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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 73-1
Part B

REPORT OF ACTIVITIES,

Part B: November 1972 to March 1973

Price, $2.00

1973

CANADA

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DEPARTMENT OF ENERGY, MINES AND RESOURCES

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INTRODUCTION

The Geological Survey of Canada, a branch of the Department of Energy, Mines and Resources, was founded in 1842 and is the principal geological agency of the federal government. Its primary role is to provide an overview of all facets of Canadian geology as a basis for national policy, for government and industrial planning and for public information.

In addition to data derived from its own field and laboratory projects, the Geological Survey receives information from provincial agencies and private companies. These results are integrated to provide the geological basis for national policy in all fields affected by geology; for the search and evaluation of Canada's potential mineral resources; for the planning by industries and governments concerned with regional and northern development; for land use and urban development; for conservation, recreation and engineering; for construction; indirectly for forestry, agriculture and water supply, and for national security.

The objectives of the Geological Survey comprise geological aspects of the objectives of the official Mineral and Energy Resources Program and the Earth Sciences Program of the Department. Current objectives of the Geological Survey are:

To provide a comprehensive inventory and understanding of the geological framework and processes in Canada as a basis for national policy and planning in all matters affected by geology, with special emphasis on:

- ascertaining our national energy and mineral resources;
- facilitating their exploration and development;
- promoting regional development in Canada;
- identifying and describing geological features and processes that affect environmental and ecological equilibrium, with particular emphasis on the effects of energy and mineral development;
- identification and inventory of Quaternary and Recent features and ongoing geomorphological processes that affect use of the terrain, engineering design, urban development and the renewable resource industries (forestry, agriculture, fisheries);
- identifying and assessing natural hazards;
- disseminating information on the Canadian landmass; and surrounding continental shelves and the resources they contain.

The 65 reports that make up this publication are arranged in broad scientific categories and present the results of some of the studies carried out by officers of the Branch between November 1, 1972 and March 31, 1973. The illustrations are reproduced without change from material submitted by the authors. Manuscripts were accepted for inclusion in this report until May 10, 1973.

ANALYTICAL CHEMISTRY

1. STUDIES IN THE APPLICATION OF INTERNATIONAL REFERENCE ROCKS

Project 690089

Sydney Abbey,
Central Laboratories and Technical Services Division, Ottawa

Because of the widely scattered values for the concentrations of individual components reported by collaborating laboratories, most of the originators of proposed "standard rocks" have hesitated to assign "accepted values". A set of "usable values" was proposed as a result of work done here[1]. Since that work appeared, additional data have been received from East German, French, South African and U.S. sources[2,3,4,5,6]. The East Germans and the French have assigned recommended values for most major and minor elements and some trace elements. Values have been assigned here to the South African and American samples, but the operations were complicated by unusual compositions in the former case and certain discrepancies in the latter. We, therefore, now have usable values for the concentrations of the most useful components for some 30 international reference samples of widely varying compositions. Limited data are available on four other samples, while 10 more are awaiting analysis or the publication of compilation of results. There is a growing need for such standard materials (and for accepted values for the concentrations of their components) as controls for the precision and accuracy of analyses, for calibrating instrumental methods, for testing proposed new methods and for comparing the work of different laboratories.

[1] Abbey, Sydney: Standard Samples of silicate rocks and minerals – A review and compilation; Geol. Surv. Can., Paper 72-30 (1972).

[2] Grassmann, Hans: Die Standard gesteinsproben des ZGI, 6. Mitteilung: Neue Auswertung der Analysen auf Hauptkomponenten der Proben Granit GM, Basalt BM, Tonschiefer TB, Kalkstein KH und erste Auswertung der Proben Anhydrit AN und Schwarzschiefer TS, Zeit. angew. Geol., v. 18, p. 280-284 (1972).

[3] Schindler, Rolf: Standard gesteinsproben des ZGI, 6. Mitteilung: Stand der Spurenelementanalyse der Gesteine GM, TB, BM und KH, ibid., p. 221-228 (1972).

[4] de la Roche, H., and Govindaraju, K.: Rapport (1972) sur quatre standards géochimiques de l'Association Nationale de la Recherche; Diorite DR-N, Serpentine UB-N, Bauxite BX-N et Disthène DT-N, Bull. Soc. française céram., in press; Etude co-opérative sur un verre synthétique proposé comme étalon analytique pour le dosage des éléments en traces dans les silicates, ANALUSIS. in press.

[5] Russell, B.G. et al.: Preliminary report on the analysis of the six NIMROC geochemical standard samples; National Institute for Metallurgy (South Africa), Report No. 1351 (1972).

[6] Flanagan, F.J.: 1972 values for international geochemical reference samples; Geochim. Cosmochim. Acta, (in press).

2. FURTHER APPLICATIONS OF THE LITHIUM-FLUOBORATE SYSTEM IN ANALYSIS OF ROCKS

Project 690090

Sydney Abbey, Naomi J. Lee and J.-L. Bouvier,
Central Laboratories and Technical Services Division, Ottawa

Sample decomposition was simplified and made less expensive by replacing the platinum crucible with one of graphite for the fusion step. Good results were obtained for most major and minor elements, except for silica, where results were erratic regardless of whether the final determination was done by atomic absorption or differential colorimetry. Slight differences in individual absorption cells are exaggerated in the latter case, because of the high absorbances used. Means of overcoming that difficulty are being studied, as is also the possibility of silica losses in the disintegration of the fusion. Better results (although somewhat slower) were obtained by the "neo-classical" scheme described in one of the following reports in this publication.

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3. IMPROVEMENTS IN X-RAY FLUORESCENCE ANALYSIS FOR MAJOR AND MINOR ELEMENTS IN ROCKS

Project 690090

J.-L. Bouvier,
Central Laboratories and Technical Services Division, Ottawa

The boric acid discs (both for fused and unfused samples) were abandoned in favour of a phenol-formaldehyde resin disc, based on that of Leake _et al._,[1] which is more stable and is easier to prepare. No fusion is required, the finely-ground sample being merely mixed with the resin powder, pressed into a disc and heated to set the resin. Duration of exposure to primary X-ray radiation is controlled by a copper "internal standard". The millivolt read-out for each element is automatically compared with those obtained on a reference sample of similar overall composition, by means of a mini-computer. The reference samples include international "standard rocks" as well as our own samples, previously analyzed by classical methods and now re-analyzed by the "neo-classical" scheme outlined in the next item. Because the x-ray scheme works only for samples for which data on closely matching standards are in storage, it is necessary to continue adding reference samples to the system until a sufficient range of compositions is covered. The work is continuing.

[1] Leake, B. E. _et al._,: The chemical analysis of rock powders by automatic X-ray fluorescence; Chem. Geol., v. 5, p. 7-86 (1969-70).

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4. A "NEO-CLASSICAL" SCHEME FOR THE ANALYSIS OF SILICATE ROCKS

Project 690090

J.-L. Bouvier,
Central Laboratories and Technical Services Division, Ottawa

A large number of accurate analyses were required in order to calibrate the X-ray fluorescence method described in the preceding item. A scheme was applied involving some features of both the modified conventional system[1] and the lithium-fluoborate method[2]. The sample is fused with lithium metaborate in a graphite crucible and the molten bead quenched in water in a Teflon dish. The mixture is stirred with HCl to disintegrate the fusion and evaporated with HCl and methanol to volatilize the boron and dehydrate the bulk of the silica. After separation, weighing and volatilization of the silica, unseparated silica (and phosphorus, where required) is determined colorimetrically in the filtrate. Dilutions of the same filtrate are then analyzed by atomic absorption for alumina, total iron, magnesium, calcium, sodium, potassium, manganese, titanium, and, if present in more than traces, barium, strontium, nickel and chromium. Advantages over the conventional scheme are speed, more complete decomposition and the ability to determine more elements on a single sample. Advantages over the lithium-fluoborate scheme are more accurate results for silica and improved sensitivity for titanium and barium.

[1] Maxwell, J.A.: Rock and Mineral Analysis; Interscience (1968).

[2] Abbey, Sydney: Analysis of rocks and minerals by atomic absorption spectroscopy. Part 3: A lithium-fluoborate scheme for seven major elements. Geol. Surv. Can., Paper 70-23 (1970).

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5. APPLICATION OF SPECTROCHEMICAL METHODS TO TRACE ELEMENT DETERMINATIONS IN GEOLOGICAL MATERIALS

Project 690090

W.H. Champ,
Central Laboratories and Technical Services Division, Ottawa

A program to improve and extend our method for determination of trace elements in iron-base samples, i.e. pyrite, hematite, magnetite, etc., has been completed. We now have over 60 analytical working curves in use which cover 36 elements between the concentration ranges of approximately .001 to 5.0%. These are essentially the same elements as we determine in silicate matrices and the obtainable precision of ±15% of value reported is comparable. Because of a scarcity of reliable reference standard samples for these materials, there may exist slight bias in some of the determinations, which however should not detract from their usefulness when alternate methods are unavailable.

Some 21 of the more than 60 working curves for silicate analysis have been extended or revised to cover greater concentration ranges and to conform more closely with the slowly increasing group of usable international reference standard samples. Biases are gradually being reduced, so that for most elements, accuracy is equivalent to precision obtained. A comprehensive program for preparing series of synthetic standards is underway in connection with this. Series for Cu, Mo, Ge have been recently completed.

Extensive alterations to the optical components of our Atomcounter spectrometer have resulted in lower limits of determination for a number of elements in our current direct-reading method for silicates. Improvements made at the same time to the sample handling and preparation system have increased precision. The spectrometer output can now be recorded on paper tape via a teletype machine. The data are then taken to the Data Centre, processed by a computer program and final reports printed as concentrations. This process enables us to handle many more samples, the limiting factor being availability of laboratory staff to operate the equipment and prepare samples. Recent acquisition of a Nova 1220 mini-computer, to be used in dedicated fashion with the spectrometer, is expected eventually to improve the system still further.

Routine analysis of silicates can be performed at present for the following elements, in the ranges stated:

Al	.10 - 15%	Be	.001 - .20	Sr	.001 - .40
Fe	.20 - 10	Ce	.20 - 5.0	V	.003 - .70
Ca	.02 - 1.0	Co	.003 - .35	Y	.008 - .80
Na	.01 - .60	Cr	.003 - .50	Yb	.001 - .125
Mg	.05 - 9.0	Cu	.001 - .15	Zn	.07 - 3.5
Ti	.02 - 5.0	La	.03 - 2.5	Ar	.01 - 2.0
Mn	.01 - 1.25	Ni	.003 - 1.0		
Ba	.002 - .30	Pb	.07 - 7.0		

Major elements are included here mainly to characterize the sample for the laboratory, so as to be sure inappropriate matrices are not included by accident. The analytical results for these elements are not expected to be as accurate as when done by other methods.

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6. FEASIBILITY OF APPLYING A COMPUTER PROGRAM TO HANDLE THE LARGE AMOUNT OF ANALYTICAL DATA RECEIVED FROM DIRECT READING OPTICAL EMISSION SPECTROMETER

Project 690090

K.A. Church,
Central Laboratories and Technical Services Division, Ottawa

The first thing that had to be accomplished was fitting a program to the large C.D.C. 6400 Computer which we could use on a cost-sharing basis. When this was established, our system was adjusted to allow us to use a teletype and Ortec control in order to convert our signal to punched paper tape.

New analytical curve co-ordinates were then programmed into the C.D.C. 6400 Computer to facilitate the concentration calculations.

At the present time, we are experimenting with a new mini-computer and this should eliminate the need for cost sharing with the large C.D.C. 6400 computer; many other laboratory operations can be applied to this type of on-line computer.

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7. FEASIBILITY OF DETERMINING THE FLUORIDE-ION CONCENTRATION IN ROCKS BY A SELECTIVE-ION PROCEDURE

Project 690090

Serge Courville,
Central Laboratories and Technical Services Division, Ottawa

This project, initiated to meet the growing demand for fluoride analysis in rocks, involved the experimental work required to establish the parameters affecting this determination. Some areas of investigation were; kind of flux required, flux to sample ratio, need for ionic strength buffer, stability of solutions, relation between millivolts readings and concentration, etc. A short computer program was devised to facilitate the concentration calculations.

A proposed analytical procedure has been tested and is now in use in our analytical laboratories.

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8. QUANTITATIVE ELECTRON MICROPROBE ANALYSIS USING AN ENERGY DISPERSIVE SPECTROMETER

Project 620308

G.R. Lachance and A.G. Plant,
Central Laboratories and Technical Services Division, Ottawa

The combination of an electron microprobe with an energy dispersive spectrometer and an on-line mini-computer forms a powerful system for the analysis of materials, and this paper outlines an empirical method for the quantitative analysis of rock-forming silicate minerals for up to 15 elements. By restricting ourselves to silicate minerals and by measuring at fixed operating parameters, the problems encountered in universal methods are minimized and their magnitude is such that, within the reproducibility of the data, their effects are negligible in the day-to-day analysis of samples and an empirical approach is feasible. For example, the problems that can arise from large variations in count rate and in the interference (non-resolution) of K, L and M spectra when the analyst is faced with analyzing a wide variety of materials for every element detectable by energy dispersive X-ray analysis are considerably reduced as silicate minerals usually contain fewer than 10 elements in reasonably well-defined concentration ranges above the 0.1% level. Also, the programming aspects are simplified in that a number of elements can be fixed, for example, we always analyze for Na, Mg, Al, Si, K, Ca, Ti, Cr, Mn and Fe, with an option for adding up to five additional elements.

The principles of energy dispersive X-ray analysis are now well established[1] and we have used a M. A. C. Model 400 electron microprobe, a Kevex Si (Li) detector (resolution at Mn Kα = 157 eV) coupled to the 5000A X-ray energy spectrometer with 1024 channels and a 16K Hewlett Packard 2100 computer. The multi-channel analyzer is operated at 10eV/channel and thus when the system is correctly calibrated, channel 174 corresponds to the 1.74 keV peak of silicon; recalibration should be carried out if peaks drift by more than one or two channels. Following display of the integrated spectrum (usually 100-300 seconds) on a CRT, the data can be transferred directly to computer memory (approx. 35 secs.) or if the spectrum is to be added to a library of spectra, a paper tape can be produced.

The first step in the data reduction sequence is to convert the measured intensities to counts per second. This allows the analyst to vary integration times when necessitated by mineralogical considerations. The data are then convoluted using the 19 point set of integers for quadratic-cubic curves proposed by Savitzky and Golay[2]. From the detailed study of many spectra obtained from a wide variety of minerals (silicates, oxides, carbonates), we have concluded that within the counting statistics of the data: (1) the channel position of the peak maxima is reproducible, (2) the distribution of the counts within the peaks is reproducible, (3) backgrounds for each element can be correlated with selected portions of the continuum, and (4) non-resolution effects and other minor residuals can be correlated to appropriate peaks in the spectrum. These conclusions have led to the adoption of the following: (a) peak intensities are measured by integration over 13 channels centred on the maximum; (b) backgrounds are calculated by reference to a normal curve for peaks of 2.5 keV or more, and for peaks less than 2.5 keV, backgrounds are calculated by interpolation; (c) non-resolution effects are calculated by an iteration process and correct for peak overlap, peak trailing, background anomalies, etc.

The weight per cent oxides obtained by direct comparison to mineral standards are subject to the usual matrix corrections. The procedures developed in our empirical method give results comparable to those obtained using wavelength dispersive analysis. To ensure that the system is maintained in an optimum state of calibration, a standard sample of the mineral, Kaersutite, which contains 8 of the 10 fixed elements in concentrations greater than 1.5%, is analyzed during each analytical session. Our analyses of this mineral over a period of several months show that the short term reproducibility is excellent, but that during this time, the sensitivity of elements having a lower energy than silicon has dropped, while it has increased for elements of higher energy. A number of tests are being conducted to define the magnitude, rate of change, etc., as a function of energy in order to trace the cause of this long term drift.

[1] Beaman, D. R., and Isasi, J. A.: Electron Beam Microanalysis; ASTM STP 506 (1972).

[2] Savitzky, A., and Golay, M. J. E.: Smoothing and differentiation of data by simplified Least Squares procedures. Anal. Chem., v. 36, p. 1627-1639 (1964).

9. THE DETERMINATION OF NOBLE AND COMMON METALS IN PLACER GOLD BY ATOMIC ABSORPTION SPECTROMETRY

Project 690090

J. G. Sen Gupta,
Central Laboratories and Technical Services Division, Ottawa

A rapid atomic absorption method has been developed for the determination of gold, silver, platinum-group metals and common metals in placer gold.

A preliminary separation of gold from traces of platinum-group metals by quinhydrone precipitation[1] was found to give low results for the platinum-group metals. However, studies with synthetic solutions revealed that it was possible to determine directly ppm amounts of the platinum-group metals in the presence of major amounts of gold by atomic absorption spectrometry in 0.5%Cu-0.5%Cd spectroscopic buffer medium, provided that the gold concentration in the final solution did not exceed $\approx$26,000 ppm.

The placer gold sample (about 150 mg) was decomposed by repeated digestion with hot aqua regia, followed by dry chlorination at 700°C of any unattacked material. The separated silver chloride was filtered out, dissolved in concentrated ammonium hydroxide (sp.gr.0.9), and from an aliquot, silver was determined by atomic absorption. Gold value, as determined from an aliquot by atomic absorption in the presence of 0.5%Cu-0.5%Cd buffer, was found to agree with quinhydrone[1] gravimetric value. A major aliquot was taken for the determination of the platinum-group metals by atomic absorption in the presence of 0.5%Cu-0.5%Cd buffer, whereas a small aliquot was used to determine the common metals in the presence of 1% lanthanum buffer[2,3].

Employing the above-mentioned technique, the analyses of six placer gold samples from British Columbia and the Yukon Territory have been completed.

[1] Beamish, F.E., Russell, J.J., and Seath, J.: The determination of gold; Ind. Eng. Chem., Anal. Ed., v. 9, p. 174 (1937).

[2] Sen Gupta, J.G.: The determination of noble and base metals in osmiridium, native platinum and sperrylite by atomic absorption spectrophotometry; Anal. Chim. Acta, v. 58, p. 23 (1972).

[3] Sen Gupta, J.G.: The determination of gold, platinum-group metals and some common metals in native silver by atomic absorption spectrometry; Anal. Chim. Acta, v. 63, p. 19 (1973).

10. SURFICIAL DISPERSION OF TRACE METALS IN ARCTIC CANADA: A NICKEL DEPOSIT, RAGLAN AREA, CAPE SMITH - WAKEHAM BAY BELT, UNGAVA (NEW QUEBEC) (35-H)

Project 700046

R.J. Allan,
Resource Geophysics and Geochemistry Division, Ottawa

Introduction

As part of a general study of dispersion in surficial materials of permafrost areas, samples were collected during the summer of 1971, in the vicinity of the Ni-Cu zones of Falconbridge Mines Ltd. in northern Quebec (approx. lat. 61°30'N; long. 73°30'W). The study area is in the moss and lichen tundra zone underlain by continuous permafrost. Sites containing known nickel mineralization for studies of nickel dispersion in the permafrost areas of Canada are limited in number. Those of known ore grade are at Rankin Inlet in the District of Keewatin, and in the Cape Smith - Wakeham Bay belt of Ungava. The former has been mined, and contamination was expected to be a major problem. The Rankin Inlet area is also affected by marine overlap. Because of these facts, the Raglan area was considered to be the better site for the study.

In June 1971, the total ore reserves at Raglan No. 2 and No. 3 areas and at nearby Katiniq (40 miles distant) were listed as 10 million tons of 2.66% Ni and 0.71% Cu. In addition, assumed extensions at these areas were estimated at 6 million tons 2.45% Ni and 0.70% Cu (Northern Miner). The ore is associated with serpentinized sills between the Churchill and Superior Provinces[1]. The ore pods do not appear to occur at any particular position in the sill, at least at Raglan. The geochemistry of the sill at Katiniq has been described by Wilson[2]. Geochemistry using surficial materials has however not been used as a method of mineral exploration in the Raglan-Katiniq area of the Cape Smith - Wakeham Bay belt.

The results given below are expected to (1) indicate the concentrations of metals to be found in surficial materials near sulphide prospects of the Raglan type; (2) to provide information on the dispersion of metals from mineralized areas like Raglan; and (3) to indicate possible materials that may be used as sample media in prospecting for nickel ores in this part of the Cape Smith - Wakeham Bay belt, and similar surficial-geochemical environments.

Methods of Analysis

Sample analyses for all materials collected is completed. Results are given below for soil, drainage sediment, and esker samples. The stream and lake water, and snow results have been presented elsewhere[3]. All soil and sediment samples were sieved to minus 80 mesh. The samples were digested on a water bath at 90°C for 1.5 hours with 6 ml of 4N - HNO_3 plus

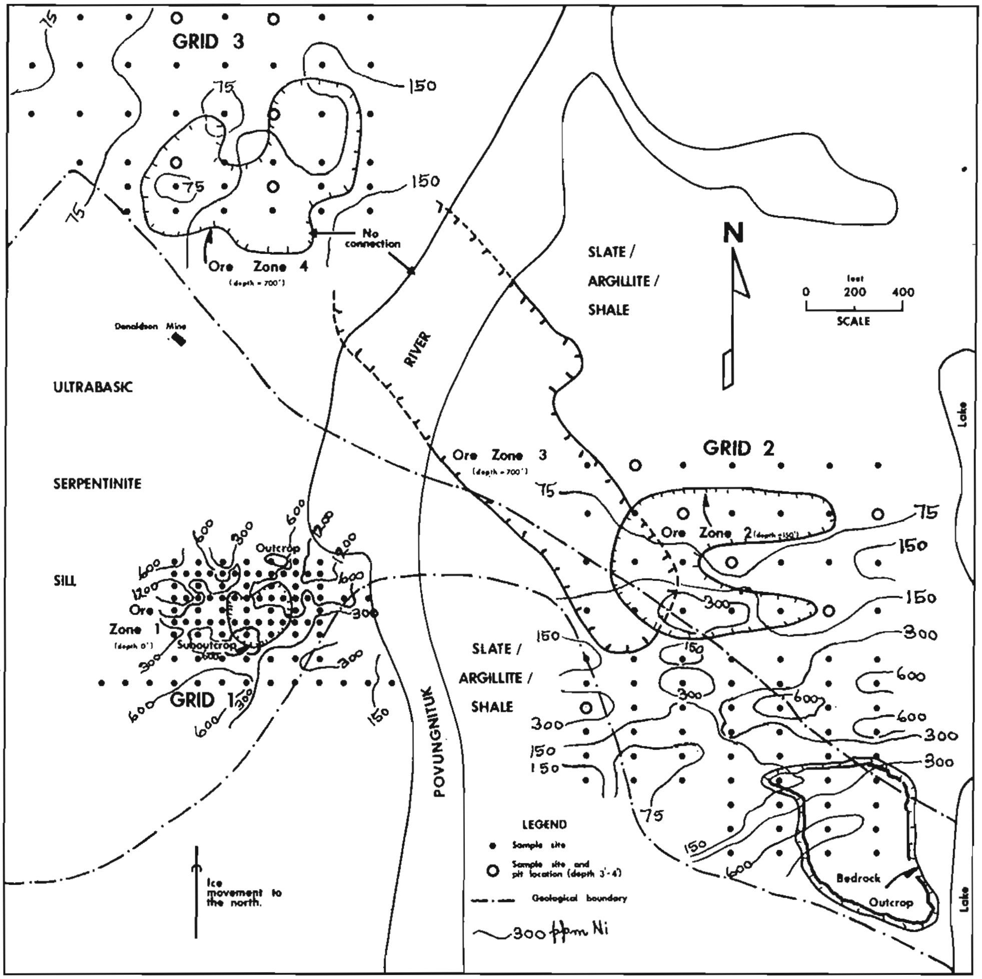

Figure 1. Ni dispersion in a continuous permafrost area: Raglan Mine, Ungava, Quebec.

two drops of concentrated HCl. The sample solutions were shaken, allowed to settle and then analyzed by atomic absorption spectrophotometry. The same procedure of analysis was used on the ball-milled, 40 to 80 mesh, esker samples. This extract when applied to soils and drainage sediments removes most of the Ni and Cu present in the samples (J.J. Lynch, pers. comm., 1973).

Results and Discussion

Soils. At the Raglan location, there are four major known ore zones. The approximate location of these is shown in Figure 1. Soil samples were collected on grids 1, 2 and 3 shown on Figure 1. Grid 1 overlies ore zone one, which sub-outcrops beneath about 6 feet of drift. Grid 2 overlies an

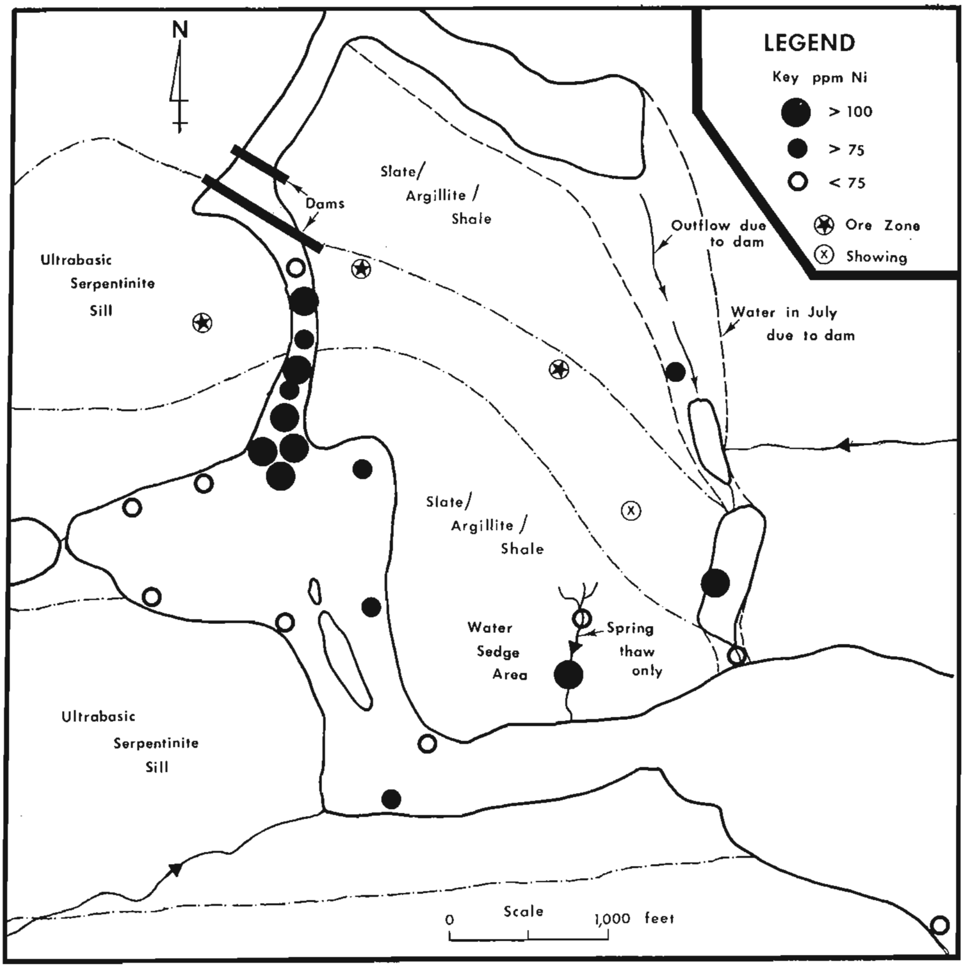

Figure 2. Ni dispersion in drainage sediments, Donaldson Mine, Ungava, Quebec.

outcrop of the ultramafic sill and ore zone two which is at a depth of about 150 feet. Grid 3 overlies ore zone four which is at a depth of about 700 feet. Only a few samples came from above ore zone three which is at a depth of about 700 feet and extends under the river.

Soil samples were taken from the surface of silty frost boils. As the sampling was carried out in early spring (July 1 to 13), depth of thaw was minimal and only the surface few inches of boils were collected. The entire area around the Raglan ore zones has seen much exploration activity over the last few years, and although only boils that appeared to be undisturbed were sampled, there remains a distinct possibility that some of the samples have been contaminated by drilling solutions. However, at each ore zone area the number of holes drilled and the grade of material intersected would be very similar and because of this it might be expected that contamination at each grid area would be of a similar degree. However, the levels of nickel obtained on the three grids were systematically different. Also, levels of nickel in the soils of Grid 3 are lower than would be expected had the area been contaminated by the drilling of ore zone four.

Grid 1: This overlies zone 1, the subcropping ore zone (Fig. 1). Overburden consists of a surface layer of large, angular, frost-heaved boulders, underlain by silty textured drift. Levels of Ni in the surface samples of the silty frost boils are shown on Figure 1. Most of the sites have concentrations of 300 ppm Ni or greater. Six sites have concentrations greater than 1,200 ppm Ni. The centrally located subcrop of the ore zone seems to be ringed by higher Ni concentrations in the soils.

Grid 2: This overlies ore zone 2 and the outcrop of the serpentinite sill (Fig. 1). At this location, drift is about 6 feet thick. This overlies about 100 feet of metamorphosed sediments, now mainly slates, that lie on top of the ultramafic sill. Fifty per cent of the grid sites have Ni levels greater than 150 ppm Ni. Levels of Ni in the southeast corner of the grid, where the sill outcrops, are in the order of 300 to over 600 ppm Ni (Fig. 1).

Grid 3: The ore zone is at a depth of 700 feet (Fig. 1) but the depth to the top of the ultramafic sill is only 100 feet. The northeast corner of the grid has levels of less than 75 ppm Ni. The remaining area has levels greater than this. Ten sites in the southeast corner have levels over 150 ppm Ni.

The averages for trace metals in soil samples over the three grids is given in Table 1. The most obvious explanation for the variation in the average grid levels for nickel (Table 1) is in relation to the bedrock geology. Grid 1 is over an ore zone, grid 2 is over a mineralized, ultramafic sill outcrop, and grid 3 is over slates (Fig. 1). However, levels of nickel at all three locations are much higher than found in four background soil samples collected over the ultramafic sill immediately south of the Raglan sill. The location of these background samples is shown by the triangle on Figure 2. The difference between these values (Table 1) and those for boils overlying the outcrop of the Raglan sill (southeast corner of grid 2 on Fig. 1) indicates that the Raglan sill is high in nickel content relative to unmineralized sills. The levels of nickel in the background samples are very low considering that the frost boils were situated between outcrop areas of an ultramafic sill. These levels could be artifically low because of drift derived from non-ultramafic bedrock being transported onto this sill from the south. Alternatively, the higher copper levels in soils over this southern sill could imply that it is deficient in nickel. The steadily increasing levels of nickel in the soils of grids 3, 2 and 1 may simply be related to the bedrock geology, as mentioned above. A more tenuous interpretation, but one that if true could have significant implications in geochemical exploration for these ore zones in the Cape Smith - Wakeham Bay sills, is that the levels of nickel are the reflection of primary dispersion haloes associated with the ore grade material. The boundaries of ore zones in these sills are economic, ore-grade limits and not a distinct break in Ni and Cu levels. Also, this concept of dispersion haloes may be more readily acceptable considering the depth to the ultramafic sill at both ore zones 2 and 4 is only about 100 feet. Primary dispersion haloes may have been formed by metal-bearing solutions moving away from the ore pods via fractures in the serpentinized, ultramafic sill and overlying rocks.

Table 1. Ni, Cu, Co, Zn, Pb, Zn and Ag in Surface Frost-Boil, Soil Samples.

Grid No.	Depth to ore	No. of Samples	Mean Concentration						Standard Deviation					
			Ni	Cu	Co	Zn	Pb	Ag	Ni	Cu	Co	Zn	Pb	Ag
			ppm						ppm					
1	0	85	605	37	43	38	6	0.5	582	32	16	7	3	0.2
2	150	88	258	10	31	45	8	0.4	298	10	19	10	4	0.2
3	700	46	125	5	21	43	7	0.4	62	2	4	6	4	0.1
BC[1]	-	4	56-67	66-80	19-26	57-77	4	0.3-0.8	-	-	-	-	-	-

[1] Background soils were sampled over a nearby ultramafic sill to that at Raglan. The samples were collected in hollows between outcropping bedrock. They are probable best compared with the values for the sites in the south-east corner of grid 2, Figure 1.

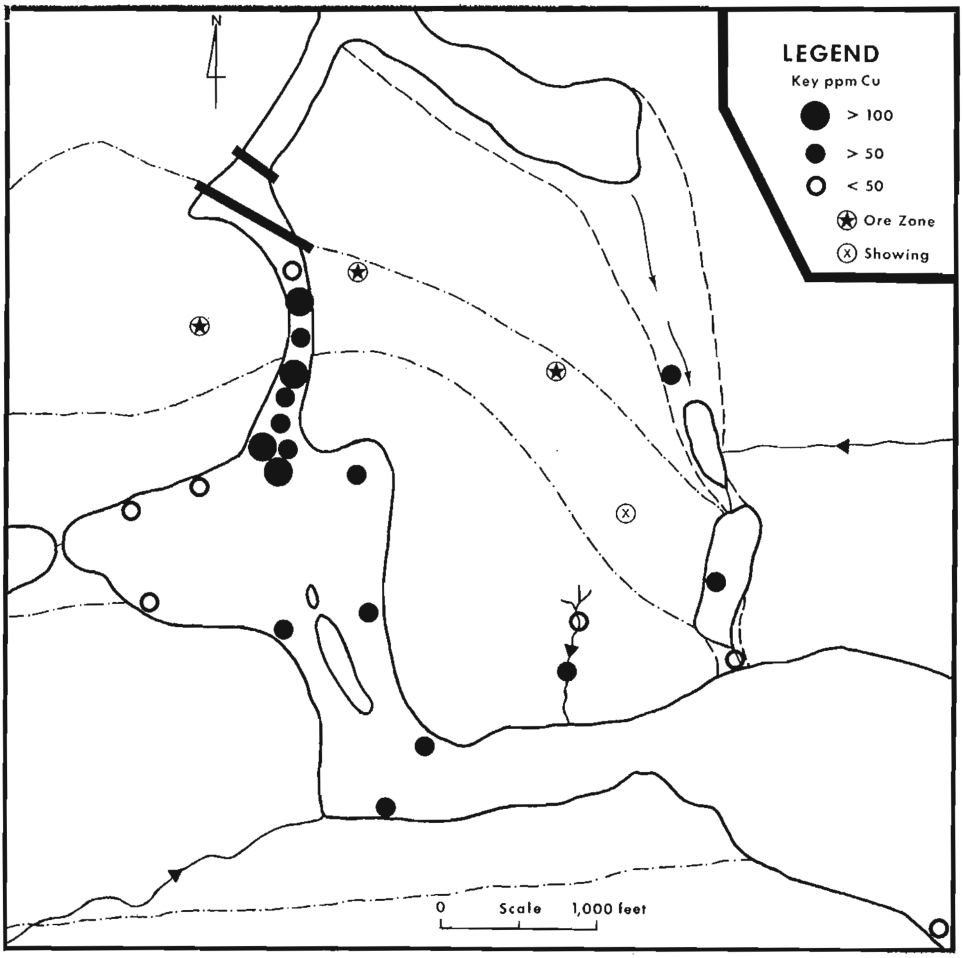

Figure 3. Cu dispersion in drainage sediments, Donaldson Mine, Ungava, Quebec.

In the Raglan area, the ore consists of Ni and Cu sulphides, but whereas in the sills most of the Cu is present as sulphides, much of the Ni is present as silicates (R. Eckstrand, pers. comm., 1973). The soils overlying the ore zones are apparently depleted in Cu relative to background levels (Table 1). The Cu in soils associated with the ore zones was present as sulphides and has been removed by weathering. The same probably applies to a large part of the Ni, again that present as sulphides. If this is true, these soil levels represent residual Ni-silicates. This concept that copper is removed from soil over ore zones is further substantiated by the following:

(1) High Ni and Cu concentrations were found in rock chip samples from boulders overlying ore zone one[3];

(2) Copper to nickel ratios are higher in drainage sediments downstream from the ore zones (Fig. 3) than in the soils overlying the ore zones (Table 1);

(3) Copper content was high in both snows overlying ore zone one and in spring run-off water downdrainage from the ore zones[3].

The low average Zn concentrations of the grid soils relative to the background soil concentrations, could indicate a similar situation occurs for this metal as for Cu. Again, as for Cu, Zn was found: (1) to be high in the snows overlying ore zone 1; and (2) to have higher concentrations relative to the averages for the soil grids, in drainage sediments immediately downstream from the ore zones.

Levels for Cu and for Zn in the background soils (Table 1) are higher than the average found in the soils of the three grids. This could be related to the further geochemical complication of vertical and horizontal trace metal zoning of these ultramafic sills.

Further investigation of bedrock trace metal variations around these Ni-Cu ore pods would be necessary to establish this primary dispersion halo concept.

Drainage Sediments

The sediments collected came from rivers. However, at many locations, the wider parts of rivers could be referred to as lakes (Figs. 2, 3 and 5). In all figures, drainage is from the north to south.

The detailed sampling was done mainly in Povungnituk River which has been dammed during mining development of the site. Because the sediments could have been significantly affected by transported debris arising from exploration activity, great care was taken to select sites where sediment was most likely to be in its original form.

In Figure 2, nickel levels are greater than 100 ppm Ni only in the river bed and at its exit into the lake. Levels of greater than 75 ppm Ni are maintained for less than 1 mile downstream. A similar pattern of dispersion occurs with copper (Fig. 3). On this basis, drainage-sediment sampling to reflect outcropping or sub-outcropping "ore" should be at a site density of one per 1,000 feet or less.

Sampling of drainage sediments on a more regional scale was limited as it had to be done on foot and the spring thaw made many rivers impassable. However, river and lake sediment was easily obtained at all sites and is a readily available sample media in this landscape. Ni and Cu concentrations in the southern, ultramafic-sill, area were obviously related to showings, with levels for nickel of greater than 75 ppm Ni within 0.5 miles of mineralization (Fig. 4). Also, copper levels were highest immediately downstream from the Raglan ore zones (Fig. 5).

There are several higher Ni and Cu levels in other parts of the area shown in Figures 4 and 5. This may be due to the following situation. When detailed geochemical sampling of drainage sediments is carried out close to known prospects, secondary dispersion trains related to these prospects are usually located and interpreted in relation to the ore zones or primary haloes associated with them. However, when large areas i.e., thousands of square miles, are surveyed geochemically using drainage sediments, anomalous areas of tens of square miles are often located. Such anomalies are unlikely to be due to a secondary dispersion process from a large occurrence, but are due to dispersion from disseminated sulphides and small showings over

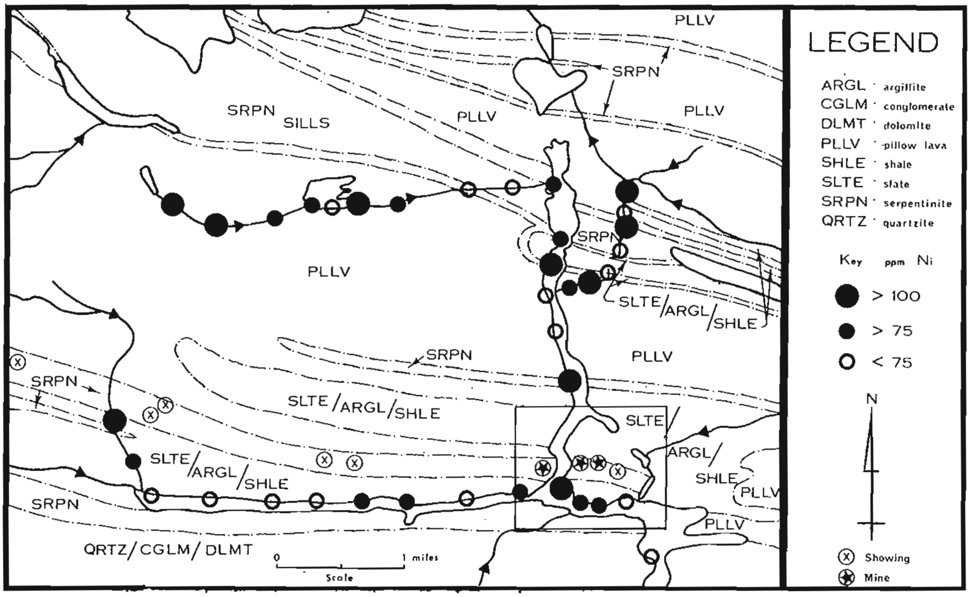

Figure 4. Ni dispersion in drainage sediments, Raglan Area, Ungava, Quebec.

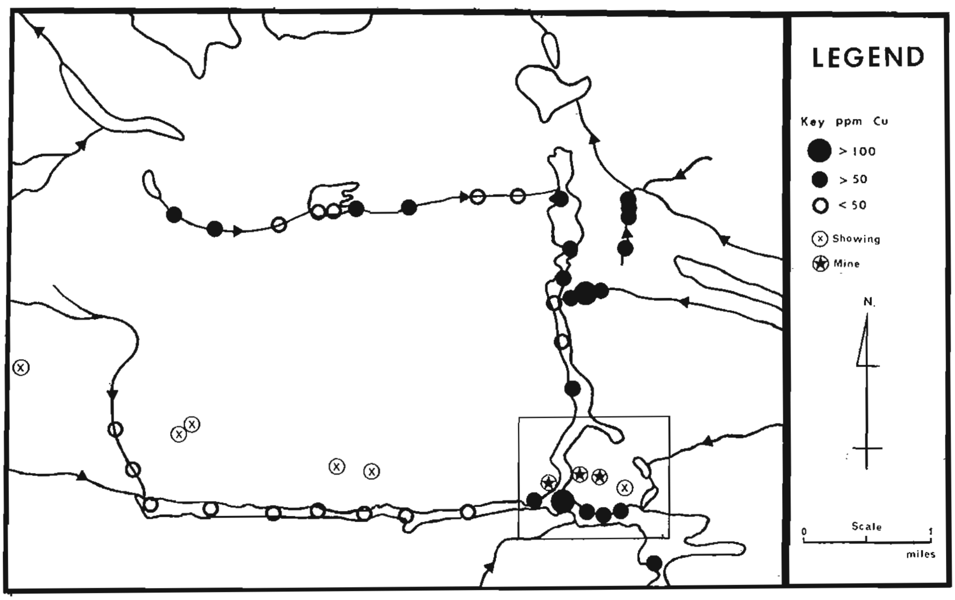

Figure 5. Cu dispersion in drainage sediments, Raglan Area, Ungava, Quebec.

a wide area. However, if the area sampled is small (Fig. 4 covers about 25 square miles) so that it lies within a regional anomaly, and the sample density used is still too wide to intersect secondary dispersion trains, there may be erratic higher concentrations not directly related to significant ore occurrences. For example, in Figure 4, nearly all of the sediment samples have greater than 75 ppm Ni over the 25-square-mile area surveyed. It may be that all of the area sampled is part of a regional anomaly for nickel of greater than 75 ppm. A much larger area of the Cape Smith -Wakeham Bay Belt would have to be geochemically surveyed to establish whether this situation exists in the area in question.

Eskers

The Cape Smith - Wakeham Bay belt area near Raglan was glaciated from south to north. Many eskers were formed during deglaciation. Transport of materials in these eskers was most likely from south to north, and was usually at right angles to the east to west strike of the ultramafic sills.

There are two sections of esker near the Raglan area, one to the south, one to the north (Fig. 6). On site investigation and airphoto study did not reveal any obvious connection. However, because the sections are "in line" and there are no other eskers in the immediate area, the two parts are taken as belonging to the same esker. If this is true, then one would expect the down-ice (north) section should have been enriched in Ni and Cu from the sill at Raglan.

The material collected was from "frost boil like" patches on the very crest of the esker ridges. Both eskers were made up of a series of hummocks of 100 to 150 feet in height (Fig. 6B). The sediment in the boils was very coarse, usually sand or gravel.

The results confirmed the above prediction. Namely, the segment of esker to the north had higher Ni and Cu levels than that to the south (Fig. 6). Generally the difference was two to threefold for Ni but much less although still consistent, for Cu. South of Raglan the esker is low in Ni and Cu even though it crosses several other ultramafic sills before reaching the Raglan area. These results show that there is a decrease in metal content of the esker immediately up-ice from the Raglan sill.

Eskers are found in most parts of the area near the Raglan sill. Their density of occurrence is similar to that for larger streams and rivers. The metal contents shown for esker-soils in Figure 6 are erratic. Dispersion is not as uniform as in a stream sediment. However, a sample site density of one per 1,000 feet should be adequate for the purpose of reflecting mineralized prospects. This would be comparable to present stream sediment site densities necessary for prospecting this area. For regional surveys, it may be possible to lower the site density considerably.

Of interest is a comparison of Figure 6 with Figures 4 and 5. Perhaps a combination of drainage materials - glacial with a south to north transport - and present-day with a north to south transport, could complement each other to focus on mineralized sites along known, mineralized, ultramafic sills. It should be mentioned that the higher nickel levels in the northern esker (Fig. 6B) are close to a present day stream with high nickel levels (northeast corner of Fig. 4). This relationship can be interpreted in several ways, two of which are: (1) the esker is high in nickel because of the

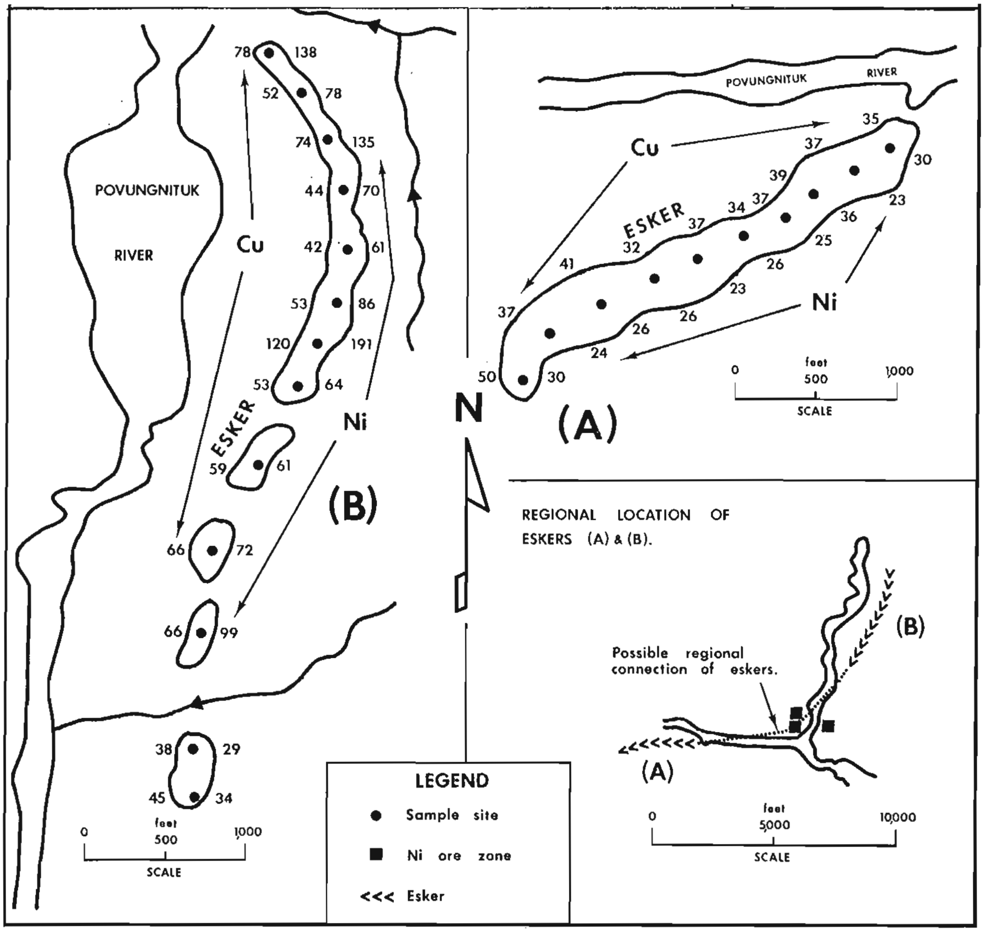

Figure 6. Ni, Cu Dispersion in Eskers, Raglan Area, Ungava, Quebec.

source of metal up-ice at Raglan; and the stream is high in nickel as its sediment is partly derived from the esker; or (2) the stream and the esker are high in nickel because the ultramafic sills underlying them in this area (Fig. 4) are high in this metal. This latter explanation would require the esker material to be very locally derived and this is not normally expected. The former may be the better explanation for the results. In this context, several of the higher nickel levels in the drainage sediments collected north of the Raglan sill (Figs. 4 and 5) may be related to south-north glacial transport.

CONCLUSIONS

Most exploration to date in the Cape Smith - Wakeham Bay belt has involved a combination of geological and geophysical techniques. The results given above indicate that geochemical techniques may compliment these other approaches when used as part of a total exploration programme.

Phase 1 (Regional): Drainage sediment surveys using low sample site densities should attempt to locate areas of higher nickel concentration. This may be combined with regional geological and geophysical surveys.

Phase 2 (Intermediate): Drainage sediment surveys using high sample site densities within interesting areas located by phase 1, should attempt to locate copper and nickel anomalies. More detailed geological and geophysical techniques are not applied at this stage.

Because (a) most rivers in the area run north-south and the stream pattern is trellised; (b) most eskers in the area run south-north; and (c) the mineralized, ultramafic sills run east-west, a situation exists where glacial (esker) and present-day drainage sediments can be used to complement each other.

Phase 3: Having located Cu-Ni anomalies several approaches are possible: (a) geophysical anomalies located during phase 1 may be found to be associated with these higher metal levels. Such anomalies would be prime drill targets; (b) geological study of the area associated with these Cu-Ni anomalies will aid at this stage in assessing its potential for mineralization; (c) ground geophysical techniques may be used to search for anomalies nearby; (d) soil sampling at very high sample site densities may be used to locate Ni anomalies of the levels given here for the ore zones; (e) rock chip sampling of ultramafic boulders may show the presence of Cu and Ni sulphides in the area. Fortunately, most of the area, at least near Raglan, is covered by apparently locally derived boulder fields.

[1] Kilburn, L.C., Wilson, H.D.B., Graham, A.R., Oguna, Y., Coates, C.J.A., and Scoates, R.F.J.: Nickel sulphide ores related to ultrabasic intrusions. Symp. Magmatic Ore Deposits, Ed. H.D.B. Wilson, Econ. Geol. Publ., p. 276-293 (1969).

[2] Wilson, E.H.D.B., Kilburn, L.C., Graham, A.R., and Ramlal, K.: Geochemistry of some Canadian nickeliferous ultrabasic intrusions. Symp. Magmatic Ore Deposits. Ed. H.D.B. Wilson. Econ. Geol. Publ., p. 294-309 (1969).

[3] Jonasson, I.R., and Allan, R.J.: Snow - a sampling medium in hydrogeochemical prospecting. Inst. Mining Met., London, Spec. Vol., 4th Internat. Geochem. Explor. Symp. London, 1972, p. 161-176 (1973).

11. GEOCHEMICAL INSTRUMENTATION

Project 700087

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The workload of the Geochemistry Section analytical laboratories at the Geological Survey of Canada, Ottawa, has now reached the point where computer automation of much of the equipment is warranted. This is due to an increasing demand for geochemical data to be produced as quickly as possible following field surveys. One of the principal techniques used for trace element analysis is that of atomic absorption. The routine procedure is straightforward but time consuming, involving manual reduction of strip chart recorder data and multiple transfer of figures by a number of different operators before analytical results are finally stored on punched cards.

Among other equipment, two Perkin Elmer model 303 double beam atomic absorption spectrophotometers are held by the Geochemistry Section and used extensively for routine analyses. Although the model 303 has been on the market for many years, the optical design differs very little from that found in more recent instruments and it was felt that rather than discard the units held, an electronics package could be designed for it which would bypass the existing vacuum tube circuitry and (a) provide for straightforward interfacing to a modern minicomputer, (b) provide some of the features, such as auto zero and peak integration, which are found on more recent instruments for use in a manually operated "stand-alone" mode.

The result of this approach is a self contained solid state interface unit measuring 11" x 5" x 8" with a single lead connection to the model 303 instrument whereby the signal is taken directly from the photomultiplier tube. The two instruments are shown in the photograph of Figure 1.

The most recent advances in integrated circuit technology are used throughout, with demodulation of the sample and reference beams by means of an integrated circuit digital phase locked-loop, together with solid state analogue switches. A logarithmic analogue/digital converter provides a 12-bit binary output at computer compatible logic levels, proportional to absorbance rather than absorbtion, with a corresponding analogue output for a chart recorder. Instant true zeroing of the signal on both outputs is under manual (foot switch) control in the "OFF LINE" mode, or under computer control in the "ON LINE" mode, as selected by a front panel switch. An analogue peak integrator is also front panel selectable for use in the "stand-alone" configuration.

Samples are in the form of test tube solutions which are aspirated into the flame via a small tube. An automatic sampler originally supplied by Perkin Elmer consisted of a tray with test tube racks sliding past a "dipper" which lowered and raised the aspirator tube into each test tube as they were detented past it. The main objection to this arrangement was the necessity for inserting calibration standards every so often in a suite of samples - a source of possible error in sample identification and of reduction in the capacity of the system. A new sample dipper has been designed which allows the aspirator tube to be inserted into a series of standard solutions stored beside the tray as well as into the unknown samples being moved in the tray. The new sample dipper has digital electronics built onto a small printed circuit board which are computer compatible and allow any one of ten standards, or the sample, or de-ionized water to be aspirated under programme control.

The system will be controlled from a Texas Instruments 960A mini-computer which will operate both the atomic absorbtion spectrophotometers (and eventually other equipment) simultaneously and independently. Calibration graphs will be constructed from the standards at the start of each run and the sample results in analytical units will then be presented with sample number both as a printout while the run is in progress, and on punched paper tape and cassette magnetic tape when it is completed.

Canadian Patents and Development Ltd. are assessing the market potential of the solid state interface unit with a view to liscensing the design to Canadian industry. The unit does not have a digital display, curve correction or other facilities for obtaining a direct readout in analytical units, since the primary purpose is to enable simple interfacing of an existing atomic absorbtion spectrophotometer to a mini computer, where the scope for such operations is almost limitless.

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12. THE USE OF SIMPLE VOLATILE COMPOUNDS IN MINERAL EXPLORATION

Project 720067

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To test the feasibility of using helium in natural waters as a tracer for uranium deposits, the helium content of 4 water samples from a uranium mine from Elliot Lake, Ontario was determined and compared to the helium content of a number of lake and stream water samples from the Elliot Lake, Ontario and the Gatineau Hills, Quebec area. The samples were collected during the period February 28 to March 8, 1973. The streams were found to be free of ice at the selected sample sites; but the lakes were covered with about two feet of ice and hence an ice auger was required to sample them. All water samples from the mine were collected from various ditches, sumps, stopes and drifts. They are not representative of the quality of the mines' drinking water. As the mine is quite dry, all water in it is piped in from the surface, used and discarded via sumps.

In Table I are listed the geometric means and ranges of the constituents of the dissolved air in the various types of water from the sampled areas. It is apparent from these results that the uranium mine, the tailing creek, and the drillhole samples show a marked enrichment in both helium and radon. This coincidence is not present in any of the other samples although the spring sample from the Gatineau Hills has a radon content and the Carlsbad Spring samples a helium content approaching that of the uranium mine samples. A more thorough investigation is required to determine whether this radon-helium coincidence in waters is characteristic of waters from uranium ore bodies.

A second feature of interest, although not so evident in the table, is the rapid depletion of oxygen in mine waters, particularly those from ore zones. No doubt, the oxidation of sulphides and/or U^{4+} is responsible for this phenomenon. However, no tests for SO_2 were carried out to confirm this, but some of the samples were very high in uranium.

A comparison of the composition of 10 mine air samples with atmospheric air showed no detectable changes in the helium, neon, argon, nitrogen, and oxygen contents. Only radon and carbon dioxide were found to fluctuate. Because a special effort was made to collect air samples from abandoned and sealed off areas, the quality of the air as shown by the analyses is not representative of mine working areas.

Table 1

Composition of dissolved air in uranium mine water and natural surface water

Sample Site and Type	Number of Sites	Geometric Mean and Range, % V/V							
		$He \times 10^4$	$Ne \times 10^4$	Ar	N_2	O_2	CO_2	CH_4*	Rn, pc/l x 10^{-3}
Gatineau Hills, Quebec									
- lakes	10	2	8	1.5	58	15	20	1	1
		2- 2	7- 9	1.5-1.6	54-62	6-23	10-31	0- 3	0- 12
- streams	2	2	8	1.6	58	27	8	1	3
		2- 2	8- 9	1.5-1.6	57-59	26-29	6-11	1- 2	2- 7
- springs	1	2	8	1.3	50	20	24	2	492
Elliot Lake, Ontario									
- lakes	12	2	8	1.5	57	12	20	1	0.4
		2- 2	7- 9	1.4-1.6	50-61	1-29	6-44	0- 5	0- 13
- streams	8	2	9	1.5	60	25	6	1	2
		2- 2	8-11	1.4-1.6	56-66	19-31	1-17	0-12	0- 22
- mines	4	195	11	1.8	66	1	20	1	323
		100-344	8-14	1.3-2.1	50-74	1- 2	11-46	0- 4	159-1600
- Tailing Creek	2	20	9	1.5	55	1	39	0	126
		8- 55	8-10	1.3-1.8	50-61	1- 1	34-45	-	99- 160
- drillholes	1	237	13	2.1	79	2	14	1	720
Carlsbad Springs, Ontario	2	56	2	0.7	23	2	5	68	1.5
		37- 86	1- 3	0.5-0.9	17-31	1- 3	3- 8	64-73	1.4-1.6

*-CH_4 content was estimated by difference after allowing for a 2% analytical bias

13. CANADA - NEWFOUNDLAND MINERAL DEVELOPMENT PROGRAM, PROJECT 6; GEOCHEMICAL - GLACIAL GEOLOGICAL SURVEY (Geochemical Phase)

Project 720036

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The objective was to outline areas in Newfoundland with good potential in metallic mineral resources, in order to facilitate discovery by exploration companies and thus contribute to the economic and social development.

Last summer's pilot studies developed and tested geochemical exploration methods. The program was carried out for, and in co-operation with, the Newfoundland Department of Mines and Energy, Mineral Development Division.

Regional and detailed geochemical exploration studies were carried out in two areas of Newfoundland in the field time available. They are: New Bay Pond area of Notre Dame Bay, for Cu-Zn sulphide mineralization in the volcanic and sedimentary rocks of the Wild Bight Group; and Daniel's Harbour area of the Northern Peninsula, for zinc mineralization associated with the St. George - Table Head disconformity.

Stream and lake sediments, lake water, B and C horizon soils and till were collected. Prepared sediments, soil and till were analyzed for Cu, Pb, Zn, Co, Ni, Ag and Mn and waters for Cu, Zn and Ni. Certain sample media were also analyzed for Fe, As and Hg. Percentage weight loss on ignition was determined for sediment samples.

All available analytical data has been evaluated and new interpretations and conclusions have been made in addition to those discussed in Hornbrook[1].

Conclusions at this time are:

New Bay Pond - Upper till, collected at the peat-till interface, and B and C soil horizon analytical data show ranges in concentration from background levels to anomalous for most elements. However, in the boggy plateau environment where the sulphide mineralization occurs, the erratic occurrence and distribution of these sample media prevent the soil and upper till sampling approach from achieving effectiveness.

In this type of boggy environment, the overburden drilling approach to obtain basal till samples to detect geochemical halos in the till is effective. Here, Cu, Zn, Pb and As anomalies, in particular, were found on, and adjacent to, known sulphide mineralization. Some of these anomalies are related to known sources and others indicate probable sources in an up-ice direction. Final stages of interpretation on such problems will be reached with the incorporation of Quaternary geology data from studies carried out by D.R. Grant of the Geological Survey. The basal till sampling approach was also effective in discriminating among those geophysical anomalies caused by sulphide occurrence in bedrock and those, for example, caused by graphite. The minus 230-mesh fraction and the heavy mineral separates in the minus 50, plus 230-mesh fraction of till were both tested. They were equally useful except that anomalies in the former may be partly or totally caused through leaching and subsequent solution migration, while those in the latter are identified with particulate material.

