



Energy, Mines and
Resources Canada

Énergie, Mines et
Ressources Canada

**GEOLOGICAL SURVEY
PAPER 74-27**

**GEOCHEMICAL STUDIES IN THE
EASTERN PART OF THE
SLAVE STRUCTURAL PROVINCE, 1973**

E. M. CAMERON and C. C. DURHAM

**With a contribution on
the petrology of the volcanic rocks**

MARIETTE TURAY

1974

Crown Copyrights reserved
Available by mail from *Information Canada*, Ottawa

from the Geological Survey of Canada
601 Booth St., Ottawa

and

Information Canada bookshops in

HALIFAX — 1683 Barrington Street
MONTREAL — 640 St. Catherine Street W.
OTTAWA — 171 Slater Street
TORONTO — 221 Yonge Street
WINNIPEG — 393 Portage Avenue
VANCOUVER — 800 Granville Street

or through your bookseller

A deposit copy of this publication is also available
for reference in public libraries across Canada

Price: \$3.50

Catalogue No. M44-74-27

Price subject to change without notice

Information Canada
Ottawa
1974

CONTENTS

	Page
Abstract/Résumé	v
Geochemical studies in the eastern part of the Slave Structural Province, 1973 by E. M. Cameron and C. C. Durham	1
Introduction	1
Sample Preparation and Analysis	2
Sampling Program	2
Agricola Lake Anomaly	2
Geology and rock geochemistry	3
Soil and gossan geochemistry	5
Lake sediment geochemistry	6
Sanctuary Lake Area	6
Geology and rock chemistry	7
Soil and gossan geochemistry	8
Lake sediment geochemistry	8
Conclusion, Sanctuary Lake area	9
Casey Lake Anomaly	9
Other Zinc-Copper Anomalies	11
Hackett River	11
East of Agricola Lake area	11
North of Malley Rapids	11
Lineament Lake Anomaly	13
Conclusions	15
Petrography of Rocks from the Agricola Lake Area by M. Turay	17
Introduction	17
Volcanic rocks	17
Granite	17
Conclusion	17
References	20
Appendix A Major element data for rock samples, Agricola Lake area, N.W.T. (V, volcanics; S, sediments; G, granites; N.F., not found; N.A., not analyzed). All values in weight percent	21
B Trace element data for rock samples, Sanctuary Lake area, N.W.T. (V-volcanics, S-sediments, G-granites, D-diabase)	22
Figure 1. Comparison of lake sediment geochemical data obtained in 1972 with data obtained in 1973	in pocket
2. Geochemical sampling, Agricola Lake area	in pocket
3. Geochemical sampling, Sanctuary Lake area	in pocket
4. Geochemical sampling, Ferric Lake area	in pocket
5a Lake sediment and soil analyses, Casey Lake area	12
5b Rock sample sites, Casey Lake area	13
6. Rock sample analyses and contours for uranium content of lake sediments, Lineament Lake area	in pocket
7. AFM diagram of volcanic rock samples, Agricola Lake area	14
8. Silica versus alumina plot, Agricola Lake volcanics	18
9. Photomicrographs of volcanic rocks Agricola Lake area	19
Table 1. Composition of anomalous lake sediment samples 2890 and 2891 from Agricola Lake compared to regional geochemical background	3
2. Index of hydrothermal alteration (Mg+Fe/Ca+Na) for rock samples, Agricola Lake area	4
3. Zn, Cu, Pb, Ag, As and Au in soil samples from traverse 641-658, Agricola Lake area	5

Contents (cont'd)

	Page
Table 4. Solubilities of heavy metal sulphates	5
5. Distribution of metals between different size fractions of a soil over- lying "B" horizon, Agricola Lake area	6
6. Composition of anomalous lake sediment sample 3358 from Uist Lake compared to regional geochemical background	7
7. Statistical data for volcanic rocks, Agricola Lake and Sanctuary Lake areas	8
8. Zn, Cu, Pb, Ag, As and Au content of gossans, Sanctuary Lake area.	8
9. Composition of anomalous lake sediment sample 2950 from near Casey Lake compared to regional geochemical background	9
10. Distribution of trace elements in rock samples from Casey Lake area .	10
11. Distribution of trace elements in rock samples from near Malley Rapids	11
12. Composition of anomalous lake sediment samples 746 and 3313, Lineament Lake area compared to regional geochemical background .	15
13. Covariation of U and organic content (as optical density) for lake sediment samples, Lineament Lake area	16

ABSTRACT

In 1972 a geochemical reconnaissance survey was carried out over 36,000 square miles of the Bear and Slave Structural Provinces of the northern Canadian Shield. This survey sampled nearshore lake sediments at an average density of one per 10 square miles. In 1973 a detailed follow-up survey was carried out in the eastern part of the survey area. Lake sediment, soil and rock samples were collected. This work was done to assist interpretation of the 1972 data and to establish the validity of the use of lake sediments for geochemical reconnaissance in the northern Shield.

The area chosen for study was the western margin of the Beechey Lake belt in the eastern part of the Slave Province. Here, the published reconnaissance geological mapping showed metasedimentary rocks in contact with granites. However, the base metal and major element geochemistry of the lake sediments collected in 1972 indicated the possible presence of massive sulphide mineralization associated with acidic volcanic rocks. Three anomalies of this type were studied in detail. Two of these anomalies were shown to be extensive and are caused by exhalative mineralization within volcanic rocks of intermediate to acidic composition. The third anomaly was found to be small in extent and caused by disseminated sulphides in basic and intermediate volcanic rocks. Other anomalies of this type were studied in less detail.

A second type of anomaly found during the reconnaissance was for U in granitic terrane. The rocks in and around the largest of these anomalies were sampled and the anomaly was shown to be caused, in part at least, by a higher background content of U in the granites. Whether the anomaly is also related to U mineralization was not established.

The success of geochemical exploration within this region derives in large part from active postglacial oxidation. This has caused the more mobile components of sulphide mineralization, such as Zn and Cu, to be carried away in solution to the lakes, while the less mobile components, such as Pb, Ag and Au, are retained in the soils overlying mineralization. This allows the use of lake samples for wide-interval reconnaissance sampling and soil sampling for detailed follow-up work. A number of other factors contribute to the success of the method. These include the relatively high relief of the volcanic rocks which allows the wide dispersion of drainage waters containing metal in solution and the general absence of precipitation barriers in the drainage system.

In addition to the information on secondary dispersion, data are given on the geochemical composition of the volcanic rocks and their petrology, and on primary dispersion around mineralization.

RÉSUMÉ

On a effectué en 1972 des levés de reconnaissance géochimique sur plus de 36,000 milles carrés dans les provinces structurales de l'Ours et des Esclaves dans le nord du Bouclier canadien. On a recueilli en moyenne un échantillon de dépôts lacustres littoraux par 10 milles carrés. On a procédé, en 1973, à un échantillonnage détaillé de la partie est de la région à l'étude. Des échantillons de sédiments lacustres, de sols et de roches ont été recueillis. On a effectué ce travail pour aider à l'interprétation des données de 1972 et pour déterminer l'utilité des sédiments lacustres dans la reconnaissance géochimique du nord du Bouclier.

On a choisi d'étudier la zone littorale ouest de la région du lac Beechey, dans la partie est de la province des Esclaves. Les cartes publiées de reconnaissance géologique indiquaient là la présence de roches métasédimentaires en contact avec des granites. Cependant la géochimie du métal commun et de l'élément majeur des sédiments lacustres recueillis en 1972 indiquait la présence probable d'une minéralisation massive de sulfure associée à des roches volcaniques acides. On a étudié en détail trois anomalies de ce genre. Deux de ces dernières sont de dimensions importantes et elles sont causées par une minéralisation par exhalaison à l'intérieur de roches volcaniques antérieurement non identifiées de composition allant d'intermédiaire à acide. La troisième anomalie est de dimensions plus modestes et elle a été causée par des sulfures disséminés dans des roches volcaniques basiques et intermédiaires. On a étudié moins en détail d'autres anomalies de ce genre.

Au cours de la reconnaissance on a trouvé un autre genre d'anomalie concernant l'uranium dans des terrains granitiques. On a échantillonné les roches à l'intérieur et autour de la plus importante de ces anomalies et il a été démontré qu'elle avait été causée, en partie du moins, par une concentration plus forte d'uranium dans les granites. Il n'a pas été déterminé si l'anomalie pouvait également être reliée à la minéralisation d'uranium.

Le succès de l'exploration géochimique dans cette région peut largement être attribué à une oxydation post-glaciaire active. Ceci a permis aux composants mobiles (comme le Zn et le Cu) de la minéralisation du sulfure d'être transportés en solution dans les lacs alors que les composants moins mobiles comme le Pb, l'Ag et l'Au sont demeurés dans les sols susjacentes à la minéralisation. Ceci permet l'utilisation d'échantillons lacustres dans la reconnaissance par intervalles bien dispersés et l'échantillonnage du sol pour des travaux ultérieurs plus détaillés. D'autres facteurs ont contribué au succès de la méthode. On compte parmi ceux-ci le relief relativement prononcé des roches volcaniques qui rend possible une grande dispersion des eaux de ruissellement contenant du métal en solution, et l'absence générale d'empêchements à la précipitation dans le réseau hydrographique.

En plus des renseignements sur la dispersion secondaire, l'auteur fournit des données sur la composition géochimique et la pétrographie des roches volcaniques, ainsi que sur la dispersion primaire autour de la minéralisation.

GEOCHEMICAL STUDIES IN THE EASTERN PART OF THE SLAVE STRUCTURAL PROVINCE, 1973

by

E. M. Cameron and C. C. Durham

INTRODUCTION

In the summer of 1972, a large scale geochemical reconnaissance of 36,000 square miles of the Bear and Slave Structural Provinces was carried out. The sample medium was near-shore lake sediments. A report (Allan *et al.*, 1973) and contoured maps for various elements (Allan and Cameron, 1973a-1973g) have been produced detailing the results of the Bear-Slave Operation. This sampling program was preceded by orientation surveys throughout the Bear and Slave Provinces (Allan *et al.*, 1972). This involved sampling the rocks and lake sediments within a number of areas. Some of the sampled areas contain known ore bodies or mineralization, while others are apparently barren.

These orientation surveys showed that known ore bodies could be located by sampling nearshore lake sediments at a reconnaissance density of one sample per ten square miles. Of particular interest was the observation that the massive sulphide occurrences at High Lake and Hackett River, both in the Slave Province, gave anomalous metal values in surrounding lake sediments. Massive sulphides may prove to be the most important mineral resource of the Slave Province. Since they are a relatively small target, it was by no means certain that they could be detected at a wide, reconnaissance sampling interval.

Despite the success of the orientation surveys, there was some measure of scepticism as to whether this new approach was a practical method of mineral exploration and resource appraisal. The objective of the 1973 follow-up studies was, therefore, to discover whether some of the anomalies could be related to previously unknown mineralization, or conversely whether they were caused by metal-rich but otherwise barren rock or by concentration processes within the drainage environment. Two areas containing prominent heavy metal anomalies were considered for follow-up studies. These were the central part of the Bear Province and the eastern part of the Slave Province. The latter area was selected for a number of reasons. Firstly, it is more remote than the Bear Province and hence less likely to receive attention from the exploration industry. Secondly, the anomalous zones in the Archean Slave Province seemed more likely to be related to massive sulphide mineralization, which presently is the most important exploration target in the Canadian Shield. Thirdly, and most intriguing, the published geology of this area of the Slave, metasedimentary rocks and

granites, was at marked variance with the character of the anomalies, which suggested base metal mineralization within volcanic rocks.

In the eastern part of the Slave Province, few of the geographic features have been given official names. In order to allow a comprehensible account to be given, the authors have named a number of lakes on a provisional basis¹. Also the name Beechey Lake sedimentary-volcanic belt is given to the principal belt in the eastern part of the Slave Province. It trends north-west and lies between latitudes 65°00' and 66°30' (Cameron and Durham, 1974, Fig. 1).

The amount of field work was governed by a budgetary limit of 100 hours (one month) of helicopter use, plus fixed-wing support. Field work was carried out throughout July from a base camp on Regan Lake. A float-equipped Cessna-180 was used for rock and soil sampling traverses and for gas caching. A Hiller 12-E helicopter was used initially for lake sediment sampling, and then for all sampling work after the crash of the Cessna-180. All lakes were ice-free on our arrival in the area on June 28, 1973.

In follow-up studies of this type it is essential to have immediate analytical results to guide sampling. Thus a simple field laboratory was established in a tent to determine Cu and Zn colorimetrically. In view of the intensive leaching of these elements from the soils overlying mineralization, it was a distinct handicap in not being able to analyze for less mobile elements, such as Pb or Ag, in the field. The significance of some of our sampling only became apparent when these elements were analyzed after our return to Ottawa. Our sampling strategy would have been somewhat different if these data had been available in the field.

The staff taking part in the field operation were: E. M. Cameron (party chief), C. C. Durham (deputy party chief), G. M. Thomas (senior assistant), R. T. Crook (analyst), K. Lawrence (helicopter pilot), D. O'Donnell (helicopter engineer), L. Yanik (fixed-wing pilot) and R. Griffin (cook). In Ottawa the samples were prepared by P. Lavergne, and analyzed by W. Alexander, Mrs. G. Aslin, J. L. Bouvier, G. Gauthier, J. Gravel, R. E. Horton, Mrs. A. MacLaurin, W. Nelson, J. C. Pelchat and Miss E. Ruzgaitis. Mr. B. Ballantyne assisted in the compilation of the data and the manuscript was typed by Mrs. R. Chaffey. The

Provisional names:

¹ Agricola Lake, Uist Lake, Tooshort Lake, Ferric Lake, Friday Lake, Sanctuary Lake, Stockwell Lake,

Original manuscript submitted: October, 1974

Final version approved for publication: May 1, 1974

authors are most grateful to all of these persons. Their hard work and interest went far beyond what is ordinarily called for. Mr. Robert Hornal, of the Department of Indian Affairs and Northern Development, Yellowknife, and his staff extended many courtesies during the field season.

SAMPLE PREPARATION AND ANALYSIS

Lake sediment and soil samples were sieved using 80- and 250-mesh screens. The minus 250-mesh material was used for the analysis of all elements other than Au; this element was determined on the minus 80-, plus 250-mesh fraction. The fist-sized rock samples were reduced to $\frac{1}{4}$ inch chips in a Chipmunk crusher, then further reduced to about 20-mesh by a Braun pulverizer with ceramic plates. Ten grams of this was sampled, then ground to approximately minus 150-mesh in an alumina ceramic mill.

