GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY,
MINES AND RESOURCES

PAPER 69-1
Part B

REPORT OF ACTIVITIES,

Part B: November 1968 to March 1969

Price, $2.00

1969

CANADA

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ABSTRACT

This report comprises thirty-seven short papers that describe research carried out by members of the Geological Survey of Canada between November 1968 and March 1969.

REPORT OF ACTIVITIES,

Part B: November 1968 to March 1969

INTRODUCTION

The thirty-seven papers that comprise this report describe the results of scientific studies conducted by members of the Geological Survey between November 1968 and March 1969. Some of these reports are in the nature of 'progress reports' and discuss only one facet of a project whereas others are complete though brief statements on some aspect of geological research. The figures used to illustrate the papers that make up this publication are reproduced without change from material supplied by the authors. Manuscripts were accepted for inclusion in this report until 15 May, 1969.

The Report of Activities (parts A and B), the reports on isotopic and radiocarbon dating, the annual index of publications, and the volume of abstracts of papers published by Geological Survey personnel in non-Survey publications provide an annual accounting of most of the scientific work of the organization. Requests for announcement cards, geological reports, maps, or information on specific areas or topics should be addressed to: Geological Survey of Canada, Department of Energy, Mines and Resources, 601 Booth Street, Ottawa 4, Canada.

ANALYTICAL CHEMISTRY

1. ATOMIC ABSORPTION SPECTROSCOPY

Project 380077

Sydney Abbey

Wherever applicable, the general scheme described in Paper 68-20 has replaced the classical methods for Mg, Ca, Na and K, resulting in a substantial saving in time, effort and cost. Preparation of standard solutions has been simplified by using 'standard' rocks instead of pure reagents.

The hydrofluoric-perchloric method of decomposition is not suitable for silica determination, and probably not for alumina. A new method of decomposition was devised, based upon features of other published methods, for producing a sample solution containing all of the major elements, including silicon, in a form suitable for determination by atomic absorption. The method involves fusion with lithium metaborate, solution of the fusion in dilute hydrofluoric acid, and complexation of the excess hydrofluoric acid with boric acid. Good results have been obtained for K, Na, Ca, Mg and Al, and the method will probably be applicable to Fe, Si, Mn and possibly Ti, Cr, Ni, Ba, etc. It may be possible to use the same master solution to determine additional elements colorimetrically. Two hundred milligrams of sample would then be sufficient to determine all of the major components (except ferrous iron, water and CO_2) on most silicates. Modifications are being studied for determining some elements in those samples where they are present in unusual concentrations.

Equipment in use has been modified by the installation of a new type of nitrous oxide burner and of several hollow cathode lamps embodying the new shielded cathode design.

2. APPLICATION OF SPECTROCHEMICAL METHODS TO TRACE ELEMENTS DETERMINATIONS IN GEOLOGICAL MATERIALS

Project 380077

W.H. Champ

1. Our fractional distillation D.C. arc method for determining some fifteen elements in the ppm ranges in silicates has been improved by incorporation of a computer program to handle computation of the data obtained from microphotometric reading of the plates. This has considerably lessened the time required to complete these analyses and has reduced operator error in handling large masses of data to a minimum.

2. Our program for trace element analysis of silicates by direct reading spectrometry has been extended and now encompasses working curves for some twenty elements, as follows:

Al	.07 - 7 %	V	.007 - .7 %
Fe	.5 - 15	Ni	.01 - 1
Ca	.025 - 2.5	Zn	.05 - 10
Mg	.07 - 7	Cu	.002 - .25
Ti	.02 - 3	Y	.01 - 1
Mn	.01 - 1.5	Co	.007 - .5
Sr	.007 - .7	La	.05 - 3
Ba	.003 - .3	Pb	.1 - 5
Cr	.008 - .8	Yb	.003 - .3
Zr	.01 - 1	Be	.002 - .2

Analyses can be performed on as little as 50 mg of material. Precision is approximately the same as for the equivalent photographic methods, that is ± 15 per cent of amount reported, but results are obtainable in half the time, or better.

3. PRECONCENTRATION OF MICROGRAM AMOUNTS OF THE RARE EARTHS IN ROCKS FOR DETERMINATION BY INSTRUMENTAL METHODS

Project 380077

J. G. Sen Gupta

The direct determination of traces of the rare earths in rocks by spectrographic or X-ray fluorescence methods is difficult because of the poor sensitivities and complexity of spectra for most of these elements. A preliminary concentration of the rare earths prior to their determination by an instrumental method will improve the sensitivity and reduce the interferences.

A preconcentration technique involving tributyl phosphate extraction[1] was tried but, although the recovery was satisfactory for Y, La, Nd and Yb, the presence of impurities caused considerable dilution of the sample and insufficient spectrographic sensitivity for Ce, Sm, Gd, Pr and Sc.

