concentrated in the lake sediments.

The variability in the intensity and location of peak metal concentrations found in the surface layer of the lake sediment and the enrichment of uranium suggest that processes other

than detrital deposition and the adsorption of metals on particulate matter as it settles in the water column may be responsible for concentrating metals in the sediment. The elongated uranium anomalies identified in both Pennys Pond and Gull Pond are oriented slightly west of north which coincides with the orientation of fractures of cluster 1, identified from the mapping of outcrops in the area (Figure 2.4), and the orientation of most of the linear features identified from aerial photographs (Figure 2.2). The shape and location of the anomalies in the sediment of these lakes suggest that the uranium anomalies could be related to fracture zones or structural features in the underlying granitic rock mass.

5.3 Results of Sediment Core Sampling

Vertical sections of sediment were sampled from three of the four lakes in this study to determine the vertical distribution of metals in the sediment. Sediment cores were taken in anomalous areas defined by surface sediment sampling as well as background areas from five locations in Gull Pond and three locations in each of Rocky Pond and Nut Brook Pond. The location of the cores within the individual lakes are shown in Figure 5.3. Most of the sediment in the retrieved cores consisted of dark brown organic silt and generally with the deepest sediment consisting mainly of grey silty sand.

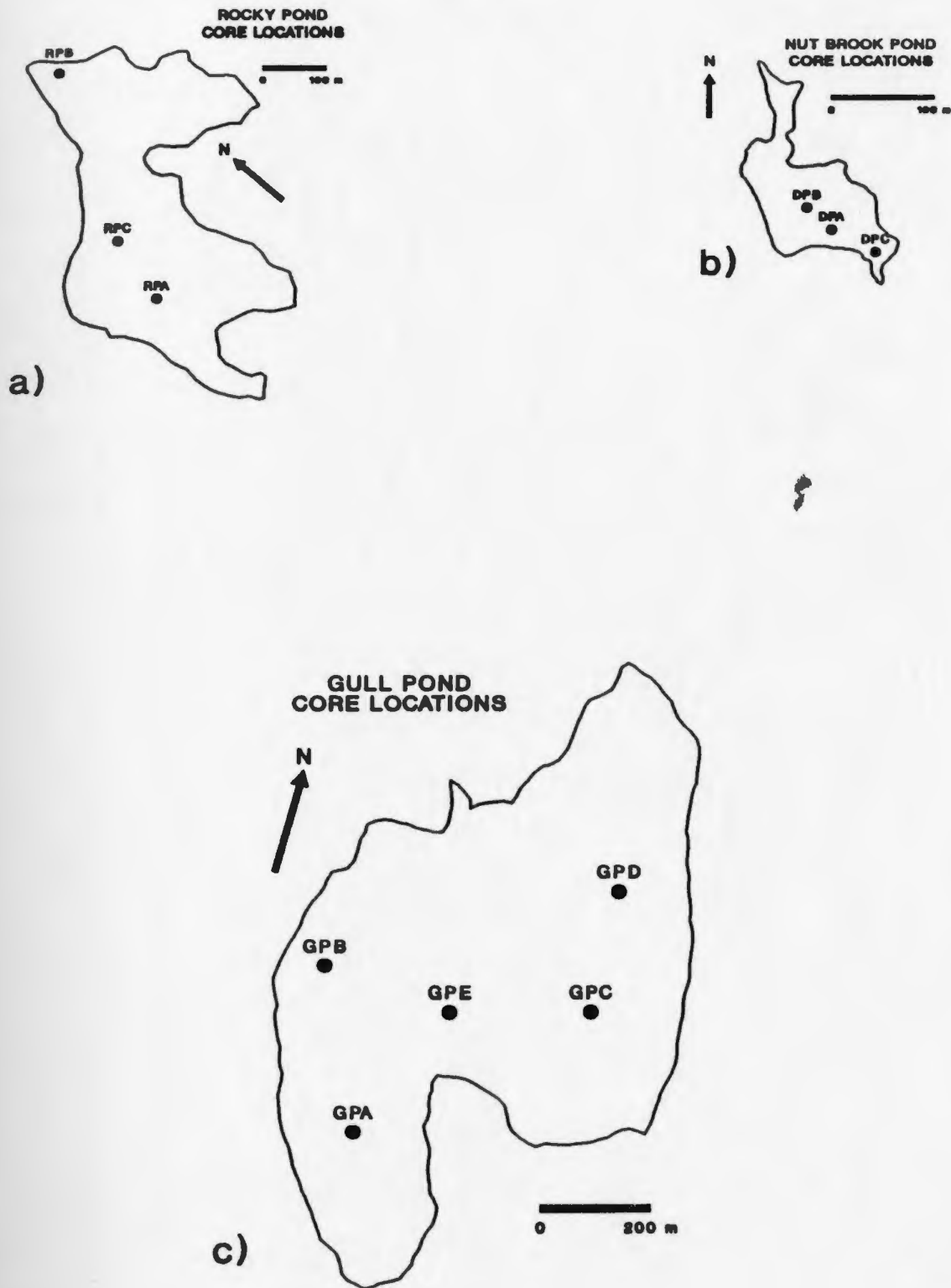


Figure 5.3 Locations at which sediment cores were collected in a) Rocky Pond, b) Nut Brook Pond and c) Gull Pond.

Sediment cores taken from other lakes on the Avalon Peninsula by MacPherson (1982) also contain sediments which consist of organic rich "gyttja" in the top sections grading to grey silty clay (indicative of accumulations of mineral sediments) in the bottom sections of the cores.

The cores ranged from 0.5 to 3.0 m in length depending on where in a particular lake the core was taken (near-shore or lake centre). Since the coring device could only penetrate as far as it could be manually pushed through the sediment it is not certain if the bottom of the cores represents the true thickness of the sediments. This uncertainty was due to the high resistance of the dense clay or sandy layers which, if encountered, could not be penetrated by the corer. Therefore it was difficult to correlate core depths and as a result there was little or no stratigraphic control between cores. Metal analyses on the core sections are tabulated in Appendix D.

The sediment cores from each lake show that metal concentrations vary vertically in the sediment column (Figure 5.4). In general, the maximum trace metal concentrations are found in the deeper part of the cores and usually exceed the concentrations found in the surface sediment sampled at those locations. However, there was no apparent correlation between

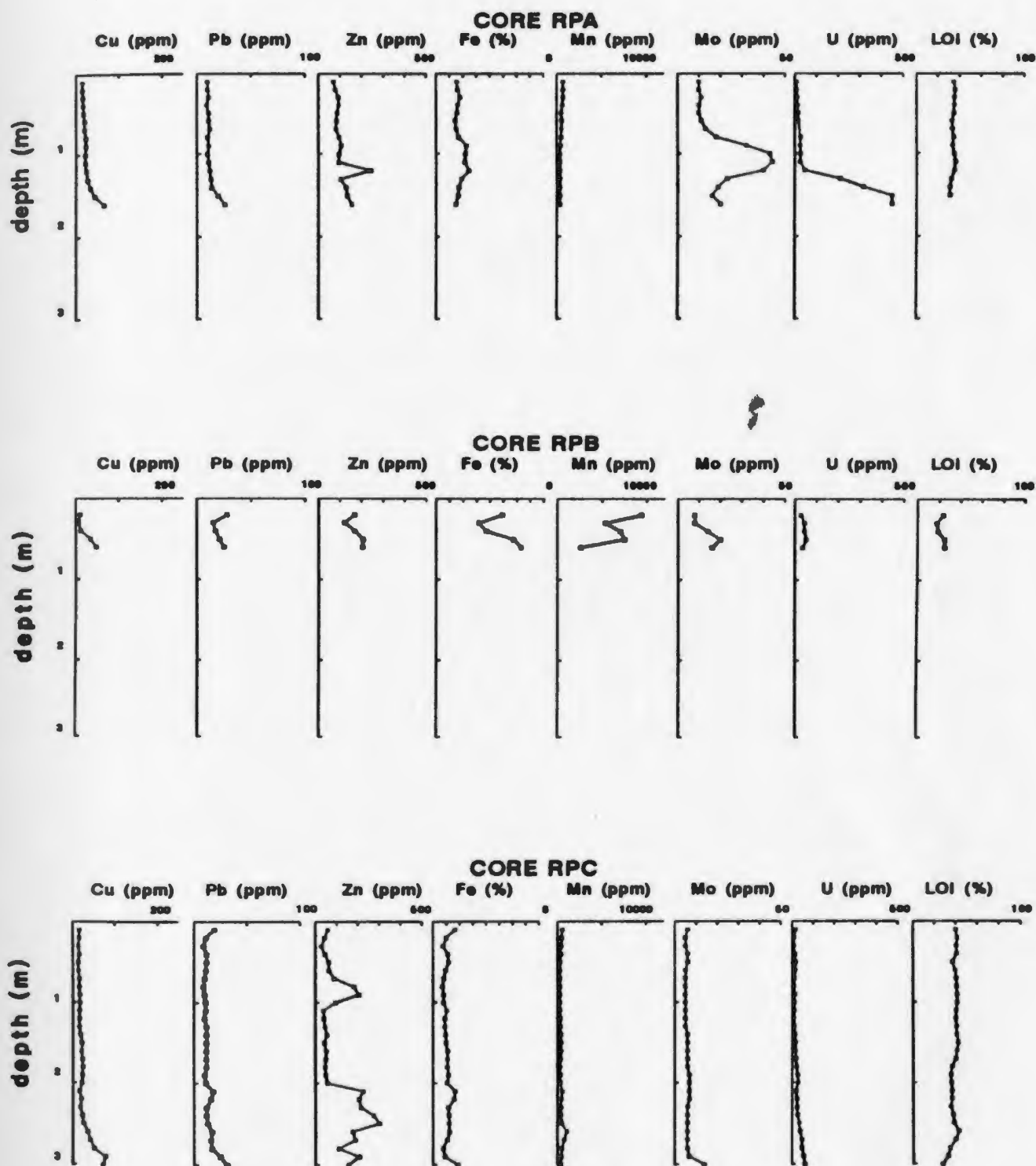


Figure 5.4 Trace metal analyses of sediment core sections from a) Rocky Pond, b) Nut Brook Pond, and c) Gull Pond.

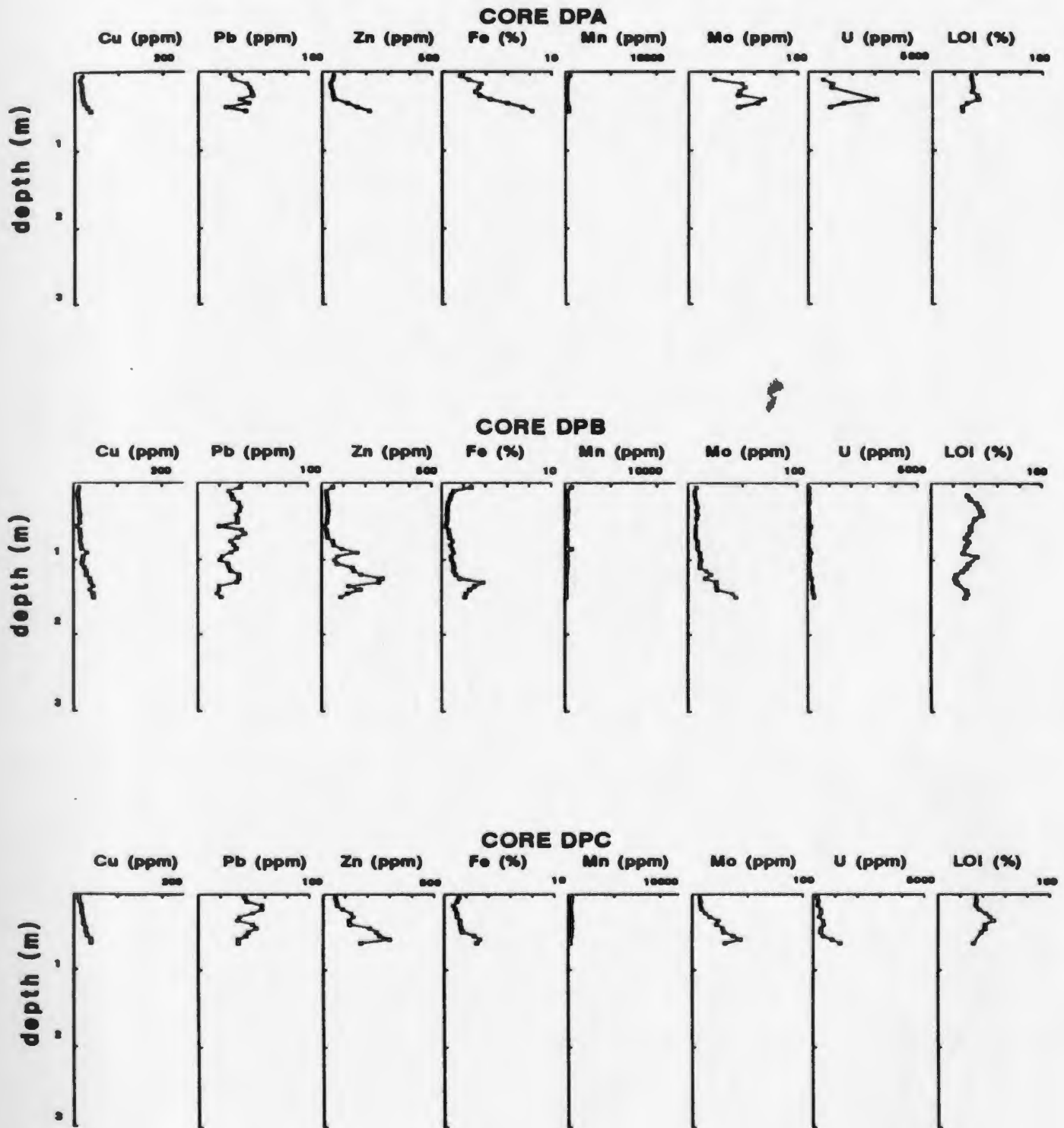


Figure 5.4 (cont'd)

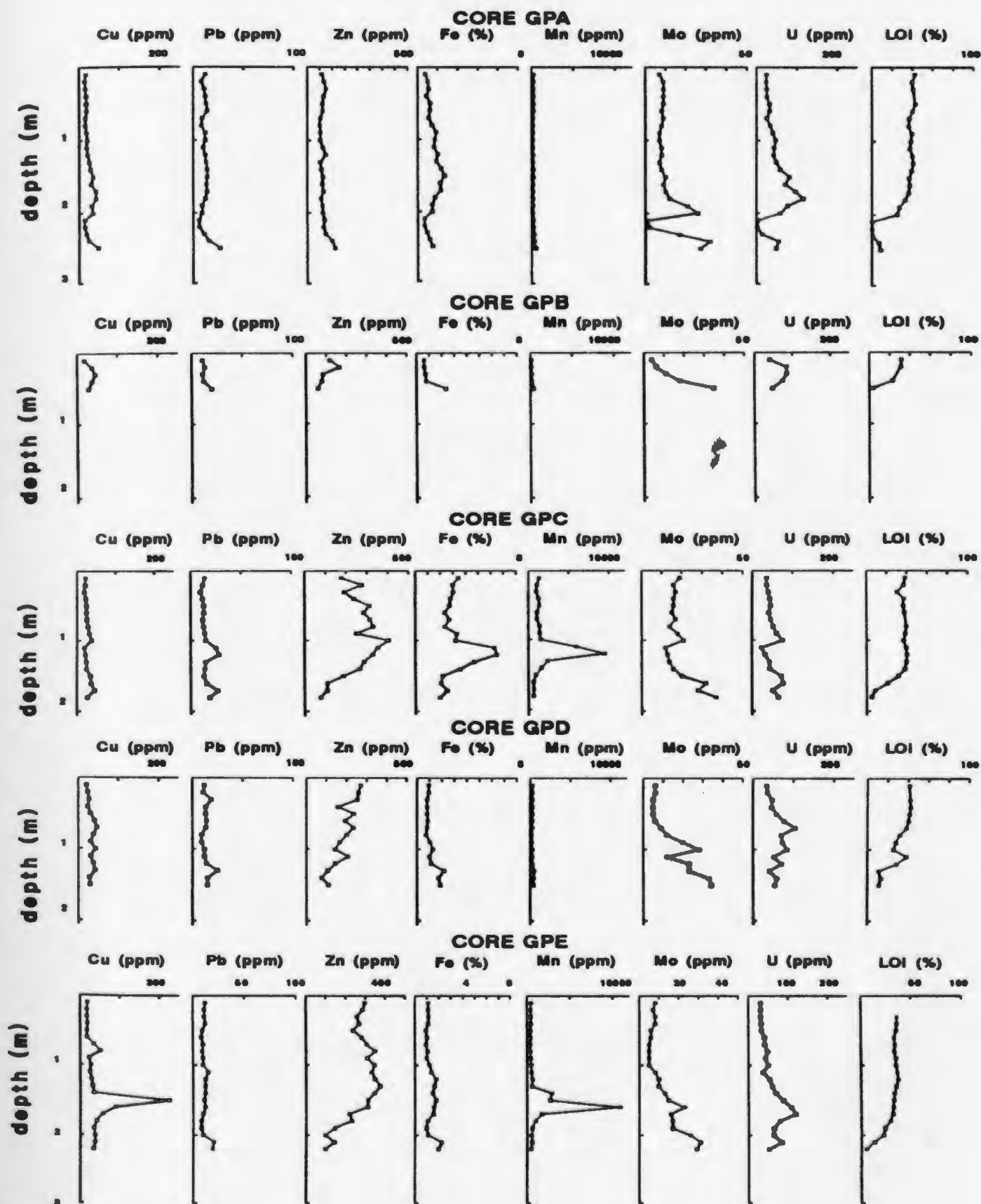


Figure 5.4 (cont'd)

the peak metal concentrations found in the sediment cores and concentrations found at the surface of the sediments. Although there did not appear to be any overall trend of increasing or decreasing trace metal concentrations in the sediment with depth for any particular element, in some cases concentrations of a particular metal would peak over a short interval of the sediment core.

5.4 Discussion of Sediment Core Samples

Since the sediment samples in the cores contain varying amounts of organic material, the results of the sediment analysis were normalized by dividing the total weight of metal in the sample by the total weight of inorganic material. The normalized results for core GPE, taken in Gull Pond near an area anomalously high in uranium, are shown in Figure 5.5. The normalized metal concentrations are indicated by X, the raw concentrations by solid squares, and the average concentrations for the granitic bedrock are drawn as solid straight lines. Normalizing the data in this manner emphasizes peak concentrations at particular depths and indicates that the peaks are not simply a function of the amount of organic content in the sediment.