The major elements, Al, Fe, Mg, Ca, Na, K, and Mn were determined by atomic absorption spectrometry following fusion with lithium tetraborate and dissolution of the fused material in HNO_3 . Silica was first determined by X-ray fluorescence of the unfused powders. Subsequently, the Agricola Lake samples were reanalyzed colorimetrically by the molybdenum blue method. For this the fused powder was dissolved in HCl . Ti was determined by X-ray fluorescence. The methods used for S and CO_2 and C are described by Bouvier *et al.* (1972), CO_2 was liberated by HCl , H_2O and FeO were determined by the conventional methods. The elements Zn, Cu, Pb, Ag, and Ni were determined by atomic absorption spectrometry. For rocks a total decomposition was used with $\text{HF-HNO}_3\text{-HClO}_4$. For lake sediments, soils and gossans a partial leach (70%-80% extraction on average) by hot $\text{HNO}_3\text{-HCl}$ was used. U in rocks was determined fluorimetrically, following dissolution of the sample in $\text{HF-HNO}_3\text{-HClO}_4$. Arsenic was extracted by a hot HCl leach, then measured colorimetrically using silver diethyldithiocarbamate. Gold in soil and gossan samples was measured by a combined fire assay-atomic absorption procedure. Some samples were below the detection limit for Pb (3 ppm), Ag (0.5 ppm), Au (5 ppb) or S (0.1%). These samples have been assigned arbitrary values of 2 ppm, 0.2 ppm, 2 ppb or 0.005% respectively.

The determination of Cu and Zn made in the field were by colorimetry, using 2, 2' biquinoline as reagent. None of these field determinations are reported in this paper. In comparing the 1973 lake sediment data with that for the 1972 Bear-Slave Operation (Allan *et al.*, 1973), it is important to note that Cu and Pb in the 1972 samples were analyzed by direct-reading emission spectrometry. Differences between the total metal content determined by emission spectrometry and the partial $\text{HNO}_3\text{-HCl}$ leach are greatest for Pb, but only slight for Cu.

SAMPLING PROGRAM

The first stage of the field program was to resample lake sediments from a 1500 square-mile portion of the

eastern Slave Province. Different lakes were sampled from those visited in 1972. This work was done to establish the reproducibility of reconnaissance lake sediment sampling. The area chosen was the western margin of the Beechey Lake belt (Fig. 1). Reconnaissance geological mapping of this area (Wright, 1957) showed that northwesterly-trending metasedimentary rocks were in contact to the west with granitic rocks. Our preliminary field work showed that there was up to 25,000 feet of metavolcanic rocks between the granites and metasediments. They form the base of the Beechey Lake sedimentary-volcanic belt. At the extreme northern margin of the sampled area, at Hackett River, there is economically important Pb-Zn-Cu-Ag massive sulphide mineralization.

The second stage of the program was to study in detail certain anomalies within the area shown in Figure 1. The areas studied in greatest detail are anomalous for Cu, Zn, As, Co, Ni and Mn. The anomalies are situated in the following areas: Agricola Lake (Fig. 2), Sanctuary and Ferric lakes (Figs. 3 and 4) and Casey Lake (Fig. 5). A number of other anomalies of this type were studied in less detail. A different type of anomaly was studied in granitic rocks to the south (Fig. 6). This area is anomalous principally for U, but also for Zn, Cu, Mo, and La.

AGRICOLA LAKE ANOMALY

This is an extensive anomaly covering approximately 200 square miles. It is centred on Agricola Lake, where in 1972 duplicate samples were collected from the same sample site on the northwestern margin of Agricola Lake (Fig. 2a). In Table 1 the complete analyses are given for these two samples and compared with the geometric mean results for Sheet 3 of the Bear-Slave survey area (see Allan *et al.*, 1973, for details of analytical method used). The geometric mean is considered here as a useful index of the regional background. Although more than one conclusion was possible, the following was our interpretation of this anomaly prior to visiting the field of 1973.

The high K may indicate acidic volcanic rocks and the Mg may come from associated basic volcanic rocks, or from chloritic hydrothermal alteration zones. The enhanced Fe and low Ca and Sr can be caused by weathering sulphides, the low pH causing the leaching of the mobile Ca and Sr from silicate minerals in the drainage system. The anomalous levels of Hg, Ag, Zn, Mn, Mo, Cu, Co and Ni were thought to have been derived by hydromorphic dispersion from oxidising base metal sulphides. Considering the typical geology and metallogeny of the Archean of the Canadian Shield, the fingerprint that these data provide points to massive sulphide mineralization associated with acidic volcanic rocks.

In 1973 further lake sediment samples were collected throughout the anomalous area and analyzed in the field for Cu and Zn. This significantly narrowed the target area and permitted detailed rock and soil sampling. It makes for a rather more coherent account to discuss the data in the reverse order from which

Table 1. Composition of anomalous lake sediment 2890 and 2891 from Agricola Lake compared to regional geochemical background. Elements listed in order of atomic weight.

Element	Sample 2890	Sample 2891	Sheet 3, Bear-Slave survey area. 1349 samples		Ratio 2890/G.M.
			Geometric mean (G.M.)	G.M. + 1 log standard deviation	
Li, ppm	39.	40.	15.5	28.3	2.5
Be, ppm	2.0	1.7	1.5	2.1	1.3
Mg, %	1.4	1.6	0.66	0.96	2.1
K, %	2.6	2.3	1.86	2.28	1.4
Ca, %	0.8	0.8	1.22	1.49	0.7
Ti, %	0.28	0.28	0.32	0.395	0.9
V, %	95.	90.	51.8	69.8	1.8
Cr, ppm	134.	129.	62.2	91.4	2.2
Mn, ppm	257.	257.	89.	154.	2.9
Fe, %	4.7	4.8	2.18	2.93	2.2
Co, ppm	64.	73.	9.7	16.4	6.6
Ni, ppm	123.	126.	23.3	42.7	5.3
Cu, ppm	161.	178.	19.6	36.6	8.2
Zn, ppm	230.	230.	31.8	58.1	7.2
As, ppm	28.	28.	2.3	6.7	12.2
Sr, ppm	170.	170.	237.	283.	0.7
Y, ppm	34.	36.	23.2	32.6	1.5
Zr, ppm	249.	262.	273.	366.	0.9
Mo, ppm	1.6	2.4	0.55	1.5	2.9
Ag, ppm	0.3	0.4	0.39	0.53	0.8
Ba, ppm	632.	611.	586.	750.	1.1
La, ppm	51.	62.	35.9	52.0	1.4
Hg, ppb	37.	43.	11.2	20.0	3.3
Pb, ppm	18.	18.	12.9	16.0	1.4
U, ppm	0.6	0.5	0.7	1.8	0.9

At the base of this sequence, in contact with the volcanics, are slates, some of which are carbonaceous. These less resistant rocks form a prominent valley containing a chain of lakes.

There are two gossan zones in the Agricola Lake area. The first is along the contact between the volcanic and sedimentary rocks. Gossans occur along this contact throughout the Beechey Lake belt. They are of variable thickness; from a few inches or feet up to two hundred feet or more of gossanous rock detritus in the vicinity of Ferric Lake. The gossanous soils and rock detritus have been derived from the oxidation of iron sulphides and carbonates. At Agricola Lake, the true thickness of this horizon, and the nature of its primary minerals, is not easily determined since it is well oxidized and occurs at the base of the ridge formed by the topmost volcanic strata. However, the thickness of the primary iron-rich horizon is estimated to be generally less than 10 feet.

This zone of gossans can be traced for many miles north and

they were obtained. Thus the geological framework and rock geochemistry will be discussed first, followed by a discussion of secondary dispersion from the mineralized volcanics.

Geology and Rock Geochemistry

A thin sequence of volcanic rocks, approximately 7,000 feet thick, lie between granitic rocks and meta-sedimentary rocks. The volcanic and metasedimentary rocks are of near vertical dip and strike north-north-west. The volcanic rocks are of relatively greater local relief (up to 100 feet) than the metasedimentary rocks (up to 30 feet). The relief of the granitic rocks is intermediate.

The main part of the volcanic succession is of intermediate composition, whereas the upper 1,500 feet is siliceous. Archean volcanic cycles typically become more siliceous from the stratigraphic base upwards. This and established knowledge of the succession in other parts of the Slave Province (McGlynn and Henderson, 1972) leaves little doubt that the volcanic sedimentary section at Agricola Lake becomes stratigraphically younger from west to east. The volcanic rocks are presumably the oldest deposited in this belt. The metasedimentary rocks are the typical Archean assemblage of argillites, siltstones and greywackes.

south of the Agricola Lake area. These gossans have been called the "A" horizon (Cameron and Durham, 1974).

The second zone of gossans, or "B" horizon, occurs within the volcanic succession at the contact between strata of dominantly intermediate composition and those of dominantly acidic composition. The horizon is thickest near the centre of the area shown in Figure 2, that is near soil samples 656 and 1118. Here too it is difficult to estimate the thickness of the unweathered iron-rich horizon, because it is thoroughly oxidized and the gossanous soils have been transported by solifluction processes. The thickness is estimated as no greater than 100 feet. This lens of maximum thickness is approximately 800 feet long. The gossans thin out rapidly north and south of this along strike and are replaced by exposures of thin iron- and silica-rich, beds in the volcanic rocks. To the west of the lens, or stratigraphically below it, there are hydrothermally altered rocks.

The nature of the primary mineralization underlying the thickest portion of the "B" horizon could not be determined because of the intensive oxidation. However, rock fragments containing pyrite and pyrrhotite have been brought up to the surface. North along strike, where the thinned-out horizon is exposed, chert, pyrite, pyrrhotite and calcite were identified and also traces of sphalerite.

The geological setting and characteristics of this "B" horizon leave little doubt that it is massive sulphide

Table 2. Index of hydrothermal alteration (Mg+Fe/Ca+Na) for rock samples, Agricola Lake area.

SAMPLE NUMBER	ROCK TYPE	Mg+Fe Ca+Na	SAMPLE NUMBER	ROCK TYPE	Mg+Fe Ca+Na
538	S	0.00	1021	S	0.00
539	V	0.27	1024	S	1.3
541	S	5.5	1025	S	13.0
542	V	2.6	1026	S	3.4
543	V	8.2	1027	S	4.8
544	V	0.31	1028	S	9.3
545	V	2.1	1029	V	0.16
546	V	1.2	1030	V	0.20
547	V	1.2	1031	V	0.17
549	S	4.3	1032	V	0.77
550	V	1.7	1033	V	7.5
551	V	2.0	1038	S	0.85
552	V	177.0	1039	S	8.4
554	V	127.0	1040	V	0.24
556	V	79.0	1041	V	0.21
558	V	3.7	1042	V	0.24
559	V	2.7	1043	V	0.22
560	V	0.50	1044	V	0.23
561	V	1.2	1045	V	0.95
562	V	0.26	1046	V	1.1
563	V	0.22	1047	V	3.3
567	S	2.2	1048	V	3.6
580	G	0.29	1049	V	0.99
581	V	0.88	1050	V	2.0
582	V	0.16	1051	V	1.4
583	V	0.63	1052	V	1.6
584	V	2.1	1053	V	1.5
585	V	1.6	1054	V	1.3
586	V	1.2	1055	V	1.3
587	V	4.6	1056	V	1.6
588	V	1.2	1057	V	1.4
589	V	116.0	1058	V	1.3
590	S	15.0	1059	V	1.2
649	V	0.18	1060	V	1.1
652	V	0.81	1061	V	0.99
655	V	83.0	1550	V	0.31
659	V	0.90	1553	V	0.56
661	V	2.2	1555	G	0.35
663	V	0.85	1556	G	0.30
665	V	1.1	1557	V	0.63
667	V	1.0	1558	V	0.00
669	V	0.18	1559	V	0.78
671	V	0.17	1568	S	0.00
673	V	0.72			

mineralization of volcanic-exhalative origin. The hydrothermally altered rocks in the footwall formed the feeder pipe for the ascending solutions. Sulphides were deposited in the Archean sea immediately above the pipe and a thinner exhalite horizon consisting of chert, iron sulphides and carbonate minerals were deposited farther out from the site of the submarine spring. After deposition of these exhalative sediments the siliceous hanging wall volcanics were deposited. The economic potential of this mineralization is completely unknown.

The chemistry of the rocks of this area can be examined by reference to the sample locations (Fig. 2c) and the major and trace element data given in Appendix A and Figure 2.

On the basis of the AFM diagram (Fig. 7) the vol-

canic rocks are of calc-alkaline composition. The volcanic rocks below the "B" horizon are of generally intermediate composition although there are more siliceous horizons and some sedimentary intercalations. Most of the samples of intermediate composition have an excess soda over potash; this is characteristic of Archean volcanics. The volcanics overlying the "B" horizon have SiO₂ contents mainly in the range 69-77%, with values to 84.5% SiO₂. Those immediately above the "B" horizon have an excess of potash over soda but the reverse is the case for the upper 1,000 feet, with total alkali contents in the range 7-8%.

CO₂ serves as an indicator of exhalative carbonate sediments. Values greater than 2% CO₂ are confined to the "B" horizon or to rocks immediately below the distal parts of this horizon. High Mn values are similarly distributed, with maximum values in the samples that are richest in CaCO₃. For these samples the Mn may be present in solid solution in calcium carbonate of exhalative origin. Similarly high Mn values were obtained from limey exhalative sediments sampled by the authors at Hackett River (Allan *et al.*, 1972). It should be noted that compared to the Hackett River area, limestones are very poorly developed in this area.

The rocks near the thickest portion of the "B" horizon exhalite show chemical effects attributable to hydrothermal alteration. Thus the Ca and Na in samples 552, 554, 556, 589 and 655 have been almost completely lost (Figure 2c; Appendix A). Al also appears to have been removed from some of the samples. One or more the components Fe, Mg, S and H₂O have been added to these altered samples. These chemical effects are characteristically found in the footwall volcanics of massive sulphides (e.g. Nilsson, 1968; Cameron, 1974b). The changes were caused by hot, chemically active solutions that passed through the footwall volcanics. As far as individual samples are concerned, this hydrothermal alteration is complex since some may show loss of one or more elements, but no noticeable addition of Fe or Mg, while for others there may have been addition of components with little loss of original material. Cameron (1974b) has therefore suggested that the ratio Fe+Mg/Ca+Na is a useful index of hydrothermal alteration associated with massive sulphides. This ratio should change with only partial metasomatism of samples. It is also moderately constant over the main range of unaltered calc-alkaline volcanics. For the volcanic rock samples from the Agricola lake area the value of this ratio is shown in Table 2. The highest ratios are found in rocks near the thickest portion of the "B" horizon exhalite with values to 177. For samples 1050-1061 the range 1.1-2.0 is typical of unaltered calc-alkaline volcanics of intermediate composition. The samples from the eastern part of this traverse (1040-1044) show lower values more typical of soda-rich siliceous volcanics. Since Ca and Na are also lost during rock weathering, the ratio Fe+Mg/Ca+Na tends to be higher in sedimentary rocks than in volcanics. Apart from the area of high values noted above, high ratios are found in samples 542-545, along strike to the south. The nature of these rock samples, which also have very high silica contents should be investigated further.