An anion-exchange separation method developed by Korkisch and Arrhenius[2] was investigated. It was found advantageous to use a larger column, and to make a preliminary removal of iron, titanium, etc. as soluble complex fluorides. The recovery of most of the rare earths from the equivalent of 1 gram of synthetic rock sample was quantitative.

The optimum conditions necessary for obtaining pure rare earths by the anion-exchange method from 1-4 gram sample weights are presently under investigation.

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[1] Boyadjieva, R.: A method for the enrichment of the rare earth elements in silicate rocks by extraction with tributyl phosphate; Bull. Geol. Inst. Geochem., Mineral. Petrog.; Bulgarian Acad. Sci., vol. 16, pp. 45-52 (1967).

[2] Korkisch, J., and Arrhenius, G.. Separation of uranium, thorium, and the rare earth elements by anion-exchange; Anal. Chem., vol. 36, pp. 850-854 (1964).

COAL RESEARCH

4. BIOSTRATIGRAPHIC ZONATION OF THE HORTON GROUP BY MEANS OF FOSSIL SPORES

Project 680109

M.S. Barss

The oldest Mississippian rocks of the Atlantic Provinces are a succession of continental conglomerates, sandstones, and shales known as the Horton Group. The Horton Group is generally overlain by the distinctive marine limestones, shales, and evaporites of the Windsor Group, and its base is marked by a prominent angular unconformity with older metamorphic and igneous rocks.

The lack of diagnostic fossils and the rapid facies changes in these continental deposits made it extremely hazardous to correlate the subdivisions of the Horton. Recent miospore studies of the Horton Group type section on Avon River, Nova Scotia, suggested two distinctive assemblage zones. The type section, however, is only 4, 125 feet thick with large concealed sections. A study was therefore carried out on the best-exposed Horton section known, namely that along southwest Mabou River in western Cape Breton Island, where 8, 000 feet of strata occur.

The study of this section, together with additional information from the type section, and several other areas, has revealed that three, possibly four, miospore assemblages are present in the Horton Group. The lowest of these assemblages is considered to be Devonian in age. Thus the Horton can no longer be regarded as only lower Mississippian age. The miospore zones are fairly distinctive, enabling correlations to be made between the various subdivisions and numerous sections of Horton rocks in the Atlantic Provinces.

Further sampling and study has to be completed to determine the Devonian-Mississippian boundary within the group and to more accurately place the boundaries of the miospore zones.

5. COAL METAMORPHISM AND HYDROCARBON POTENTIAL IN THE UPPER PALEOZOIC OF THE ATLANTIC PROVINCES

Project 680102

P.A. Hacquebard and J.R. Donaldson

Coal rank is used to evaluate the hydrocarbon potential by applying the principles of the 'carbon ratio' theory. The rank was obtained from the vitrinite reflectance of true coal seams and coaly inclusions in sandstones. This permitted a regional and vertical rank study not only of the actual