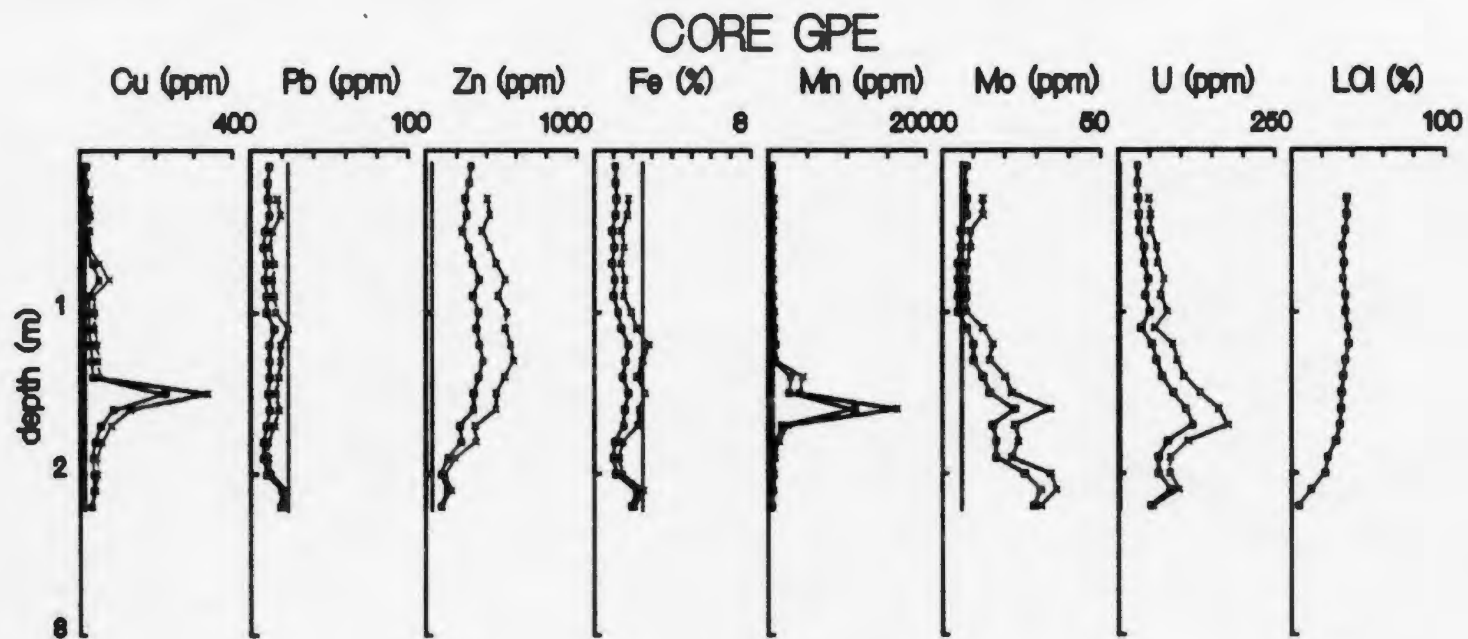


Figure 5.5 Trace metal analyses of sediment core section GPE. Raw data are indicated by solid squares, normalized data are indicated by X, and average granite rock concentrations are indicated by a straight solid line.

In most cores, the concentrations of the elements iron, manganese and lead are generally equal to, or slightly less than detrital levels, while concentrations of zinc, molybdenum and uranium appear to be enriched in the sediment. Increased concentrations of Fe and Mn would not be expected in the sediment since they are both soluble over the range of Eh-pH conditions that would exist during weathering processes, and solid phases only occur under higher oxidizing conditions. Based on published Eh-pH diagrams (Brookins, 1988), lead is soluble only at very low pH (less than 1) and therefore would tend not to be mobilized from the granite by groundwater. On the other hand Cu, Zn, Mo and U are all soluble over a wide range of Eh-pH conditions suggesting that groundwater could be a transport agent for these elements.

In general, the concentrations of metals in core GPE can be explained to some degree by direct input of rock detritus, together with input of dissolved metals on organic matter. However, like core GPE, most of the sediment cores collected in this study show metal concentrations which peak at depth, and whose peaks are not directly correlated with organic content. Therefore, there appear to be other processes that can enrich the sediment in selected metals at certain depths.

Biological processes could possibly have caused trace metal enrichment in the lake sediment at selected levels. Periods of high algal or diatom growth at a particular time in the sediment history of the lake could have concentrated certain elements from lake waters. MacPherson (pers. comm., 1990) has reported the frequent occurrence of an algae named *Pediastrum* in basal inorganic lake sediments on the Avalon Peninsula, but since most of the peak concentrations in this study were located in sediments above the basal inorganic sediments, it is not known whether this organism may be a factor in controlling the metal concentrations measured in this study.

In cores which have a localized, high uranium concentration, the uranium peak coincides with the point at which there is an abrupt decrease in the organic content (indicated by LOI) in the bottom section of the core. Peak uranium concentrations ranged from twice background levels as in Gull Pond cores up to a peak of over 3000 ppm in one of the cores from Hut Brook Pond. In some cases other metals show peak concentrations over the same depth interval, but this pattern is not consistent. The relationship between increased uranium concentrations at the point where organic content suddenly drops off does not appear to be related to the core length or location of core within the lake. The same trend was seen in

both shorter cores taken near-shore and in long cores taken in the middle of the lake.

It appears that the peaks in uranium concentrations are mainly associated with an abrupt change in organic content in the sediment. It is hypothesised that the peak concentrations are a result of the change in oxidation potential experienced when oxidized metal species interact with the reduced organic rich sediment. If uranium were present in an oxidizing groundwater it would exist in its hexavalent state; when it encountered sediments with increased organic content the uranium would tend to be reduced to its tetravalent state and be adsorbed or precipitated within the sediment.

Core GPC shows coincident peaks of iron and manganese and possibly lead which correlate with a sharp decline in the concentrations of Cu, Zn, Mo, and U (Figure 5.6). The high concentrations of the iron and manganese oxides suggest that oxidizing conditions may exist at this depth, supported by the presence of insoluble oxides of Fe^{III} and Mn^{IV} . Therefore, dissolved metals carried by groundwater, which otherwise would precipitate at this depth in the sediment, would tend to remain oxidized and be mobilized out of the sediment leaving them relatively depleted at this particular depth. In addition, any metals initially deposited with detrital

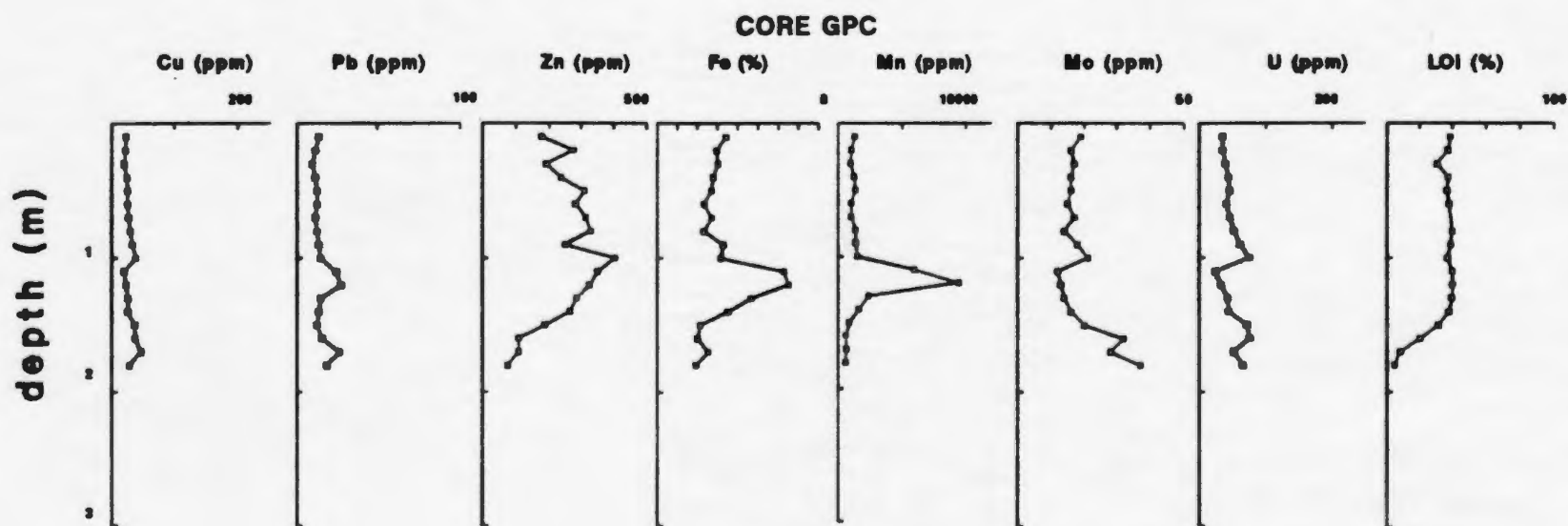


Figure 5.6 Trace metal analyses of sediment core section GPC.

sediment would tend to be oxidized by the Fe and Mn oxides and also be mobilized out of the sediment with time. The high concentrations of uranium observed in groundwater compared to surface water in the study area suggests that groundwater may be a source from which uranium (and other metals) may be concentrated in the sediment. To test this hypothesis, the amount of uranium precipitated in sediments through which groundwater discharges was calculated. Assuming 100% of the uranium in the groundwater would precipitate in the sediment, approximately 2 million litres of groundwater with an average uranium concentration of 90 ppb would be needed to precipitate an amount of 100 g of uranium in 1 m³ of sediment. This is equivalent to a seepage flux of 0.00113 m³/day over 5000 years, which is in the range of seepage fluxes observed in lake sediments near the study area with similar hydraulic gradients (Schillereff, pers. comm., 1988).

Following the same assumptions, the amount of other metals that could be precipitated in the sediment from the same volume of groundwater was calculated. The calculated concentrations that could be deposited from the groundwater are in the range of typical concentrations found in the sediment (Table 5.4). With the exception of Fe, Mn, and Mo the calculated average metal concentrations in the hypothetical lake sediment are within a factor of 3 of the

Table 5.4 Comparison of average trace metal concentrations found in groundwaters, with computed and actual concentrations found in the sediment.

	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	U ppm
Average Groundwater	0.0359	0.0102	0.7090	0.4080	0.0044	0.0017	0.0900
Calculated Sediment	40	11	80	456	6.1	2	100
Actual Sediment (Core GPE)	57	10	220	1730	1.2	16	119

observed average metal concentrations in Gull Pond sediment core E. Therefore it appears that there is a sufficient amount of dissolved metals in groundwater to account for the amount of metals found in the sediment, in addition to the possibility of being transported as detrital material, providing that the geochemical conditions are present for the metals to precipitate.

In order to determine the ionic state in which various metals would exist as they moved through the rock mass, an Eh-pH stability diagram was constructed with the aid of PHREEQE (Parkhurst et al., 1980). PHREEQE is a fortran computer program designed to model geochemical reactions and has the capability to calculate the composition of solutions in equilibrium with multiple phases. Chemical data typical of

groundwater in the Pennys Pond area were used as input to the model. The metal concentrations used to construct the Eh-pH diagram are given in Table 5.5. Consecutive model runs were performed allowing the modelled groundwater composition to equilibrate at different oxidation conditions by adjusting the Eh level, thus simulating the effects of reduction by organic carbon reduction. Several runs were also made with different amounts of dissolved inorganic carbon present to determine the phase changes associated with increased inorganic carbon concentrations.

Results from this equilibrium modelling exercise along with data from Brookins (1988), Garrels and Christ (1965) and Krauskopf (1967), were then used to plot the phase boundaries that would exist for the various elements on an Eh-pH diagram (Figure 5.7). The results indicate that, given high Eh and low pH conditions, most of the trace metals would be soluble in groundwater, and could thus be transported by groundwater.

Table 5.5 Concentrations of total inorganic species used to construct Eh-pH diagram.

Ca	Mg	Na	K	SiO ₄	Cl	HCO ₃	S	Cu	Pb	Zn	Mn	Fe	U
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppb	ppb	ppb	ppb	ppb
46.4	3.0	40.2	3.3	4.4	0.6	139	73	6	16	18	539	600	133

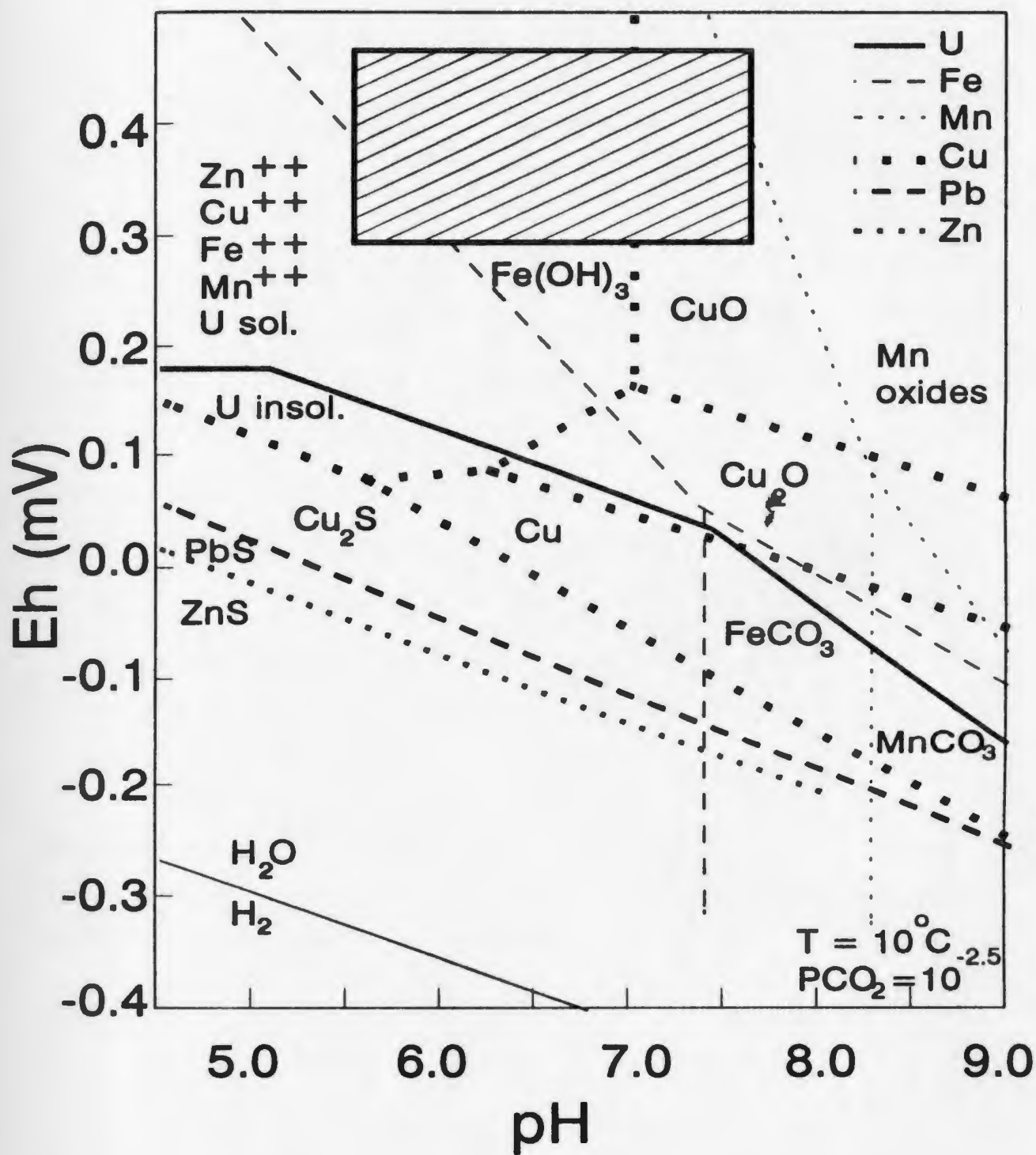


Figure 5.7 Eh-pH diagram showing stability fields for various solid phases with respect to dissolved metals. The cross hatched area indicates the range of Eh-pH values measured in groundwaters in the area.

Groundwaters sampled from granitic rock in the Foxtrap - Holyrood area have a range of pH (5 to 8) and relatively high Eh (approximately +300 to +500 millivolts) which indicates that the groundwaters are oxidizing. If these groundwaters discharge into a lake bottom they will interact with organic rich sediments in which a lower oxidation potential may exist. From Figure 5.7 it can be seen that it would only take a small decrease in Eh for soluble uranium in an oxidizing groundwater to be reduced to an insoluble uranium oxide. The uranium phase boundary is the first to be encountered as oxidation potential is lowered, which may explain why increased uranium concentrations show the strongest correlation with a rapid change in LOI. It would take a much greater reduction in Eh to reach a phase boundary for other elements such as copper or zinc. Since insoluble iron and manganese oxides are stable at higher oxidation potentials than observed in these groundwaters, they might be expected to be deposited as particulate material together with detrital sediments.

The phase boundaries indicated in the Eh-pH diagram may also help to explain concentrations of other metals observed in the sediment, when compared to the granite host rock (Table 5.3). Groundwaters fall into the $\text{Fe}(\text{OH})_3$, CuO , and PbSO_4 fields (Figure 5.7; Brookins, 1988) for the observed Eh and pH conditions. Therefore metals such as iron, copper, and lead

would tend not to be transported as dissolved species but rather as detrital material. This is consistent with the ratios of these trace metal concentrations in lake sediment relative to original rock. In contrast, the precipitation of dissolved uranium in the sediment from oxidizing groundwaters by reduction with organic sediment could account for the observed enrichment of uranium in lake sediments relative to bedrock concentrations.

Chapter 6 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Detailed sampling of lake sediment from the four lakes in this study over a regular grid pattern has shown that trace metal concentrations are not evenly distributed in the lake sediment and that peak concentrations of metals in the sediment are not restricted to a common location in each lake. Therefore, sampling the sediment from only the deepest or most central area of a lake, where trace metals are thought to be concentrated (Hornbrook and Garrett, 1975; Lush, 1984), may not always provide a sample which represents the distribution of trace metals in the sediment of that lake. A comparison between the concentrations of metals found in the sediment and those found in the granitic bedrock suggests that the metals in the sediment may be derived from detrital material. However, elevated values of some elements, such as uranium, suggest that metals are being enriched in the sediment relative to bedrock concentrations.

Vertical profiles of sediments provide additional information on the processes or mechanisms by which trace metals are transported and concentrated in the sediment. It was found that metal concentrations also varied in the sediment column, and in some cases very high concentrations of a particular metal occurred over a short section of the core. In cores

which had a uranium concentration peak, the peak often coincided with the point at which there was a rapid change in the organic content in the sediment near the bottom of the core. It is proposed that the peak uranium concentrations are a result of the change in oxidation potential produced when oxidizing groundwater interacts with reducing, organic-rich sediment. It would thus be possible for uranium, which would be soluble in an oxidizing groundwater which was discharging in to a lake bottom, to be reduced and absorbed or precipitated in the sediment when it encountered sediments with increased organic content. While the source of metals found in lake sediment is generally thought to be from detrital inputs it is proposed that oxidizing groundwaters discharging into a lake may provide an alternative source of dissolved metal species which may become concentrated in the lake sediment.