Turning to the trace elements, there are anomalous levels of Zn, Cu, and Pb in the rocks along or near the "B" horizon, with values to 1400 ppm Zn, 347 ppm Cu and 253 ppm Pb. Apart from this very obvious feature there are lesser anomalies in volcanic rock samples 546 and 547 and in shale 549. These samples which are on strike from each other, likely occur at another break in the volcanic succession, with exhalite development. It is of interest to note that along traverse 1040-1061, there are heavy metal peaks along strike from the "B" horizon (1049-1051) and also at samples 1059-1060 along strike from samples 546-549. Systematic sampling and analysis, such as along this traverse, can help to define favourable horizons for prospecting for massive sulphides. Field examination of the rocks along this traverse showed little of possible economic significance.

Cameron (1974a, 1974b) has shown that the S content of volcanic rocks, specifically the more siliceous varieties, may be an effective indicator of their potential for massive sulphide deposits. Thus, in barren sequences, only a fractional percentage (<5%) of siliceous ($\leq 68\%$ SiO_2) contain 0.1% or more S, compared to 25% or greater of samples from Noranda, Quebec, and High Lake, N.W.T. Both of these two areas contain Zn-Cu massive sulphides. This observation is confirmed by the volcanic rocks at Agricola Lake. Out of 32 samples with 68% SiO_2 or greater, 14 contain 0.1% S or more. The majority of these 14 are not close to the lensoid portion of the "B" horizon, and may be considered as "background" rock. In this area where there is good exposure and excellent secondary dispersion of ore metals, this further indication of potential for massive sulphides is perhaps superfluous. However, it assumes greater importance in other parts of the region and elsewhere in the Shield, where exposure and secondary dispersion is not as favourable.

Soil and Gossan Geochemistry

The soil sampling sites and analytical data are shown in Figure 2b. Soils were sampled at a depth of

Table 3. Zn, Cu, Pb, Ag, As and Au in soil samples from traverse 641-658, Agricola Lake area.

SOIL SAMPLE	Zn ppm	Cu ppm	Pb ppm	Ag ppm	As ppm	Au ppb
641	37	25	15	0.2	44	<5
642	67	44	10	0.2	309	5
643	31	31	20	0.2	239	<5
644	14	10	15	0.7	92	5
645	26	20	10	0.2	72	5
646	79	297	83	3.4	317	<5
647	112	206	271	3.1	92	10
648	47	116	2	0.2	7	5
650	136	856	1,370	23.0	145	80
651	26	56	206	4.7	13	20
653	141	163	189	0.2	28	5
654	42	450	12,600	41.0	890	810
656	126	189	259	3.1	7	25
657	93	158	644	11.0	22	60
658	75	38	25	1.0	12	<5

6-8 inches, generally from the centre of frost boils. Some of the samples are buff coloured and may be considered gossanous. The highest values for Pb and Ag were obtained where traverse 641-658 crosses the thickest portion of the "B" horizon. Traverse 1110-1118, taken along the strike of the "B" horizon, shows an increase in metal values as the gossan zone thickens. Traverses 660-672 and 2024-2033 do not show anomalies over the thinner lateral parts of this exhalite. The most northerly traverse, 2038-2061, does, however, show a weak anomaly for Pb and Ag over the presumed extension of the "B" horizon. There are lesser peaks for Zn, Cu, Pb, Ag and As at various sites along the "A" horizon. These anomalies are much weaker than those over the lensoid part of the "B" horizon.

Since preparing Figure 2, analytical data for Au have been obtained. These are shown for traverse 641-658 in Table 3. As anticipated Au closely parallels the distribution of Pb and Ag.

Our interpretation of these data is that the principal source of heavy metals is the massive sulphide mineralization in the "B" horizon near samples 654-657. Zn, Cu, Pb, Ag and As sulphides are present, along with Au. The richest concentrations of these metals are in the thickest portion of this exhalite, immediately above the alteration pipe. There has been active postglacial oxidation of this mineralization. The dispersion of metals from this oxidized zone may be, simplistically, predicted by the solubilities of their sulphates (Table 4). The most soluble sulphate, Zn, is almost entirely removed from the gossan and soils and is dispersed in solution throughout the drainage system. The least soluble sulphate, Pb, is very largely retained in the soils and is not dispersed in solution. In sample 654, it is present as the sulphates anglesite and plumbojarosite. Silver, being relatively insoluble is also retained in the soils. Copper behaves similarly to Zn, but it does appear to be less thoroughly leached from the soils above and downslope from mineralization. Arsenic is fixed in the iron-rich soils, but also shows some dispersion in the drainage system. As well as being associated with the "A" and "B" horizons, As is enriched in many of the soil and lake sediments overlying the slaty metasediments above the volcanic contact. It is presumed to be enriched in these slates.

Table 4. Solubilities of heavy metal sulphates

SULPHATE	SOLUBILITY IN g/100 ml
ZnSO_4	86.5 at 80°C
$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	96.5 at 20°C
$\text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$	117.5 at 40°C
CuSO_4	14.3 at 0°C
CuSO_4	75.4 at 100°C
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	31.6 at 0°C
Ag_2SO_4	0.57 at 0°C
AgSO_4	1.41 at 100°C
PbSO_4	0.004 at 25°C

Table 5. Distribution of metals between different size fractions of a soil overlying "B" horizon, Agricola Lake area.

SIZE FRACTION	OPENING mm	Zn ppm	Cu ppm	Pb ppm	Ag ppm	Fe percent
+ 10	> 2.0	23	138	9000	7.9	1.7
-10 + 20	2.0 - 0.84	22	138	9500	10.2	1.7
-20 + 35	0.84- 0.5	26	185	11667	10.2	2.2
-35 + 60	0.5 - 0.25	131	146	9000	10.2	1.7
-60 + 80	0.25- 0.18	373	162	20000	10.2	2.0
-80 + 250	0.18- 0.06	30	185	21338	10.8	2.2
-250	0.06	25	254	9500	12.5	2.8

The mechanisms for sulphide oxidation and metal dispersion in permafrost regions have been briefly reviewed by Cameron (1974b), with specific reference to the Agricola Lake area. Rather than repeat this discussion here, it is sufficient to say that the permafrost environment presents no serious handicap to oxidation of sulphide bodies and the wide dispersion of the derived salts.

A soil sample collected near sample 654 was separated into its different size fractions and analyzed by atomic absorption spectrometry following a hot $\text{HNO}_3\text{-HCl}$ (Table 5). While the distribution of Cu, Pb, Ag and Fe is relatively uniform there is a sharp peak in Zn in the -30 to +80-mesh fractions. This interesting feature is presently being studied. The data show that the middle size fractions are suitable for geochemical studies. This is a useful feature, since these fractions are more easily sieved under field conditions. For mineral exploration it may be quite suitable to use unsieved soils.

Lake Sediment Geochemistry

Drainage waters flow off the area of volcanic rocks that has relatively high relief, into and along the valley paralleling the volcanic/sedimentary contact. The flow direction is then eastwards across the area of sedimentary rocks. The pattern of metal distribution in lake sediments complements that shown by the soil data. The immobile elements, Pb and Ag, are virtually absent from these sediments. The mobile elements, Zn and Cu, derived by oxidation of massive sulphide mineralization, are widely dispersed along the Tooshort Lake-Agricola Lake system. It is informative to note the even distribution of Zn over several miles of drainage. It shows no peak near its presumed source. Copper is not so evenly dispersed, reaching values of 322 and 359 ppm in the lake samples closest to the source. Arsenic is also highly concentrated in this lake; perhaps, in large part, this is derived from the underlying slaty rocks. Unfortunately, sediment samples could not be obtained from the lake immediately north of sample 253 which is even closer to the "B" horizon gossan.

The breakdown of our pH meter prevented measurement of the acidity of this drainage system, but it is surmised that Zn and Cu are being transported initially in slightly acid waters. There are no limestone horizons or extensive development of organic material in the Tooshort Lake-Agricola Lake drainage, that might act as precipitation barriers to the wide dispersion of these components.

Turning now to the southern part of the Agricola Lake area, it may be observed that sample 259 (Fig. 2a) is the only lake sediment sample from the entire area that is highly anomalous for Pb and Ag. It is also anomalous for Cu and As, but not for Zn. This lake lies on the strike of the "B" horizon. The Pb and Ag have probably been derived in particulate form from the immediate vicinity of the lake. The low Zn content of the sample may be caused by a low pH in this lake. In the

northwestern arm of Friday Lake, down drainage from sample 259, highly anomalous values for Zn were obtained. These samples are also anomalous for Cu, but not for Pb or Ag. Farther east, anomalous levels of Zn and Cu persist in samples along the main drainage flow. Much lower values are found in samples from isolated bays (88, 261, 350).

Anomalous values for Zn and Cu are also found in lakes within the main volcanic sequence, west of the "B" horizon. These values may be related to other exhalative horizons. For instance, the lakes with anomalous samples 73 and 245 lie along strike from anomalous rock samples 546 and 547.

In reconnaissance sampling of the main drainage system of this area, it would indeed be difficult to avoid obtaining anomalous values, even at very wide sampling intervals. It is therefore pertinent to consider the causes for this widespread dispersion of ore metals. They are as follows:

1. Within the volcanic rocks of the area mineralization of volcanic-exhalative origin, rich in base metals, is extensively developed.
2. There has been active postglacial oxidation of this mineralization.
3. The area of volcanic rocks is of relatively higher relief than the adjacent area of metasedimentary rocks. This allows the widespread flow of drainage waters and their dissolved salts. The gradients are, however, generally too low to allow much dispersion of metals in particulate form through the drainage system.
4. The drainage systems of the area contain no important precipitation barriers, such as carbonate-bearing bedrock, or organic-rich bottom sediments or swamps which might restrict the dispersion of heavy metals in solution.

SANCTUARY LAKE AREA

On the basis of the 1972 survey results this area contained weaker and less extensive anomalies for the same elements as the Agricola Lake anomaly. The anomalous contours were largely based on the results from sample 3358 (Table 6). This area was chosen for detailed study partly because it was an example of this much weaker anomaly and partly because of the very notable development of gossans here. The area was

Table 6. Composition of anomalous lake sediment sample 3358 from Uist Lake compared to regional geochemical background.

Element	Sample 3358	Sheet 3, Bear Slave survey area. 1349 samples		Ratio 3358/G.M.
		Geometric mean (G.M.)	G.M. + 1 log standard deviation	
Li, ppm	35.	15.5	28.3	2.3
Be, ppm	1.9	1.5	2.1	1.3
Mg, %	1.2	0.66	0.96	1.8
K, %	2.3	1.86	2.28	1.2
Ca, %	1.4	1.22	1.49	1.2
Ti, %	0.33	0.32	0.395	1.0
V, %	92.	51.8	69.8	1.8
Cr, ppm	106.	62.2	91.4	1.7
Mn, ppm	338.	89.	154.	3.8
Fe, %	3.8	2.18	2.93	1.7
Co, ppm	30.	9.7	16.4	3.1
Ni, ppm	73.	23.3	42.7	3.1
Cu, ppm	41.	19.6	36.6	2.1
An, ppm	118.	31.8	58.1	3.7
As, ppm	5.9	2.3	6.7	2.6
Sr, ppm	209.	237.	283.	0.9
Y, ppm	24.	23.2	32.6	1.0
Zr, ppm	245.	273.	366.	0.9
Mo, ppm	1.7	0.55	1.5	3.1
Ag, ppm	0.4	0.39	0.53	1.0
Ba, ppm	632.	586.	750.	1.1
La, ppm	33.	35.9	52.	0.9
Hg, ppb	16.	11.2	20.	1.4
Pb, ppm	13.	12.9	16.	1.0
U, ppm	0.1	0.7	1.8	0.1

sampled for rocks, soils and gossans, and lake sediments in a similar manner to the Agricola Lake area. In Figure 3a the lake sediment sample sites and analytical data are shown and in Figure 3b the sample sites for rocks and gossans. A high density of samples were collected in the Ferric lake part of the area. These data are shown in Figure 4a-4c.

Geology and Rock Chemistry

The geology of the Sanctuary Lake area is quite similar to that found at Agricola Lake. Volcanic rocks of mainly intermediate and acidic composition lie between granitic and sedimentary rocks. Here, however, the volcanic rocks are much thicker - approximately 25,000 feet - and strike east-southeast. The sedimentary rocks lie to the south of the volcanics. Both are near vertically dipping. The area is cut by at least one prominent north-east fault and is more structurally complex than the Agricola Lake area.

As at Agricola Lake, the metasediments immediately above the volcanic contact are slates. These being softer also form a prominent depression running parallel to the volcanic contact and containing a chain of lakes. There is also a zone of gossans that may be followed along this contact throughout the area shown in Figure 3. They reach their maximum thickness on the north shore of Ferric Lake, where the iron-rich rocks may exceed 200 feet in thickness. Compared to the rather small and subdued gossans at Agricola Lake, these are very extensive and well developed. In terms

of visual expression they rival those of the Hackett River camp. This likely accounts for the fact that in the past some claim staking has taken place over the gossans. Since these gossans occur in the same stratigraphic position as the "A" horizon at Agricola Lake they will be referred to as the "A" horizon. There are also gossans developed within the main volcanic succession, north of Ferric Lake, and approximately 4,000 feet down from the "A" horizon. These, like the "B" level gossans at Agricola Lake, are quite limited in lateral extent. They are up to a few tens of feet thick and are best developed near samples 820-821 (Fig. 3b). For convenience they will be here referred to as the "B" horizon. This is not intended to convey any implication that they are stratigraphically equivalent to the "B" level gossans at Agricola Lake, although further study may show them to be so related.

At the time of writing this report (April, 1974), analysis of rock samples from this area is incomplete. Thus in Appendix B data are only given for Zn, Cu, Pb, and Ni. The available data confirm that the volcanic succession is of intermediate and acidic composition, with a few more basic samples near the base

of the succession. There is a tendency for the rocks to become more siliceous upwards. The ratio Fe+Mg/Ca+Na has been calculated for many of the samples. This shows that anomalous values are rare compared to the Agricola Lake area. Thus in the region of the "B" horizon gossans north of Ferric Lake there are only slightly anomalous values in the range 2-3. In the volcanics immediately below the "A" horizon at Ferric Lake there are more anomalous values, up to 65. This indicates intense hydrothermal alteration. Like the Agricola Lake area, soda exceeds potash in most of the volcanic rock samples. But, again like Agricola Lake, samples with an excess of potash over soda occur stratigraphically above the "B" horizon (samples 1197-1199, 611-613 and 602-604). Samples 614-615 are limey and contain 21.6% and 10.3% CaO respectively. These samples are also rich in Mn. This indicates that these samples likely contain carbonates of exhalative origin. They may be along strike from the "B" horizon gossans near samples 820-821.