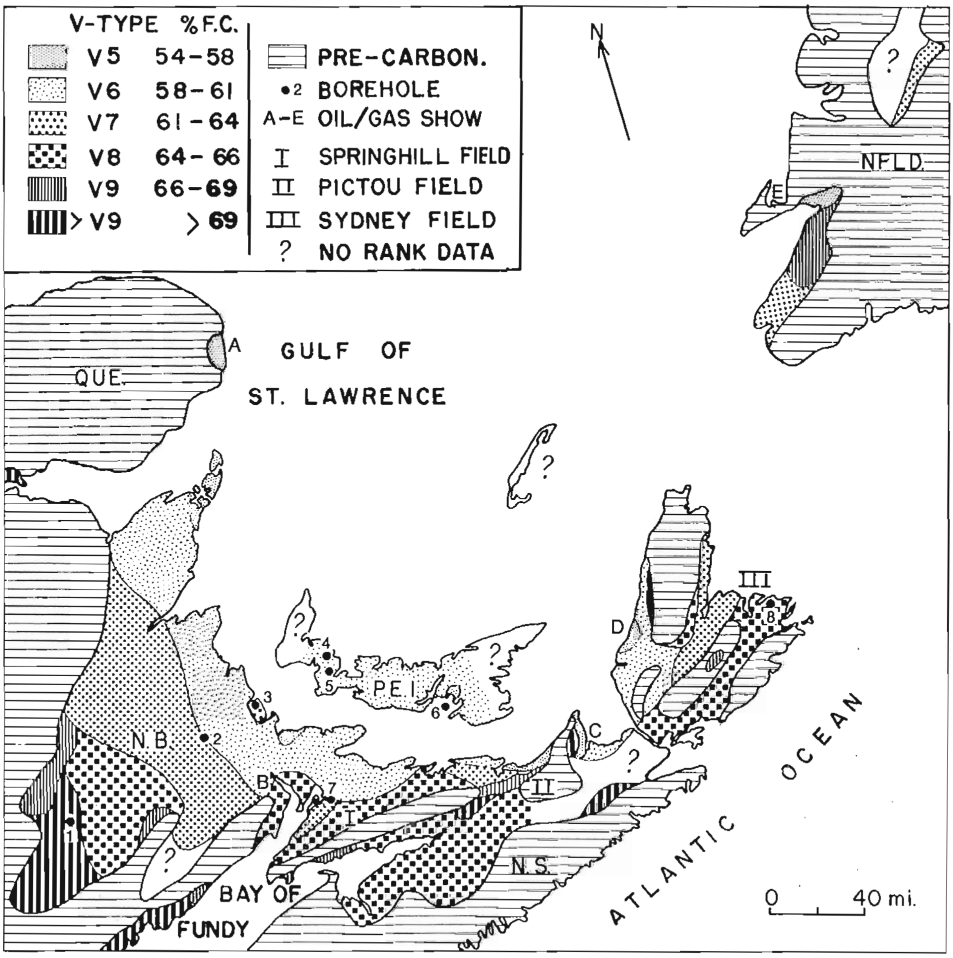

Figure 1. Isoreflectance map showing areas of equal coal metamorphism (V-types) in upper Paleozoic surface rocks of the Atlantic Provinces.

coalfields, but also of the non-productive areas of terrestrial deposition. Nearly the entire area of upper Paleozoic surface rocks could thus be included.

In the Atlantic region the coalification is predominantly postorogenic, being caused by the depth of overburden that existed after folding. The effect of preorogenic coalification, which is related to the original or stratigraphic depth, is only minor.

It was found that in coals possessing more than 62 per cent fixed carbon (F. C.) the increase in rank with depth can be measured with the reflectance (% Ro). Different Ro-depth factors were obtained in different areas, but all showed a progressive increase with a general advance on the coalification curve. The different factors could be equated with different geothermal gradients, that ranged from 34 to 46 m/1°C.

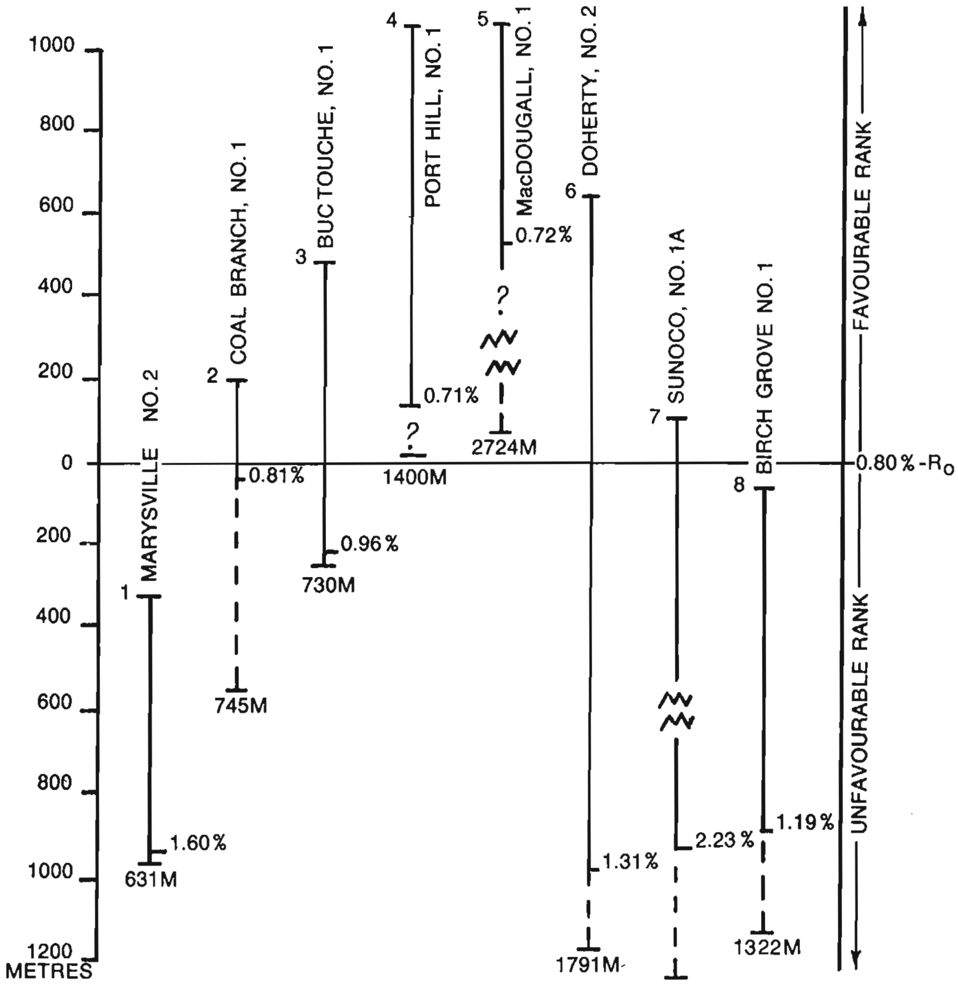

Figure 2. Total depths, maximum observed reflectances and position of oil 'deadline' (at 0.80 %-Ro) in exploration wells in New Brunswick and Nova Scotia.