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Zinc compared to Cu and Ni and probably Hg, was the most useful element to determine in lake waters. The plotted distribution of Zn content in waters defined a trend that was improved on, and confirmed by the lake and stream sediment data.

Plotted lake and stream sediment anomalies for minus 80-mesh material define certain high metal trends in the area that were not inconsistent with the known geology. Many of the anomalies are multi-element and further define target areas within the regional trends. Metal associations in known sulphide occurrences are possibly reflected in various multi-element anomalies. Although the major known source of sulphide mineralization occurs in a bog plateau area, it was detected by anomalous As, Zn and Pb concentrations in adjacent stream sediments. The major source was not detected by lake sediments partly because the boggy environment is not conducive to long distance migration of elements in solution and because of the lack of suitable lakes for sampling in the immediate vicinity. However, lake and stream sediment data did produce strong trends and target anomalies in other parts of the study area remote from large bog plateaus.

Fluctuation of metal content in sediments unrelated to mineralization presents problems in the interpretation of analytical data. Frequently, a significant amount of fluctuation can be caused by the scavenging of metal elements from water by Fe, Mn and organic material in combination or separately. The scavenging, by precipitation and/or adsorption, causes a metal enrichment in lake or stream sediments producing an apparent high concentration of metals.

Rose and Suhr[2] have used regression analysis to investigate relationships between metal elements and measured variables such as, in this program, Fe, Mn and organic content of sediments. A regression equation is established, and the predicted and actual metal values calculated can be compared, and anomalous samples with a large positive difference between these values (residuals) identified for interpretation. Thus, the metal residual values for each sample have the influence of one or more of the measured variables removed for interpretation. A similar approach to processing stream and lake sediment data was used in this program.

The lake and stream sediment data discussed previously was regressed against Mn only. But, further processing by regression against Fe and organic content has revealed some suspected interesting relationships. For example, in stream sediments, Fe rather than Mn, accounts for most of the fluctuation in the Cu, Zn, Ni and Ag content and is as important as Mn for Pb, Co and As. Also, in lake sediments, variation in the organic content of samples influences only the Hg, and has no significant effect on the content of other metals determined. The other metals, Cu, Zn, Pb, Ni and Ag are influenced primarily by Mn and to lesser degree by the Fe content. These relationships indicate that, depending on the metal and sample media, Fe, Mn and organic content all play an important role. Each metal will have to be interpreted individually as the above complex relationships indicate.

<u>Daniel's Harbour</u> - Where less than 5 feet of till cover predominated, soil sampling was an effective approach to detecting suboutcrop exposures of mineralization. The C horizon has a higher metal content than the B. Where till depths exceed those suitable for soil sampling, overburden drilling to obtain basal till samples was carried out. The basal till sampling approach was a positive means of detecting mineralized material in the till and the probable suboutcrop source of mineralization. Thus, depending on depth of till, soil and till, geochemical sampling approaches successfully defined known areas of mineralization.

Anomaly maps of Zn content in lake waters outlined known areas of mineralization and indicated regional trends of high Zn distribution. These were better outlined and indicated by lake and stream sediment data.

Zinc was the most effective element among those determined in lake and stream sediments for exploration geochemistry. Zinc anomalies in the sediments effectively defined known areas of mineralization as well as indicating many others, some of which were associated with the St. George - Table Head disconformity. The adverse aspects of lake and/or stream sediment geochemistry is the erratic distribution of lakes and streams in the carbonate terrain.

[1] Hornbrook, E.H.W.: in Report of Activities, April to October, 1972; Geol. Surv. Can., Paper 73-1, Pt. A, p. 56 (1973).

[2] Rose, A.W., and Suhr, N.H.: Major element content as a means of allowing for background variation in stream sediment geochemical exploration: International Geochemical Exploration Symposium, Ed. Boyle, R.W., Can. Inst. Mining Met., Spec. Vol. 11, p. 587-593.

14. A GEOLOGICAL DATA BANK FOR STATISTICAL ANALYSIS

Project 710039

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An extensive data base is a prerequisite for a statistical evaluation of mineral potential when the assumption is made that the geology, as it is known today, is correlated with the occurrence of various types of mineralizations in the area of study.

A statistical approach to the prediction of mineral potential of large areas by using geological information is of relatively recent application[1,2,3]. A first fully quantitative estimate by the Geological Survey of Canada of the undiscovered mineral resources of a region based on statistical appraisal of certain geological and geophysical parameters was published on 1:500,000 maps[4].

A data bank is now available for large parts of the Superior and Southern Provinces of the Canadian Shield. It consists of (1) a geological data file with information on 42 geological variables (Table 1), and (2) a geomathematical mineral deposit file with data on approximately 500 mineral deposits in the Superior Province. The area covered by these files is subdivided into four blocks numbered 1 to 4 (Fig. 1).

For this project, 10-km-square cells have been used in quantifying the 42 variables of Table I according to the UTM grid systems for Zones 15, 16, 17, and 18. The areas of outcrop of each variable have been estimated for every cell by point-counting geological maps. A grid with 20 x 20 = 400 intersections was used and points were recorded by means of an electronic point counter[5]. For every cell the results were entered into coding forms especially designed for punching the data into IBM computer cards.

The geological data represent the areas per cell occupied by the 42 variables that were coded; published 1 inch to 4 mile geological compilation maps - occasionally 1 inch to 2 mile maps - were used and these were upgraded by consulting, where possible, more recent sources of information. For this geological compilation the author consulted most published and unpublished geological maps available for the area of study.

The present geological file contains data on the composition of about 8,500 10-km UTM cells. It covers approximately 850,000 square kilometres (328,187 square miles) and represents 49 per cent of the area of the Superior and Southern Provinces, whose total area (Canada and the United States) is about 675,000 square miles. The file is subdivided into four irregular blocks of data, approximately in accordance with the UTM zones in this part of Canada (i.e., Zones 15, 16, 17 and 18). Data block No. 3, centred in UTM Zone 17 is shown in Figure 2 for example. Table II provides more detailed information on the sizes of the data blocks numbered 1 to 4 (see Fig. 1) and with the compositional percentage values for the 42 variables quantified. About half the variables apply to the Superior Province.

The mineral deposit data file was collected in parallel with the geological data file. It contains limited information on metal deposits within the Superior Province only. The data were specifically selected for statistical

TABLE I

LIST OF THE GEOLOGICAL VARIABLES QUANTIFIED

AGE	VARIABLES	DESCRIPTIONS
	G 1	Mafic metavolcanic rocks
	G 2	Felsic to intermediate metavolcanic rocks
	G 3	Sedimentary rocks (cf. As on map 1[2])
	G 4	Metamorphic rocks (cf. An on map 1[2])
Archean	G 5	Anorthosite
	G 6	Ultramafic intrusive rocks except anorthosite
	G 7	Mafic intrusive rocks
	G 8	Granulite complexes (Kapuskasing and Pikwitonei)
	G 9	Granitic gneisses, migmatites, includes some unmapped areas (cf. Agn on map 1[1])
	G10	Felsic intrusive rocks (cf. Ag on map 1[1])
	G11	Carbonatite and alkalic complexes (cf. 16 on map 2[2])
Proterozoic	G12	Late felsic igneous rocks (cf. 15 on map 2[2])
	G13	Late mafic igneous rocks (cf. 14 on map 2[2])
	G14	Lakes and rivers, drainage and coastal waters
	G15	Unmapped areas and/or Cenozoic (drift covered areas)
	G16	Paleozoic
Archean	G17	Amphibolites: mainly metamorphosed basic extrusive and intrusive rocks (cf. Am on map 1[1])
	G18	Elliot Lake Gp. Matinenda Formation
	G19	Elliot Lake Gp. McKim Formation
	G20	Elliot Lake Gp. acidic volcanics
	G21	Elliot Lake Gp. mafic volcanics
	G22	Hough Lake Gp. (Ramsay Lake F., Pecors F., Mississagi F.)
	G23	Quirke Lake Gp. (Bruce F., Espanola F., Serpent F.)
Aphebian	G24	Cobalt Gp. Gowganda Formation
	G25	Cobalt Gp. Lorrain Formation
	G26	Cobalt Gp. (Gordon Lake F., Bar River F.)
	G27	Creighton and Murray Granites
	G28	Nipissing Diabase
	G29	Animikie Gp.
	G30	Whitewater Gp. Onaping Formation
	G31	Whitewater Gp. (Chelmsford F., Onwatin F.)
Aphebian and Helikian	G32	Killarney and Cutler and associated granites
	G33	Sudbury Irruptive (Felsic Norite)
Aphebian	G34	Sudbury Irruptive (Transition Zone)
	G35	Sudbury Irruptive (Micropegmatite)
Precambrian	G36	Rocks of the Grenville Province
	G37	Sibley Gp.
	G38	Osler Gp.
Helikian	G39	Coldwell and Killala Lake complexes (gabbro part)
	G40	Coldwell and Killala Lake complexes (syenite part)
Aphebian	G41	Mistassini Gp.
Precambrian	G42	Rocks of the Churchill Province

(1) map 1 = Geological Survey of Canada, Map 1250A, 1969, scale 1:5,000,000.

(2) map 2 = Ontario Department of Mines and Northern Affairs, Ontario Geological Map (Maps No. 2197, 2198, 2199, 2200, and 2201), 1971, scale 1" to 16 miles.

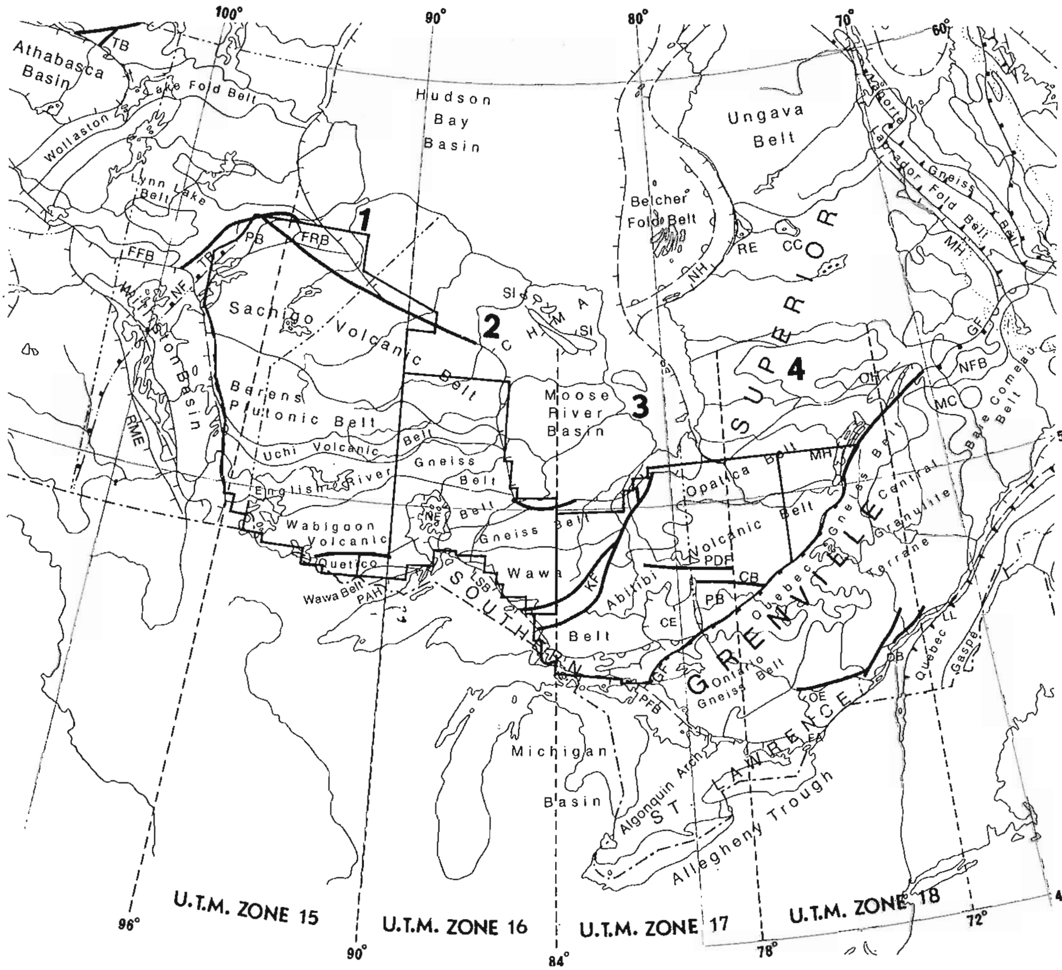

Figure 1. Distribution of the area covered in the present compilations. The numbers 1 through 4 indicate the data blocks of the Geological Data File. Modified after Douglas (1973).

analysis and are listed in Table III. The information of Table III was computerized for every commodity for which tonnage and grade figures were available according to a procedure analogous to that used for the geological data file. The amount of metal produced plus that in the reserves for the commodities of a given deposit can be calculated by multiplying the figures for tons of ore by their grades. The total amount of metal for a specific commodity (sum of production and reserve figures) provides an estimate of the size of that deposit with respect to that commodity.

In total, 975 commodity entries representing 492 deposits were described in this manner. Some statistical details about the distribution of commodities and deposits within the four data blocks are represented in Table IV.

TABLE II

PERCENTAGES OF AREAS OF THE FOUR DATA-BLOCKS (NUMBERED 1 TO 4) OCCUPIED BY THE VARIOUS GEOLOGICAL VARIABLES QUANTIFIED (NUMBERED G 1 TO G42).

Variable No.	Data Blocks and File Names			
	(1) GEOD 15	(2) GEOD 16	(3) GEOD 17	(4) GEOD 18
	%	%	%	%
G 1	6.34	8.15	14.32	11.79
G 2	.76	.58	2.47	6.81
G 3	2.28	1.84	4.81	1.97
G 4	4.08	10.51	7.83	3.15
G 5	.01	.005	.76	1.06
G 6	.05	.07	.31	.16
G 7	.56	1.09	.78	2.06
G 8	1.19	-	.74	-
G 9	34.42	28.98	17.72	41.41
G10	20.51	10.33	19.34	5.06
G11	.07	.04	.12	-
G12	.14	.24	.005	-
G13	.06	4.26	.04	-
G14	14.64	12.47	6.93	13.29
G15	13.89	16.76	12.55	.78
G16	.46	2.35	1.83	-
G17	.31	.02	.65	4.43
G18	-	-	.12	-
G19	-	-	.18	-
G20	-	-	.04	-
G21	-	-	.03	-
G22	-	-	.59	-
G23	-	-	.31	-
G24	-	-	2.59	-
G25	-	-	2.16	-
G26	-	-	.09	-
G27	-	-	.03	-
G28	-	-	1.39	-
G29	-	.81	-	-
G30	-	-	.15	-
G31	-	-	.14	-
G32	-	-	.08	-
G33	-	-	.07	-
G34	-	-	.01	-
G35	-	-	.13	-
G36	-	-	.62	4.08
G37	-	.84	.05	.19
G38	-	.36	.04	-
G39	-	.04	-	-
G40	-	.18	-	-
G41	-	-	-	3.75
G42	.23	-	-	-
Total %	100.00	99.93	100.03	99.99
km^2	380,100	189,000	254,100	36,600

TABLE III

DATA COLLECTED ON MINERAL DEPOSITS FOR THE FOLLOWING COMMODITIES:

Cu, Ni, Zn, Pb, Au, Ag

1 commodity described
2 deposit number (for identification)
3 UTM Zone
4 northing in metres
5 easting in metres
6 X-coordinate of 10-km cell in which the deposit occurs (a different system of coordinates was used for each of the 4 UTM Zones covering the area studied)
7 Y-coordinate of 10-km cell
8 other above-mentioned commodities present in the deposit
9 tons of ore milled (short tons)
10 grade of ore milled (per cent/ton for base metals, ozs/ton for precious metals)
11 tons of ore in reserves (short tons)
12 grade of reserves (same units as in 10 above)
13 other above-mentioned commodities in production and/or reserves
14 data block (could be 1, 2, 3, or 4, and identifies the system of coordinates chosen for the cell containing the deposit described and the geological data coded according to the UTM Zones 15, 16, 17, or 18 respectively)
15 name of the deposit and/or operating company

TABLE IV

DISTRIBUTION OF DEPOSITS IN THE FOUR UTM ZONES STUDIED IN THE SUPERIOR PROVINCE (NO DEPOSITS HAVE BEEN CODED IN THE SOUTHERN PROVINCE). DATA-BLOCKS ARE IN BRACKETS.

Deposit type (defined by the commodity with the largest grade value)	UTM Zones				Totals
	15 (1)	16 (2)	17 (3)	18 (4)	
Cu	7	3	54	23	87
Ni	8	3	10	--	21
Zn	5	6	29	1	41
Pb	--	3	3	--	6
Au	95	44	172	3	314
Ag	8	3	15	--	26
Totals	123	62	283	27	495

TABLE V

COMPOSITION AND METAL CONTENT (PRODUCTION PLUS RESERVES) OF SOME LITHO-TECTONIC BELTS DISTINGUISHED IN THE SUPERIOR AND SOUTHERN PROVINCES BY DOUGLAS (1972, 1973)

GEOLOGICAL VARIABLES (TABLE I)	BELTS OR SUBPROVINCES (DATA BLOCKS INTERESTED)													
	Abitibi (3, 4)	Wawa (1, 2, 3)	Opatica (3, 4)	Unnamed (3, 4)	Pontiac (3)	Kapuska sing (3)	Southern (3)	Southern (2)	Quetico (1, 2, 3)	Wabigoon (1, 2)	English R. (1, 2)	Uchi (1, 2)	Berens (1, 2)	Sachigo (1, 2)
G 1	36.46	9.37		.08	4.58	.01	.72	.20	2.00	15.60	2.14	22.28	.41	5.68
G 2	7.58	1.48		.001	.63		.93		.02	1.68	.42	3.00	.06	.34
G 3	8.04	1.25	24.64	.01	.17	.20	.36		7.88	2.19	3.78	5.09	.11	2.32
G 4	.14	1.04	11.19	9.69	26.98	8.37	.003	.21	43.18	6.43	15.20	2.90	1.92	.91
G 5	.97	.11	.006			21.07	.005		.009	.02	.02	.03		.005
G 6	.71	.05	.11	.04	.09	1.43			.005	.008		.05	.04	.06
G 7	2.28	.35	2.32		.70	.03	.39		.15	.89	.22	1.67	.06	1.38
G 8		.01				31.66								
G 9	12.04	32.65	.64	44.90	46.13	21.76	1.95	1.80	28.18	36.77	43.69	13.36	32.95	33.52
G10	24.09	26.77	.76	13.15	1.38	2.66	5.68	.002	2.36	9.76	8.66	27.13	37.24	19.52
G11	.08	.13				.72	.22		.35	.14	.003	.23	.09	.04
G12		.02					.04	.77		.45		.31	.37	
G13	.003	.14		.01	.19	1.22		30.89	.22	1.38	.38			.04
G14	6.76	8.83	9.12	6.02	9.22	3.66	11.59	38.61	6.58	15.98	11.95	11.89	10.98	14.06
G15	.29	17.01	1.50	25.41	9.66	7.17	3.29	8.78	8.86	8.62	13.49	11.09	15.73	21.61
G16	.008	.004		.41			1.91		.09	.07		.08	.07	.08
G17	.48	.004	49.71	.23	.28				.005	.007	.03	.88		.45
G18							1.10							
G19							1.79							
G20							.40							
G21							.24							
G22		.01					5.24							
G23		.02					2.81							
G24	.034	.03					23.45							
G25		.04					19.46							
G26							.81							

Table V (cont.)

GEOLOGICAL VARIABLES (TABLE I)	BELTS OR SUBPROVINCES (DATA BLOCKS INTERESTED)													
	Abitibi (3, 4)	Wawa (1, 2, 3)	Opatica (3, 4)	Unnamed (3, 4)	Pontiac (3)	Kapuskasing (3)	Southern (3)	Southern (2)	Quetico (1, 2, 3)	Wabigoon (1, 2)	English R. (1, 2)	Uchi (1, 2)	Berens (1, 2)	Sachigo (1, 2)
G27							.24							
G28	.003	.27					11.68							
G29		.003						8.05						
G30							1.38							
G31							1.26							
G32							.72							
G33		.004					.56							
G34							.12							
G35							1.14							
G36	.008						.001							
G37							.18	7.46		.007				
G38		.003					.34	3.22						
G39		.07					.01		.01					
G40		.33							.10					
G41	.03													
G42														
km^2	101,731	84,170	4,512	51,984	3,441	1,475	27,529	21,225	53,850	82,287	68,442	34,288	90,625	174,238
'000 short tons														
Cu	5,975	138			19				969	184	24	32		
Ni	3,248	10			12					54	61			
Zn	13,591	25			7				2,123	978		159		19
Pb	335	6			1				39	108		.3		15
'000 ounces														
Au	123,349	1,902			2,063				4,291	1,1091	2	14,535		539
Ag	500,966	1,384			452				88,322	40,527	1	6,084		12,630

[1] The term "Unnamed" refers to the plutonic terrains within the Opatica Belt of Figure 1. Similarly the term "Opatica" refers to the volcanic terrains in this belt.

A preliminary statistical analysis of these data consisted of subdividing the files into litho-tectonic belts as defined by Douglas[6,7]. Subfiles were made of all the data collected for the belts represented in Figure 1. The statistical compilation of Table V shows the geological composition of several belts or subprovinces as percentages of areas per variable, total areas of the belts (in km^2), and total amount of metal (production plus reserves) known to date (1971) as calculated from the data in the mineral deposit file.

The data bank made available through the project can now be subjected to various types of statistical analyses with a dual scope: (1) to aid in prediction of the regional mineral potential in large part of the Superior Province of the Canadian Shield, and (2) to experiment on the use of new and more sophisticated statistical and mathematical methods for the study of geological phenomena on a regional scale.

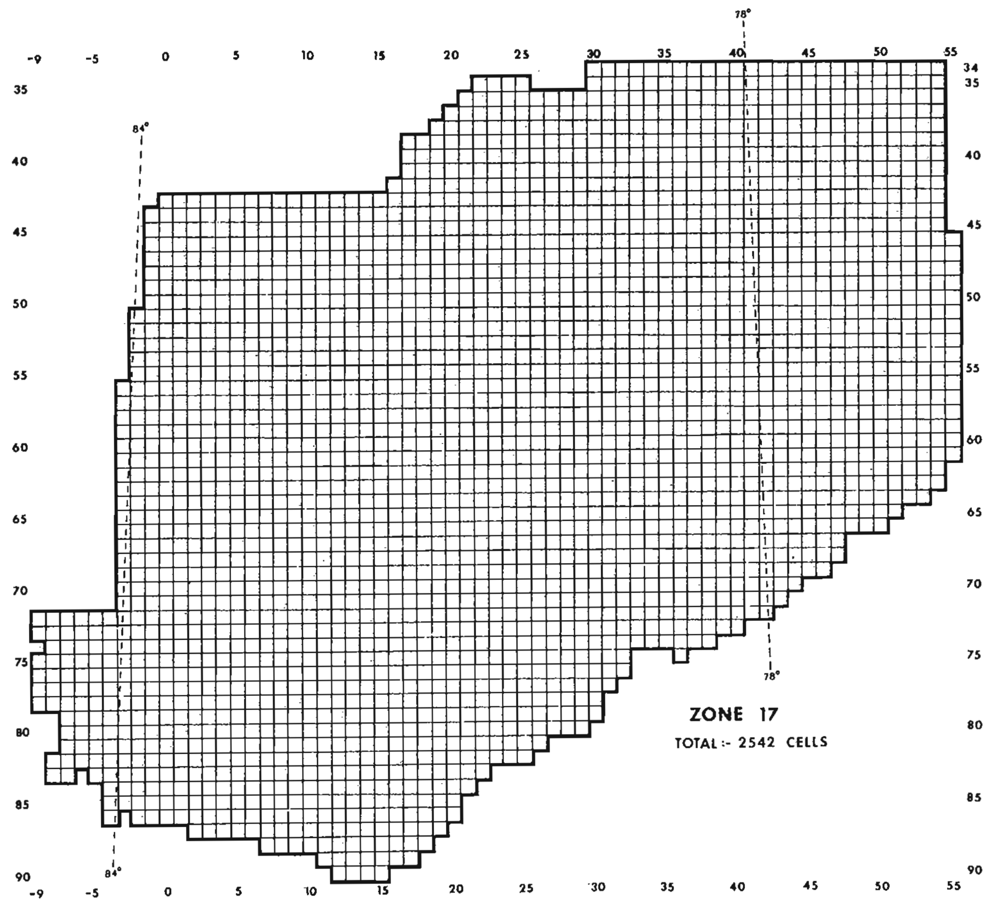

Figure 2. Data block No. 3 for the present file; corresponds to UTM Zone 17. Zone boundaries are indicated by broken lines.

[1]Harris, D.P.: An application of multivariate statistical analysis to mineral exploration; Unpubl. Ph.D. thesis, the Pennsylvania State University, University Park, Pennsylvania, 266 p. (1965).

[2]Harris, D.P.: Alaska's Base and Precious Metals Resources; a Probabilistic Regional Appraisal; Colo. Sch. Mines Quart., v. 64, no. 3, p. 295-328 (1969).

[3]Kelly, A.M., and Sheriff: A statistical examination of the metallic mineral resources of British Columbia; Proc. Symposium on Decision-Making in Mineral Exploration II, Vancouver, Canada, February, 1969 (1969).

[4]Agterberg, F.P., Chung, C.F., Fabbri, A.G., Kelly, A.M., and Springer, J.A.: Geomathematical evaluation of copper and zinc potential of the Abitibi area, Ontario and Quebec; Geol. Surv. Can., Paper 71-41 (1972).

[5]Voisey, P.W.: An Instrument for Counting Experimental Material, Can. J. Plant Sci., v. 47, p. 225-228 (1967).

[6]Douglas, R.J.W.: Summary of the Geology of Canada; Earth-Science Reviews, v. 8, p. 84-100 (1972).

[7]Douglas, R.J.W.: Geological Provinces, Sheet No. MCR1124; The National Atlas of Canada, Surveys and Mapping Branch, Ottawa, Canada; 4th edition, p. 27-28 (1973).

GEOPHYSICS

15. AIRBORNE GAMMA-RAY SPECTROMETRY AS AN AID TO GEOLOGICAL MAPPING TOWNSHIP 155 ELLIOT LAKE AREA, ONTARIO

Project 720071

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A number of experimental airborne radioactivity surveys have been carried out by the Geological Survey of Canada in recent years. One of these surveys[1] in the area of Elliot Lake, Ontario, illustrates the potential of airborne gamma-ray spectrometry as an aid to geological mapping, and the results of ground investigations in the area of this survey and the Bancroft, Ontario, and Fort Smith, N.W.T. surveys[2, 3] indicate the effects of overburden on the surface radioactivity that is measured from the air.

The geology map[4] and the airborne uranium and thorium distribution maps of Township 155 from the Elliot Lake survey are shown in Figure 1. The Matinenda and Gowganda Formations are both relatively high in uranium and thorium, the combined Mississagi and Pecors Formations and the granite basement rocks are low. Figure 2 shows three radioelement ratio maps of Township 155. The U/K and Th/K ratios are highest in the Matinenda Formation, high in the Gowganda Formation, low in the Mississagi and Pecors Formations, and lowest in the basement rocks. The U/Th map lacks a distinctive pattern. Ground gamma-ray spectrometry measurements showed that all the rock types of Township 155 have U/Th ratios close to a crustal average of 0.25. It should be noted that no economic uranium mineralization occurs at or near surface in this township.

Figure 3 shows the locations of measurements made with a portable gamma-ray spectrometer in the Elliot Lake area. At each location 10 outcrop analyses were made within an area of a few hundred square yards. Table I lists the results of the ground measurements, and the ground measurements are compared with airborne measurements for the four major geological units in Table II. The outcrop and airborne values show similar relative variations among the geological units, and this is significant since the surface of the area is predominantly covered with ground moraine (approximately 10 per cent outcrop). This indicates that the overburden material is largely locally derived and reflects the radioelement composition of the underlying bedrock, as reported previously[5].

The relationship between radioelement content of outcrop and overburden is further illustrated in Figure 4, a compilation of thorium determinations over 43 test areas where ground measurements were made on 65-metre grids over approximately 1-km-square areas. The points are plotted in increasing order of thorium concentration in outcrop. These test areas, located in the vicinity of Elliot Lake, Bancroft and Fort Smith and designated by the letters E, B and F respectively, followed by two additional letters indicating detailed location, cover a wide range of rock types from gabbro to granite plus sedimentary and volcanic rocks. Figure 4 represents over 3,000 field gamma-ray spectrometric determinations on outcrop and overburden

Geol. Surv. Can., Paper 73-1, Part B

(which was measured at 27 of the 43 localities). Similar data exist for the other radioelements. The data which are reported in this diagram were gathered by several Branch personnel over a number of years.

The general conclusions relating to Figure 5 are that the thorium concentration in overburden increases with that of underlying bedrock; thorium concentrations in bedrock and associated overburden are in close agreement up to about 8 ppm thorium. Above this concentration, values for overburden

TABLE I

GROUND LEVEL RADIOELEMENT CONCENTRATIONS IN BEDROCK

LOCALITY	K%	U ppm	Th ppm	U/Th	U/K x 10^{-4}	TH/K x 10^{-4}
		COBALT GROUP			Gowganda formation	
10	2.86	5.77	27.14	0.21	2.02	9.49
9	3.72	7.20	27.86	0.26	1.93	7.49
	3.29	6.49	27.50	0.24	1.98	8.49
		QUIRKE LAKE GROUP			Espanola formation	
		HOUGH LAKE GROUP		Mississagi & Pecors Formations combined		
8	0.94	0.85	3.57	0.23	0.90	3.80
7	1.09	2.15	7.14	0.30	1.97	6.55
	1.02	1.50	5.36	0.27	1.44	5.18
		ELLIOT LAKE GROUP		Matinenda formation		
6	2.24	7.83	38.91	0.20	3.50	17.37
5	1.18	2.38	8.34	0.29	2.02	7.07
4	1.88	7.50	20.00	0.38	3.98	10.64
	1.77	5.90	22.41	0.29	3.16	11.69
		ARCHEAN		Granite basement		
3	1.62	0.41	3.75	0.11	0.25	2.31
2	1.73	1.23	5.71	0.22	0.71	3.30
1	1.46	1.18	2.85	0.29	0.80	1.95
	1.60	0.94	4.10	0.21	0.59	2.52

TOWNSHIP 155

ELLIOT LAKE

GEOLOGICAL LEGEND (REVISED 1971)

PROTEROZOIC
HURONIAN

Gowganda Formation

Espanola Formation

10 Mississagi Formation

9 Pecors formation

7 McKim Formation

5 Matinenda Formation

3 a,b Acid Intrusive Rocks

--- Geological contact, approximate

- — Fault or lineament

COBALT GROUP

conglomerate, greywacke, quartzite, argillite

QUIRKE LAKE GROUP

limestone, dolomite, calcareous siltstone, quartzite, conglomerate

HOUGH LAKE GROUP

quartzite, conglomerate

argillite, quartzite

ELLIOT LAKE GROUP

siltstone, argillite, quartzite

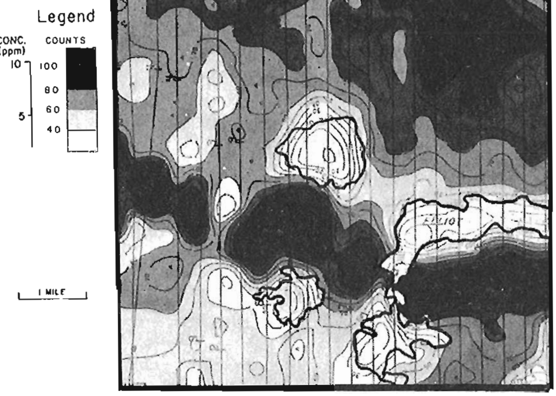
quartzite, arkose, uranium bearing conglomerate

ARCHEAN

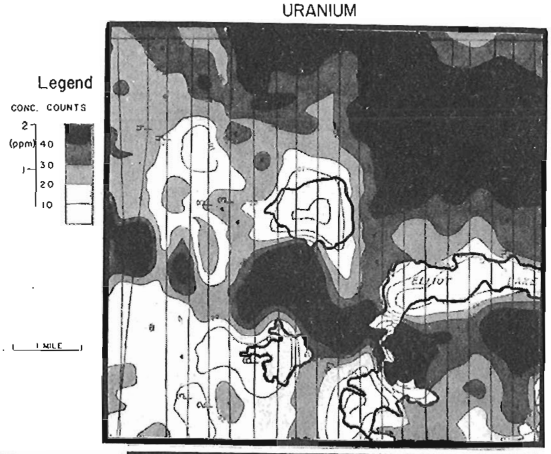
a) Variable granitic rocks ± inclusions

b) quartz monzonite

RADIOMETRIC SURVEY 1970
THORIUM



RADIOMETRIC SURVEY 1970
URANIUM



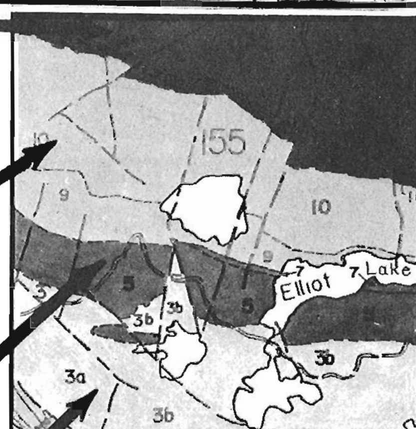


Figure 1.

TOWNSHIP 155

ELLIOT LAKE

RADIOMETRIC SURVEY 1970

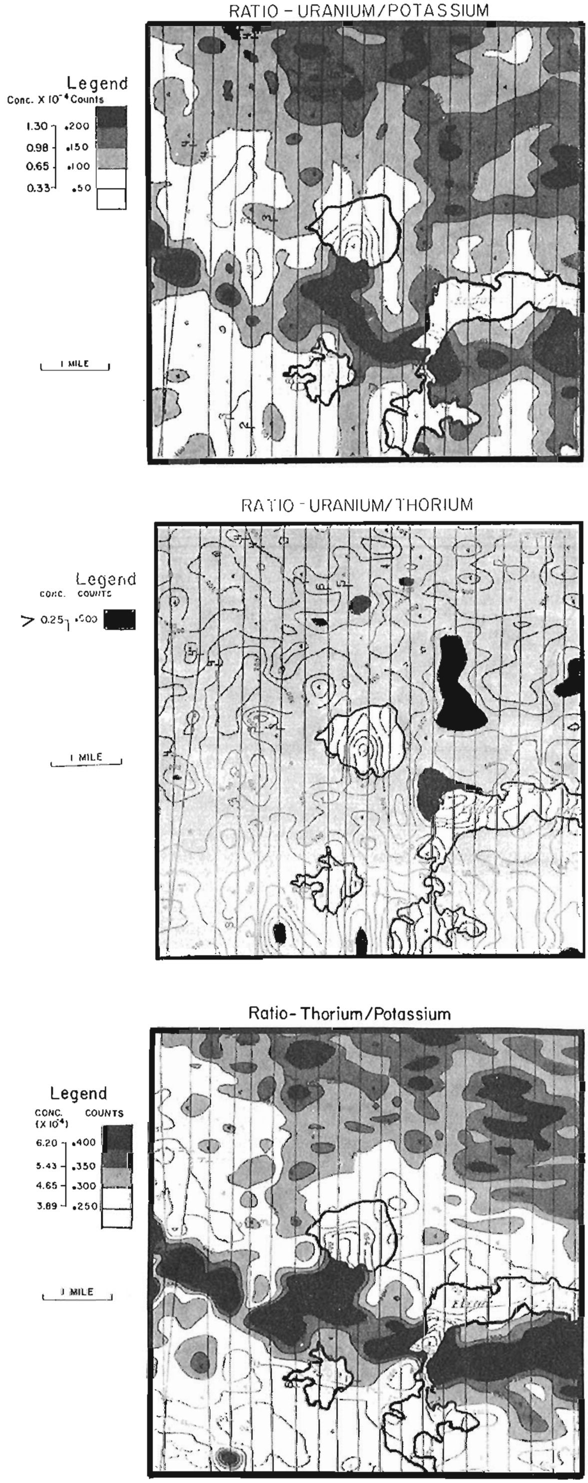


Figure 2.

TABLE II

COMPARISON OF AIRBORNE vs BEDROCK VALUES FOR FORMATIONS IN TWP 155

	Potassium %		Uranium ppm		Thorium ppm		Uranium/ Thorium		$\frac{\text{Uranium}}{\text{Potassium}} \times 10^{-4}$		$\frac{\text{Thorium}}{\text{Potassium}} \times 10^{-4}$	
	A	G	A	G	A	G	A	G	A	G	A	G
COBALT GROUP												
Gowganda formation	1.77	3.29	1.73	6.49	10.00	27.50	0.17	0.24	0.98	1.98	5.43	8.49
QUIRKE LAKE GROUP												
HOUGH LAKE GROUP												
Mississagi formation + Pecors formation combined	1.32	1.02	0.96	1.50	6.36	5.36	0.17	0.27	0.65	1.44	4.65	5.18
ELLIOT LAKE GROUP												
Matinenda formation	1.47	1.77	1.92	5.90	10.90	22.41	0.17	0.29	1.30	3.16	6.98	11.69
ARCHEAN												
Granite basement	1.32	1.60	0.77	0.94	4.54	4.10	0.17	0.21	0.63	0.59	3.43	2.52

A = Airborne G = Ground

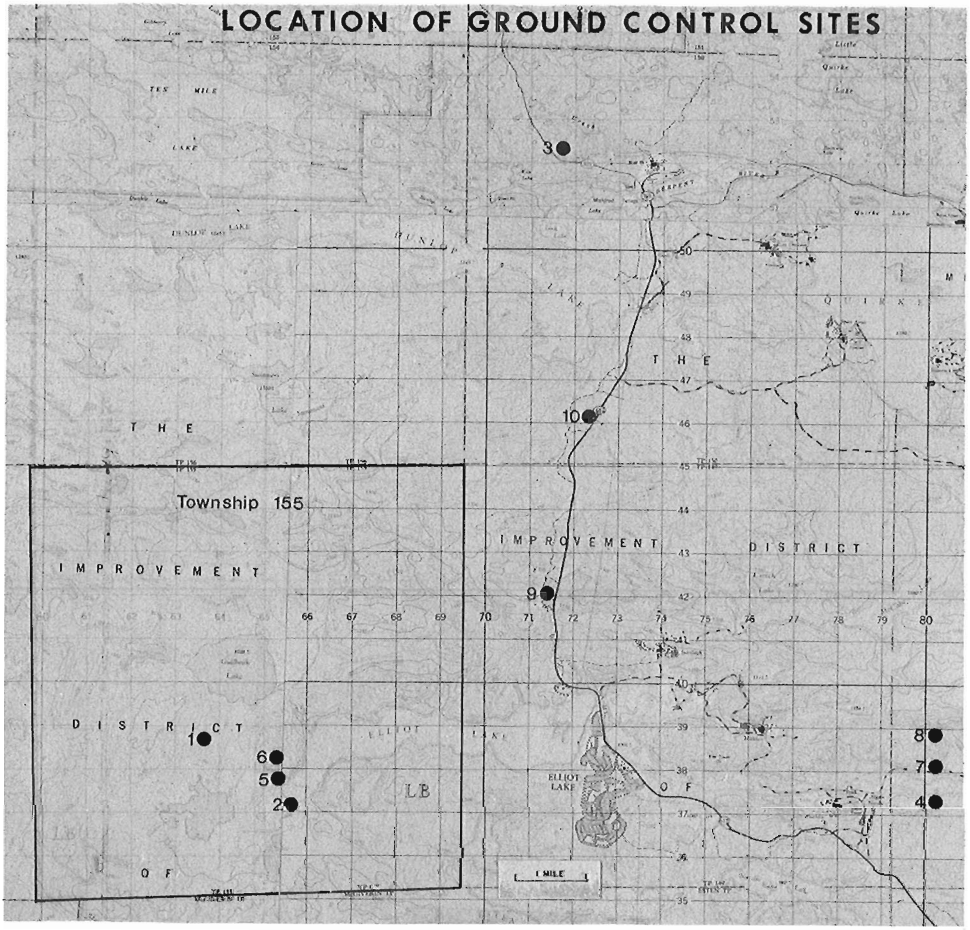


Figure 3.

increase more slowly than for bedrock. Over a highly radioactive bedrock, dilution of the overburden with transported material of more normal radioactivity would produce the relationship shown in Figure 4. (Likewise, over rocks of extremely low radioactivity, the overburden would tend to be somewhat more radioactive than the bedrock). A second factor that can reduce the apparent radioelement content of overburden is absorption of radioactivity by water contained in the overburden. Similar conclusions can be demonstrated for the other radioelements K and U.

Figure 5 shows airborne magnetometer survey data over Township 155 (part of GSC map 3237G). In contrast to the radioactivity maps, the magnetic map gives little information about the Huronian formations, and the magnetic anomalies shown relate to the underlying granitic rocks, in particular to inclusion bearing granitic rock.

The data discussed in this paper relate specifically to Township No. 155. Ground studies by Killeen[6] and Bottrill[7] examined the radioelement concentrations of the Quirke Lake syncline as a whole and are particularly useful in studying the whole survey. Where these results relate to Township No. 155 they are consistent with the results reported above.

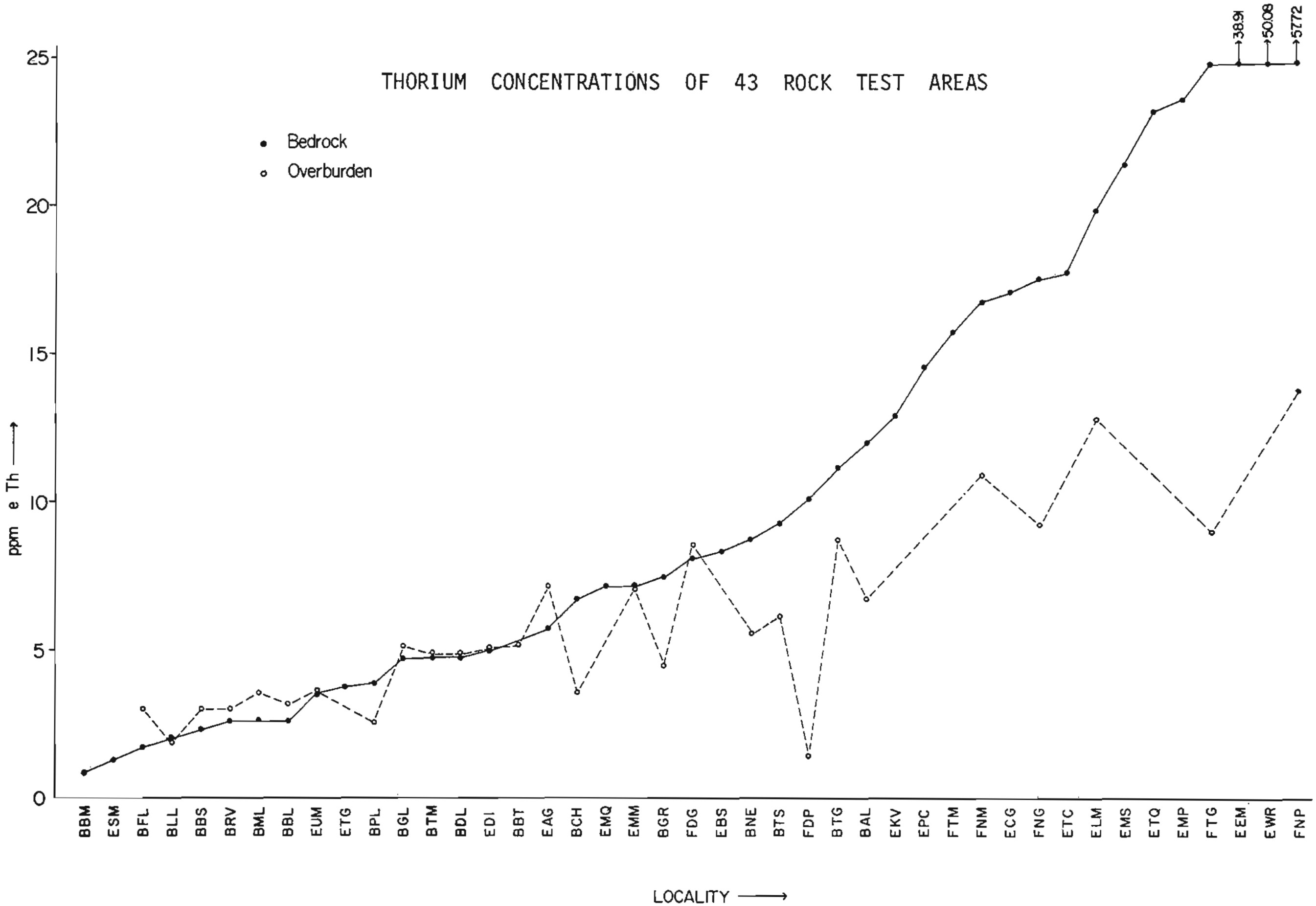

THORIUM CONCENTRATIONS OF 43 ROCK TEST AREAS
Bedrock
Overburden
ppm e Th
0
5
10
15
20
25
38.91
50.08
57.72
BBM
ESM
BFL
BLL
BBS
BRV
BML
BBL
EUM
ETG
BPL
BGL
BTM
BDL
EDI
BBT
EAG
BCH
EMQ
EMM
BGR
FDG
EBS
BNE
BTS
FDP
BTG
BAL
EKV
EPC
FTM
FNM
ECG
FNG
ETC
ELM
EMS
ETQ
EMP
FTG
EEM
EWR
FNP
LOCALITY

Figure 4.

TOWNSHIP 155
ELLIOT LAKE
FLUXGATE MAGNETOMETER SURVEY 1954-56

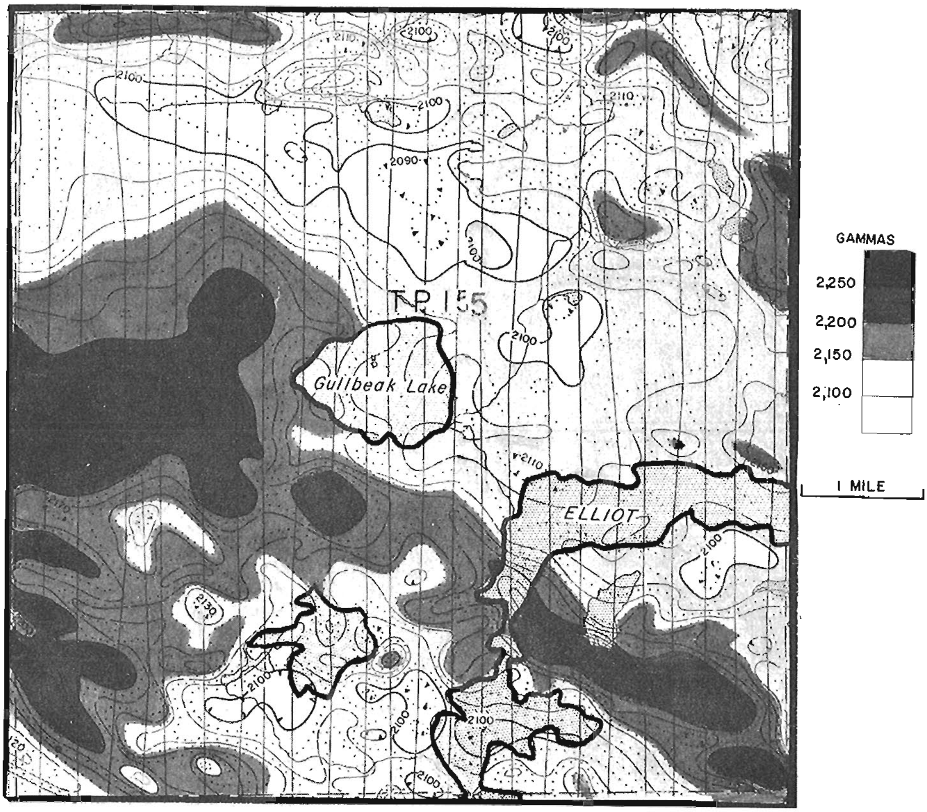


Figure 5. Part of 3237G

[1] Darnley, A. G. and Grasty, R. L.: Airborne radiometric survey of the Elliot Lake area; Geol. Surv. Can., Open File No. 75 (1971).

[2] Darnley, A. G. and Grasty, R. L.: Airborne radiometric survey of the Bancroft area; Geol. Surv. Can., Open File No. 45 (1970).

[3] Darnley, A. G. and Grasty, R. L.: Airborne radiometric survey of the Fort Smith area; Geol. Surv. Can., Open File No. 101 (1972).

[4] Robertson, J. A.: Blind River - Elliot Lake Sheet, Geological compilation Ontario Department of Mines and Northern Affairs, Map P-304 revised 1971 (1971).

[5] Darnley, A. G., Grasty, R. L., Charbonneau, B. W.: A Radiometric profile across part of the Canadian Shield; Geol. Surv. Can., Paper 70-46 (1972).

[6]Killeen, P. G.: A Gamma-ray spectrometer study of the radioelement distribution of the Quirke Lake syncline, Blind River Area, Ontario; Unpubl. M. Sc. thesis, Univ. Western Ontario (1966).

[7]Bottrill, T. J.: The stratigraphic relationships of Uraniferous Conglomerates, Associated Strata and Volcanic Units at Elliot Lake, Ontario; in Report of Activities, Pt. A, April to October, 1970; Geol. Surv. Can., Paper 71-1, p. 77-83 (1971).

16. URANIUM ENRICHMENT ASSOCIATED WITH THE DELORO STOCK, SOUTHERN ONTARIO

Project 720084

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Resources Geophysics and Geochemistry Division, Ottawa

In October 1972 a series of gamma-ray spectrometer profiles were carried out over southern Ontario as preliminary base level flights for an experimental snow survey[1]. Two of these profiles were flown over the Deloro Stock, a granitic intrusion in Hastings County, Ontario, and anomalies indicative of possible uranium mineralization were found at its margins.

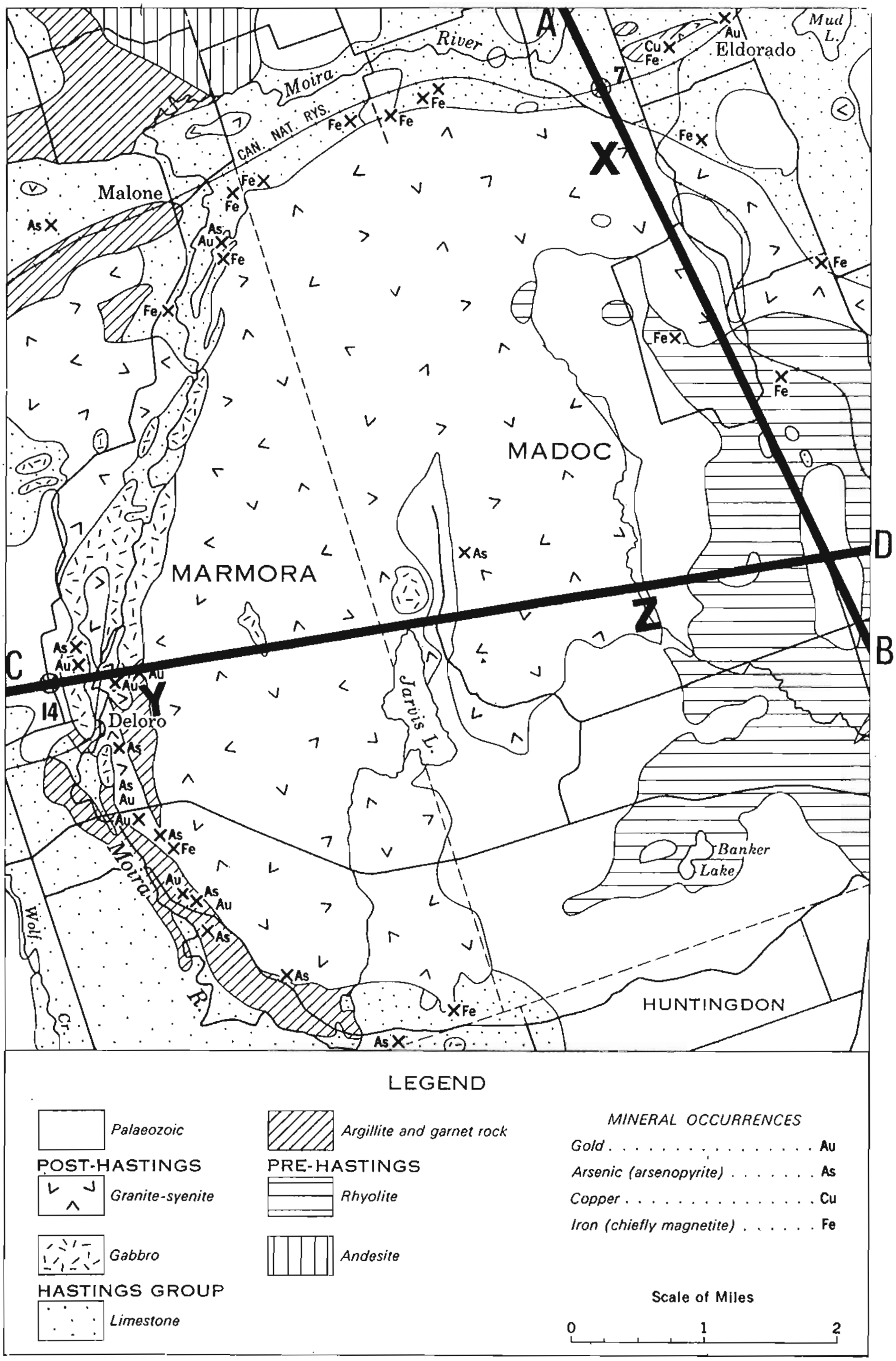
Figure 1 shows the geology of the area[2] and the location of the flight lines. Figure 2 shows the two sections of gamma-ray profiles flown over the Deloro Stock.

The profiles show:

1. Integral counts per 0.5 secs (0.41 to 2.81 MeV)
2. Postassium counts per 2.5 secs (1.37 to 1.57 MeV); 1% K $\simeq$ 150 counts.
3. Uranium counts per 2.5 secs (1.66 to 1.86 MeV); 1 ppm eU $\simeq$ 24 counts.
4. Thorium counts per 2.5 secs (2.41 to 2.81 MeV); 1 ppm eTH $\simeq$ 9 counts.
5. Uranium/Thorium counts.
6. Uranium/Potassium counts.
7. Thorium/Potassium counts.

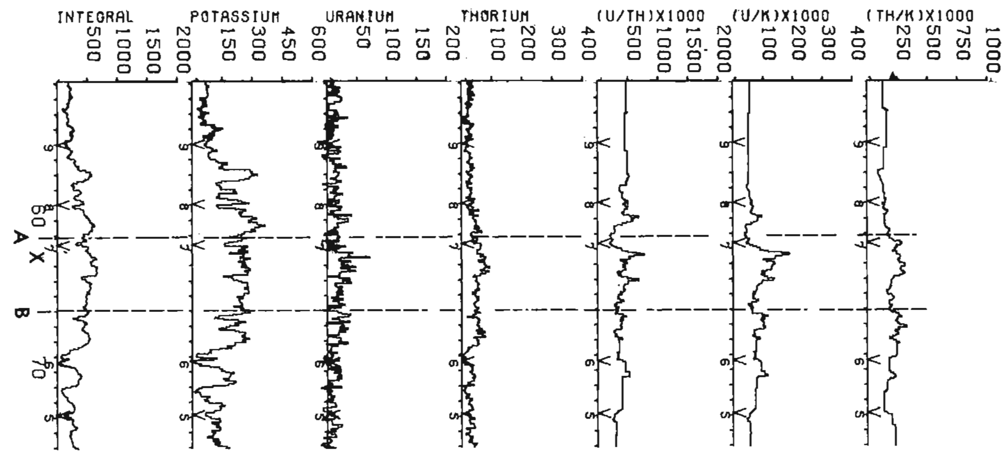
All count rates have been corrected for atmospheric background radiation, Compton scattering in the crystals and deviation from the nominal flying height of 500 feet. The ratio plots (5 and 6) accentuate any enrichment of uranium/potassium or uranium/thorium ratios are possible indicators of uranium mineralization. Uranium/potassium and uranium/thorium anomalies marked by X, Y and Z in Figures 1 and 2 are found to lie along the margins of the Deloro stock which occupies a roughly elliptical-shaped area some 7 by 5 miles.

The geological relationship of the intrusion has been described by Wilson[2]. The eastern margin of the granitic mass is largely covered by Paleozoic limestone and where not covered is in intrusive contact with pre-Hastings Group volcanic rocks. At its other margins it intrudes Hastings Group metasediments or gabbro. Wilson stated, "The outstanding feature of the Deloro granitic stock is its massive character, its moderately coarse texture, its intrusive relationships, the mineralization occurring along its margin and its variation into three phases: 1. perthitic granite; 2. micro-pegmatitic granite; and 3. syenite. The syenite is restricted to the marginal parts of the stock and may have resulted from assimilation of country rocks. The mineral deposits associated with the Deloro stock belong to three classes: 1) Magnetite; 2) gold-bearing arseno-pyrite in veins of quartz and 3) a contact zone of copper sulphides, pyrite and magnetite."

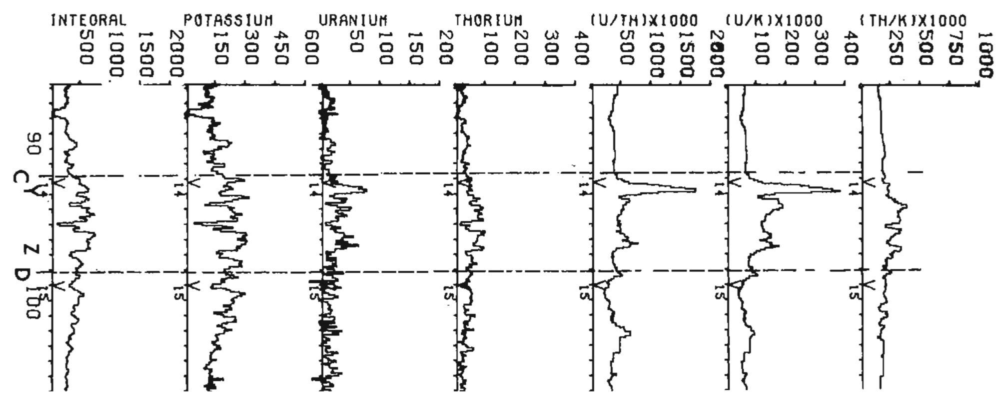


Moira River
CAN. NAT. RYS.
Malone
Eldorado
Mud L.
MADOC
MARMORA
Jarvis L.
Deloro
Moira R.
Wolf Cr.
Banker Lake
HUNTINGDON
A
B
C
D
X
Y
Z
7
14
LEGEND
Palaeozoic
POST-HASTINGS
Granite-syenite
Gabbro
HASTINGS GROUP
Limestone
Argillite and garnet rock
PRE-HASTINGS
Rhyolite
Andesite
MINERAL OCCURRENCES
Gold . . . . Au
Arsenic (arsenopyrite) . . . . As
Copper . . . . Cu
Iron (chiefly magnetite) . . . . . . Fe
Scale of Miles
0 1 2

OCTOBER 1972 PRE-SNOW FLIGHT
LINE 4



OCTOBER 1972 PRE-SNOW FLIGHT
LINE 15



The contact zone on the southwestern part of the intrusion contains numerous veins of quartz containing up to 10 per cent gold-bearing arsenopyrite. These veins are parallel to the margins of the intrusion and dip away shallowly to 55 degrees. Ankerite, biotite, chalcopyrite, feldspar, fluorite, magnetite, muscovite, pyrite, tourmaline are found in veins indicating high temperature origin[2].