The trace elements display background levels over most of this area. The only extensive zone of anomalous results is in the acidic volcanics and slates forming the north shore of Ferric Lake. Here Zn values in the range 100-5700 ppm were obtained along with anomalous values for Cu in the range 100-855 ppm and slightly anomalous values for Pb (10-58 ppm) and Ni (up to 111 ppm). The rocks in the area of the "B" horizon gossan (samples 820 and vicinity) are definitely not anomalous; but one half mile to the north samples 829-833 are anomalous for Zn and Cu. The metasediments

Table 7. Statistical data for volcanic rocks, Agricola Lake and Sanctuary Lake areas.

	Number of Samples	Arithmetic Mean	Standard Deviation	Geometric Mean	Median	90 Percentile	95 Percentile
Zinc, ppm							
Agricola Lake	70	122.	186.	76.	68.	233.	300.
Sanctuary Lake	154	76.	169.	50.	48.	115.	139.
Copper, ppm							
Agricola Lake	70	29.	47.	13.	13.	66.	94.
Sanctuary Lake	154	38.	61.	17.	19.	85.	109.
Lead, ppm							
Agricola Lake	70	17.	43.	5.3	2.	21.	71.
Sanctuary Lake	154	4.0	5.9	2.7	2.	10.	13.
Nickel, ppm							
Agricola Lake	70	47.	41.	28.	38.	101.	122.
Sanctuary Lake	154	48.	125.	23.	23.	96.	137.

(1628-1631) overlying the slates are anomalous for Zn with values up to 821 ppm. Finally, near the base of the volcanic succession, a sample of basic composition (1529) is highly anomalous for Cu (475 ppm) and Ni (1500 ppm).

In Table 7 statistical data for the volcanic rock samples from Sanctuary and Agricola Lakes are compared. Since the sampling of the two areas is greatly biased towards certain locations and stratigraphic levels, comparison of the two areas is not statistically valid. Bearing this in mind, Zn is rather more abundant in the Agricola Lake samples. For Cu, the samples from Sanctuary Lake have a higher content. For most of the samples from both areas Pb is below the detection limit. However, at Agricola Lake there is a much higher frequency of samples with amounts greater than the detection limit, namely 43% compared to 16% for Sanctuary Lake, and a higher average Pb content.

Soil and Gossan Geochemistry

Consider first the traverses along the volcanic/sedimentary contact shown in Figure 4b. Anomalous

base metal values are found in two principal areas, one on the north shore of Ferric Lake and the other immediately west of Sanctuary Lake. Red, gossanous soils are very extensive on the north shore of Ferric Lake, being 200 feet or more thick and up to 1,000 feet or more in length. Here again it is difficult to estimate the thickness of the primary iron-rich strata, but in places they must exceed 100 feet. These soils contain up to 820 ppm Zn and 437 ppm Cu. Pb and Ag are low compared to the Agricola Lake area, with maxima of 88 ppm and 9 ppm respectively. The maximum As value is 185 ppm. Gossan samples from immediately west of Sanctuary Lake contain the highest amounts of Pb (134 ppm), Ag (21 ppm), and As (212 ppm) found in this area. A prominent northeasterly-trending diabase dyke cuts the succession near samples 760 and 761. "A" horizon gossan samples from outside the limits shown in Figure 4 were taken. These sample sites are illustrated in Figure 3b and the chemical data in Table 8. Samples taken from the "B" horizon gossan (1621 and 1622, Fig. 4b) are decidedly lower in all base metals.

Table 8. Zn, Cu, Pb, Ag, As and Au content of gossans, Sanctuary Lake area (Fig. 3b).

SAMPLE NUMBER	Zn ppm	Cu ppm	Pb ppm	Ag ppm	As ppm	Au ppb
535	9	25	2	0.2	0.5	<5
537	11	25	2	0.2	4	15
1609	11	25	2	1.0	4	10
1610	6	16	2	0.2	11	10
1611	11	38	2	0.2	3	5
1612	18	29	2	1.0	1	130
1613	43	40	2	1.5	2	10
1614	15	30	2	0.2	0.5	<5
1615	12	21	2	0.2	2	<5
1616	95	77	2	0.2	4	<5
1623	10	26	2	0.2	4	<5
1624	95	178	2	1.0	15	5

Lake Sediment Geochemistry

The rock, soil and gossan data from the area described above show that there are at least two areas of anomalous base metal content. Both are within the "A" horizon. The first of these is along the north shore of Ferric Lake and the second along the northwestern shore of Sanctuary Lake. In Ferric Lake and the lake to its northwest, lake samples were obtained giving much higher values for Zn (to 762 ppm) and Cu (to 1167 ppm) than were obtained in the Agricola Lake area. In general, Zn and Cu are less evenly distributed in these two lakes than in the Tooshort Lake-Agricola Lake drainage. In part this may be related to the larger volume of Ferric Lake and its neighbours compared to the upper part of the Tooshort Lake-Agricola Lake drainage. This may cause low pH waters derived from sulphide weathering to be more rapidly diluted,

allowing precipitation of iron oxides with co-precipitation of Zn and Cu. However, there does appear to be good dispersion of Cu and particularly Zn into the outlet bay of Ferric Lake (sample 816) and through the main drainage flow of the lake to the south of Ferric Lake (samples 367, 216 and 366). Both Zn and Cu reach background levels before these drainage waters enter into Stockwell Lake (see samples 365 and 3354, Fig. 3a).

Samples taken from the western part of Sanctuary Lake are highly anomalous for Zn (to 643 ppm) and Cu (to 228 ppm) Figure 4a. Samples from lakes along the "A" horizon between Ferric Lake and Sanctuary Lake are also anomalous. There is widespread dispersion of Zn around Sanctuary Lake and practically all of the 13 samples taken from this lake (Fig. 3a and 4a) can be considered anomalous. Of particular interest is the anomalous value for the outlet bay (sample 141, Fig. 3a). Elsewhere on the "A" horizon samples are anomalous for Zn and Cu as far east as sample 153 (Fig. 3a). Stockwell Lake and Uist Lake, the large lakes to the south, in the main sedimentary sequence, have many samples close to background. Sample 198, near the northern inlet of Uist Lake, is anomalous as is the nearby sample 3358 collected in 1972. Elsewhere along the shores of Uist Lake and Stockwell Lake high Zn and Cu values may be caused by nearby sedimentary rocks richer than average in base metals. Many of the small lakes in the main volcanic sequence (Fig. 3a) have Zn and Cu levels in excess of the geometric mean results of 32 ppm Zn and

20 ppm Cu for Sheet 3, Bear Slave Operation. There are, however, few truly high results comparable to those found in lakes in the main volcanic sequence at Agricola Lake.

Conclusions, Sanctuary Lake Area

Zn- and Cu-bearing mineralization in the Sanctuary Lake area appears to be largely contained in the strata underlying the "A" horizon gossans. The "A" horizon exhalite, if it be exhalite, is not of the type generally associated with massive sulphide mineralization, since it is so extensively developed along this stratigraphic zone. As mentioned earlier in this report, these gossans can be found along the volcanic/sedimentary contact virtually everywhere within the Beechey Lake belt. The considerable thickness of iron-rich rocks at Ferric Lake may indicate that this is near the centre of volcanism from which the "A" horizon mineralization came. At Ferric Lake there is little Pb or Ag accompanying the Cu and Zn, but rather more of the former metals along the western shore of Sanctuary Lake. In the case of Zn-Cu mineralization that lacks Pb or Ag, it is difficult to evaluate the ore potential without drilling, since the Zn and Cu are leached from the overlying soils. For such mineralization Au is perhaps the best indicator element in soils, since it is less mobile. Although volcanic-exhalative mineralization is developed in the main volcanic sequence, below the "A" horizon, there is a general lack of base metal mineralization

within the area shown in Figure 3a. This is reflected in low to moderate levels of Zn and Cu in lake sediments and low contents of base metals in the rocks and gossans of the area. Also, rocks that have been severely altered by hydrothermal action have not been found within the main volcanic sequence. It is of interest that the impression given by the lake sediment data are confirmed by the data obtained from the rock samples.

CASEY LAKE ANOMALY

The sedimentary rocks exposed in the Agricola Lake and Sanctuary Lake areas are relatively unmetamorphosed. In the southwestern part of the Beechey Lake belt mapping by Wright (1957) and Tremblay (1971) has shown there is a transition into higher grade metamorphic terrain and the sedimentary succession is there represented by nodular schist. The nodules are composed of andalusite and cordierite (Tremblay, 1971).

The mapped contact between the nodular schists and granitic

Table 9. Composition of anomalous lake sediment sample 2950 from near Casey Lake compared to regional geochemical background.

Element	Sample 2950	Sheet 3, Bear-Slave survey area. 1349 samples		Ratio 2950/G.M.
		Geometric mean (G.M.)	G.M. + 1 log standard deviation	
Li, ppm	26.	15.5	28.3	1.7
Be, ppm	2.7	1.5	2.1	1.8
Mg, %	0.5	0.66	0.96	0.8
K, %	1.3	1.86	2.28	0.7
Ca, %	0.6	1.22	1.49	0.5
Ti, %	0.16	0.32	0.395	0.5
V, ppm	40.	51.8	69.8	0.8
Cr, ppm	50.	62.2	91.4	0.8
Mn, ppm	100.	89.	154.	1.1
Fe, %	3.7	2.18	2.93	1.7
Co, ppm	92.	9.7	16.4	9.5
Ni, ppm	219.	23.3	42.7	9.4
Cu, ppm	257.	19.6	36.6	13.1
Zn, ppm	413.	31.8	58.1	13.0
As, ppm	7.8	2.3	6.7	3.4
Sr, ppm	101.	237.	283.	0.4
Y, ppm	45.	23.2	32.6	1.9
Zr, ppm	223.	273.	366.	0.8
Mo, ppm	1.2	0.55	1.5	2.2
Ag, ppm	0.2	0.39	0.53	0.5
Ba, ppm	411.	586.	750.	0.7
La, ppm	61.	35.9	52.0	1.7
Hg, ppb	55.	11.2	20.0	4.9
Pb, ppm	8.	12.9	16.	0.6
U, ppm	1.8	0.7	1.8	2.6

Table 10. Distribution of trace elements in rock samples from Casey Lake area.

Sample Number	Contents in ppm			
	Zn	Cu	Pb	Ni
Volcanics				
504	143	114	2	93
505	510	184	13	132
506	171	15	13	58
508	357	167	2	121
509	118	102	2	120
510	132	338	33	94
511	189	130	25	118
1506	350	166	2	129
1507	362	120	2	114
1508	698	244	2	114
1509	225	125	2	129
520	168	114	13	101
519	114	23	2	52
513	107	102	13	118
1502	500	189	2	35
768	500	138	8	109
766	108	50	12	106
524	91	26	25	64
Schists				
500	125	44	13	76
501	66	15	25	40
502	69	23	13	59
503	78	26	2	73
512	75	9	33	55
1505	75	52	2	86
786	57	34	12	33
784	84	63	2	43
782	79	28	12	69
780	78	34	17	74
778	59	38	17	28
776	65	22	8	31
774	81	72	8	85
772	67	22	12	40
770	68	91	17	51
Granites				
507	22	8	33	2
518	32	4	29	5
517	36	4	13	5
516	36	4	19	5
515	53	4	25	2
514	25	4	33	2
523	19	4	29	5
522	46	8	25	5
521	53	4	33	5

terrane passes along a southeasterly trend through Casey Lake. Sample 2950 was collected in 1972 from a small lake approximately 2,000 feet southwest of Casey Lake. This sample is highly anomalous for many of the elements that were anomalous at Agricola Lake (Table 9). Note, however, that it is not anomalous for Mg and K.

In order to interpret this anomaly lake sediment, soil, and rock samples were collected from the immediate vicinity of this unnamed lake. These data are shown in Figures 5a and 5b. Our brief sampling work in this area showed a thin succession of intermediate and basic

volcanic rocks lying between the schists and the granites. The distribution of these different units may be gauged from the sample identifications shown in Figure 5b. The granite is coarse grained and bears an intrusive relationship to the volcanic rocks. Its contact is highly irregular. The schists are more siliceous in composition than the volcanic rocks. It is possible, but not probable, that they are metamorphosed acidic volcanics. They have the appearance of metamorphosed sediments.

In Table 10 the trace element contents of the three groups of rocks are given. The granites have very uniform abundance of trace elements and except for Pb, are rather low in these elements. The sedimentary samples have uniform and moderate amounts of all four trace elements. The volcanic rocks, on the other hand, have an unusually high background level of Zn and a generally high level of Cu. Compare the data in Table 10 to the mean content of Zn of 70 ppm, 70 ppm and 67 ppm for basic, intermediate and acidic rocks from Noranda (Cameron, 1974). In comparison, the Agricola Lake volcanic samples have a lower average level of Zn and Cu, but a greater spread of values. At Agricola Lake these elements give the impression of having been concentrated in certain parts of the succession, while at Casey Lake the metals are dispersed. At Casey Lake there are no high values for Pb comparable to those measured at Agricola Lake. The impression of uniform dispersion given by the trace element distribution in the Casey Lake volcanic samples is confirmed by their mineralogy. Pyrite and pyrrhotite with traces of chalcopyrite and sphalerite can be found dispersed through many of the samples, but we found no concentrations in any of the rocks of the latter two minerals.

Turning now to the soil analyses (Fig. 5a) we found no unusual concentrations of Zn, Cu, Pb, Ag or As. The lake sediment samples show some anomalous concentrations for Zn and Cu on the southwestern side of the unnamed lake, flanking the volcanic rocks. No samples were found with element values as anomalous as the 1972 sample 2950.

We interpret the lake sediment anomaly discovered in the 1972 survey as being caused by volcanic rocks with a high background level of Zn and Cu. There is very limited distribution of Zn and Cu in the drainage system of this area. This is probably due to the absence of any large masses of sulphides which, on oxidation, would lower the pH of the local groundwaters and lake waters and supply large amounts of metals. The present knowledge of the relation of trace metal distributions within volcanic rocks to their ore potential is fragmentary. Bearing this in mind, we would suggest that the rather even distribution of Zn and Cu in these intermediate and basic volcanic rocks is not indicative of concentration processes that might lead to ore formation. More intriguing is the question of the ore potential of acidic volcanics which may, in places, be associated with such metal-rich intermediate and the basic volcanics.

Table 11. Distribution of trace elements in rock samples from near Malley Rapids.