In coals with less than 62 per cent F. C., rank predictions at depth from surface Ro data cannot be made. In these coals the reflectance parameter is less suitable, because it changes too slowly with a change in rank. However, on appropriate borehole samples the average rank can still be measured with the reflectance, and the metamorphic boundary for the occurrence of oil and gas be determined. This boundary, according to the 'carbon ratio' theory, lies at approximately 65 per cent F. C., or a reflectance of V 8. In the exploration wells, marked 1 to 8 in Figure 1, the hydrocarbon 'deadline' could thus be established. Its position, along the 0.80 per cent-Ro baseline, is shown in Figure 2.

The regional changes in metamorphism, when plotted on an isorank map (Fig. 1) show a distinct pattern, which in general conforms with the tectonic development of the Appalachian region. On this map only the areas below V 8 are considered to have a favourable degree of organic metamorphism for the occurrence of oil and gas. This is substantiated by the known occurrences of the region (marked A to E), which coincide with the areas of lowest metamorphism.

From the rank-depth relationships that have been found, it is obvious that the depth of any potential oil-bearing formation (of Paleozoic age) is of crucial importance in the Atlantic region. This depth is related to the rank of the surface sediments. The lower this rank, the deeper will be the subsurface position of the oil 'deadline'. The offshore regions in the Gulf of St. Lawrence appear to hold most promise, particularly in those parts where the marine pre-Pennsylvanian lies at shallow depth. As the Pennsylvanian and Permian are entirely continental, they are not regarded favourable for oil or gas accumulations.

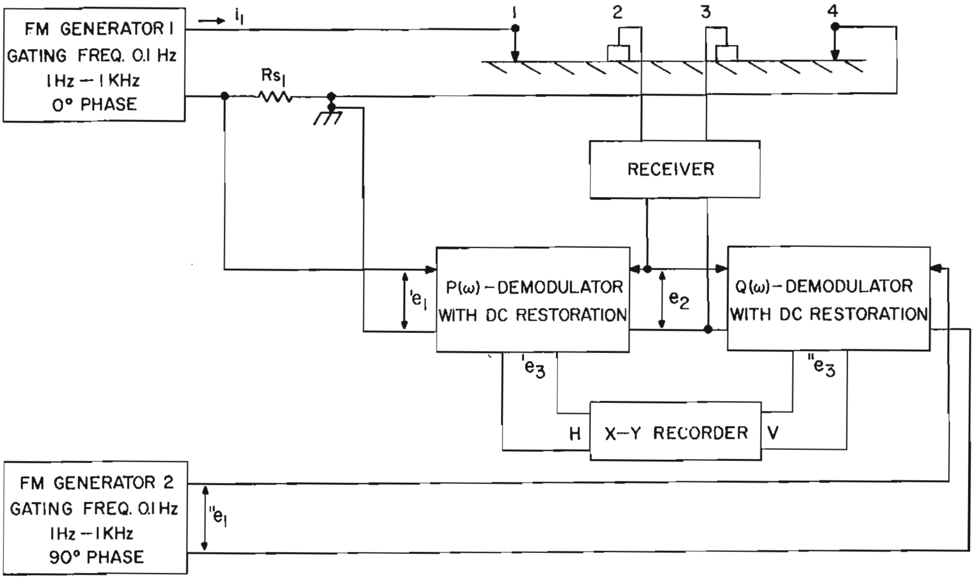

Figure 1. Block diagram of 'P-Q' demodulator.