An interpretation of the hydrogeological framework of the area surrounding the four lakes in this study included an analysis of the fracture networks that exist in the underlying fractured granitic bedrock. Analysis of the fracture geometry in the area has indicated that on a regional scale, fractures orientated slightly west of north are likely to dominate the direction of groundwater flow. Elongated zones of anomalous uranium concentrations in both Pennys Pond and Gull Pond,

identified from grid sampling of lake sediment, are aligned approximately in the same orientation as the major lineaments and fractures in the area. This suggests that fracture controlled groundwater input to the lake could be contributing to the formation these anomalies. In this respect, fracture intersections may provide a vertical pathway for groundwater discharge, which could result in the localized distribution of metals in lake sediment, as observed in Gull Pond and Pennys Pond.

Given the possibility that dissolved metals transported in groundwater may be concentrated in lake sediment, an estimate was made of the time required to produce a trace metal anomaly of the observed magnitude under present conditions. Assuming a constant seepage rate, constant groundwater metal concentrations and 100% efficiency in removal of metals in solution, it can be shown that groundwater with a uranium concentration of 90 ppb seeping into a lake at a rate of $0.00113 \text{ m}^3/\text{day}$ (measured seepage for lake bottom sediment in adjacent area, Schillereff, pers. comm., 1988) would take approximately 5000 years to produce an anomaly of 100 ppm uranium in 1 m^3 of sediment (Appendix E). Radiocarbon and pollen analysis of core samples collected from lakes on the Avalon Peninsula indicate that ice from the last glaciation retreated about 9300 years ago (MacPherson 1982). Therefore,

it is possible that groundwaters are responsible for the observed lake sediment metal anomalies, which have developed since the end of the last glacial period.

Seepage rates may be quite variable throughout a lake. The rate at which groundwater discharges through lake bottom sediment will affect the amount of time required for anomalous concentrations of metals to accumulate in the sediment. In future studies, the location and amount of groundwater seeping through lake bottom sediments should be more clearly defined. This could be achieved quite simply in a small lake, such as Pennys Pond, using a series of seepage meters such as the one described by Lee (1977). For a larger lake a three dimensional numerical model may be useful, both for defining the area of local discharge as well as regional flow paths in and around the lake.

It has been shown that it is possible for groundwaters to contribute to the formation of trace metal anomalies in lake sediments. Understanding the relationship between the concentrations of trace metals in groundwater and lake sediments may prove to be a useful tool in mineral exploration. Determining the composition of groundwater, at points along the flowpath up-gradient of an area having known anomalous concentrations of trace metals in lake sediment may

provide information on the source of metals. In the case of this study, it is possible that the source of uranium may be traced back to Pennys Hill, which is a common point of recharge for all four lakes in this study which all showed some enrichment of uranium in their sediment.

Lake bottom sediments comprise a very complex environment where there are many possible physical, chemical and biological processes taking place. It is difficult to identify the contribution of any single one of these processes to the concentration of metals in the sediment. However, a mechanism has been suggested by which fracture-controlled groundwaters can transport dissolved metal species and concentrate these metals in lake sediment by inorganic chemical processes described above. Although more than one mechanism may be responsible for the concentration of metals in the lake sediment, the role of groundwater cannot be ignored, especially in lakes located in known areas of groundwater discharge.

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APPENDICES

Appendix A Description of Scanline Mapping Procedures and Fracture Data File

A.1 Data Collection

Fracture data were collected from rock outcrops using detailed aerial photographs, taken from a helicopter, as base maps. Scanlines, varying in length, were laid out in perpendicular directions on each outcrop and fractures that intersected the scanlines were numbered and traced on mylar overlays. The number of scanlines used per outcrop ranged from two to ten depending on the number needed to adequately sample each outcrop area. Data were collected for each fracture including the location of the fracture intersection with the scanline, dip, dip direction, trace length, degree of censoring, termination style and other descriptive fracture characteristics. Due to time constraints when collecting fracture data over a large area and the fact that fractures shorter than the mean fracture spacing are thought to have a minimal contribution to the total flux through a fracture system, only fracture traces longer than 0.5 metres were sampled.

A.2 Analysis

Contoured lower hemisphere stereoplots of the poles to fracture planes for each of the outcrops mapped were created to determine the distribution of fracture orientations in the rock mass in the study area (Figure A.1). Although density of fractures are biased by the orientation of the scanlines, since fractures perpendicular to the scanline are more likely to be sampled, in most cases two distinct sub-vertical sets can be identified and in some cases a third, weaker set appears to be present. Since all the outcrops were in the same vicinity and there appeared to be little spatial variability between outcrops, to simplify the analysis of the fracture geometry in the area, all the data were combined to define clusters for the region. Table A.1 gives a summary of the parameters that characterize the fracture geometry that exists in the rock mass in the area surrounding the study lakes.

Appendix A

Table A.1. Summary of fracture characterization parameters.

	Cluster 1	Cluster 2
# of fractures	270	390
ORIENTATION		
mean dip azimuth	69.5	158.4
std. dev.	23.1	
mean dip	82.5	73.4
std. dev.	18.9	
general trend	NW-SE	NE-SW
TRACE LENGTH		
mean (m)	3.96	2.57
std. dev.	4.12	2.57
min.	0.50	0.50
max.	25.00	24.50
SPACING		
mean (m)	0.77	0.57
std. dev.	0.93	0.58
max.	6.11	3.62

Appendix A

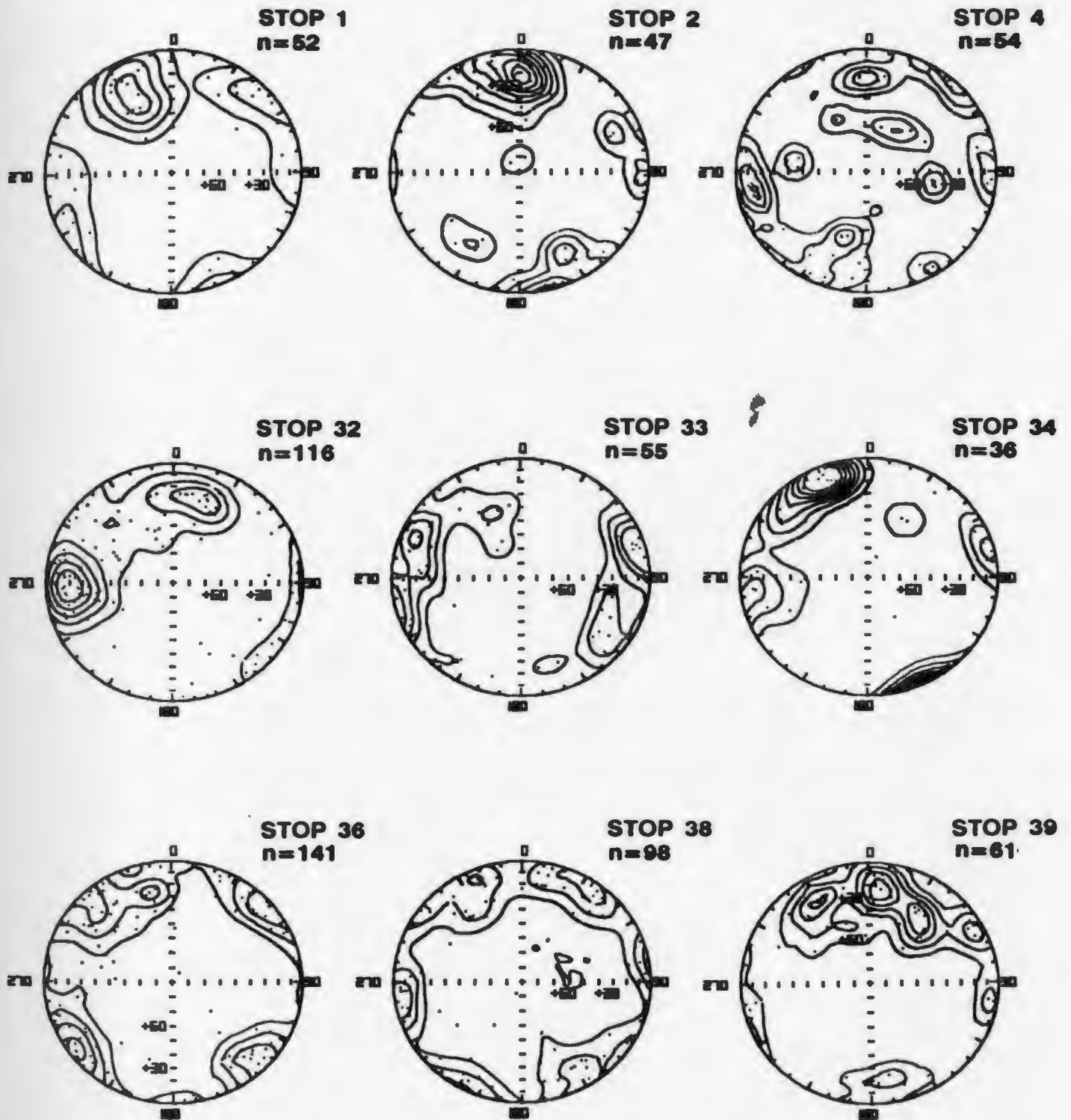


Figure A.1 Contoured lower hemisphere stereoplots of poles to fracture planes for each mapping location indicated in Figure 2.2.

Appendix A

A.3 Structure and Codes for Fracture Data File

Columns 1-2	Flag	
	11 - Fracture Data	33 - Comments
Columns 3-7	Photo number	
Columns 8-10	Scanline trend (0 - 360 degrees)	
Columns 11-12	Scanline plunge (0 - 90 degrees)	
Columns 13-16	Sequential fracture number	
Columns 17-22	Scanline intersection in metres	
Columns 23-24	Fracture Type	
	JT - joint	FZ - fracture zone
	CN - rock contact	VN - vein
Columns 25-28	Dip direction (0 - 360 degrees)	
Columns 29-30	Dip (0 - 90 degrees)	
Columns 31-35	Trace length in metres	
Columns 36-37	Type of censoring	
	0 = both ends exposed	1 = one end covered
	2 = both ends covered	
Columns 38-41	Mineral infilling	
	Q = quartz	H = hematite
	E = epidote	R = rock rubble
Column 42	Large scale roughness	
	P = planar	C = Curved
	U = undulating	S = Stepped
Column 43	Small scale roughness	
	S = smooth	R = rough
Column 44	Rock Type	G = granite
Column 45	Termination mode	
	0 = both ends free	1 = one end free
	2 = both against another	3 = splay
46 - 80	Comments	

Appendix A

A.4 Fracture Data File

STOP 1

33 PHOTO S1-02 LINE A

110102A07900 1 0.60JT 26985 1.5 0 PRG0
 110102A07900 2 1.65JT 26980 2.0 0 R SSG0
 110102A07900 3 2.60JT 18051 1.0 0 CSG1 ENDS AT 2
 110102A07900 4 3.70FZ 23290 17.0 1 R URG
 110102A07900 5 4.50FZ 23290 25.0 2 R URG
 110102A07900 6 4.95JT 22585 4.5 0 CSG3 JOINS FZ 5
 110102A07900 7 5.55JT 23485 5.0 0 PSG0 SLIGHT FOLIATION;STR:054
 33 DIP:SUBVERT

110102A07900 8 5.95JT 10078 2.8 0 PSG1 ENDS AT 7
 110102A07900 9 10.65JT 29084 3.0 0 R SSG0
 110102A07900 10 12.20JT 8166 2.5 1 R SRG SPLAYS TO N
 110102A07900 11 12.65JT 7073 1.0 1 PSG
 110102A07900 12 13.65FZ 22577 25.0 2 RQ --G
 110102A07900 13 15.40FZ 13062 8.0 1 R SRG ENDS AT 12
 110102A07900 14 17.05JT 26175 8.0 1 R URG ENDS AT 12

33 LINE A CONTINUES ON PHOTO S1-03

33
 110103A07900 15 20.60FZ 7080 10.0 2 R --G
 110103A07900 16 22.50JT 14590 4.0 0 R URG1 ENDS AT 15
 110103A07900 17 25.14VN 24480 6.5 2 QE PSG
 110103A07900 18 25.84JT 9370 3.0 1 R CSG SPLAY END OF JT; JOINS V
 110103A07900 19 28.35JT 9057 4.0 1 R CRG SPLAY END
 110103A07900 20 29.50FZ 15078 7.0 0 R URG2
 110103A07900 30.00 90 0 EOL

33

33 PHOTO S1-03 LINE B

110103B35005 21 0.85JT 5369 3.0 1 R URG ENDS AT 2
 110103B35005 22 1.01JT 14063 2.0 1 PSG
 110103B35005 23 1.75FZ 16070 4.0 2 R PRG ENDS AT 15
 110103B35005 24 3.23JT 15374 2.0 1 R URG
 110103B35005 25 5.20CN 21575 1 USA AP DIKE; OFFSET BY NUMER

33 LAT. FAULTS; APOPHYSES SUBPARALLEL

110103B35005 26 6.10JT 34075 5.0 1 R URG
 110103B35005 27 7.20JT 35090 2.0 1 R PSG ENDS AT 15
 110103B17015 28 7.60FZ 34075 5.0 2 R URG ENDS AT 12 & 15
 110103B17015 29 9.95FZ 15570 4.5 2 R URG ENDS AT 12 & 15
 110103C35508 30 0.00JT 33369 2.0 2 R PSG
 110103C35508 31 1.30JT 23551 1.5 2 PSG PROJECTED PLANE UP TO SC
 110103C35508 32 3.69JT 16584 1.0 1 R PRG
 110103C35508 33 4.15CN 21871 9.0 2 --A 10 CM AP DYKE
 110103C35508 34 4.25JT 6376 12.0 2 R URG CROSSCUTS 33; 33 CROSSCU

33 PARALLEL 2CM AP DYKE; 34:10 CM RT. LAT. MOVEMENT

110103C35508 35 5.90CN 20071 9.5 2 --A
 110103C35508 36 6.25JT 14428 3.0 0 R PSG1 ENDS AT 34
 110103C35508 37 6.83CN 21062 9.0 2 PSA SIM. TO 33 & 35
 110103C35508 38 8.45FZ 14550 7.0 0 R USG0
 110103C35508 39 8.74JT 14571 3.0 0 R SSG3
 110103C35508 40 10.08JT 15050 8.0 0 R USG1
 110103C35508 41 10.42JT 15549 3.0 0 R PSG3 JOINS 40
 110103C35508 42 11.05JT 15446 3.0 2 R SSG
 110103C35508 43 11.40JT 15446 1.0 2 PSG

33

33 PHOTO S1-02 LINE D

110102D12310 44 0.50JT 16377 11.0 1 R PRG
 110102D12310 45 1.65JT 16550 3.0 0 PSG3 SPLAYS TO NE

Appendix A

110102012310 46 2.15JT 16680 2.0 : R PSG SPLAYS TO NE
 110102012310 47 2.45JT 29032 2.0 0 CSG3
 110102012310 48 3.05JT 27759 1.5 0 R CSG3 PART OF SPLAY; SAME AS 4
 110102012310 49 3.45JT 16340 7.0 2 R PSG
 110102012310 50 4.30JT 16348 3.0 2 R PSG
 110102012310 51 5.10JT 15859 7.0 1 R SSG
 110102012310 52 9.00FZ 14776 4.0 0 R --GO FINELY BROKEN BLOCKY ZON

STOP 2

33 STOP 2 PHOTO-S1-07 LINE A
 110107A34105 1 0.07JT 20257 1.9 1 PSG
 110107A34105 2 1.31JT 137 8 1.0 0 PSGO
 110107A34105 3 1.67JT 18244 0.6 0 PSG1
 110107A34105 4 1.94JT 16246 0.9 0 USG1 FORKS TO W; ENDS AT 11
 110107A34105 5 2.17JT 18735 0.7 0 PSG1 ENDS AT 11
 110107A34105 6 2.54JT 19377 1.0 0 CSG1 ENDS AT 11
 110107A34105 7 2.88JT 19063 0.9 0 PSG1 ENDS AT 11
 110107A34105 8 3.18JT 18064 1.5 0 PSG1 ENDS AT 11
 110107A34105 9 3.27JT 18076 1.7 0 PSG1 ENDS AT 11
 110107A34105 10 4.25FZ 17157 2.1 2 R USG MOSS; SPANS:3.85-4.50; S
 33 IN ZONE 2-10MM
 110107A34105 11 5.00FZ 24574 15.7 1 RH USG FAULT;MOST EW JTS FND AT
 33 DIVIDES TO NW
 110107A34105 12 5.60FZ 18764 2.3 1 PSG SPANS:5.4-5.8; ENDS AT 1
 110107A34105 13 6.18JT 15565 0.8 0 SSGO ZIGZAG PATTERN
 110107A34105 14 7.30JT 15360 1.4 0 PSG1 ENDS AT 11
 110107A34105 15 5.81JT 14583 1.3 0 SSG1 ENDS AT 11
 110107A34105 16 9.85JT 15778 1.4 0 PSGO
 110107A34105 17 10.36JT 17868 1.3 0 PRG1 ENDS AT 11
 110107A34105 18 11.16JT 15985 1.5 0 CSGO
 110107A34105 19 11.91FZ 17764 2.0 0 PSG1 SPANS:11.8-12.2; ENDS AT
 33 SPACING IN ZONE 1-5MM
 110107A34105 20 12.32JT 33470 1.7 0 PSG2 ENDS AT 11 & 21
 110107A34105 21 12.67JT 378 3.0 0 PSG1 EN ECHELOW PAR JT AT 11
 110107A34105 22 12.90JT 18379 1.7 0 PSG1 ENDS AT 11
 110107A34100 23 13.32JT 18082 3.5 0 R PSG1 MOSS; STR. SPLAYS TO NW
 110107A34100 24 13.45JT 24768 0.8 0 PSG2 ENDS AT 23 & 26
 110107A34100 25 13.62JT 33162 6.0 1 R PSG JOINS 23
 110107A34100 26 14.14JT 33761 0.7 0 CSG1
 110107A34100 27 14.50JT 17976 3.8 1 R USG MOSS
 110107A34100 28 16.50FZ 19063 2.0 0 PSG1 SPANS:16.4-16.6; INTERNA
 33 1-2MM
 110107A34100 29 18.07JT 31682 1.1 0 PSGO
 110107A34100 30 18.28JT 32974 1.4 0 PSGO
 110107A34100 31 18.54JT 33058 1.3 1 R SSG MOSS
 110107A34100 32 18.70JT 34885 1.0 0 PSG1
 110107A34100 33 20.57JT 16875 1.6 0 H PSG1
 110107A34100 34 21.50JT 16782 1.2 0 H USG1
 110107A34100 35 22.35JT 17090 1.2 0 PSGO
 110107A34100 24.50 90 0 EOL
 33
 33 PHOTO-S1-07 LINE B
 110107B25107 36 0.28JT 26585 8.2 1 H PSG MOSS
 110107B25107 37 1.13JT 18557 4.1 0 R PSG2 MOSS; ENDS AT 36 & 41
 110107B25107 38 3.92JT 2753 1.8 0 SSGO
 110107B25107 39 6.45FZ 2862 5.0 1 R PSG MOSS; SPANS:6.2-6.7; END
 110107B25107 40 7.42JT 13886 2.0 0 R PSG1 MOSS; ENDS AT 41
 110107B25107 41 8.17JT 24865 7.0 2 R PSG LEFT LAT. SPLAYS AT S EN
 110107B25107 42 8.30JT 5355 1.4 0 CRG3 SPLAY FROM 41
 110107B25107 43 8.47JT 4066 1.7 0 CRG3 SPLAY FROM 41