SAMPLE NUMBER	Zn ppm	Cu ppm	Pb ppm	Ni ppm
1573 (Granite)	97	12	2	25
1574	59	23	2	73
1576	49	8	25	65
1577	61	25	25	42
1578	72	31	33	92
1579	54	38	13	77
1580	71	67	25	69
1581	60	27	33	19
1582	65	129	2	96
1583	71	17	2	85
1584	111	52	2	96
1585 (Granite)	52	6	13	6

OTHER ZINC-COPPER ANOMALIES

Hackett River

This locality contains an undeveloped massive sulphide deposit (the Camp Lake deposit) with an estimated 10M tons of 8% combined Pb-Zn and 9 oz/ton Ag. Other prospects are being drilled in the area, including the Cleaver Lake zone. A cluster of samples were collected from the Hackett River area in 1973. The analyses for Cu and Zn in these samples are shown in Figures 1a and 1b respectively. The area is located near the northern boundary of the region illustrated in Figure 1. In this figure the Camp Lake deposit is located close to the sample containing 219 ppm Cu and 126 ppm Zn, and the Cleaver Lake zone near the sample with 656 ppm Cu and 875 ppm Zn.

Compared to the Agricola Lake drainage, there is relatively restricted dispersion down-drainage from these highly anomalous sediment samples. Lake sediment sample from outside the immediate area of mineralized rocks have low to moderate levels of Cu and Zn.

The Hackett River mineralization occurs in siliceous volcanic rocks and sediments that have a low median content of base metals (Allan *et al.*, 1972). This probably accounts for the low level of these elements in lake sediment samples from outside the area of mineralized volcanics. In the absence of any data on the physico-chemical composition of the groundwaters and lake-waters, it is difficult to arrive at firm conclusions about the limited dispersion of Zn and Cu in drainage waters. It is certainly not because of a lack of oxidation. The Hackett River camp has, perhaps, the most extensive and striking development of gossans found in the Slave Province. Perhaps the most likely explanation lies in the thick limestones of exhalative origin found at Hackett River. Such limestones may neutralize acidic groundwaters and lakewaters derived from oxidizing sulphides. This may cause the precipitation, or co-precipitation with iron oxides, of base metals dissolved in the drainage waters.

East of Agricola Lake

In 1972 a base metal anomaly was found in the lake approximately 6 miles east of Agricola Lake. This sample contains 146 ppm Cu and 162 ppm Zn. In 1973 there was difficulty in obtaining other samples from near this anomalous site. However, three samples were obtained from adjacent lakes containing 207, 158 and 52 ppm Cu and 97, 125 and 55 ppm Zn (Fig. 1). The area has not been traversed on foot, but on the basis of low passes in the helicopter during lake sampling, the bedrock is believed to be mainly argillite and greywacke. There appears to be a small intrusive body south of the sample registering 158 ppm Cu. Note that this anomaly cannot have been caused by drainage eastwards from the Agricola Lake area. Since there is a general absence of transported glacial sediments in the area, the anomaly is not likely to be derived from this material. In any event glacial transport was northwest (Tremblay, 1971).

In the Slave Province, volcanic rocks are believed to have been mainly a marginal facies of the sedimentary-volcanic belts (McGlynn and Henderson, 1972). The volcanics grade into sedimentary rocks towards the axis of the belts. In view of their mode of origin, exhalite horizons should continue across such facies boundaries. If exhalites are found within the Agricola Lake volcanics it is reasonable to expect the distal facies of these in the sedimentary rocks of the axial portion of the Beechey Lake belt. This may account for the anomalous values noted above that occur east of Agricola Lake. This can only be resolved by ground traversing and sampling. It should be noted that the interruption in the deposition of volcanic rocks during which exhalites formed need not be matched by an equivalent halt in sedimentation within the axial portion of these belts. Thus, some exhalite horizons in volcanic rocks may be stratigraphically equivalent to moderate thicknesses of metal-rich strata. In Figure 1, the reader may discern other anomalous sites towards the axis of the Beechey Lake belt, for which the above explanation should be also considered.

North of Malley Rapids

The granites to the north of Malley Rapids are fringed by rocks mapped as metasedimentary (Wright, 1957; Tremblay, 1971). The area of metasediments to be considered lie just outside Tremblay's zone of cordierite-andalusite-staurolite-bearing schists. Anomalous values of 107, 104 and 118 ppm Cu and 135, 81 and 164 ppm Zn were found in the area in 1972 (Fig. 1). Limited resampling in 1973 confirmed this anomaly. The most anomalous sites occur along a slight valley feature trending northwest. The Zn values 153, 295, 164, 282 and 135 and Cu values 60, 172, 118, 215 and 107 (Fig. 1) come from different sites along this valley. The feature runs parallel to the strike of the schistose rocks and may be stratigraphically controlled. It can be traced in a southeasterly direction towards Casey Lake.

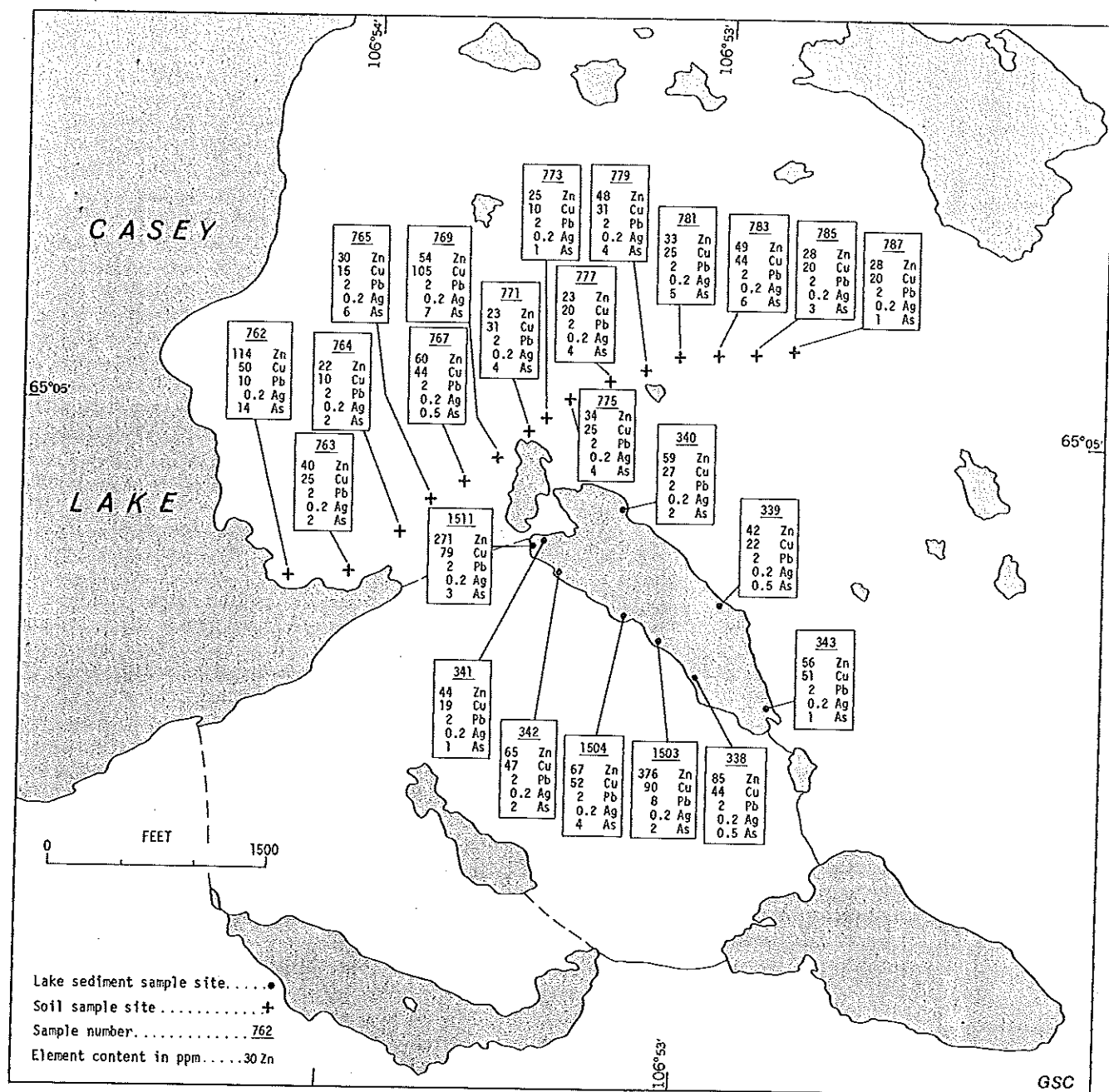


Figure 5a. Lake Sediment and Soil Analyses, Casey Lake Area, Northwest Territories.

A sampling traverse was made from the Malley Rapids granites northeastwards across the schistose rocks to another granitic body at sample 1585 (Fig. 6). The southern part of this traverse is across an area of moderately high aeromagnetic intensity and relief. Despite this, the schistose rocks do appear to be of sedimentary origin. The second half of the traverse from the valley feature north, is underlain by bedrock of more problematical origin. In part, at least, these rocks may be metavolcanic, but identification is difficult.

The rock samples collected along this traverse, contain no unusual base metal values (Table 11), cer-

tainly insufficient to account for the lake sediment anomaly along the valley feature. Neither can the anomalous values be explained by secondary dispersion along the valley from a single source. The samples containing 153 and 295 ppm Zn are not on the same drainage system as the samples with 164, 282 and 135 ppm Zn. At present our only explanation of these anomalous samples is that the valley feature is formed by a less resistant stratigraphic zone, which may contain scattered mineralization similar to that of the "A" horizon described for the Agricola Lake and Sanctuary Lake areas.

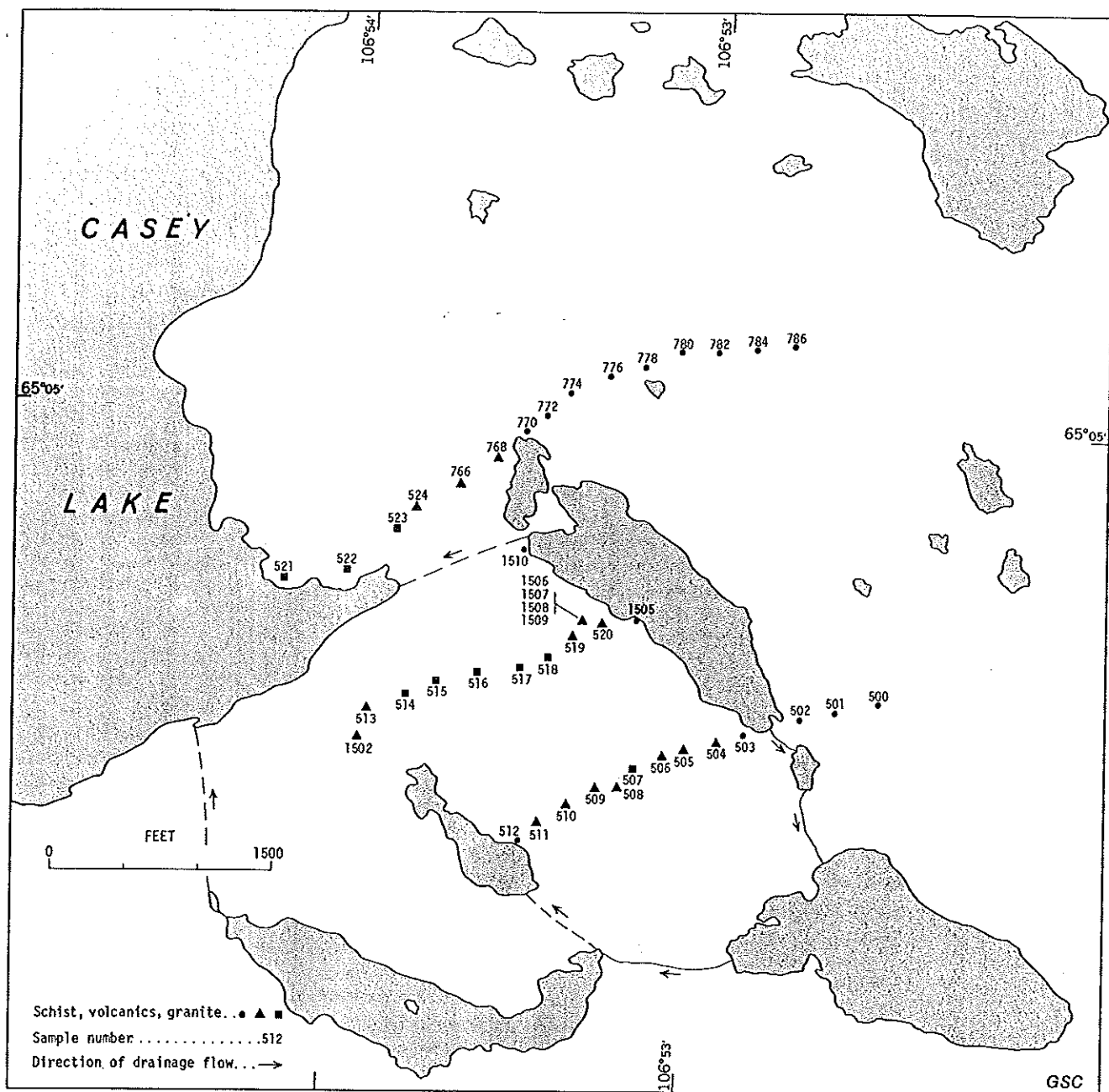


Figure 5b. Rock Sample Sites, Casey Lake Area, Northwest Territories

LINEAMENT LAKE ANOMALY

The Lineament Lake anomaly is perhaps the most visually striking of the element anomalies within Sheet 3 of the Bear-Slave survey area (Allan and Cameron, 1973a-1973g). It is defined by the 2 ppm U contour and rises to a maximum of 70 ppm U. The anomaly occupies an area of approximately 300 square miles within granitic terrane. It is made up of 30 lake sediment samples containing 3 ppm U or greater. The Lineament Lake anomaly is striking because most of the remainder of Sheet 3 has a uniformly low U content. For this sheet

the arithmetic mean of the 1349 lake sediment samples collected in 1972 is 1.3 ppm U and the geometric mean is 0.7 ppm. These values are in accord with the low level of abundance of U in Archean rocks of the Canadian Shield as documented by Eade and Fahrig (1971). An interesting feature is that the anomaly correlates with a regional gravity low (Hornal and Boyd, 1972).

The two most anomalous samples from this area are listed in Table 12 and compared to the geometric mean element values for Sheet 3. While U is the most anomalous element in these samples they are also anomalous for a number of other metals.