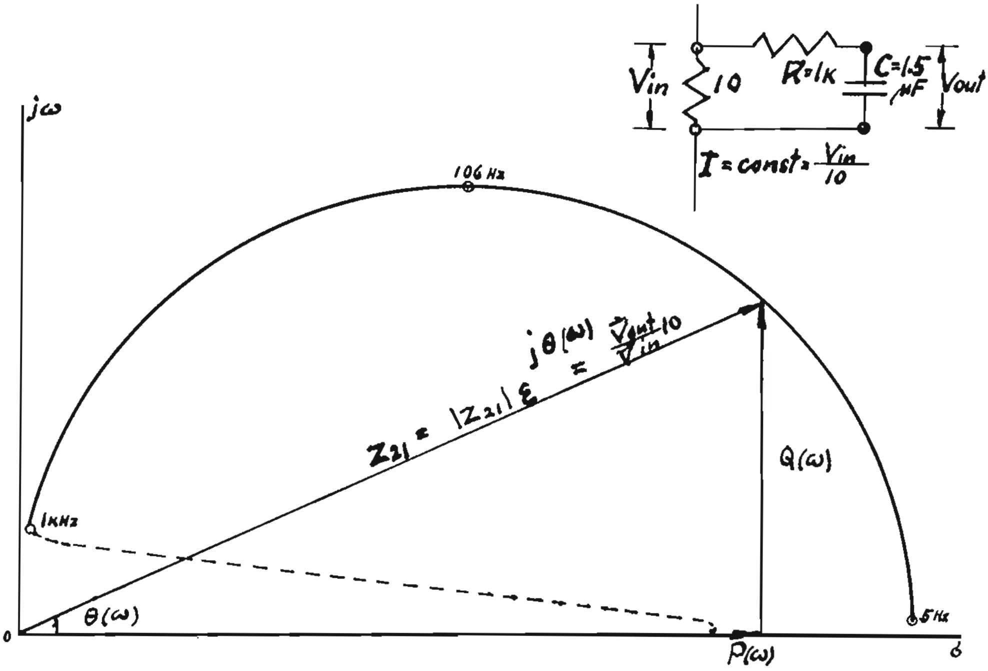

Figure 2. Transfer impedance X-Y plot of an RC-low-pass filter.

EXPLORATION GEOPHYSICS

6. TRANSFER FUNCTION PLOTTER

Project 620056

R.H. Ahrens

With the introduction of AC current methods in exploration geophysical field work using transmitting and receiving electrodes, the application of methods of network theory are practical and useful. Considering the investigated soil with its applied input and output electrodes as a 'black box', it is quite natural to relate the output voltage to the applied input current. Both magnitudes are vectors and therefore their ratio presents two measurements, the amplitude and the phase. By sweeping the transmitted frequency, both the amplitude value and phase angle vary. By plotting the vector in the complex plane each point on the curve represents three parameters, namely, amplitude, phase angle and frequency. The equipment can also be used for plotting one of the components of Z_{21}, P(w) or Q(w). There is a unique relation between either P(w) or Q(w) and the unit-step response A(t). Using the analysis in the paper by T. Murakami and M.S. Corrington (RCA Review, vol. 9, pp. 602-631, Dec. 1948) the transient response from P(w) or Q(w) can be computed. These facts led to the development of the 'Transfer Function Plotter' which may be illustrated in a simplified block-diagram of Figure 1. Figure 2 shows the XY-plot of an RC-low-pass filter using the transfer function plotter. The transfer function is defined by $Z_{21}(p) = \frac{L[l_2(t)]}{L[i_1(t)]}$, where p = jw for steady state condition. When evaluated,

$$Z_{21}(p) = \left| Z_{21}(jw) \right| \epsilon^{j\theta(w)} = P(w) + jQ(w)$$

$$\tan\theta(w) = \frac{Q(w)}{P(w)}$$

The sweep is controlled by a diode wave shaper for almost the full duration of frequency variable sine waves. In addition a point by point plot at crystal controlled frequencies from 0.3 Hz to 1 KHz is possible.

7. AIRBORNE GAMMA-RAY SPECTROMETRY AND GROUND SUPPORT OPERATIONS

Projects 670050, 670052

A. G. Darnley, R. L. Grasty and B. W. Charbonneau

Data collected over the five concrete calibration slabs at Uplands Airport, Ottawa with three different spectrometer-detector combinations have been analyzed to determine the Compton scattering corrections appropriate to each instrument and the various count rates per unit concentration for K, eU and eTh. The instruments for which comparative measurements have been made are a portable field spectrometer with a 3 x 3 inch NaI (Tl) detector; a helicopter-mounted unit with 3 (5 x 5) inch NaI (Tl); and a fixed-wing aircraft system with 12 (9 x 4) inch NaI (Tl).

The calculated values have been used to correct field data gathered in the summer of 1968 on 15 test sites in the Bancroft area of Ontario. A very good correlation has been obtained between ground and airborne results over areas of approximately 1/4 square mile showing that surface geochemistry can be carried out from the air. If necessary surface resolution could be finer. A sympathetic variation between K, eU and eTh content has been noted for the majority of rock types measured, including marble, metasediment and various basic and acid igneous rocks.

The only exceptions are nepheline syenite from Blue Mountain, notable for an unusually high K: (U + Th) ratio and syenite and marble containing small showings of uranium mineralization in the vicinity of the Silver Crater Mine west of Bancroft, which show abnormal U:Th ratios. This emphasizes the importance of reliable ratio measurements in radioactive mineral exploration.