An auriferous radioactive hydrocarbon, thucolite has been identified in samples from the Richardson (Eldorado) Mine, which is located on the northern margin of the Deloro stock. The sample consists of two small hand specimens of dark calc-silicate rock containing rounded masses and veinlets of radioactive black hydrocarbon with quartz. Under the microscope this material can be seen to contain ragged grains of gold[3].

The gamma-ray spectrometry anomalies are stronger along the southwestern margins near the Deloro gold property than along the northern boundary in the vicinity of the Richardson property. A more detailed survey would be necessary to locate the best possible areas for further study.

[1] Grasty, R. L. and Holman, P. B.: The measurement of snow water equivalent using natural gamma radiation. First Canadian Symposium on Remote Sensing, 1972.

[2] Wilson, M. E.: The Deloro Stock and its mineralized auriole. Econ. Geol., v. 60, p. 163-167 (1965).

[3] Boyle, R. W. and Steacy, H. R.: An auriferous radioactive hydrocarbon from the Richardson Mine, Eldorado, Ontario; in Report of Activities, Pt. A, April to October, 1972; Geol. Surv. Can., Paper 73-1, p. 282-285 (1973).

17. BEDROCK SURVEYS BY SEISMIC METHODS, GARSON AND SPRINGFIELD AREAS, MANITOBA

Project 680037

George D. Hobson and R.M. Gagne,
Resource Geophysics and Geochemistry Division, Ottawa

The Garson soil complex in Manitoba is developed on reworked calcareous boulder till and is usually surrounded by the Semple soil association, which is developed on thin glacial lake deposits[1]. These soil associations in the area surrounding the quarry at Garson, from which the Ordovician Tyndall limestone is obtained, suggest the presence of a bedrock high.

A seismic survey was proposed by J.S. Scott, Terrain Sciences Division, Geological Survey of Canada, to determine the bedrock configuration underlying the Garson soil complex, in an attempt to confirm the hypothesis that bedrock highs can be determined from soil survey information.

Two areas were chosen for the test. These are, Area A, where a quarry does exist, and Area B, two miles west of Area A, which contains no quarry. The low natural fertility and non-arable constituency of the soil makes the area well suited toward the quarrying industry.

A model FS-2 seismograph, manufactured by Huntec Ltd., with a non-explosive source (a sledge hammer striking an iron plate), was used for the survey in 1962.

Results

A histogram of apparent velocities observed indicates three possible groupings of velocities. A definite peak of 1,150 feet per second is correlated with a surface layer. Velocities in a very broad range from 2,400 to 11,000 feet per second may represent clays and tills. Bedrock is interpreted to display a velocity in excess of 11,000 feet per second. This histogram compares favourably with that presented in an earlier publication[2].

To assure the validity of calculated seismic depths to bedrock, several comparisons were made with drilled wells in the areas. Errors in depth determinations of less than 10 per cent were noted.

Discussion of Area A

Seismic depth determinations were made over an area of 18 square miles near the Garson quarry in Townships 12 and 13, Range 6 E.P.M. (Figs. 3A and B). The surface relief of the area varies by approximately 50 feet, ranging from elevations of 769 to 819 feet above sea level. The bedrock relief varies from 687 to 810 feet above sea level, a range of 123 feet. In general the surface relief does reflect the bedrock surface, although the bedrock topography is more severe. When the surface soils of the area are studied in conjunction with the surface topography, a high positive correlation between the occurrence of the Garson soil complex and surface highs is evident. A definite association also exists between the Garson soil complex and bedrock highs and thin drift areas.

Geol. Surv. Can., Paper 73-1, Part B

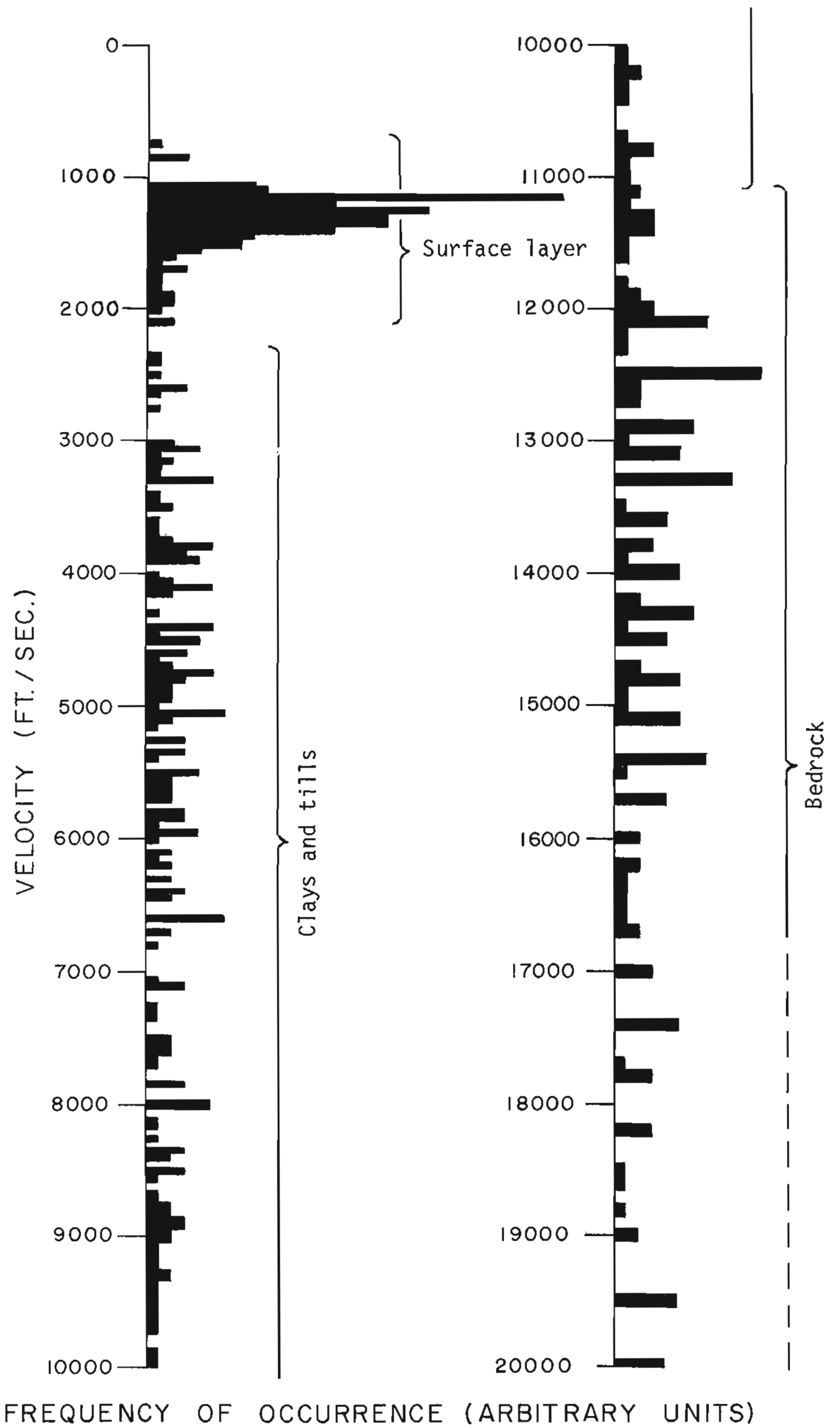

VELOCITY (FT./SEC.)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
Surface layer
Clays and tills
Bedrock
FREQUENCY OF OCCURRENCE (ARBITRARY UNITS)

Figure 1.

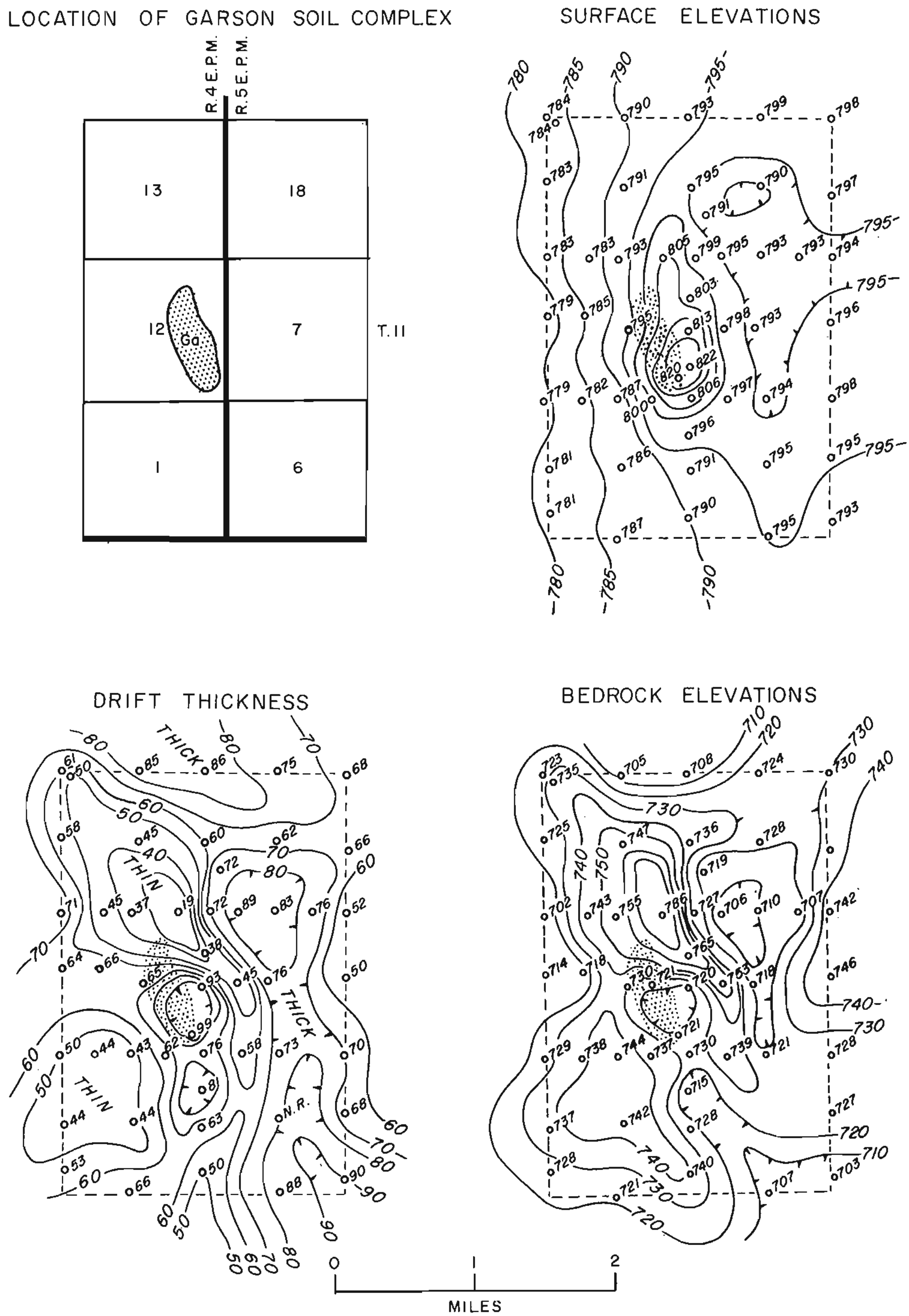

LOCATION OF GARSON SOIL COMPLEX
R.4 E.P.M.
R.5 E.P.M.
13
18
12
Ga
7
T.11
1
6
SURFACE ELEVATIONS
DRIFT THICKNESS
THICK
THIN
BEDROCK ELEVATIONS
0
1
2
MILES

Figure 2.

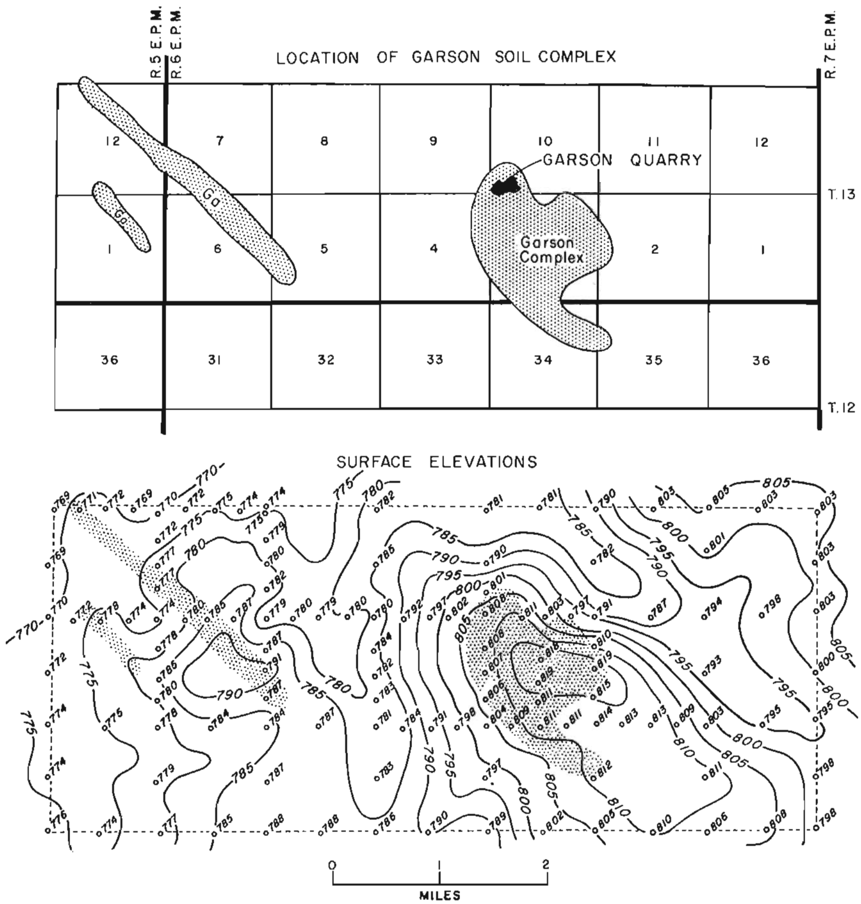


Figure 3a.

Discussion of Area B

Area B, near Springfield in Township 11, Ranges 4 and 5 E.P.M. was investigated by the same method as Area A (Fig. 2). The surface relief of this area varies by approximately 43 feet, between 779 and 822 feet above sea level. Bedrock surface elevations vary between 703 and 786 feet above sea level, a range of 83 feet. As in the case of Area A, the Garson soil complex is located on surface elevation highs. Contrary to Area A, the Garson soil complex of Area B is not located ober an area of thin drift but over a localized bedrock low, less than a quarter of a mile wide; however, in the eastern portion of Area B, the surface elevation does reflect bedrock topography.

Conclusion

Bedrock topography determined from this survey does not establish that bedrock highs can be prognosticated from soil survey information. Area A

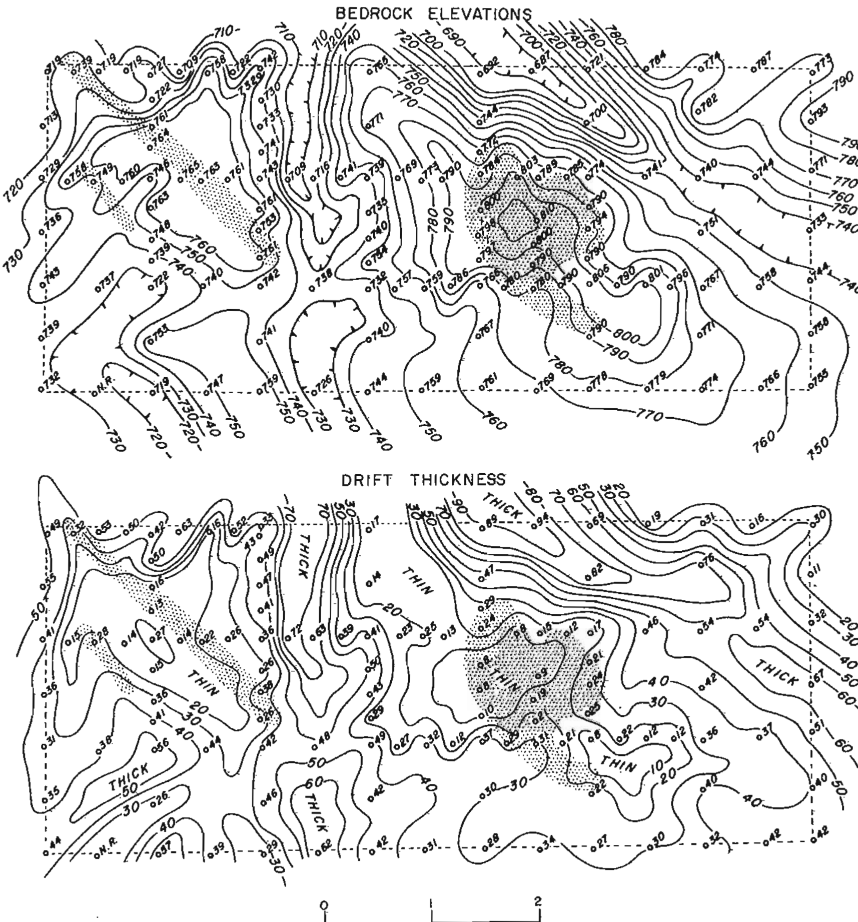


Figure 3b.

does support the hypothesis, since the Garson soil complex is associated with bedrock highs and thin drift. However, Area B does not support the hypothesis, since the Garson soil is associated with a bedrock low and a localized area of thicker drift.

The study does indicate that the seismic method can be a useful exploration and development tool for the quarry industry in the Garson area, both in expansion of existing sites and to determine the thickness of overburden at a new site.

[1] Ehrlich, W.A., Poyser, E.A., Pratt, L.E., and Ellis, J.H.: Report of reconnaissance soil survey of Winnipeg and Morris map sheet areas; Manitoba Soil Survey, Soils Report No. 5, Can. Dept. Agriculture and Man. Dept. Agriculture (1953).

[2] Hobson, G.D., Scott, J.S., and van Everdingen, R.O.: Geotechnical investigations Red River Floodway, Winnipeg, Manitoba; Geol. Surv. Can., Paper 64-18 (1964).

18. SHALLOW MARINE REFRACTION SURVEYING IN THE MACKENZIE DELTA AND BEAUFORT SEA

Project 680037

J.A. Hunter,
Resource Geophysics and Geochemistry Division, Ottawa

A marine seismic refraction technique, for the delineation of permafrost below sea bottom, was tested in the Kugmallit Bay - Mackenzie Bay areas of the Mackenzie Delta, Northwest Territories. The aim of the experiment was to map the occurrence and upper boundary of permafrost using the seismic velocity variation between frozen and unfrozen sediments as the criterion for interpretation. This method is valid in areas of thick overburden where velocities of frozen sediments cannot be misinterpreted as velocities of unfrozen consolidated rock. The method may be inaccurate in measuring permafrost velocities in clays, since velocity contrasts between the frozen and unfrozen states are low and a considerable velocity-temperature dependence exists below zero degrees centigrade[1]. However, much of the shoreline along the Arctic coastal plain in this area consists of substantial thicknesses of predominantly coarse-grained materials[2] and, with the exception of the fine-grained materials of the Mackenzie Delta, these materials should constitute the sea bottom sediments near the shoreline. Detailed accounts of the sub-bottom surficial geology in the area are given by Shearer[3,4,5]. High seismic velocities on surface have been measured in the Tuktoyaktuk area[6].

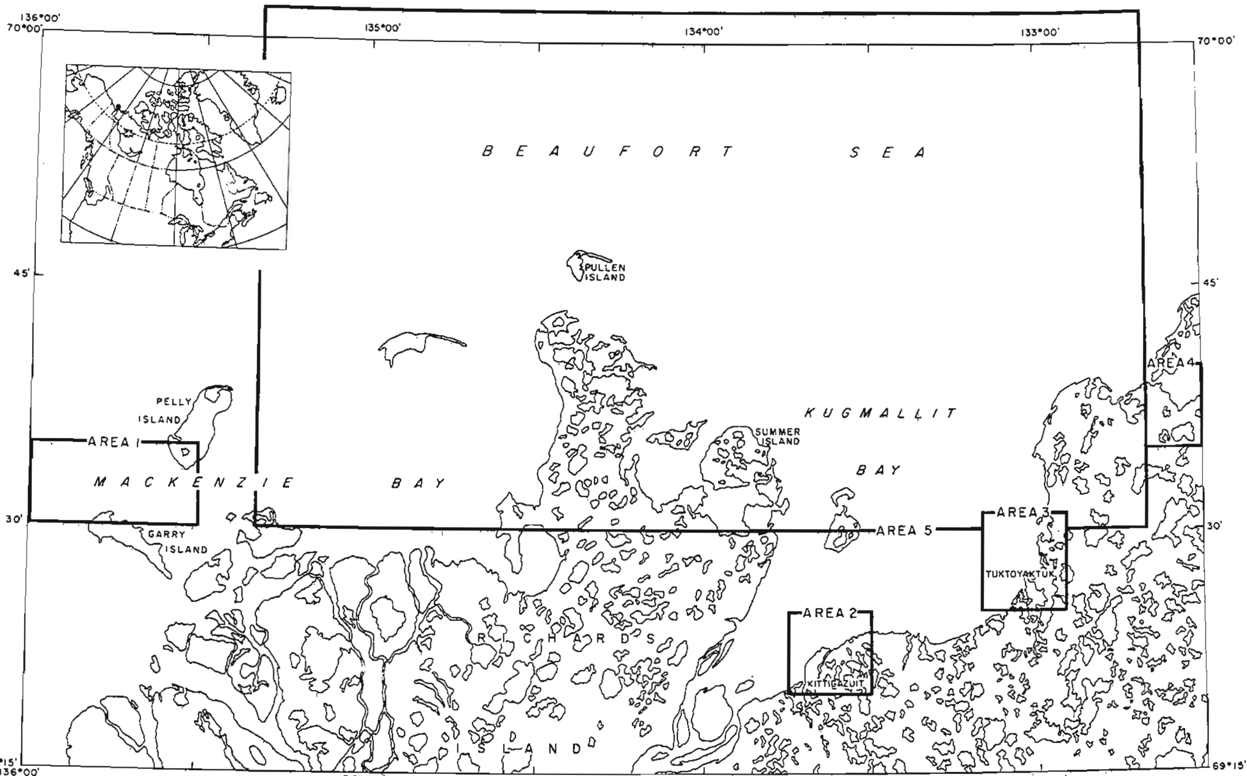
The refraction seismic array used in the survey consisted of a 600-foot (183 m) cable with twelve hydrophones attached at 50-foot (15 m) intervals towed behind a shallow draught recording boat. The hydrophones were buoyed to hang at 3 feet (1 m) below the water surface. An explosive source of one-quarter pounds of geogel was detonated off the end of the boat in line with the cable. A Texas Instrument Series 8000 refraction-reflection seismograph recorded the seismic energy at two levels, a high level used for the first arrival time breaks and a low level (30 db down) used for possible identification of later events and amplitude analysis.

Shots were detonated immediately after the recording boat stopped, so that cable drift was negligible. Shot-geophone distances calculated from waterbreak arrivals are estimated to be within ±2 feet, for most profiles. On some profiles the shot was placed to one side of the hydrophone line and corrections were made on the travel-time plots for shot-geophone distances. Permafrost was interpreted where seismic velocities greater than 8,000 ft/sec (2,560 m/sec) were obtained.

The sites occupied in the Delta area are shown in Figure 1. A brief description of the sites follow.

Area 1 - Garry Island area (Fig. 2)

A series of profiles was shot to the north of Garry Island in a westerly direction as well as in a northeasterly direction towards Pelly Island in an attempt to obtain permafrost velocities. Only three locations detected high velocities; sites 19 and 20 where two high velocity layers were observed; and site 18 where the hydrophone line placed close to shore at Mackay's site



136°00'
70°00'
135°00'
134°00'
133°00'
70°00'
45'
30'
69°15'
136°00'
135°00'
134°00'
133°00'
69°15'
B E A U F O R T S E A
PULLEN ISLAND
PELLY ISLAND
AREA 1
M A C K E N Z I E B A Y
GARRY ISLAND
K U G M A L L I T B A Y
SUMMER ISLAND
AREA 4
AREA 3
AREA 5
TUKTOYAKTUK
AREA 2
KITTIGAZUIT
R I C H A R D S I S L A N D

Figure 1.

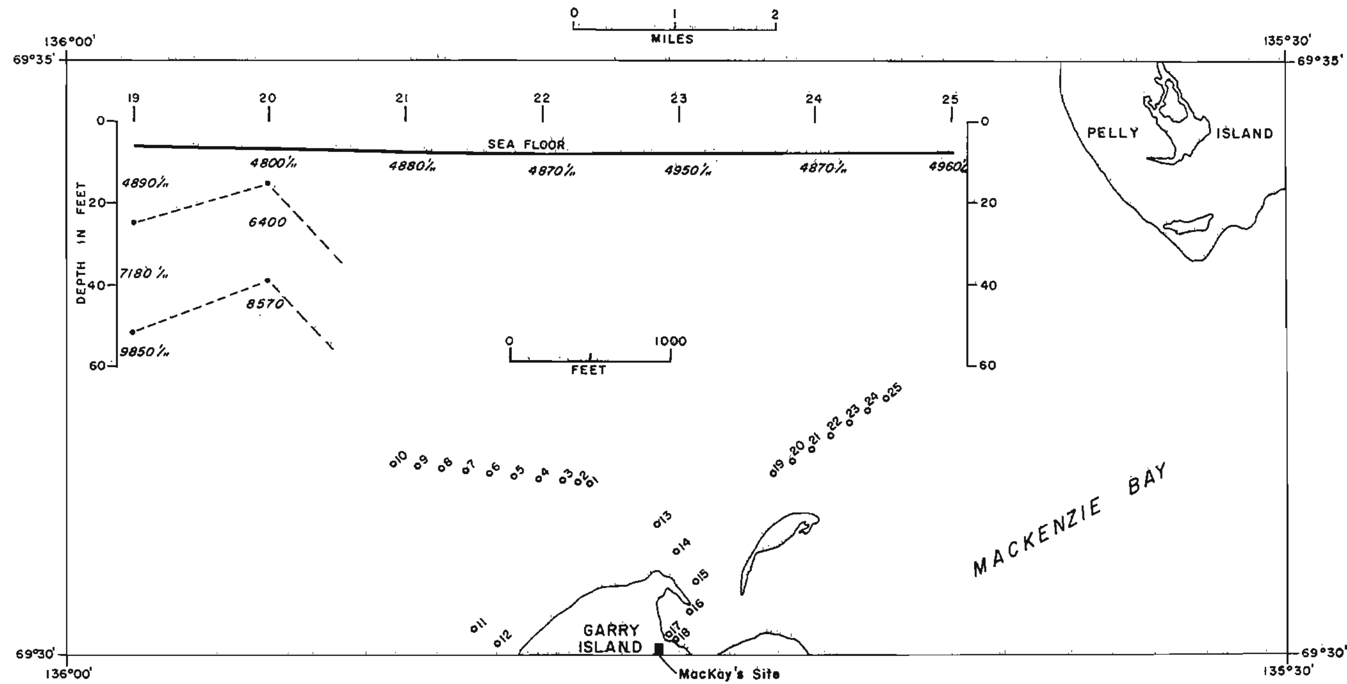

0
1
2
MILES
136°00'
69°35'
135°30'
69°35'
19
20
21
22
23
24
25
0
20
40
60
DEPTH IN FEET
SEA FLOOR
4890‰
4800‰
4880‰
4870‰
4950‰
4870‰
4960‰
6400
7180‰
8570
9850‰
0
1000
FEET
PELLY
ISLAND
MACKENZIE BAY
GARRY
ISLAND
MacKay's Site
69°30'
136°00'
69°30'
135°30'

Figure 2.

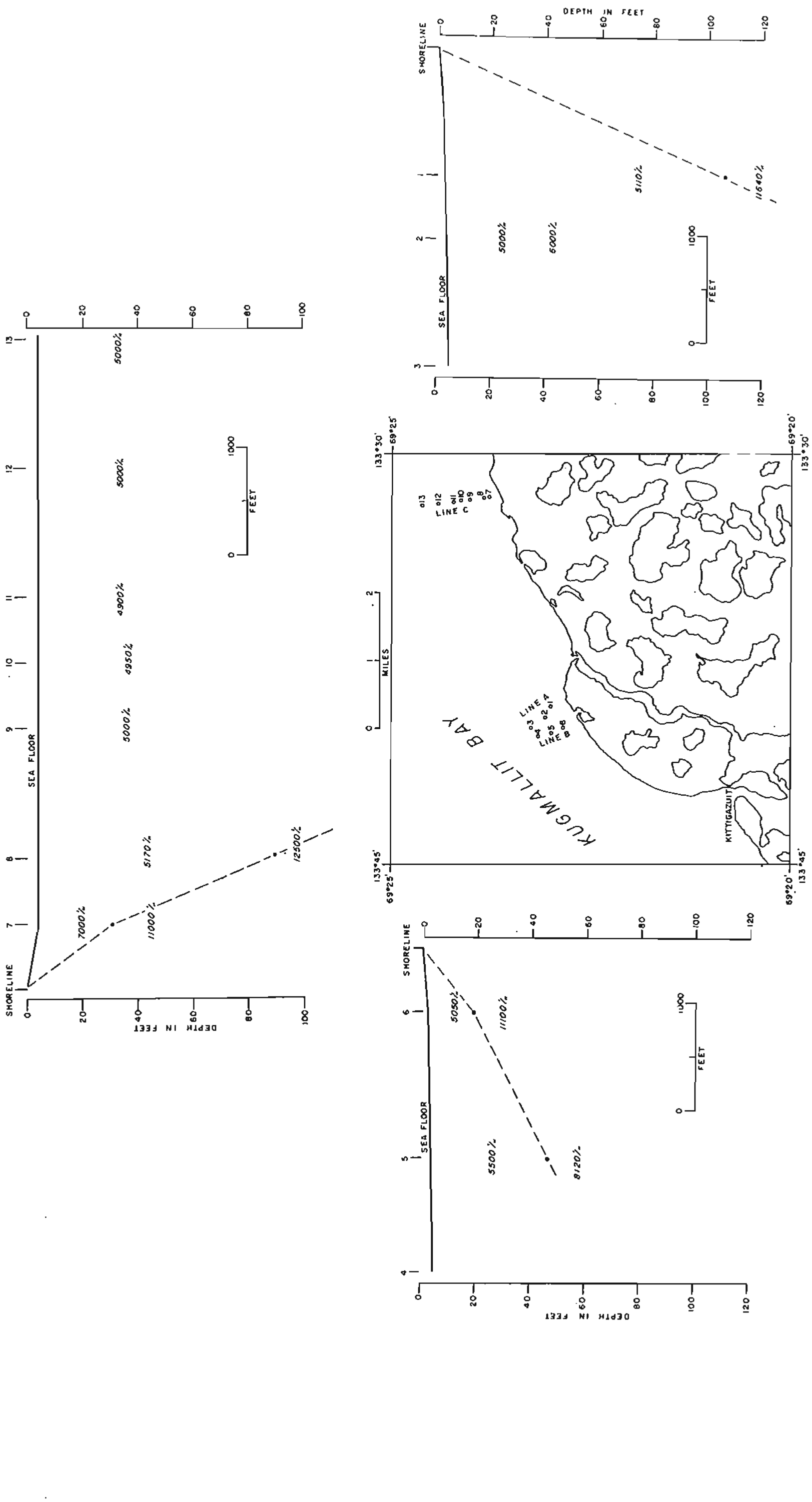

SHORELINE
SEA FLOOR
DEPTH IN FEET
FEET
MILES
KUGMALLIT BAY
KITTIGAZUIT
LINE A
LINE B
LINE C
133°30'
133°45'
69°20'
69°25'
5000'/s
6000'/s
5110'/s
11640'/s
5050'/s
11100'/s
5500'/s
8120'/s
7000'/s
11000'/s
5170'/s
12500'/s
4950'/s
4900'/s

Figure 3.

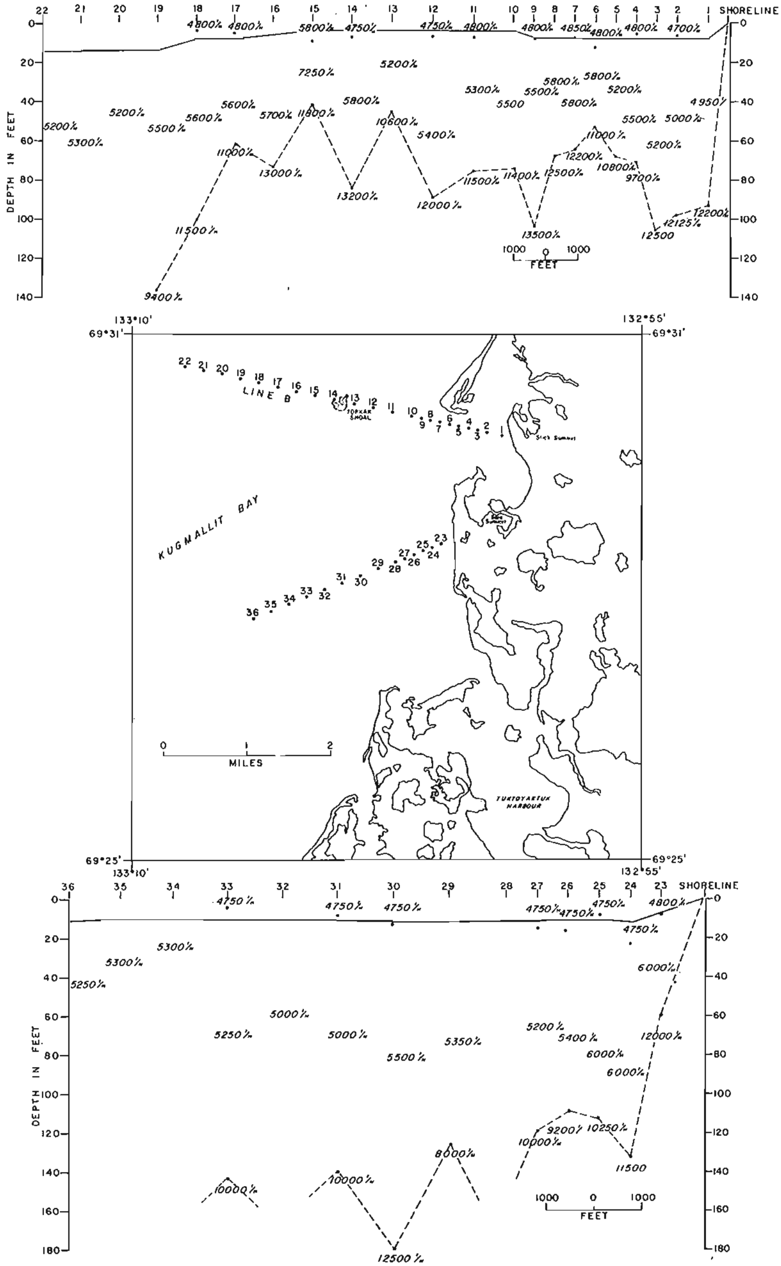

SHORELINE
DEPTH IN FEET
FEET
133°10'
132°55'
69°31'
69°25'
LINE B
TOPKAK SHOAL
KUGMALLIT BAY
MILES
TUKTOYAKTUK HARBOUR

Figure 4.

(see Fig. 2) detected a velocity of 6,800 ft/sec (2,173 m/sec) at a depth of 42 feet (13.4 m). The average velocity of the sea bottom sediments throughout the survey area was 5,000 ft/sec (1,600 m/sec), a value which is in the same range as seawater. Water depths shown on the seismic sections are taken from nautical charts of the area.

If high permafrost velocities are present beneath the seismic lines but were not detected, permafrost must be deeper than 180 feet (58 m) below sea level (the approximate limit of vertical resolution of refraction interfaces for a 600-foot (192 m) hydrophone array).

Area 2 - Kittigazuit - Whitefish area (Fig. 3)

Seismic line A and line B shot close to Kittigazuit detected high velocities below the sea bottom which could be traced offshore for considerable distance. The interpreted seismic section of line C shows that the top of permafrost drops rapidly seaward and high velocities are not detected beyond the second profile location. This area is one of rapid coastal erosion and permafrost should occur on or below sea bottom for some distance from shore.

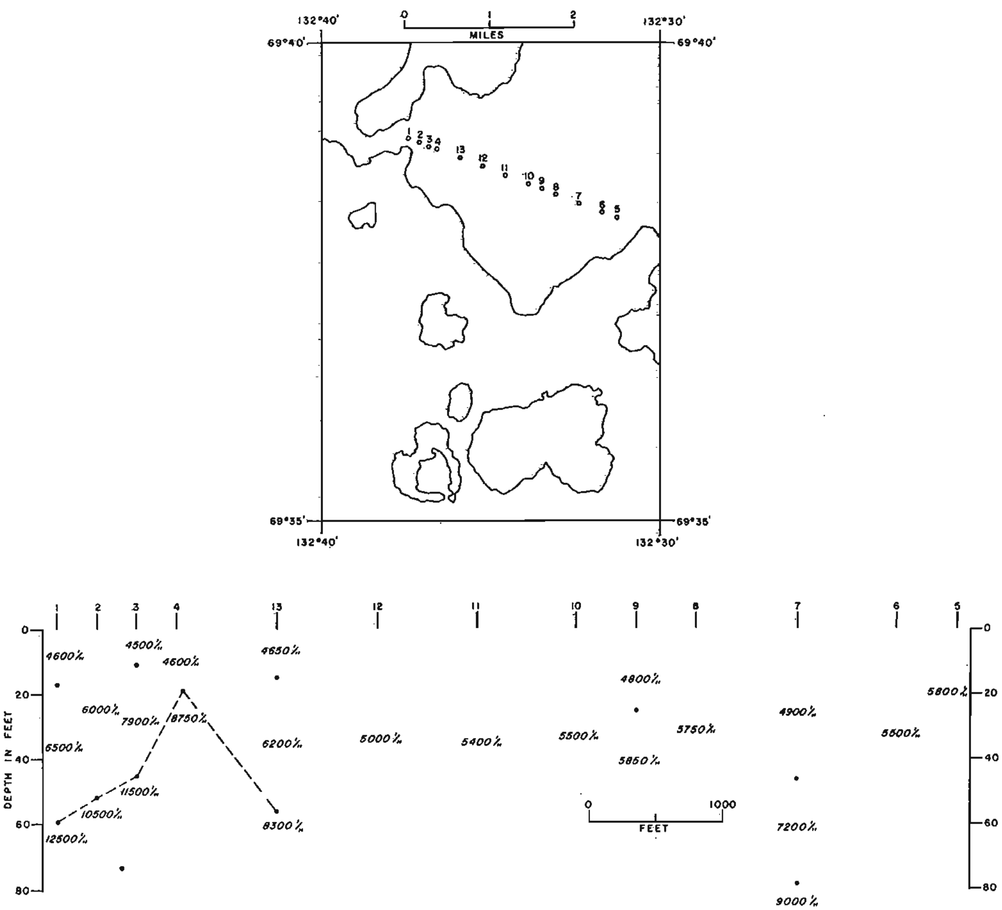


Figure 5.

Area 3 - Bare Summit - Stick Summit area (Fig. 4)

Line A was shot in an area of shallow water north of Tuktoyaktuk perpendicular to the coast. A high velocity refractor interpreted as the upper permafrost boundary was mapped beneath the sea bottom, dropping rapidly with distance from shore and becoming "patchy" or intermittent to the seaward. Lack of high velocities at profiles 28 and 32 suggest either that permafrost is missing or below a depth of 180 feet, or that the sediments in the area are fine-grained but frozen, hence a low velocity contrast with unfrozen materials.

Line B was shot in shallow water similar to the previous site. The high velocity (permafrost) horizon drops sharply from the shoreline but comes back up again under the Topkak shoal. Seaward of the shoal the high velocity interface drops sharply again and disappears. There is a broad correlation between the depth to the top of this horizon and the depth of water as determined from the nautical charts (i.e., locations 3, 15, 19).

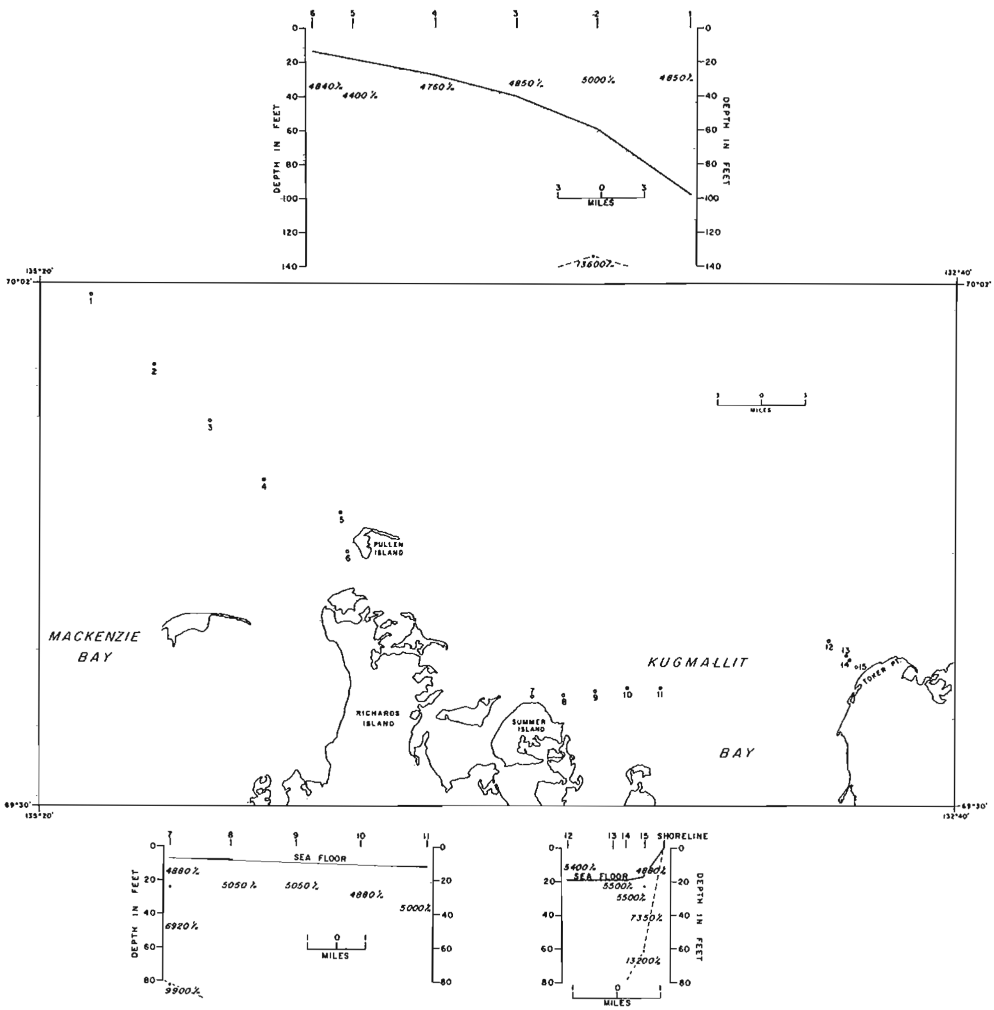


Figure 6.

Area 4 - Large Lake near Toker Point (Fig. 5)

This site was chosen because of access by sea from a narrow channel and also because water depths were estimated to be greater than six feet (the maximum ice thickness formed in winter, one of the variables controlling the occurrence of permafrost under lake bottoms). A high velocity sub-bottom refractor was mapped on the west side of the lake, but for most of the section, with the exception of location 7, permafrost velocities were not detected. No information on water depth of the lake are available at present, however depth calculations from the refraction profiles suggest that water depth may be in excess of 20 feet in the middle of the lake.

Area 5 - Pullen Island, Summer Island, Toker Point (Fig. 6)

The line of profiles shot near Toker Point and perpendicular to the shoreline shows a high velocity interface (top of permafrost) dropping to greater depth as distance from shoreline increases. In the Summer Island area, only one profile detected a high velocity; this profile was shot close to shore. Either permafrost is absent in this area or the sub-seabottom must consist of a thick section of fine-grained silts and muds with a low seismic contrast between frozen and unfrozen state.

Profiles were also shot in the Pullen Island area in a northwesterly direction for approximately 30 miles with a spacing of approximately 6 miles. Only at one location was a high velocity event detected which could be interpreted as a permafrost velocity. A sea-bottom temperature of -1°C was obtained at this locality (J.M. Shearer, pers. comm.). This suggests that in much of the area northwest of Pullen Island either permafrost is absent or is not detectable in fine-grained materials.

[1] Muller, G.: "Geschwendegkeitsbestimmungen Elastischer Wellen in Gefrorenen Gesteinen und die Anwendung Akustischer Messungen auf Untersuchungen des Frostmantels an Gefrierschachten". Geophys. Prospecting, v. 9, p. 276-295 (1961).

[2] Rampton, V.N.: Quaternary geology, Mackenzie Delta and Arctic Coastal Plain, District of Mackenzie; in Report of Activities, April to October, 1970, Geol. Surv. Can., Paper 71-1, Pt. A, p. 173-177 (1971).

[3] Shearer, J.M.: Preliminary interpretation of shallow seismic reflection profiles from the west side of Mackenzie Bay, Beaufort Sea; in Report of Activities, November 1970 to March 1971, Geol. Surv. Can., Paper 71-1, Pt. B, p. 131-138 (1971).

[4] Shearer, J.M.: Geological structure of the Mackenzie Canyon area of the Beaufort Sea; in Report of Activities, April to October, 1971, Geol. Surv. Can., Paper 72-1, Pt. A, p. 179-180 (1972).

[5] Shearer, J.M.: Surficial geology and geomorphology, Mackenzie Bay, Continental Shelf; in Report of Activities, April to October, 1972, Geol. Surv. Can., Paper 73-1, Pt. A, p. 242 (1973).

[6] Wyder, J., Hunter, J., and Rampton, V.: Geophysical investigations of surficial deposits at Tuktoyaktuk, N.W.T., Geol. Surv. Can. Open File Rept. 128 (1973).

19. A COMPARATIVE TEST OF SEISMIC SOURCES FOR SHALLOW SEISMIC SURVEYING

Project 680037

J. A. Hunter, R. Good and H. A. MacAulay,
Resource Geophysics and Geochemistry Division, Ottawa

On January 12, 1973 a test was conducted at a site near North Gower, Ontario to determine the effectiveness of three non-explosive seismic sources; the 16-lb (7.25 kg) sledgehammer hit on an 8 inch x 8 inch x 1 inch steel plate; a 50-lb (22.7 kg) rock crushing hammer hit on the same plate; and a 12-gauge shotgun fired at the plate from a distance of 15 centimetres.

The site was chosen because of its relative simple subsurface geology. A till layer less than 20 feet (6.1 m) thick overlies a thick section of limestone of the March-Oxford Formations. Thus high amplitude refracted waves from bedrock should be easily observed.

An array of 12 geophones in-line was laid out with a geophone spacing of 13.5 feet (4.1 m). The seismic sources were placed 25 feet (7.6 m) from the nearest geophone and an SIE RS-4 seismograph was used to record the seismic event.

The 50-lb hammer was hit against the plate and against the frozen ground. Very little difference in record amplitude was observed between the

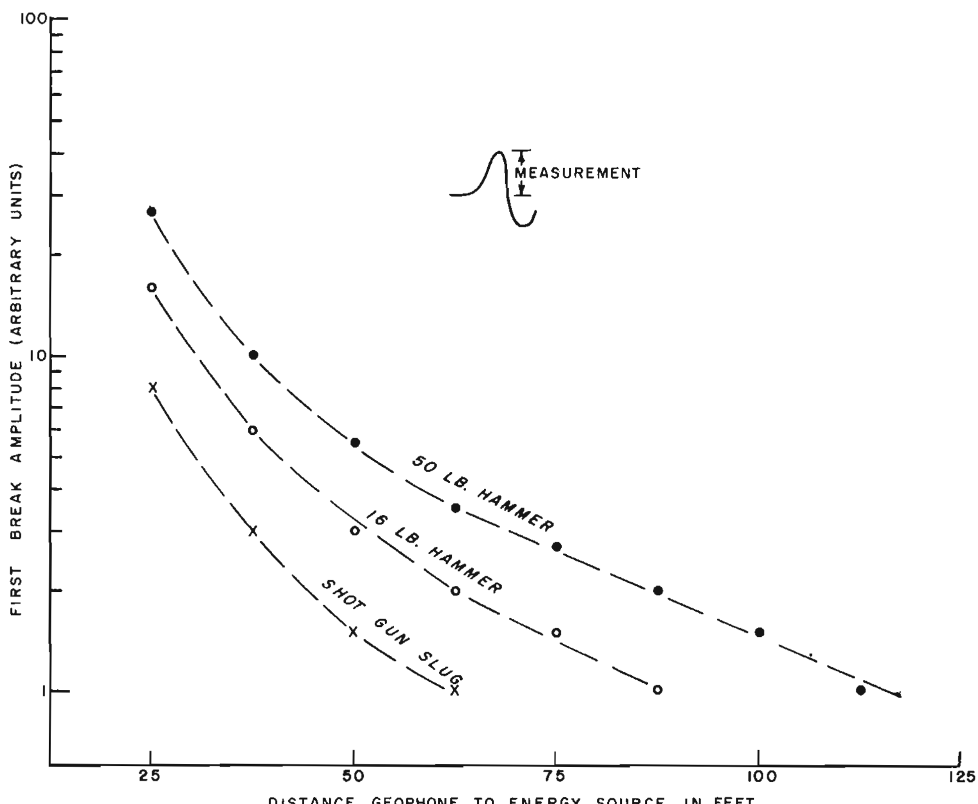


Figure 1.

two methods. Similarly the shotgun slug was fired at the plate and at the ground with little difference in amplitudes of recorded signals.

A comparison of the amplitude versus geophone distance of the three seismic sources is shown in Figure 1. Measurements of the first refracted wave arrival were taken from the first break to first peak of the recorded sinisoid to minimize interference from later events. The amplitude from the shotgun slug was only half of that given from the 16-lb hammer which in turn was almost half of that from the 50-lb hammer. A comparison of the dominant frequency of the pulses from the three sources at a distance of 25 feet showed that within the limits of measurement error all three source frequencies were identically 90 hertz.

In summary, the 50-lb hammer hit on the frozen ground is a better energy source than the 16-lb sledgehammer hit on a plate. The shotgun slug is the least efficient of all sources tested.

20. MAGNETIC TEST RANGE NEAR TIMMINS, ONTARIO

Project 720080

L. J. Kornik and P. H. McGrath,
Resource Geophysics and Geochemistry Division, Ottawa

A project to evaluate the usefulness of high resolution aeromagnetic data as an aid to detailed geological mapping programs has been initiated by the Geological Survey of Canada. During the summer of 1972 a test range was established in Godfrey Township, near Timmins, Ontario[1]. Ground magnetometer and in situ magnetic susceptibility measurements were taken over the test range, oriented drill cores were collected, and the geology was mapped. The bottom two profiles shown in Figure 1 are a geological cross-section and a ground magnetometer profile along Line 1 of the test range. A comparison of the magnetic data and geological information indicates that the

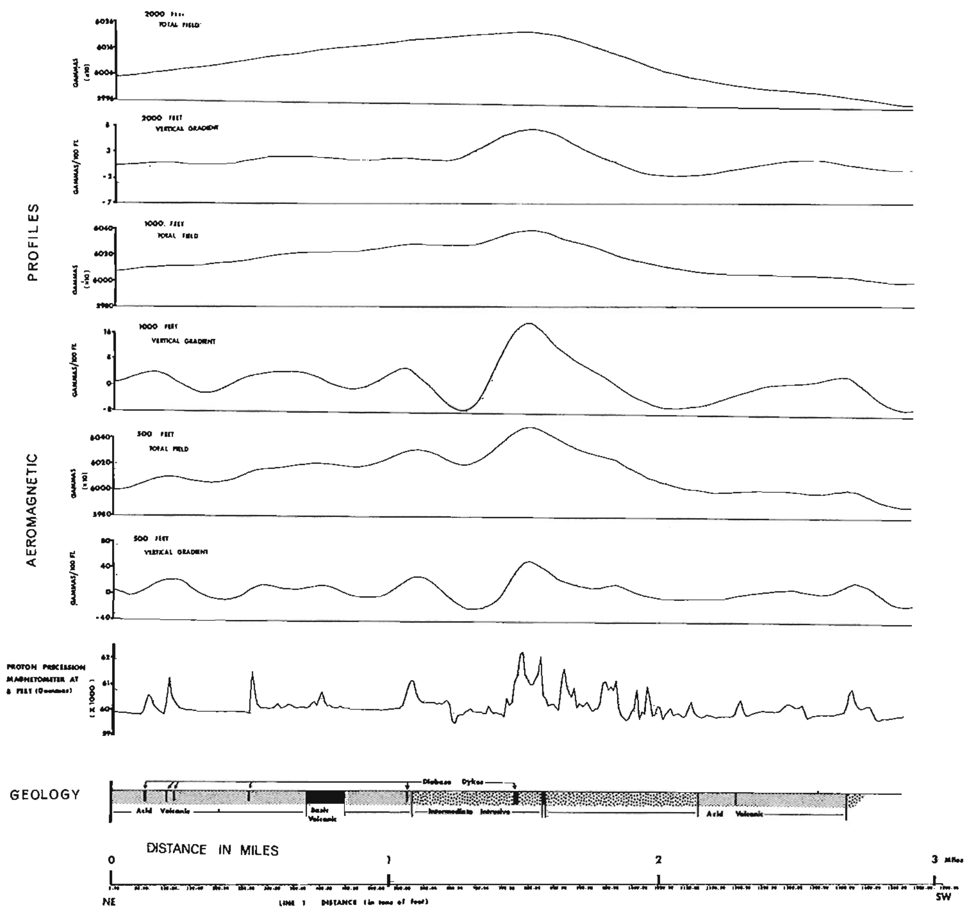


Figure 1. Total field aeromagnetic and computed vertical gradient profiles at 500, 1,000 and 2,000 feet above Line 1, with corresponding ground magnetometer profile and geological cross-section along Line 1.

magnetic anomalies are caused by susceptibility and remanent magnetization variations within the dykes, intermediate intrusives and the basic volcanic rocks.

The test range was flown at 500, 1,000 and 2,000 feet with the high resolution optical absorption magnetometer system aboard the Geological Survey of Canada's Queenair aircraft. Figure 1 also shows three of the total field aeromagnetic profiles measured over Line 1 of the test range and three vertical gradient profiles which were computed from the total field values. Note the rapid loss of resolution and anomaly amplitude of the vertical gradient data with increasing flight altitude. A comparison of the total field and vertical gradient data reveals that the vertical gradient operator resolves slight inflections and interfering anomalies in the total field data into more distinct and separate anomalies. The vertical gradient operator accentuates small wavelength anomalies at the expense of the larger anomalies, and hence the vertical gradient data appear much more like the ground magnetic data than do the total field data. The similarity would be better had the sampling intervals (ground - 50 feet; airborne - 120 feet) been the same. The ground data contain small fluctuations which are above the Nyquist frequency of the airborne data, and hence impossible to resolve using high pass or derivative filters on the airborne data. The vertical gradient data do show, however, an improved resolution of near surface geological sources, and hence maps compiled from vertical gradient data will be much more useful to the geologist in support of field mapping programs.

[1] Kornik, L.J., and McGrath, P.H.: Magnetic Test Range near Timmins, Ontario; in Report of Activities, April to October, 1972; Geol. Surv. Can., Paper 73-1, Pt. A, p. 90-92 (1973).

21. MARTIN-GRAHAM DIGITAL FILTERS

Project 720080

P.H. McGrath and M. Bower,
Resource Geophysics and Geochemistry Division, Ottawa

The Geological Survey of Canada in cooperation with the provinces has published aeromagnetic maps for most of the Canadian Shield. These maps have been used by the field geologist to delineate continuity of structures, e.g. dykes, contacts. Typically an aeromagnetic map is composed of a whole spectrum of information which is caused both by sources at the earth's surface and at varying depths within the crust. Through the application to the magnetic data of a numerical filter it is possible to enhance those anomalies which are more closely allied to the near surface geological variations. For instance, a particular filter could be designed to separate out the local magnetic variations in the data from the more regional information. A class of filter which can be used for this purpose is the Martin-Graham filter[1]. A Martin-Graham filter is defined as one whose transfer function, H(f), possesses the Martin-Graham roll-off, where for a band pass filter

$$H(f) = \begin{cases} 1 & , f_{-c} < f < f_c \\ 1/2 \left[\dfrac{1 + \cos\,(f - (f_c - f_o))\,\pi}{\Delta f} \right] & , f_c < f < f_c + \Delta f \\ 0 & , f_c + \Delta f < f \end{cases}$$

and f_o = central frequency of the band pass,
f_{-c} = lower cut-off frequency,
f_c = upper cut-off frequency,
Δf = length of the Martin-Graham roll-off.

The weights for the various Martin-Graham filters are calculated using the following formulae;

Low Pass Filter

$$h_o = 2\,\bar{f} + \Delta f$$
$$h_n = \left[\cos\,(n\pi\,\Delta f)\,\sin\,(n\pi\,h_o)\right] \Big/ \left[n\pi(1-4\,\Delta f^2 n^2)\right]$$

First Horizontal Derivative

$$y_o^1 = 0$$
$$y_n^1 = \left[(\bar{f} + \Delta f)\cos\,(2n\pi\,(\bar{f} + \Delta f)) + \bar{f}\cos\,(2n\pi\,\bar{f}) - h_n\,(1-12\Delta f^2 n^2)\right] \Big/ \left[n\,(1-4\,\Delta f^2 n^2)\right]$$

Second Horizontal Derivative

$$y_o^2 = 8\,\Delta f^2 h_o - 4/3\,\pi^2\,((\bar{f} + \Delta f)^3 + \bar{f}^3)$$

$$y_n^2 = -2 \left[\pi \left((\bar{f} + \Delta f)^2 \sin (2n\pi (\bar{f} + \Delta f)) + \bar{f}^2 \sin (2n\pi \bar{f}) \right) - 12n \Delta f^2 h_n + y_n^1 (1 - 12n^2 \Delta f^2) \right] \Big/ \left[n (1 - 4n^2 \Delta f^2) \right]$$

Band Pass Filter

$$b_o = 2 h_o$$
$$b_n = 2 \cos (2n\pi f_o) h_n$$

Band Pass First Horizontal Derivative

$$b_o^1 = 0$$
$$b_n^1 = 2 h_n f_o \sin (2n\pi f_o) - y_n^1 \cos (2n\pi f_o) \Big/ \pi$$

Band Pass Second Horizontal Derivative

$$b_o^2 = 2 \left[\frac{2 h_o \Delta f^2}{\pi^2} - \frac{1}{3} \left((\bar{f} + \Delta f)^3 + \bar{f}^3 \right) - h_o f_o^2 \right]$$

$$b_n^2 = \frac{1}{2\pi^2} \left[y_n^2 - 4\pi^2 h_n f_o^2 \cos (2n\pi f_o) - 4\pi y_n^1 f_o \sin (2n\pi f_o) \right]$$

where $\bar{f} = f_c$ for low pass and derivative formulae,

$= (f_c - f_{-c}) / 2$ for band pass and band pass derivative formulae.

$n = 1, N$

The number of weights, $2N + 1$, required for the various filters is dependent upon the sharpness of the roll-off. Anders et al[1] suggest that $N \geq 1.25/\Delta f$.