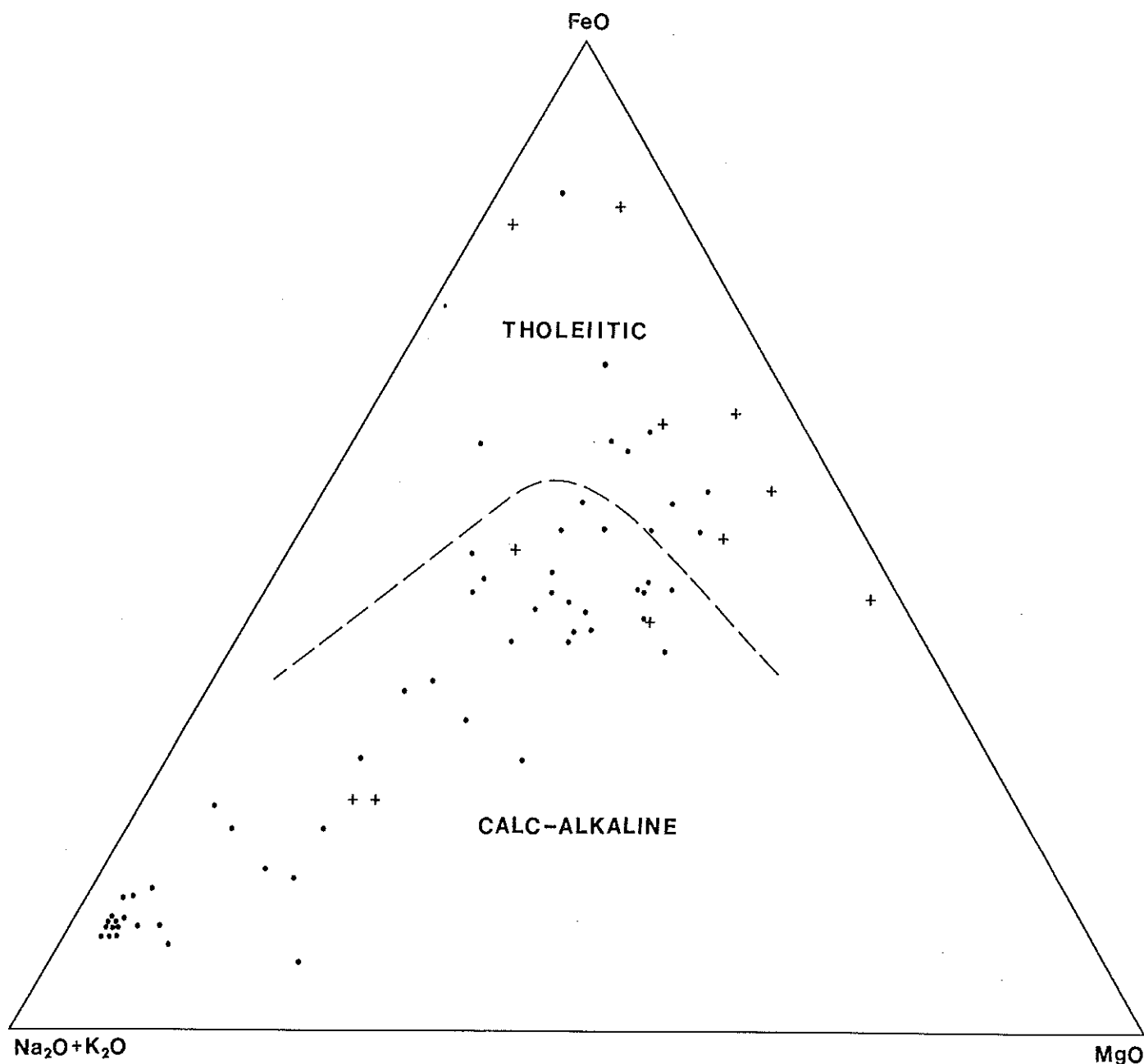


Figure 7. AFM diagram of volcanic rock samples, Agricola Lake area Northwest Territories. Crosses show samples with $(Mg+Fe/Ca+Na)$ greater than 3, indicating possible hydrothermal alteration.

In the 1973 follow-up studies, field work was restricted to sampling of bedrock within and outside the anomalous area and to scintillometer traverses on the ground. The location of the rock sampling traverses and the analytical data for these samples are given in Figure 6.

The scintillometer measurements showed that the granitic rocks within the area of the anomaly had a total count radioactivity approximately two times that measured outside the anomaly. In the course of these limited scintillometer traverses no radioactive veins were located or other unusual concentrations of radioactive elements. In places there was a noticeable, but not marked, increase in radioactivity over joints in

granites. The chemical determinations of the rock samples (Fig. 6) confirm the approximately two-fold increase in the U content of the granites within the anomalous area, compared to those outside. Zn is not notably enriched in the rocks of the anomaly, but they do contain higher concentrations than are present in the Agricola Lake granites (Appendix A). The mean Pb content of some of the traverses is also substantially higher than for the Agricola Lake samples. The granitic rocks of this region are potash-rich.

On the basis of the data given in Figure 6 it appears that the Lineament Lake anomaly is, in part at least, caused by higher background levels of U in the granitic bedrock. Whether the U anomaly also reflects the

Table 12. Composition of anomalous lake sediment samples 746 and 3313, Lineament Lake area compared to regional geochemical background.

Element	Sample 746	Sample 3313	Sheet 3, Bear-Slave survey area. 1349 samples		Ratio 746/G.M.
			Geometric Mean (G.M.)	G.M. + 1 log standard deviation	
Li, ppm	37	60	15.5	28.3	2.4
Be, ppm	4.1	2.4	1.5	2.1	2.7
Mg, %	0.5	1.0	0.66	0.96	0.8
K, %	1.7	2.5	1.86	2.28	0.9
Ca, %	0.5	0.6	1.22	1.49	0.4
Ti, %	0.16	0.23	0.32	0.395	0.5
V, ppm	40	69	51.8	69.8	0.8
Cr, ppm	63	93	62.2	91.4	1.0
Mn, ppm	100	253	89	154	1.1
Fe, %	2.0	3.7	2.18	2.93	0.9
Co, ppm	6	34	9.7	16.4	0.6
Ni, ppm	32	72	23.3	42.7	1.4
Cu, ppm	73	93	19.6	36.6	3.7
Zn, ppm	227	158	31.8	58.1	7.1
As, ppm	3.2	12	2.3	6.7	1.4
Sr, ppm	90	101	237	283	0.4
Y, ppm	60	67	23.2	32.	2.6
Zr, ppm	223	276	273	366	0.8
Mo, ppm	3.2	2.3	0.55	1.5	5.8
Ag, ppm	0.2	0.3	0.39	0.53	0.5
Ba, ppm	330	440	586	750	0.6
La, ppm	192	93	35.9	52	5.4
Hg, ppb	49	25	11.2	20	4.4
Pb, ppm	25	20	12.9	16	1.9
U, ppm	70	35	0.7	1.8	100

presence of discrete concentrations of U-rich minerals is not known. It has long been recognized that U mineralization is often found in areas where one or more of the rock units have a high background content of this element.

In the case of this anomaly, the possible role of organic material in determining the anomalous trace metal content of the lake sediment samples should be considered. This is because the two samples most anomalous for U also have a relatively high content of organic carbon as determined by the optical density of an acid leach of the samples (Lynch et al., 1973). The sequestering action of organic compounds on certain metals can cause their enrichment in lake sediments. It is our belief that in northern Canadian lakes such processes may enhance anomalies, but rarely create false anomalies of any magnitude. This is because a source of the metal in solution is required before concentration can take place. For the same reasons only a fractional percentage of carbonaceous shales contain high concentrations of base metals.

The Lineament Lake anomaly is soundly based on a large number of samples, of low to moderate organic content. The modest correlation coefficient of 0.47 (for log transformed data, Table 13) indicates that within the anomaly there may be some local enhancement of U by organic material. On average, the lake sediments from the anomaly have a higher average optical density reading than Sheet 3 as a whole. However, this is not a high level, the geometric mean content of 0.03 being equivalent to a percentage weight loss,

120-800°C, of 4% (Lynch et al., 1973). Increases in organic content at this low level may be related to increased nutrient contents over the granite (e.g., higher K or P).

Much less extensive anomalies for uranium are found in granites near Malley Rapids and over the granite plug at 65°25'N, 197°30'W. The anomalous sample from the latter area collected in 1972 was anomalous for Zn and further samples collected in this area in 1973 are shown to be anomalous for Zn (Fig. 6).

CONCLUSIONS

Three anomalies in lake sediments for Zn, Cu and associated elements, which were discovered during the 1972 reconnaissance, have been studied in detail. For two of these—one in the Agricola Lake area and the other in the Sanctuary Lake area—the anomalies have been shown to be caused by

exhalative-type mineralization in previously unreported volcanic rocks. These calc-alkaline volcanics are intermediate to acidic in composition. In the case of the third anomaly from near Casey Lake, the anomaly is not extensive and has been caused by disseminated sulphide mineralization in volcanic rocks of intermediate to basic composition.

Lake sediments were sampled across a 1500-square-mile-area along the western margin of the Beechey Lake sedimentary-volcanic belt, thus repeating a part of the 1972 Bear-Slave reconnaissance survey, but using different lakes. For Zn, Cu and associated metals this showed (Fig. 1):

1. Extensive (multiple sample) anomalies discovered in 1972 were in every case confirmed by additional sampling.
2. Some single sample anomalies were confirmed and shown to be more extensive with similarly anomalous values in adjacent lakes.
3. Other single sample anomalies (such as Casey Lake) were shown to be quite restricted in size, being confined to one lake or to part of a lake.
4. No major anomalies were discovered during the 1973 resampling that had not been located in 1972.

It may therefore be concluded that the sampling method and the one per 10 square mile sampling interval

Table 13. Covariation of U and organic content (as optical density) for lake sediment samples, Lineament Lake area.

SAMPLE NUMBER	U, ppm	OPTICAL DENSITY
746	70	0.158
747	30	0.030
748	9.0	0.010
749	4.5	0.003
750	28	0.063
751	3.5	0.025
752	6.0	0.060
761	8.5	0.055
764	5.0	0.138
765	6.0	0.040
766	12	0.018
775	10	0.033
776	6.5	0.033
777	4.5	0.023
779	8.0	0.033
780	3.3	0.003
890	4.0	0.020
3296	3.0	0.025
3301	7.5	0.075
3302	17	0.070
3304	20	0.050
3305	6.8	0.065
3306	20	0.110
3308	4.8	0.010
3309	19	0.075
3310	11	0.001
3311	24	0.045
3312	60	0.060
3313	35	0.150
5086	7.0	0.020
Arithmetic Mean	15.1	0.050
Geometric Mean	10.2	0.032
Correlation coefficient for log transformed data	0.47	
Geometric Mean, Sheet 3, Bear-Slave survey area, 1349 samples	0.7	0.011

used for the 1972 Bear-Slave Operation is satisfactory. Wherever possible, samples should be taken from the outlet bay of moderately sized lakes ($\sim 1/5$ square mile). Other isolated bays in moderate to large sized lakes may reflect mainly the composition of the bedrock near the bay. Also, the lakes chosen for reconnaissance sampling should, where possible, be part of a clearly defined drainage system.

The apparent success of lake sediment geochemistry in this area stems from the following conditions:

1. Where massive sulphide mineralization is present this exhalative-type mineralization is extensively developed along stratigraphic contacts in the volcanic rocks. Thus, anomalous levels of ore and indicator metals are not confined to one or more relatively small massive sulphide bodies.
2. Postglacial oxidation has been active. This has caused the chemical separation of the chemical components of sulphide mineralization. For massive sulphide mineralization, the relatively mobile Zn and Cu are carried away in solution to the lakes, while the less mobile Pb, Ag and Au are retained in the soils overlying the sulphide bodies. This allows the Zn and Cu content of lake sediments to be used for reconnaissance, wide interval sampling and the Pb, Ag and Au for detail follow-up work.
3. Glacial drift is generally thin throughout this part of northern Canada (Tremblay, 1971) and poses no serious problem to geochemical exploration.
4. The volcanic rocks, which are host to massive sulphide mineralization, have a higher relief than adjoining areas of sedimentary rocks. Dispersion of metals in solution is therefore wide. The relief is not, however, sufficient for more than limited transportation of ore metals (such as Pb, Ag or Au) in particulate form.
5. Precipitation barriers, such as limestones or organic-rich muds, are generally absent in the drainage systems. This favours the wide dispersion of many metals in solution. Where such barriers are present, as in the area of the Hackett River massive sulphides, dispersion of metals is more restricted.

Volcanic rocks are well exposed in this region and provide an excellent opportunity for studies of primary dispersion around ore bodies. This may provide a further basis for geochemical exploration in parts of the Shield where secondary dispersion is not as well developed and for the discovery of deep ore deposits.

PETROGRAPHY OF ROCKS FROM THE AGRICOLA LAKE AREA

by

Mariette Turay

INTRODUCTION

The following description and interpretation is based on the microscopic examination of 62 rock samples chosen from those shown in Fig. 2c. The names attributed to the different rock types are principally based on the chemical analyses (Appendix A) because metamorphism has changed the original mineralogical composition of the rocks. A density contouring of $\text{Al}_2\text{O}_3/\text{SiO}_2$ plots (Ridler, 1973) is shown in Figure 8. It shows two main populations: one rhyolite and the other andesite-dacite. The low aluminous rhyolite is less common and may represent recrystallised sediments of volcanic origin. Photomicrographs of typical volcanic rocks from the area are shown in Figure 9. We are indebted to R. Ridler and J. Maley for the plot shown in Figure 8.

Volcanic rocks

The lower part of the unit in contact with granite is of andesitic and dacitic composition. In texture and composition the samples do not differ noticeably from other intermediate volcanics located higher in the succession. Microscopically they are fine to medium grained and their texture is mainly intersertal (fig. 9d). The Ca-rich plagioclase is twinned and more or less altered to sericite. The hornblende can occur as small and acicular crystals or in aggregates or as coarse irregular grains (fig. 9a). There is little or no interstitial quartz and biotite and chlorite are present only in finely granular rocks in which the quartz is more abundant in vacuole-like aggregates. Opaque minerals, apatite and sometimes sphene are accessory.

The andesites and dacites of the upper half of the succession are very similar though several samples have additional calcite, in vacuoles with quartz or in veins or disseminated throughout the rock (sample 558, 659, 663, 1041, 1055, 1058). Calcite is particularly abundant in sample 1049 (fig. 9b).

As one nears the "B" horizon several samples show a high content of iron sulphide (30-40%) as pyrite and pyrrhotite in a fine grained quartz-rich rock. Some of these samples also contain talc and chlorite (samples 559 and 589). In this hydrothermal alteration zone one also finds greenschists, composed of fine grained quartz, chlorite, talc, sometimes epidote (552, 554, 1057, 1058). These greenschists are poor in opaque minerals.

The degree of lineation, schistosity, varies from sample to sample in the intermediate volcanics.

Above the gossan horizon the succession becomes more and more acidic and consists of porphyritic dacites

to rhyodacites and rhyolites. They contain euhedral phenocrysts of feldspar, mainly plagioclase, that is often altered; rounded and irregular phenocrysts of quartz, in a matrix of similar composition with a few clusters of biotite, and small amounts of opaque minerals.

Microscopically, samples 652, 661, 1038 and 1045 appear to be sedimentary rocks of volcanogenic origin. These rocks are fine grained, subequigranular to almost porphyritic. Some other samples (1047, 1048) are texturally very similar to porphyritic dacites, but their chemical composition, with higher Si and K, is similar to these sedimentary rocks.