8. RADIOISOTOPE X-RAY FLUORESCENCE ANALYSIS OF URANIUM AND THORIUM

Project 670053

A. G. Darnley, R. L. Grasty and L. Ostrihansky

Radioisotope X-ray fluorescence analysis can provide a direct estimate of the elemental concentration of uranium and thorium whereas gamma-ray spectrometry can make only an indirect measurement. Estimation of actual uranium and thorium concentration by gamma-ray spectrometry is based on an assumption that the respective radioactive decay series are in equilibrium. This assumption is not necessarily valid especially in the case of soils and weathered rock samples.

In order to investigate this problem further, and at the same time gain experience in a technique with potential field applications, a Ge (Li) solid state detector has been assembled for laboratory use with a ^{57}Co radioisotope source. Excellent resolution has been obtained (better than 900 eV) at the 100 keV level sufficient to resolve the individual UK_{α} and ThK_{α} spectral lines.

9. A HAMMER SEISMIC SURVEY, PENNFIELD AREA, NEW BRUNSWICK, 21 G/2

Project 680037

R.M. Gagné

The Pennfield project area is in the extreme southwestern portion of New Brunswick, approximately 40 miles west of Saint John and 29 miles east of St. Andrews. The survey was conducted June 4 to 18, 1968 to assist in the mapping of surficial deposits of map-sheet 21 G/2[1].

A portable seismograph, model FS-3, by Huntec Limited, was used to record all seismic data. Energy, generated by a 16-lb sledge hammer striking a steel plate on the ground, was detected through a single geophone channel and recorded by a moving stylus on electro-sensitive paper.

Eighty-four seismic stations were surveyed by single-ended profiles (Fig. 1). Surface elevation at these stations was obtained by altimeter carried from a geodetic bench mark.

The project area is underlain by a complex of sedimentary and volcanic intrusive rocks chiefly acidic to basic flows and tuffs. The age of these formations is Silurian, pre-Silurian and Precambrian[2]. During the Pleistocene, the Labrador ice sheet overrode the area leaving an overburden of unconsolidated glacial and glaciofluvial deposits of varying thickness; numerous kames, eskers and outwash plains have been left in the area.

The histogram of observed seismic velocities versus frequency of occurrence, Figure 2, indicates five possible ranges of apparent velocities and these have been correlated with Pleistocene materials and bedrock.

All five velocity groups are observed extensively over the area. In summary, the following table correlates velocity with formation:

layer	velocity range, feet per second	suggested material
1	300 - 1600	aerated surface zone
2	1600 - 4600	sand, gravel, boulders (dry)
3	4800 - 6500	clay, marine or other
4	6800 - 11,800	compacted glacial till
5	>12,000	bedrock undifferentiated

Layer 1 ranges in thickness between 1 foot and 12 feet over the area. In places, materials of layer 3 may be similar to those of layer 2 because the higher seismic velocity may be due to the fact that the materials are saturated with water. This layer is present where depth calculations show the existence of a bedrock 'low'. The existence of clay material at the bottom of