Appendix A

110107825100 44 9.00FZ 27581 2.9 1 R CSG SPANS:8.95-9.05; JOINS 4
 110107825100 45 9.50JT 34485 0.9 0 PSGO
 110107825100 46 12.10FZ 27287 1.9 2 PSG SPANS:12.01-12.05; FORMS
 33 FACE AT NE END
 110107825100 47 13.55JT 20010 0.7 1 PSG EXFOLIATION
 110107825100 11 16.07FZ 24574 15.7 1 RH USG
 110107825100 10 16.30FZ 17157 2.1 2 R USG
 110107825100 17.50 90 0 EOL

STOP 4

33 STOP 4 PHOTO-S1-13 LINE A
 110113A25020 1 0.26JT 9851 0.8 1 R SSG
 110113A25020 2 0.74JT 7573 8.0 2 R SSG MOSS
 110113A25020 3 1.57JT 3270 2.6 0 CSG1 ENDS AT 2
 110113A25020 4 2.60JT 22539 1.5 0 CSG0 EN ECHELON AT SW END
 110113A25020 5 3.80JT 21534 1.4 0 PSG1 ENDS AT 7
 110113A25020 6 4.12JT 24242 0.7 0 CSG1 ENDS AT 7
 110113A25020 7 4.90FZ 9478 10.0 2 R PSG MOSS; SPANS:4.4-5.4; INTE
 33 SPACING 1-10CM
 110113A25020 8 5.86JT 10083 3.4 1 R PSG STR. SPLAYS AT BOTH ENDS
 110113A25020 9 6.80FZ 7575 8.3 2 USG SPANS:6.6-7.0
 110113A25020 10 7.25FZ 26377 6.0 1 H USG SPANS:7.15-7.35; INTERNAL
 33 SPACING 3-4M; PARALLEL N-CLOTS
 110113A25020 11 7.56JT 8477 4.0 1 PSG
 110113A25020 12 7.74JT 8380 3.0 0 PSG3 JOINS 11
 110113A25020 13 8.00JT 27486 10.1 1 R CSG
 110113A25020 14 9.90JT 23489 2.2 0 CSG3 JOINS 16
 110113A25020 15 10.10JT 7672 1.4 0 CSG3
 110113A25020 16 10.65JT 25776 9.5 1 O CSG DIP REVERSES DIRECTION O
 33 FACE TO NW
 110113A25020 17 11.50JT 27842 0.8 0 PSGO
 110113A25020 18 11.62JT 28345 0.9 0 PSGO
 110113A25020 19 12.25JT 28144 0.9 0 PSGO
 110113A25020 20 12.90JT 33276 1.6 0 PSGO
 110113A25020 21 13.30JT 19068 2.6 0 PSGO STR. SPLAYS AT W END
 110113A25020 22 14.55JT 10244 2.1 1 SSG EN ECHELON TO N END; STE
 110113A25020 23 14.63JT 9444 1.3 0 PSGO
 110113A25020 24 15.20JT 5368 1.8 2 PSG L.E. 1CM SHEAR ZONE; FLA
 33 QUARTZ & FELD.
 110113A25020 15.70 90 0 EOL

33

33 PHOTO-S1-13 LINE B

110113B16502 25 0.30JT 19731 1.7 0 R CRGO MOSS
 110113B16502 26 0.95FZ 27683 2.8 1 PSG MOSS; SPANS:0.9-1.0; LEF
 33 SPLAY AT SE END
 110113B16502 27 0.95JT 2063 1.1 0 PRGO
 110113B16502 28 1.54JT 2784 1.0 0 PRG1 ENDS AT 26
 110113B16502 29 1.73JT 2082 0.8 0 PSG1 ENDS AT 26
 110113B16502 30 2.05JT 2047 1.7 0 CSG2 ENDS AT 26 & 2
 110113B16502 31 2.30JT 1948 0.9 0 PSG1 ENDS AT 26
 110113B16502 32 2.70JT 3363 1.1 0 USG3 SPLAY FROM 26
 110113B16502 33 4.25JT 3270 2.6 0 CSG1
 110113B16502 34 4.85JT 17263 1.3 0 CSG0
 110113B16502 35 5.03JT 641 0.9 0 PSG2 ENDS AT 33 & 2
 110113B16502 36 5.32JT 34425 2.1 0 PSG1 ENDS AT 2
 110113B16502 37 5.82JT 22890 1.1 0 PSG1 ENDS AT 35
 110113B16502 38 6.54JT 21887 2.9 0 USG1
 110113B16502 39 7.43JT 23175 1.3 0 PSGO S END HAS STR. SPLAYS
 110113B16502 40 7.80JT 21331 1.6 0 CSG1 ENDS AT 2
 110113B16502 8.70JT 17668 1.3 1 CSG

Appendix A

110113B16502	41	9.61JT	20182	1.0	0	PSG0	
110113B16502	42	10.08JT	21088	1.7	1	H PSG	STR. SPLAYS AT W END
110113B16502	43	10.61JT	32783	0.6	1	SSG	MOSS
110113B16502	44	10.69FZ	465	6.0	2	R USG	MOSS; WIDENS TO 60CM TO
110113B16502	45	11.31JT	778	0.7	0	PSG0	
110113B16502	46	12.36JT	14890	0.8	0	PSG0	
110113B16502	47	12.66JT	18764	1.1	0	SSG0	
110113B16502	48	13.40FZ	14664	2.5	1	R USG	SPANS:13.35-13.45
110113B16502	49	14.03:2	1546	2.3	1	R PSG	SPANS:13.95-14.10
110113B16502	50	14.10CM	15140	4.1	2	PSF	5CM FELSITE DYKE;PROJECT
33 SCAN LINE							
110113B16502	51	14.45CM	15140	3.7	2	PSF	1 CM FELSITE DYKE
110113B16502	52	15.41JT	22384	0.9	0	PSG1	
110113B16502	53	15.88JT	17666	1.1	0	PSG0	
110113B16502	54	16.05JT	17833	0.8	0	PSG0	PROJECTED UP TO SCAN LIN
110113B16502		16.50	90	0			EOL

STOP 32

110519A04400	1	0.06JT	8251	1.4	1	PSG	
110519A04400	2	0.37JT	8348	1.8	2	PSG	
110519A04400	3	0.56JT	8474	4.4	2	CSG	
110519A04400	4	1.15JT	11768	1.4	0	CSG3	
110519A04400	5	1.58JT	8654	6.1	1	H PSG	BRAIDED; IN SPOTS 2 OR 3
33							RIGHT LATERAL SPLAYS AT W END
110519A04400	6	1.94JT	8764	2.2	0	PSG0	
110519A04400	7	2.08JT	8776	3.4	0	H PSG0	
110519A04400	8	2.50FZ	8363	6.9	2	H PSG0	2.35 - 2.65 PARALLEL JO
33							GAPS UP TO 2 MM
110519A04400	9	2.86JT	8982	2.3	0	H PSG0	RIGHT LATERAL SPLAYS AT
110519A04400	10	3.45JT	16664	0.6	0	USG2	DIFFUSE MICROJOINTS
110519A04400	11	3.72JT	8484	3.1		H USG	GAP UP TO 1 CM
110519A04400	12	4.01JT	8663	2.3	1	H PSG	RIGHT LATERAL SPLAYS W E
110519A04400	13	4.20JT	21035	0.7		CSG2	
110519A04400	14	4.24JT	8474	1.4	0	H PSG1	
110519A04400	15	4.54JT	7882	4.3	2	H PSG	DIFFUSE PARALLEL MICROJO
33							BRAIDED IN SPOTS
110519A04400	16	4.76JT	7868	1.2	1	H PSG	
110519A04400	17	4.95JT	8258	4.0	2	PSG	
110519A04400	18	5.67JT	7041	4.7	1	USG	
110519A04400	19	6.46JT	8160	3.3	1	PSG	
110519A04400	20	6.58JT	7753	3.1	1	H PSG	
110519A04400	21	6.94JT	35586	0.8	0	PSG0	
110519A04400	22	7.18JT	19866	0.8	0	PSG2	
110519A04400	23	7.45JT	19176	0.8	0	PSG2	
110519A04400	24	8.05JT	20861	0.9	0	PSG0	
110519A04400	25	8.11JT	10577	5.1	0	USG0	
110519A04400	26	8.40JT	20158	2.1	1	PSG	DIFFUSE
110519A04400	27	8.61JT	19661	1.4	0	PSG0	
110519A04400	28	8.86JT	19165	1.8	1	PSG	
110519A04400	29	9.20JT	19843	1.7	1	PSG	DIFFUSE PARALLEL JOINTS
110519A04400	30	9.43JT	9374	3.0	0	PSG3	DIFFUSE MICROJOINTS
110519A04400	31	9.44JT	20163	2.3	0	PSG3	
110519A04400	32	9.64JT	20760	1.3	0	PSG2	
110519A04400	33	9.71JT	20555	1.3	0	PSG2	
110519A04400	34	9.88JT	20572	1.7	0	PSG1	
110519A04400	35	10.08JT	7550	6.0	1	H USG	DIFFUSE ZONE 2 - 3 CM
110519A04400	36	10.54JT	8756	0.8	0	PSG0	
110519A04400	37	10.80JT	9566	9.2	1	HE USG	LENSOID EPIDOTE IN GAPS
33							1 CM
110519A04400	38	11.04JT	20064	1.3	0	PSA1	

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110519A04400	39	11.35JT	9363	2.8	1	H	PSG	
110519A04400	40	11.35JT	20556	0.8	0		PSA1	
110519A04400	41	12.06JT	7271	7.0	1	H	USG	GAP UP TO 3 MM
110519A04400	42	12.70FZ	6037	3.3	1	H	USG	12.55 - 12.85 BRAIDED S
33								ZONES WITH FE MATRIX IN PLACES
33								COMMUNUTED AND LAMINATED.
110519A04400	43	12.97JT	18764	1.2	0		CSG1	
110519A04400	44	13.00JT	11538	0.8	0	H	PSG0	DIFFUSE LEFT LATERAL
33								SPLAYS AT BOTH ENDS.
110519A04400		13.00	90	0				E.O.L
33								
110519B13103	45	0.17JT	18864	1.1	0		PSG0	
110519B13103	46	0.61JT	34488	0.7	0		CSG3	
110519B13103	47	0.84JT	11944	1.7	1		CSG	
110519B13103	48	1.16JT	9863	2.9	2	H	PSG	PATCHY FE INFILL
110519B13103	49	1.42JT	9578	0.9	2		PSG	
110519B13103	50	1.77JT	27582	0.6	2		PRG	
110519B13103	51	2.09JT	10879	3.0	2		PSG	DIP ESTIMATED
110519B13103	52	2.30JT	10375	9.3	2		USG	
110519B13103	53	2.57JT	10280	2.5	1		USG	
110519B13103	54	3.20JT	16664	0.9	0		PSG1	
110519B13103	55	3.21JT	9470	1.8	0	HR	CSG0	
110519B13103	56	3.56JT	10062	3.3	0	H	USG0	
110519B13103	57	3.60JT	17070	0.8	1		PSG	
110519B13103	58	4.35JT	29085	2.0	2		PSG	DIP ESTIMATED
110519B13103	59	4.58JT	10949	2.0	1		PSG	
110519B13103	60	4.89JT	17065	1.8	0		PSG2	
110519B13103	61	4.99JT	17571	1.9	0		PSG2	
110519B13103	62	5.85JT	17861	1.5	0		PSG0	
110519B13103	63	6.20JT	17963	1.1	0		PSG	LEFT LATERAL SPLAY AT N
110519B13103	64	7.17FZ	32366	2.3	0		USG0	7.05 - 7.30 DENSE MICRO
33								SPACING 1 - 3 MM BRITTLE
33								SHEAR ZONE
110519B13103	65	7.77JT	29081	4.9	2	H	PSG	
110519B13103	66	8.48JT	8874	6.9	0	HE	PSG2	
33								
110519B13100	67	8.85JT	7078	5.2	1	H	USG	GAP UP TO 1 CM.
33								BRAIDED SPOTS
110519B13100	68	9.15JT	9580	1.0	0	HE	PSG3	DIP VARIES ALONG STRIKE
110519B13100	69	9.55JT	8078	4.1	2	H	PSG	
110519B13100	70	9.62JT	31378	0.7	0		CSG1	
110519B13100	71	10.02JT	33746	0.7	0		PSG2	
110519B13100	72	10.05JT	8481	4.1	2	HE	USG	
110519B13100	73	10.17JT	9366	2.5	1	EH	USG	DIFFUSE BRAIDED ZONE 2 -
110519B13100	74	10.55JT	7773	1.8	1	H	PSG	
110519B13100	75	11.21JT	13489	8.0	2		CSG	DIP ESTIMATED
110519B13100	76	11.95FZ	10083	2.3	1	HE	USG	11.80 - 12.10. SUBPARALL
33								JOINTS SPACING 2 - 7CM BRAIDED
110519B13100	77	12.35JT	12683	0.8	0		PSG3	
110519B13100	78	12.69JT	19967	0.7	0		PSG2	
110519B13100	79	12.73JT	12386	3.7	1	H	USG	
110519B13100	9	12.82	90	0				
110519B13100		13.00	90	0				E.O.L
33								
33								
110521A26008	1	0.50JT	13583	0.9	0		USG0	
110521A26008	2	0.55JT	30481	0.7	1		PSG	
110521A26008	3	0.90JT	14852	0.8	0		PSG0	
110521A26008	4	2.37JT	12849	0.9	1		PSG	
110521A26008	5	2.58JT	11657	0.6	1		PSG	
110521A26008	6	2.75JT	14563	1.7	2		USG	
110521A26008	7	3.80JT	26585	2.4	1		USG	

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110521A26008	8	3.83JT 31783	3.5 0	USG2	LEFT LATERAL SPLAYS AT
33					ENDS
110521A26008	9	4.18JT 25490	1.4 0	CSG1	
110521A26008	10	4.65JT 22877	0.9 0	PSG0	
110521A26008	11	5.95JT 14971	1.4 0	PSG1	
110521A26008	12	6.19JT 4060	1.3 0	H PSG3	LEFT LATERAL SPLAY AT S
110521A26008	13	6.70FZ 24175	9.5 0	H PSG1	6.55 - 6.85. BRAIDED JO
33					FE CLOTS
110521A26008	14	8.20JT 9575	4.9 0	URG1	
110521A26008	15	8.75JT 15623	0.9 0	CSG1	
110521A26008	16	8.99JT 20955	0.8 0	PSG0	
110521A26008	17	9.30JT 18464	1.2 0	PRG0	
110521A26008	18	9.56JT 21351	1.4 0	PSG0	EN ECHELON RIGHT.
33					PLANAR SMOOTH SECTIONS
110521A26008	19	9.90JT 29563	0.8 0	H PSG0	DIFFUSE MICROJOINTS. FE
110521A26008		10.00 90 0			E.O.L
33					
110521B15100	20	0.76JT 26563	0.9 0	PSG1	
110521B15100	21	1.21JT 17348	1.0 0	USG3	
110521B15100	22	1.60JT 17151	0.8 0	PSG1	
110521B15100	23	1.82JT 35075	0.6 0	CSG2	
110521B15100	24	2.32JT 32384	3.1 2	URG	DIP AVERAGED
110521B15100	25	3.50JT 15641	0.6 1	EH PSG	EN ECHELON LEFT
110521B15100	26	4.10JT 16238	1.6 1	USG	
110521B15100	27	4.80JT 6563	0.5 0	PSG0	
110521B15100	28	5.08JT 33556	1.5 1	SSG	
110521B15100	29	5.80FZ 16032	1.9 0	PSG0	5.65 - 5.95 PARALLEL
33					DISCONTINUOUS JOINTS
110521B15100	30	6.46JT 16639	1.1 0	USG0	DIFFUSE TRACES
110521B15100	31	6.57JT 13169	1.2 0	USG0	DIFFUSE TRACES
110521B15100	32	7.12JT 13483	2.0 0	USG0	DIFFUSE TRACES. BRAIDED
110521B15100	33	7.52JT 16526	1.4 0	USG0	
110521B15100	34	7.90JT 7378	1.2 0	HE CSG0	
110521B15100	35	8.85JT 8373	0.8 0	H USG3	
110521B15100	36	9.85JT 11741	0.6 0	H USG1	
110521B15100	37	10.00JT 10234	0.8 0	PSG3	
110521B15100		10.00 90 0			E.O.L

STOP 33

110528A23800	1	1.32JT 33866	1.3 0	CSG1	
110528A23800	2	1.50JT 25585	3.2 2	HR PSG	CRUSH ZONE UP TO 1 CM
110528A23800	3	1.50JT 3472	0.9 0	USG1	
110528A23800	4	1.93JT 35066	0.9 0	PSG1	
110528A23811	5	2.30JT 1575	1.1 0	CSG1	
110528A23811	6	2.53JT 27758	2.3 1	PSG	ENDS AT AN E-W JOINT
110528A23811	7	3.29JT 28362	1.1 1	PSG	ENDS AT AN E-W JOINT
110528A23811	8	4.00JT 14974	1.9 1	HR USG	LENSOID Fe CRUSH ZONE FI
110528A23811	9	5.40JT 15528	0.6 1	USG	EXFOLATION
110528A23811	10	5.87JT 25573	2.5 2	PSG	
110528A23811	11	6.70JT 14224	1.1 1	USG	
110528A23811	12	7.29JT 30673	3.3 2	HR PSG	SPREADS INTO 30 CM FRACT
33					ZONE TO E CRUSH ZONE 1 - 5 M
33					NO SLIP SENSE SEEN.
110528A23811	13	8.10JT 31482	1.1 0	PSG1	
110528A23811	14	8.89JT 30765	2.0 1	USG	
110528A23811	15	9.11JT 6647	0.7 1	USG	ENDS AT 16
110528A23811	16	9.87JT 31479	3.1 1	USG	PARALLEL MICROJOINTS; AV
33					TRACE LENGTH 30 CM.
110528A23811		11.00 90 0			E.O.L