Granite

The granite in contact with the lower part of the volcanic succession is characterized by coarse and irregular crystals of quartz (35%) and feldspar (60%), plagioclase and microcline. Other minerals are biotite, secondary chlorite, sometimes sphene, and accessory opaque minerals. The samples have a micrographic texture.

Conclusion

The andesitic-dacitic-rhyolitic succession is a typical metavolcanic unit. Because of its metamorphism to greenschist or low amphibolite facies it is sometimes difficult to distinguish the original mode of emplacement of the rock. The porphyritic rhyodacites and rhyolites may be intrusive or extrusive. However, the presence of flow structure in the mica-rich matrix of some of the specimens (fig. 9c) shows that at least part of it was extrusive (sample 1047, 1048).

Similarly, the andesitic-dacite fine-grained rocks do not always preserve much of their original texture and could easily be confused with dykes. However, some specimens show an intermediate degree of recrystallization and the fine-grained matrix, and the quartz-rich vacuoles favour an extrusive origin also (sample 1060). Beside the quartz-filled vacuoles and a few quartz veins there is no evidence of silicification, and in any case no replacement by quartz. Nor is there any extensive brecciation in the volcanics.

The iron-rich specimens near the "B" gossan horizon and the calcite-rich samples nearby are characteristic of a sulphide facies and carbonate facies of an exhalite zone in felsic volcanics. Also typical is the alteration zone or "pipe" (552-554, 556) where rocks are leached of much of their silica, and alkali, and considerably enriched in Fe, Mg, Zn and Pb. The graphitic slates are also of common occurrence near those volcanic centres.

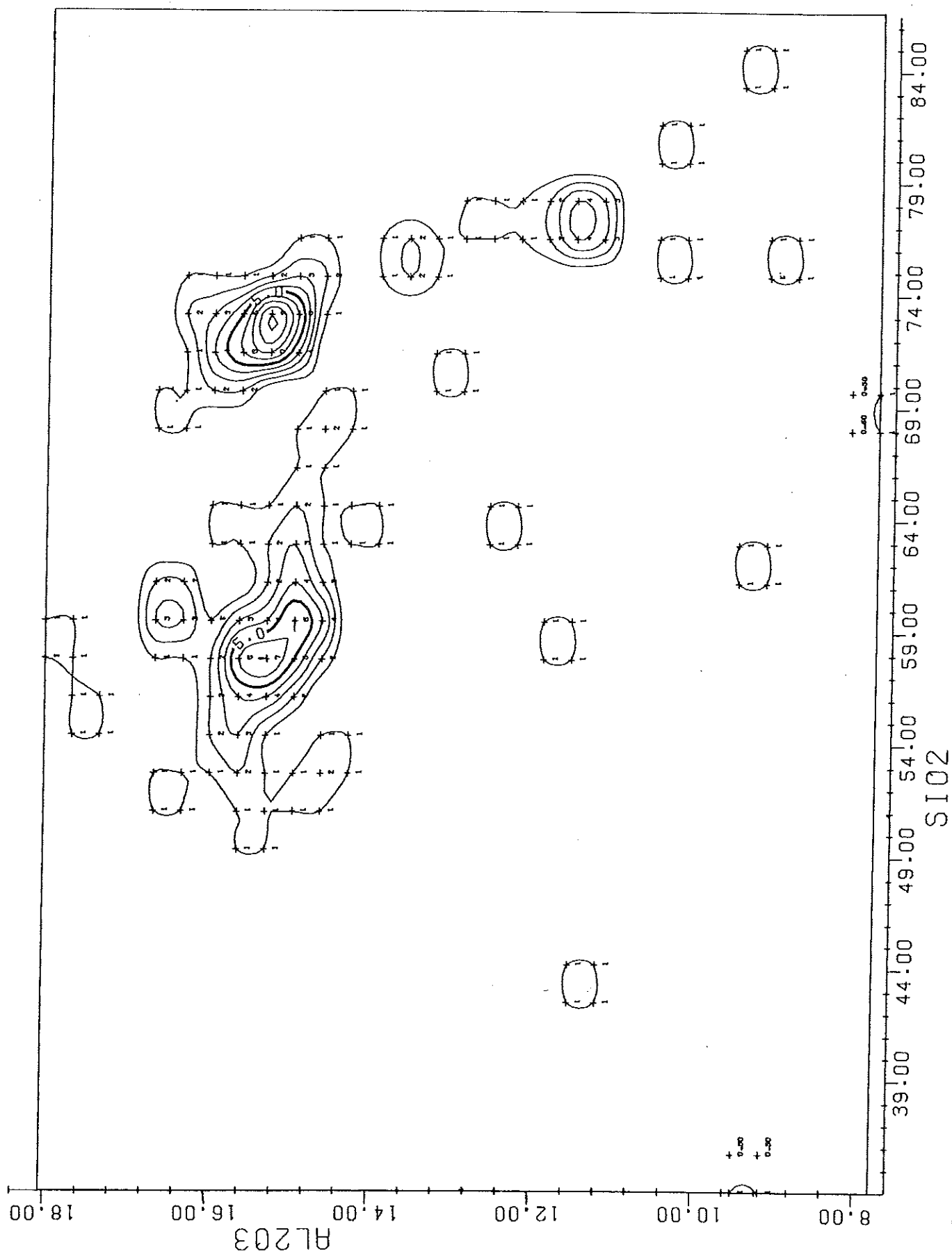


Figure 8. Silica versus alumina plot, Agricola Lake volcanics Northwest Territories.

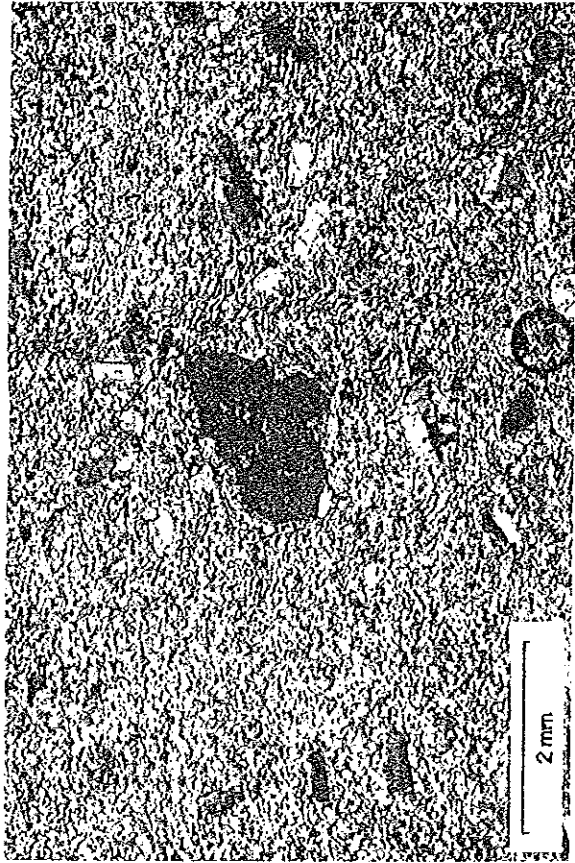
Figure 9. Photomicrographs of volcanic rocks Agricola Lake area.



a. Partly recrystallized andesite-dacite (No. 1060) Crossed nicols. 202520-A.



b. Carbonate facies of the exhalative zone (No. 1049) large calcite crystals with fine-grained amphibole-feldspar. Plane light. 202520-D.



c. Mica showing some flow alignment around the plagioclase phenocrysts (No. 1048). Crossed nicols. 202520.



d. Intersertal structure in andesite (No. 581) Plane light. 202520B.

REFERENCES

- Allan, R. J. and Cameron, E. M.
 1973a: Uranium content of lake sediments, Bear-Slave Operation, District of Mackenzie; Geol. Surv. Can., Map 9-1972 (3 sheets).
 1973b: Zinc content of lake sediments, Bear-Slave Operation, District of Mackenzie; Geol. Surv. Can., Map 10-1972 (3 sheets).
 1973c: Lead content of lake sediments, Bear-Slave Operation, District of Mackenzie; Geol. Surv. Can., Map 11-1972 (3 sheets).
 1973d: Manganese, iron and organic content of lake sediments, Bear-Slave Operation, District of Mackenzie; Geol. Surv. Can., Map 12-1972 (3 sheets).
 1973e: Copper content of lake sediments, Bear-Slave Operation, District of Mackenzie; Geol. Surv. Can., Map 13-1972 (3 sheets).
 1973f: Nickel content of lake sediments, Bear-Slave Operation, District of Mackenzie; Geol. Surv. Can., Map 14-1972 (3 sheets).
 1973g: Potassium content of lake sediments, Bear-Slave Operation, District of Mackenzie; Geol. Surv. Can., Map 15-1972 (3 sheets).
- Allan, R. J., Cameron, E. M. and Durham, C. C.
 1972: Lake geochemistry--a low sample density technique for reconnaissance geochemical exploration of the Canadian Shield; Geochem. Exploration, 1972, Proc. Int. Geochem. Explor. Symp. 4th 1972, 131-160. Ed. Jones, M. J., Inst. Mining Met., London.
 1973: Reconnaissance geochemistry using lake sediments of a 36,000-square-mile area of the Northwestern Canadian Shield; Geol. Surv. Can., Paper 72-50, 70 p.
- Bouvier, J. L., Sen Gupta, J. G. and Abbey, S.
 1972: Use of an "automatic sulphur titrator" in rock and mineral analysis: determination of sulphur, total carbon, carbonate and ferrous iron; Geol. Surv. Can., Paper 72-31, 22 p.
- Cameron, E. M.
 1974a: Sulphur in Archean volcanic rocks of the Canadian Shield; Geol. Surv. Can., Paper 74-18, 9 p.
- Cameron, E. M. (cont'd)
 1974b: Geochemical methods of exploration for massive sulphide mineralization in the Canadian Shield. Proc. Fifth Int. Geochem. Explor. Sym., Vancouver, 1974 (in press).
- Cameron, E. M. and Durham, C. C.
 1974: Follow-up investigations on the Bear-Slave Geochemical Operation; in Report of Activities April to October 1973, Geol. Surv. Can., Paper 74-1, Part A, p. 53-60.
- Eade, K. E. and Fahrig, W. F.
 1971: Geochemical evolutionary trends of continental plates--a preliminary study of the Canadian Shield; Geol. Surv. Can. Bulletin 179, 51 p.
- Hornal, R. W. and Boyd, J. B.
 1972: Gravity Map 92--Upper Back River; Earth Physics Branch, Dept. of Energy Mines and Resources, Ottawa.
- Lynch, J. J., Garrett, R. G. and Jonasson, I. R.
 1973: A rapid estimation of organic carbon in silty lake sediments; J. Geochem. Explor., v. 2, p. 171-174.
- McGlynn, J. C. and Henderson, J. B.
 1972: The Slave Province; in: Geol. Assoc. Can. Spec. Paper 11, p. 505-526.
- Nilsson, C. A.
 1968: Wall rock alteration in the Boliden Deposit, Sweden; Econ. Geol., v. 63, p. 472-494.
- Ridler, R. H.
 1973: Automated contoured variation diagrams; in: volcanism and volcanic rocks; Geol. Surv. Can. Open File Rept. 164.
- Tremblay, L. P.
 1971: Geology of Beechey Lake map-area, District of Mackenzie; Geol. Surv. Can. Mem. 365, 56 p.
- Wright, G. M.
 1957: Geological notes on eastern District of Mackenzie, Northwest Territories; Geol. Surv. Can., Paper 56-10.

APPENDIX A

Major element data for rock samples, Agricola Lake area, N.W.T.
(V - volcanics, S - sediments, G - granites, NF - not found, NA - not analysed). All values in weight percent.