The following symmetry relations are used for the filters.

$$h_{-n} = h_n$$
$$y_{-n}^1 = -y_n^1$$
$$y_{-n}^2 = y_n^2$$
$$b_{-n} = b_n$$
$$b_{-n}^1 = -b_n^1$$
$$b_{-n}^2 = b_n^2$$

In order to preserve the mean of the magnetic data, the filter weight sets were normalized according to the following relations;

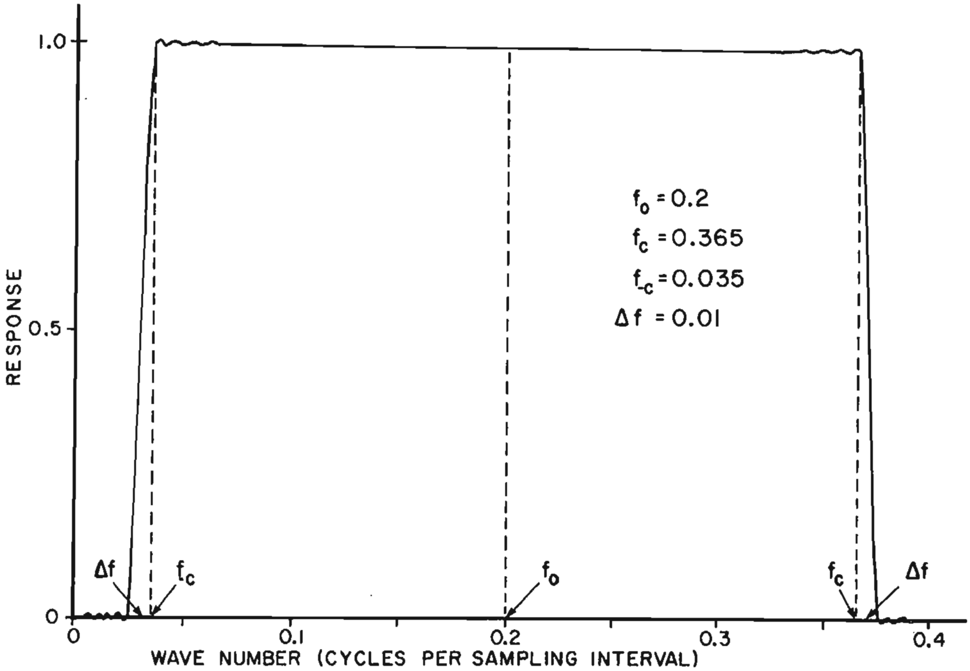


Figure 1. Filter response curve for a 201 point Martin-Graham band pass filter.

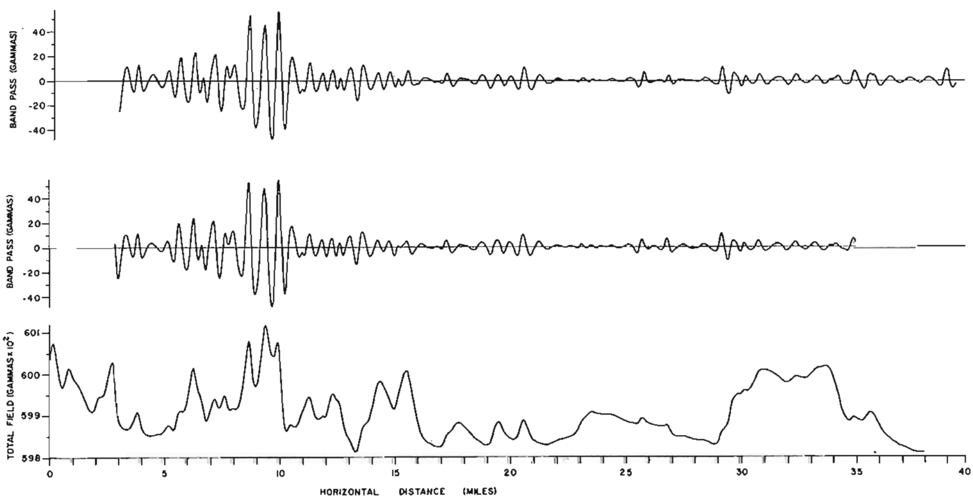


Figure 2. The lower trace is a total field aeromagnetic profile, the middle trace is a band pass filtered output of the lower trace, and the upper trace is a similar filtered output for a second flight over the same line.

$$\sum_{n=-N}^{N} h_n = 1$$

$$\sum_{n=-N}^{N} y_n^2 = 0$$

$$\sum_{n=-N}^{N} b_n = 0$$

$$\sum_{n=-N}^{N} b_n^2 = 0$$

Figure 1 is a recovered transfer function (filter response curve) for a set of weights which were calculated and normalized using the parameters shown in the figure and the band pass equations presented above. In this case N was chosen to be 100. The filter weights were convolved with the total field aeromagnetic data shown in the lower portion of Figure 2. The flight elevation for the data was 1,000 feet and the sampling interval 150 feet. The filter passed all frequency components in the data having wavelengths between 411 and 4,286 feet. The results of the convolution are shown in the middle portion of Figure 2. One hundred points were lost at each end of the data due to the convolution process. It can be seen in Figure 2 that many of the smaller anomalies in the data in the total field profile are much better defined in the filtered data. The small anomalies are caused by variations in susceptibility and remanent magnetization of near surface sources. Proof of this statement is illustrated in the upper portion of Figure 2 which is a filtered trace of the return flight over the same line. Note that the filtered traces for the two flights are almost identical. The band pass filter has separated the smaller anomalies caused by near surface sources from the masking effect of the larger anomalies which are related to large scale near surface geological bodies and to deep crustal sources. Hence a map compiled from filtered data has better resolution of the near surface sources, and hence is much more useful to the field geologist as an aid to field mapping.

The use of the derivative filters requires high quality data such as is now available from high sensitivity magnetometers. The reason for this is that the amplitude, of for example a second derivative trace, is only a few gammas and can readily be lost if the round-off errors in the data are too large.

[1] Anders, E.B. et al.: Digital Filters; United States Dept. of Commerce, NASA CR-136, 132 p. (1964).

22. GEOCHEMICAL INTERACTIONS BETWEEN WATER AND PARTICULATE SOLIDS AND MODELS FOR THE MECHANISMS OF METAL DISPERSION AND ACCUMULATION IN MARINE ENVIRONMENTS

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Trace Metal Concentrations in Continental Shelf Bottom Waters:

Trace metal concentrations for four stations sampled on the Nova Scotian Continental Shelf[1] have been determined in bottom water. Chelation - solvent extraction and atomic absorption analyses were done for nine trace elements (Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb, Al) under two conditions. Chelation at natural pH conditions were applied as a means of determining the amount of naturally extractable metal, while low pH conditions allowed the determination of total extractable metal. Total dissolved mercury was also determined in the bottom waters. The results indicate that differences in concentration of these trace elements are not significant at the four different locations. Also, the differences between low and natural pH analyses were not significant. Suspended particulate concentrations were similar (1.2 - 1.7 mg/ℓ) at all shelf locations.

Since the trace metal concentrations and suspended particulate concentrations are constant across the shelf, it would be expected that deposition of trace metals should be homogeneous. However, anomalous amounts of some trace elements are found in some marine sediments[3]. The geochemistry of water-sediment interfaces will have to be studied in greater detail to understand trace metal accumulation processes.

Nature and Concentration of Suspended Particulate Matter:

The nature and concentration of suspended particulate matter is of special importance because of its ability to adsorb and exchange dissolved trace metals and thereby affect the distribution of metals in deposited sediments. An optical attenuance metre was used to determine the concentration of particulate matter over the Continental Shelf (June/72), Gulf of St. Lawrence (Nov./72), Bay of Chaleur (Nov./72), Strait of Belle Isle (Nov./72) and Chedabucto Bay (Feb./73). The attenuance data indicate that many areas contain nephaloid layers (layers of high particulate matter concentration near water-sediment interface) with thicknesses of 10 to 80 m and concentrations of 1 to 3 mg particulate matter per litre of water.

Water samples were collected, filtered and examined by a scanning electron microscope. The surface waters contained a majority of biogenic fragments and whole tests with a mean diameter of 6 μm. It was found that intermediate waters contained a bimodal size distribution of 2 μm inorganic particles and 6 μm biogenic material. Suspended matter in the nephaloid layer contained more than 90 per cent inorganic material with a mean diameter of 3 μm. These inorganic particulate layers have an extremely large large capability of transporting trace metals by adsorption and ion exchange because of their surface charge and large surface area.

In addition to white light attenuation measurements, attenuation of different wavelengths of visible light was measured in an attempt to evaluate properties of water containing particulate matter and dissolved organics. Nearshore areas associated with freshwater inputs attenuated blue light to a greater extent than red light, while offshore (>5 km) did not show this difference. The high blue attenuation was attributed in part to dissolved organics in the water. This information is important since dissolved organics can form organo-metallic chelates prior to precipitation or adsorption onto suspended matter. Conversely, suspended particulates can be coated with dissolved organics, thus masking the surface active adsorption sites.

Sea Water - Suspended Particulate Matter Equilibrium:

Further effort has been made to understand geochemical interactions in the marine environment which aid in understanding equilibrium controls between natural waters and sediments. A sampling project in the LaHave River and Estuary and in the Bay of Fundy included concentrated suspended matter collections and water sampling. The suspended matter was stored in its original water for six months, then the water and suspended material were analyzed for major and minor elements. Factor analysis[2] was applied to the data, resulting in three major groups of parameters.

The most important factor accounted for 49 per cent of the total problem variance. It contained all major sea water parameters as well as all major silicate parameters. Particulate organic carbon and all trace elements in the water varied inversely with the major elements. Since the sampling program included river water containing high particulate organic concentrations as well as sea water containing clay-sized inorganic particles, this factor is a sample location indicator. The trace metals are associated with freshwater, while all major elements are related to the oceanic environment.

The second factor includes suspended matter concentrations and dissolved silicon. This relationship was the only significant result observed as a result of storing a large amount of inorganic material in natural water. Zinc concentrations in the water showed a negative correlation in this factor, suggesting that as silicon is released, zinc adsorption is occurring. The third significant factor included dissolved Fe and Mn and particulate organic carbon. It appears that Fe and Mn are removed from fresh water by organo-metallic precipitation which occurs at a sharp salinity boundary. When fresh water meets this boundary, organic precipitation causes flocculation and removal of these trace metals. Beyond this boundary, Fe, Mn and organic carbon values are small, thus the factor did not include parameters which are indicative of the open marine environment.

[1] Buckley, D. E.: In Report of Activities, Part A, April to October, 1972; Geol. Surv. Can., Paper 73-1, Pt. A, p. 104-106 (1973).

[2] Cameron, E. M.: A computer program for factor analyses of geochemical and other data; Geol. Surv. Can., Paper 67-34 (1967).

[3] Hoffman, T. M.: Geochemical Data Report (Geochemistry of Scotian Shelf sediments); Can. Dept. Energy, Mines and Resources; Data Series 1970-3-D (1970).

23. BIOSTRATIGRAPHIC ZONATION (NANNOFOSSILS) OF THE MESOZOIC AND CENOZOIC ROCKS OF THE ATLANTIC SHELF

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Work was begun in October, 1972 on nannofossils from wells drilled in exploration for oil and gas on the Atlantic continental margin of Eastern Canada. This is the first major study of calcareous nannofossils to be conducted in the northwestern Atlantic Ocean for the purposes of biostratigraphic zonation. Prolific numbers of these microfossils have been found in the Tertiary and chalk layers of the Late Cretaceous.

Nannofossil dating has been extended to shelf sediments of the Pleistocene, Miocene, Late Eocene-Early Oligoclase, Paleocene, Late Cretaceous and Early Cretaceous age.

In 150,000 feet of section examined to date, eight zones of Late Cretaceous species have been identified. Principally they are: Nephrolithus frequens zone, Tetralithus aculeus zone, Marthasterites furcatus zone, and the Carollithion exiguum zone. In the Tertiary and Quaternary sediments the species identified are: Markalius inversus zone (NP 1), Chiasmolithus oamareunsis zone (NP 18), Sphenolithus predistentus zone (NP 23), Reticulofenestra pseudoumbilica (NN 15) and Gephyrocapsa oceanica zone (NN 19).

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24. SHIPBOARD METHODS FOR MARINE GEOCHEMICAL ANALYSES

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Duplicate mercury analyses were performed on 117 ocean water samples as part of a joint project with personnel from the Department of the Environment to establish baseline values for an ocean section between Halifax and Bermuda. A major problem encountered in analyses of trace elements in natural waters is a result of adsorption of the metals on suspended matter in the sample and on the walls of the container during sample storage. To overcome these losses during storage, a mercury analysis technique was adapted to shipboard operation. In addition to analyzing the samples at sea, 32 subsamples were stored at pH 1 for 10 days and analyzed at the land laboratory. The loss of mercury in the stored samples was significant. The land analyses were an average of 57 per cent lower than the shipboard analyses. Most of the literature values for mercury in the sea are reported as land based analyses, thus requiring some storage time. A majority of the literature values are less than 0.100 $\mu g/\ell$ total Hg. All of our land based analyses were below 0.100 $\mu g/\ell$, while a majority of the shipboard analyses were above 0.100 $\mu g/\ell$, with a mean of 0.150 $\mu g/\ell$. It is obvious that sound laboratory procedures are of great importance in obtaining meaningful trace metal data for natural waters.

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25. COMPILATION OF GEOSCIENTIFIC DATA IN THE PALEOZOIC BASINS OF EASTERN CANADA

Project 710061

R.D. Howie

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The Acadian (Devonian) orogeny stabalized the Appalachian Geosyncline from the northeastern part of the St. Lawrence Platform (Anticosti Basin), to the edge of the present Continental Shelf. This newly formed cratonic area initiated a sequence of unique tectonic elements that prevailed from Late Devonian through the Carboniferous into the Permian. Late stage warping (Maritime Disturbance), appears to have been mainly confined to a narrow northeast trending lens shaped epieugeosyncline that accumulated up to 15 thousand feet of clastics in the Acadian Basin (Bay of Fundy) and 30 thousand feet of clastics and evaporites in the Magdalen Basin (Gulf of St. Lawrence and adjacent parts of Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland).

In the deepest part of the Magdalen Basin between eastern Prince Edward Island and the Magdalen Islands 5,000 to 8,000 feet of evaporites were deposited. Data from offshore drillholes, seismic, gravity, ship and air magnetometer surveys indicate the area east of the Magdalen Islands is structurally very complex due to the migration of evaporites into ridges, pillows, anticlines, domes and diapirs.

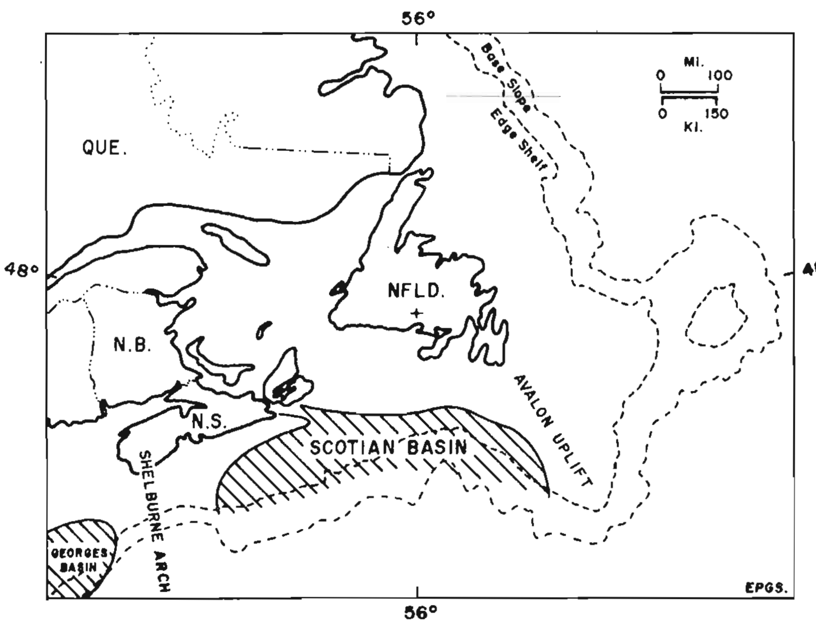

FIGURE 1. Structure elements off Eastern Canada.

26. STRATIGRAPHY AND SEDIMENTOLOGY OF THE MESOZOIC AND TERTIARY ROCKS OF THE ATLANTIC SHELF

Project 710059

L. F. Jansa

Atlantic Geoscience Centre, Dartmouth

A study of the Mesozoic and Tertiary sequences of the Atlantic continental margin was initiated in 1971 and to date these investigations have been concentrated on the Scotian Shelf area. An objective of this study is to establish the lithostratigraphic framework of the Mesozoic and Tertiary rocks, the space and time distribution of rock units and the major depositional systems which governed the sedimentary processes and influenced the development of reservoir rocks and stratigraphic traps. The stratigraphic nomenclature as proposed by McIvor[1] for the Scotian Shelf has been adopted with some minor modifications.

The Atlantic continental margin under present study can be defined as a miogeocline[2] which can be subdivided into several structural provinces. The eastern part of the Scotian Shelf and southern part of Grand Banks where more than 15, 000 m of sediments were accumulated is named the Scotian Basin. This basin open to the eastward is about 1, 100 km long and 200 km wide.

Deep wells located on the margin of the depocentre penetrated the basement at several localities. The composition of basement rocks indicate that the Scotian Basin at the southwestern and western side is underlain and surrounded by metasedimentary rocks, probably of lower Paleozoic age, intruded by granites. Beneath the western part of the basin the basement rocks contain gneisses, which are remarkably similar to the Precambrian gneissic rocks of Cape Breton Island. South of Newfoundland the Mesozoic basin overlies Carboniferous sediments, and on the northeastern side of Grand Banks is surrounded by and overlies metasedimentary rocks probably of a lower Paleozoic or older age.

The depositional history of the Scotian Basin started in the Late Triassic, when as a result of tensional movement a series of fault basins were formed along the entire length of North America[1]. At the Scotian Shelf province, linear basins such as the Acadian Basin (Bay of Fundy), Orpheus trough and probably several other troughs indicated by deep seismic profiles were formed and were filled by fluviolacustrine deposits. The terrigenous arid deposition, which continued into the Lower Jurassic and spread over most of the Scotian Basin area, was interrupted by a marine invasion during the Lower Jurassic, which led to the deposition of a thick evaporitic sequence named the Argo Salt by McIvor[3]. In the Orpheus trough, the Shell Argo F-35 well penetrated 1100 m of salt, but all of the wells which confirm the presence of salt in the outer shelf areas penetrated only the tops of salt diapirs. Diapiric flows disturbed the original thickness of the salt strata, which is estimated to have reached thicknesses of about 2, 000 m. The overlying Iroquois Formation is an evaporite-carbonate-shale sequence approximately 700 m thick. Lithological composition of this formation varies according to its geographic position in the basin. In the marginal areas red terrigenous clastics and anhydrites were deposited in diastal basin areas with pelleted and oolitic limestones. The overlying, relatively thin, terrigenous Mohawk Formation, composed of about 300 m of reddish coloured feldspathic sandstones and brownish red coloured shales with rare conglomeratic and carbonate beds, indicate a short period of regression east of Nova Scotia.

The second major Jurassic transgression which began in the Late Middle Jurassic deposited three facies-controlled formations with a cumulative thickness exceeding 2, 000 m. They are the Abenaki, Verrill Canyon and Mic Mac formations. The Abenaki Formation is composed of shallow water, high energy carbonates, represented by oolitic and oncolitic grainstones and packestones, which grade upward into a deeper, open shelf skeletal wackestones and packestones. In the upper part of the formation shallow-water carbonates are mixed with terrigenous deposits. Seaward of the carbonate banks, shaly sediments of the Verrill Canyon Formation accumulated. The Mic Mac Formation, which is the heteropic facies of the Abenaki and Verrill Canyon formations, is a shale-sandstone-carbonate sequence in excess of 2, 000 m thick. The lithology and microfauna indicate deposition in an inner neritic environment, where reworking and redistribution of sediments were frequent. In the area east of Cape Breton Island the Mic Mac Formation is comprised mainly of sandstone facies deposited in fluviatile and deltaic environments. The depocentre of the coarse clastic accumulation is offset in a northeasterly direction in comparison to the Mohawk Formation, which suggests a structural rearrangement of the downwarped and downfaulted basement blocks.

The Jurassic-Cretaceous boundary was a time of significant change of sediment composition and depositional systems. As a result of an epirogenetic uplifting of the landmass adjacent to the basin, a thick clastic wedge of Lower Cretaceous strata up to 1200 m thick was deposited south of Cape Breton Island and southeast of Newfoundland. This unit, comprising the Missisauga Formation, represents a typical seaward prograding delta complex. The laterally equivalent prodeltaic shaly sediments are included in the Verrill Canyon Formation southwest of the Scotian Basin. The Missisauga Formation consists of mixed carbonate and terrigenous clastics of Neocomian age, although in places the basal part of the formation is of uppermost Jurassic age.

A short period of nondeposition and erosion which in the southwestern part of the Scotian Shelf extended through the Aptian, marks the top of the Missisauga Formation. In most of the Scotian Basin area deposition continued during a major transgression which commenced in the Lower Aptian and lasted up to and including the Tertiary. Transgression progressed in the form of pulses, which deposited alternating sequences of sandstone and shales of the Logan Canyon Formation. Deposition occurred in a shallow neritic environment, but deltaic facies are also present at the northwest side of the basin. The continuing transgression during the Late Cenomanian resulted in a decrease of sand supply, and shaly sediments of the Logan Canyon Formation were deposited in the resulting neritic environment. Glauconitic sandstone beds and intensive bioturbation suggest slow deposition with periods of nondeposition.

The Cretaceous transgression culminated in the Senonian, when chalky carbonates of the Wyandot Formation were accumulated in the outer neritic and epibathyal environments of the Scotian Basin. During the subsequent period, the sea slowly regressed to its maximum low stand in the Pleistocene. The stratigraphic hiatus in parts of the basin is developed in the Upper Eocene. It was during the slow regression in the Tertiary that the continental shelves off Nova Scotia and Newfoundland were constructed.

Petrographic analysis of sandstones indicates significant diagenetic changes in their composition with increasing depth of burial. Clastic grains in sandstones of the Logan Canyon Formation are loosely packed with spotted diagenetic cement consisting of zeolites, kaolinite, siderite and seldom silica overgrowth of the quartz grains. Good primary porosity is preserved in these sandstones. Sandstones in the Missisauga Formation have a higher degree of grain packing, silica cement is more frequent, but in general, diagenetic cementation is of a similar nature to the Logan Canyon Formation. In the Jurassic, clastic grains commonly have pressure-solution welded contacts, and grain packing is dense. Silica cement is frequent and clay minerals indicate transformation into hydromicas, which in the Lower Jurassic are preferentially oriented. Preferential orientation was acquired through morphological transformation of the hydromicas as a reaction to the overburden pressure. Primary porosity in Jurassic sandstones is mostly destroyed by epigenetic processes. Possibility of hydrocarbon reservoir development in these rocks is extremely scant.

[1] Ballard, R.D. and Uchupi, E.: Carboniferous and Triassic rifting: A preliminary outline of the tectonic history of the Gulf of Maine; Geol. Soc. Am. Bull., v. 83; p. 2285-2302 (1972).

[2] Dietz, R.S. and Holden, J.C.: Miogeoclines (Miogeosynclines) in space and time; J. Geol.; p. 566-583 (1966).

[3] McIvor, N.L.: Cenozoic and Mesozoic Stratigraphy of the Nova Scotia Shelf; Can. J. Earth Sci.; v. 9, p. 54-70 (1972).

27. SUBSURFACE DATA FILE SYSTEM OF EASTERN CANADA SEDIMENTARY BASINS

I. A. Newman,
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An inventory of wells drilled in Eastern Canada sedimentary basins (Hudson Platform to the Atlantic offshore region inclusive) has been initiated for the purpose of establishing a complete and up-to-date well card index system. To prepare this inventory, provincial agencies and petroleum companies were either contacted or visited to obtain accurate details on the wells completed to date in Eastern Canada. At present there is data recorded on 1,676 wells (east of southern Ontario) comprising drilling footage of some 2.5 million feet on file at the Eastern Petroleum Geology Subdivision. It is anticipated that by late 1973 there will exist a complete compilation of all Eastern Canada wells completed in the onshore and offshore areas. At that time the system will be converted to a computer program from which isopachous, structure contour, facies maps etc. can be rapidly plotted.

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28. DEPOSITIONAL HISTORY AND FACIES DISTRIBUTION OF THE TERTIARY SYSTEM ON THE SCOTIAN SHELF

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In March 1973 a subsurface study of the Tertiary System was initiated on the Scotian Shelf of Eastern offshore Canada. The area of study (Scotian Shelf) covers an area of some 60,000 square miles which is underlain by a thick wedge of sedimentary rocks varying from Triassic to Tertiary age. This project involves the study of the uppermost portion of the sequence comprising the Tertiary System which may attain a thickness of up to 6,000 feet at the edge of the Continental Shelf. Although a number of wells have penetrated these sediments and shows of oil and gas have locally been encountered, very little is presently known about this part of the section. Thus, this project is the first attempt to interpret the detailed depositional history of the Tertiary System and a suite of maps is presently under construction showing the distribution, facies and structure of Tertiary strata in the Scotian Shelf area. It is anticipated that this study will demonstrate the most favourable areas for future exploration for oil and gas in this part of the stratigraphic succession.

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29. CLASTIC SEDIMENTATION IN ARCTIC FLUVIAL-DELTAIC-MARINE SYSTEMS, DISTRICT OF FRANKLIN, CANADA

B.R. Pelletier,
Atlantic Geoscience Centre, Dartmouth

This study was undertaken as a joint research project between Acadia University (Department of Geology), Wolfville, Nova Scotia, and the Atlantic Geoscience Centre (Department of Energy, Mines and Resources, Canada), Dartmouth, Nova Scotia. At Acadia University the following graduate students participated: A.P. Beardow, A.C. Durocher, J.D. Hill, D.J. Macdonald, J.P. Thompson and L.R. Thorpe. A suite of sediments from an Arctic river and associated delta on the south side of Marie Bay, Melville Island, was subjected to textural analyses at Acadia University, while a comparable suite of sediments from the north side of Marie Bay, as well as samples from adjacent channels, was analyzed in the laboratories of the Atlantic Geoscience Centre. The direction and co-ordination of the project was under B.R. Pelletier of the Atlantic Geoscience Centre.

TABLE 1
Average Textural Values for Sediments from Various Arctic Environments

ENVIRONMENTS

Property	Fluvial - Deltaic						
	North River		South River				Offshore
	River	Delta	River	Total Delta	Inner Delta	Outer Delta	Marine Channels
Phi Mean Diameter	-2.37	6.39	-3.18	0.72	-3.72	5.89	6.04
Standard Deviation	2.61	1.87	2.63	-	-	2.65	1.95
Relative Entropy	40.36	47.62	63.62	59.0	46.95	65.3	47.49
% Gravel	74.73	.05	81.47	46.41	92.72	0.11	0.72
% Sand	20.78	11.08	17.08	23.7	7.1	44.52	8.48
% Mud	4.49	88.56	1.45	29.92	0.08	52.37	90.82
% Silt	3.69	51.11	1.02	15.44	0.0	35.6	59.45
% Clay	0.68	35.23	0.24	14.48	0.0	25.9	31.38
Silt / Clay	5.42	1.48	4.25	1.07	0.0	1.37	2.37
No. of Chief Modes	3.13	2.74	3.14	2.10	1.4	2.89	3.06

The analytical data were studied and assembled into six main categories based on environmental and geographical parameters. These are as follows: North River, North Delta, South Delta (inshore), South Delta (offshore), and the channels. North and South river were distinguished as separate environments because of the contrasting physiography in the source area. The local relief in the North River System ranges from sea level to 300 feet whereas in the South River system it ranges from sea level to altitudes of 2,000 feet. Because of the immediate high relief adjacent to South Delta, a mechanical difference in inshore and offshore sedimentation resulted, and two sub-systems to South Delta developed. The channel environment varies in depth but essentially the samples showed similar properties.

From the 90 samples studied, the textural parameters examined include the following: mean diameter, standard deviation, entropy, modality, per cent gravel, per cent sand, per cent mud, per cent silt, per cent clay, and the silt clay ratio (Table 1). The average value of these characteristics was compared for each environment. This approach revealed a separate pattern of sedimentation for these environments. In some cases a trend could be detected where the concept of distance versus change in textural property was examined. However the main reason for the study was to distinguish separate sub-systems of sedimentation in the main framework of clastic sedimentation in Arctic waters.

30. PRELIMINARY TRIALS ON HARVESTING OF METALS FROM SEAWATER BY USING PEATMOSS AS ABSORBANT

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Dilution of metals in seawater is the most frustrating problem encountered in any endeavour related to their recovery. Our previous investigations indicate that humic compounds can absorb appreciable quantities of metals by cation exchange or chelation reaction[1,2]. These properties of humic compounds could open a new avenue for harvesting of metals from seawater by using peatmoss as an absorbant. Peatmoss is rich in humic acid and we are one of the largest peat producing countries of the world.

A few laboratory investigations were conducted to investigate the metal absorption capacity of peat. The results indicate that every 100 g of peatmoss can absorb a total of 15 mg of metals from solutions containing equal concentrations of Cu, Co, Ni, Mn and Zn. Certain metals appear to get preferentially absorbed on peatmoss; for example, Cu constituted about 50 per cent of the absorbed metals.

Taking advantage of this observation, preliminary field studies were carried out in which seawater was pumped continuously on peatmoss columns for about 60 days keeping the rate of flow at 2,000 litres per day. Samples of peat were drawn at regular intervals which are being analyzed for their metal content.

[1] Rashid, M.A.: Contribution of humic substances to the cation exchange capacity of different marine sediments; Maritime Sed., v. 5, p. 44-50 (1969).

[2] Rashid, M.A.: Role of humic acids of marine origin and their different molecular weight fractions in complexing di- and tri-valent metals; Soil. Sci., v. 111, p. 298-306 (1971).

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31. MODIFICATIONS IN THE SOLUBILITY AND PRECIPITATION BEHAVIOUR OF VARIOUS METALS AS A RESULT OF THEIR INTERACTION WITH SEDIMENTARY HUMIC ACID

M.A. Rashid and J.D. Leonard,
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Although organic compounds constitute only 2-3 per cent of the sediment and their concentration in natural waters rarely exceeds a maximum of 20 mg/ℓ, they are believed to play an important role in various geochemical processes, such as the solubility, mobility, concentration and accumulation of metals. Humic compounds are the major constituents of organic matter associated with soils, sedimentary deposits, and natural waters. Some aspects of their influence on mineral accumulation were investigated in recent years and reviewed briefly in an earlier publication[1]; however, our knowledge of the migratory processes and mechanisms of metal accumulation is still very limited. In order to understand fully the economy of trace metals and to predict the rates and mechanisms of their solubility in natural waters and their precipitation in sedimentary deposits, a great deal of additional information is required on organo-metal relationships especially about the modifications occurring in the properties of metals when they enter into reactions with organic matter. The main objectives of the investigations reported here were to ascertain the effect of humic compounds on the solubility of various metals from their insoluble salts and precipitation behaviour of these metals as carbonates, hydroxides and sulphides.

The results of the investigations indicate that the sedimentary humic acid or its acid-hydrolysate, consisting of various amino acids, is effective in dissolving unusually large quantities of metals (up to 682 mg/g of organic matter) from their insoluble salts. The results also indicate that the presence of humic acid in the reaction media which had favourable conditions for the precipitation of metals as carbonates, hydroxides or sulphides, hindered considerably the formation of insoluble residues and thus delayed the precipitation of metals. This thermodynamic effect which eventually stems from metal dissolving properties of organic matter can be explained by the probable formation of chelates in which the metallic properties of the cations are modified considerably. Once the metals are complexed by humic acid, the solutions behave as though other ions are not present in the reaction media and the metal ions become unavailable to sulphides, hydroxide and carbonates to form insoluble salts. The infrared analysis confirmed that the metals added to various amionic systems and humic acid do not react with the anion. The most likely mechanism of reaction appears to be a complex formation between metals and organic matter which keeps the metal in solution.

The enhanced solubility and decreased precipitation of metals under the influence of humic compounds, as evidenced in these studies should play a leading role in the accumulation of metals in sedimentary deposits.

[1] Rashid, M.A.: Role of humic acids of marine origin and their different molecular weight fractions in complexing di- and tri-valent metals; Soil Sci., v. 111, p. 298-306 (1971).

32. EFFECT OF ORGANIC MATTER ON THE MOBILITY AND MIGRATION OF METALS

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The role of sedimentary humic compounds in the enhanced solubility and the decreased precipitation of various metals was discussed in a previous report in this publication. The metal-complexing capacities of these compounds were also investigated and reported earlier[1]. These and a few other studies carried out previously indicate that humic compounds can play a leading role in dissolving unusually large quantities of metals from their insoluble salts, and also in exhibiting the precipitation of metals under conditions otherwise suitable for their insoluble salt formation. Such reactions would undoubtedly lead to the migration, redistribution and accumulation of metals. The purpose of the investigation reported here was to determine the effect of organic exudates of marine algae on the mobility and migration of metals in sedimentary columns. These investigations were conducted under reducing as well as oxidizing conditions.

The results of these investigations are being analyzed. The indications are that the organic matter exerts considerable influence on the solubility and mobility of metals. The reducing conditions of the media appear to be more conducive in the mobility of metals than the oxidizing conditions.

[1] Rashid, M. A.: Role of humic acids of marine origin and their different molecular weight fractions in complexing di- and tri-valent metals; Soil Sci., v. 111, p. 298-306 (1971).

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33. GEOCHEMICAL EVALUATION OF HYDROCARBON POTENTIALS OF THE OIL WELL CUTTINGS OBTAINED FROM THE EASTERN SEABOARD REGIONS

M. A. Rashid and J. D. Leonard,
Atlantic Geoscience Centre, Dartmouth

In order to evaluate the hydrocarbon potential of the oil wells being drilled on the Scotian Shelf and Grand Bank areas, a comprehensive program for the geochemical analysis of core cuttings was initiated during the period under report and about 1,500 samples from seven oil wells were analyzed for gaseous hydrocarbons (C_1-C_4), total and organic carbon. High molecular weight organic compounds (hydrocarbons and non-hydrocarbons) were extracted from 40 samples. Fractionation of the extracts for aliphatic and aromatic hydrocarbons and resin and asphaltic constituents was completed on 25 extracts. Detailed analysis of the fractionated compounds is underway.

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34. SURFICIAL GEOLOGY AND LITHOGENESIS OF SEDIMENTS ON MID-ATLANTIC RIDGE MOUNTAIN TOPS

C. T. Schafer,
Atlantic Geoscience Centre, Dartmouth

Surficial sediment types on Ridge mountain tops near 45°N (Fig. 1) are the product of biogenic and volcanic activity modulated by local topography, bottom currents and earthquake-triggered slides. These forces give rise to a number of sediment types that reflect both water depth and proximity to a particular detrital source. In addition, ice-rafted material is recognized as a significant source in parts of this area, especially west of the median valley.

Bedrock outcrops out at all water depths between 950 and 2,600 m while boulders and cobbles cover up to 25 per cent of the bottom between 1,600 and 2,400 m. Pebbles have a wide range of distribution; they are generally basaltic, well sorted and range between one and three cm in maximum diameter. Mud deposits (ooze) are observed at all water depths between 950-2,600 m where they usually comprise from 10 to 100 per cent of the substrate. The existence of features such as intersecting pebble waves, pebble lag deposits and sediment-free rock outcrops on bottom photographs denotes the presence of significant bottom currents of varying direction and intensity.

Lithostratigraphy

The study of the shallow subsurface geology of the Mid-Atlantic Ridge mountain tops was undertaken using a hydrostatic rock drill developed at the

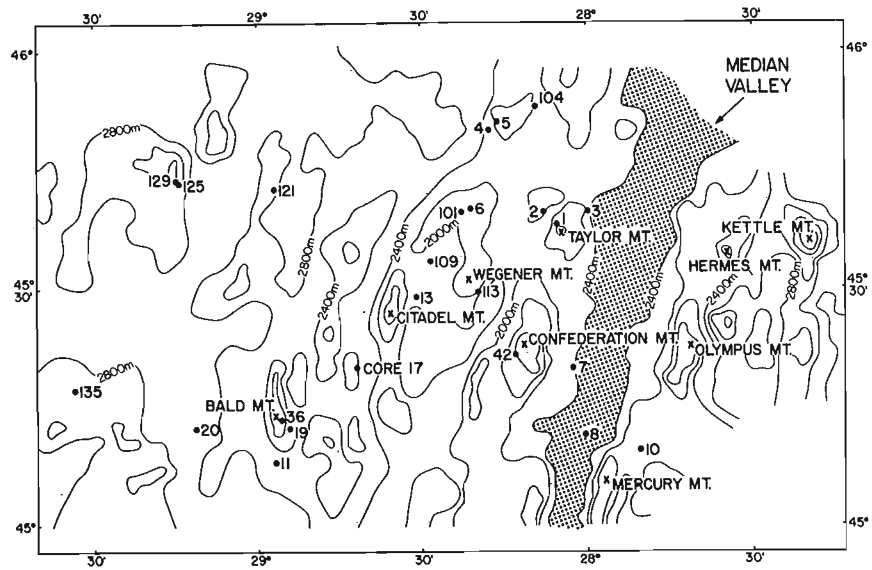

Figure 1. Location of bottom camera stations and drilling sites (X) on the crestal mountains and high fractured plateau of the Mid-Atlantic Ridge.

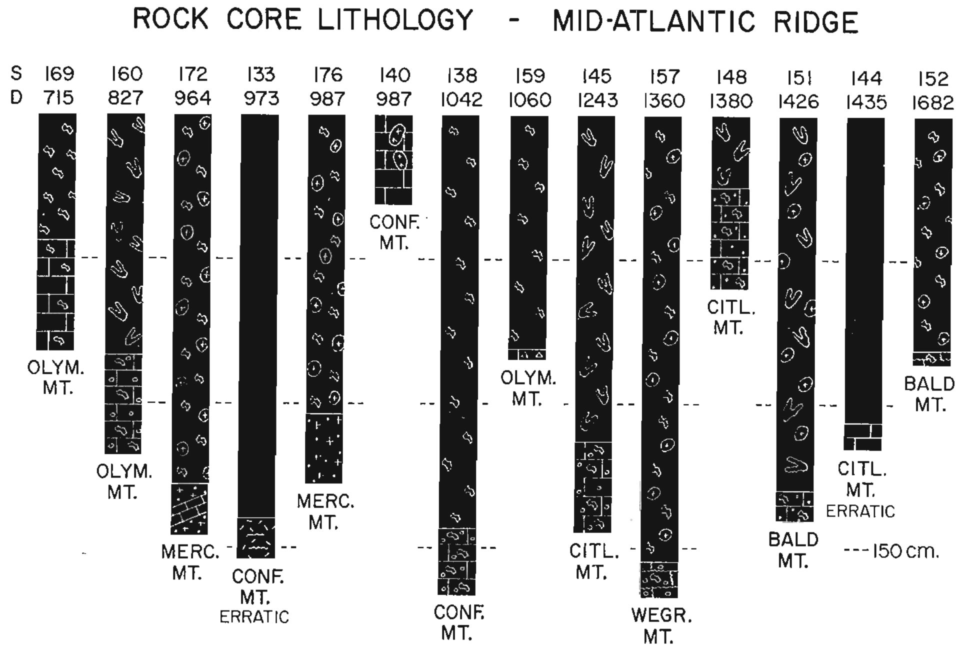

Figure 2. Relationship of coralline limestone and basalt to overlying unconsolidated sediments as determined from acoustically telemetered drilling data and rock core samples. A station number (S) and water depth in metres (D) is given for each core. Material overlying core 160 is presumed to be, in part, living coral as opposed to coral detritus, pebbles and ooze (e.g. Core 138). Cores 144 and 133 bottomed in rock identified as glacial erratics (Aumento, pers. comm.); while vesicular basalt was penetrated at sites 172 and 176 on Mercury Mt.

Bedford Institute. Of the 21 successful drill penetrations, 43 per cent bottomed in friable to well indurated coralline limestone which was overlain either by ooze, lag pebbles, coral skeletal fragments or a combination of these ranging from 0 to 160 cm in thickness (Fig. 2). Absolute age data (^{14}C) suggest that cementation of the limestones was probably initiated during the latter part of a late Middle Wisconsin interstadial about 42,000 to 23,000 years BP. When the coccolith-rich nature and the ^{14}C dates of these cores are considered along with other paleontological evidence, the deposition and primary lithification of this material under climatic conditions closely related to those of the present is strongly suggested.

35. PLANKTONIC FORAMINIFERA IN THE WATER COLUMN AND SEDIMENTS IN THE CANADIAN ARCTIC

Project 720114

G. Vilks,
Atlantic Geoscience Centre, Dartmouth

The distribution of planktonic foraminifera in the surface waters of the Arctic Ocean is affected adversely by the cover of ice and the vicinity of land. Large numbers of planktonic foraminifera are found in the open water during the summer in the southeastern Beaufort Sea and at the eastern end of Lancaster Sound. The former is an area of upwelling and the latter an area of extensive lateral mixing.

In addition to the productivity in the surface waters, the distribution of planktonic foraminifera in the sediment is dependent on the preservation rates of the tests and the supply rates of terrestrial material. On the continental shelf off the Mackenzie River delta the relatively small numbers of planktonic foraminifera reflect the high local terrestrial sedimentation, but in the eastern end of the Lancaster Sound and Baffin Bay the paucity of preserved planktonic foraminifera reflect poor conditions of preservation in addition to high sedimentation rates of terrestrial material.

In the Arctic environment robust specimens are preserved more readily than the fragile tests. Adult planktonic foraminifera with arrested reproductive cycles secrete thick test walls with the prolonged residence times in the water column. Reproductive cycles are arrested by adverse conditions, therefore stratified waters with a diluted surface layer contains relatively more thick-shelled adults than mixed waters. The high numbers of planktonic foraminifera in the mixed waters of eastern Lancaster Sound and northern Baffin Bay produce only thin-shelled adults, which are dissolved after death. The stratified waters of McClure Strait, Viscount Melville Sound and the Beaufort Sea contain high percentages of the robust adults, which are preserved in the sediments. Therefore, layers rich in planktonic foraminifera in the Arctic sediment cores are indicative of low sedimentation rates and open, but stratified surface water. Such waters are typical of semi-permanent polynya and open leads in the cover of ice.

Geol. Surv. Can., Paper 73-1, Part B

36. MICROMORPHOLOGY OF ORBULINA UNIVERSA D'ORBIGNY

Project 720114

G. Vilks and D.A. Walker,
Atlantic Geoscience Centre, Dartmouth

The adult phenotype of the planktonic foraminifer Orbulina universa contains two seemingly unrelated forms: the inner trochospiral and the outer spherical (Fig. 1). Owing to the difficulties in obtaining well preserved trochospiral specimens, the taxonomy of the species has been questioned.

To demonstrate the relationship of this species to other planktonic foraminifera, scanning electron micrographs were studied on specimens collected in surface waters of the Atlantic and Pacific Oceans and the Caribbean Sea.

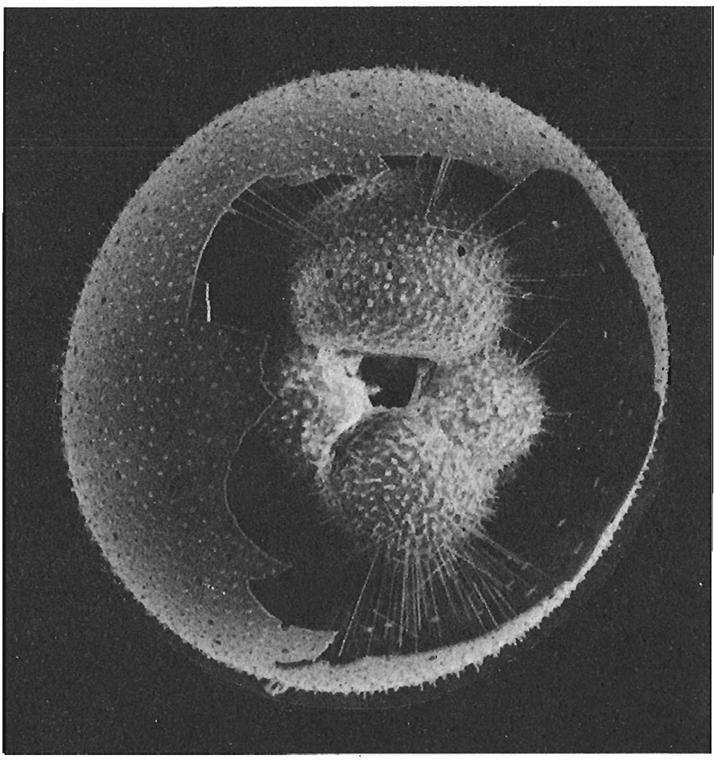

Figure 1. Orbulina universa d'Orbigny magnified X185 collected from surface waters Lat. 42°48.2'N, Long. 140°52.0'W.

Most trochospiral forms contain secondary apertures, therefore the species is not related to Globigerina d'Orbigny as maintained by several authors. All specimens possess triradiate spines, which are different from any species of the genus Globigerinoides, indicating a basic difference between the two genera. Hastigerina Thomson and Globigerinella Cushman also contain triradiate spines, but these genera are planispiral and therefore different from O. universa.

The micromorphology of Orbulina universa is distinct from the other forms of planktonic foraminifera and therefore it is a valid taxon.

37. REGIONAL GEOLOGY OF THE MESOZOIC-CENOZOIC SEDIMENTS OFF NOVA SCOTIA AND NEWFOUNDLAND

Project 720104

John A. Wade,
Atlantic Geoscience Centre, Dartmouth

Work was initiated in June 1972 on a study of the regional subsurface geology of the Atlantic continental margin of Canada south of 52°N. From maps prepared from seismic profiles, and well data, two major depocentres are recognized:

(1) The Scotian Basin, which lies between the southerly trending Shelburne high off southern Nova Scotia and the Avalon uplift which runs from Avalon Peninsula to the southern tip of the Grand Banks of Newfoundland, may contain up to 40,000 feet of Mesozoic and Cenozoic sediments and is characterized by a large number of halokinetic structures.

(2) The East Newfoundland Basin, lying northeast of the Avalon uplift and west of Flemish Cap, may contain in excess of 40,000 feet of Mesozoic, Cenozoic and possibly Paleozoic sediments. Deep-seated salt structures are indicated on seismic profiles across this basin.

The pattern of deposition in the Scotian Basin reflects the rifted origin of the Atlantic continental margin. The accumulation of early Jurassic salt in an elongate basin beneath the outer shelf and continental slope probably marks the site of this rifting. The Avalon uplift appears to be a post-Jurassic feature containing troughs of compressionally deformed Jurassic and possible Carboniferous, Triassic and Cretaceous sediment which are overlain by relatively undisturbed sediments of Late Cretaceous and Tertiary age.

Well data from the Scotian Shelf indicates sediments of Jurassic age are divisible into two major cycles: a lower red bed-evaporite-carbonate-clastic sequence and an overlying sequence of marine limestones and shales and shallow marine to nonmarine clastics. Seismic, and limited well data, indicate similar sediments occur locally beneath the Grand Banks. In Early Cretaceous time thick, seaward prograding, deltaic complexes were developed south of Cape Breton Island and east of Newfoundland. Major regional transgression commenced in the late Early Cretaceous and culminated, with the deposition of the Wyandot chalk, in Senonian time after which the seas slowly regressed to their maximum low stand during the Pleistocene. It was during this time that the continental shelves off Nova Scotia and Newfoundland were constructed.

The major economic potential for the region will be gas and oil mainly from rocks of Jurassic, Cretaceous and Tertiary ages. Two significant finds and several encouraging shows have been announced from the Scotian Basin, however, the "pull apart" origin of this region, together with the long period as an open continental margin with relatively slow rates of deposition indicate below average hydrocarbon potential. The East Newfoundland Basin, on the other hand, although as yet untested, appears to have been semi-restricted during much of its development and as such may have above average petroleum potential.

38. MORPHOGENESIS AND TEST SURFACE ULTRASTRUCTURE OF BENTHONIC FORAMINIFERA OF NOVA SCOTIA

D. A. Walker,
Atlantic Geoscience Centre, Dartmouth

Foraminifera were collected biweekly for a period of one year from several tidepools on the south shore of Nova Scotia. The natural biological, ecological and morphogenetic processes are under investigation. Test surface ultrastructure is under investigation by use of scanning electron microscopy. With initial emphasis on pore morphology, results indicate that for juveniles of Cibicides lobatulus there is a range of ratios of average pore diameter to greatest test diameter distinct from that range determined for the adults of the same species. In addition, there are distinct differences in pore morphology between generations, so that perhaps in areas of rapid sedimentation winter and summer populations can be distinguished.

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39. AN INVESTIGATION OF STAINING METHODS TO DIFFERENTIATE LIVING AND NON-LIVING FORAMINIFERA

D. A. Walker and C. T. Schafer,
Atlantic Geoscience Centre, Dartmouth

The Rose Bengal method for differentiating living and non-living foraminifera, as described by Walton[1], is inaccurate and unreliable. Symbiotic algae and bacteria commonly found in association with living and non-living foraminifera react positively to rose bengal, masking its real effect on foraminiferal protoplasm.

Three major problems had to be solved: (1) employing a suitable fixative prior to the staining process; (2) employing a stain specific only to the protoplasm of a living foraminifer and; (3) penetration of the stain into the earlier chambers. A basic fixative was used since calcite tests become etched and ultimately decalcify if exposed to an acid medium of pH <4. Solutions of formaldehyde and isopropyl alcohol, diluted with sea water and buffered to pH 8.1, were tested with respect to their effectiveness in preserving foraminiferal protoplasm. Extended pseudopodia immediately disintegrated when exposed to isopropyl alcohol. The solution of formaldehyde, however, rendered the pseudopodia intact with no signs of retraction.

Formaldehyde forms an acidic compound with protein, thus the protein becomes basophilic. In order that a basic dye stains efficiently it should be used in a basic solution of about pH 8.1. Several basic stains were investigated and experimental results indicate that heated sudan black B is specific, exclusively to protoplasm and internal organic lining of the test. This stain, when heated, penetrated up to and including the fourth chamber, rendering the protoplasm dark blue and clearly differentiated.

In the light of this investigation it is suggested that the published results of many workers incorporating those methods of Rose Bengal staining be reviewed.

[1] Walton, W.R.: Technique for Recognition of Living Foraminifera; Cushman Found. Foraminiferal Res., Contrib., v. 3, p. 56-60 (1952).

MINERALOGY

40. MINERALOGICAL NOTES ON THE URANIUM OCCURRENCES AT SOUTH MARCH AND ELDORADO, ONTARIO

Projects 550101*, 650438**, 720084**

H. R. Steacy*, R. W. Boyle**, B. W. Charbonneau** and R. L. Grasty**

Central Laboratories and Technical Services Division*, Ottawa
Resource Geophysics and Geochemistry Division**, Ottawa

First reports of these two occurrences appeared in Geological Survey Paper 73-1, Part A. Near South March, uranium occurs in Paleozoic sediments[1]. At Eldorado, Precambrian calc-silicate rocks have yielded specimens containing a uranian hydrocarbon associated with native gold[2]. Continuing laboratory work on samples from the two occurrences has now provided additional information.

The radioactivity of the samples collected from the March Formation near South March, Ontario, is found to be associated mainly with a black hydrocarbon. The host rock, apparently a calcirudite, parts rather easily, and on noticeably radioactive partings the hydrocarbon may be seen as black grains and as splotchy patches up to two inches in diameter. Under magnification, the material closely resembles coal, with an uneven to conchoidal fracture (Fig. 1) and specks of green malachite are commonly seen associated with it. In a polished section cut normal to the bedding, the hydrocarbon appears as individual rounded-to-irregular-shaped grains, down to microscopic size (Fig. 2); as clusters and strings of such grains; and as elongate masses. Generally, these grain groupings and masses represent sections through the aforementioned patches, many of which mantle or partly envelope grains of quartz. Because of its almost ubiquitous association with chalcopyrite, clean unadulterated grains of the hydrocarbon of manageable size are difficult, if not impossible, to separate. However, tests on grains carefully selected under the binocular microscope indicate a density of about 1.4 and an ash content of approximately 20 per cent. A relatively pure sample of the hydrocarbon, obtained as a float fraction in a heavy liquid of 2.50 density, showed a content of 0.71 per cent U_3O_8. Heavy mineral concentrates, separated from finely-sized rock fractions on the superpanner, consisted essentially of sulphides and zircon with a little rutile. The discrete radioactive grains mentioned in the previous account[1] and in part associated with the hydrocarbon, have so far eluded identification although there is evidence that at least some are secondary uranium compounds.

Information on the geology of the South March region is provided by Wilson[3]. As regards the origin of the uranium, the following excerpt from this report may have particular significance: "the largest and most continuous supplies of potable well water are obtained from the March formation. The covering of Oxford dolomite is relatively impervious, and the porosity of the March sandstone layers allows free movement within the formation"[4]. The postulate to be made here is that uranium may have been collected from circulating meteoric waters by previously emplaced hydrocarbon or that it may have been carried as a dissolved uranyl-hydrocarbon colloid or emulsion

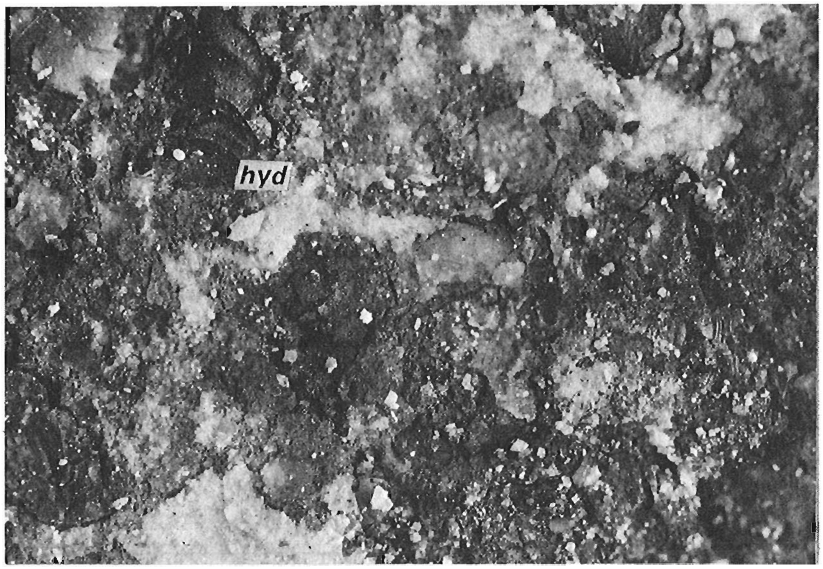

Figure 1. Photograph in reflected light, of a two-inch diameter patch of uranian hydrocarbon (hyd) on a parting of sandy dolomite from the March Formation. Note the conchoidal fracture. x 15

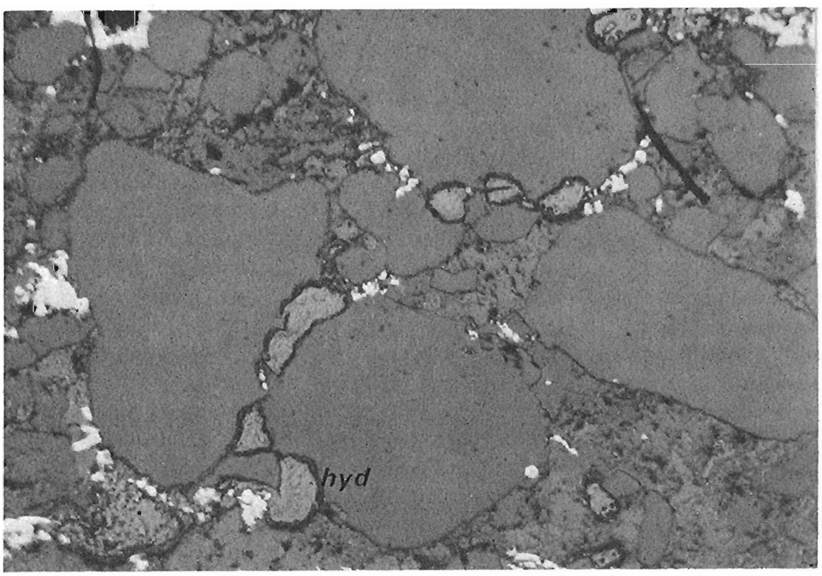

Figure 2. Photomicrograph of a polished section of a different portion of the sandy dolomite showing grains of the uranian hydrocarbon (hyd). The large rounded grains are quartz and the white grains, mainly chalcopyrite. The matrix is essentially quartz and calcite. x 78

that was ultimately coagulated along partings and other open spaces. Wilson also refers to two springs occurring in the tongue of Paleozoic rocks extending northwest up the Ottawa River Valley, noting that one, occurring on lot 26, conc. XII, Pakenham tp., is radioactive but that "it loses its activity quickly because of the small amounts of radium dissolved in the water"[5]. Several radioactive springs in the Ottawa-St. Lawrence area are described by Satterly and Elworthy[6] although the authors, based on rather scanty field and laboratory evidence and without measuring the uranium contents of the waters, make the general observation (p. 53) that "no Canadian water, however, gave results which would indicate the presence of radioactive minerals in its neighbourhood".

The occurrence of uranium as a uranian hydrocarbon at Eldorado, Ontario was first noted in the examination of samples from the old Richardson Gold Mine. Two additional radioactive specimens from the Richardson Mine have since been examined and, quite unlike the first, have been found to contain as their principal radioactive constituent the uranium-titanate, brannerite. One of these latter specimens (ROM 8429) was obtained from the Royal Ontario Museum, Toronto, and the second (Be 92) from the National Museum of Natural Sciences, Ottawa. Although from separate sources and collected by different individuals, the specimens are quite similar with the brannerite occurring as brownish black masses in a matrix of coarsely crystalline calcite associated with mica, tourmaline and pyrite. Of special interest is the fact that native gold is intimately associated with the brannerite and appears to replace it. Gold-brannerite associations are known from at least three localities in the world, but the association at the Richardson Mine is believed to be the first recorded in Canada. A paper on the association is currently in preparation.

[1] Grasty, R. L., Charbonneau, B. W. and Steacy, H. R.: A uranium occurrence in Paleozoic rocks west of Ottawa; in Report of Activities, April to October 1972, Geol. Surv. Can., Paper 73-1, Pt. A, p. 286-289 (1973).

[2] Boyle, R. W. and Steacy, H. R.: An auriferous radioactive hydrocarbon from the Richardson Mine, Eldorado, Ontario; in Report of Activities, April to October 1972, Geol. Surv. Can., Paper 73-I, Pt. A, p. 282-285 (1973).

[3] Wilson, Alice E.: Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec. Geol. Surv. Can., Mem. 241 (1946).

[4] Ibid, p. 41.

[5] Ibid, p. 42.

[6] Satterly, John and Elworthy, R. T.: Mineral Springs of Canada, Part 1. The radioactivity of some Canadian mineral springs; Can. Mines Br., Bull. 16 (1917).

MINERAL DEPOSITS

41. BARIUM, FLUORINE AND STRONTIUM DEPOSITS

Project 720095

K. R. Dawson

Regional and Economic Geology Division, Ottawa

A study of the distribution and distinctive characteristics of barium, fluorine and strontium occurrences listed in Canadian geological literature is being carried out. A total of 694 sites have been identified in which one or more of the three elements have been reported either as the chief constituent or as gangue minerals. Of the 694 sites 616 have no published production; 19 have produced barite; 14 have produced fluorite, 2 produced celestite, and the remaining 41 produced one or more of lead, zinc, silver, manganese, molybdenum, gold or niobium. 654 sites are without published reserves.