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33
 110527A11500 1 0.00JT 11163 1.2 2 H USG
 110527A11500 2 0.45JT 17252 0.6 0 PSG1 PARALLEL SHORT TRACES OV
 33 SPACED 1 - 2 CM
 110527A11500 3 0.82JT 8958 0.7 0 PSG3
 110527A11500 4 0.92FZ 9863 2.0 2 H USG FAULT. 5 CM BRECCIA BRAI
 33 ZONE SLIP SENSE?
 110527A11500 5 1.04JT 26465 1.2 0 PSG3
 110527A11500 6 1.53JT 8479 2.0 1 HR USG PATCHY CRUSH ZONES UP TO
 33 LONG 5 CM WIDE.
 110527A11500 7 1.67JT 9366 1.9 1 HR PSG PATCHY CRUSH ZONES UP TO
 33 LONG 5 MM WIDE.
 110527A11500 8 1.75JT 17973 1.0 0 CSG1
 110527A11500 9 2.28JT 27084 0.8 1 PSG
 110527A11500 10 2.40JT 15143 0.8 1 USG
 110527A11500 11 3.10JT 26489 3.3 1 H CSG
 110527A11500 12 3.45JT 15054 1.1 1 PSG
 110527A11500 13 3.57FZ 25579 1.8 0HR USG3 3.45 - 3.70. BRAIDED SH
 33 ZONES. ESTIMATED DIP.
 110527A11500 14 3.57FZ 7677 5.3 1 USG
 110527A11500 15 4.05JT 9568 1.0 1HR PSG
 110527A11500 16 4.38JT 6788 1.4 1 PSG
 110527A11500 17 4.59JT 24572 1.4 1 HR PSG PATCHY CRUSH ZONES UP T
 33 LAMINATED COMMINUTED. SLIP=?
 110527A11500 18 4.85JT 14164 1.3 1 H PSG
 110527A11500 19 5.35JT 29358 1.2 2 HE PSG
 110527A11500 20 5.52JT 12572 0.5 1 HE PSG
 110527A11500 21 5.70JT 11586 1.0 2 PSG
 110527A11500 22 5.70JT 23572 0.7 1 PSG
 110527A11500 23 6.39JT 11682 1.3 2 PSG
 110527A11500 24 6.66JT 25280 1.3 2 USG
 110527A11500 25 7.30JT 29068 1.2 2 USG
 110527A11500 26 8.11JT 11475 2.9 2 HE USG
 110527A11500 27 8.48JT 31264 0.8 0 USG2
 110527A11500 28 8.54JT 16350 0.6 0 PSG2
 110527A11500 29 8.95JT 10976 2.3 1 H USG
 110527A11500 30 9.15JT 10578 1.4 0 CSG3
 110527A11500 31 9.25JT 25383 1.3 2 H PSG1
 110527A11500 32 9.46JT 12272 1.3 1 PSG
 110527A11500 33 9.52JT 29666 0.8 0 PSG1
 110527A11500 34 9.58JT 26885 2.0 1 H PSG BRAIDED DISCONTINUOUS
 110527A11500 35 9.73JT 6584 1.6 0 PSG3
 110527A11500 36 9.78JT 8685 2.5 1 USG
 110527A11500 37 10.13JT 6881 6.1 2 CSG
 110527A11500 38 10.27JT 4485 0.9 1 PSG
 110527A11500 39 10.90FZ 24480 2.9 1 HE USG 10.60 - 11.20 PARALLEL
 33 DIFFUSE MICROJOINT ZONES
 33 AVERAGE SPACING 3 CM
 110527A11500 11.20 90 0 E.O.L

STOP 36

33 STOP 36 PHOTO-S5-30 LINE A
 110530A26405 1 0.00JT 9375 6.1 2 R P-G MOSS; PROBABLY CONTINUES
 33 N; FAULT?
 110530A26405 2 0.46JT 24580 1.6 2 R SSG
 110530A26405 3 2.22FZ 25283 9.2 2 R USG MOSS; CONTINUES TO N ;
 33 SPANS: 2.1-2.34
 110530A26405 4 2.25JT 14787 2.0 1 R CSG MOSS; ENDS AT 3
 110530A26405 5 3.38JT 26182 7.0 2 R USG MOSS

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110530A26405 6 4.35FZ 8377 9.1 2 R PRG MOSS; SPANS:4.1-4.6; S HA
 33 MOSS, LEFT LAT. SPLAYS AT SCAN LINE
 110530A26405 7 5.45JT 8479 8.1 1 R PSG MOSS
 110530A26405 8 6.51JT 12469 2.6 0 PSG1 MOSS
 110530A26405 9 7.03JT 12672 1.9 0 R CSG1 LEFT LAT. HOOK AT S END
 110530A26405 10 7.70JT 14178 2.7 0 PSG0 8,9,10 APPEAR TO BE LEFT
 33 SPLAYS OF MESOSCOPIC FAULT
 110530A26414 11 9.64FZ 25787 23.0 2 R URG SPANS:9.55-9.72; MAJOR FA
 33 SHOULD BE VISIBLE ON AP
 110530A26414 12 10.20JT 8759 2.9 0 R USG0
 110530A26414 13 11.30JT 8643 7.0 0 R URG1 MOSS; ENDS AT 14
 110530A26414 14 11.45JT 6556 6.0 0 R CRG1
 110530A26414 15 12.05JT 7271 11.9 1 R URG MOSS
 110530A26414 16 13.40JT 13078 3.8 0 R USG0
 110530A26414 17 13.86JT 20015 1.5 0 USG0
 110530A26414 13.90 90 0 EOL
 33
 33 PHOTO-S5-30 LINE B
 110530B15600 11 0.72FZ 25787 23.0 2 R URG
 110530B15600 18 1.70JT 15786 6.1 0 R SSG2 MOSS; ENDS AT 11 & 6
 110530B15600 19 2.75JT 33281 1.1 0 PSG0
 110530B15600 20 3.09JT 32832 2.9 0 SSG1 ENDS AT 11
 110530B15600 21 3.75FZ 15976 24.5 2 R USG MOSS; SPANS:3.3-4.2; NARR
 33 20CM ZONE TO E & W; ZONE LESS CLEAR DUE W
 110530B15600 22 4.60JT 15882 7.9 0 SSG0
 110530B15600 23 5.85JT 14679 7.5 1 URG BRAIDED; EN PASSENT
 110530B15600 24 6.23JT 16374 1.0 0 R SSG1 MOSS; LEFT LAT. SPLAYS A
 33 ENDS AT 11; CROSS JTS BETWEEN MESOSCOPIC SPLAYS
 110530B15600 25 7.42JT 13457 4.2 0 R PRG1 MOSS; E END RT. LAT. SPL
 33 AT 11
 110530B15600 26 8.36FZ 15785 15.0 2 R PSG MOSS; SPANS:7.7-9.03
 110530B15600 27 9.26JT 16175 3.1 2 R USG MOSS
 110530B15600 28 9.75JT 33585 2.0 0 R CSG1 MOSS; DIP SHIFTS FROM W
 33 ENO; ENDS AT 11
 110530B15600 29 11.00JT 15580 4.2 0 R URG0
 110530B15600 30 11.55JT 20847 4.0 1 R CSG MOSS; ENDS AT 29
 110530B15600 31 13.13JT 16684 1.2 1 CSG
 110530B15600 32 13.13JT 21347 3.0 0 R CSG2 ENDS AT 11 & 33
 110530B15600 33 13.95JT 15567 1.3 2 R PRG
 110530B15600 34 14.25JT 16774 0.6 1 PSG
 110530B15600 35 14.55JT 21677 3.2 1 R URG
 110530B15600 36 14.74FZ 16171 0.9 1 PSG SUBPAR. JTS
 110530B15600 15.00 90 0 EOL

STOP 36

33 STOP 36 PHOTO-S6-14 LINE A
 110614A04809 1 0.14JT 23375 1.4 0 USG0 ROCK TYPE: FINE GRAINED
 33 (1-2mm) WITH 0 PHENOCRYSTS(5-6mm)
 110614A04809 2 1.39JT 7282 6.2 1 R USG SPLAYS AT N END
 110614A04809 3 1.55JT 17890 1.9 1 URG ENDS AT 2
 110614A04809 4 2.96JT 22675 0.7 1 URG
 110614A04809 5 3.44JT 7779 2.9 0 PRG0 MOSS
 110614A04809 6 6.12JT 4360 5.7 0 CRG1
 110614A04809 7 7.05JT 6068 2.0 0 URG1
 110614A04809 8 7.49JT 22975 5.3 1 URG
 110614A04809 9 8.15JT 4588 10.7 2 R URG MOSS
 110614A04809 10 8.79JT 4381 3.2 0 PSG0 SPLAYS AT BOTH ENDS
 110614A04809 11 9.32JT 21877 4.0 0 CRG0 EN ECHELON AT N END
 110614A04809 12 9.62JT 3479 9.0 0 R URG2 MOSS; SPLAYS AT S END
 110614A04809 13 11.20FZ 22067 9.1 1 R CSG MOSS; SPANS:11.0-11.39; B

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33 WIDENS AT N END; LEFT LAT. SPLAYS AT SCAN LINE
 110614A04809 14 12.05JT 22376 1.9 0 PSGO
 110614A04809 15 12.60JT 213 8 3.4 1 PSG
 110614A22817 16 13.43JT 22775 2.0 1 PSG
 110614A22817 17 13.93FZ 22065 6.0 2 R USG SPANS:13.8-14.05;BRAIDED
 110614A22817 14.20 90 0 EOL
 33
 33 PHOTO-S6-14 LINE B
 110614B10505 18 0.23JT 30264 3.0 1 PSG STR. SPLAYS AT SW END
 110614B10505 19 1.34JT 33167 2.9 1 USG SPLAY FROM 20
 110614B10505 20 1.80FZ 31283 11.2 2 R P-G MOSS; SPANS:1.7-1.9; MAJO
 33 FRACTURE; MOST OF TRACE MOSS COVERED
 110614B10505 21 2.75JT 31776 8.0 0 PRG1 Q AT W END
 110614B10505 22 3.37CN 30480 2 PSA SPANS:3.3-3.43
 110614B10505 23 3.67CN 30480 1 PSA SPANS:3.65-3.69
 110614B10505 24 3.80JT 4184 3.1 0 PRG1 ENDS AT 20
 110614B10505 25 3.86JT 14387 1.2 0 PRG1
 110614B10505 26 5.04JT 14581 1.9 0 PRG0
 110614B10505 6 5.10JT 4042 4.0 0 PRG1 ENDS AT 26; 20CM RT. LAT
 33 N END
 110614B10505 27 5.90JT 13451 1.7 0 USG1 ENDS AT 6
 110614B10505 28 6.58FZ 12662 5.0 0 PSGO SPANS: 6.18-6.98
 110614B10505 8 6.80JT 22975 5.3 1 URG
 110614B10505 29 6.98JT 12789 2.7 0 R URG2 ENDS AT 6 & 11
 110614B10505 9 8.20JT 4588 10.7 2 R URG
 110614B10505 30 8.60FZ 31971 7.5 0 PRG1 NARROWS TOWARD E; SPANS:
 110614B10505 31 10.10CN 13852 1 URF 4CM WIDE
 110614B10505 32 11.05FZ 31765 6.0 1 PSG SPANS:10.9-11.2; DISCONT
 33 SUBPAR
 110614B10505 12 12.00JT 3479 9.0 0 R URG2
 110614B10505 33 13.25CN 31031 1 M PEG. ALONG UPPER SURFACE
 33 PEG 5-15CM THICK; Q XTALS UP TO 6CM; 12 ENDS AT 33; SPANS:12.75-13.8
 110614B10505 34 13.69FZ 9884 7.1 2 R PRG SPANS:13.6-13.77; SMALL
 33 LAT. SPLAYS AT NE END
 110614B10505 35 13.87JT 5869 2.6 0 R CSG3 SPLAY FROM 34
 110614B10505 36 14.40JT 15281 1.0 0 CSG1 ENDS AT 35
 110614B10505 37 15.58FZ 32564 8.1 1 R PRG SPANS:15.45-15.70 MOSS
 110614B10505 38 15.75JT 5377 4.0 1 R PRG MOSS
 110614B10505 16.00 90 0 EOL
 33
 33 STOP 36 PHOTO-S6-01 LINE A
 110601A17000 1 0.42JT 14639 1.2 0 R PSG1
 110601A17000 2 0.70JT 14843 1.4 0 R USG1
 110601A17000 3 1.25JT 17921 0.9 1 USG
 110601A17000 4 1.95JT 24077 1.6 1 USG
 110601A17000 5 2.93FZ 33074 8.6 2 U-G SPANS:2.5-3.35 ; BRAIDED
 110601A17000 6 3.27JT 5086 5.2 1 M PSG 1CM FeO HALO EITHER SIDE
 110601A17000 7 3.42JT 23379 15.2 0 M PSGO MOSS; STR. SPLAYS BOTH E
 33 SAME HALO AS 6
 110601A17000 8 4.98JT 14786 1.0 0 PSGO
 110601A17000 9 5.05JT 23689 5.1 1 PSG MOSS
 110601A17000 10 5.14FZ 32387 2.7 0 M PSG1 MOSS; 5CM WIDE FZ; EN ECH
 33 LENSOID FeO INFILL
 110601A17000 11 5.95JT 32872 2.1 0 R PSG1 ENDS AT 7; STR. SPLAY AT
 110601A17000 12 5.95FZ 5681 13.0 1 M PSG 5CM WIDE FZ; EN ECHELON;
 33 LENSOID FeO INFILL; FORMS FACE AT NW END OF OUTCROP
 110601A17000 13 6.55JT 17363 1.3 0 PSG1 SPLAY END AT SCAN LINE
 110601A17000 14 6.89JT 16850 4.8 0 USG2 ENDS AT 7; PHOTO S8-3
 110601A17000 15 7.08FZ 24086 12.5 0 M USG1 MOSS; SPANS:6.9-7.25; Fe
 33 BOTH SIDES OF FRACTURE; SLIGHT CW BEND AT N END
 110601A17000 16 8.10JT 17363 1.2 0 PSGO
 110601A17000 17 8.28JT 16969 1.3 0 PSGO

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110601A17000 18 8.50JT 17268 1.1 0 PSGO
 110601A17000 19 8.65JT 17167 1.1 0 PSGO
 110601A17000 20 8.77JT 16765 3.6 1 R CSG
 33
 33 LINE A CONTINUES ON PHOTO-S6-00
 33 PHOTO-S6-00 LINE A
 110600A17000 1 9.20JT 17585 1.1 1 PSG
 110600A17000 2 9.66JT 17069 3.2 1 R USG MOSS; STR. SPLAY AT E EN
 110600A17000 3 10.76FZ 16563 2.6 1 H PSG CLOSE SPACED Fe FILLED
 33 DISCONTINUOUS JTS; SPANS: 10.73-10.80
 110600A17000 4 10.85FZ 6366 4.5 1 HR USG 12CM OF LEFT LAT. SLIP O
 110600A17000 5 11.88JT 16363 2.6 0 PSGO
 110600A17000 6 11.90JT 4678 7.8 0 R SSG1 MOSS
 110600A17000 7 12.30FZ 16068 3.0 0 CRG0 SPANS: 12.28-12.32; MOSS
 110600A17000 8 12.80JT 15450 1.1 0 SRG1 MOSS
 110600A17000 9 13.34FZ 16957 8.1 2 PSG MOSS; SPANS: 13.27-13.40
 110600A17000 10 13.90JT 27090 1.5 0 CSG2 ENDS AT 9; S END SPLAYS
 33 OBTUSE ANGLE
 110600A17000 11 14.58JT 14868 2.0 0 PSGO RT. LAT. SPLAYS AT SW EN
 110600A17000 15.00 90 0 EOL
 33
 33 PHOTO-S6-01 LINE B
 110601B07900 21 0.41JT 8064 0.9 1 PSG
 110601B07900 22 0.46CN 8664 4.0 2 PRF 1CM FELSITE DYKE
 110601B07900 23 1.35FZ 29974 4.9 2 R USG JOINS 5; SPANS:1.1-1.6
 110601B07900 24 2.00JT 22082 1.2 2 RH PRG SLIGHT Fco INFILL
 110601B07900 25 3.35JT 4380 1.5 0 PSGO RT. LAT.SPLAYS AT SCAN
 110601B07900 15 3.86FZ 24086 12.5 0 H USG1
 110601B07900 12 4.35FZ 5681 13.0 1 H PSG
 110601B07900 11 4.90JT 32872 2.1 0 R PSG1
 110601B07900 7 5.42JT 23379 15.2 0 H PSGO
 110601B07900 6 5.60JT 5086 5.2 1 H PSG
 110601B07900 26 6.65JT 4869 3.1 0 R URGO MOSS
 110601B07900 27 7.63JT 5384 13.0 1 USG MOSS
 110601B07900 28 8.40JT 5284 3.2 1 R PSG MOSS; COVERED BY RUBBLE
 33 LINE ; SPLAY FROM 29
 110601B07900 29 8.80FZ 6676 10.0 2 R U-G SPANS:8.4-9.2
 110601B07900 30 9.60JT 5777 1.0 2 R PRG
 110601B07900 31 10.80JT 8157 1.1 2 R CSG
 110601B07900 32 11.67FZ 5775 7.0 2 R PRG 10CM WIDE ZONE; FAULT WI
 33 RT. LAT. COMPONENT
 110601B07900 33 12.27JT 22888 0.8 0 PSGO
 110601B07900 12.50 90 0 EOL
 33
 33 STOP 36 PHOTO-S6-24 LINE A
 110624A02010 1 0.40JT 5885 2.1 1 SSG
 110624A02010 2 0.55JT 31860 2.2 0 R URG1 ENDS AT 5
 110624A02010 3 0.71JT 6578 1.5 0 R USG1 ENDS AT 2
 110624A02010 4 1.20FZ 32863 1.9 0 PSG2 SPANS:1.0-1.4 ; DISCONTI
 33 JTS; SPACING 2-10CM
 110624A02010 5 2.62FZ 24587 10.0 2 R CRG SPANS:2.54-2.80 ; MOSS
 110624A02010 6 3.05JT 9436 1.4 0 R USGO
 110624A02010 7 5.78JT 21984 2.5 0 R URGO NUMEROUS LEFT LAT. SPLAY
 33 SCAN LINE AND H END; MOSS
 110624A02010 8 5.92JT 30879 1.9 0 R USG2 MOSS
 110624A02010 9 6.52JT 31574 2.3 0 R CSG0 MOSS
 110624A02010 10 8.43FZ 25884 10.0 2 R URG MOSS; SPANS:8.2-8.65
 110624A02010 11 8.97JT 090 1.5 0 R CSG0
 110624A02010 12 9.28JT 6887 4.1 0 R USG3 SPLAY FROM FRACTURE ZONE
 110624A02010 13 9.65JT 18290 5.5 0 R USG1
 110624A02010 14 10.45JT 24584 1.8 0 R PSG2
 110624A02010 15 10.50JT 30090 4.7 0 R SRG1 MOSS; ENDS AT 13