Sample Number	Rock Type	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	MnO	H ₂ O	CO ₂	C	S	Less O for S	Totals
538	S	80.5	10.6	0.2	0.2	0.41	0.00	0.00	3.38	0.39	0.01	1.7	0.10	3.38	0.22	0.06	101.0
539	V	74.5	14.9	0.3	0.5	0.41	0.25	4.00	3.20	0.14	0.01	1.1	0.01	NA	0.22	0.06	99.5
541	S	70.5	15.5	0.4	NA	1.29	0.11	0.15	3.92	0.64	0.03	3.0	0.04	5.80	0.16	0.04	101.5
542	V	84.5	9.4	0.9	0.6	0.41	0.03	0.66	3.69	0.11	0.01	0.9	NF	NA	0.31	0.08	101.4
543	V	80.0	10.2	2.5	1.3	1.46	0.04	0.55	1.77	0.16	0.03	1.9	0.07	NA	0.68	0.17	100.5
544	V	77.0	12.2	0.5	0.5	0.30	0.21	3.67	3.28	0.18	0.01	1.0	NF	NA	0.00	0.00	98.9
545	V	77.0	12.8	0.7	0.5	0.98	0.70	0.28	4.51	0.08	0.03	1.8	0.05	NA	0.04	0.01	99.5
546	V	56.7	15.1	1.6	6.2	3.96	6.49	2.97	1.86	0.96	0.15	1.7	2.16	NA	0.80	0.20	100.5
547	V	57.3	15.5	1.9	6.7	3.68	6.03	3.81	0.57	0.85	0.26	1.7	0.54	NA	0.64	0.16	99.3
549	S	80.0	12.0	0.4	NA	0.60	0.01	0.19	3.59	0.45	0.01	2.1	NF	2.16	0.18	0.05	101.6
550	V	61.4	14.8	1.0	6.7	4.46	6.20	0.73	1.51	0.92	0.12	2.1	0.05	NA	0.27	0.07	100.2
551	V	67.3	14.7	0.9	6.1	3.02	4.39	0.58	2.49	0.92	0.11	1.8	0.05	NA	0.40	0.10	102.6
552	V	54.3	14.6	0.6	8.7	11.56	0.03	0.08	0.55	1.15	0.12	7.5	NF	NA	0.02	0.01	99.2
554	V	52.4	16.5	1.6	11.1	9.12	0.06	0.11	1.20	1.30	0.32	7.0	NF	NA	0.31	0.08	100.9
556	V	68.8	7.8	3.3	8.0	0.38	0.00	0.15	1.93	0.10	0.01	2.2	NF	NA	9.32	0.08	101.9
558	V	61.6	9.4	6.5	8.0	1.91	4.39	0.15	2.58	0.20	0.47	2.8	0.38	NA	4.62	0.20	100.8
559	V	43.5	11.3	9.5	9.6	1.84	8.32	0.78	0.10	0.62	0.69	1.9	4.22	NA	7.16	0.04	101.0
560	V	33.7	9.4	1.1	8.4	2.55	22.88	1.81	0.23	1.66	0.77	2.2	16.34	NA	0.07	0.02	101.1
561	V	50.5	15.6	1.5	8.4	5.75	9.05	3.42	0.18	1.19	0.35	2.5	1.00	NA	0.07	0.02	99.5
562	V	70.0	15.7	0.2	0.8	0.75	0.70	5.54	2.20	0.13	0.03	0.9	0.63	NA	0.04	0.01	97.6
563	V	73.5	16.0	0.6	0.5	0.38	0.70	5.62	2.01	0.14	0.01	0.7	NF	NA	0.22	0.06	100.3
567	S	67.6	15.3	0.5	3.4	2.55	0.24	2.55	3.02	0.58	0.04	2.7	0.05	0.06	0.10	0.03	98.7
580	G	76.8	12.0	0.9	0.7	0.08	0.59	5.08	1.18	0.20	0.02	0.5	NF	NA	0.00	0.00	98.1
581	V	57.6	15.1	0.5	5.8	4.69	7.84	4.19	0.81	0.80	0.06	0.6	NF	NA	0.02	0.01	98.0
582	V	78.3	11.5	0.3	0.5	0.27	0.76	5.92	0.30	0.19	0.01	0.7	NF	NA	0.01	0.00	98.8
583	V	60.5	16.3	0.3	4.4	3.58	6.06	6.47	0.20	0.86	0.07	0.8	NF	NA	0.01	0.00	99.6
584	V	60.5	14.9	0.7	7.8	4.38	3.36	2.66	1.07	0.80	0.14	3.0	NF	NA	0.03	0.01	99.3
585	V	50.9	14.6	1.0	9.7	7.34	8.61	2.36	0.67	1.22	0.22	2.5	0.02	NA	0.00	0.00	99.1
586	V	70.3	13.0	0.9	3.1	1.64	2.11	2.66	0.61	0.56	0.04	2.1	NF	NA	1.06	0.30	97.8
587	V	59.0	14.6	0.3	11.0	4.81	1.65	1.81	0.55	0.70	0.19	4.5	NF	NA	0.03	0.01	99.1
588	V	60.4	15.1	0.7	5.6	3.55	5.04	3.34	0.90	0.65	0.13	2.4	1.34	NA	0.04	0.01	99.2
589	V	58.2	11.7	2.2	10.8	6.63	0.07	0.09	0.98	0.76	0.19	5.6	0.03	NA	2.05	0.51	98.8
590	S	68.7	11.5	0.5	NA	0.71	0.00	0.07	3.45	0.52	0.01	2.1	NF	14.26	0.15	0.04	101.9
649	V	73.7	15.5	0.4	0.6	0.30	1.25	5.67	1.79	0.13	0.01	0.6	NF	NA	0.02	0.01	100.0
652	V	77.3	11.7	0.2	1.4	1.84	2.74	1.28	1.19	0.15	0.04	1.6	NF	NA	0.09	0.02	99.5
655	V	58.3	15.5	1.7	7.2	6.65	0.00	0.18	2.11	1.33	0.12	6.0	0.07	NA	0.09	0.02	99.2
659	V	74.5	9.1	0.3	2.3	1.91	4.39	0.43	1.34	0.13	0.10	1.5	2.06	NA	0.02	0.01	98.1
661	V	62.7	15.1	0.1	7.5	3.23	4.51	0.42	1.77	0.95	0.10	2.4	0.06	NA	0.26	0.07	99.0
663	V	53.8	15.5	0.6	7.3	2.65	7.15	5.34	0.42	1.33	0.23	1.2	2.76	NA	0.21	0.05	98.4
665	V	56.2	17.7	0.7	5.8	3.71	6.03	3.46	1.37	0.88	0.16	1.6	0.11	NA	0.15	0.04	97.8
667	V	58.2	15.7	0.4	6.1	3.93	9.08	0.94	0.46	0.78	0.12	1.7	0.89	NA	0.84	0.21	98.9
669	V	72.0	15.7	0.4	0.5	0.31	1.08	5.19	2.12	0.14	0.01	1.0	0.11	NA	0.10	0.03	98.6
671	V	71.7	15.0	0.3	0.7	0.35	1.40	5.85	1.54	0.15	0.01	0.7	0.47	NA	0.22	0.06	98.3
673	V	74.7	13.6	0.0	2.8	1.24	1.33	2.28	2.28	0.36	0.03	1.6	NF	NA	0.94	0.24	100.9
1021	S	82.3	9.8	0.5	NA	0.56	0.00	0.00	3.36	0.48	0.01	1.4	NF	3.27	0.03	0.01	101.7
1024	S	58.0	14.1	0.1	5.7	6.12	5.71	3.09	0.42	0.66	0.09	2.9	0.88	0.10	0.22	0.06	98.0
1025	S	62.2	19.8	3.9	NA	2.59	0.04	0.42	3.81	0.81	0.05	4.9	NF	3.49	0.02	0.01	102.0
1026	S	76.4	13.2	0.3	NA	0.55	0.00	0.20	3.32	0.57	0.01	2.5	0.03	4.96	0.08	0.02	102.1
1027	S	73.7	13.4	0.7	NA	0.56	0.00	0.23	3.20	0.47	0.01	3.3	NF	4.61	0.44	0.11	100.5
1028	S	76.9	13.3	0.4	NA	0.60	0.00	0.09	4.00	0.45	0.01	2.4	NF	3.36	0.04	0.01	101.5
1029	V	71.5	16.3	0.3	0.6	0.22	0.90	5.78	1.81	0.13	0.01	0.9	0.27	NA	0.12	0.03	98.8
1030	V	72.7	15.3	0.5	0.4	0.30	0.32	5.63	1.94	0.14	0.00	1.1	NF	NA	0.03	0.01	98.4
1031	V	72.5	15.2	0.3	0.5	0.31	0.90	5.24	1.94	0.14	0.02	1.2	0.34	NA	0.11	0.03	98.7
1032	V	69.3	14.4	0.0	3.3	1.54	2.67	3.32	1.01	0.48	0.06	1.7	0.09	NA	0.00	0.00	97.9
1033	V	75.2	13.6	0.6	1.0	1.18	0.03	0.31	3.45	0.16	0.01	2.4	NF	NA	0.00	0.00	97.9
1038	S	74.2	11.5	0.9	2.0	1.38	1.40	3.45	1.25	0.48	0.04	1.0	NF	0.04	0.10	0.03	97.7
1039	S	67.8	14.3	0.3	NA	0.73	0.00	0.11	6.04	0.70	0.01	2.6	NF	7.36	0.18	0.05	100.1
1040	V	71.1	15.7	0.2	0.8	0.43	0.46	5.08	3.10	0.14	0.01	0.9	NF	NA	0.02	0.01	97.9
1041	V	73.2	15.3	0.7	0.3	0.50	1.19	5.24	1.99	0.13	0.02	0.9	0.39	NA	0.27	0.07	99.1
1042	V	71.7	15.5	1.0	0.4	0.35	0.45	6.15	1.60	0.14	0.01	0.7	0.12	NA	0.09	0.02	98.2
1043	V	72.0	15.5	0.5	0.6	0.35	0.49	5.74	2.20	0.13	0.01	0.9	NF	NA	0.07	0.02	98.5
1044	V	73.0	15.6	0.8	0.5	0.36	0.34	6.67	1.37	0.16	0.02	1.0	NF	NA	0.24	0.06	100.0
1045	V	78.3	11.3	0.3	1.8	1.29	0.34	3.11	1.19	0.34	0.02	1.3	NF	NA	0.04	0.01	99.3
1046	V	68.7	16.4	0.5	1.7	0.96	0.57	2.25	5.18	0.30	0.02	1.9	NF	NA	0.00	0.00	98.5
1047	V	73.7	14.9	0.5	1.6	1.76	0.32	0.77	4.11	0.25	0.02	2.3	NF	NA	0.00	0.00	100.2
1048	V	76.2	10.3	0.0	3.2	2.35	0.94	0.43	1.12	0.14	0.04	2.4	NF	NA	0.64	0.16	97.6
1049	V	52.7	15.9	1.3	7.8	1.74	8.55	2.68	1.78	1.34	0.22	1.4	3.01	NA	0.05	0.01	98.5
1050	V	57.3	15.2	0.1	8.0	6.45	4.58	2.47	1.10	0.90	0.12	2.4	0.15	NA	0.02	0.01	98.8
1051	V	61.7	15.1	0.7	6.6	2.70	5.83	1.46	0.63	0.99	0.15	2.0	NF	NA	0.39	0.10	98.2
1052	V	63.8	14.1	0.7	6.7	3.12	5.50	1.27	0.37	0.92	0.11	2.0	0.06	NA	0.02	0.01	97.7
1053	V	56.7	15.8	0.0	7.6	5.67	4.88	3.50	0.30	0.94	0.15	3.0	NF	NA	0.00	0.00	98.5
1054	V	55.8	15.8	0.6	7.1	5.50	7.05	2.79	1.05	0.91	0.17	1.9	NF	NA	0.39	0.10	99.0
1055	V	63.8	15.7	0.2	5.8	2.40	3.25	3.40	1.24	1.05	0.10	1.7	NF	NA	0.20	0.05	98.8
1056	V	64.0	12.3	0.2	5.9	5.17	4.58	2.40	1.13	0.53	0.14	1.8	NF	NA	0.02	0.01	98.2
1057	V	58.0	15.5	0.1	6.0	6.00	4.88	3.40	0.33	0.69	0.10	2.6	NF	NA	0.00	0.00	97.6
1058	V	56.8	15.4	0.1	7.6	5.49	4.93	4.85	0.31	0.92	0.14	1.5	NF	NA	0.00	0.00	98.0
1059	V	58.8	14.8	0.5	6.1	4.81	7.22	2.43	0.76	0.65	0.14	1.5	0.88	NA	0.08	0.02	98.7
1060	V	58.8	16.3	0.9	6.4	4.49	5.83	4.34									

APPENDIX B

Trace element data for rock samples, Sanctuary Lake, N.W.T.
(V - volcanics, S - sediments, G - granites, D - diabase).

Sample No.	Rock Type	Content in ppm	Content in ppm	Content in ppm	Sample No.	Rock Type	Content in ppm	Content in ppm	Content in ppm
		Zn	Cu	Pb			Zn	Cu	Pb
534	V	81	19	13	842	V	29	2	2
536	V	129	68	2	843	V	40	82	2
591	V	91	56	14	844	V	84	28	2
592	V	151	38	2	845	V	37	11	2
593	V	55	21	13	846	V	37	22	2
594	V	49	44	14	847	V	48	3	2
595	V	21	12	2	1000	V	62	7	2
597	V	48	29	2	1001	V	37	6	2
598	V	41	8	6	1002	V	33	56	2
599	V	54	44	2	1003	V	50	22	2
600	V	36	29	2	1004	V	55	17	2
601	V	27	15	2	1005	V	23	6	2
602	V	36	4	6	1006	V	44	3	2
603	V	29	4	2	1007	V	29	56	2
604	V	48	4	2	1008	V	44	8	13
606	V	36	12	2	1009	V	55	34	2
607	V	13	2	2	1010	V	60	106	2
608	V	41	2	6	1011	V	48	3	2
609	V	117	82	2	1012	V	65	31	2
610	V	50	10	2	1013	V	82	19	2
611	V	12	4	2	1014	V	65	53	2
612	V	43	25	2	1015	V	71	90	13
613	V	49	19	2	1016	V	34	2	2
614	V	66	19	2	1017	V	126	291	37
615	V	67	64	2	1018	V	55	855	2
616	V	114	97	2	1019	V	82	94	2
617	V	61	6	2	1020	V	65	24	2
618	V	98	31	2	1064	G	41	103	10
619	V	70	16	8	1079	V	112	177	2
621	V	110	41	2	1081	S	400	212	30
622	V	46	22	2	1088	V	21	2	2
623	G	83	31	2	1119	V	34	11	2
624	V	70	13	8	1135	V	119	33	30
625	G	98	20	2	1137	V	45	39	10
820	V	21	13	12	1139	V	45	2	2
821	V	37	8	2	1141	V	475	75	2
822	V	42	25	2	1143	V	10	25	2
823	V	15	47	2	1145	V	500	146	36
824	V	15	3	2	1147	V	11	2	2
825	V	23	3	2	1150	V	29	11	2
826	V	19	11	2	1152	V	192	109	10
827	V	19	3	2	1154	S	47	2	10
828	V	69	41	2	1156	V	21	2	2
829	V	625	297	2	1158	S	21	2	2
830	V	180	56	2	1160	S	19	2	2
831	V	99	171	2	1162	V	30	2	2
832	V	46	14	2	1163	V	13	2	2
833	V	52	197	2	1164	V	26	2	2
834	V	132	62	2	1165	V	47	36	2
835	V	6	3	2	1166	V	39	2	2
836	V	50	31	2	1167	V	23	2	2
837	V	84	31	2	1168	V	10	2	2
838	V	103	17	2	1169	V	3	2	2
839	V	139	53	2	1170	V	47	2	2
840	V	25	6	2	1171	V	39	2	2
841	V	29	2	2	1172	V	23	2	2
1173	V	11	2	10	1540	V	44	4	2
1174	V	47	39	2	1546	V	59	13	2
1175	V	96	21	2	1547	G	66	13	2
1176	V	50	18	2	1625	V	12	4	2
1177	V	53	50	2	1626	V	193	8	42
1178	V	53	25	2	1627	D	157	164	2
1179	V	64	56	2	1628	S	821	21	2
1180	V	46	44	2	1629	S	98	4	2
1181	V	81	36	2	1630	S	101	94	2
1182	V	64	37	2	1631	S	300	107	2
1183	V	91	46	2	1632	V	38	10	13
1184	V	87	37	2	1633	V	45	17	2
1185	V	65	27	2	1634	V	74	27	2
1186	V	75	19	2	1663	V	96	69	2
1187	V	69	65	2					
1188	V	39	19	2					
1189	V	33	12	2					
1190	V	35	67	2					
1191	V	52	8	2					
1192	V	20	13	2					
1193	V	48	8	2					
1194	V	16	6	2					
1195	V	24	8	2					
1196	V	37	6	2					
1197	V	20	15	2					
1198	V	59	10	2					
1199	V	36	8	2					
1200	V	20	13	2					
1201	V	17	23	2					
1202	V	54	25	2					
1526	V	40	25	2					
1527	V	64	4	2					
1528	V	96	63	2					
1529	V	74	475	2					
1530	V	86	38	2					
1531	G	61	23	2					
1532	G	34	2	25					
1533	G	62	8	2					
1534	V	66	35	2					
1535	V	81	85	33					
1536	V	86	29	2					
1537	G	76	46	2					
1538	G	51	15	2					
1539	V	79	42	2					
1540	V	44	4	2					
1546	V	59	13	2					
1547	G	66	13	2					
1625	V	12	4	2					
1626	V	193	8	42					
1627	D	157	164	2					
1628	S	821	21	2					
1629	S	98	4	2					
1630	S	101	94	2					
1631	S	300	107	2					
1632	V	38	10	13					
1633	V	45	17	2					
1634	V	74	27	2					
1663	V	96	69	2					