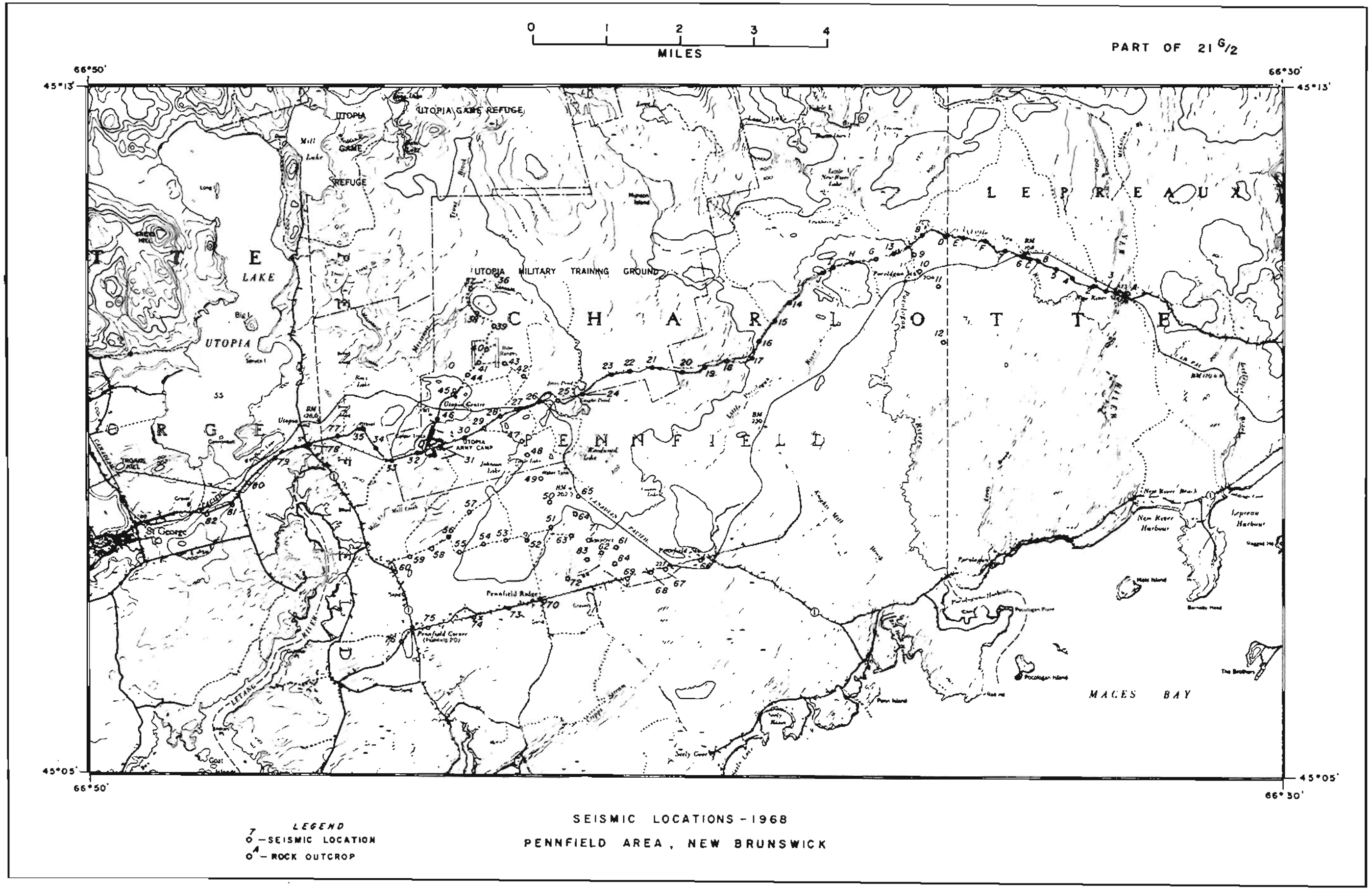

Figure 1. Seismic location map, Pennfield area, New Brunswick.

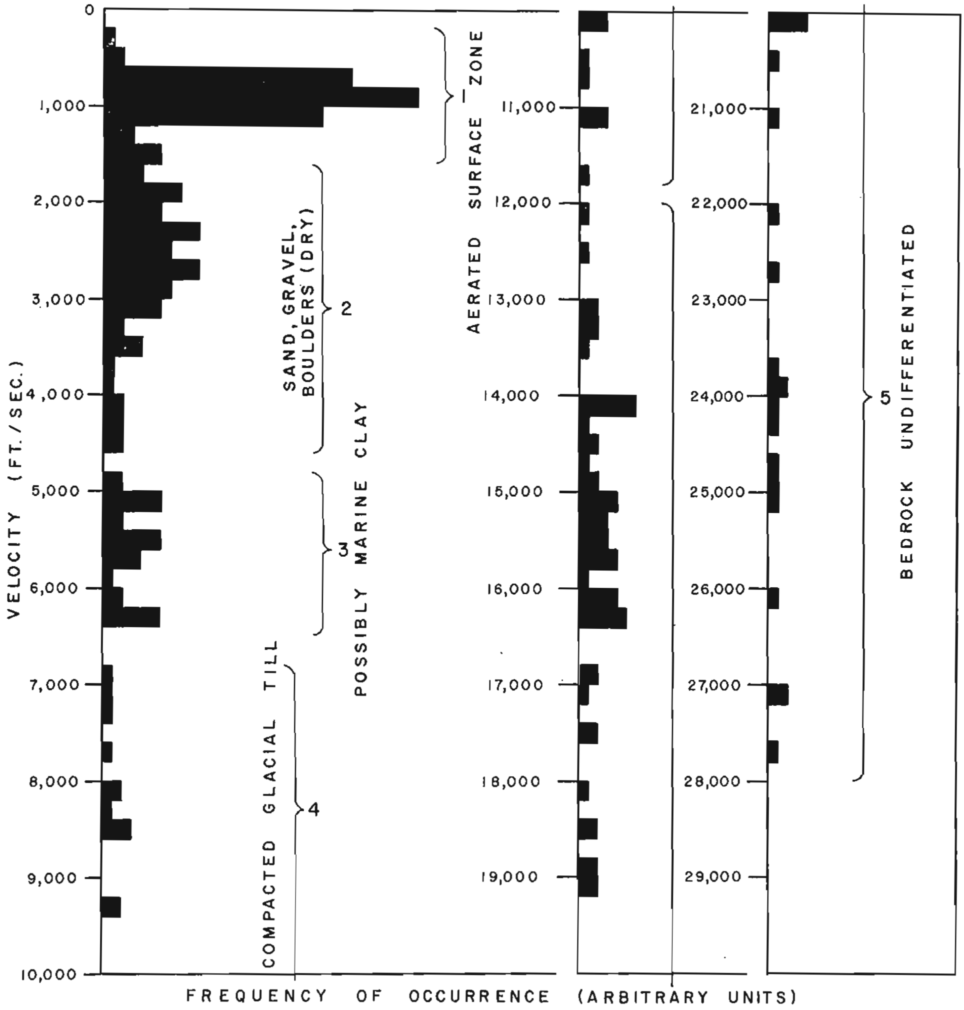

Figure 2. Histogram of observed velocities versus frequency of occurrence, Pennfield area.