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110624A02010 16 12.60JT 30369 5.1 0 R USG1
 110624A02010 17 13.74JT 3854 1.4 0 R PSG1 LEFT LAT. SPLAYS AT SCAN
 110624A02010 18 17.21JT 32046 4.4 0 USG0 MOSS; EN ECHELON
 110624A02010 17.70 90 0 EOL
 33
 33 PHOTO-S6-24 LINE B
 110624B13609 19 0.90JT 32268 1.3 0 PSG2
 110624B13609 20 1.85JT 10347 1.4 0 R CRG1 MOSS
 110624B13609 21 2.50JT 7384 2.0 0 R PRG0 MOSS
 110624B13609 22 2.89JT 12284 1.8 0 R CSG1
 110624B13609 23 3.15JT 31372 1.2 0 R PRG0 STR. SPLAYS AT W END
 110624B13609 24 4.50JT 18889 0.9 0 PSG1
 110624B13609 25 5.67JT 23677 3.0 0 RH USG0
 110624B13609 10 6.45FZ 25884 10.0 2 R URG
 110624B13609 12 6.60JT 6887 4.1 0 R USG3
 110624B13609 15 6.80JT 30090 4.7 0 R SRG1
 110624B13600 13 7.10JT 18290 5.5 0 R USG1
 110624B13600 26 9.10FZ 32282 10.3 1 R PSG SPANS: 8.9-9.3; ENDS AT
 33 SW END COVERED BY MOSS
 110624B13600 27 9.66JT 10361 0.6 1 R CRG MOSS
 110624B13600 28 10.26JT 18337 2.3 0 PSG1 ENDS AT 26
 110624B13600 29 10.69JT 12290 3.8 0 R CRG2 MOSS; ENDS AT 10
 110624B13600 30 10.74JT 35587 4.0 0 R URG1 MOSS
 110624B13600 31 12.00JT 27585 3.6 1 R PRG MOSS; ENDS AT 26
 110624B13600 12.00 90 0 EOL
 33
 33 STOP 36 PHOTO-S6-10 LINE A
 110610A33902 1 0.50FZ 12867 4.6 1 R PSG FZ: 3CM WIDE
 110610A33902 2 0.85JT 12755 4.0 2 R PRG
 110610A33902 3 1.08JT 12572 1.2 2 R PSG SPLAY FROM 2
 110610A33902 4 1.37JT 14062 1.2 2 R PSG SPLAY FROM 2
 110610A33902 5 1.87JT 13175 2.0 2 R URG
 110610A33902 6 2.25JT 11780 3.0 1 R PRG
 110610A33902 7 2.90FZ 12668 14.0 2 R CSG SPANS:2.35-3.45; SPACING
 33 IN ZONE
 110610A33902 8 3.65JT 35184 1.2 0 R PRG1 ENDS AT 9
 110610A33902 9 4.17FZ 12766 3.0 2 R PSG SPANS:4.07-4.27; MUSCOVI
 33 BEARING PEG. IN GRANITE
 110610A33902 10 4.98JT 13586 2.0 0 USG0 MUSCOVITE BEARING PEG. I
 110610A33902 11 5.16JT 14066 4.0 1 R PSG MUSCOVITE BEARING PEG. I
 110610A33902 12 5.52JT 31889 2.1 0 R PSG0
 110610A33902 13 5.69JT 13885 1.2 0 R PSG0
 110610A33902 14 6.48JT 14567 2.0 0 O CSG1 INFILL OF GARNET AND MUS
 33 PHOTO S8-4 ANDRADITE GARNET & SAMPLE S6-10-14
 110610A33902 15 7.13JT 14767 4.0 2 R USG
 110610A33902 16 7.37JT 1656 3.0 1 R PSG MOSS ; ENDS AT 15
 110610A33902 17 7.63JT 13576 3.0 1 R SSG
 110610A33902 18 9.10FZ 13768 5.0 1 R PSG SPANS:8.5-9.7
 110610A33902 19 10.18JT 31683 5.0 1 R CSG RT. LAT. SPLAY AT W END
 110610A33902 20 11.70JT 14281 2.0 1 R U-G
 110610A33902 15.00 90 0 EOL
 33
 33 PHOTO-S6-10 LINE B
 110610B05500 21 2.15FZ 10190 4.5 1 R USG ENDS AT 18; SPANS:1.75-2
 110610B05500 22 5.38JT 20787 1.2 1 R PSG
 110610B05500 23 7.40JT 20480 3.0 1 R USG
 110610B05500 24 7.60JT 11140 2.1 2 R P-G
 110610B05500 25 8.45JT 11854 2.2 0 R PSG2 MOSS; SPLAY AS IS 24;END
 110610B05500 26 9.19FZ 20384 3.0 2 R PSG MOSS;SPANS:9.0-9.37; SPA
 33 ZONE:5CM
 110610B05500 27 10.82JT 20667 2.4 1 PSG MOSS
 110610B05500 28 12.59FZ 20790 2.1 2 R CSG MOSS; SPANS:12.40-12.77;

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33	10-20CM						
110610805500	13.45	90	0	EOL			
STOP 38							
110628A13400	1	0.14JT	20080	1.8	1	PSG	
110628A13400	2	0.50JT	15487	4.4	1	PSG	
110628A13400	3	0.57JT	15082	3.1	1	PSG ESTIMATED DIP. JOINS 2 W	
33						SHORT CROSS JT. WITH SAME	
33						ORIGIN AS 2	
110628A13400	4	1.32JT	31478	3.9	0	USG1	
110628A13400	5	1.40JT	15880	2.9	1	PSG EN PASSANT LEFT	
110628A13400	6	1.50JT	30370	1.6	0	PSG2	
110628A13400	7	1.97JT	32735	2.1	0	PSG0 ESTIMATED DIP	
110628A13400	8	2.20JT	12490	1.1	0	USG0 VARIABLE DIP plus or min	
33						FROM VERTICAL	
110628A13400	9	2.33JT	33070	2.4	0	PSG3 EN ECHELON LEFT	
110628A13400	10	2.54JT	33270	4.0	1	PSG EN ECHELON LEFT	
110628A13400	11	2.92JT	32576	4.0	1	USG SPLAY FROM 12	
110628A13400	12	3.19JT	32371	6.0	2	USG	
110628A13400	13	3.35JT	9668	0.9	0	PSG1	
110628A13400	14	3.56JT	30265	1.2	0	USG3	
110628A13400	15	3.76JT	12788	0.8	0	PSG1	
110628A13400	16	4.61JT	34175	1.2	0	CSG3	
110628A13400	17	4.72JT	32569	4.1	1	USG	
110628A13400	18	4.78JT	26082	5.5	1	USG NUMEROUS RIGHT LATERAL S	
33						ALONG E SIDE	
110628A13400	19	4.80JT	33462	0.8	0	CSG3	
110628A13400	20	5.03JT	33652	0.8	0	CSG1	
110628A13400	21	5.60JT	26073	5.0	1	CSG	
110628A13400	22	5.70JT	16073	1.7	0	PSG3	
110628A13400	23	5.76JT	15881	1.3	0	PSG3	
110628A13400	24	5.90JT	26685	2.3	1	USG	
33							
110628A13419	25	6.08JT	34138	0.7	0	PSG1	
110628A13419	26	6.45JT	18888	1.2	0	CSG3	
110628A13419	27	7.01JT	2085	5.4	1	USG	
110628A13419	28	7.38JT	29885	0.9	0	PSG2	
110628A13419	29	8.30JT	25	9	2.5	0	URG1 EXFOLIATION
110628A13419	30	8.73JT	34037	1.2	0	PSG0	
110628A13419	31	9.52JT	34873	0.9	0	SSG0 STEPS LEFT	
110628A13419		10.00	90	0		E.O.L	
33							
33							
33							
110628B06826	32	0.35JT	22064	1.4	2	PSG BRAIDED DISCONTINUOUS JO	
110628B06826	33	0.53JT	22972	1.0	2	PSG	
110628B06826	34	0.73FZ	22581	13.0	2	USG 0.60 - 0.85. Moss filled	
33						outcrop faces NW & SE parallel	
33						joints spacing 5 cm with 1 cm	
33						spaced oblique cross-joints:	
33						str 102 dip 90. May be left	
33						lateral tension gashes.	
110628B06826	35	1.38JT	21988	1.7	0	PSG3	
110628B06826	36	1.59JT	2781	1.3	1	CSG	
110628B06826	37	1.74JT	4579	7.0	1	USG	
110628B06826	38	1.74JT	7283	1.5	0	PSG2	
33							
110628B06803	39	2.34JT	7785	1.6	0	PSG1	
110628B06803	40	2.42JT	7681	1.3	0	PSG1	
110628B06803	41	2.50JT	7281	2.9	0	PSG2	

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110628806803	42	2.60JT	25487	1.8 0	PSG1	EN ECHELON LEFT
110628806803	43	2.75JT	21473	1.3 1	CSG	
110628806803	44	4.40JT	25090	6.6 2	USG	
110628806803	45	4.93JT	3264	0.8 0	PSG0	
110628806803	46	5.07JT	8784	2.3 0	USG0	
110628806803	47	6.70JT	5452	0.8 0	PSG0	DISCONTINUOUS SUBPARALL
110628806803	48	7.00JT	20090	2.4 0	USG0	
110628806803	27	7.62	90 0			
110628806803	21	8.16	90 0			
110628806803	49	8.84JT	10589	3.7 1	USG	
110628806803	50	9.17JT	9086	1.7 0	USG3	
110628806803	51	9.95JT	2374	0.8 0	PSG0	
110628806803		10.00	90 0			E.O.L
33						
110631A12300	1	0.16JT	16777	2.5 0	USG2	
110631A12300	2	0.21JT	8580	1.5 0	PSG0	
110631A12300	3	0.23JT	16260	0.6 1	PSG	
110631A12300	4	0.30JT	8583	1.7 1	PSG	
110631A12300	5	1.17JT	14362	2.3 0	USG1	
110631A12300	6	2.05JT	13766	4.0 2	PRG	
110631A12300	7	2.23JT	18066	1.7 0	CSG3	
110631A12300	8	2.70JT	15885	12.1 1	USG	
110631A12300	9	2.80JT	8584	1.7 0	PSG1	
110631A12300	10	3.18JT	18880	1.1 0	PSG3	
110631A12300	11	3.35JT	8579	3.4 1	PSG	
110631A12300	12	3.94JT	19370	3.3 0	USG1	
110631A12300	13	4.60JT	34858	4.0 1	CSG	
110631A12300	14	4.88JT	25282	1.2 0	PSG1	
110631A12300	15	6.06JT	15051	2.0 0	PSG0	
110631A12300	16	6.71JT	15761	4.3 0	USG2	
110631A12300	17	7.20JT	15351	1.3 0	URG1	
110631A12300	18	7.87FZ	12054	7.0 1KMR	USG	7.80 - 7.95. ALTERED BRE
33						ZONE. STRIKE AND DIP VARIABLE
110631A12300	19	8.26JT	14377	0.9 0	USG2	
110631A12300	20	8.48JT	13083	2.9 0	USG1	
110631A12300	21	8.65JT	3090	2.0 0	USG2	
110631A12300	22	10.14JT	12981	2.7 0	PSG2	
110631A12300	23	10.28JT	13084	2.3 0	USG0	
110631A12300		10.50	90 0			E.O.L
33						
110631B19519	24	0.10JT	19170	0.9 0	PSG0	
110631B19519	25	0.17JT	3178	1.5 1	USG	
110631B19519	26	0.63JT	21485	2.0 1	CSG	
110631B19519	27	0.75JT	14357	2.6 0	H USG2	
110631B19519	28	1.30JT	6958	1.3 0	PSG0	
110631B19519	29	1.58JT	23276	2.4 0	SSG0	ESTIMATED DIP
110631B19519	30	2.11JT	3135	1.5 0	USG2	
110631B19519	31	2.27JT	16188	1.8 1	USG	
110631B19519	32	2.80JT	21488	3.5 0	USG2	
110631B19519	33	3.18JT	19486	3.3 0	USG0	
110631B19519	34	3.37JT	1579	2.4 0	USG1	
110631B19519	35	3.91JT	16075	2.3 1	PSG	
110631B19519	36	4.72JT	21559	1.8 0	PRG1	
110631B19519	13	5.37	90 0			
110631B19519	37	6.81JT	18870	0.9 0	CSG2	
110631B19519	38	7.40FZ	20373	12.0 2	USG	7.05 - 7.75. BRAIDED SM
33						JOINTS. SPACING 2 - 6 CM
110631B19519	39	7.93JT	14556	1.1 0	USG1	
110631B19519	40	8.67JT	19379	4.4 0	CSG2	
110631B19519	41	9.02JT	22282	1.6 0	PSG1	
110631B19519	42	9.36JT	30286	2.3 0	CSG2	
110631B19519	43	9.55JT	22267	1.8 0	PSG0	

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110631B19519	44	9.67JT	21879	1.7 0	CSG3
110631B19519	45	9.70JT	12184	0.9 0	PSG0
110631B19519	46	9.87JT	21884	3.5 1	PSG
110631B19519	47	10.02JT	9376	1.4 1	USG
110631B19519		10.50	90 0		E.O.L

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110633A12404	1	0.57JT	16044	3.1 1	SSG
110633A12404	2	0.66JT	27081	3.0 1	PSG
110633A12404	3	0.93JT	28580	2.2 0	PSG3
110633A12404	4	0.94JT	373	1.1 0	USG3
110633A12404	5	2.40JT	14061	2.5 2	USG
110633A12404	6	2.72JT	15069	1.8 2	USG
110633A12404	7	2.75JT	14548	2.4 1	USG
110633A12404	8	3.22JT	7785	0.7 0	CSG1
110633A12404	9	3.36JT	34377	0.6 0	PSG0
110633A12404	10	3.40JT	24784	1.8 0	CSG1
110633A12404	11	3.94JT	34464	1.1 0	USG1
110633A12404	12	4.47JT	14063	1.0 0	USG0
110633A12404	13	4.60JT	23783	3.2 0	USG2
110633A12404	14	4.83JT	13050	0.7 0	PSG3
110633A12404	15	5.20FZ	15669	17.1 2	USG
33					FAULT BRECCIA ZONE 10 CM
33					FRAGMENTS. NO SLICKS SEEN.
					EXTENDS W OFF PHOTO
110633A12404	16	5.38JT	18057	2.1 0	USG3
110633A12404	17	6.02JT	14670	1.5 0	CSG0
110633A12404	18	6.13JT	18469	0.8 0	PSG0
110633A12404	19	6.17JT	13374	1.2 0	CSG1
110633A12404	20	6.66JT	8079	0.7 0	PSG2
110633A12404	21	6.83JT	16670	6.3 0	CSG3
110633A12404	22	7.00JT	10390	1.6 0	USG0
110633A12404	23	7.09JT	18183	2.0 0	USG3
110633A12404	24	7.30JT	18767	1.4 0	CSG0
110633A12404	25	7.50JT	18472	2.1 0	USG1
110633A12404	26	7.57JT	11466	0.8 0	PSG0
110633A12404	27	8.11JT	18779	2.9 0	CSG1
110633A12404	28	8.11JT	27982	0.8 0	PSG0
110633A12404	29	8.25JT	35066	1.1 0	PSG3
110633A12404	30	8.70JT	18356	2.4 0	USG0
110633A12404	31	9.00JT	18859	3.0 0	PSG1
110633A12404	32	9.73JT	18378	0.8 0	PSG0
110633A12404		10.00	90 0		E.O.L
33					
110633B21600	33	0.55JT	33078	1.3 1	PSG
110633B21600	34	0.85JT	22232	1.6 0	PSG1
110633B21600	35	0.95JT	17633	1.9 1	USG
110633B21600	36	1.30JT	22450	1.3 0	PSG1
110633B21600	37	1.52JT	24580	1.5 0	PSG0
110633B21600	38	1.79JT	24290	1.3 1	USG
33					VARIABLE DIP Plus or Min
					FROM VERTICAL
110633B21600	39	2.07JT	22544	0.8 0	PSG1
110633B21600	13	2.33	90 0		
110633B21600	11	2.77	90 0		
110633B21611	10	2.84	90 0		
110633B21611	40	3.07JT	24568	1.6 0	PSG1
110633B21611	41	3.30JT	12342	0.9 0	CSG0
110633B21611	42	3.62JT	24078	1.9 0	PSG2
110633B21611	43	4.17JT	20645	0.7 0	PSG1
110633B21611	44	4.28JT	23563	1.9 0	PSG2
110633B21611	45	4.33JT	22746	1.3 0	PSG3

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110633821611	46	4.62JT	19383	0.8 1	PSG	
110633821611	47	5.20JT	15275	4.0 0	USG2	
110633821611	15	5.55	90 0			
110633821611	21	5.82	90 0			
110633821611	48	6.27JT	19368	1.9 1	CSG	
110633821611	49	6.64JT	17488	2.8 0	CSG3	
110633821611	50	7.22JT	16339	1.8 0	USG0	
110633821611	51	7.94JT	15467	1.0 0	PSG1	
110633821611	52	8.04JT	19462	3.2 1	CSG	
110633821611	53	8.16JT	18358	1.5 0	CSG0	
110633821611	54	8.70JT	22452	1.9 1	H CSG	DIFFUSE DISCONTINUOUS MI
110633821611	55	9.08JT	1469	1.4 1	PSG	
110633821611	56	9.33JT	21361	1.9 0	PSG1	
110633821611	57	9.42JT	21061	1.8 0	PSG1	
110633821611	58	9.58JT	21165	1.7 0	PSG1	
110633821611	59	9.64JT	35672	2.3 2	PSG	
110633821611	60	9.81JT	21258	2.5 0	PSG1	PARALLEL SHORT JOINTS S
33						1 CM. MAKE UP 3 CM ZONE.
110633821611	61	10.00JT	21860	2.3 0	USG1	
110633821611		10.00	90 0			E.O.L

Appendix B Regional Water Chemistry Data

Surface Waters

Sample ID	Mg mg/l	Na mg/l	K mg/l	Ca mg/l	SO ₄ mg/l	Alk mg/l	pH	Cl mg/l
RP2	0.2	5.3	0.12	0.4	2.6	0.0		8.4
WH3040	0.7	5.5	0.29	1.8	2.4	3.5		10.2
RP3040	1.6	40.8	0.52	4.6	5.4	0.0		74.6
P07	1.4	50.1	1.19	6.8			5.86	
P11	1.8	86.8	2	8.5			5.73	
P13	0.5	3.71	0.27	1.3			5.5	
P14A	0.5	4.08	0.28	1.8			5.6	
P14B	0.6	5.86	0.36	1.4			5.18	
P25	0.5	3.12	0.39	1.2			5.52	
P33	0.5	4.1	0.3	1.1			5.57	
P34	0.5	4.08	0.32	1.7			5.7	
P37	0.3	2.8	0.3	0.7			4.56	
P40	0.5	4.2	0.3	1.3			4.72	
P42	0.6	3.9	0.4	1.3			5.63	
P44	0.5	3.4	0.4	1			4.43	
P50	0.6	3.8	0.4	1.4			5.1	
P62	0.4	2.8	0.3	1			4.45	
P64	0.5	8.2	0.3	1.4			4.75	
P85	0.4	7.3	0.3	1.3			4.7	
P136	0.5	4.4	0.3	1.3			5.1	
P137	0.4	3.6	0.3	1.1			4.7	
P173	0.8	9.2	0.31	1.5			5.77	
P174	0.4	3	0.4	0.7			5.13	
P174-1	0.55	5.1	0.12	0.51				
P174-2	0.57	4.73	0.11	0.68				
P174-3	0.56	4.76	0.11	0.58				
P174-4	0.58	4.76	0.11	0.73				
P174-M	0.61	5.08	0.11	0.85				
P175	2	173.6	0.95	11.1			6	
P176	0.6	9.4	0.4	1.7			5.5	
P176-1	0.53	9.05	0.28	1.07				
P177	0.5	5.6	0.4	1.1			4.9	
P177-1	0.59	6.84	0.2	0.71				
P178	0.8	31.9	0.5	2.7			5.14	
P181	0.7	13.1	0.5	1.8			4.4	
P183A	0.4	2.97	0.22	0.8				
P183B	0.4	3	0.4	0.9			3.94	
P184A	0.3	2.5	0.3	0.8			5	
P184B	0.5	3.6	0.3	1.1			5.31	
P186	0.5	3.3	0.4	1.2			4.7	
P213	0.4	3.1	0.3	1			5	
WHALE	0.3	2.3	0.2	0.8			5.2	