The following properties have been classified as either producers or past producers. Fluorite has been produced in Canada from the Rock Candy Mine, B. C. ; the Madoc area of Ontario; and St. Lawrence, Newfoundland. Barite has been produced at Lake Ainslie and Walton, Nova Scotia; Parson Station, Brisco and the Giant Mine in British Columbia. Celestite is being produced at Loch Lomond, Nova Scotia.

Barium occurs most frequently in the mineral barite ($BaSO_4$) and less commonly as witherite ($BaCO_3$); fluorine occurs almost exclusively in the mineral fluorite (CaF_2); and strontium occurs mainly in the mineral celestite ($SrSO_4$). The barium and fluorine minerals occur as gangue minerals with copper, lead, zinc, silver ores and less commonly with manganese, molybdenum, gold or niobium. The strontium mineral celestite either occurs alone or in association with gypsum.

The file is operated as a MARS (Multiple access retrieval system) data bank on the Departmental CDC 6400 computer. The MARS system offers the advantages of speed and flexibility for retrieval and file maintenance that have been used to compile the file and support the project.

Tiphane, Marcel: Barite and fluorite in Quebec; Dept. Nat. Resources, Quebec; Spec. Paper 13 (1972).

Guillet, G. R. : Fluorspar in Ontario; Ont. Dept. Mines, Indus. Min. Rept. No. 12 (1964).

Barite in Ontario; Ont. Dept. Mines, Indus. Min.; Rept. No. 10 (1966).

Ross, J. S. : The Barium Industry in Canada; Mines Br., Canada; Inform. Circ. 126 (1960).

Wilson, M. E. : Fluorspar Deposits of Canada; Geol. Surv. Can., Econ. Geol. Ser. 6 (1929).

Spence, H. S. : Barium and Strontium in Canada; Mines Br., Canada, Rept. No. 670 (1922).

PRECAMBRIAN GEOLOGY

42. SOME NOTES ON THE PRECAMBRIAN ROCKS OF THE GROS MORNE NATIONAL PARK, WESTERN NEWFOUNDLAND

Project 680130

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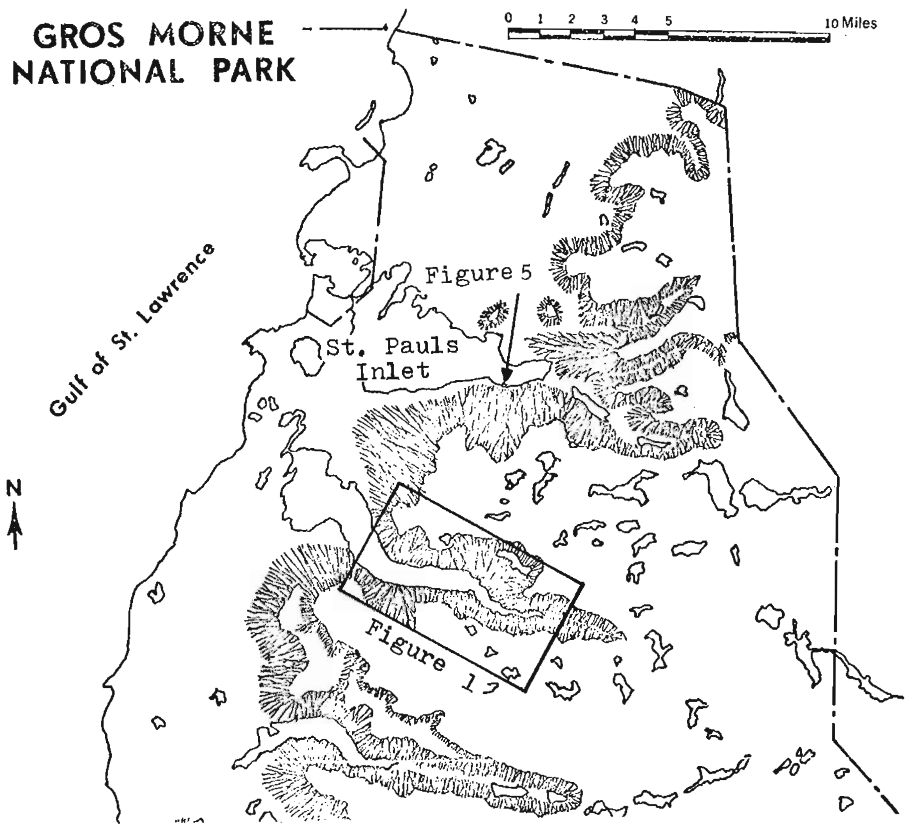
Regional and Economic Geology, Division, Ottawa

The newly designated Gros Morne National Park is an area of approximately 750 square miles, situated along the west coast of Newfoundland, 60 miles north of Corner Brook. A dominant landscape area of the Park is the high plateau underlain by Precambrian rocks of the Long Range complex[1].



Index map of the northern part of Gros Morne National Park showing the location of St. Pauls Inlet and figures 1 and 5.

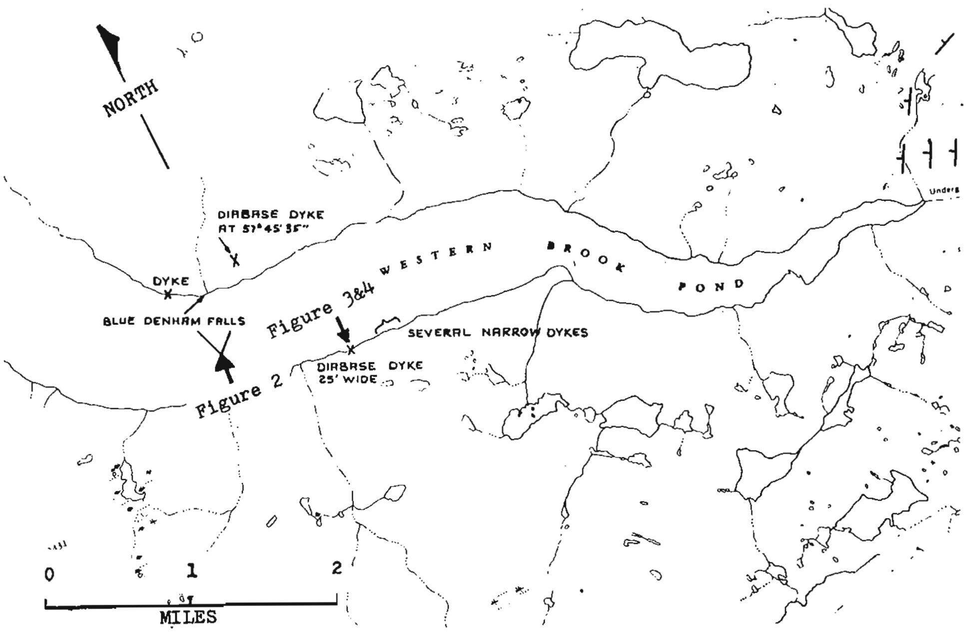


Figure 1. Eastern part of gorge at Western Brook Pond showing location of dykes and Figures 2, 3 and 4.

The Long Range complex is an uplifted crustal block which is an inlier of basement rocks of the Grenville province. This inlier is rectangular in plan and trends northeast. It is 110 miles long and 30 miles wide. The main wilderness area of the Park comprises 350 square miles of a southwestern portion of this inlier.

The following descriptions indicate some of the variety of Precambrian rocks that occur in the northern part of the Park, at St. Pauls Inlet and Western Brook (see index map and Fig. 1). Some comparisons are drawn with rocks of similar age in the northern part of the Long Range.

The writers wish to acknowledge the co-operation of Park's Branch personnel at the Rocky Harbour headquarters. Park Superintendent D. J. Learmonth collected a bedrock specimen from the plateau above Western Brook Pond during a helicopter traverse to that area. Park Naturalist P. R. Hope collected two specimens from a talus slide near the eastern end of the pond. Also, Professor W. D. Brückner, Department of Geology, Memorial University contributed useful field information about the geology of the area.

Precambrian Gneiss

One area within the Park boundaries where the Precambrian rocks have been described in a reconnaissance fashion is near the northeast corner. There the gneisses were described by Fritts[1] as follows:-

"From the head of St. Pauls Inlet eastward for a distance of 25 miles, a banded complex of gneisses is exposed. The constituent members of this

Figure 2. Diabase dykes intrude Precambrian granulite facies rocks, north shore of Western Brook Pond at Long. 57°45'35"W. Dykes outcrop near the pinnacles on the upper right and also in the gully shown at the left margin of the photo. GSC Photo 202236.

complex are commonly either acidic or basic in composition. The two most typical types are granular, granite gneiss and hornblende-diorite gneiss. Grain size usually averages between 1 and 2 millimeters, but some variations occur. Banding may be strong and in the more basic bands, a definite schistosity is occasionally developed. These rocks in many places are highly contorted, and regional discontinuities in strike are common. The rocks have been intruded by numerous pegmatite and quartz veins and it is frequently impossible to distinguish between injected material of igneous origin and the original granite ingredients within the gneiss complex."

These rocks display essentially the same composition as the gneisses which are exposed in other parts of the Long Range, and appear to have had a similar origin. The principal difference between these gneisses and those which are exposed farther north is the higher degree of metamorphism which is displayed by the rocks within the Park area.

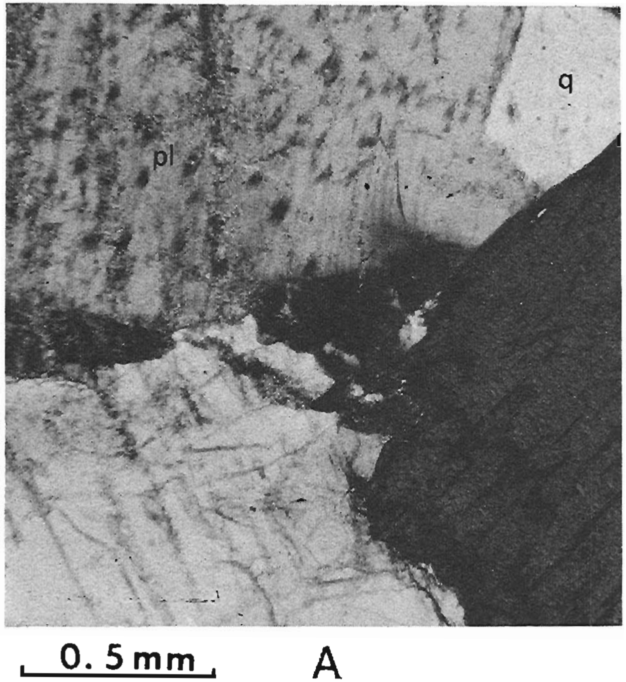
Petrography

Examination of thin sections of specimens collected in the Park indicates that they are of four groups. The first group, from the drift 1.5 miles east of the east end of Western Brook Pond, is of somewhat exotic rocks (anorthositic gabbro and calc-silicate gneiss), unusual within better

TABLE 1

Group	Rock Name	Textures	Mineralogy (minerals in order of decreasing abundance)	Alteration
(1)	Anorthositic Gabbro (?)	coarse grained (7 mm), massive, equigranular, allotriomorphic; plagioclase slightly antiperthitic.	plagioclase (andesine), pyroxene (?), biotite, opaques, quartz.	pyroxene (?) completely altered.
	Aluminous calc-silicate gneiss (?)	medium-grained variable, massive allotriomorphic.	plagioclase (labradorite), quartz carbonate, muscovite, garnet, opaques, spinel, zircon, apatite.	plagioclase finely sericitized.
(2)	Norite (?)	medium-grained (1 1/2 mm) equigranular, massive, allotriomorphic.	plagioclase (andesine), clinopyroxene, hornblende, hypersthene, opaques, apatite.	plagioclase slightly sericitized hypersthene altered along rims and fractures.
	hypersthene-quartz-plagioclase-gneiss	medium-grained variable, massive, allotriomorphic	plagioclase (oligoclase), quartz, hypersthene, hornblende, biotite, opaques, zircon, apatite.	hypersthene altered along rims and fractures.
(3)	Hornblende-quartz-feldspar-gneiss	medium-grained (2 mm), equigranular, slightly schistose, allotriomorphic, quartz strained.	plagioclase (oligoclase), quartz, microcline, hornblende, biotite, chlorite, opaques, apatite, zircon, allanite.	feldspar finely sericitized, biotite and chlorite contain exsolution? products along cleavage.
(4)	Dolerite	fine-grained, massive, slightly ophitic.	plagioclase (sodic), clinopyroxene, amphibole, chlorite, epidote, opaques, quartz, apatite	plagioclase sausuritized; pyroxene partly altered to amphibole and chlorite.

Plate I



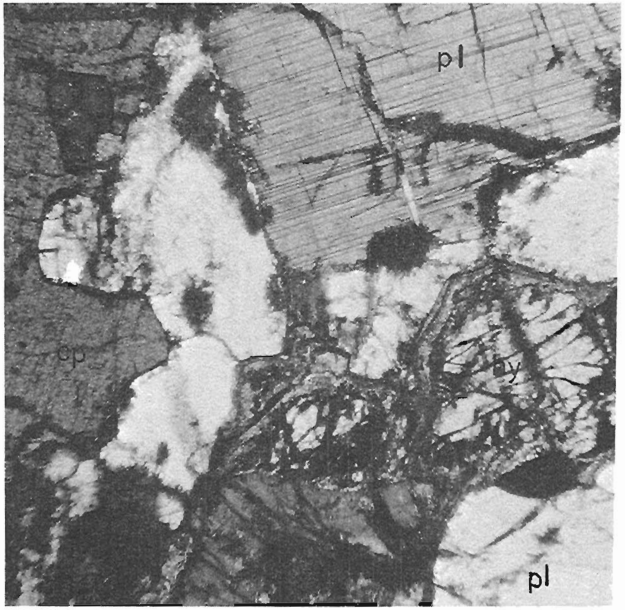
A

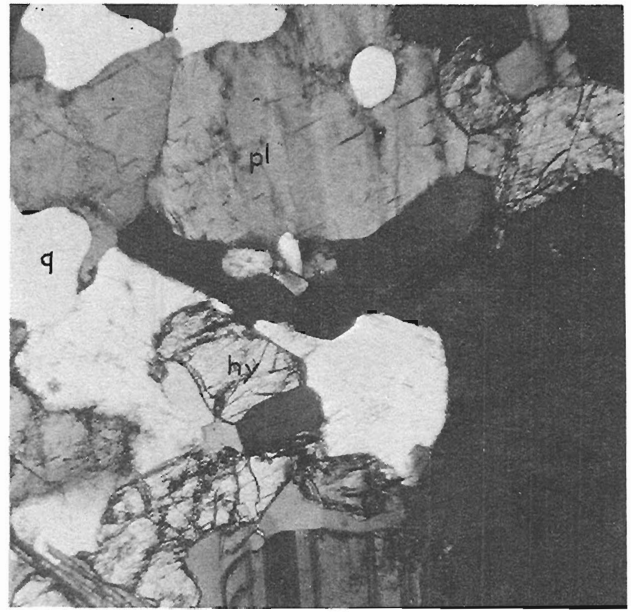
B

A. Altered anorthositic gabbro erratic showing antiperthitic plagioclase (pl), biotite (b), and minor quartz (q).

B. Calc-silicate erratic showing plagioclase (pl), garnet (g), spinel (s), and opaques.

Plate I cont'd.



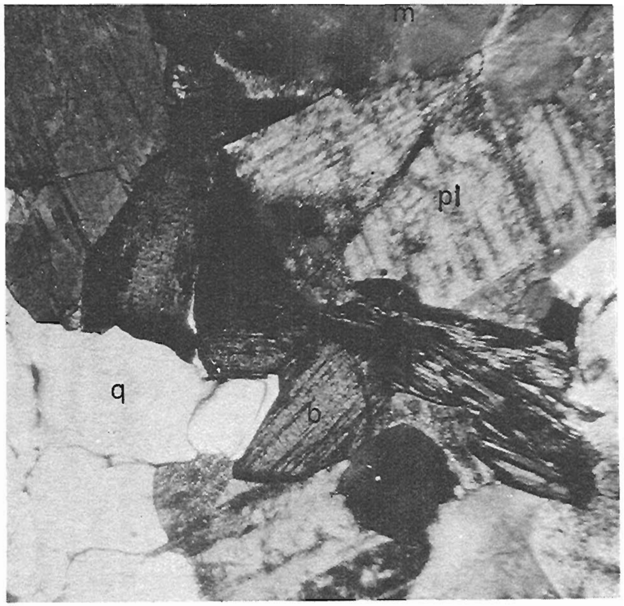


0.5 mm C D

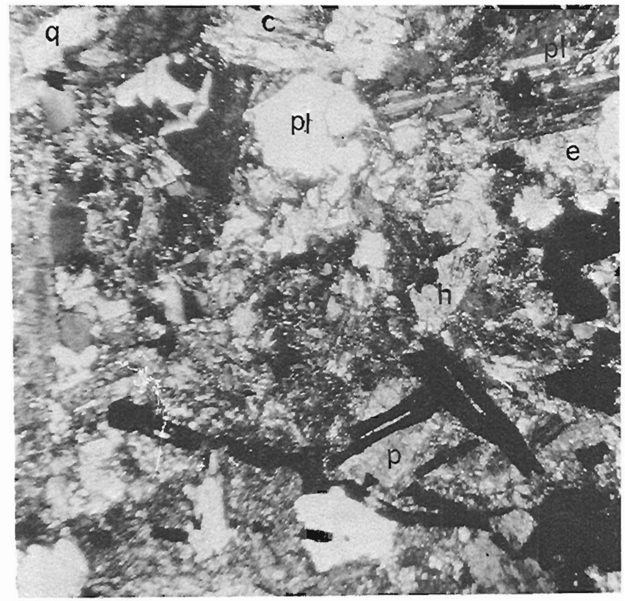
C. Norite showing altered hypersthene (hy), plagioclase (pl), quartz (q), and clinopyroxene (cp).

D. Hypersthene-quartz = plagioclase gneiss showing hypersthene (hy), quartz (q), and plagioclase (pl).

Plate I cont'd.



0.5 mm E



F

E. Hornblende-quartz-feldspar gneiss showing hornblende (h), quartz (q), microcline (m), and plagioclase (pl).

F. Saussuritized dolerite showing plagioclase (pl), hornblende (h), pyroxene (p), epidote (e), chlorite (c), and quartz (q).

Figure 3. Diabase dyke, south shore of Western Brook Pond, at Long. 57°45'00"W. The dyke is 25 feet wide and is accessible by boat at the base of this 2,000-foot, nearly vertical, cliff. Note that within the dyke is a wall rock inclusion, 50 feet in length. GSC Photo 202237.

known parts of the Long Range Grenville inlier. The second group, from south of Western Brook Pond, are of high metamorphic rank (granulite facies) rocks that contrast with gneisses in the northern part of the inlier in which traces of hypersthene are only locally present. The third group comprises a single specimen of intermediate metamorphic rank (amphibolite facies) gneiss from St. Pauls Inlet, that is more nearly comparable to gneisses in the northern part of the inlier. The last group consists of a single specimen from a dolerite dyke, likely a member of the Long Range dyke swarm, intrusive into the granulite facies rocks south of Western Brook Pond. The texture and mineralogy of these rocks are described in Table 1, and illustrated in Plate 1.

Discussion

The anorthositic gabbro erratic of group (1) is of interest because known bodies of similar rock are confined to the southeast margin of the Grenville inlier[3]. It is likely that late Pleistocene glacial ice moving from the interior of Newfoundland into the Bonne Bay area overlapped into Western Brook Pond and may have carried such erratics from a source near Humber River (Grant, D.R., pers. comm.). On the other hand, the geology of the interior highlands of the park is not well enough known to preclude the

Figure 4. Close-up of the wall rock inclusion shown in Figure 3. The elongate fragment is estimated to be fifty feet long. It probably collapsed into the molten dyke material due to a pulsing mechanism associated with the injection of dyke magma.

existance of other relatively small bodies of anorthositic rocks closer by, from which the specimen might have been derived.

By analogy with better known parts of the northern Long Range, small lenses of calc-silicate gneiss are likely to be rare but widespread within the Park. Boulders from these lenses although spectacular in the drift may be difficult to trace to their source without detailed knowledge of the local geology.

Specimens of group (2) are of hypersthene-bearing gneisses and thus, whether ultimately of igneous or sedimentary origin, they imply high rank (granulite facies) metamorphism or conditions approaching thereto.

Similar rocks are present on the north shore of the Strait of Belle Isle[4] and in the Precambrian rocks of the Indian Head Range near Stephenville. Intervening gneisses in the northern Long Range show traces of granulite facies metamorphism indicating that they have barely reached granulite facies conditions or have been mostly retrograded during later granitic plutonism.

The specimen of gneiss from St. Pauls Inlet (group 3) bears a mineral assemblage common in rocks of amphibolite facies rank and is comparable to melanocratic gneisses in the northern part of the inlier. It differs from the granulite facies rocks in the presence of late chlorite, allanite, and of simple perthitic (as opposed to mesoperthitic or sub-mesoperthitic) potash feldspar, and in the absence of hypersthene.

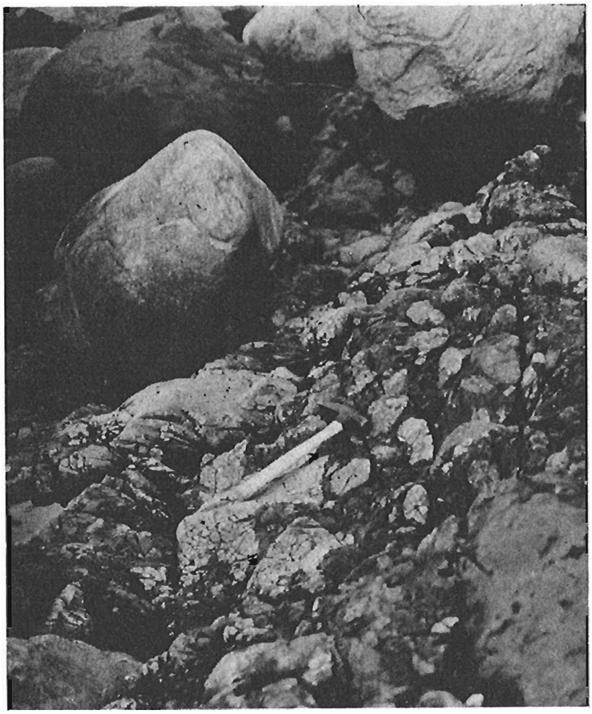


Figure 5. Fault-brecciated Precambrian gneiss, south shore of St. Pauls Inlet at Lat. 49°49'04"N; Long. 57°41'40"W. This locality is near the foot of the fault-line escarpment which forms the western margin of the Long Range complex. GSC Photo 201825-P.

The specimen of dolerite (group 4) is comparable to specimens from dykes of the Long Range swarm[5] that extends southwestward from the northeast end of the inlier near Canada Bay. In the northern part of the swarm, alteration of these dykes increases toward the east and this alteration is in part due to late (Ordovician) greenschist facies metamorphism near the coast, and in part to deuteric alteration arising from the reaction of the rock with volatiles at the time of emplacement. Alteration of the dyke at Western Brook Pond is moderate, and in view of the relatively less altered condition of specimens from the surrounding gneisses, it appears likely that it has been of deuteric origin.

[1]Cumming, L.M.: Geology of the proposed Gros Morne National Park, Western Newfoundland; in Report of Activities, April to October 1972, Geol. Surv. Can., Paper 73-1, Pt. A, p. 5-7 (1973).

[2]Fritts, C.E.: Geological reconnaissance across the Great Northern Peninsula of Newfoundland; Nfld. Geol. Surv., Rept. No. 4 (1953).

[3]Baird, D. M.: Geology of Sandy Lake (west half) Newfoundland; Geol. Surv. Can., Map 47-1959 (1960).

[4]Bostock, H. H.: Precambrian rocks of the Strait of Belle Isle Region; Northwest Newfoundland, Southeast Labrador, Belle Isle and part of southeastern Quebec; Geol. Surv. Can., Paper (in prep.).

[5]Clifford, P. and Baird, D. M.: Great Northern Peninsula of Newfoundland-Grenville Inlier; Bull. Canadian Inst. Mining Met., v. 55, p. 150-157 and 276-277 (1962).

QUATERNARY GEOLOGY: INVENTORY MAPPING AND STRATIGRAPHIC STUDIES

43. TERRAIN CONDITIONS, GROS MORNE NATIONAL PARK, WESTERN NEWFOUNDLAND

Project 720028

D.R. Grant,
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The surficial geology of the coastal lowlands of Western Newfoundland, underlain by lower Paleozoic carbonate rocks, is being mapped at 1:50,000 scale as a basis for the design, sampling, and interpretation of results of a reconnaissance geochemical survey planned for 1973. The inventory is an interpretation of the identity, origin and composition of the earth's relief features and surface deposits, supplemented by notations on stratigraphic sequence where observed or inferred. For that portion of the lowlands, and part of the adjacent plateau massif lying within the newly established Gros Morne National Park, the information has been adapted and herein discussed for use a basis for park planning and development, following a request from the Resource Inventory Task Force of the National and Historic Parks Branch.

Terrain conditions (Figs. 1 and 2) vary from sheer rock cliffs to endless peat bogs, from extensive summit areas of patterned ground and felsenmeer prairies to landslides and earthflows, from wide swaths of raised beach ridges to chaotic end moraine, and from ragged coastal promontories to white crescent beaches and active sand dunes. Basically, however, the area comprises two main terrain complexes: the coastal lowland underlain by gently inclined, mainly carbonate, sedimentary rocks thickly buried beneath marine and glacial deposits, except for a few rock ridges and headlands; and the slopes and summits of the Long Range plateau where rock is everywhere at or near the surface. The transition is an escarpment breached by spectacular fiords and lake-filled troughs. From the fiords the lower slopes rise steeply over massive talus cones and aprons (map-unit Rx) to shear rock walls (R) that meet the plateau surface abruptly at 1,500 to 2,000 feet. Near the escarpment the tablelands are covered with block fields of felsenmeer (Rw) from which rise slightly higher rounded summits covered with a colluvial mantle (C) characterized either by peat polygons or solifluction strips in a thin organic mat. Farther inland the plateau is virtually bare rock, deeply etched by fracture lineaments and igneous rock foliation trends. The locally strong weathering on the coastal summits is thought to be in part relict from a nunatak phase of valley deglaciation[1], and in part due to present climate, which at elevations exceeding 2,000 feet, could theoretically produce permafrost effects (R.J.E. Brown, pers. comm., 1972).

On the lowland is a complex array of glacial and marine features. The distribution of deposits simplifies considerably when interpreted in terms of a piedmont glacier phase when expanded-foot valley glaciers formerly terminated in a sea that once stood about 350 feet higher, and which transgressed inland to that elevation as the glaciers receded up the troughs. Thus, the arcuate outlines of end moraines may be discerned looping around the mouths of escarpment valleys. The trend of the moraines contrasts with coastwise, narrow, linear rock ridges (Rc) which represent the upturned edges of resistant clastic rock units repeated by thrust faulting (Fig. 1). Near the escarpment, where they were constructed at the confluence of two adjacent ice

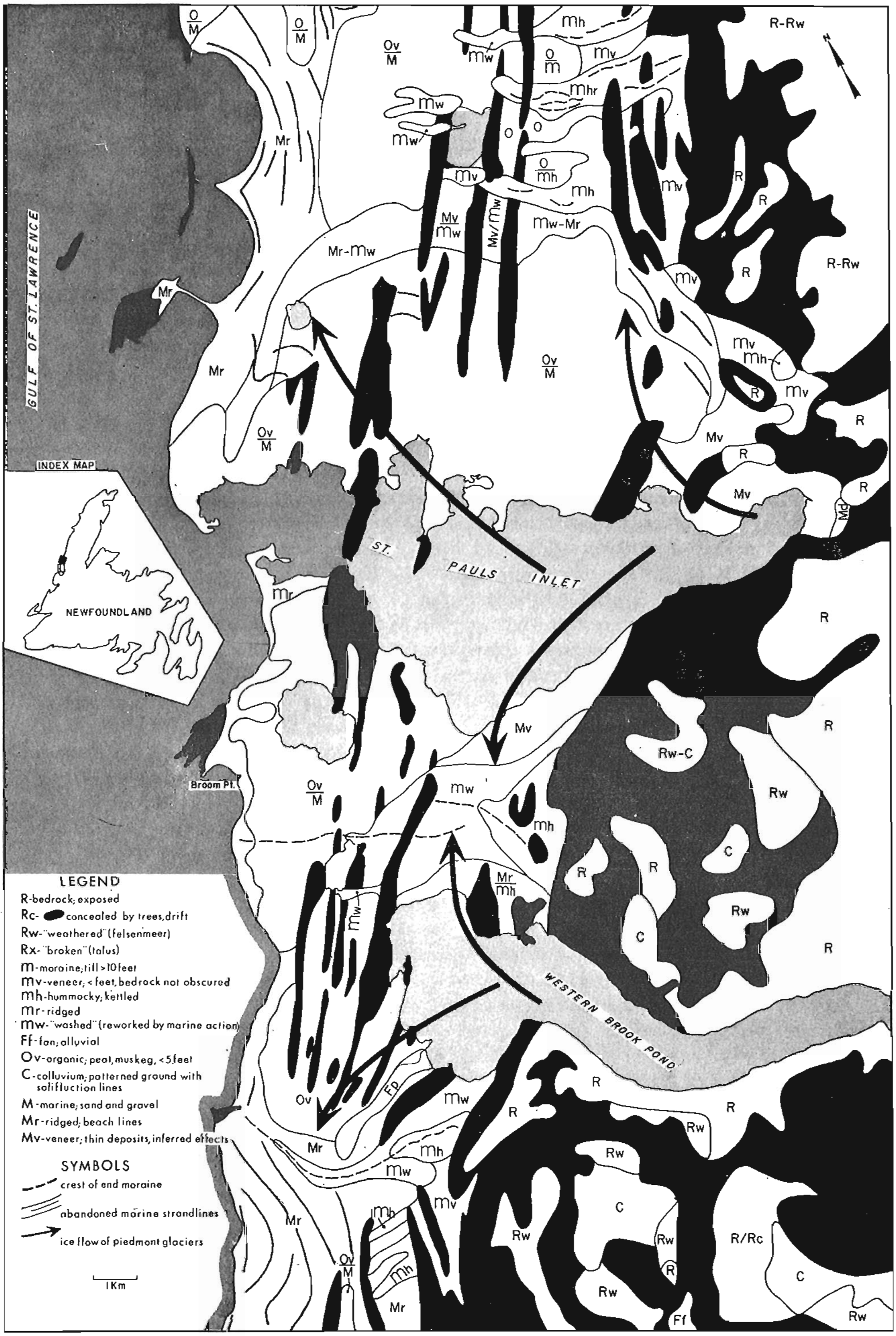

GULF OF ST. LAWRENCE
INDEX MAP
NEWFOUNDLAND
Broom Pt.
ST. PAULS INLET
WESTERN BROOK POND
LEGEND
R-bedrock; exposed
Rc- concealed by trees, drift
Rw-"weathered" (felsenmeer)
Rx-"broken" (talus)
m-moraine; till >10 feet
mv-veneer; < feet, bedrock not obscured
mh-hummocky; kettled
mr-ridged
mw-"washed" (reworked by marine action)
Ff-fan; alluvial
Ov-organic; peat, muskeg, <5 feet
C-colluvium; patterned ground with solifluction lines
M-marine; sand and gravel
Mr-ridged; beach lines
Mv-veneer; thin deposits, inferred effects
SYMBOLS
crest of end moraine
abandoned marine strandlines
ice flow of piedmont glaciers
1 Km

Figure 1.

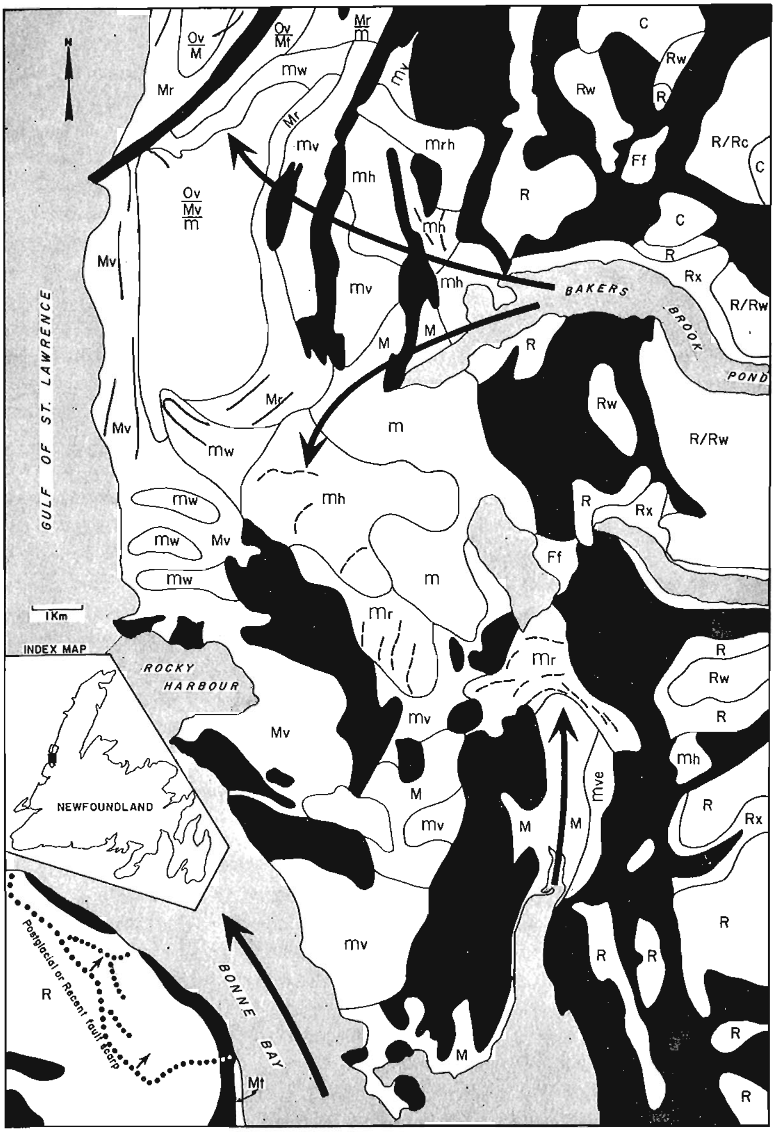

GULF OF ST. LAWRENCE
BAKERS BROOK POND
ROCKY HARBOUR
BONNE BAY
INDEX MAP
NEWFOUNDLAND
1Km
N
Postglacial or Recent fault scarp

Figure 2.

tongues, the moraines are hummocky (Mh), with chaotic conical mounds and depressions, and ridged (Mr) and are composed of very coarse till littered with gigantic erratic boulders. Below the level of former marine submergence, the moraines are reworked (Mw), have a boulder-lag pavement, are etched by shoreline terraces and ribbed with beach ridges. At lower elevations the moraines are buried beneath 20 to 50 feet of gravelly marine sand.

Extensive bogs blanket the former marine plain that was aggraded over the intervening areas between moraine and bedrock ridges. The peat, oddly enough, is generally only a few feet thick, as shown by exposures and the bouldery floors of bog lakes, but these extensive areas still present an obstacle and traffic-sensitive terrain, to access to the scenic features of the hinterland. The bogs, however, can be skirted by choosing routes along the intersecting rock and moraine ridges, which moreover offer several interesting possibilities for interpretation trails. One, for example, could lead from Martin Point, traverse a multitude of closely-spaced sandy beach ridges, follow the crest of a wave-washed end moraine, cross the prominent wave-incised marine limit at 300 feet, thence along the hummocky, kettled interlobate moraine littered with erratic blocks, and up over felsenmeer "prairies" to the 2,100-foot-high precipice overlooking the magnificent winding fiord of Western Brook Pond.

A blanket of marine sediment, generally thickening towards the coast, lies on the flanks of the moraine ridges and in intervening swales. It consists of an upper unit of 5 to 10 feet of plane-bedded sandy gravel, locally bouldery where representing a former sea-level stand, and a lower unit resting either on rock or basal till, best described as stony marine clay. It has a greasy, plastic texture and contains both intact and fragmented marine shells, and is interpreted as a submarine 'till' formed by the accumulation of debris dropped from floating ice and from the ice shelf that extended seaward from the piedmont glacier. This material is noted for its poor trafficability and susceptibility to failure. In wet years (e.g. 1972) numerous slumps, slides and earthflows occur along the coastal cliff between Green Point and St. Pauls. In many places the main highway will be shortlived.

Coastal erosion is aggravating the tendency toward bank failure. In fact, the shoreline is generally receding, except locally near river mouths and at minor cuspate forelands. The erosion is attributed to a relative rise of sea level probably resulting from subsidence of the earth's crust. Dating of marine shells in raised beaches just above the modern beach gives unexpectedly old ages (e.g. 8430 ± 150 yr. (GSC-1763) at elev. 13 feet; 8650 ± 140 yr. (GSC-1762) at elev. 24 feet; and 8300 ± 200 yr. (GSC-1768) at elev. 25 feet). These suggest there has been a reversal of the trend of postglacial crustal rebound that initially caused the shoreline to recede from its former high level.

A less obvious, but potentially more hazardous situation involves a large rock failure on the west side of Bonne Bay, opposite the town of Rocky Harbour, the largest community and proposed Park headquarters. Winding across the fractured igneous tableland (near "Lookout Hills"), and descending to the shores of Bonne Bay, is a conspicuous rock scarp more than 200 feet high, and several subsidiary scarps that slash the terrain, and displace the glacially rounded rock knobs. The main scarp also appears to truncate the postglacial marine terrace fringing Bonne Bay at about 200 feet. The area up to at least 2,000 feet (the total relief) is underlain by igneous rocks comprising a massive thrust sheet (klippe) that was transported on top of mainly carbonate sedimentary rocks, forming the floor of Bonne Bay. The interpretation of this feature, developed jointly with L.M. Cumming (pers. comm., 1972), is that following retreat of the ice tongue that oversteepened and overdeepened the walls and floor of Bonne Bay, and some time after the raised marine terrace was built, there was failure of the shoulder of Bonne Bay trough. This was due either to removal of the formerly supportive glacier, or by collapse of the underlying soluble strata, or by gravity slip of the fractured rock mass. Equilibrium may have been attained, but perhaps further movement will occur. The possible instability of this 2-cubic-mile rock mass warrants further study: (1) to define the fault plane at depth, (2) to determine the depth and composition of the underlying supposedly incompetent sedimentary rocks, and (3) to elucidate the nature and timing of the fault movement(s).

[1] Grant, D.R.: Late Pleistocene readvance of piedmont glaciers in western Newfoundland; Maritime Seds., v. 5, no. 6, p. 126-128 (1970).

[2] Grant, D.R.: Postglacial emergence of Northern Newfoundland; in Report of Activities, Part B: November 1971 to March 1972, Geol. Surv. Can., Paper 72-1, Pt. B, p. 100-102 (1972).

44. DATED PALEOSOL FROM BELOW MAZAMA (?) TEPHRA

Project 650027

J. E. Harrison,
Terrain Sciences Division, Ottawa

Figure 1 illustrates the stratigraphy in a pit 90 m north of Highway No. 1 and 1.6 km west of Calgary. The pit, on the southwest corner of the intersection of 83rd Ave. and Highway No. 1, reveals about 5 m of massive sands and silts containing a tephra bed, buried paleosol and bone fragments.

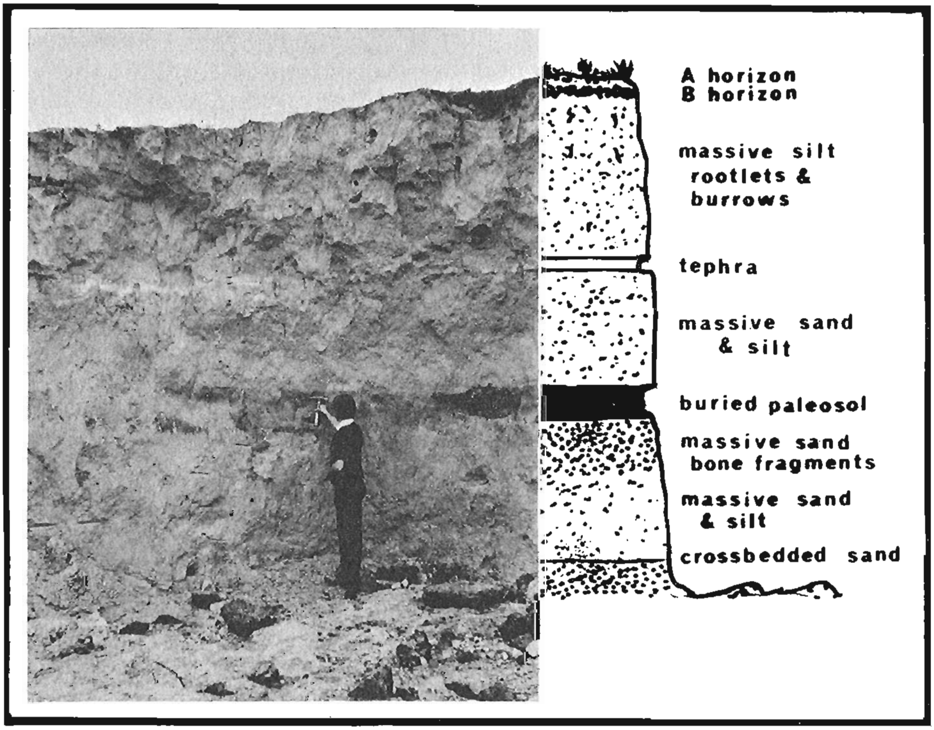


Figure 1. Borrow pit with buried paleosol and tephra bed. (Photo GSC- 202199F).

Overlying crossbedded sand at the base is 60 cm of massive silt grading into 20-30 cm of sand containing small mammal bone fragments. Above this unit and 2.6 m below the surface is a buried paleosol varying in thickness from 30-45 cm. The strongly developed soil horizon, sloping 5-10 degrees to the north (left of the picture) splits into two distinct bands downslope. Carbonized twig fragments 1-5 mm in diameter can be found throughout the horizon. These fragments were hand collected and gave a radiocarbon date of 8400 ± 150 years B.P. (GSC-1819). Separated from the paleosol by massive sand and silt is a continuous 5 cm thick band of tephra (volcanic ash). The ash, 1.5 m below the surface can be traced continuously across the exposure a distance of about 8 m.

The pit, located at an elevation of 1128 m (3700 ft.), is 61 m (200 ft.) above the river at the top outer edge of an eroded bench which may represent the maximum extent of valley fill during the existence of "Glacial Lake Calgary". The paleosol, the massive nature of the silt and the position of the deposit, suggest that the material in the section is mostly colluvium. On the other hand the unbroken regular layer of tephra indicates it was deposited in standing water, perhaps a now drained depression.

45. LANDSCAPE, AND LATE-GLACIAL HISTORY, HEAD OF VENDOM FIORD, ELLESMERE ISLAND

Projects 720081, 720082

D. A. Hodgson,
Terrain Sciences Division, Ottawa

The head of Vendom Fiord is one of several areas in which more detailed studies were conducted in the course of reconnaissance mapping of surficial materials in central Ellesmere Island[1]. The area lies on a possible pipeline route between Fosheim Peninsula and Makinson Inlet (Fig. 1), and is of particular interest as it contains large volumes of granular material of glaciofluvial and fluvial origin. However, if construction were to take place, seasonal discharge of meltwater from the adjacent ice cap could pose problems at river crossings.

A geomorphological map, with morphostratigraphic units grouped according to differences in the texture of surficial materials, has been compiled from field data and airphoto interpretation, and is presented together with a descriptive legend (Fig. 2). This classification is tentative, and will not necessarily be applied to other areas. The main valley at the head of the

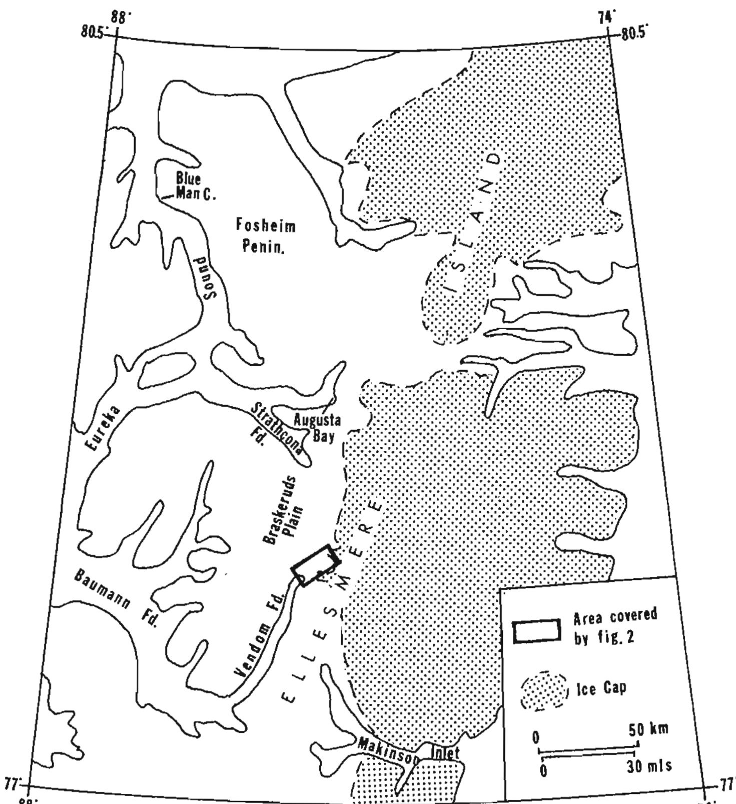


Figure 1. Location map.

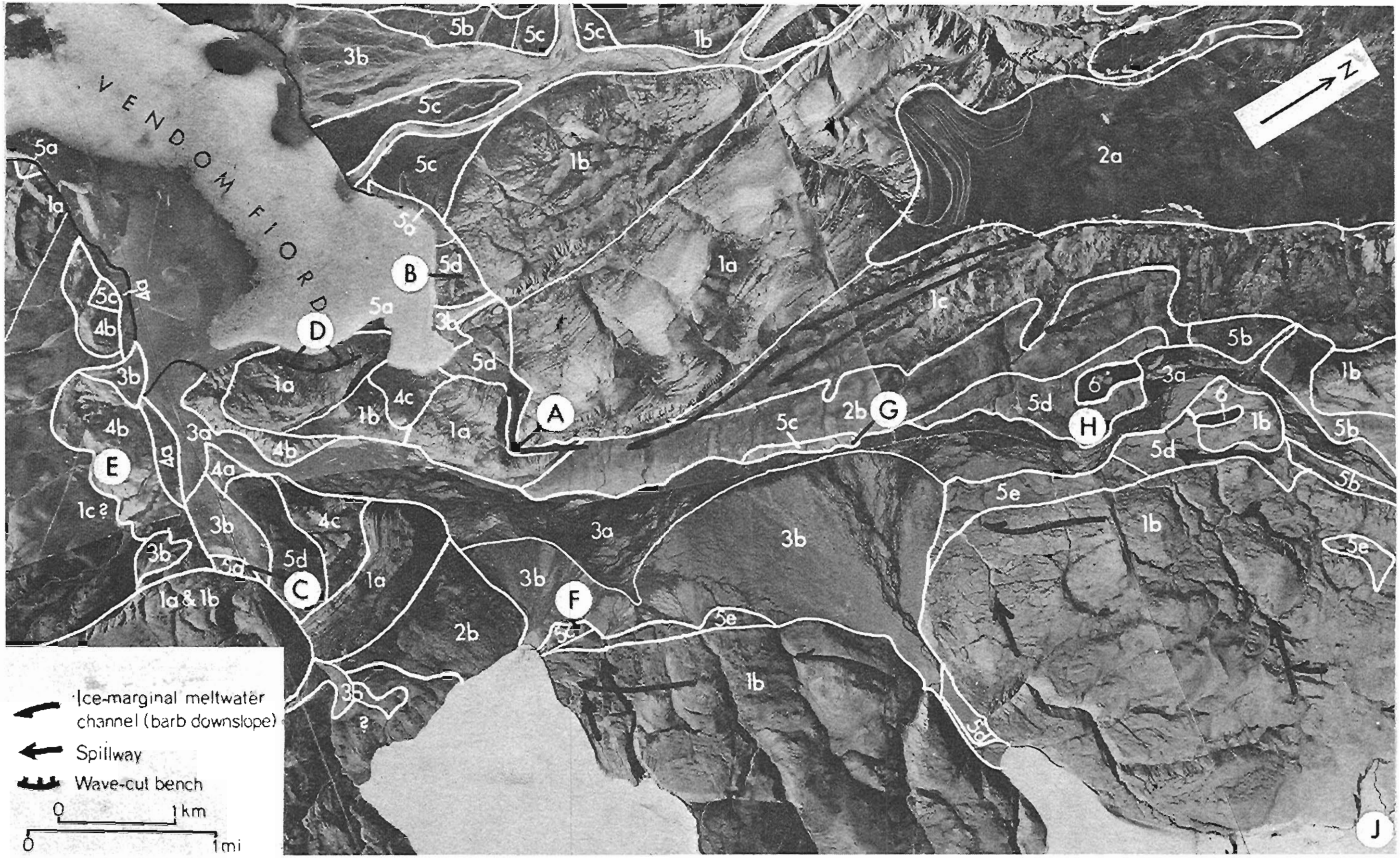


Figure 2. Photomosaic of the head of Vendom Fiord, showing geomorphological units (numbered, described on opposite page), and locations referred to in the text (lettered).

Descriptive Legend for Figure 2 - Geomorphological Units

1. Bedrock and rock rubble.

   1a Rugged hogsback ridges, mainly limestone and dolomite, some interbedded sandstone and shale. Surface is outcrop and rubble (felsenmeer, talus).

   1b Upland, less rugged than 1a, limestone, dolomite, sandstone, siltstone. Surface is outcrop and discontinuous veneer of gravel, some fines, possibly till.

   1c Valley slope cut in poorly lithified sandstone, shale, coal. Dissected by long, shallow-gradient ice marginal channels running parallel to valley axis. Surface is outcrop, rubble, some peat in depressions.

2. Glacial till and till veneer.

   2a Low relief plateau with little microrelief. Surface is sand loam with stones, and appears to be a till of undetermined age. Dark tone due to cover of mosses and dwarf shrubs. Light tone lines represent boulder-floored intermittent drainage channels. This is the southeast corner of Braskeruds Plain[4]. Maximum depth of frost table is 35 cm.

   2b Till and gravel plain and slopes. Fine sand to boulders over sandstone and siltstone. Granite erratics (from east and north) common. Large polygons, shallow troughs.

3. Active fluvial surfaces - mixed materials.

   3a Alluvial floodplain. One or two main channels up to 2 m deep, and an anastamosing network of channels. Mainly sand, silt, with minor gravel, boulders.

   3b Alluvial fans and deltas. Anastomosing channels, though generally only one sector of a fan or delta active at any one time. Boulder to sand size material, with silt and thin filling (50 cm) of peat and algae in minor channels and those not recently active.

4. Alluvial terraces - fine-grained surface material.

   4a Low terrace or estuarine flat. Silt, fine sand, shallow depressions with peat and algae.

   4b Massive deltaic sediments. Silt, fine sand. Steeper slopes gullied and subject to flowslides.

   4c Veneer (?) of marine silt with discontinuous gravel cover.

5. Alluvial and marine terraces - coarse-grained surface material.

   5a Flights of low beach ridges. Platy fragments and gravel. Possibly a veneer (1 m thick) over fine-grained littoral deposits. Shallow polygon trenches.

   5b Stratified sand terrace, 10 m thick.

   5c Terraces with veneer of coarse topset bed material (sand, gravel, up to 3 m thick) over fine-grained deltaic deposits. Ice lenses and wedges common in the fines, and polygon trenches up to 1 m deep in the surface material.

   5d Perched alluvial fans and terraces constructed almost entirely of sand to boulder size material deposited by glacial meltwater. Upper and most extensive surfaces of the fans are graded to a sea level ca. 70 m. Intermittent thin cover of silt and algae on top surfaces. Few polygonal cracks.

   5e Glaciofluvial (ice-contact) terraces, fans, kame terraces, of sand to boulder size material. Hummocks and ridges common, due probably to collapse and slumping of supraglacial outwash into the valley floor.

6. Kettles.

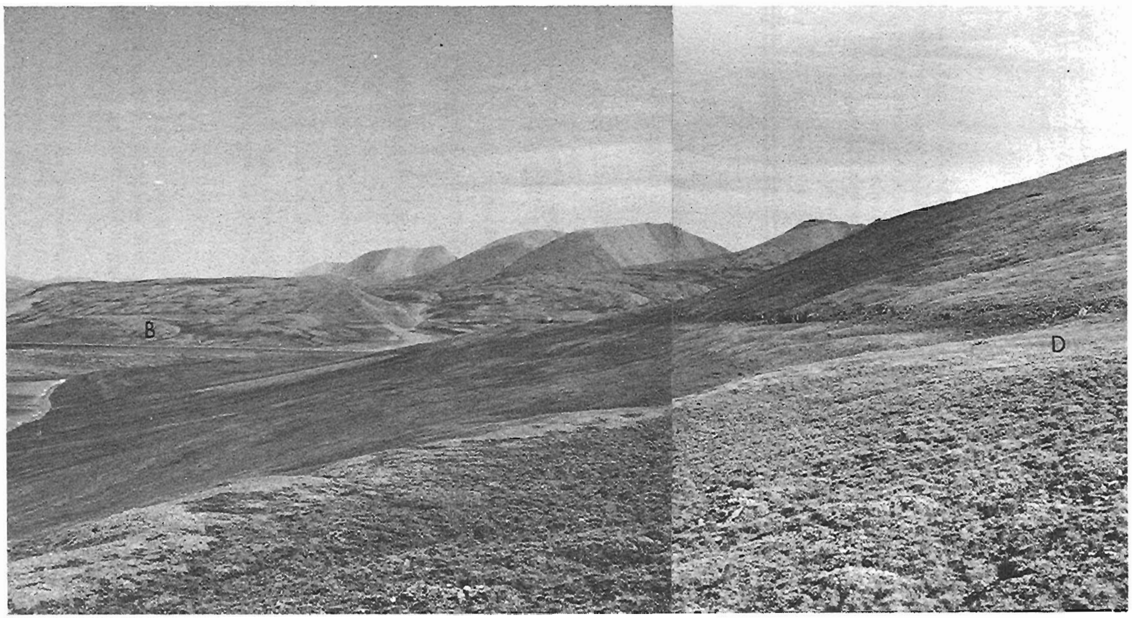


Figure 3. Wave-cut bench at 68 m elevation, head of Vendom Fiord (location D, see Fig. 2). View north, with perched delta B in the middle location.

fiord shows evidence of a late-Wisconsin age glacial stage believed to be comparable in age with the Cockburn Glacial Phase of Baffin Island.

Honda A.T.C.'s were used as transport in the field, and the assistance of R. Richardson during this period is acknowledged.

Landscape

The broad trough of Vendom Fiord narrows near the head and splits into two valleys. The easternmost valley, occupied by 'Bentham River' described by Norris[2], is the major tributary, and extends for 30 km until blocked by the margin of an ice cap. This valley is 6 km wide from plateau rim to rim, 300 m deep, and is partially filled by sediments, which provide a flat floor up to 2 km in width. Descriptions of bedrock lithology are provided by Norris, and by Thorsteinsson[3].

Surficial materials not directly derived from underlying bedrock are restricted to valley floors and lower slopes, and to the margins of the fiord with the exception of the Braskeruds Plain[4] (unit 2a, Fig. 2). This is essentially a till-covered plateau lying at an altitude of 300 m to 500 m. Deposits in the middle and upper reaches of the 'Bentham' valley are largely of sand size or coarser sediments, from the following sources: outwash from a late-Wisconsin age ice front retreating up the valley (units 5d, e and part of 2b); outwash from the present ice cap (unit 3b); and fluvial deposits forming the floodplain of the 'Bentham River', which are in turn mainly reworked outwash (unit 3a). In the lower valley, the floodplain is largely fine sand and silt, whereas exposures in terraces show fine-grained deltaic or marine bottom sediments appearing beneath one to three metres of coarse-grained topset or channel-bed deposits (unit 5c). At the junction of valley and fiord, most sediments are fine grained (largely silt), range in thickness from less than 1 m to over 40 m, and occur at elevations up to 65 m (units 4a, b, c). Gravel beach ridges are presently forming where coarse outwash material is available onshore, or where currents or wave action concentrate such material (unit 5a).

It is not anticipated that vehicle movement over units in categories 1 and 5 would cause more than superficial disturbance. Categories 2 and 3 might show damage (i.e. rutting and lowering of the seasonal frost table) where fine-grained materials are present. Units in category 4, most of which are fine grained, could pose problems in terms of trafficability and construction. There is a possibility of a short-term exceptionally high meltwater discharge rate being caused by unusually high temperatures or rainfall, or by a jökulhlaup should the ice damming any one of a number of proglacial lakes break. Location J, Figure 2, marks one such lake (with ice pans on the water surface).

Late-glacial history

Proglacial landforms

There is much evidence that glacial ice re-occupied the 'Bentham River' valley at some period following the break-up and/or retreat of the Innuitian Ice Sheet[5, 6] over west-central Ellesmere Island. Although there are no end moraines, marginal meltwater channels and perched outwash deltas indicate a standstill of an ice margin at the mouth of 'Bentham River'. Meltwater entered the spillway A (Fig. 2) at an elevation of 90 m and sediment was deposited downstream in an outwash fan, apex elevation 70 m, outer margin 62 m. The smaller perched delta B (see also Fig. 3), was graded to a 70 m sea level. The apex of delta C is at 77 m and the front of the upper (and most extensive) surface has an elevation of 66 m. A wave-cut bench, 1 km long and up to 15 m broad, location D (see also Fig. 3), has been cut into sandstone. The elevation of the base of the backwall is 68 m. No evidence of a sea level higher than 70 m was found at the head of the fiord, but no ground observations were made elsewhere in the fiord. Marine or estuarine silts at E did not exceed an elevation of 65 m. Within the valley, remnants of terraces were found at locations F (54 m elevation) and G (63 m), and an extensive ice-contact outwash surface at H has an upper level at 63 m.

Radiocarbon-dated samples

Material suitable for radiocarbon dating was found at a number of locations. Lenses and beds of marine shells were noted in fine-grained sediments; beds and lenses of woody material, including twigs, are common in delta topset beds; and driftwood logs were seen on beaches, though mainly at the modern storm-water line. Three samples had been radiocarbon-dated at the time of writing.

Marine pelecypod shells, including Hiatella arctica, Mya truncata, Yoldia sp., and a small unidentified gastropod, were collected at an altitude of 52 m in a terrace remnant F (Fig. 2), from fine sand and silt beds below 50 cm of pebbly delta topset beds and above silt and clay bottom-set beds. The Hiatella arctica, which included thin, paired valves, provided a date of 6980 ± 80 yrs. B.P. (GSC-1858). The date is a minimum for retreat of the valley ice lobe.

A single twig (Salix sp. 7) taken from organic material, altitude 65 m, in topset beds of delta C was dated at >30,000 yrs. B.P. (GSC-1832), and a driftwood log (Larix sp.) found on a flight of beach ridges near location B, at an altitude of 5 m, was dated at >36,000 yrs. (GSC-1789). The wood samples were probably transported from accumulations of wood, resembling those in the Beaufort Formation, found in central Ellesmere Island[1,8]. They indicate that caution should be exercised in sampling organic deposits in this region, particularly mixed peaty material.

Discussion

Ice-contact deltas graded to sea levels between 60 and 80 m higher than present, and well-defined lateral and terminal moraine ridges were noted elsewhere in central Ellesmere Island at distances up to 20 km from the western margins of the present ice caps. J.G. Fyles collected shells dated at 6370 ± 100 (GSC-118) from silt beneath a raised beach, altitude 37 m, on the distal side of one such terminal moraine at Augusta Bay[9], (see Fig. 1). Fyles has obtained radiocarbon ages for a number of samples collected farther to the west of this glacial stage, including the following: peat from the head of Strathcona Fiord, altitude 400 m, 7680 ± 150 (GSC-175)[9]; shells in Strathcona Fiord, altitude 75 m, 77 m, 7750 ± 160 (GSC-170)[9]; shells in outer

Baumann Fiord, altitude 117 m, 8480 ± 140 (GSC-244)[10]; and shells at Blue Man Cape, Eureka Sound, altitude 140 m, 8710 ± 140 (GSC-254)[10].

The age range between shells collected near the present ice caps (though on the distal side of the glacial stage being discussed) and those collected over 100 km farther west is only 1000 ^{14}C years, although the marine limit rises from ca. 70 to 160 m in this distance. Blake[5] has concluded that western Ellesmere Island was covered by part of the Innuitian Ice Sheet, which had an axis running northeast through Eureka Sound, and that rapid break-up of glacial ice in the inter-island channels and the fiords led to complete decay of the ice filling the channels by 8000 ^{14}C years ago. Isostatic rebound has been greatest where the ice was thickest.

It is suggested here that the Vendom Fiord stage, and those moraines and glaciofluvial features to the north, represent an advance of ice from a remnant of the Innuitian Ice Sheet, which by that time had become an independent ice cap in eastern Ellesmere Island. This event followed the general deglaciation of west-central Ellesmere (i.e. before 8000 B.P.?) but occured prior to deposition of the shells dated at 6980 ± 80 years (GSC-1858). The advance and retreat are thus comparable in age with the Cockburn Glacial Phase of Baffin Island[11].

Portions of the margin of the ice cap east of Vendom Fiord have subsequently re-advanced, though following a different pattern from that of the earlier advance. A glacier now approaches to within 500 m of terrace remnant F (Fig. 2), overrunning meltwater channels cut at the time that ice occupied the lower 'Bentham River' valley. In the period since air photographs were taken in 1959, the snout of this glacier has retreated up to 10 m, and one meltwater channel has been abandoned.

[1]Hodgson, D.A.: Surficial geology and geomorphology of central Ellesmere Island; in Report of Activities, Part A, April to October, 1972; Geol. Surv. Can., Paper 73-1, Pt. A, p. 203 (1972).

[2]Norris, A.W.: Upper Vendom Fiord; in Geology of the north-central part of the Arctic Archipelago, Northwest Territories (Operation Franklin), Y.O. Fortier et al.; Geol. Surv. Can., Mem. 320, p. 338-354 (1963).

[3]Thorsteinsson, R.: Geology, Strathcona Fiord, District of Franklin; Geol. Surv. Can., Map 1307A (1972).

[4]Holtedahl, O.: Summary of geological results; in Report of the Norwegian Expedition in the Fram; Vidensk-Selsk. I Kristiana, v. 4, no. 36, 27 p. (1917).

[5]Blake, W., Jr.: Studies of glacial history in Arctic Canada. 1. Pumice, radiocarbon dates, and differential uplift in the eastern Queen Elizabeth Islands; Can. J. Earth Sci., v. 7, p. 634-664 (1970).

[6]Blake, W., Jr.: Climatic implications of radiocarbon-dated driftwood in the Queen Elizabeth Islands, Arctic Canada; in Climatic changes in Arctic areas during the last ten-thousand years, eds. Y. Vasari, H. Hyvärinen, and S. Hicks; Proc. Symp. at Oulanka and Kevo, Finland, October 1971; Acta Univ. Ouluensis, Ser. A, Sci. Rerum Nat., no. 3, Geol. no. 1, p. 77-104 (1972).

[7]Wood identified by R.J. Mott, Pleistocene Palynology Laboratory.

[8]Craig, B.G., and Fyles, J.G.: Quaternary of Arctic Canada; in Antropogenovye period v Arktike i Subarkitiki; Naucho-Issl. Inst. Geol. Arktiki Trudy, 143, p. 5-33 (1965) (in Russian with English summary).

[9]Dyck, W., and Fyles, J.G.: Geological Survey of Canada radiocarbon dates III; Radiocarbon, v. 6, p. 167-181 (1964).

[10]Dyck, W., Fyles, J.G., and Blake, W., Jr.: Geological Survey of Canada radiocarbon dates IV; Radiocarbon, v. 7, p. 24-46 (1965).

[11]Falconer, G., Ives, J.D., Løken, O.H., and Andrews, J.T.: Major end moraines in eastern and central Arctic Canada; Geograph. Bull., v. 7, no. 2, p. 137-153 (1965).

QUATERNARY GEOLOGY: PALEONTOLOGY AND GEOCHRONOLOGY

46. RADIOCARBON DATES FROM EASTERN MELVILLE ISLAND

Project 710041

D.M. Barnett

Terrain Sciences Division, Ottawa

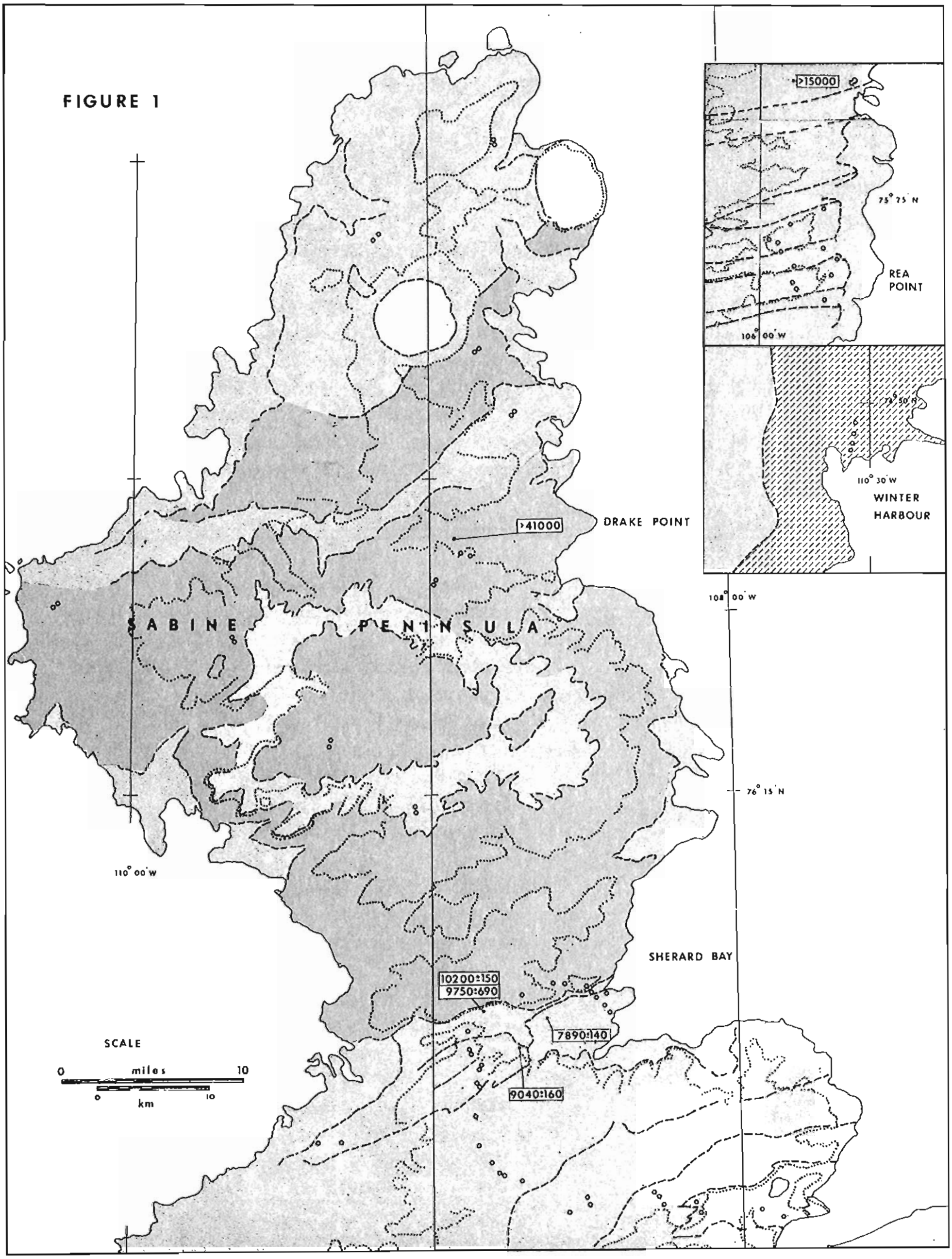
This report deals in a preliminary way with six radiocarbon dates processed in connection with this project[1,2]. The dates are listed in Table 1, and the locations of the samples are shown in Figure 1.

The two dates which are not finite may be discussed together. The >15,000 B.P. date (GSC-1835) is an indication of smallness of sample (one piece of wood, weighing 1.8 g) rather than of 'youthfulness' as compared to GSC-1609, >41,000 years, also obtained on a single piece of wood (11.5 g).

TABLE I

Location	Sample elevation (m)	Dated material	Laboratory dating no.	Date
Drake Point	69	Driftwood fragment (*Larix* sp.)	GSC-1609	>41,000
North-northwest of Rea Point	32	Driftwood fragment (*Pinus* sp.)	GSC-1835	>15,000
Sherard Valley	50	Shells (*Hiatella arctica*)	GSC-1752	10,200 ± 150
Sherard Valley	50	Shell (1) (*Hiatella arctica*)	GSC-1636	9,750 ± 690
Sherard Valley	52	Moss peat (mainly *Calliergon sarmentosum*)	GSC-1708	9,040 ± 160
Sherard Valley	24	Driftwood log (*Picea* sp.)	GSC-1624	7,890 ± 140

Wood species determined by R.J. Mott and L.D. Wilson; moss species determined by M. Kuc.



LEGEND

------ Approximate formation boundaries (in part after Tozer & Thorsteinsson 1964)

.... Approximate limit of postglacial marine transgression

o Core sites

DOMINANT LITHOLOGY

Shale

Sand, sandstone

Till, till veneer

>15000 Radiocarbon Date

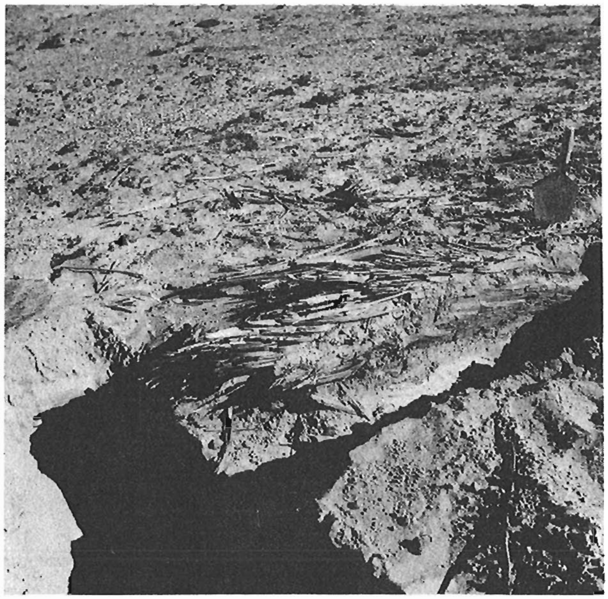


Figure 2: Driftwood log (Picea) dated at 7,890 ± 140 showing splitting of upper part and more solid wood exposed by digging in deltaic sands.

If a larger piece of wood had been available for GSC-1835, a value similar to that obtained for GSC-1609 might well have resulted. A possible source for these 'old' pieces of wood is the Beaufort Formation. The samples at both localities were composed of several fragments which may have been moved and redeposited during higher postglacial sea levels. Their significance lies in demonstrating the presence of wood of more than one age range at different levels.

Samples GSC-1636 and -1752 are from the same sample of *Hiatella arctica* shells collected near the postglacial marine limit. The first to be dated was a single valve, to assess whether the larger sample, GSC-1752, might contain shells of more than one age. Good agreement is apparent, and so one can be confident that the oldest postglacial marine deposits were laid down close to 10,000 years B.P., at which time Sabine Peninsula was separated from the rest of Melville Island (Fig. 1).

Submergence was short-lived at this elevation, as moss peat dated at 9040 ± 160 years (GSC-1708) was collected from virtually the same elevation 5 km to the southeast. The stratigraphic sequence below 40 cm of peat (dated sample near base) was: 7 m deltaic sand with detrital plant material, 5 m of brown silty sand, and at the base, 2 m of fossiliferous marine silty clay.

The highest driftwood from the Sherard Valley was found at 24 m and dated at 7890 ± 140 years (GSC-1624). This log, which was 160 cm long and 35 cm maximum diameter, was partially buried in deltaic sands. The exposed part had dried out and split whereas the lower part, resting in coarse sand, had remained more intact, indicating that it had lain at this location for a considerable period of time (Fig. 2). This is the highest dated postglacial log (as opposed to fragments) discovered on Melville Island thus far.

[1]Barnett, D.M.: Surficial geology and geomorphology of Melville Island, District of Franklin; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, Pt. A, p. 152-153 (1972).

[2]Barnett, D.M.; and Forbes, D.L.: Surficial geology and geomorphology of Melville Island; in Report of Activities, Part A, April to October, 1972; Geol. Surv. Can., Paper 73-1, Pt. A, p. 189-192 (1973).

47. AGE OF PUMICE ON RAISED BEACHES, EASTERN ARCTIC CANADA

Project 680065

W. Blake, Jr.

Terrain Sciences Division, Ottawa

As noted in an earlier report on this project[1], during the 1970 field season new collections of pumice were made at several sites around western Jones Sound, on both Ellesmere and Devon Islands. In each locality samples of driftwood were collected in close proximity to the pumice, and six of these pieces of wood have now been dated. In addition, another sample of charred fat (seal?) collected in 1967 by A.A. Dekin, Jr. at a Pre-Dorset archeological site (KdDq-11-8) on Cape Tanfield, southern Baffin Island, has been dated also[2]. The pertinent data, including some age determinations reported earlier, are summarized in Table 1.

These dates confirm the validity of the suggestion made previously[3,4] that the pumice is of the order of 5000 years old (conventional radiocarbon years). Samples of wood collected more than 0.5 m below the level of the pumice are without exception clearly less than 5000 years old and samples collected above the level of the pumice are in all cases more than 5000 years old.

[1]Blake, W. Jr.: Pumice on raised beaches, eastern Arctic Canada; in Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, p. 182 (1971).

[2]Lowdon, J.A., Wilmeth, R., and Blake, W. Jr.: Geological Survey of Canada radiocarbon dates XII; Geol. Surv. Can., Paper 72-7, 26 p. (1972).

[3]Blake, W. Jr.: Studies of glacial history in Arctic Canada. I. Pumice, radiocarbon dates, and differential postglacial uplift in the eastern Queen Elizabeth Islands; Can. J. Earth Sci., v. 7, p. 634-664 (1970).

[4]Blake, W. Jr.: Climatic implications of radiocarbon-dated driftwood in the Queen Elizabeth Islands, Arctic Canada; in Climatic changes in Arctic areas during the last ten-thousand years (Y. Vasari, H. Hyvärinen, and S. Hicks, eds.); Proc. of a symposium held in Oulanka and Kevo, Finland, October 1971; Acta Univ. Ouluensis, Ser. A, Scientiae Rerum Naturalium no. 3, Geologica no. 1, p. 77-104 (1972).

[5]Willis, E.M., Tauber, H., and Münnich, K.O.: Variations in the atmospheric radiocarbon concentration over the past 1300 years; Am. J. Sci., Radiocarbon Supplement, v. 2, p. 1-4 (1960).

[6]Dyck, W.: Secular variations in the C^{14} concentration of Douglas fir tree rings. Proc. Sixth International Conf. Radiocarbon and Tritium Dating, Pullman, Washington, 1965. U.S. Atomic Energy Commission, Conf.-650652, 784 p. (1965).

[7]Olsson, I. U.: Explanation of Plate IV; in Radiocarbon variations and absolute chronology (I. U. Olsson, ed.); Proc. 12th Nobel Symposium, Uppsala, Sweden, 1969. Wiley Interscience Div.: New York, London, Sydney; Almqvist and Wiksell: Stockholm, 657 p. (1970).

TABLE I

Radiocarbon dates on materials with pumic, eastern Arctic Canada

Approx. Sample elev. (m)	Type of material*	Field sample no.	Laboratory dating no.	Corrected age (conventional ^{14}C years before 1950)**
SOUTH CAPE FIORD, ELLESMERE ISLAND; 76°26'N., 85°00'W.				
17.5	Several pieces of pumice			
17.0	driftwood (*Picea* sp.)	114-68	GSC-1047	4710 ± 60
CAPE STORM, ELLESMERE ISLAND; 76°22.5-24'N., 87°30-32'W.				
23.0	driftwood (*Picea* or *Larix*)	70-60	GSC-1714	5180 ± 60
22.5	driftwood (*Picea* or *Larix*)	55-67	GSC- 826	5100 ± 50
22.0 to 22.5	Abundant pumice			
22.0	driftwood (*Picea* or *Larix*)	70-59	GSC-1410	5040 ± 60
21.5	driftwood (*Picea* or *Larix*)	70-97	GSC-1512	4770 ± 60
19.0	driftwood	70-269	GSC-1537	4540 ± 60
CAPE VERA, DEVON ISLAND; 76°13.5'N., 89°58'W.				
25.5	Single cobble of pumice			
25.0	driftwood (*Picea* sp.)	70-246	GSC-1704	5020 ± 80
BOAT POINT, DEVON ISLAND; 75°58.5'N., 89°58'W.				
26.5	driftwood (*Picea* sp.)	173-67	GSC-1072	5250 ± 60
26.0	Single cobble of pumice			
24.0	driftwood (*Picea* sp.)	70-250	GSC-1606	4500 ± 60
CAPE TANFIELD, BAFFIN ISLAND; 62°39'N., 69°39'W.				
14.0	Several pieces of pumice			
14.0	charred fat (seal?)	67-11, 8-1	GSC-1382	4690 ± 360

* Identification of driftwood samples by R. J. Mott and L. D. Wilson.

** Recalculated dates omitting that part of the error term previously applied[5,6] to account for the average variation of ±1.5% in the ^{14}C concentration of the atmosphere over the past 1100 years. Recent research[7] has shown that the variations over the past 7500 years have been as much as 15%.

48. PLANT MACROFOSSILS IN TERTIARY COAL AND AMBER FROM NORTHERN LAKE HAZEN, ELLESMERE ISLAND, N.W.T.

Project 690044

M. Kuc

Terrain Sciences Division, Ottawa

Several hundred amber nodules (max. 2 cm long and 1.5 cm wide) collected on beaches at the northeast corner of Lake Hazen (approx. 81°55'N. and 69°30'W.) by D.R. Oliver[1], and coal with amber grains extracted by G. Hattersley-Smith from beds exposed on the northern side of Lake Hazen between Abbé River and Gilman River (81°50' to 55'N. and 69°25' to 71°00'W) were macerated by organic reagents. Detailed examination of fossil remains yielded the following taxa: coniferous wood (the dominant component of macerated coal), non-coniferous wood (both constitute the lignitic part of coal); and mosses, occurring in amorphic coal masses between lignitic layers and around amber. Mosses are represented by Calliergon sp., most similar to the extinct species C. aftonianum Steere[2], Drepanocladus sp. cf. exannulatus (B.S.G.) Warnst., Sphagnum sp., and one nearly entire specimen of Bryidae (cf. Grimmiales). These remains occur also on the surfaces of amber nodules but are absent in their interiors, which do not contain even pollen, known to be abundant in the coal; i.e., Abietineaepollenites, Pinus, Alnus, Carya, Pterocarya, Castanea and others, as reported by McGregor[3]. The lack of microfossils in the interiors of the nodules can be explained by their relatively quick deposition in peat.

The mosses extracted are representatives of the Holarctic moss flora. They indicate the presence of this flora in the northern parts of the Canadian Arctic Archipelago in early Tertiary times[3, 4], and indicate the presence of extensive forested areas (Pinus – Carya forests) producing organic deposits up to 1 m thick. Calliergon, Drepanocladus and Sphagnum are peat-formers that also indicate the presence of bogs associated with forests.

[1]McAlpine, J.F., and Martin, J.E.H.: Canadian amber; The Beaver, Outfit 300, Summer 1969, p. 28-37 (1969).

[2]Kuc, M.: Calliergon aftonianum Steere in late Tertiary and Pleistocene deposits of Canada; Geol. Surv. Can., Paper (in press).

[3]Christie, R.L.: Geological reconnaissance of northeastern Ellesmere Island, District of Franklin; (120, 340, parts of) Geol. Surv. Can., Mem. 331, 79 p. (1964)

[4]Christie, R.L.: Northeastern Ellesmere Island, District of Franklin; Geol. Surv. Can., Paper 62-10, 15 p. (1962).

49. RADIOCARBON DATES FROM NORTHERN MANITOBA

Project 690064

R. J. Mott

Terrain Sciences Division, Ottawa

Radiocarbon dates on basal organic sediments from three lakes in northern Manitoba were obtained to aid in palynological and geochronological studies of the area being mapped by R. W. Klassen (Project 710092). The dates are listed below and are shown on Figure 1 along with the major morainic features, the area formerly covered by glacial lakes and the extent of marine incursion (Tyrrell Sea) derived from the Glacial Map of Canada[1].

Site 1. GSC-1825 – 8080 ± 150

Site 2. GSC-1818 – 6920 ± 150

Site 3. GSC-1782 – 5430 ± 210

Site 1 (Fig. 1) is a small unnamed lake occupying a bedrock basin located about 7 miles (11 km) east-southeast of Flin Flon, Manitoba (54°44.5'N., 101°40.8'W). The surface elevation of the lake is slightly above 1000 feet (305 m) with a maximum water depth of 27 feet (8 m). Algal gyttja and laminated gyttja which gradually became more clayey with depth were encountered to 376 cm below the mud/water interface. The laminated gyttja overlies laminated clay with minor organic content to a depth of about 500 cm and in turn overlies light grey clay. The radiocarbon date of 8080 ± 150 years (GSC-1825) is on laminated gyttja from the interval 371 to 376 cm, which is the deepest sediment containing enough organic matter to produce a date. Since the lake is probably above the maximum limit of Glacial Lake Agassiz in this area the date is a minimum for deglaciation. However, Prest[2] speculates that the ice stood at this point about 10,500 years B.P. This makes a date of 8230 to 7930 years much younger than would be expected for deglaciation, and inundation by a glacial lake phase should not be ruled out until more detailed work on lake limits is done.

The second lake (Site 2, Fig. 1) is located about 40 miles (64 km) north of Thompson, Manitoba (56°18.7'N., 97°57.5'W.) on a long morainic ridge. The ridge is covered by numerous kettle lakes of varying size and depth of water as well as beach ridges which mark levels of the former glacial lake. The sampling site was a small lake at an elevation of slightly less than 1,000 feet (305 m) with a maximum water depth of 22 feet (7 m). The sediment core showed algal gyttja to a depth of 172 cm below the mud/water interface where it was in sharp contact with grey sand. The sand at the contact was somewhat organic and contained a twig of Larix sp. and small fragments of Salix sp. and Picea sp. or Larix sp. wood. This organic debris from the 172 to 175 cm interval was used to produce the date of 6920 ± 150 years (GSC-1818). The date places an age on the beginning of organic accumulation in the kettle hole and is only a minimum for deglaciation and draining of the local phase of Glacial Lake Agassiz.

A second small, unnamed kettle lake (Site 3, Fig. 1) on the same morainic ridge but about 51 miles (82 km) north of Thompson (56°28.6'N., 97°44'W.) was also cored. Elevation of the surface is just greater than

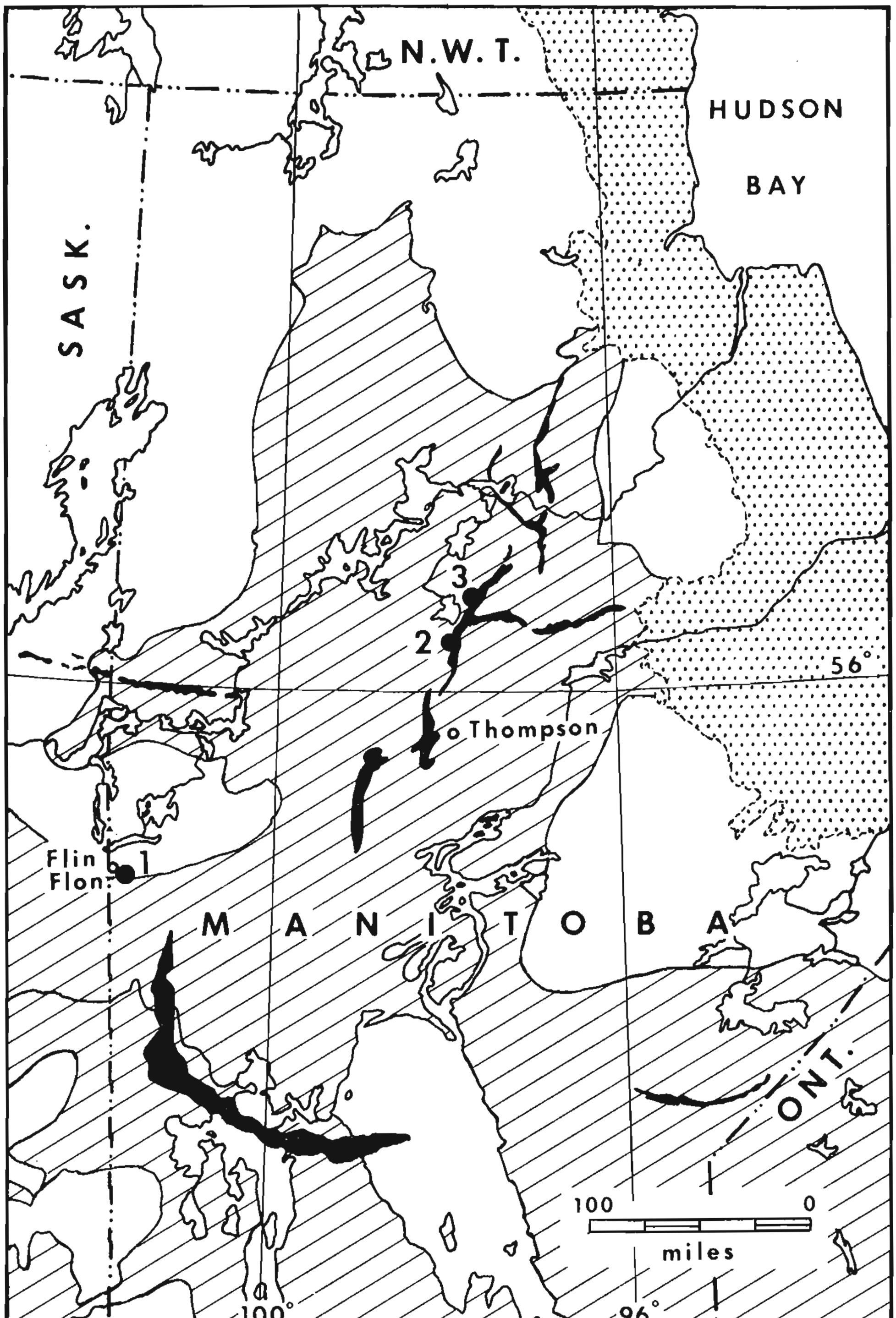


Figure 1. Map of northern Manitoba showing sampling sites (1), morainic ridges (solid black), area covered by glacial lakes (lined pattern) and area covered by marine incursion (Tyrrell Sea)(dotted pattern).

1, 000 feet (305 m), and the maximum water depth is 21 feet (6.4 m). The sediment profile has laminated buff and brown gyttja 270 cm thick overlying a layer of aquatic mosses which extends to a depth of at least 428 cm below the mud/water interface. Near the top of the moss layer the moss fragments are mixed with gyttja, but at the base the material is almost pure moss remains. This fibrous mat of remains was too tough to be penetrated completely with the sampling tube and, therefore, the total depth to which the organic remains extend and the character of the underlying sediment are not known. A radiocarbon date of 5430 ± 210 years (GSC-1782) was obtained on the moss remains from the interval 423 to 428 cm.

The mosses were identified by M. Kuc (unpublished Bryological Report No. 200, Sept. 1972) as the submerged aquatic form of Drepanocladus exannulatus and Calliergon trifarium, an aquatic species. The depth at which these mosses normally grow is much less than the depth below the present lake surface (11 m) from which they were recovered. This indicates the lake was shallower at the time of deposition, probably due to a lower water table. The date is much too young for time of deglaciation[2] or emergence from a glacial lake and simply provides an age for the 5-cm-thick sediment increment.

[1] Prest, V.K., Grant, D.R., and Rampton, V.N.: Glacial Map of Canada; Geol. Surv. Can., Map 1253A (1967).

[2] Prest, V.K.: Retreat of Wisconsin and recent ice in North America (speculative ice-marginal positions during recession of last ice-sheet complex); Geol. Surv. Can., Map 1257A (1969).

50. PRELIMINARY PALEOMAGNETIC STUDIES OF FRESHWATER LAKE SEDIMENT CORES OF LATE PLEISTOCENE AGE

Project 690064

R.J. Mott* and J.H. Foster**

Paleomagnetic stratigraphy of the Pleistocene, derived mainly from studies of terrestrial lavas and deep-sea sediment cores, is well known[1]. The Brunhes normal epoch, the magnetic epoch which began about 690,000 years ago, was thought to be characterized by normal polarity throughout until the discovery of the Blake and Laschamp events or magnetic excursions as Opdyke[1] prefers they be called. The upper and lower boundaries of the former were placed at 108,000 and 114,000 years ago, respectively, by Smith and Foster[2], whereas the age of the latter is still not well defined but estimated by Bonhommet and Zahringer[3] to be between 8,000 and 20,000 years ago. However, these limits and especially the younger limits have not been substantiated by further work. Mörner et al.[4] reported reversed polarity in the lowermost marine clay unit of a core from southwestern Sweden which they correlate with Agard Interstadial time, the upper limit of which has been dated elsewhere at 12,400 years B.P. The lower end of the reversal could not be delineated. Mörner et al. speculated that the reversal might be the upper part of the more or less undated Laschamp event.

Because a discernable paleomagnetic event in the 12,000 to 13,000 year range would be a useful stratigraphic marker in the study of Late-Pleistocene history, the basal parts of several lake sediment cores from eastern Canada were analyzed. The cores were originally collected for palynological rather than paleomagnetic studies and, therefore, they were not oriented to any azimuth. In fact, the half metre segments into which the cores were cut for storage were not oriented relative to each other. However, the detection of a magnetic reversal does not require an oriented core as inclination is not dependent on orientation.

Measurements of the natural remnant magnetization, after partial demagnetization in a 100 oersted alternating magnetic field, were made on a spinner magnetometer. Core increments 2.4 cm long pared down to fit the sample holder were used. Intensities varied from 10^{-4} gauss for the mineral sediments to 10^{-7} gauss for the highly organic units.

The results obtained from three cores in widely separated areas serve to illustrate the character of the magnetic profiles and the possibilities for further work.

The stratigraphy and three radiocarbon dates for the basal part of a core from Basswood Road Lake in southwestern New Brunswick (45°15.2'N, 67°20'W) are shown in Figure 1. Sediment composition is highly variable, ranging from a completely organic lake sediment (gyttja) to an inorganic clay which was possibly deposited in a glacial lake. The plot of the magnetic inclination shows a fairly steady angle of between 40 and 70 degrees for most of the core until the basal clay is reached. Then three samples show negative inclinations with one almost completely reversed. Below this the values are positive but fluctuate widely between about 10 and 70 degrees. The age of this possible excursion is older than 12,600 years B.P. but no more than a few hundred years older since the basal clay was probably laid down over a relatively short period of time. If this excursion is real it may correspond

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**Regional and Economic Geology Division, Ottawa

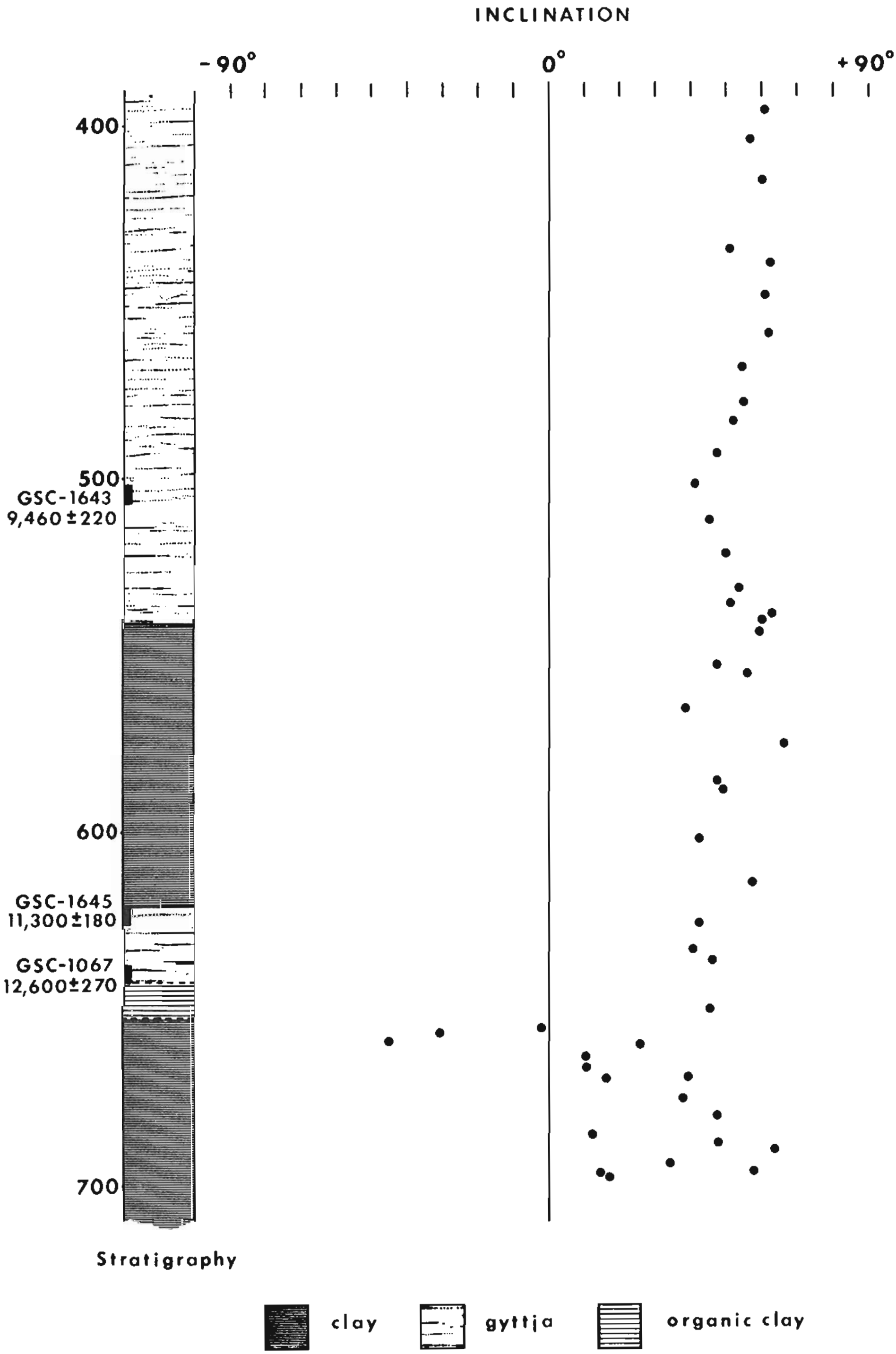


Figure 1. Stratigraphy, radiocarbon dates and paleomagnetic inclination of the basal part of a sediment core from Basswood Road Lake, New Brunswick.

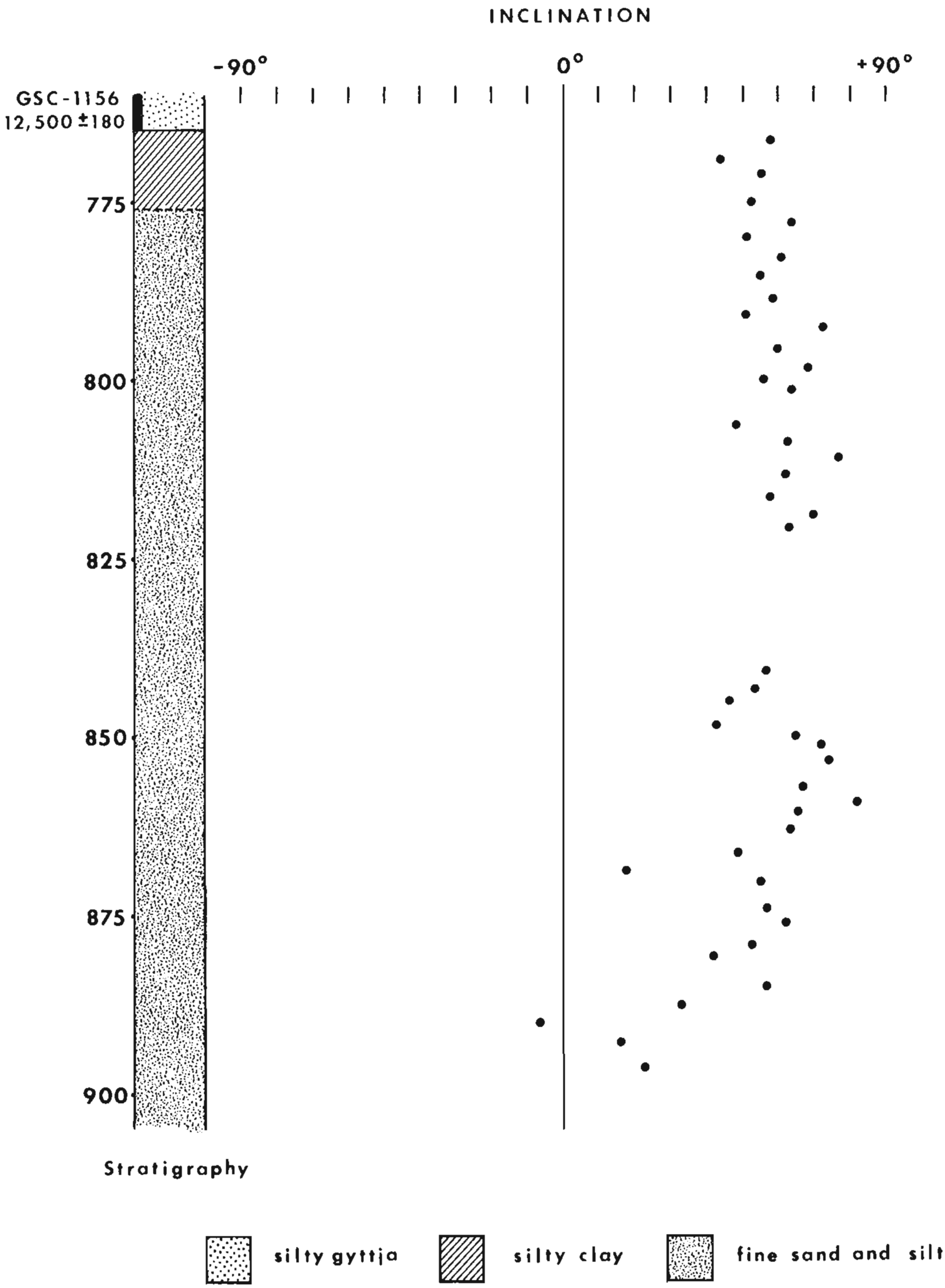


Figure 2. Stratigraphy, radiocarbon date and paleomagnetic inclination of the basal part of a sediment core from 'Maple Hurst' Lake, Ontario.

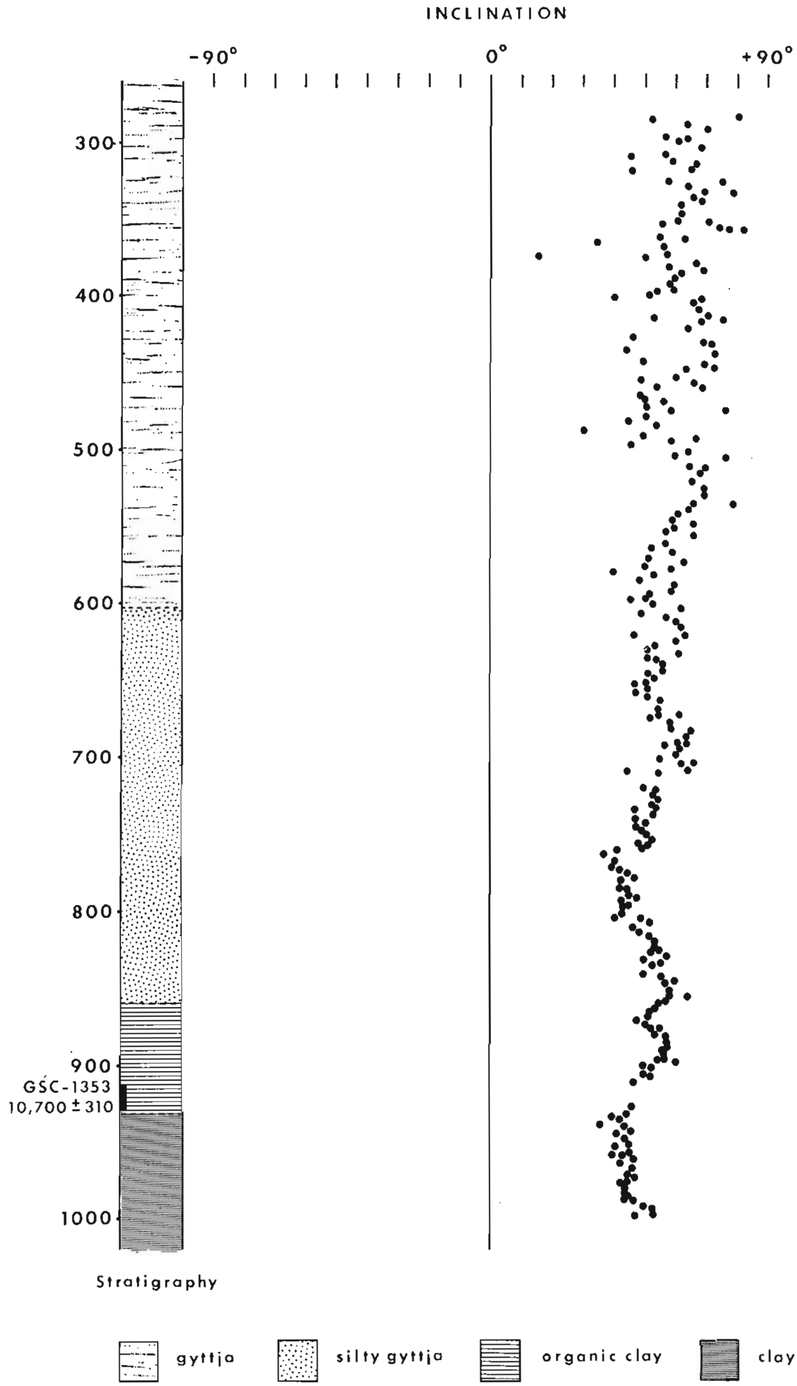


Figure 3. Stratigraphy, radiocarbon date and paleomagnetic inclination of a sediment core from Lac aux Araignées, Quebec.

to the reversal reported by Mörner _et al._[4], however, because of the brief character of the event more work on oriented cores is required for it to be properly delineated.

The second example is from a lake site in southern Ontario. 'Maple Hurst' Lake (43°15.5'N, 80°39.5'W) is a small kettle lake with a sedimentary sequence of organic sediment (gyttja) overlying silty gyttja, silty clay and fine sand and silt. The paleomagnetism was measured on the more mineral sediment at the base below the radiocarbon dated interval as shown in Figure 2. Here again the magnetic inclination is fairly stable in the upper part of the profile, fluctuating between 40 and 80 degrees. Near the base the fluctuations are greater and the angle of inclination decreases but only one sample interval showed a slightly negative result. The fine sand and silt was probably deposited over a very short period of time which means that although the negative excursion, if real, was small, it occurred at about the same time as in the previous example. Results from both lakes, especially 'Maple Hurst' Lake, are too weak to warrant any far-reaching conclusions at this time.

The third example included is a much longer profile obtained on a core from Lac aux Araignées, a lake in southeastern Quebec (45°28'N, 70°45'W). This lake is large and the sediment has a greater mineral content than the sediment of smaller lakes. The organic content of the clay increases very gradually from the base upward until the sediment becomes a highly organic gyttja in the top third of the sequence. Because of the higher mineral content of the sediment the magnetic intensity is strong until the organic unit is reached. Then the intensity gradually decreases and magnetic properties fluctuate more widely. Although no reversals or excursions were encountered because of the young age of 10,700 ±310 (GSC-1353) this example illustrates that correlations between profiles may be possible using the characteristics of the magnetic profile.

More work on delineating magnetic reversals or excursions and characterizing magnetic profiles of freshwater lake cores is required before it can become a useful stratigraphic tool but the preliminary results obtained show promise. Other aspects to be examined are the correlation of pollen and magnetic profiles and the relationship between intensity and climate.

[1] Opdyke, Neil D.: Paleomagnetism of deep-sea cores; Rev. Geophys. Space Phys., v. 10, p. 213-249 (1972).

[2] Smith, J.D., and Foster, J.H.: Geomagnetic reversal in Brunhes normal polarity epoch; Science, v. 163, p. 565-567 (1969).

[3] Bonhommet, N., and Zahringer, J.: Paleomagnetism and potassium argon age determinations of the Laschamp geomagnetic polarity event; Earth Planet. Sci. Lett., v. 6, p. 43-46 (1969).

[4] Mörner, N.A., Lanser, J.P., and Hospers, J.: Late Weichselian paleomagnetic reversal; Nature, v. 234, p. 173-174 (1971).

51. TERRAIN SENSITIVITY AND MAPPING MACKENZIE VALLEY TRANSPORTATION CORRIDOR

Project 710077

P.J. Kurfurst and D.F. VanDine,
Terrain Sciences Division, Ottawa

A three-week drilling program was carried out in the Norman Wells map area (96 E) by P.J. Kurfurst and D.F. VanDine in March and April 1973. This was a follow-up program to drilling and geophysical exploration carried out in the same area in spring and summer 1972[1,2,3,4]. The main objectives of the program were:

1. To obtain geological information on materials and ground ice underlying the Canol Road, Camp Canol Airfield, and CNT line.
2. To collect chip samples in a thawed state for the determination of engineering properties of the various soil types.
3. To collect frozen core samples for ultrasonic testing.
4. To install thermistor cables in appropriate boreholes to increase knowledge of the regional ground thermal regime.
5. To co-operate with the Research Geophysics and Geochemistry Division working in the same area.

Eight sites were drilled (Fig. 1) during a two-week period. Four were along the Canol Road, one on the abandoned Camp Canol Airfield, two along the CNT line and one on a small lake northeast of the CNT line. These sites were selected because they contained both different geological terrains and various degrees of natural and man-made disturbance.

The Canol Road and abandoned airfield were covered by 1-2 metres of snow. The CNT line, used as a winter road, was covered by 5-15 cm of hard packed snow. The small lake was 2 metres deep 30 metres from shore. The ice was 1.8 metres thick and was covered by 0.5 metres of snow. Except for the small lake site (TL1), the drilling sites were cleared of snow and brush by a caterpillar tractor.

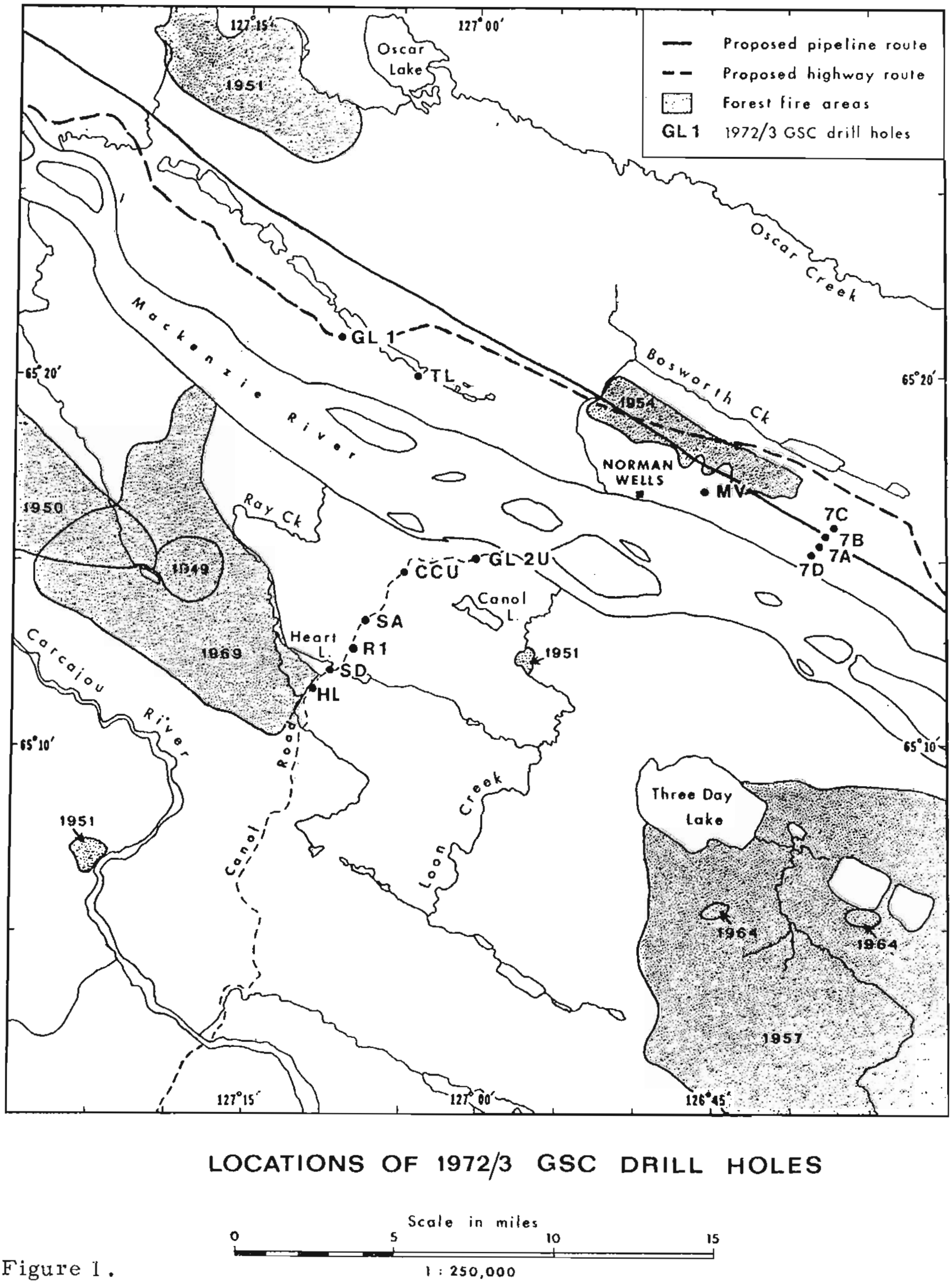
At the five Canol sites twenty-four holes varying from 5 to 36 metres in depth were drilled with a truck-mounted B-61 continuous flight auger. Emphasis was placed on drill sites HL and GL2U where nine and five holes respectively were drilled. Detailed profiles across the Canol Road at these two sites are presented in Figures 2 and 3 with detailed description given in another paper[5].

At the R1 site two holes were drilled to a maximum depth of 25 metres in the previously cleared right-of-way for the Canol Road. No ground ice was encountered in the till or clay underlying the road. Difficulty of access prevented drilling in the undisturbed areas to the sides of the road.

A five-hole profile across the road was drilled at the CC site. The maximum depth drilled was 30 metres where sandstone was encountered. No ground ice was observed in either the 10 metres of sand or the underlying silty clay layer.

At the CA site three holes were drilled across the Canol Airfield to a maximum depth of 36 metres. Neither the upper layer of till nor the lower layer of clay contained any ground ice. Dry dense clay halted drilling at 36 metres. The absence of permafrost at the above described sites was confirmed later by the thermistor cable temperature readings.

Thermistor cables varying in length between 13 and 33 metres were installed with at least one cable at each drill site. The boreholes containing the thermistor cables were backfilled with a mixture of diesel fuel and soil to



LOCATIONS OF 1972/3 GSC DRILL HOLES

Figure 1.

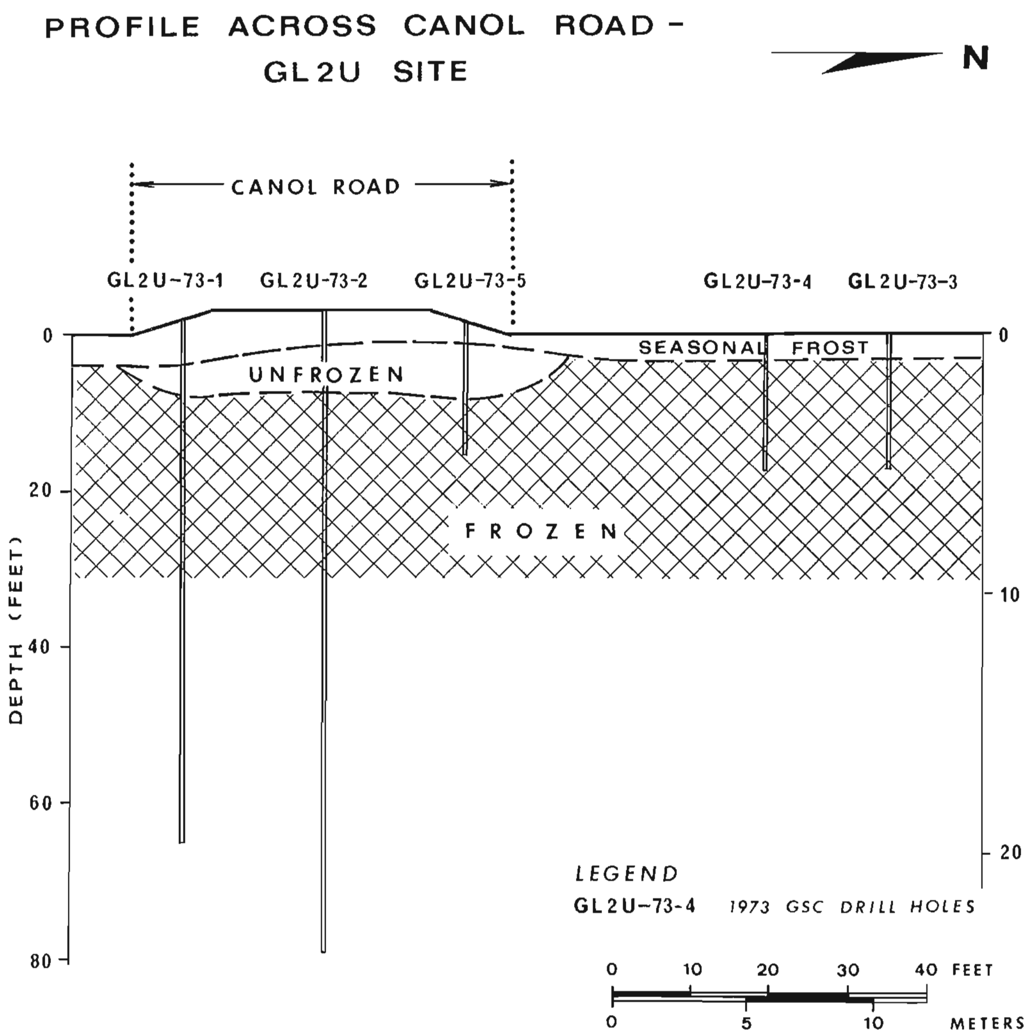
hasten equilibrium conditions around the cable. Readings from these cables are being taken manually at regular intervals to obtain additional information about the ground temperatures at various depths.

Seismic uphole wavefront shooting was done in two boreholes at the HL site and in one borehole at the CA site.

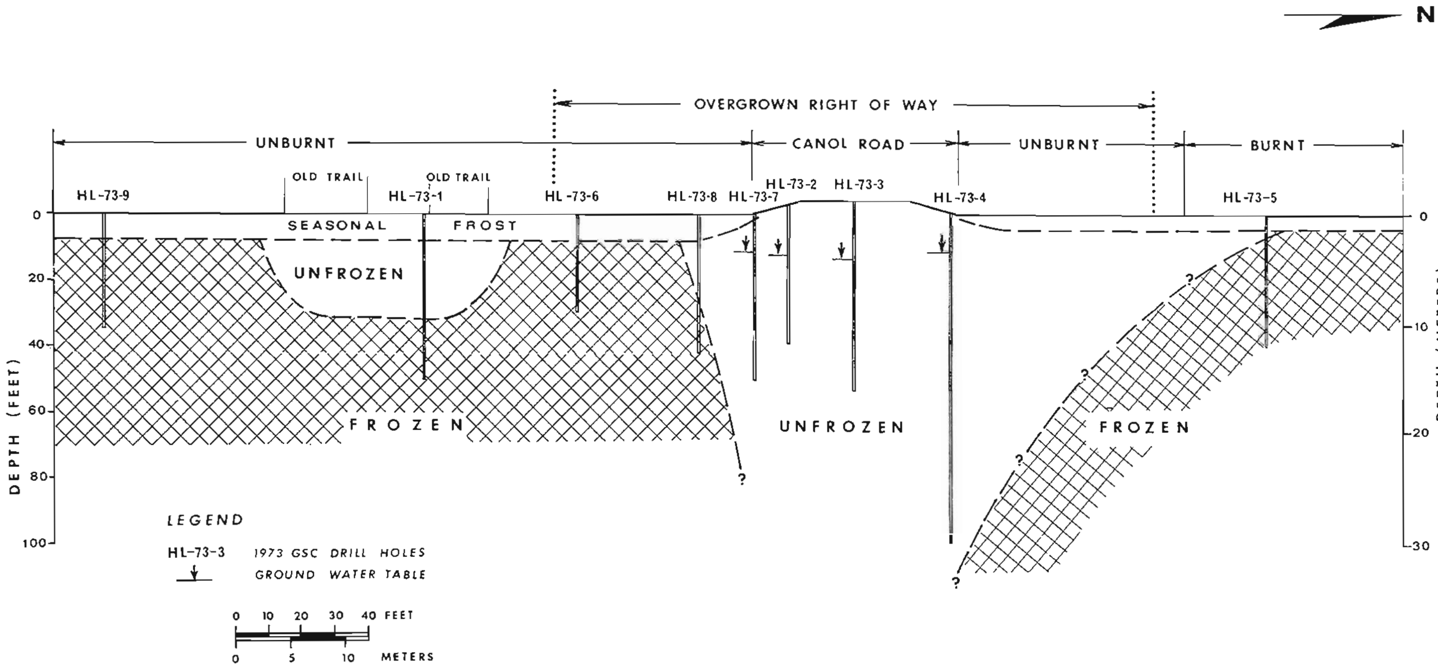
Electric resistivity surveys were done at the HL and GL2U sites.

Seven holes varying from 5-10 metres in depth were drilled with a 12 inch Texoma auger drill along the CNT line. A six-hole profile was drilled at GL1 and a single hole was drilled at TL.

The maximum depth of these drillholes was 10 metres - the maximum drilling depth of the rig. The stratigraphy at these two sites is simplified to be clay, overlain by silty clay, clayey silt, overlain by sand. Permafrost was usually found just below the seasonal frost with visible ice in quantities up to 60 per cent volume.



PROFILE ACROSS CANOL ROAD –
HEART LAKE SITE



A thermistor cable was installed in the centre of the CNT line at GL1 using an experimental method. A five-inch diameter PVC pipe was used as casing in the 10 metre hole. After the borehole was backfilled with material, the thermistor cable was placed inside the PVC pipe and the pipe was filled with diesel fuel. This thermistor cable is also being read at regular intervals.