Appendix B

S326-1	0.72	7.56	0.11	0.43				
S326-A	0.43	4.23	0.05	0.29				
S326-B	0.52	5.41	0.08	0.24				
S327-1	0.57	4.74	0.11	0.75				
RP3040	1.6	40.8	0.52	4.6				
WH3040	0.7	5.5	0.29	1.8				
RP2	0.2	5.3	0.12	0.4				
H2	0.9	4.5	0.6	6.7				
GP6512	1.1	11.4	0.42	2.2	2.4	3.7		21.2
GP2030	1.1	12	0.42	2.2	2.4	5.0		21.4
GP2	0.6	7.6	0.28	1	2.6	1.1		13
DP8565	3.1	163.2	1.05	15.2	12.7	2.8		278
DP2	0.5	38.9	0.5	1.8	4	<1.0		62.8
BP2	0.4	4.7	0.27	0.9	2.6	1.3		7.6
BP1-1	1.92	15.18	0.54	8.79				
BP1515	1.1	10.1	0.37	3.2	2.4			19.6
PPLAKE	1.1	5.3	0.2	0.9	2.4	3.9	4.64	0.5
GP1AKE	1.4	14.5	0.4	3	2.6	7.8	6.04	1.3

Appendix B

Groundwaters

Sample ID	Mg mg/l	Na mg/l	K mg/l	Ca mg/l	SO4 mg/l	Alk mg/l	pH	Cl mg/l
CB003	3.7	23.1	0.9	71.9	11	146.22	7.52	72.3
CB007	2.8	9.9	0.5	39.2	8	127.32	7.65	18.4
CB010	9.2	71.5	1.3	35.9	6.6	14.79	5.7	192
CB014	4.9	19.4	0.6	27.6	13.8	100.63	6.92	26.8
CB017	2.1	8.5	0.7	26.9	5.6	86.66	7.35	12.3
CB020	3.6	82.4	1.3	7.6	16.6	2.26	4.82	81
CB024	2.5	118.7	1.9	11.9	7.5	275.19	9.05	55.8
CB028	6.1	21.8	1.4	20.7	12	50.52	6.16	48
CB031	4.4	11.7	0.8	10.5	11.2	22.18	6.05	25
CB034	4.5	15.3	1.7	47.7	5.2	145.81	7.63	34
CB038	0.1	123.9	0.2	0.6	9.9	277.2	9.94	19.6
CB041	2.8	11	0.7	42.3	6.5	6.16	5.27	23
CB044	8.3	18.3	1.1	17.7	13.8	17.25	5.71	49.3
CB047	3.4	8.8	0.7	24.7	14.7	33.27	7.15	14.9
CB050	4.7	8.3	2.3	9.1	15	0.8	4.5	18.6
CB053	5	35.3	1.2	46.1	12	42.71	6.89	69
CB058	15.9	51.4	3.6	41.7	126.5	4.11	4.88	111.5
CB062	2.9	13.7	0.7	29	15	38.2	6.59	14.4
CB066	1.4	7.7	3.5	12.1	7	17.25	5.78	12.4
CB069	9.3	32.4	3.1	17.6	12	3.29	5.11	97.5
CB072	3.8	23.9	3.7	10.7	12.3	2.46	4.44	44
CB076	4.7	10.1	1.4	38	14.7	58.73	7.24	13.1
CB079	5.2	8.4	1.1	15.2	15.6	25.05	5.85	12.9
CB082	4.9	10.3	1.2	31.4	9.8	48.06	7.21	20
CB087	10.9	12.1	1	53.2	5.5	47.64	7.53	73
CB091	0.2	88.3	0.5	1.6	5.7	96.93	9.8	11.7
CB094	0.1	100.1	0.4	1.3		115.83	9.12	10.1
CB097	3.9	9.1	1.4	21.2	4	55.86	6.98	11
CB101	6.5	31.2	0.9	36.1	26	83.79	7.04	68.7
CB105	3.5	10.8	1.6	27.6	16.6	87.9	7.2	17.6
CB109	4	19.9	0.9	8.6	4.2	22.18	5.31	34
CB112	3.6	13.1	1	11.5	4.2	41.07	6.15	26.6
CB116	2.5	58.3	1.2	20.7		204.55	9.05	34.8
CB120	2.5	21.7	1.2	32	7.8	137.6	7.83	10.8
CB123	0.9	7.5	0.5	3	4.2	10.68	4.8	10.4
CB127	7.9	15.8	1.6	68.9	39.3	94.47	6.51	78
CB131	5.4	9.3	0.7	45		168.4	7.71	13.2
CB134	4.2	14	2.1	28.4	9.4	111.72	6.64	19.8
CB138	0.7	44.7	0.8	2.3	7.2	108.43	6.24	12.2
CB142	3.5	7.3	0.9	29.5	3.6	103.09	7.65	8
CB145	4.6	32.1	1.1	15.5	8.7	34.91	6.08	71.3
CB149	2.9	30.1	1.1	39	22	108.84	7.49	43.7
CB153	3.1	20	1.2	26.5	5.6	52.78	6.28	41.1

Appendix B

CB157	2.6	7	0.7	25	11.8	77.12	6.4	9.4
H2851	0.8	4.6	0.7	3.4	2.4	11.96	5.04	7.4
H2852	0.6	3.9	0.7	2.9			4.92	6.2
H2853	0.6	3.8	0.7	2.6			5.26	6.2
H2854	0.6	3.9	0.7	2.6	2.6	3.99	5.23	8.8
H2855	0.5	3.2	0.6	2.5			5.23	5.2
H2856A	0.5	3.6	0.7	2.6			4.75	5.2
H2856C	0.6	3.8	0.7	2.5			4.78	5.2
H285B4	1.5	8.2	0.9	18.4	4.2	50.97	7	17.8
H285B5	1.6	8.3	1	18.8	2.6	61	6.1	14.4
H285B6	1.4	8.1	1	17.9	2	59.1	6.03	13.4
H3852	3.7	8.3	0.7	32.5	5.2	127.51		8.2
H3854	3.7	8.4	0.6	32.7	3.8	128.1		7.8
H41	1	4.9	0.5	5.1	3.6	14.2		8.2
H46	1	4.9	0.5	5.2	3.6	13.1		8.4
H418	1	4.8	0.5	5.2	3.6	14		8
H424	1.2	5.3	0.9	9.3	4.2	30.4		9.6
BP1	3.7	7.2	0.5	41.2	2.4	130.3	8.08	18
BP2	3.4	6.7	0.5	38.9	2.4	119.4	8.43	18.6
BP3	3.7	7	0.5	41.5	2.4	129.72	8.6	18.6
BP4	3.1	6	0.4	36.1		113.53	8.48	16.8
BP5	3.3	6.5	0.4	37.9	4.4	120.24	7.83	14.2
H213.4	0.8	4	0.5	7.5				
GPGW	2.9	16.2	1	11.8	1.2	46.3	6.66	1.5
PP1	2.7	7	0.2	43.2	4.1	123.4	7.21	0.4
PP2	3	40.2	3.3	46.4	73.1	138.9	7.44	0.7
PP3	2.6	9.1	0.5	41.5	9.4	123.4	7.2	0.4
NS-1	0.72	50.7	0.41	15.8	5.48	195.2		34.6
NS-2	2.4	12.7	1.05	8.4	4.69	12.2		23
NS-3	0.6	53.8	0.34	10.6	8.6	97.6		32.3
NS-4	2.65	17.7	0.46	42.9	3.9	152.5		7.7
NS-5	2.8	60.5	1.63	33	10	134		65.7
NS-6	3.4	29.1	1.32	33.1	3.33	79.3		63.7
NS-7	4.5	40.9	5.51	53.7	15.8	152.5		57.8
NS-8	13.8	2493	6.51	101.8	45.5	61		4797

Appendix C Analytical Results of Pond Sediment Samples

Gull Pond Surface Lake Sediment Analysis

sample #	x loc	y loc	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	Cd ppm	U ppm	LOI %
1001	100	200	14	19	92	544	1.27	8	.9	24.5	34.0
1002	100	300	15	20	81	499	3.20	11	.5	20.8	36.4
1003	100	400	14	17	82	1800	5.10	11	.6	29.6	36.4
1004	100	500	15	21	94	818	2.79	11	.6	21.3	32.2
1005	100	600	14	17	101	817	3.25	11	.6	20.3	34.8
1006	100	700	26	20	88	553	2.07	11	.8	102.0	12.0
1007	200	100	14	31	45	10760	4.62	13	.2	21.0	18.8
1008	200	200	13	17	86	695	1.58	8	.8	23.3	34.0
1009	200	300	15	17	102	5420	5.99	12	.7	20.4	35.4
1011	200	400	15	17	92	941	4.19	13	.6	19.9	34.2
1012	200	500	10	16	77	159	1.10	6	.7	19.2	28.8
1013	200	600	15	19	92	404	1.14	8	1.0	25.7	32.2
1014	300	500	12	13	74	374	1.49	6	.3	23.1	25.6
1015	400	500	21	18	87	503	1.89	8	.5	50.3	12.0
1016	400	600	35	23	177	435	1.69	11	1.5	85.8	31.6
1017	400	900	7	16	72	28600	5.54	20	.6	25.2	12.4
1018	500	500	18	20	127	6100	6.29	16	.9	21.1	33.6
1019	500	600	18	36	140	25100	7.11	11	1.0	18.1	29.8
1021	500	800	7	19	50	9940	4.32	7	<.1	18.3	17.2
1022	500	900	33	14	104	358	.96	11	1.0	65.3	28.6
1023	500	1000	17	23	98	904	1.63	7	.9	21.8	30.8
1024	600	500	17	27	70	660	2.25	7	.6	19.1	41.6
1025	600	600	16	21	87	3790	3.27	9	.8	18.9	38.6
1026	600	1100	16	20	104	486	3.08	11	.6	19.6	33.2
1027	650	1150	25	19	70	463	1.85	9	.2	40.6	3.2
1028	685	800	16	21	121	10270	6.39	10	.9	17.5	35.0
2001	100	650	14	18	93	475	2.19	10	<.1	15.4	37.1
2002	100	750	24	16	110	274	.55	6	1.1	37.0	33.5
2003	150	550	15	14	116	2210	5.19	13	.8	18.0	37.8
2004	150	650	16	20	117	2540	2.41	11	.9	48.1	33.2
2005	150	700	28	13	185	248	.72	6	1.4	62.7	32.6
2006	150	750	21	16	154	548	.77	6	1.1	42.4	34.3
2007	200	800	16	16	138	390	.55	4	.9	26.9	36.5
2008	250	550	15	14	107	281	.79	6	1.0	27.0	35.8
2009	250	750	17	17	139	179	.50	4	1.4	27.0	40.9
2011	300	600	52	18	139	253	1.05	12	1.6	159.0	27.8
2012	350	600	32	17	81	401	1.86	18	.4	71.0	12.7
2013	350	650	31	22	88	501	2.05	14	.3	60.1	7.6
2014	400	550	39	12	139	339	1.50	10	1.2	87.0	34.2
2015	400	650	19	15	149	623	.87	5	1.3	35.4	38.5
2016	450	550	21	26	153	3350	4.86	16	1.1	44.5	30.2

Appendix C

2017	450	600	14	18	108	685	3.16	13	.7	14.6	37.4
2018	450	650	20	15	118	339	1.21	7	1.1	38.9	36.1
2019	500	410	18	22	102	981	3.05	30	.5	18.8	34.8
2021	500	700	21	20	78	593	1.72	21	.2	52.7	2.8
2022	500	450	15	15	134	8800	6.83	14	.8	16.9	36.5
2023	550	550	16	15	134	3440	6.01	11	.7	16.5	38.0
2024	550	650	15	17	107	523	2.39	11	.6	14.9	37.7
2025	550	950	15	18	125	611	1.70	3	.7	16.7	19.2
2026	600	400	18	18	106	435	3.05	13	.9	21.3	40.0
2027	600	600	15	14	103	3480	6.05	11	.6	15.1	41.6
2028	600	900	16	16	141	4400	5.57	11	.9	16.0	37.1
2029	600	1000	15	15	127	3420	5.36	11	.8	16.0	39.3
2031	650	550	15	18	74	789	2.68	10	.6	16.0	44.2
2032	650	650	15	15	81	1500	4.79	10	.6	16.0	42.9
2033	650	750	21	54	138	2780	5.00	11	.8	17.1	39.6
2034	650	850	16	15	67	605	2.08	7	.5	15.5	43.6
2035	650	950	17	15	102	567	3.61	10	.6	16.8	38.2
2036	700	600	15	16	101	686	5.30	11	.6	15.3	39.1
2037	700	700	15	15	115	972	5.77	18	.5	14.9	36.9
2038	700	800	16	16	139	5020	5.21	10	.9	14.0	39.1
2039	700	900	16	17	138	3730	5.14	11	.9	15.0	38.0
2041	700	1000	15	17	102	525	3.73	12	.6	13.4	38.4

Appendix C

Nut Brook Pond Surface Lake Sediment Analysis

sample #	x loc	y loc	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	Cd ppm	U ppm	LOI %
1054	25	100	9	33	20	536	1.46	5	.2	39.8	25.6
1055	25	125	13	30	17	65	.38	6	.4	34.8	27.2
1056	50	50	15	46	16	206	.45	10	.4	79.9	32.8
1057	50	75	11	45	27	377	.83	9	.4	76.9	30.4
1058	50	100	10	27	15	145	.63	6	.3	31.9	35.4
1059	50	125	12	23	18	120	.63	4	.2	39.6	34.6
1061	50	150	10	23	4	35	.35	3	.1	30.8	22.8
1062	50	175	17	34	3	34	.27	3	.1	46.9	19.8
1063	75	50	16	53	23	372	.66	12	.6	126.0	40.6
1064	75	75	17	44	124	296	1.54	12	1.5	126.0	15.0
1065	75	100	19	41	15	76	.60	7	.3	96.5	26.4
1066	100	50	10	43	35	116	1.21	10	.4	250.0	34.2
1067	100	75	15	53	16	217	.62	9	.5	144.0	30.2
1068	100	100	13	27	5	79	.43	6	.2	51.5	24.4
1069	125	50	15	60	72	272	1.14	13	1.0	233.0	34.8
1071	125	75	21	40	13	104	.56	6	.3	63.9	27.6

Appendix C

Pennys Pond Surface Lake Sediment Analysis

sample #	x loc	y loc	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	Cd ppm	U ppm	LOI %
25	125	175	4	12	7	20	.60	3	<.1	18.8	13.0
26	75	175	5	15	6	38	.70	4	<.1	31.5	12.1
27	75	125	4	10	5	14	.51	4	<.1	19.1	15.3
28	125	50	8	14	6	18	.30	3	<.1	17.1	22.5
29	100	50	5	12	4	13	.17	3	<.1	17.5	16.5
31	100	75	4	16	7	37	.50	4	<.1	17.5	16.0
34	100	100	5	20	8	<2	1.55	5	<.1	19.5	18.5
35	75	100	4	13	5	29	.49	3	<.1	16.4	17.2
36	50	75	5	11	5	48	.28	4	<.1	22.3	25.0
38	100	125	4	13	7	84	1.13	5	<.1	17.6	15.4
39	50	125	4	16	8	75	.81	4	<.1	22.1	16.2
41	100	150	4	12	4	10	.53	3	<.1	15.9	11.2
42	75	150	4	24	14	76	.85	4	<.1	69.1	11.6
43	50	150	4	15	10	194	.80	5	<.1	28.3	15.1
45	100	175	9	23	19	22	.52	4	<.1	106.0	14.5
46	50	175	5	16	11	102	.58	4	<.1	41.5	16.8
47	150	200	11	26	29	74	1.87	5	<.1	142.0	17.4
48	125	200	9	19	13	33	.70	3	<.1	71.6	13.9
49	100	200	9	34	33	70	1.30	7	<.1	309.0	16.3
50	75	200	3	12	5	109	2.50	5	<.1	17.0	12.3
51	150	225	29	47	15	19	.20	10	<.1	94.7	37.1
52	125	225	4	16	9	89	1.10	6	<.1	25.1	12.4
54	100	225	3	13	5	94	1.00	5	<.1	19.2	12.2
55	75	225	3	15	13	30	.20	7	<.1	31.6	16.9
56	125	250	3	16	5	19	.60	4	<.1	27.5	1.1
57	100	250	4	17	5	23	.70	4	<.1	31.4	11.8
58	75	250	6	18	6	53	.40	4	<.1	30.8	16.3
59	100	275	7	15	4	13	.50	4	<.1	16.5	16.9

Appendix C

Rocky Pond Lake Sediment Analysis

sample #	x loc	y loc	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Mo ppm	Cd ppm	U ppm	LOI %
1041	100	500	15	22	83	448	1.32	10	.6	16.0	18.6
1042	200	100	8	15	33	8920	7.46	10	<.1	17.1	15.2
1043	200	200	12	12	23	1260	3.84	6	<.1	7.1	28.6
1044	200	400	15	14	38	467	1.75	7	.4	13.9	34.6
1045	200	500	12	11	44	980	2.28	8	.4	11.6	32.4
1046	200	600	15	18	71	355	1.07	6	.6	11.2	32.0
1047	300	100	11	11	38	1510	1.92	5	.3	8.1	31.8
1048	300	200	8	10	32	943	4.44	6	<.1	15.7	11.2
1049	300	300	24	29	72	449	3.03	3	<.1	41.1	10.8
1051	300	400	14	17	54	920	2.77	9	.4	23.8	34.8
1052	300	500	14	16	48	740	2.33	8	.4	20.5	35.2
1053	400	100	11	22	23	2880	4.18	9	<.1	69.0	16.8
2042	150	150	9	8	36	2390	11.72	14	<.1	6.2	23.5
2043	150	450	12	18	42	7090	4.18	8	.3	8.5	29.7
2044	200	150	11	14	35	6740	4.14	5	.2	7.7	32.8
2045	200	450	13	15	45	527	1.78	5	.2	12.5	37.6
2046	250	100	9	14	39	13350	7.80	10	<.1	9.6	23.6
2047	250	150	11	13	30	2680	9.40	7	<.1	6.5	29.3
2048	250	200	9	9	59	50600	8.43	68	.5	8.1	20.1
2049	250	300	9	27	98	27100	6.27	10	.3	42.2	17.6
2051	250	350	13	11	53	678	2.37	7	.3	9.2	36.9
2052	250	400	14	12	34	584	1.51	5	.2	11.4	39.9
2053	250	450	12	11	50	850	2.30	9	.3	9.6	35.5
2054	250	500	12	9	44	945	2.66	12	.3	14.8	36.7
2055	250	550	11	10	30	539	1.29	4	.2	8.7	36.1
2056	300	150	9	11	38	5090	11.20	11	<.1	6.2	23.8
2057	300	350	13	12	40	945	3.19	9	.2	10.6	37.8
2058	300	450	14	12	31	508	1.09	4	.2	10.0	40.3
2059	350	100	10	12	30	399	4.68	4	<.1	7.8	16.9
2061	350	150	10	12	35	1670	1.87	4	.2	6.2	34.7
2062	350	250	14	16	92	1320	2.38	7	.6	10.0	36.0
2063	350	300	13	14	69	1210	2.37	8	.4	9.5	37.7
2064	350	350	14	11	61	926	3.07	8	.2	9.8	35.7
2065	350	400	12	10	42	995	2.54	9	.2	11.3	36.1
2066	350	450	12	10	40	862	2.24	7	.2	10.9	36.7
2067	350	500	12	10	50	734	2.49	14	.2	9.9	35.8