No thermistor cables were installed at TL.

A single hole to a depth of 5 metres was hand augered with a 1 3/4-inch Oakfield auger through the ice and into the lake bottom at TL1. PVC pipe 1 1/2-inch diameter was used as casing. As long as the borehole was cased, hand augering was successful, but the casing could not be pushed greater than 4 metres by hand. The lake bottom stratigraphy consists of clay with interbedded sand layers overlain by loose organic rich silt. No permafrost was encountered beneath the lake to the depth of drilling.

At the eight drill sites a variety of material was drilled. Both types of mechanical augers worked very well in frozen and unfrozen sand, silt, clay and till.

Approximately fifty ship samples were collected and shipped to Ottawa in heat-sealed plastic bags. These thawed samples will be used to determine the engineering properties of the soil.

Unfortunately, a breakdown in drilling equipment and an early spring prevented any coring of frozen samples, so this phase of the drilling program had to be cancelled.

Additional drilling and geophysical work is to be carried out this summer.

Data for this report were obtained from investigations carried out under the Environmental-Social Program, Northern Pipelines, of the Task Force on Northern Oil Development, Government of Canada.

[1] Heginbottom, J.A., and Kurfurst, P.J.: Terrain Sensitivity and Mapping, Mackenzie Valley Transportation Corridor; in Report of Activities, April to October 1972, Geol. Surv. Can., Paper 73-1, Pt. A, p. 226-229 (1973).

[2] Hunter, J.A.: A Model Study of Reflected Seismic Waves from the Bottom of a Permafrost Layer; in Report of Activities, November 1971 to March 1972, Geol. Surv. Can., Paper 72-1, Pt. B, p. 44-46 (1972).

[3] Hunter, J.A., Burns, R.A., Good, R., and Bazeley, P.: Shallow Seismic Refraction Survey Mackenzie River Valley; in Report of Activities, April to October 1972, Geol. Surv. Can., Paper 73-1, Pt. A, p. 86-87 (1973).

[4] Isaacs, R.M.: Engineering Geology Mackenzie Valley Transportation Corridor; in Report of Activities, April to October 1972, Geol. Surv. Can., Paper 73-1, Pt. A, p. 230-231 (1973).

[5] Kurfurst, P.J., Hunter, J.A., and Scott, W.J.: Permafrost Studies in the Norman Wells Region, N.W.T., Geol. Surv. Can., Paper (in prep.)

52. WINTER CRACKING (1967-1973) OF ICE-WEDGES, GARRY ISLAND, N.W.T. (107 C)

Project 680047

J. Ross Mackay*,
Terrain Sciences Division

In the summer of 1967, about 110 ice-wedge sections at three sites at Garry Island, N.W.T., were selected for the long term study of summer-winter ice-wedge cracking and the growth rates of the ice-wedges[1]. The ice-wedges outline tundra polygons which are typically 10 to 20 m in diameter. The polygons at the three sites range from those with poorly defined troughs, through well developed low-centred polygons, to high centred polygons. The following discussion deals with 100 ice-wedge sections for the 1967-1973 period. All sections have been checked in both summer and winter.

Frequency and time of ice-wedge cracking (1967-1973)

During the six winters of observation, the percentage (or number) of ice-wedges which cracked were:

1967-68	40%
1968-69	38%
1969-70	36%
1970-71	32%
1971-72	15%
1972-73	31%

The frequency with which individual ice-wedge sections cracked were:

Number of years	Frequency
never cracked	35
one year	16
two years	11
three years	12
four years	15
five years	8
six years	3

Most ice-wedges at Garry Island crack in February-March. Very few ice-wedges crack before February or after March. A heavy winter snowfall or abnormally warm temperatures will tend to delay the time of cracking and reduce the number of cracks.

Widths and Depths of the Cracks

The widths and depths of the cracks have been measured with probes 9 mm, 7 mm, 5 mm, 3 mm, and 1 mm in diameter. The crack widths within the active layer of the troughs, above the ice-wedges, may reach 2 cm at the

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Figure 1. Ice-wedge crack, February 13, 1970. The upright pencil is in the fresh 1970 crack; the wooden dowel to the left of the crack marks the 1968 and 1969 crack locations. The snow depth, in the trough, was about 60 cm. Garry Island, N.W.T.

top (Fig. 1) and 1 cm at the bottom. Probing to a depth of more than 50 cm is difficult, even when an ice-wedge crack is wide and deep, because of curvatures and offsets in the cracks. Nevertheless, numerous measurements show that ice-wedge cracks frequently extend to depths of 3 to 5 m, and may be 5 mm wide at a depth of 3 m.

Closing the Cracks

Detailed summer-winter measurements of the growth rates of ice-wedges show that the annual growth rate is far less than the winter crack width, perhaps by one order of magnitude. As the ice-wedges grow by the freezing of meltwater in the cracks, it follows that the cracks must partially close before meltwater can trickle down into them. The evidence shows that the cracks commence to close when the ground begins to warm in late March or early April, and that appreciable closing has taken place by mid-May. Indeed, some cracks appear to be completely closed, or nearly so, before the snow in the troughs above them can melt.

Practical Implications

The widespread distribution of vertical ice-wedge open cracks extending to depths of 3 to 5 m and spaced 10 to 20 m apart may have an effect upon some near-surface geophysical mapping from February to May. Open ice-wedge cracks may also permit movement of water and resulting thermal erosion of ice-wedges, if a water source is made available. For example, the sudden natural drainage of some lakes, by way of ice-wedges, may well be the result of the enlargement of ice-wedge cracks.

[1] Mackay, J.R.: Some observations on ice-wedges, Garry Island, N.W.T.; in Mackenzie Delta Area Monograph, D.E. Kerfoot (Ed.), 22nd International Geographical Congress, p. 131-140 (1972).

53. POSITION OF FROST TABLE IN THE NEAR-SHORE ZONE, TUKTOYAKTUK PENINSULA, DISTRICT OF MACKENZIE

Projects 720079, 690047

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Terrain Sciences Division, Ottawa

Holes drilled as part of a seismic program along the northwest coast of the Tuktoyaktuk Peninsula (Fig. 1) have provided an opportunity to study lithologic changes and the position of the frost table in the near-shore zone. Holes, ranging from 10 to 35 m deep, were spaced 245 m apart along lines that started onshore and carried offshore for a few kilometres. Most offshore holes were drilled using double-walled drill stem with compressed air forcing cuttings up the inner stem. This made it possible to collect clean, relatively unaltered samples. The program was carried out between February 14 and March 22, 1973. The authors appreciate the full co-operation offered by Imperial Oil Limited in carrying out this study. The data for this report were obtained as a result of investigations carried out under the Environmental-Social Program, Northern Pipelines, of the Task Force on Northern Oil Development, Government of Canada.

Selected profiles are shown in Figure 2. Sea-ice thickness was relatively constant at about 1.5 m, although it varied between 1.2 and 2.4 m (profile D). The predominant sediment type was fine to medium sand. Farther offshore finer-grained units commonly overlay sand. Spits and offshore bars consisted almost entirely of sand with, at most, a few scattered pebbles. Minor lenses of gravel were encountered but only at considerable depth.

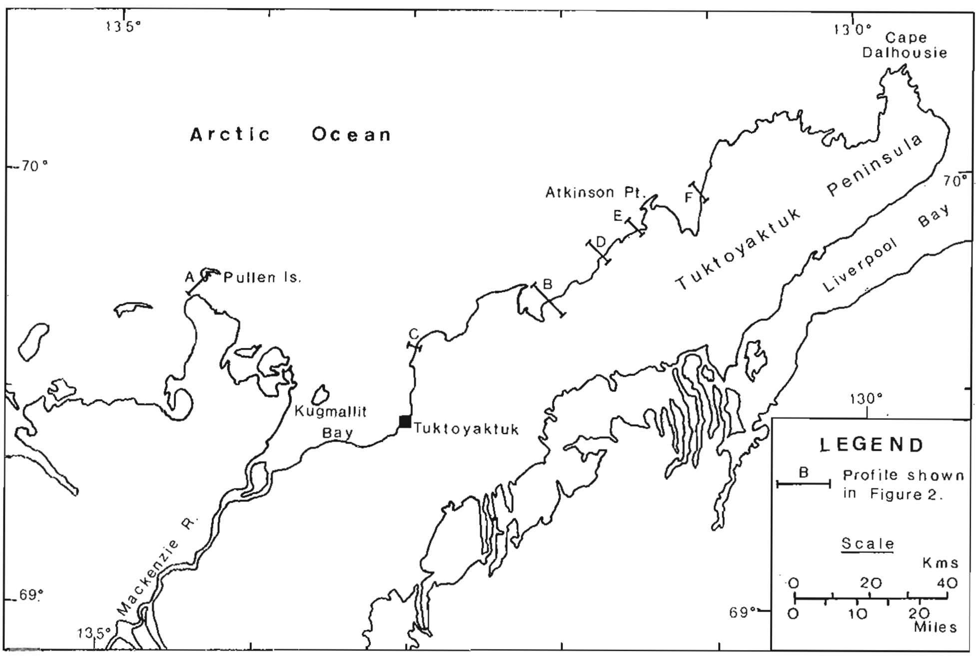


Figure 1. Tuktoyaktuk Peninsula, showing locations of profiles.

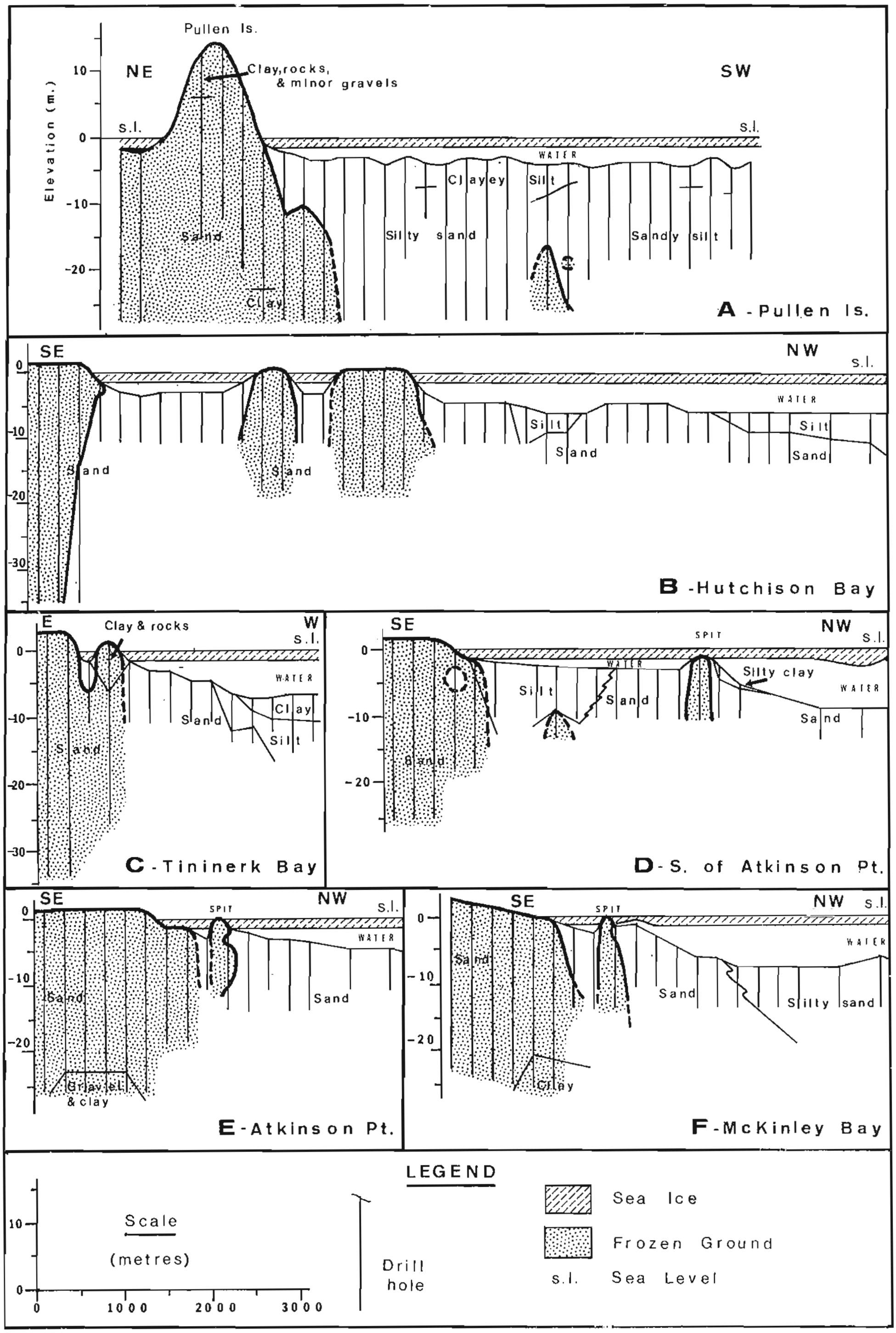


Figure 2. Selected profiles, showing lithologic variations and distribution of frozen ground.

Characteristics of the frost table are as follows:

1. Bathymetry appears to be a primary control on the depth to the frost table. Where the sea is frozen to the bottom the frost table almost always lies within 5 m of the sea bed. The presence of even a small amount of water beneath the sea ice can have a considerable effect on the frost table. In the vicinity of Atkinson Point three holes were drilled within 5 metres of each other. In two holes the sea was frozen to the sea bed and the frost table was encountered 5 m beneath the sea bed. The third hole was 5 metres seaward of the first two; 0.5 m of water lay beneath the sea ice and the frost table lay 10 m below the sea bed. The frost table rises beneath offshore spits as abruptly as at the mainland shore (profiles D, E, F). Near profile D, the advance of a spit tip has brought the sea bed to within 1.5 m of sea level. Frost appears to be aggrading from the top down, because the drill penetrated 6 m of frozen sand before breaking through to unfrozen sand for the remaining 5 m of the hole. Freshwater lakes in the vicinity of profile C show the same dependence of the frost table on bathymetry. In some localities (profiles A, D) frost was encountered at depth beneath the sea bed where an appreciable water column underlay the sea ice. Minor irregularities of the configuration of the frost table in the near-shore zone occur, e.g. at profile B where the frost table dips landward;
2. Unfrozen zones exist locally within frozen sediment (profile D). In McKinley Bay, a hole penetrated an unfrozen pocket in which a large quantity of water was under pressure and was pumped out with the sand;
3. Seasonal freezing of a thin upper portion of the sea bed can be seen near the shore in profiles B and E. In each case the sea ice was 1.5 m thick and frozen to the bed; the drill penetrated about a metre of frozen sand, then encountered unfrozen material again; and
4. In a number of holes (e.g. in profile A) thin frozen layers were encountered at depth. These may result from subtle textural variations. In profile D the occurrence of frozen ground beneath the sea bed is coincident with a change from silt to sand.

Ground ice occurred as infrequent layers of relatively pure ice as thick as 1.5 m and as pore ice in the sand. Numerous ice layers were encountered about 16 m beneath the sea bed near the southeast shore of McKinley Bay. An ice layer 1.5 m thick was penetrated at a depth of 15 m below the sea bed, 3 km southwest of Pullen Island (profile A). The ice content was measured by melting the frozen sample and recording the volume of water in excess of saturation as a proportion of total sample volume. Of 84 sand samples collected 45 per cent had no excess water. The remaining 55 per cent averaged 7.5 per cent excess water and ranged up to 16 per cent.

Although this study was conducted in more detail and over a much more restricted zone than that of Hunter[1] the results are complementary and they confirm the rapid descent of the frost table in the near-shore zone. Mackay[2] has shown that during the summer the sea-bottom water temperature in this region is warmed to above 0°C by Mackenzie River discharge.

The steep descent of the near-shore frost table, coupled with the presence offshore of frozen ground at depth beneath the sea bed, supports the hypothesis that the mean annual sea-bottom temperature in this region is also above 0°C, and that the offshore frost table is associated with relict permafrost and is being lowered.

[1]Hunter, J.A.: Shallow marine refraction surveying in the Mackenzie delta and Beaufort Sea; this publication, report no. 18 (1973).

[2]Mackay, J.R.: Offshore permafrost and ground ice, southern Beaufort Sea, Canada; Can. J. Earth Sci., v. 9, p. 1550-1561 (1972).

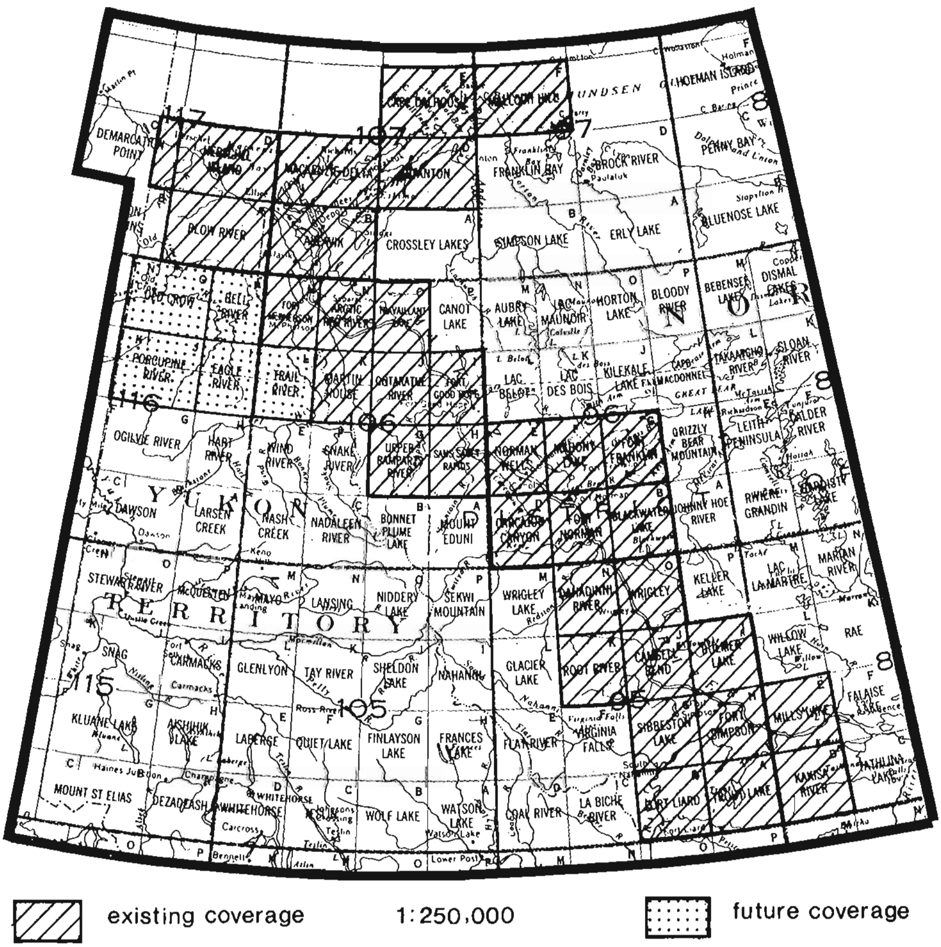
54. TERRAIN CLASSIFICATION AND SENSITIVITY MAP SERIES MACKENZIE VALLEY

Project 720100

R. L. Monroe,
Terrain Sciences Division, Ottawa

The first 30 map-sheets with accompanying legends of "Terrain Classification and Sensitivity Rating" maps for the Mackenzie Valley were completed and released on Open File at the Geological Survey of Canada. These are "derived" maps designed to illustrate and rate land capability and performance with respect to construction activities related to northern development.

Early stages of the project were devoted to the design and development of an acceptable mapping scheme which began with the establishment of a working definition of "Terrain Sensitivity", followed by the identification



and extensive description of the relevant physical constituents involved, (i.e. moisture content, ice content of soils, drainage characteristics, etc.). The derivation of terrain units consisted of simplifying existing surficial geological information into larger mappable units, displaying similar geologic, lithologic, and hydrologic properties: these units are projected to exhibit similar reactions to terrain disturbance.

Performance rating tables accompany the maps and legends. These are designed to identify significant hazards of individual terrain units in coded form, and numerically rate the severity of environmental disturbance, performance of newly thawed materials, and performance of unfrozen material in both permafrost and non-permafrost sites.

A bedrock "sensitivity index" map was constructed to supplement each of the Terrain Classification and Sensitivity series maps, initially to provide information on the coherence of bedrock material in areas of shallow surficial cover, and in addition to deliniate the suitability of local bedrock for use as rip rap in construction activities. Data for this report were obtained as a result of investigations carried out under the Environmental-Social Program, Northern Pipelines, of the Task Force on Northern Oil Development, Government of Canada.

55. TUKTOYAKTUK PENINSULA TERTIARY AND MESOZOIC BIOSTRATIGRAPHY CORRELATIONS

Project 700064

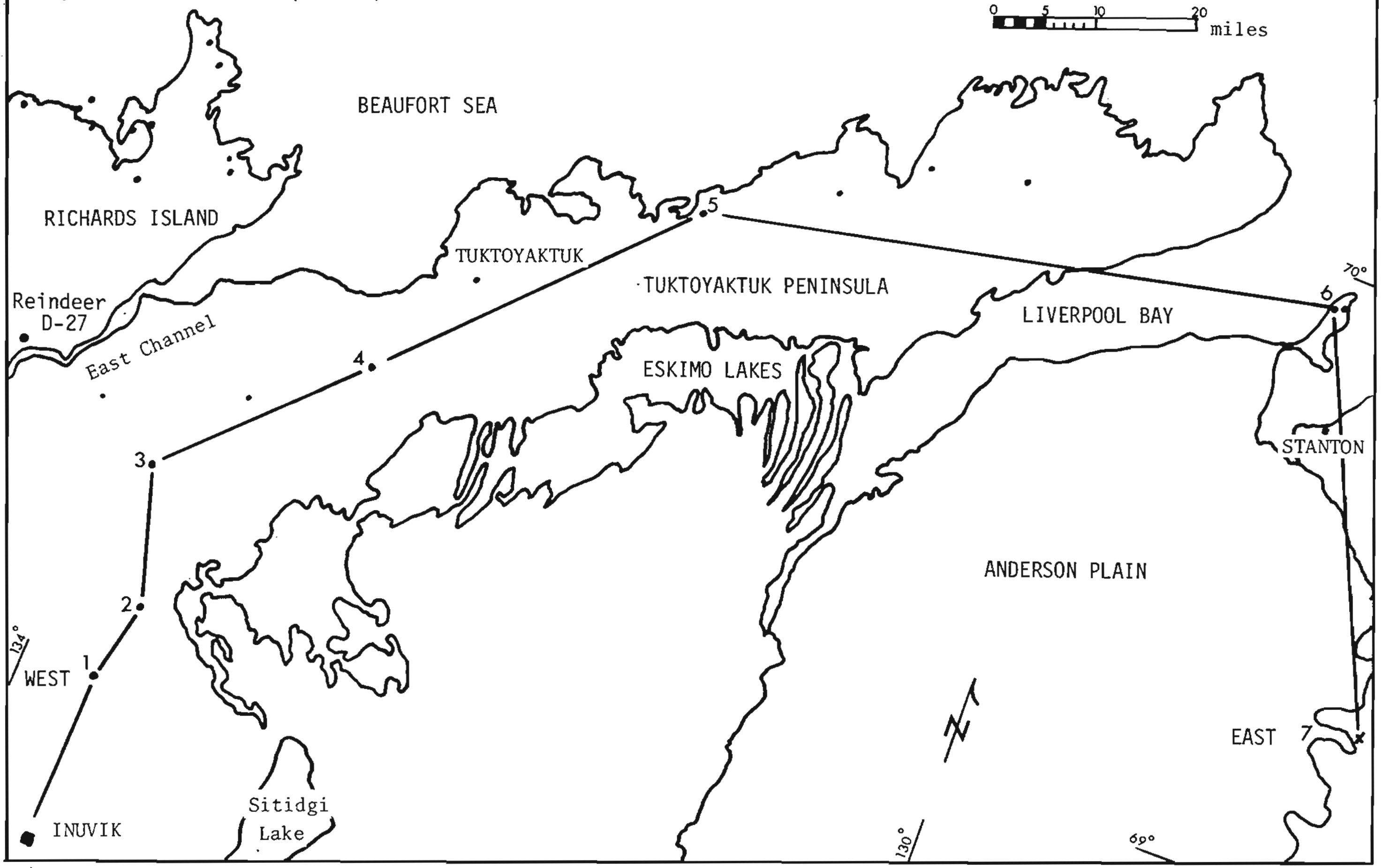
T.P. Chamney,
Institute of Sedimentary and Petroleum Geology, Calgary

This paper presents a simplified sequence of microfossil markers (assemblages) used with fairly reasonable success for a rapid biostratigraphic study completed recently for the Institute of Sedimentary and Petroleum Geology. Beside the species used, numerous additional species are present in the samples of each section, some of which likely will be proven to be more reliable as markers than those selected for this study. The biostratigraphic subdivisions interpreted for the Tuktoyaktuk Peninsula are compared with those of the first delta borehole, Reindeer D-27[1,2] as shown on Figure 3 and Table 1. Similar studies must be completed for each of the other more closely related local basins within the Mackenzie River Delta complex, the flanking mainland (Arctic Coastal Plains and Northern Interior Plains) and the Beaufort Sea area. Upon completion of these studies, integration of all recognized sequences of biostratigraphic subdivisions will be made. From this integrated comparison the sequential depositional history, including missing and/or additional intervals, will be constructed for the total area.

Locations of the sections in this study from west to east are as follows (see Fig. 1):

Section	Name and company	Location	Approximate depth to datum (feet)
1.	East Reindeer P60, Gulf Oil Canada	68°39'45"N, 133°43'00"W	1,510
2.	East Reindeer C38, Gulf Oil Canada	68°47'10"N, 133°39'15"W	3,240
3.	East Reindeer G04, Gulf-Mobil Oil Canada	68°53'16"N, 133°46'03"W	5,300
4.	Tuk F-18, Imperial Oil Enterprises	69°17'29"N, 133°04'01"W	8,590
5.	Atkinson M-33, Imperial Oil Enterprises	69°42'48"N, 131°54'43"W	5,700
6.	Nicholson Point Texaco Canada Composite G56 N45	69°55'28"N, 128°58'34"W 69°54'59"N, 128°56'00"W	1,700
7.	T.P. Chamney 1968 Composite Anderson R. Horton R.	69°16'00"N, 128°13'00"W 69°27'30"N, 126°58'00"W	

Figure 1. Location map Tuktoyaktuk Peninsula



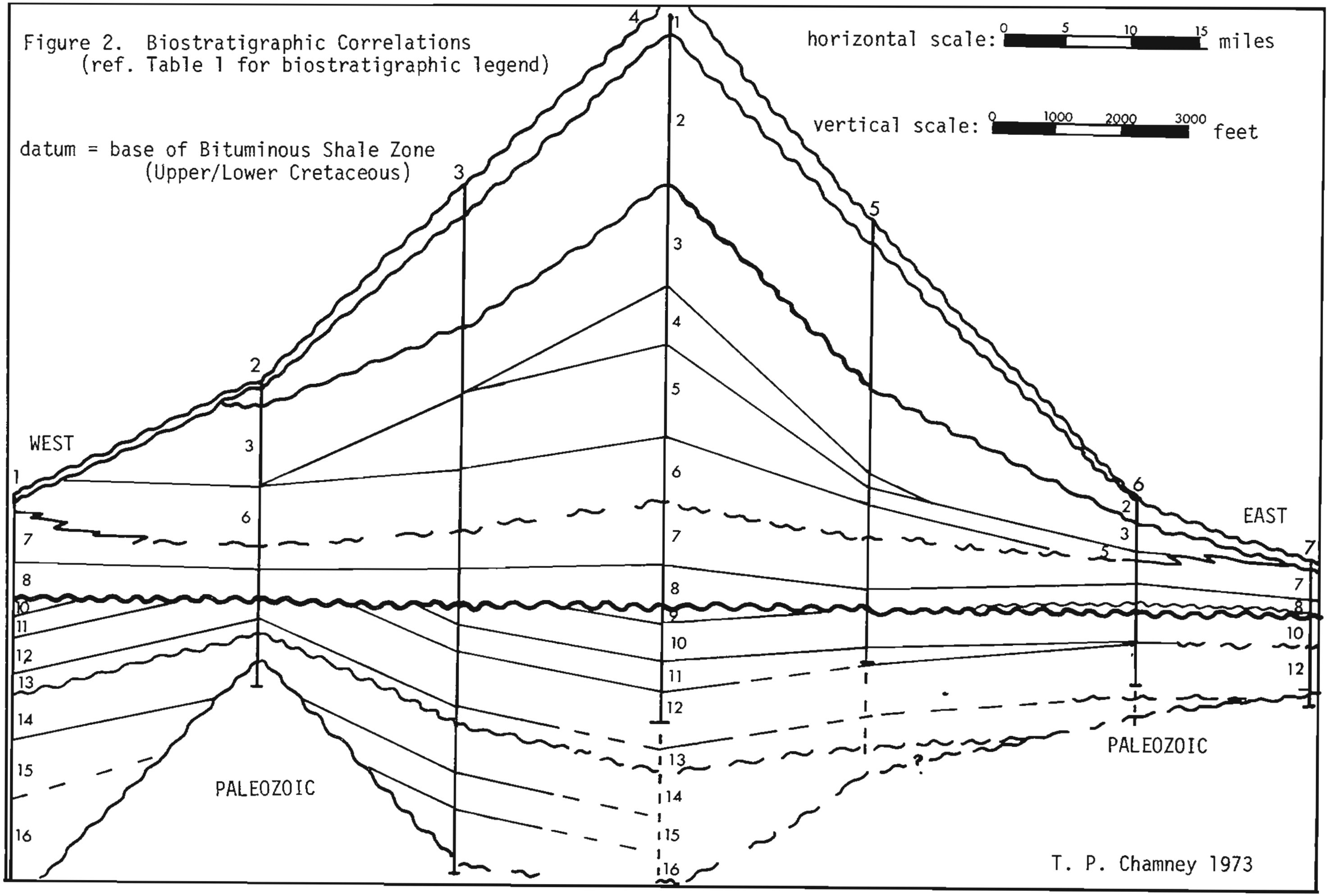


Figure 2. Biostratigraphic Correlations
(ref. Table 1 for biostratigraphic legend)

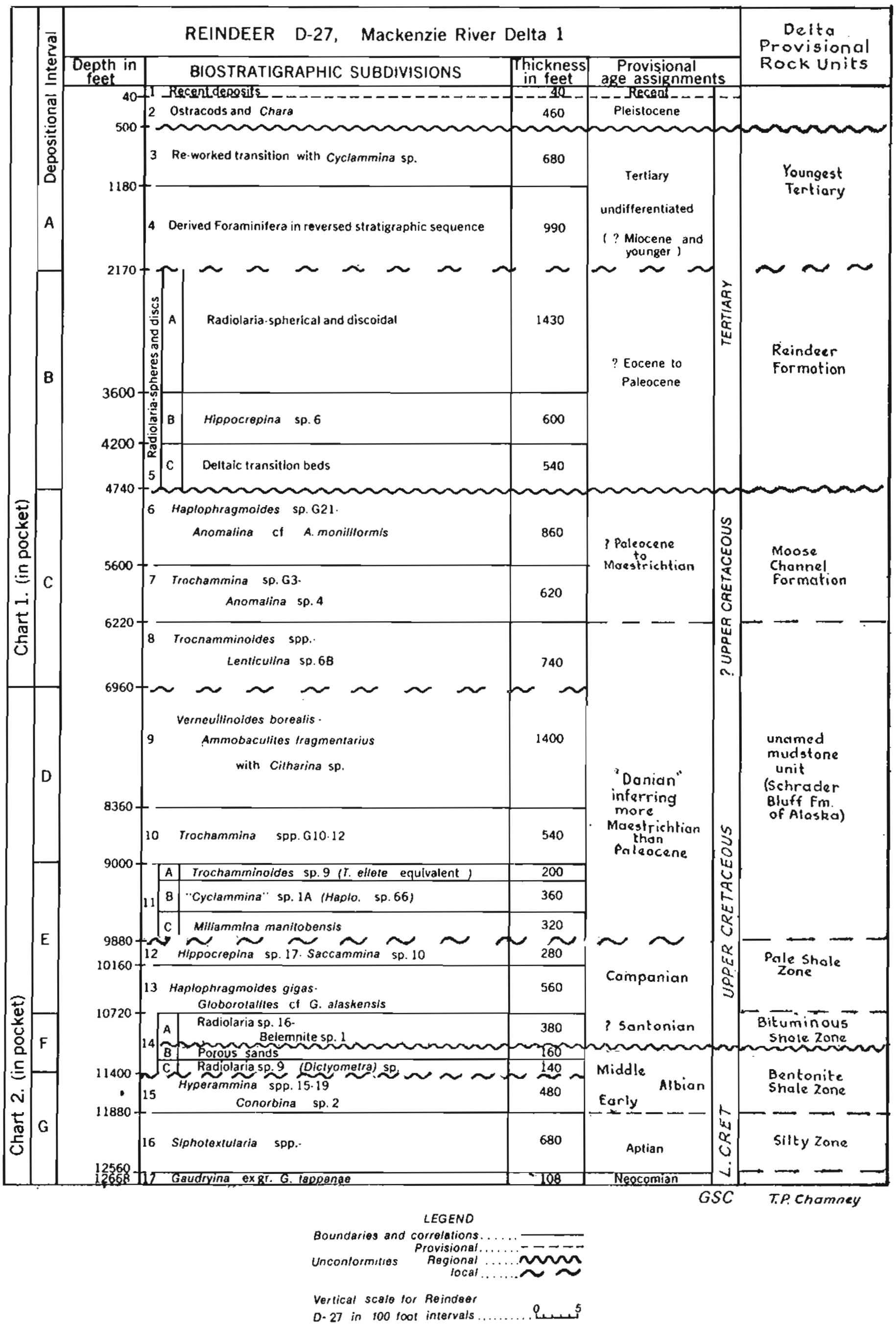


Figure 3. Summary of biostratigraphy, age and rock unit correlation.

TABLE I				
UNITS	MICROFOSSIL ASSEMBLAGES	PROVISIONAL AGE ASSIGNMENTS	ROCK UNIT EQUIVALENTS	D-27
1.	plants, pyritized wood & shell frag.	Quaternary	Recent & Pleistocene undif.	1-2
2.	vertebrates & chara	Tertiary-Eocene & younger	Reindeer Fm.	5
3.	*Haplophragmoides* n.sp. *Bacutriletes* spp.	Paleocene (?Eocene) with some Maestrichtian indicators (?"Danian")	Moose Channel Fm. w/middle shale	6 7
4.	*Quinqueloculina* ex gr. *Q. sphaera* & *Trochamminoides* sp. 9	Maestrichtian of some Interior Plains equivalents	additional shale unit within the deep axis of the Delta	8
5.	Upper *"Cyclammina"* sp. 1A (white) & *Verneuilinoides* ex gr. *V. fischeri*	"Danian" inferring more indicators of Maestrichtian than Paleocene age	unamed shale unit (?Schrader Bluff Fm.)	9 10
6.	Middle *"Cyclammina"* sp. 1A (vitreous) & ?*Hedbergella* sp. & radiolaria	(basal	black chert pebble conglomerate)	11
7.	Lower ?*Cyclammina-Reticulophragmium* *Trochammina* sp. (exotic)	Campanian	Pale Shale Zone (*Mosasaur* Beds)	12 13
8.	Bone Beds & radiolaria spp.	Early Campanian to Late Santonian	Bituminous Shale Zone (*Hesperornis* Beds) (Morden Unconformity)	14A
9.	*Gaudryina canadensis* *Ammobaculites fragmentarius*	Albian undif., ?Middle	Bentonitic Shale Zone &	14B
10.	*Marginulinopsis collinsi* & *Dictyometra* sp. 9 *Arenobulimina* sp.	Early Albian marker at base	Sans Sault Fm. in sandstone facies	14C 15
11.	*Quadrimorphina albertensis* & *Siphotextularia rayi*	Early Albian to Late Aptian	Silty Zone (?Upper) SS. facies to the NE.=Isachsen Fm.	16
12.	*Metacypris* spp. & *Siphotextularia* spp.	Aptian to Late Neocomian	Sh. facies to the SW.=Upper Shale	
13.	*Haplophragmoides goodenoughensis*	Neocomian	Siltstone Division	17
14.	*Arenoturrispirillina waltoni*, *G. milleri* *Ammobaculites alaskensis*, *H. canui*	Jurassic Late	Husky Fm.	
15.	*Ammodiscus thomsi* *Marginulinopsis phragmites*	Jurassic Middle	Kingak Fm.	
16.	?*Triplasia* ex gr. *T. kingakensis*	Jurassic Early	Kingak Fm.	

Note: Column "D-27" shows approximate equivalent microfossil assemblages for the borehole Reindeer D-27 (Chamney, 1970

Possibly more significant to the success of this biostratigraphic correlation study is the choice of the datum to which each of the study sections has been referred (Fig. 2). The datum chosen is the base of the Bituminous Shale Zone equivalent which represents the Upper/Lower Cretaceous boundary. The reasons for this choice are:

1. It is represented by distinctive microfossil facies changes above and below and is associated with a very distinctive physical property of the radio log signature from the Borehole Compensated Sonic Log, gamma ray trace (pers. comm., D. W. Myhr).
2. The datum is selected in the middle of the total stratigraphic sequence which the study is attempting to subdivide and correlate. By so doing, the sequence of subdivisions above and below the common datum are placed more in juxtaposition than if mean sea level, the top of the Paleozoic or Tertiary had been chosen.
3. The Upper/Lower Cretaceous boundary is here represented by the Morden Unconformity[3] which has been demonstrated to be of vast regional extent and to represent missing depositional intervals in terms of a thousand feet or more. The very high radioactive property exhibited at this boundary may be due to a fossil soil zone of weathered material. It thus approximates a reliable datum as opposed to lithofacies boundaries which could be more diachronous in nature. The importance of selecting the proper datum for correlation studies cannot be overstressed. The success of this micropaleontological research can be attributed in part to this most significant datum.

The interpreted biostratigraphic units are numbered 1 to 16 in descending order as penetrated by the drill in the correlation profile of Figure 1 and the detailed legend provided by Table 1. A brief discussion of these subdivisions should be prefaced by a note on evidence of some structural (faulting) complexities. This was brought to light by evidence of "stretched" microfossil assemblages and some questionable repetition within these assemblages. Such structural anomalies could be interpreted in the easterly flanking Jurassic strata abutting the Aklavik Arch (section 2). En echelon faulting[7], contemporaneous with deposition basinwards off the edge of the Jurassic continental platform, would be comparable with the evidence for "stretched" zones.

Brief notes on significant bedding relationships

Unit 2: The bedding relationship between the Reindeer and the underlying Moose Channel Formation is considered to be unconformable. There is some evidence to indicate offlap conditions basinwards into the Beaufort Sea basin similar to the bedding relationship shown on the east flank of the line of section (Fig. 2, Sec. 7). At this latter location near Windy Bend on the Anderson River, a 10-foot-thick conglomerate with bituminous cement rests unconformable on the Upper Cretaceous, Pale Shale Zone. If this bedding relationship persists northward, Unit 2 could rest unconformably on older beds under the Beaufort Sea.

Units 4 and 5: These are additional depositional intervals of the more complete sequence in the deeper parts of the Delta basin and possible represent marine "shale" facies of Unit 3.

Unit 6: The basal black chert conglomerate appears to be intraformational and is confined to higher energy media of rapid deposition. The bedding relationship on both the east and west flanks (Fig. 2, Sec. 1 and 7) are shown as lithofacies boundaries with the underlying Unit 7.

The Late Cretaceous (Maastrichtian) Middle "Cyclammina" sp. 1A (vitreous form with single aperture) of Unit 6 was recovered by the writer from outcrop on the Fish River, west flank of the delta located at 68°30'30"N, 136°23'50"W[2]. This microfossil assemblage is within the mudstones with floating black chert pebbles some fifty feet above the basal black chert conglomerate in the unnamed shale unit approximately 1,200 feet below the basal sandstones of the Moose Channel Formation. The Late "Cyclammina" sp. (white, weathered) Zone equivalent is only 100 feet or so below the basal sandstones of the Moose Channel Formation. The Reindeer D-27 "Cyclammina" sp. 1A, Unit 11 represents only the Middle "Cyclammina" spp. Zone. It is assumed that the depositional environment during this equivalent time interval of Units 8 and 9 in Reindeer D-27 was unfavourable for the existence of this foraminiferal assemblage. Recently, a Tertiary (Oligocene to Miocene) age assignment has been established for Unit 11 of Reindeer D-27 and, erroneously, Coal Mine Lake, District of Mackenzie[4]. This age assignment is based on some very minute (0.10 to 0.125 mm diameters) Rotaliina foraminifera and some polynomorphs identified and dated by G. Fournier. The foraminifera were recovered from core number 17 between 9,573 and 9,575 feet, by Kingsly Nash of Mobil Oil Corporation, Dallas, Texas. Petracca illustrated hypotypes referred to their areas of collection in the United States and other geographic locations.

After eight years and some twenty-seven boreholes which penetrate the equivalent strata, no similar minute calcareous foraminiferal assemblages have been reported by the numerous micropaleontology workers in the area. Many palynologists and recently paleobotanists refer this zone and overlying equivalent intervals up to Unit 6 of Reindeer D-27, as Maastrichtian. Megaspores of the taxa Minerisporites spp. and Bacutriletes spp. have been identified by A.R. Sweet of this Institute from the Reindeer D-27, Unit 6 equivalent. These are primarily indicators of Maastrichtian age but in this comparatively new geological province could range slightly younger in age.

There are many associated, agglutinated foraminifers from Core number 17[1] and equivalent strata which Petracca did not include in his publication. The following are but a few taxa upon which the Maastrichtian Late Cretaceous age was assigned by the writer:

Reticulophragmium spp. as used by Imperial Oil Enterprises (pers. comm., J.E. Van Hinte) for taxa assigned by Petracca to the "Cyclammina" (single aperture).

Haplophragmoides rota Nauss and H. rota Nauss fide Mellos, 1969[5] of the large, many-chambered planispiral agglutinated "Cyclammina" forms (single aperture).

Haplophragmoides ex gr. H. collyra Nauss[6] of the group tending to evolute forms in a morphological series with reported Trochamminoides sp. 9 and sp. 9B Verneuilinoides ex g. V. fischeri Tappan associated with other agglutinated taxa of the Schraeder Bluff Formation of Alaska.

Unit 8: The basal contact as previously discussed, represents the Morden Unconformity. There are at least three major biofacies within the Bituminous Shale Zone which are influenced by different bathymetric environments of deposition. But common to all biofacies are the well-preserved dark brown, shiny, vertebrate bone fragments. These appear to persist for great distances as a distinctive microfossil marker even as far distant as the Shale Wall Member of the Seabee Formation in Alaska[2].

Units 9 and 10: These Albian depositional intervals are regionally characteristic in biofacies, lithofacies and thicknesses indicating more or less normal, nearshore, marine deposits.

Units 11, 12 and 13: These units differ in lithofacies and thickness but appear somewhat similar in their biofacies, hence, the same marine source. Paleoenvironmental interpretation for Unit 12 indicates "dumping" or quite rapid rates of deposition. The overlying and underlying units appear to be deposited in a more normal, nearshore, marine environment. Unit 13 exhibits a greater amount of coarser clastic detritus, in particular near the Aklavik Arch, and could represent condensed sedimentation of more than one geological time stage.

Units 14, 15 and 16: These are all genetically related in lithofacies and biofacies but are anomalously thick and the microfossil assemblages are "stretched" as previously discussed.

[1] Chamney, T.P.: Tertiary and Cretaceous biostratigraphic divisions in Reindeer D-27 borehole, Mackenzie River Delta; Geol. Surv. Can., Paper 70-30 (1971).

[2] Chamney, T.P.: Biostratigraphic contributions from the Arctic Coastal Plain west of the Mackenzie River Delta; Geol. Surv. Can., Paper 72-1, Pt. A, p. 202-203 (1972).

[3] Chamney, T.P.: Microfossil study points to prospective anomalies; Oilweek, v. 20, no. 5, 3 figs., p. 7-8 (1969).

[4] Petracca, A.N.: Tertiary microfauna, Mackenzie Delta area, Arctic Canada; Micropaleontology, v. 18, no. 3, p. 355-368 (1972).

[5] Mello, J.F.: Foraminifera and stratigraphy of the upper part of the Pierre Shale and lower part of Foxhills Sandstone (Cretaceous) North-Central South Dakota; U.S. Geol. Surv., Prof. Paper 611 (1969).

[6] Nauss, A.W.: Cretaceous microfossils of the Vermilion area, Alberta; J. Paleontology, v. 21, no. 4, p. 329-343 (1947).

[7] Norris, D.K.: Structural Geometry and Geological History of the northern Canadian Cordillera; Proc. First Nat. Symposium Can. Soc. Geophysicists, Calgary, April, 1973 (1973).

56. SOME PRELIMINARY PALYNOLOGICAL CONCLUSIONS ON THE ALBIAN AND UPPER CRETACEOUS STRATA OF AMUND AND ELLEF RINGNES ISLANDS, DISTRICT OF FRANKLIN

Project 680068

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During parts of the summers of 1971 and 1972, the writer collected samples for palynological analysis from rock formations comprising the Albian and Upper Cretaceous of Ellef and Amund Ringnes Islands. Although analysis is not yet complete, a few preliminary remarks seem to be in order.

The Albian of the Sverdrup Basin is represented essentially by the dark marine shales of the Christopher Formation. Immediately overlying, and apparently conformable with, the Christopher is the Hassel Formation, a dominently continental unit, composed of sand with carbonaceous zones. The Hassel appears to be latest Albian and/or Cenomanian in age. Overlying the Hassel is the dark marine shale unit called the Kanguk Formation which, on Ellef and Amund Ringnes Islands, appears to be Turonian to Campanian in age. Immediately above the Kanguk lies the Eureka Sound Formation, the basal part of which is marine and is Maastrichtian in age. The stratigraphically higher portions of this formation, which are Tertiary in age, have not yet been systematically examined on these islands.

Several palynological sections from Ellef Ringnes Island were analyzed as well as a number of "grab" samples from Amund Ringnes Island. Biostratigraphic sections were prepared which show the general distribution of major plant types. From this, some climatic and environmental conclusions were drawn.

Some of the more obvious results of the work to date are outlined in the following paragraphs. The bisaccate pollen representing the Pineaceae, and the pollen of the Taxodiaceae and possibly Cupressaceae are abundant throughout the Upper Cretaceous and, with the exception of the Maastrichtian, are the dominant pollen types throughout the section. Taxodium and Glyptostrobus, both characteristic of a swampy and warm temperate climate, occur throughout the section but are especially abundant in the upper Hassel and lower Kanguk Formations. They reach another peak of abundance in the basal Eureka Sound Formation. Metasequoia occurs sporadically throughout the section. Tsuga, or hemlock, appears sporadically from the Albian to the Campanian. Environmental significance of Tsuga is extremely uncertain because the biological status of the genus is in dispute and, even now, Tsuga seems to be a rapidly evolving genus. Consequently, the environmental significance of this genus in the Late Cretaceous is doubtful. Generally, the conifers seem to suggest a warm temperate climate during the Late Cretaceous.

Fern spores present a clearer picture of climatic trends. The Schizaeaceae, an essentially subtropical family, is abundant in the Christopher and Hassel but diminishes in frequency upward. It is absent essentially in the Maastrichtian. The family Gleicheniaceae, which today is warm temperate to tropical in distribution, follows a similar pattern, declining from maximum abundance in the Albian to absence in the Maastrichtian. The family

Osmundaceae also shows a progressive decline throughout the Upper Cretaceous. Other fern families are represented but their frequency of occurrence is so low that the significance is difficult to determine.

The fern spore evidence would seem to indicate a progressive cooling of the climate through Late Cretaceous time. However, the evidence, not only of the ferns but also of the conifers Metasequoia, Taxodium and Glyptostrobus, would indicate that the temperatures even at the end of the Cretaceous seldom, if ever, reached the freezing point. Perhaps the Albian could be considered subtropical to warm temperate whereas the Maastrichtian would be warm temperate to temperate.

Of considerable interest is the obviously rapid rate of evolution and the rapidly increasing numbers of species of angiosperms. The first small and comparatively simple tricolpate pollen grains occur, in very small number, in the upper Christopher (Albian) and rapidly increase in number, in diversity and in size during the Upper Cretaceous. The first triporate pollen grains of modern aspect arise in the upper Kanguk (probably Campanian), although a very few isolated forms referable to the Normapollis group occur somewhat lower in the Kanguk. The more exotic angiosperm pollen grains such as the genera Aquilapollenites, Wodehouseia, Orbiculapollis and Expressipollis appear in the upper Kanguk and lower Eureka Sound Formations. Aquilapollenites and Expressipollis locally occur in such large numbers that they are the dominant element in several Maastrichtian samples. It is unfortunate that these pollen grains cannot be assigned definitively to modern botanical taxa because their very large number would certainly suggest that they represented a substantial portion of the plant community. In the extreme upper part of the Maastrichtian, Alnus (alder) and Betula (birch) make their first appearance. These latter two genera now are restricted essentially to temperate environments and, therefore, add evidence of the general Late Cretaceous climatic deterioration indicated by other plant groups.

This study, even in this preliminary stage, would suggest the following general conclusions:

1) There appears to have been a steady, although not rapid, cooling of the climate from Albian to Maastrichtian. The data are not sufficient to show local or temporary reversals of this trend.

2) The Albian flora appears to have been dominantly a fern-conifer complex.

3) The Maastrichtian flora seems to have been dominated by angiosperms with abundant conifers. Ferns seem to be a much less ubiquitous element.

4) The first definitely identified angiosperms appear to have arisen in the Albian and apparently diversified almost exponentially during the later Cretaceous.

5) Although the data are still not conclusive, deposition seems to have been essentially continuous. Minor diastems may be present in the Albian-Maastrichtian sediments of Ellef and Amund Ringnes Islands, but no major or prolonged periods of non-deposition or erosion are indicated.

57. DEVONIAN AND OLDER PALEOZOIC ROCKS, NORTHWEST TERRITORIES

Projects 710010, 700060

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About 50,000 feet of core, samples, and geophysical logs from 12 exploratory wells completed in 1970, between north latitudes 64 and 68 degrees in the Yukon and Northwest Territories, were examined and geological markers provided for the Department of Indian Affairs and Northern Development.

A sequence of echinoderm debris beds with graded texture, overlying the Ramparts Formation in one of the wells drilled south of Carcajou Ridge, was described and published as an outside paper. The echinoderm beds south of Carcajou Lake are similar to beds of echinoderm debris described from a Ramparts Formation, carbonate bank-margin outcrop at Powell Creek in the Mackenzie Mountains, but differ in being located several miles away from the bank margin. The skeletal debris presumably occupies depressions on an irregular erosional surface of the Ramparts Formation and, consequently, indicates proximity to topographic highs on the carbonate bank that are likely to be of interest to industry.

Paleontology from 1972 field work by A.E.H. Pedder and T.T. Uyeno of the Geological Survey, has established that a sandstone unit, formerly consigned to the base of the Canol Formation (post-Waterways), belongs in the upper part of the Ramparts Formation (pre-Waterways). The sandstone unit occupies an area of about 5,000 square miles north-northwest of Fort Good Hope in the Northwest Territories.

[1] MacKenzie, W.S.: Allochthonous Reef Debris - Limestone Turbidites, Powell Creek, Northwest Territories; Bull. Can. Petrol. Geol., v. 18, no. 4, p. 474-492 (1970).

[2] MacKenzie, W.S.: Upper Devonian Echinoderm Debris Beds with Graded Texture, District of Mackenzie, Northwest Territories; Can. J. Earth Sci., v. 10, no. 4, p. 519-528 (1973).

58. LOWER PALEOZOIC AND PROTEROZOIC STRATIGRAPHY, MOBIL COLVILLE HILLS E-15 WELL AND ENVIRONS, INTERIOR PLATFORM, DISTRICT OF MACKENZIE

Projects 670068, 710010

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Introduction

Regional surface geological studies by Aitken, Balkwill, Cook, Macqueen[1-8], and others on Operation Norman indicate that the lower Paleozoic succession to be expected in the Colville Hills area of the Interior Platform is that given in Table 1. Study of the essentially flat-lying lower Paleozoic rocks of the region is hindered, however, by relatively poor and discontinuous exposures, and by lack of data in the vertical dimension. Mobil Colville Hills E-15 well, located on the axis of the Colville Ridge anticlinal structure[5] and released from confidential status in October, 1972, is therefore highly significant to the lower Paleozoic geology of the area. The well was cored from a position close to the top of the Franklin Mountain Formation (see below) at 300 feet (90 m) to a final depth of 5,996 feet (1828 m) in Proterozoic sediments. The core was described by W.S. MacKenzie, using the informal terminology of Macqueen[7,8] for units within the interval herein assigned to the Franklin Mountain Formation, and that used by Balkwill[2], Cook and Aitken[4,5], and Aitken, Macqueen, and Usher[11] for lower units. Eighteen collections of trilobites from the Mount Cap - Old Fort Island interval were identified by W.H. Fritz (GSC internal report C6-1973-WHF); Macqueen contributed regional data.

Earlier Operation Norman publications[1-8] on the geology of the Interior Platform applied the name "Ronning Group" to the interval herein described as Franklin Mountain Formation, and to overlying beds now assigned to the Mount Kindle Formation but not present in the Colville Hills E-15 well. It is now clear that the Franklin Mountain and Mount Kindle Formations, as seen at the type sections in the Franklin Mountains near Wrigley[9,10], are recognizable over a large part of the Lower Mackenzie River region, including much of the subsurface and the original "Ronning Group" type locality at Dodo Canyon along the Mackenzie Mountain front in map-area 96 D. Accordingly the names Franklin Mountain and Mount Kindle take precedence for use over most of the Lower Mackenzie River area[11], with "Ronning Group" used only as a reconnaissance term where Franklin Mountain and/or Mount Kindle are not recognized.

Franklin Mountain Formation

The stratigraphically highest unit of the Franklin Mountain is the informal cherty unit, which is made up of finely to predominantly medium to coarsely crystalline dolomite, characterized in the Interior Platform by an abundance of silica occurring as clear drusy quartz crystals and milky white chert, and commonly including silicified oolites and stromatolites[7]. The unit in the Colville Hills E-15 well consists of dolomite which is variably siliceous, with blebs, 1 to 4 inches (2.5 - 10 cm) thick, of white chert conspicuous at many levels, and many vugs lined with white chert and drusy, euhedral quartz crystals. Silicified oolites are evident at some levels. Brecciation and fracturing are characteristic of these beds, and oil staining is common along fractures and in vugs. There is little porosity except for the interval between 940 and 1,000 feet (287 - 305 m) which has good vuggy porosity. Also present are crenulated bedding, geopetal fabrics, cut-and-fill structures, and abrupt changes in dip of bedding. These beds are widely known in the subsurface of the Lower Mackenzie River area[12].

Although the cherty unit is indicated as only 500 to 700 feet (≈150-210 m) thick from surface studies[3-5,7], some 2,420 feet (738 m) are assigned to the unit in the Colville Hills E-15 well. It is not known at present whether or not this significant increase in thickness over that expected is entirely depositional, or is due in part to repetition by faulting. The Colville Ridge structure on which the well is located has been interpreted as a compressional structure[6], and repetition by thrust faulting along the axis of the structure is a possibility. Despite the common brecciation and fracturing, however, there is no obvious indication of repetition of strata within the well. In addition, topographic and structural considerations indicate that only a small percentage of the increased thickness of the interval over that expected from surface observations can be accounted for by thrust faulting associated with the Colville Hills anticlinal structure. Hence much or most of the cherty unit thickness apparently is of depositional origin in the Colville Hills E-15 well.

Underlying the cherty unit is the informal <u>rhythmic unit</u>, which consists of interbedded finely crystalline silty dolomite and finely to medium crystalline, locally oolitic dolomite in surface exposures[7,8]. The distinctive sedimentary rhythms characteristic of surface exposures in the northern Franklin Mountains and eastern Mackenzie Mountains are recognizable only with difficulty in surface outcrops on the Interior Platform; in the Colville Hills E-15 well these rhythms are not apparent. The interval, which is 620 feet (189 m) thick, contains interbeds of grey and green-grey shale or very argillaceous dolomite.

The <u>cyclic unit</u>, which is 420 feet (128 m) thick in the Colville Hills E-15 well, contains interbedded finely crystalline to locally coarsely crystalline dolomite, and waxy green and brown, pyritic shale. Also present at several levels are the distinctive flat-pebble conglomerates which characterize this unit in surface exposures over a wide area[7,8].

<u>Saline River Formation</u>

Two units make up the Saline River Formation in the Colville Hills E-15 well. These are: an upper shale unit, 386 feet (118 m) thick consisting of interbedded green and rust-coloured dolomitic shale and anhydrite showing common brecciation and fracturing; and a lower evaporitic unit, 404 feet (123 m) thick, consisting of interbedded halite, green and rust-coloured and commonly glauconitic shale and anhydrite. The upper unit is similar to surface exposures of the Saline River examined to the east along the updip edge of lower Paleozoic rocks flanking the Canadian Shield[2-5,7,11], whereas the lower, mainly halite unit is not exposed on the surface in the region.

TABLE 1

Lower Paleozoic and Proterozoic Stratigraphy,
Great Bear Lake area including Colville Hills, Interior Platform.

	Stratigraphic Unit	Age	Thickness	
			Surface[1-8]	Mobil Colville Hills E-15 Well*
	Bear Rock Formation	Early Devonian	-	300' (0'-300') (90m; 0-90m)
	(unconformity)			
Lower Paleozoic	Franklin Mountain Formation	Late Cambrian - Early Ordovician	≃ 1200' -1600' (≃ 370-490m)	3460' (300'-3760') (1055m; 91-1146m)
Lower Paleozoic	cherty member	?Late Cambrian - Early Orodovician	?500'-700' (≃ 150-210m)	2420' (300'-2720') (738m; 91-829m)
Lower Paleozoic	rhythmic member	Late Cambrian	≃ 500' (≃ 150m)	620' (2720'-3340') (189m; 829-1018m)
Lower Paleozoic	cyclic member	Late Cambrian	≃ 200'-400' (≃ 60-120m)	420' (3340'-3760') (128m; 1018-1146m)
Lower Paleozoic	Saline River Formation	?Late Cambrian[11]	? 100'-150' (≃ 30-45m)	790' (3760' -4550') (241m; 1146-1387m)
Lower Paleozoic	(unconformity)			
Lower Paleozoic	Mount Cap Formation	Early and Middle Cambrian	≃ 200' -300' (≃ 60 - 90m)	
Lower Paleozoic	Old Fort Island Formation	Early Cambrian	0' -≃ 250' (0 -≃ 80m)	468' (4550' -5018') (143m; 1387-1530m)
	(unconformity)			
	Proterozoic, undivided	Proterozoic (Helikian or Hadrynian)	6000' +[15] (≃ 1830m)	978' (5018' -5996' T.D.D.) (incomplete) (298m; 1530-1828m)

* Latitude 67° 14'18"N; Longitude 126° 18'25"W.

Mount Cap - Old Fort Island Formation

This interval contains beds of green-grey, glauconitic and locally anhydritic shale and calcareous shale or limestone in the upper part, and glauconitic and pyritic, extensively burrowed and crossbedded siltstone and fine- to medium-grained sandstone (quartz arenite) in the lower part. The lithology of surface exposures of the Mount Cap to the north on Hornaday River (97D)[3,7] and to the south and west at Mount Clark in the Franklin Mountains (96C)[11] suggests that all of the Mount Cap - Old Fort Island interval in the Colville Hills E-15 well could be assigned to the Mount Cap, although the quartz arenites at the base closely resemble those normally found in the Old Fort Island Formation[2,4,5,7,13]. In the southern part of Great Bear Plain of the Interior Platform, the Old Fort Island is discontinuous, occupying paleo-depressions between knobs and ridges on the Precambrian erosion surface, and thinning to the vanishing point where the unit abuts against Precambrian high areas[2,13]. In the Colville-Coppermine map-area[5], and to the north of the Colville Hills area in the Erly Lake map-area[4], the Old Fort Island is somewhat more continuous, although commonly showing relief of up to 200 feet (≃60 m) on the lower surface[5]. Mobil Colville Hills E-15 well thus may have intersected a Precambrian topographic high, on which the Old Fort

Island was either thin, not deposited, or not preserved. An interpretation that the Old Fort Island was either not deposited or not preserved (i.e., the interval 4,550 - 5,018 ft. (1,387 - 1,530 m) is entirely assigned to the Mount Cap) is supported by the presence of abundant glauconite within the quartz arenites of the interval between 4,550 and 5,018 feet in the Colville Hills E-15 well. Glauconite, although common in the Mount Cap, is very rare or absent in the Old Fort Island quartz arenites we have examined[2-5, 7, 11, 13].

Trilobites of early Middle Cambrian age, including Amecephalus sp., and Glossopleura sp., are present in 16 fossil collections from the upper part of the Mount Cap - Old Fort Island interval (4,755 ft. - 4,837 ft.; 1,449 - 1,474 m); GSC loc. C-23650, C-23669, C-23683). Trilobites of late Early Cambrian age, from the Bonnia-Olenellus Zone, were found in two collections from somewhat lower in the Mount Cap - Old Fort Island interval, and indicate that little or no Lower Cambrian strata were removed prior to deposition of Middle Cambrian sediments (4,900 ft., 4,902 ft.; 1,494 m: GSC loc. C-23684, C-23685). The lithology and fauna of these fossiliferous beds of the Colville Hills E-15 well are similar to the Mount Cap succession at Dodo Canyon[14], Mackenzie Mountain front (96D), the type section of the "Macdougal Group" (obsolete)[11]. The presence of Lower and Middle Cambrian rocks in the Mount Cap - Old Fort Island interval accords with regional data on these formations in the Interior Platform[11].

Proterozoic, undivided

The basal 978 feet (298 m) of strata in Mobil Colville Hills E-15 well consist of shale, siltstone, and sandstone that is crossbedded and pyritic in the lower part. Beds of breccia and chert pebble conglomerate are present near the base of the interval. This sequence is assigned to the Proterozoic. Further regional study will be necessary to determine the relationship of these beds to rocks assigned to the Shaler Group of the Coppermine Arch to the northeast, and the Proterozoic clastic sequence to the southwest at Cap Mountain in the Franklin Mountains, now suggested to be entirely Helikian[11, 15].

[1] Aitken, J.D., Cook, D.G., and Balkwill, H.R.: Operation Norman, District of Mackenzie; in Report of Activities, Pt. A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 202-206 (1970).

[2] Balkwill, H.R.: Reconnaissance Geology, southern Great Bear Plain, District of Mackenzie; Geol. Surv. Can., Paper 71-11 (1971).

[3] Balkwill, H.R., and Yorath, C.J.: Brock River map-area, District of Mackenzie; Geol. Surv. Can., Paper 70-32 (1970).

[4] Cook, D.G., and Aitken, J.D.: Erly Lake, District of Mackenzie; Geol. Surv. Can., Prelim. Ser. Map 5-1969 (1969).

[5] Cook, D.G., and Aitken, J.D.: Geology, Colville Lake map-area and part of Coppermine map-area, Northwest Territories; Geol. Surv. Can., Paper 70-12 (1971).

[6]Cook, D.G., and Aitken, J.D.: Tectonics of northern Franklin Mountains and Colville Hills, District of Mackenzie, Canada; Am. Assoc. Petrol. Geol., Arctic Symposium (1970), Memoir (in press).

[7]Macqueen, R.W.: Lower Paleozoic stratigraphy, Operation Norman, 1968; in Report of Activities, Pt. A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 238-241 (1969).

[8]Macqueen, R.W.: Lower Paleozoic stratigraphy and sedimentology; eastern Mackenzie Mountains, northern Franklin Mountains; in Report of Activities, Pt. A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 225-230 (1970).

[9]Williams, M.Y.: Exploration east of Mackenzie River between Simpson and Wrigley; Geol. Surv. Can., Sum. Rept. 1921, Pt. B, p. 56-66 (1922).

[10]Williams, M.Y.: Reconnaissance across northeastern British Columbia and the geology of the northern extension of Franklin Mountains, N.W.T.; Geol. Surv. Can., Sum. Rept. 1922, Pt. B, p. 65-87 (1923).

[11]Aitken, J.D., Macqueen, R.W., and Usher, J.L.: Reconnaissance studies of Proterozoic and Cambrian stratigraphy, Lower Mackenzie River area (Operation Norman), District of Mackenzie; Geol. Surv. Can., Paper 73-9 (in press).

[12]Tassonyi, E.J.: Subsurface geology, Lower Mackenzie River and Anderson River area, District of Mackenzie; Geol. Surv. Can., Paper 68-25 (1969).

[13]Norris, A.W.: Stratigraphy of Middle Devonian and older Paleozoic rocks of the Great Slave Lake region, Northwest Territories, Geol. Surv. Can., Mem. 322 (1965).

[14]Fritz, W.H.: Cambrian biostratigraphy in the Canadian Cordillera; in Report of Activities, Pt. A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 110 (1970).

[15]Aitken, J.D., Macqueen, R.W., and Foscolos, A.E.: A Proterozoic sedimentary succession with traces of copper mineralization, Cap Mountain, southern Franklin Mountains, District of Mackenzie; in Report of Activities, Pt. A, April to October, 1972; Geol. Surv. Can., Paper 73-1, Pt. A, p. 243-246 (1973).

59. THE MILK RIVER FORMATION IN THE SUFFIELD AND MEDICINE HAT AREAS, ALBERTA

Project 720077

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The Transition beds and the lateral equivalents of the Deadhorse Coulee Member of the Milk River Formation are both gas-bearing north of the Virgelle sandstone pinch-out[1,2,3]. Production comes from thin beds and very thin lenses of very fine grained, silty sand which is interbedded with argillaceous siltstone and silty shale. The Milk River Formation has a thickness of between 280 and 300 feet and extends over a large area in southern Alberta and Saskatchewan. Up to February 19, 1972, 1,738 wells had been drilled in search for gas in an area marked by township 9, range 1W4 to township 18, range 15W4 in southern Alberta and only 8 wells had cored intervals in the Milk River Formation. Because difficulties arose in evaluating the gas reserves of the Milk River Formation without a knowledge of the lithology, detailed descriptions of the cores were made. E-log and gamma-ray log cross-sections were used to correlate the cores in different wells and the character of the logs was checked against the lithology known from the available cores and a few sample examinations.

In the Bantry, Suffield and Medicine Hat areas, the Milk River Formation comprises an interval of interbedded very fine grained argillaceous sandstone, siltstone and silty shale marked at the top by a thin cherty pebble bed. It is overlain by shales of the Pakowki Formation and underlain by white speckled calcareous shales of the Alberta Formation. In the area under consideration, the Milk River Formation can be subdivided into an upper and lower part. The boundary between the two parts is not sharp.

The upper part of the Milk River Formation consists of variably argillaceous, very fine grained sandstone, interbedded with siltstone and silty shale. At or near the top of the formation is a thin pebble bed consisting of well-rounded black chert and light-coloured quartzites in an argillaceous, poorly sorted, fine- to very coarse-grained sandstone matrix. This pebble bed is, in places, sideritic. There are poorly defined bands and nodules of siderite scattered throughout the Milk River Formation.

Bedding is poorly developed and individual beds are not sharply defined. The argillaceous sandstone and siltstone beds have a mottled appearance. Light grey, clean, well-sorted, porous sand and silt occur in laminated beds or lenses, 1/8 to 1 inch thick, and as burrow-like structures in the argillaceous matrix. The lenses are present either isolated in the matrix or piled up on top of each other to form poorly defined beds, 6 to 8 inches thick. They have laminations similar to current ripples and are thought to be the products of current and wave action. The mottled, argillaceous sediments were deposited in slack water.

Near the base of the upper part of the Milk River Formation is a greenish grey bentonitic shale bed, 2 to 4 feet thick. Although this shale bed can be recognized on electrical logs and can be correlated for some distance from one borehole to the other, it is not a consistent marker.

The lower part of the Milk River Formation is less sandy than the upper part and consists of silty shale interbedded with argillaceous siltstone.

Geol. Surv. Can., Paper 73-1, Part B

Scattered throughout the interval are thin (1/8 - 1 inch thick), light grey, clean, well-sorted, porous, very fine grained, silty sand lenses which are ripple crossbedded. In the top part, the laminated lenses in places form beds from 2 to 6 inches thick. Towards the base the thin, light grey, porous, silty sand lenses become scarce, and disappear altogether where the shale becomes calcareous. The base of the Milk River Formation is transitional through a thin interval and is placed at the top of the calcareous white speckled shale. The lithology of the lower part is characteristic of a tidal-flat environment and represents the prodelta facies.

Good porosity and permeability is confined to the clean, isolated, silty sand lenses and the closely packed sand lenses that form beds. The argillaceous sandstone beds have little porosity and lack permeability. Porosity and permeability tests were performed on a number of cores by Core Laboratories of Canada.

The most useful measurements are from the ARCO Alderson well (10-4-15-10W4) and the ARCO IOD Medicine Hat well (10-14-15-4W4), because the lithology could be checked in the core. Permeabilities for the clean, well-sorted silt lenses (1/2 - 2 inches thick) vary from 2.75 to 259.00 MD and porosity percentages range from 17.3 to 26.0. In the shales and argillaceous siltstones porosity varies from 5.9 to 24.4 per cent with permeabilities smaller than 0.0163.

It is evident that the thin, porous, silty sand lenses and beds are the channels through which the gas flows into the borehole and it is assumed that the bulk of the gas reserve is held in the same beds. It is also evident that these thin porous sandstone and siltstone beds are not indicated on the mechanical logs as separate units; they are "averaged out" over three to five feet. This explains the difficulties encountered in assigning net pay figures for individual wells on the basis of log evaluation. Since the gas in the Milk River Formation occurs downdip from a freshwater aquifer (the Virgelle sandstone member), it appears to have been formed locally in the shale and to have migrated into the porous, silty sand lenses where it is trapped.

[1] Meyboom, P.: Geology and groundwater resources of the Milk River Sandstone in southern Alberta; Alberta Res. Council, Mem. 2 (1960).

[2] Slipper, S.E., and Hunter, H.M.: Stratigraphy of Foremost, Pakowki and Milk River Formations of Southern Plains of Alberta, Bull. Assoc. Petrol. Geol., v. 15, no. 10, p. 1181-1196 (1931).

[3] Tovell, W.M.: Some aspects of the geology of the Milk River and Pakowki Formations (Southern Alberta); University of Toronto, thesis (1956).

[4] Wells having cored intervals in the Milk River Formation:

H.B. Winnifred No. 1 in 11-6-12-9W4
Cores 1, 2, 3, 4, and 5

Dome Cecil in 6-28-13-12W4
Cores 1, 2, 3, 4, 5, and 6

Gander Med. Hat in 6-1-14-7W4
Core 1

AEG Alderson in 7-30-14-9W4
Cores 1, 2, 3, and 4

ARCO IOD Med. Hat in 10-14-15-4W4
Cores 1, 2, 3, 4, 5, 6, and 7

DND Suffield in 10-4-15-9W4
Core 1

ARCO Alderson in 10-4-15-10W4
Cores 1, 2, 3, 4, 5, and 6

N.W. Tilley No. 5 in 3-17-17-12W4
Cores 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10

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60. SOME OBSERVATIONS ON THE MILK RIVER GAS RESERVOIR

Project 720077

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In southern Alberta the Upper Cretaceous Milk River Formation has been yielding a modest amount of gas for many years. A field of about three square miles supplies gas for the military establishment at Suffield. Recently several oil companies have begun a program of closely spaced drilling to tap the Milk River gas reserves on a major scale.

The main purpose of this study was to investigate factors controlling the gas accumulation and to determine whether or not a more detailed geological study would contribute to the accuracy of reserve calculations. Figure 2 shows the locations of wells from which cores or samples were examined. In or near the gas-producing area only eight wells have cores from the Milk River Formation.

Regional studies[1,2] of the Milk River Formation show that the formation has the character and geometry of a delta complex. A lobe of sandstone in southern Alberta grades northward to shale. The main sandstone development is coincident with the area of artesian water (Fig. 1), and this area probably represents the lower deltaic plain with bar and distributary sands. The gas producing area lies within the marine delta plain or prodelta.

The lithology within the productive belt, as illustrated by the cores, is a marine silty mudstone with laminae and lenses a fraction of an inch thick of silt to very fine grained sand. These silt lenses are isolated either in the mudstone or stacked on top of each other to form poorly defined beds a few inches thick. The amount of clay matrix within the silt or sand is variable. Analyses of clean beds yield porosities up to 26 per cent with horizontal permeabilities up to 259 md. Analyses of mudstone or clay layers yield porosities as high as 42 per cent. Due to the nature of the rock it is very difficult to estimate the net amount of permeable beds from a visual examination of the core.

The sample study covered an area spanning a range of facies from sandstone to silty mudstone. The sample quality is good enough to determine the nature of the sands or silts, and to judge grain size, sorting, composition, cement and, in some places, porosity. However, samples are never good enough to compile reliable sand- or silt-to-shale ratios or to estimate the net amount of porous or permeable rock. In mud-drilled wells, some caving is invariably present. Shales are especially prone to cave and, since much of the shale in the overlying formations is indistinguishable from Milk River shale, a quantitative estimate is impossible. Caving in air-drilled wells in the gas-producing area is not a problem since most wells are cased into the top of the Milk River Formation. However, in such wells, the rock has disintegrated largely into silt grains and clay dust; there is no way to determine the amount of permeable siltstone present.

The proportion of shale is difficult to estimate from either logs or cuttings. The grain size of the silt-sand fraction, however, can be observed in samples. Figure 2 is a map showing the regional change in the sand to silt ratio. From southwest to northeast there is a gradation from predominantly very fine to fine-grained sands to predominantly silt (.25 mm or finer).

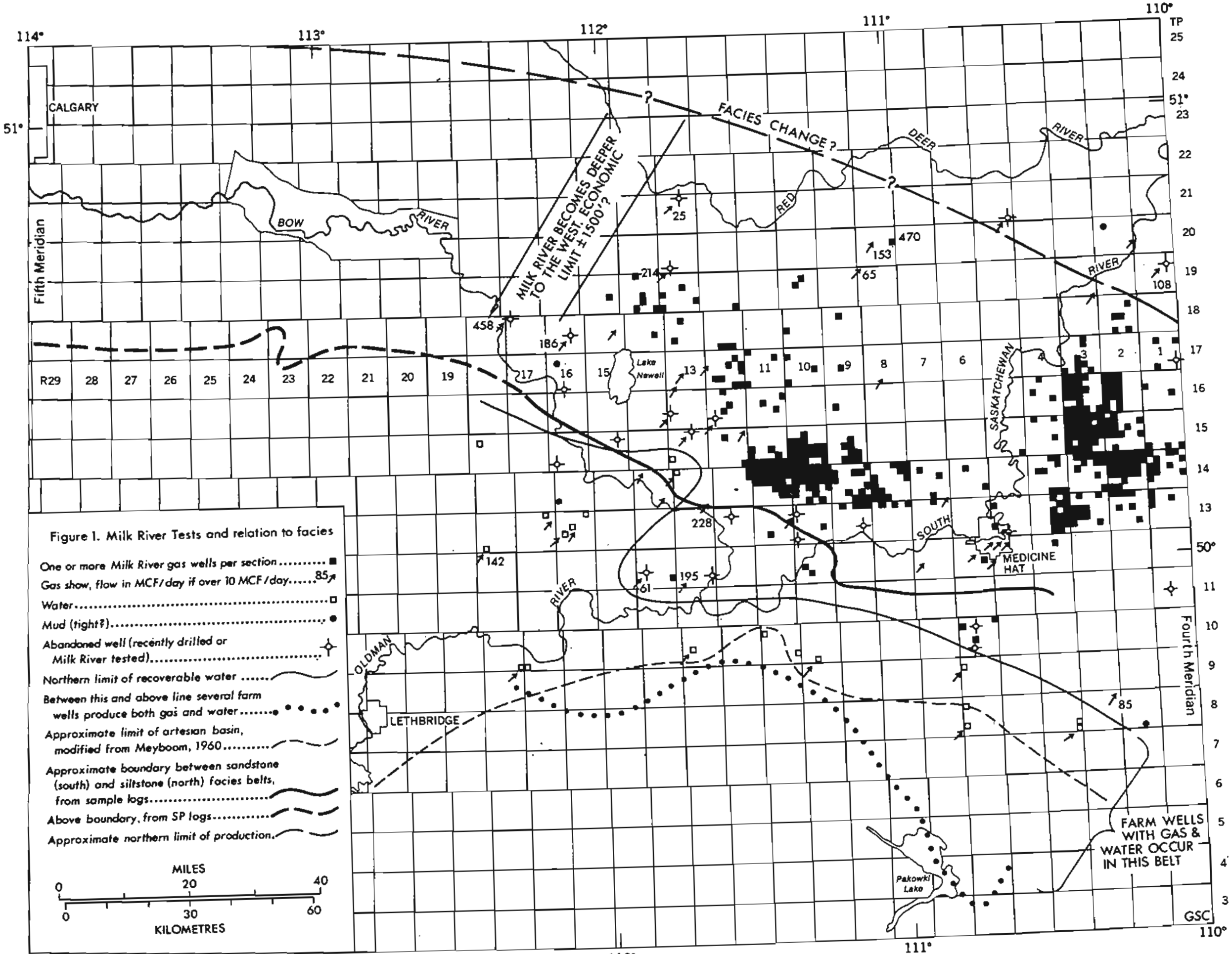
Figure 1. Milk River Tests and relation to facies
One or more Milk River gas wells per section
Gas show, flow in MCF/day if over 10 MCF/day
Water
Mud (tight?)
Abandoned well (recently drilled or Milk River tested)
Northern limit of recoverable water
Between this and above line several farm wells produce both gas and water
Approximate limit of artesian basin, modified from Meyboom, 1960
Approximate boundary between sandstone (south) and siltstone (north) facies belts, from sample logs
Above boundary, from SP logs
Approximate northern limit of production
MILES
0
20
40
0
30
60
KILOMETRES
114°
113°
112°
111°
110°
51°
50°
CALGARY
Fifth Meridian
Fourth Meridian
BOW RIVER
RED DEER RIVER
SOUTH SASKATCHEWAN RIVER
OLDMAN RIVER
FACIES CHANGE ?
MILK RIVER BECOMES DEEPER TO THE WEST. ECONOMIC LIMIT ± 1500'?
Lake Newell
MEDICINE HAT
LETHBRIDGE
Pakowki Lake
FARM WELLS WITH GAS & WATER OCCUR IN THIS BELT
TP
R29
GSC

Figure 1.

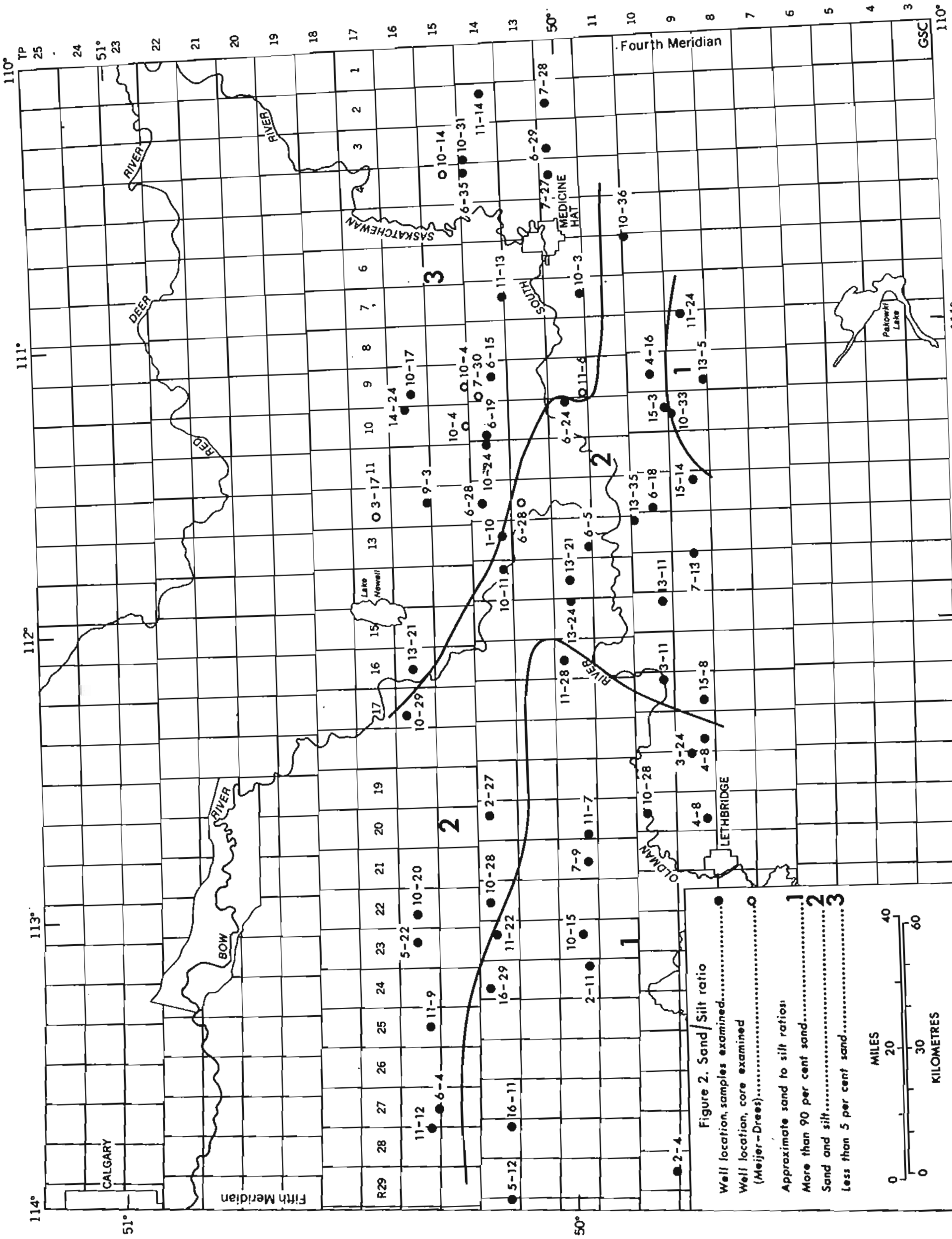
Figure 2. Sand/Silt ratio
Well location, samples examined
Well location, core examined (Meijer-Drees)
Approximate sand to silt ratios:
More than 90 per cent sand 1
Sand and silt 2
Less than 5 per cent sand 3
MILES
KILOMETRES
Fourth Meridian
Fifth Meridian
CALGARY
MEDICINE HAT
LETHBRIDGE
Lake Newell
Pakowki Lake
RED DEER RIVER
BOW RIVER
SOUTH SASKATCHEWAN RIVER
OLDMAN RIVER
GSC

Figure 2.

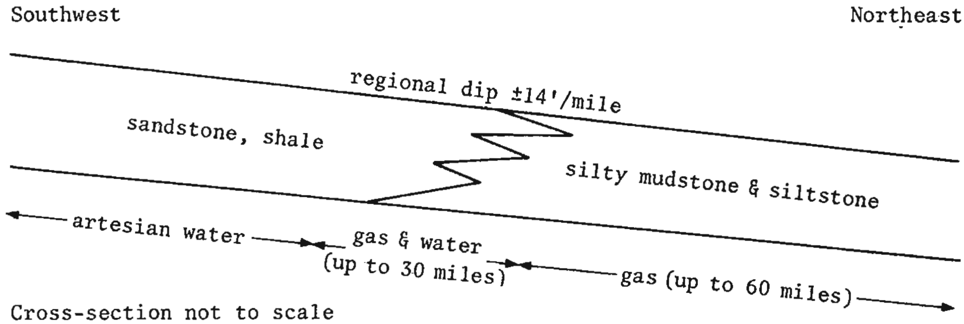

Figure 3. Diagrammatic cross-section illustrating the regional setting of the Milk River gas field.

It is evident from Figures 1 and 2 that the fluid content bears a close relation to the grain size of the formation. Where sand predominates the formation produces fresh water. In the transition belt water as well as some gas is produced. In the silt facies gas with no water is encountered.

Mechanical logs can be used, with caution, to interpret the lithology in the sandstone and transitional belts. In the silty facies, or productive belt, permeable beds are too thin to be differentiated on logs. Resistivity logs must be suspect because, as shown by the cores, calcareous and ferruginous beds are common. These, as well as gas-saturated silt beds give a high reading. No reliable method was found to relate net pay or deliverability to logs or to samples.

A map was constructed plotting the maximum SP deflection for each well. The 10 millivolt line coincides very closely with the sand/silt transition as determined from samples. Deflections of more than 10 millivolts do occur within the silt facies, but these are very thin, sharp peaks. The 10 millivolt line has been used to map the sand/silt boundary in the area north of the sample study on Figure 1.

The Milk River gas accumulations are situated immediately down-dip from a freshwater aquifer (Fig. 3). Gas without significant water is limited, with rare exceptions, to the silty mudstone facies and occurs throughout the formation from top to bottom. In the transition zone, where discrete sandstone layers are present, water or water with some gas is present. It is apparent from Figure 1 that the northern limit of the permeable aquifer coincides with the southern limit of the gas area, and that this limit coincides with the grain size decrease from sand to silt.

Several factors indicate that the Milk River gas reservoir does not have good permeability: the small gas flows, the nature of the core, and the regional setting. The fact that some core analyses show good permeability indicates that the thin, relatively clean siltstone layers lack lateral continuity. The occurrence of gas and water together in the down-dip edge of the sandstone aquifer suggests that the gas is migrating. The fact that any gas remains under these structural conditions (Fig. 3), which have probably existed for some tens of millions of years, gives some indication of the low permeability of the gas-saturated rocks.

It is doubtful that the densely drilled areas are discrete pools. Gas shows from the Milk River are very common over an area much greater than that containing completed Milk River gas wells and some of these shows are flows higher in volume than many of the tests of wells completed as gas wells. Some of the wells have been completed and classified as gas wells with air-flow tests of a mere 9 M cf/day. With such standards, possibly the entire belt down-dip from the sand/silt transition could be rated as one areally extensive gas field.

The gas shows suggest that the silt facies of the formation is saturated with gas over a belt at least 60 miles wide. The northeastern limit to the area of potential gas in unknown and, although one might anticipate a decrease in silt content in that direction, mechanical logs reveal the same character to the northeast, well into Saskatchewan. The northwestern limit of commercial gas will be controlled by economics even if the geological conditions do not change. Virtually all of the wells completed as Milk River gas wells lie in an area where the formation is roughly 1,000 feet from the surface. To the northwest, the formation dip, together with a topographic rise, carried the zone below economic range.

Until many more cores are obtained, geology can be of little help in estimating reserves. Some empirical method will perhaps be worked out to relate net pay or deliverability to mechanical logs. In the meantime engineering data and production history must be the main criteria in calculating reserves.

[1]Meyboom, P.: Geology and groundwater resources of the Milk River sandstone in southern Alberta; Res. Council Alberta, Mem. 2 (1960).

[2]Figure 12-10 in Geological History of western Canada; Amer. Assoc. Petrol. Geol., Ed. R.G. McCrossan et al.

61. A PRELIMINARY EVALUATION OF THE APPLICABILITY OF THE HELIUM SURVEY TECHNIQUE TO PROSPECTING FOR PETROLEUM

Project 720064

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Introduction

A co-operative study by the Geological Survey of Canada, Chemical Projects Limited* and the National Research Council was undertaken in the summer and fall of 1972 in order to make a preliminary field evaluation of a surface geochemical prospecting technique being developed by Chemical Projects Limited. The tests were carried out over a known oil and gas pool, and in an area with numerous wells but no discovered oil or gas pools.

The conceptual model proposed by Chemical Projects Limited for this exploration technique assumes a constant flux of radiogenic helium from the lithologic column including the crust. Evidence for this flux is found in the sea[1] where the concentration of dissolved helium increases with depth and in the atmosphere where the helium level (5,200 ppb) remains essentially constant despite the continuous loss of helium to outer space. The concept assumes that helium is trapped in the lithologic column in a manner similar to oil and gas. This assumption is supported by the fact that helium tends to accumulate in oil and natural gas reservoirs in concentrations of up to several thousand parts per million.

Because helium has a small atomic radius and is chemically inert, it is presumed to diffuse upward through the cap rocks to the surface where it locally increases the general helium flux, and produces anomalies that can be measured and mapped. These anomalies are identified by obtaining soil-gas samples at or near the ground surface (<3 ft.) and determining the total amount of helium present in these samples. The anomalies are areas of relatively high concentration.

The two areas tested, Bowden and Carseland, were chosen by the Geological Survey of Canada because a well-defined oil/gas pool, the Innisfail Field, has been found in the first area and significant quantities of oil and gas have not been found in the second area. The Innisfail pool is a bioherm of Late Devonian age (Leduc Formation) with an area of 7,000 acres. The elevation of the gas/oil contact is -5,345 feet (at a depth of approximately 8,450 ft.) and the oil/water contact is 145 feet lower. The estimated oil in place is 128 million stock tank barrels, of which 64 million barrels are recoverable. The analysis of the gas cap by the Alberta Oil and Gas Conservation Board shows a helium content of 0.06% (600,000 ppb) by volume.

The Carseland area contains a number of dry holes in the vicinity of the test area, some of which had minor gas shows when drill stem tested, but nothing approaching that required for economic production. It was assumed, on the basis of this testing, to be an area of low potential with respect to commercial amounts of oil and/or gas.

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Method

The soil gas samples were collected using two methods:

1. Probes were hammered 3 feet into the ground, a foot valve opened, and a 2.8 c.c. sample of interstitial soil gas removed and stored.
2. Extruded aluminum cylinders were hammered 6 inches into the soil with the open end down, leaving an air space at the top. These were left for one week after which a hole was punched through the top of the can and a gas sample removed and stored.

Chemical Projects has developed a device for gas sample collection and storage called the Bistable Gas Sampler(R) which consists of two 2-inch concave stainless steel discs welded together along the edges with a small needle inserted in the teld. When the container is snapped, one disc changes from concave to convex, drawing in the gas sample. The sample can be expelled by squeezing the container; storage is accomplished by crimping a soft metal section of the needle.

A number of different sampling patterns were used:

1) Lines across pools in which the length of the line off the pool was four times the length of the portion overlying the pool. Samples were taken 0.2 mile apart;
2) Pairs of lines two miles in length at right angles to each other. The samples were spaced 200 feet apart.
3) Pairs of lines one mile long at right angles to each other. The sample spacing was varied from 1 foot for the first 10 feet, to 10 feet for the next hundred feet, to 100 feet for the next 1,000 feet, and five samples were collected 1,000 feet apart;
4) Grid samples, with the spacing between samples ranging from 6 inches to 200 feet apart.

In all the above sampling arrangements, a large number of duplicates were taken (usually at every third station) in order to test whether or not the results could be reproduced. All the above patterns also were sampled over, adjacent to, and away from oil and/or gas pools.

The prospecting method was tested with respect to the sampling, and analytical accuracy, and dependability, as well as the relationship of the helium anomalies to oil and/or gas pools. The helium content of the air was assumed to be constant, and daily air samples were taken to check this. As well, many additional air samples were taken, and included in the soil sample sets. To test the accuracy of the analysis (and partly the dependability of the sample containers), twenty samples were taken in a geochemical laboratory in which there was a high helium concentration in the air. This concentration was assumed to be constant during the two-minute period in which the samples were collected. All the soil gas samples, extra air samples, and laboratory samples were randomly numbered before being submitted for analysis in order to eliminate any possibility of bias in the analysis.

For the first part of the test (in the Innisfail area), both probe and extruded aluminum can samples were taken in an attempt to find which of the two methods gave the better results. The probe method was quick and easy, as the sample was recovered immediately, requiring only one sampling traverse through an area.

However, difficulty was experienced due to probe breakage and to the probe plugging in wet ground, with the result that the sample quality was always in doubt. The cans required a two-step operation:

The cans were planted in the desired patterns, and the date of planting recorded;
They were then left a week to allow equalization of helium concentration in the air space at the top of the can.

Following this seven-day implanation period, the tops of the cans were punctured, and a gas sample removed. Although this can method was more time consuming, the results were better than with the probe method. Because of the poor results from the probes, none of this type was taken in the Carseland area.

The helium content of the samples was analyzed by a mass-spectrometer especially designed and modified to do rapid analysis.

Results

Data were obtained for 923 probe samples and 1,378 samples taken in cans as well as 25 air samples from the field and 20 air samples taken in a laboratory which had an anomalous helium concentration. The probe samples had helium contents ranging from 0 to 800 parts per billion (all data reported relative to the helium content in air) and that of the samples taken in cans ranged from 0 to 1,000 parts per billion. Of the 25 air samples taken in the field, four were above the normal air level of 5,200 parts per billion (40, 50, 50 and 120 ppb above); and of the 20 samples taken in the high helium atmosphere in the laboratory, three were zero, one was 2,500 and the other sixteen ranged from 5,500 to 6,400 parts per billion.

The results of the samples taken in the laboratory showed that 20 per cent of the values were in error. Part of this error was probably due to leakage of the container, as a stage in the construction of the containers was found to be damaging some of them (this has since been rectified). The rest of the error must be attributed to the analysis.

The data were then examined statistically and were found to be neither normally nor log-normally distributed, which precluded the possibility of using most common statistical tests. However, one test, the Kolmogorov-Smirnov test, is a non-parametric statistical test which has been used successfully in interpreting geochemical data. In this test, cumulative percentage frequency histograms are examined to see if two data sets are similar enough to be from the same population. (R.G. Garret, pers. comm.).

The duplicate field samples were examined using this test and the two sets (i.e. all the first samples at each station as one set, and all the second samples as the other set) were found to be from the same population. Because the test examines the distribution of each set and does not compare the samples from one station to each other, the test says nothing about duplication between two samples, and the two sets do appear similar. However, when each sample was compared with its duplicate, there were a large number of pairs that had large differences in helium content. This was especially true for the duplicate probe samples, and indicated that the values obtained from the probe samples were not reliable. (A close examination of the results of the probe samples showed very poor reproducibility of the values between duplicate samples, and in a group of fifty very closely spaced samples - area 3 feet by 5 feet - the values ranged from 0-400 ppb, with 74% of the values zero).

The Kolmogorov-Smirnov test was also applied to other groups of samples, and the following results were obtained:

1. Can samples over the oil and/or gas pool in the Bowden area were from a different and higher valued population than the can samples away from the pool.
2. Can samples in the petroliferous Bowden area were from a different and higher valued population than those in the barren Carseland area.
3. Probe samples over the oil and/or gas pool in the Bowden area were from a different and lower value population than those away from the pool. This result is probably due to a higher sampling error in the samples over the pool than away from the pool, due to the wetter ground in the area of the pool.

Conclusions

The preliminary test of this prospecting technique showed a measurable amount of helium present in the soil gas, and that the amount varied in concentration in different areas. The samples taken using a three-foot probe inserted in the soil were found to be undependable, but samples collected from shallow-planted cylindrical cans proved to be reasonably reliable because of smaller variance between duplicates.

The mean of the can sample values taken over the oil and gas pool was significantly higher than the mean of the values from can samples taken in an area presumed to be barren of oil and gas. This is empirical evidence that the conceptual model is valid, and that the sampling and analytical techniques are capable of determining regional differences in concentrations of helium in soil gas.

More data from other productive and barren areas must be obtained in order to firmly establish whether or not the correlations observed are general and predictable. Also, testing must be done to determine whether or not helium may be trapped in a reservoir without hydrocarbons being present. The errors found in either the sampling storage or analysis was high, but a substantial amount has been eliminated by improving the construction of the sample container. Further development is required (and is presently being done) on the sample collection technique, which should greatly improve the duplication of results.

[1] Bieri, R.H., Koide, M., and Goldberg, E.D.: The Noble Gas Contents of Pacific Seawaters, J. Geophys. Res., v. 71, no. 22, p. 5243-5265, (1966).

62. THE KIRKJUFELL ERUPTION, ICELAND, 1973

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Three members of the Geological Survey of Canada had the unique opportunity to witness the eruption of "Kirkjufell" - Iceland's newest volcano (Figs. 1 and 2) on the island of Heimaey, the largest of the Westmann Islands. For five days, between January 30 and February 6, 1973, observations were made of the explosive eruptions from the central vents, the formation and deposition of tephra, the nature and movement of the lava flow and resulting devastation in the town of Vestmannaeyjar. This experience provides an invaluable background for understanding and interpreting the structures and processes that formed older volcanic rocks. A short 16 mm colour movie film, documenting the eruption, is in preparation and will be on permanent file at the Geological Survey of Canada.

The eruption, which was preceded by a swarm of small earthquakes, began at about 2:00 A.M. January 23. It started with fountaining along the entire length of a 1,500-metre fissure, but within a half a day the activity concentrated along the middle part of the fissure in three main vents[1]. The early phases of the eruption were dominated by pyroclastic activity which during the first week built a cinder cone 160 metres high. Damage to the town of Vestmannaeyjar during this period mainly resulted from fires started by glowing bombs falling through windows and roofs of buildings, complete burial of homes and collapse of roofs by the weight of thick tephra accumulations.

Figure 1. Looking southeasterly over the town of Vestmannaeyjar with Kirkjufell in the background. Billowing clouds of steam issuing from lava flows entering the harbour.

Figure 2. Twin eruption plumes of Kirkjufell viewed from the inner harbour.

Later phases of the eruption were dominated by the lava flow which at first flowed harmlessly eastward into the ocean but later turned northward and encroached upon the town and the harbour. The lava formed a very rough, clinkery, viscous flow of the aa type, which during the early part of the eruption had the composition of Hawaiite but gradually changed to a more normal basalt[2]. The rate of flow was estimated to be 60 cubic metres per second and by February 13th it covered an area of 3 square kilometres and its volume was 110 million cubic metres[2].

This volcanic eruption has destroyed the town of Vestmannaeyjar, ruined the fish packing industry and closed-off the harbour which was vital to Iceland's fishing industry.

[1] Thorarinsson, S., Steinthorsson, S., Einarsson, T., Kristmannsdottir, H., Oskarsson, N.: The eruption of Heimaey, Iceland; Nature, v. 241, p. 372-375 (1973).

[2] Thorarinsson, S.: Helgafell volcanic eruption; Smithsonian Institution; Centre for short lived phenomea, Event 11-73, no. 1567, Feb. 13 (1973).

63. MICA GROUP MINERALS AND RELATED SILICATES IN CANADIAN MINERAL DEPOSITS

Project 700067

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Laboratory research on specimens collected during field seasons of 1970-71-72 continued with: Petrological study of thin sections in order to determine genetic relationships between mica and ore in mineralized rocks; and study of replacement of silicates by oxides and electron probe study of mica - (Fe, Ni) S - H_2O reactions on specimens from oxidizing environment pertaining to the origin of lateritic nickel deposits.

1. Optical study of the relationship between ore minerals and micas. Selection of specimens for mineral concentration and analyses.

In addition to pyrrhotite-pentlandite-spinel-serpentine-mica associations selected for research and described in previous reports[1], the following suites of thin sections were studied and suitable specimens selected for research:

Commodity	Deposit (Mines) Location (NTS map-sheet)	Mica Paragenesis
Pb-Zn	Anvil-Faro, Yukon (105)	Ore-Bio-Chl.-
	" " "	Musc.-Ser.;
"	Sullivan, B.C. (82)	Ore-Ser.-
	" "	Musc.-Bio.-
	" "	Phlg.-Chl.;
Au-Sb	Giant Yellowknife, N.W.T. (85)	Ore-Musc.-
	" " "	Ser.-Flds.;
Cu-Ni $\mp$ Cu-Zn	Lynn Lake, Fox Lake, Man. (64)	Po-Cpy. $\mp$
	" " " " "	Sph.-Oxides-
	" " " " "	Hbl.-Amph.-
	" " " " "	Bio.-Chl.-
	" " " " "	Ol.-Phl.;
Cu-Zn-Au-Ag-Cd-Se-Te	Flin Flon, Chisel, Anderson L., Man. (63)	Py.-Cpy.-
		Sph.-Chl.-
	" " " " "	Ser.-Musc.-
	" " " " "	Bio.-Amph.-
	" " " " "	Kyan.-Sill.-
	" " " " "	Staur.-Garnet
Co-Ni	Werner Lake, Ont. (52)	(Co, Ni, Fe)
	" " "	S-Bio.-Phlg.-
	" " "	Hbl.-Amph.-
	" " "	Ol.-Spin.

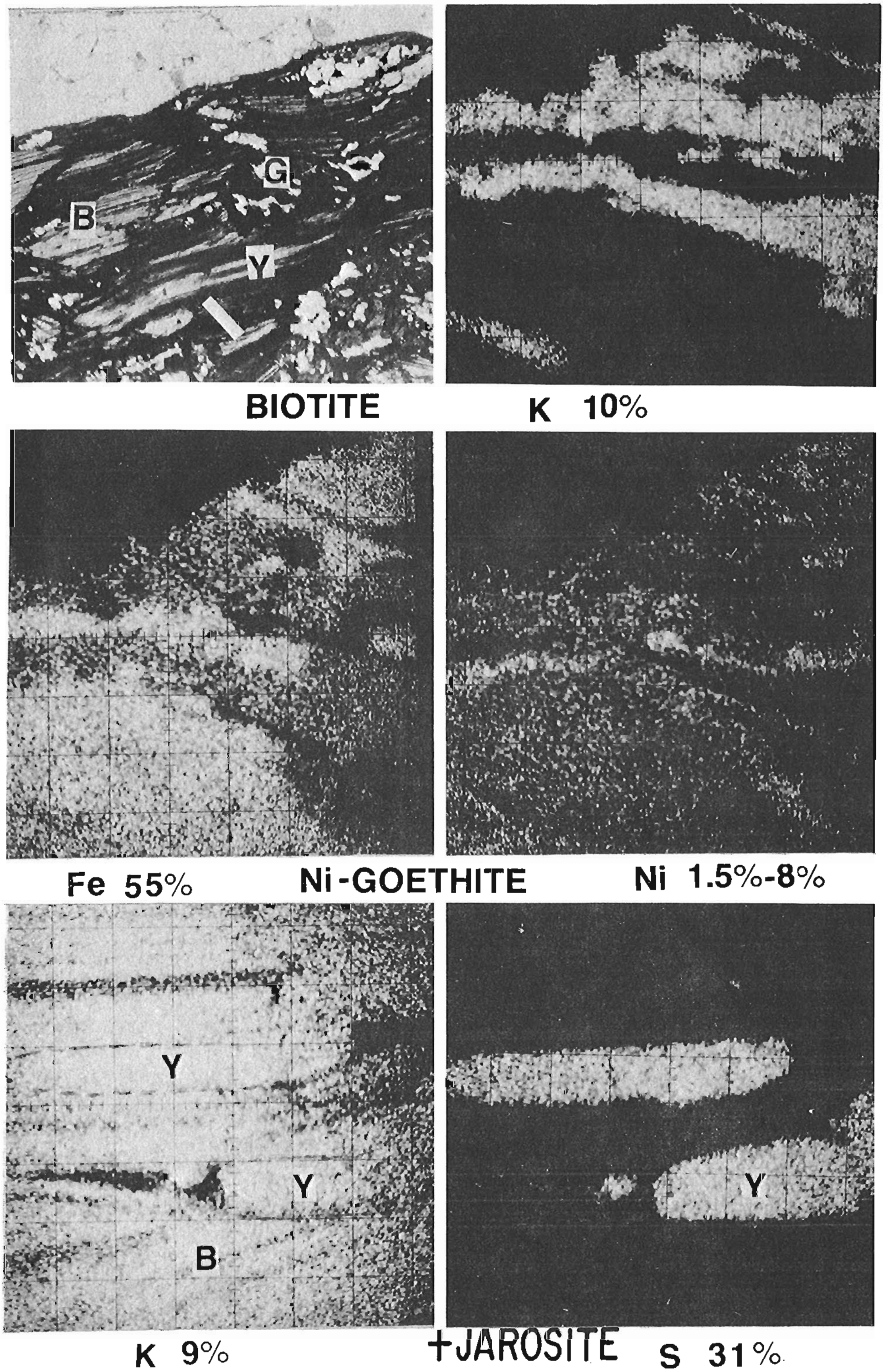
B
G
Y
BIOTITE
K 10%
Fe 55%
Ni-GOETHITE
Ni 1.5%-8%
Y
Y
B
Y
K 9%
+JAROSITE
S 31%

Figure 1 (opposite). Upper left, photomicrograph of biotite (B) partly altered to goethite (G) and jarosite (Y), (x 50); and X-ray scanning pictures for K, Fe, Ni, and S showing the distribution of the oxides and variation of Ni% in goethite. Scanning area 150 x 150 microns. Electron probe analysis by G.R. Lachance.

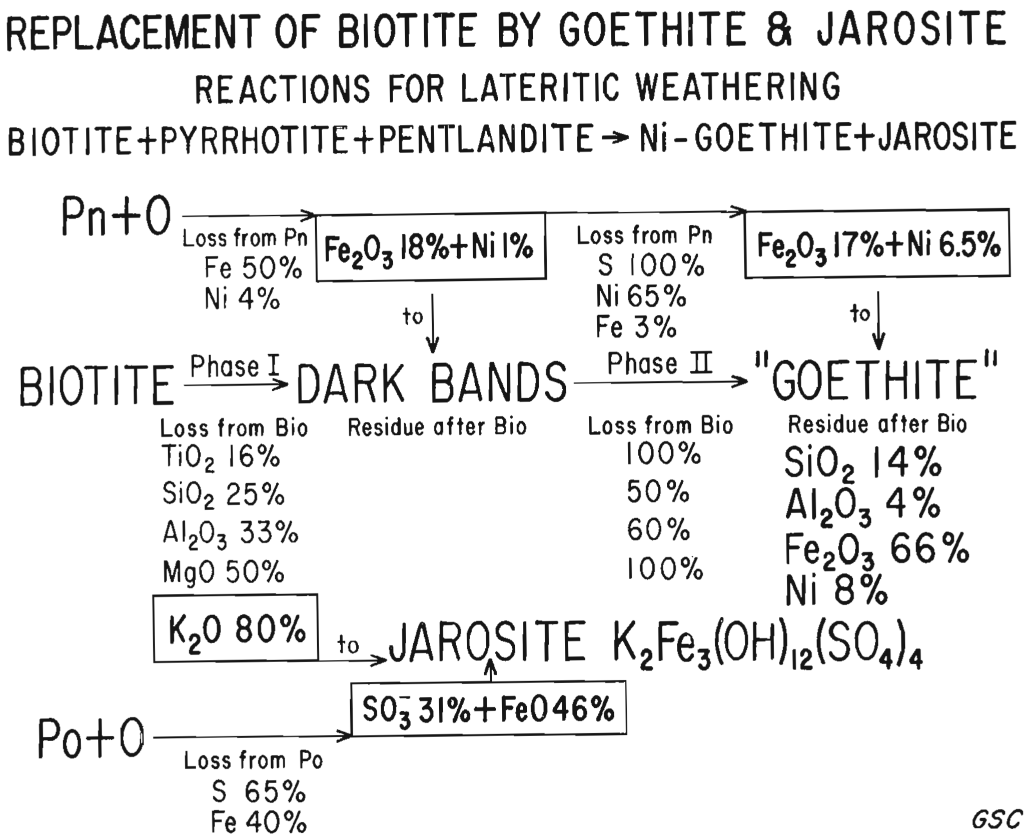

Figure 2. Suggested reactions for the first (initial) and second (advanced) phases of replacement of biotite by jarosite and goethite. Iron, Ni and SO_3^- supplied by partly-decomposed and oxidized pyrrhotite (Po) and pentlandite (Pn).

2. Replacement of silicates by oxides and electron probe study of Mica– (Fe, Ni) S-H_2O reactions on natural specimens from oxidizing environment pertaining to the origin of lateritic mineral deposits.

In many ore deposits, silicates are replaced by oxides and/or sulphides. Micas in particular are frequent hosts for ore minerals. The replacement is in part mechanical (ore minerals enter into fractures of the mica) and/or chemical when ore gradually replaces the silicate. The replacement mechanism and related chemical changes were studied by electron microprobe in polished thin sections and by classical chemical analyses of concentrates prepared from fresh remnants of mica and on portions replaced by hematite, Ni-goethite and jarosite.

2a. Replacement of phlogopite by hematite.

Chemical analyses have been completed of fresh phlogopite and of the altered surface layer of the same phlogopite which was coated with hematite crusts. The analyses indicate the following losses of ions from the altered portions of the phlogopite:

(i) total removal of K, Na, and Mn;
(ii) 50% to 75% loss of Ti and F;
(iii) 50% or less loss of Si, Al and Rb.

The hematite coating contains increased quantities of Ni (800 ppm) and Zn (8,000 ppm) as well as chert and carbonate impurities. The latter account for increased Sr content in the altered surface layer of the phlogopite. This study provides quantitative data on fluorine, alkalis and the other ions removed from the mica lattice during its replacement by hematite in an oxidizing environment, and suggests that high pH due to liberated potassium on the surface of the phlogopite provided favourable conditions for precipitation of iron and crystallization of hematite plates of the coating.

2b. Replacement of biotite by nickeliferous goethite and jarosite in the oxidation zone.

In the oxidation zone of a selected Ni-deposit, rocks are crumbling to red and yellow fragments with a strong odour of sulphur. Red crusts and bright yellow powder were identified by X-ray methods as goethite and jarosite. Electron probe microanalyses of polished thin sections prepared from mineralized biotite schist in various degrees of oxidation and disintegration indicated gradual replacement of biotite by goethite and jarosite along basal cleavage planes. At the initial stage of alteration, the biotite consists of dark (altered) and lighter (fresh) bands (Fig. 1). Dark bands are partly coated by Fe-hydroxides, resembling the replacement of mica by hematite as described above. With increasing degree of alteration and replacement, the goethite content in dark bands increases and jarosite lenses form in basal fractures of remnant biotite. The goethite adjacent to biotite contains higher concentrations of nickel (ca 8%) which can be seen in the X-ray scanning picture for Ni in Figure 1, left. The jarosite retains much of the potassium released from the host biotite and part of the oxidized sulphur released from decomposed (Fe, Ni)-Sulphides (lower part of Fig. 1). The suggested replacement mechanism of biotite by jarosite and goethite at the initial and advanced phases is illustrated in a diagram in Figure 2.

At the initial stage (phase 1), biotite loses mainly alkalis which increases the pH of circulating aqueous solutions thereby providing favourable conditions for the removal of silica and precipitation of iron along biotite fractures (dark bands). The iron, nickel and sulphur are supplied by Fe, Ni-sulphides which become unstable in the hydrous oxidizing environment. With advancing oxidation (second phase), potassium liberated from the biotite reacts with sulphur and iron released from sulphides to form jarosite. These reactions continue till primary silicates are replaced by hydroxides and the rock crumbles to small fragments, red crusts and powder. In the proposed mechanism of replacement, sulphides act as a supplier of Fe, Ni and S, and the biotite is both a supplier (of K) and a host for jarosite and goethite.

64. FABRIC FROM MAGNETIC ANISOTROPY: SULPHIDE DEPOSITS NEAR SUDBURY, ONTARIO

Project 700054

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The magnetic anisotropy of a number of sulphide ore deposits has been studied in order to use this parameter in the determination of the fabric of these deposits.

The magnetic minerals in massive sulphide deposits are usually magnetite (Fe_3O_4) and pyrrhotite ($Fe_{1-x}S$; where x=0 to 0.125). Magnetite is cubic so the various crystallographic directions show very little difference in magnetic susceptibility. The shape of the magnetite grains, however, usually produces a directional difference in susceptibility. On the other hand, pyrrhotite of type Fe_7S_8 (where x= 0.125) shows extremely large differences in susceptibility between directions in the basal plane and those at the right angles to this plane (c axis). In this case the shape of the individual pyrrhotite grains has a negligible effect on the total directional differences. The other commonly observed pyrrhotite type (Fe_9S_{10}; x=0.10) is very weakly magnetic so its effect can be ignored even though it may be intergrown with Fe_7S_8. This is because the intergrowths are parallel to the basal plane of the Fe_7S_8 and thus do not affect the high-susceptibility directions of the Fe_7S_8 pyrrhotite type. Difference in directional susceptibility (k) is called magnetic anisotropy and is usually defined as k maximal/k minimal. Consequently, the expectation is that a substantial (k max/k min > 1.1) anisotropy in deposits containing both Fe_3O_4 and Fe_7O_8 indicate: Preferred alignment of pyrrhotite crystals, and/or layering of randomly oriented pyrrhotite crystals.

Very high anisotropies (e.g. k max/k min = 1.5 or more) are likely to indicate crystal alignment rather than layering only. Both possibilities should give essentially uniaxial anisotropies that can be represented as oblate ellipsoids.

The anisotropy of magnetic susceptibility is rapidly and conveniently determined by measuring the susceptibility in various (at least 6) directions in a sample. The susceptibility values are used to calculate an ellipsoid which is comparable to the indicatrix obtained by measuring indices of refraction in optical mineralogy. The next step is the computation of the magnitudes and directions of the three principal axes of the susceptibility ellipsoid and their directions in terms of the geographic coordinate system if the field-orientation of the samples is known.

Initial testing of this method on sulphide deposits was carried out on samples from four deposits in the Sudbury area. The results show good within sample consistency and accuracy and the results fall into three groups:

1. Those with a concentration of minimal susceptibility directions suggesting a tendency for basal plan orientation (and/or layering of Fe_7S_8) parallel to the lower norite contact, e.g. the Strathcona deposit.
2. Those with a concentration of intermediate susceptibility directions and a girdle of minimal susceptibility directions e.g., the Falconbridge deposit. This pattern is consistent with the occurrence of a large east-west fault at Falconbridge.

3. Those with a concentration of maximum susceptibility directions at right angles to, and random distribution of the intermediate and minimum directions in, the horizontal plane, e.g. Copper Cliff North and Little Stobie deposits. In terms of stress distribution, these patterns would suggest tension along the vertical in the Copper Cliff North and to some extent in the Little Stobie deposits. The Copper Cliff North deposit is enclosed in a vertical plate-like off-shoot of the differentiated norite complex.

The three different anisotropy patterns correspond to at least three different geological environments but final interpretation must await the completion of the testing. The marked tendency for k maximal/k intermediate to be substantially smaller than k intermediate/k minimal suggests a tendency for uniaxial anistropy and indicates the presence of a simple, single anisotropy pattern in all three groups. The study of fabric in sulphide ore deposits should be valuable in tracing their geological history (i.e. the imprint of a period of metamorphism) and therefore in understanding the geological framework of these deposits.

65. A MILLERITE OCCURRENCE IN OVERBURDEN NORTHEAST OF TIMMINS, ONTARIO

Project 710080

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Results from the 1971-72 winter works overburden drilling and geochemical sampling project in the Abitibi were released in November 1972[1]. Follow-up, in progress, involving microscopic examination of excess sample material included a drill hole (FH-68) in Gowan Township, Ontario. This hole is interesting because of its high Ni-Cu values. The geochemical and sediment stratigraphy of hole FH-68 is shown below.

HOLE - FH - 68 GOWAN TOWNSHIP, ONTARIO FRACTION E

SAMPLE NUMBER	SEDIMENT TYPE	COPPER	LEAD	ZINC	COBALT	NICKEL	SILVER	DEPTH (FT.)
		PARTS PER MILLION						
6	4	70	40	60	55	65	1.5	61
7	3	100	25	73	45	55	1.6	65
8	3	310	20	187	44	80	1.8	72
9	3	155	25	87	45	50	1.8	74
10	1	140	30	33	38	40	1.8	75
11	3	130	28	70	35	40	1.8	79
12	1	230	28	100	45	55	1.9	81
13	1	230	48	83	55	95	1.9	84
14	1	205	35	90	78	80	1.9	86
15	1	170	27	73	60	70	1.9	88
17	1	145	40	53	65	60	2.0	92
18	1	60	70	80	55	50	1.7	96
19	1	145	318	193	55	90	1.5	100
21	1	270	50	118	70	137	12.5	106
22	1	175	30	112	99	348	1.7	110
23	1	95	318	168	60	106	1.7	114
24	1	130	49	340	55	80	1.6	118
25	1	160	55	80	50	75	1.4	121
26	3	105	43	50	30	35	1.5	126
27	3	85	33	98	64	60	2.0	127
32	3	1100	132	304	242	350	3.2	152
33	3	1200	448	635	458	480	3.7	156
35	3	4100	340	750	385	1540	4.2	164
37	3	4300	740	376	970	2090	6.1	172
38	3	12000	268	274	2500	35800	7.3	179

Sediment types: 1 - till; 3 - sandy till/sand/gravel; 4 - silt.

The values in the above table are for the heavy mineral fraction (S.G. $\geq$ 3.3; 60-250 mesh, minus magnetic grains). Rapid visual estimates of per cent of sulphides were done routinely in the field laboratory after removal of magnetic grains. A few grains of pyrite (<1% of heavy mineral fraction) occur in nearly every sample, however the lower few samples with high Ni-Cu values have significant amounts of sulphides (FH-68-32, 2%; -34, 10%; -35, 5%; - 38, 10%). The high nickel (3.5%) and copper (1.2%) in the heavy mineral separate of FH-68-38 prompted further study. Another heavy mineral separate was made from excess sample, then the grains mounted and polished. The polished section was examined by R. McLeod, Regional and Economic Division. He reports the following minerals in order of decreasing importance: magnetite (normally removed for geochemical analyses), pyrite, illmenite-rutile-leucoxene, millerite, pentlandite-chalcopyrite and others. Millerite, pentlandite and chalcopyrite occur in the same grains. In addition, rock chips (>10 mesh) were picked from the sample for polished sectioning. Because the heavy mineral separate contained so much magnetite (>50%), the rock chips were picked out of the bulk sample with the use of a magnet, thus selecting rock types most likely related to the high Ni-Cu-magnetite association. The mineralogy of these chips consists of a serpentine-talc matrix with abundant magnetite. Calcite and sulphides are present. One carbonate grain contained a millerite inclusion adjacent to a pentlandite-chalcopyrite grain. It is likely that this rock type is at least partly responsible for the high Ni-Cu values in FH-68.

The direction of glacial movement in the area was from west of north as suggested by the orientation of eskers and striations[2]. About one mile up-ice from FH-68 there is an aeromagnetic anomaly over serpentinized dunite where diamond drilling has indicated asbestos and pyrite[3]. This serpentinite could be the source of the millerite in till at FH-68. Eckstrand[4] has emphasized the potential of this rock-type for nickel mineralization.

[1] Skinner, R.G.: Drift prospecting in the Abitibi Clay Belt; Geol. Surv. Can., Open File 116 (1972).

[2] Boissonneau, A.N.: Surficial Geology of Algoma-Cochrane area; Ont. Dept. Lands and Forests, Map S365 (1965).

[3] Bright, E.G., and Hunt, D.S.: Gowan Township, District of Cochrane; Ont. Dept. Mines Northern Affairs, Prelim. Map P.729, Timmins Data Series, scale 1 inch to 1/4 mile. Data compiled 1971.

[4] Eckstrand, O.R.: The nickel potential of serpentinized ultramafic rocks; Can. Mining J., v. 92, no. 4, p. 40-42, 45 (1971).

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