Appendix D Analytical Results of Lake Sediment Cores

Nut Brook Pond Lake Sediment Analysis
Core DPA (75 75)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2242	0.05	17	29	52	513	1.66	0.3	na	na	35.3
2243	0.10	13	32	48	284	2.45	0.2	24	691	36.3
2244	0.15	16	44	40	172	3.55	0.4	49	1110	36.9
2245	0.20	17	47	43	182	3.36	0.3	52	1060	37.1
2246	0.25	17	49	49	167	3.07	0.5	47	na	35.9
2247	0.30	18	50	51	195	3.45	0.5	46	na	41.2
2248	0.35	20	38	57	182	4.39	0.6	69	3080	42.4
2249	0.40	23	46	116	276	5.98	1.2	63	1620	31.9
2251	0.45	29	25	159	423	7.38	1.3	46	985	27.1
2252	0.50	37	43	216	382	8.21	1.7	na	na	27.4

na - no analysis, insufficient sample

Nut Brook Pond Lake Sediment Analysis
Core DPB (50 100)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2253	0.05	13	39	50	679	2.70	0.2	8	79.3	na
2254	0.10	11	28	23	252	1.08	0.1	6	62.0	na
2255	0.15	10	31	23	204	0.89	0.1	6	56.8	33.1
2256	0.20	11	32	25	215	0.77	0.2	7	58.7	39
2257	0.25	13	37	28	259	0.59	0.2	8	66.0	41.4
2258	0.30	13	39	28	246	0.55	0.3	9	na	43.4
2259	0.35	14	38	30	279	0.56	0.3	8	68.2	45.3
2261	0.40	15	35	29	251	0.50	0.3	9	72.3	46.5
2262	0.45	14	36	26	217	0.54	0.3	8	62.8	39.9
2263	0.50	16	36	26	208	0.50	0.4	na	74.4	na
2264	0.55	8	19	14	115	0.37	0.1	7	164.0	35.6
2265	0.60	15	40	24	235	0.66	0.2	7	76.2	35.6
2266	0.65	16	43	25	180	0.73	0.2	7	78.1	33.6
2267	0.70	17	36	29	175	0.76	0.2	7	na	31.1
2268	0.75	16	30	52	214	1.01	0.4	9	na	34.3
2269	0.80	18	33	55	191	0.81	0.4	9	na	32.0
2271	0.85	20	35	92	688	1.00	0.8	9	87.9	na
2272	0.90	31	30	162	179	1.08	1.4	11	155.0	28.9
2273	0.95	23	22	74	235	0.88	0.8	11	106.0	41.9
2274	1.00	21	20	60	234	0.93	0.7	12	91.9	na
2275	1.05	20	27	71	237	1.11	0.7	11	na	34.0
2276	1.10	25	28	140	221	1.14	1.2	11	na	31.9
2277	1.15	29	30	148	179	1.12	1.1	17	na	28.4
2278	1.20	29	37	179	118	1.32	1.0	21	na	23.1
2279	1.25	38	37	276	109	1.66	1.6	16	188.0	22.0
2281	1.30	39	35	259	95	3.79	0.8	26	na	23.4
2282	1.35	44	19	124	128	3.01	0.4	26	221.0	na
2283	1.40	37	19	176	126	2.56	0.8	27	223.0	32.3
2284	1.45	44	17	119	119	2.24	0.9	41	270.0	32.9
2285	1.50	46	21	87	106	2.12	1.1	44	303.0	31.4

na - no analysis, insufficient sample

Nut Brook Pond Lake Sediment Analysis
Core DPC (125 50)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2286	0.05	11	42	54	411	1.32	0.3	7	181	34.0
2287	0.10	12	44	61	357	1.17	0.2	8	242	34.2
2288	0.15	16	57	63	248	0.84	0.3	8	228	33.7
2289	0.20	18	57	88	252	0.99	0.8	9	363	36.8
2291	0.25	18	49	126	309	1.15	1.3	12	351	42.4
2292	0.30	20	37	136	384	1.17	1.0	16	278	46.5
2293	0.35	22	35	116	393	1.46	1.0	24	458	49.6
2294	0.40	22	49	118	371	1.42	1.0	22	471	41.9
2295	0.45	27	52	211	390	1.53	1.3	28	369	41.8
2296	0.50	27	45	241	312	1.67	1.2	29	341	38.4
2297	0.55	31	43	255	360	2.71	1.7	37	459	na
2298	0.60	39	36	300	208	3.20	2.0	44	858	na
2299	0.65	39	36	169	212	2.92	1.0	30	1220	31.7

na - no analysis, insufficient sample

Gull Pond Lake Sediment Analysis
Core GPA (150 350)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2085	0.1	17	12	39	279	1.17	0.5	7	24.0	42.4
2086	0.2	15	8	51	250	1.35	0.4	9	23.6	39.4
2087	0.3	16	11	56	261	1.50	0.5	9	24.8	40.6
2088	0.4	18	12	43	246	1.28	0.5	9	24.9	na
2089	0.5	18	13	64	241	1.20	0.5	9	31.1	42.6
2091	0.6	19	14	60	257	1.21	0.6	8	31.9	39.7
2092	0.7	16	9	56	211	1.04	0.6	9	24.7	36.7
2093	0.8	16	8	72	205	1.00	0.6	8	33.6	36.0
2094	0.9	19	12	93	213	1.04	0.7	7	40.3	39.3
2095	1.0	20	12	85	227	1.03	0.6	7	47.0	38.4
2096	1.1	19	10	81	227	1.23	0.6	8	43.3	37.3
2097	1.2	22	12	100	235	1.46	0.6	8	41.1	40.1
2098	1.3	26	13	94	226	1.03	0.7	7	48.5	40.6
2099	1.4	29	14	117	241	1.10	0.7	8	58.7	39.1
2101	1.5	35	14	133	230	1.24	0.6	10	81.4	36.5
2102	1.6	30	13	111	221	1.20	0.8	9	71.3	37.3
2103	1.7	42	14	115	224	1.27	0.9	10	96.8	36.1
2104	1.8	42	12	86	193	1.08	0.9	12	116.0	32.7
2105	1.9	32	9	73	192	1.22	0.7	21	77.1	27.3
2106	2.0	34	9	72	210	1.23	0.6	26	58.6	24.9
2107	2.1	14	6	34	297	1.39	0.1	1	3.2	0.4
2108	2.2	14	6	34	292	1.29	0.1	2	1.9	0.4
2109	2.3	19	11	46	366	1.49	0.1	17	14.4	1.0
2111	2.4	25	16	60	400	1.99	0.3	32	54.8	7.2
2112	2.5	48	27	74	498	2.22	0.3	27	48.4	8.6

na - no analysis, insufficient sample

Gull Pond Lake Sediment Analysis
Core GPB (100 700)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2113	0.1	18	11	119	130	0.60	1.2	4	40.2	31.8
2114	0.2	37	13	167	136	0.61	1.5	6	84.4	31.0
2115	0.3	45	11	85	152	0.71	1.0	11	85.3	na
2116	0.4	37	12	78	186	0.78	0.6	18	73.7	22.7
2117	0.5	29	20	60	369	2.36	0.1	35	47.9	3.8

na - no analysis, insufficient sample

Gull Pond Lake Sediment Analysis
Core GPC (600 600)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2118	0.1	22	14	177	1310	3.43	0.9	19	34.9	38.6
2119	0.2	21	12	277	1060	2.96	0.9	16	34.8	37.0
2121	0.3	19	10	191	992	3.03	1.0	17	39.2	30.7
2122	0.4	23	12	237	1270	2.80	1.1	16	43.8	37.2
2123	0.5	24	13	311	1360	2.70	1.1	16	45.6	36.6
2124	0.6	24	13	283	1070	2.35	1.1	15	40.8	37.8
2125	0.7	26	12	315	1050	2.71	1.1	17	46.3	na
2126	0.8	29	13	331	1390	2.34	1.1	14	51.9	39.8
2127	0.9	32	14	249	1400	3.30	1.1	18	61.1	38.8
2128	1.0	38	15	405	1520	3.19	1.2	21	75.1	37.0
2129	1.1	19	25	352	5940	6.28	1.0	12	23.9	39.8
2131	1.2	22	28	327	9450	6.50	1.0	13	32.7	40.0
2132	1.3	25	15	286	2390	4.67	0.9	14	43.1	39.6
2133	1.4	25	14	266	1640	3.54	0.9	16	44.1	37.8
2134	1.5	36	13	187	927	2.15	0.9	20	71.9	31.4
2135	1.6	37	16	108	632	2.02	0.6	32	76.2	20.5
2136	1.7	46	27	108	666	2.55	0.3	28	51.6	8.4
2137	1.8	27	19	75	609	1.95	0.2	37	65.4	4.8

na - no analysis, insufficient sample

Gull Pond Lake Sediment Analysis
Core GPD (650 850)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2138	0.1	20	12	270	293	0.96	0.7	6	33.9	41.2
2139	0.2	24	11	259	303	0.94	0.7	6	36.2	na
2141	0.3	27	19	254	273	0.82	0.8	5	47.6	41.7
2142	0.4	24	13	157	294	0.83	0.8	5	47.1	42.3
2143	0.5	31	13	237	298	0.84	0.8	5	58.5	41.1
2144	0.6	40	14	195	273	0.87	0.8	6	77.1	40.0
2145	0.7	46	13	235	249	0.83	0.9	9	105.0	38.0
2146	0.8	38	9	201	214	0.73	0.7	12	70.4	31.5
2147	0.9	31	9	167	217	1.06	0.7	20	73.3	27.6
2148	1.0	43	12	144	245	1.29	0.6	28	84.9	25.3
2149	1.1	30	12	206	274	1.01	0.7	12	51.7	38.1
2151	1.2	37	14	144	299	1.14	0.6	23	71.1	28.3
2152	1.3	42	25	107	498	2.17	0.4	23	40.9	10.8
2153	1.4	28	15	76	406	1.71	0.3	33	59.5	13.1
2154	1.5	29	15	111	407	1.87	0.3	34	54.1	11.2

na - no analysis, insufficient sample

Gull Pond Lake Sediment Analysis
Core GPE (425 600)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2155	0.1	19	12	298	457	1.09	1.3	8	30.8	na
2156	0.2	18	11	286	434	1.12	1.1	7	30.8	na
2157	0.3	18	11	258	469	1.14	1.1	8	31.2	36.4
2158	0.4	19	12	269	448	1.10	1.1	8	32.6	36.3
2159	0.5	18	9	238	398	0.91	1.1	6	33.2	35.5
2161	0.6	17	8	282	404	1.03	1.0	6	40.7	33.4
2162	0.7	35	10	307	387	0.91	1.1	5	41.3	34.4
2163	0.8	52	9	349	428	1.05	1.1	5	48.1	33.8
2164	0.9	23	10	310	448	0.99	1.1	5	43.4	35.3
2165	1.0	27	10	347	489	1.23	1.2	5	50.2	35.5
2166	1.1	25	15	333	542	1.39	1.1	8	36.5	36.9
2167	1.2	29	12	349	634	1.77	1.1	10	53.8	37.8
2168	1.3	32	12	376	593	1.63	1.2	10	60.4	35.4
2169	1.4	35	12	346	2920	1.47	1.3	13	69.3	33.9
2171	1.5	225	11	313	2690	1.77	1.4	15	87.5	32.9
2172	1.6	90	12	312	10940	1.58	1.5	23	108.0	32.7
2173	1.7	57	10	220	1730	1.53	1.2	16	119.0	31.9
2174	1.8	42	8	231	973	1.05	1.0	17	78.6	29.4
2175	1.9	35	8	145	619	0.97	0.7	17	63.6	24.0
2176	2.0	37	10	98	560	1.12	0.6	26	63.8	22.4
2177	2.1	38	20	143	585	2.22	0.4	31	83.9	13.2
2178	2.2	33	19	98	484	1.96	0.2	29	51.8	5.4

Rocky Pond Lake Sediment Analysis
Core RPA (250 500)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2179	0.1	15	10	71	714	1.56	0.5	10	8.7	34.5
2181	0.2	15	10	80	697	1.62	0.4	10	9.2	35.9
2182	0.3	16	11	93	695	1.79	0.5	11	11.6	35.2
2183	0.4	17	9	94	633	1.60	0.6	10	12.4	35.0
2184	0.5	18	11	87	522	1.54	0.5	10	15.5	34.6
2185	0.6	20	11	85	579	1.43	0.5	11	17.3	33.1
2186	0.7	21	12	82	544	1.52	0.6	13	na	33.2
2187	0.8	23	10	97	490	1.70	0.7	18	26.8	34.5
2188	0.9	23	11	107	420	2.28	0.6	32	26.0	33.6
2189	1.0	22	10	96	386	2.19	0.5	43	26.6	35.3
2191	1.1	22	11	94	401	2.12	0.7	44	25.9	36.3
2192	1.2	25	12	246	369	2.44	4.6	40	47.0	35.2
2193	1.3	27	13	103	395	1.89	1.3	23	211.0	32.2
2194	1.4	34	14	129	397	1.70	1.2	19	317.0	31.0
2195	1.5	44	20	134	381	1.63	1.1	16	449.0	31.1
2196	1.6	66	26	156	355	1.48	2.8	20	449.0	na

na - no analysis, insufficient sample

Rocky Pond Lake Sediment Analysis
Core RPB (400 100)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2197	0.2	10	28	169	9410	4.91	0.5	8	29.6	23.8
2198	0.3	6	15	120	5350	3.21	0.3	8	44.7	17.8
2199	0.4	12	17	169	7030	3.72	0.4	14	45.9	18.8
2201	0.5	35	21	208	7490	5.74	0.5	20	54.5	24.8
2202	0.6	48	25	206	2600	6.31	0.1	16	37.4	25.0

Rocky Pond Lake Sediment Analysis
Core RPC (300 400)

#	depth (m)	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Cd ppm	Mo ppm	U ppm	LOI %
2203	0.1	16	19	59	569	1.66	0.3	6	16.1	40.0
2204	0.2	15	11	44	488	0.97	0.2	5	8.3	41.4
2205	0.3	14	9	29	411	0.75	0.2	5	7.8	40.6
2206	0.4	16	12	45	382	1.11	0.2	6	12.6	41.0
2207	0.5	13	12	63	312	1.15	0.2	6	18.1	36.9
2208	0.6	14	11	63	311	0.93	0.2	5	13.0	39.6
2209	0.7	16	10	89	283	0.79	0.2	5	10.5	40.6
2211	0.8	16	9	182	282	0.70	0.2	5	8.5	41.1
2212	0.9	17	10	205	281	0.81	0.2	5	12.6	41.6
2213	1.0	17	11	94	285	0.78	0.2	5	10.5	41.5
2214	1.1	16	11	38	303	1.04	0.2	5	10.7	40.5
2215	1.2	16	10	41	360	0.87	0.3	5	9.0	40.5
2216	1.3	16	12	45	361	0.90	0.3	5	10.5	40.9
2217	1.4	19	12	54	392	0.95	0.3	6	14.3	41.4
2218	1.5	22	12	42	421	0.98	0.3	6	15.9	42.9
2219	1.6	21	12	51	408	1.10	0.3	6	18.0	41.3
2221	1.7	23	12	49	366	1.09	0.3	6	18.5	40.2
2222	1.8	24	12	46	318	1.08	0.3	6	21.9	37.1
2223	1.9	23	10	49	325	1.17	0.3	7	27.4	35.7
2224	2.0	22	11	57	329	1.05	0.4	7	29.3	36.6
2225	2.1	16	18	224	537	1.66	0.4	7	19.6	36.9
2226	2.2	20	16	206	450	1.58	0.4	7	25.0	36.8
2227	2.3	18	12	215	384	1.16	0.3	6	24.6	36.1
2228	2.4	23	12	275	418	1.18	0.4	6	26.7	38.2
2229	2.5	26	13	301	485	1.21	0.4	6	34.6	38.8
2231	2.6	36	17	177	1070	1.26	0.5	6	38.6	43.1
2232	2.7	42	16	188	751	1.06	0.5	6	46.8	40.6
2233	2.8	51	17	110	507	0.76	0.5	6	48.3	35.0
2234	2.9	78	25	207	454	0.92	0.5	7	56.6	33.0
2235	3.0	72	31	155	366	1.88	0.4	14	60.9	27.9

Appendix E Sample Calculation

Calculation of time required to produce observed uranium concentrations in lake sediment from groundwater under present day conditions.

U = mass of uranium in 1 m^3 of lake sediment
 U_s = concentration of uranium in lake sediment
 U_{gw} = concentration of uranium in groundwater
 ρ_s = bulk density of sediment
 Q = seepage flux
 t = time

The amount of uranium (U) in 1 m^3 of lake sediment having a concentration of U_s is;

$$U = \rho_s * U_s;$$

which is equal to groundwater with a uranium concentration of U_{gw} seeping through 1 m^3 of lake sediment at a rate of Q over a period of time t .

$$U = U_{gw} * Q * t$$

Therefore the time required to accumulate a given amount of uranium in 1 m^3 of lake sediment at a given seepage flux is,

$$t = \frac{\rho_s * U_s}{U_{gw} * Q}$$

Given;

$Q = 0.00113 \text{ m}^3/\text{day}$
 $U_s = 100 \text{ (g/1*10}^6\text{g)}$
 $U_{gw} = 0.090 \text{ (g/m}^3\text{)}$
 $\rho_s = 1.8*10^6 \text{ g/m}^3 \text{ (assumed)}$

then;

$$\begin{aligned}
 t &= \frac{1.8*10^6 \text{ g/m}^3 * 100 \text{ g/1*10}^6\text{g} * 1 \text{ m}^3}{0.090 \text{ g/m}^3 * 0.00113 \text{ m}^3/\text{day}} \\
 &= 1769911 \text{ days} \\
 &= 4849 \text{ years}
 \end{aligned}$$