some local gravel pits and marine clay exposures to the south of the project area lead the author to conclude that layer 3 is possibly a marine clay. Layer 4 was also found to be present in bedrock 'lows'; the relatively high velocity in this layer leads to the designation as a compacted glacial till. This same layer might also be a sand or gravel highly compacted and partially cemented by an early overriding ice sheet or perhaps a friable sandstone or a shale bedrock formation. These latter suggestions however are not upheld by any exposures of such rock in the area.

The results of this seismic survey are graphically portrayed by the sections of Figures 3, 4, and 5 and by the overburden thickness map (Fig. 6). An attempt was made to contour the bedrock topography but this was abandoned due to a lack of sufficient control. The overburden thickness map

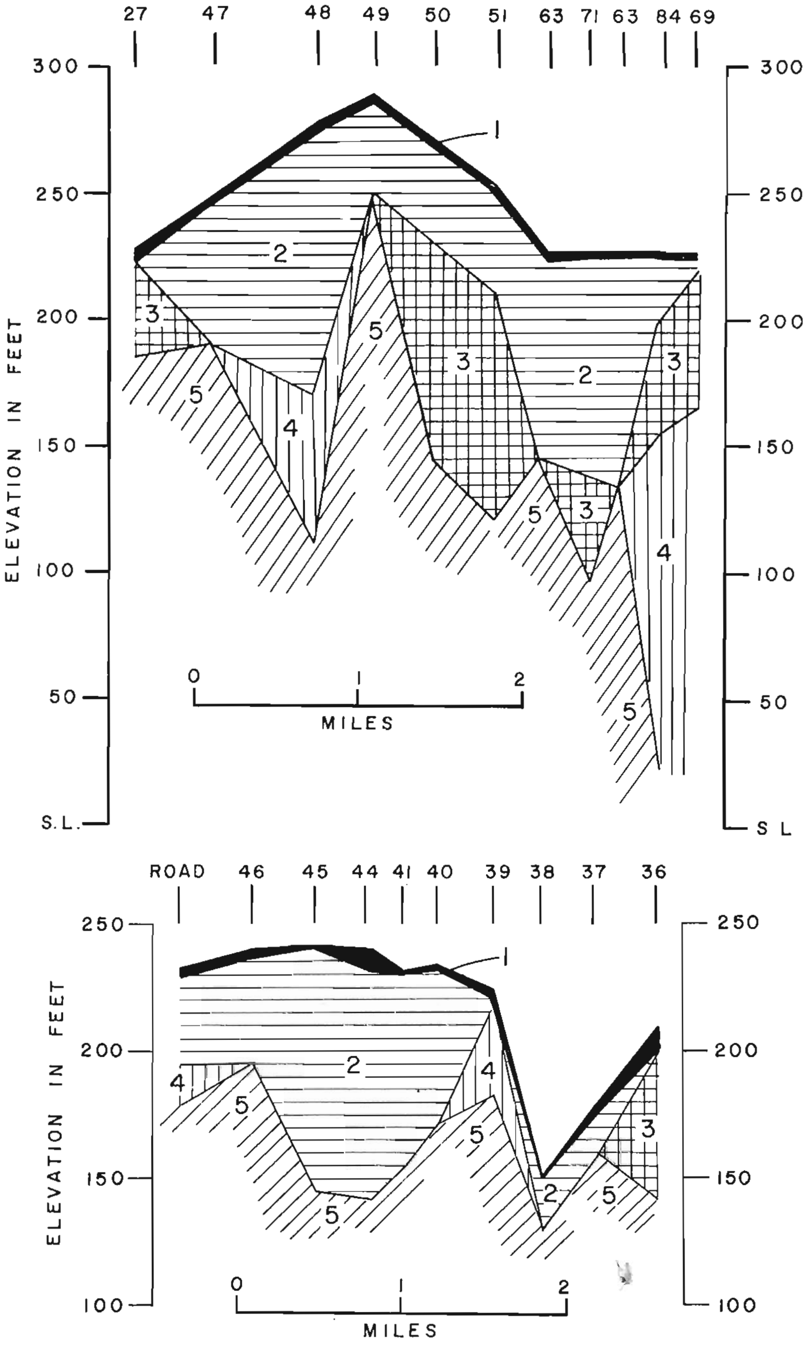

Figure 3. Seismic section, Pennfield area.

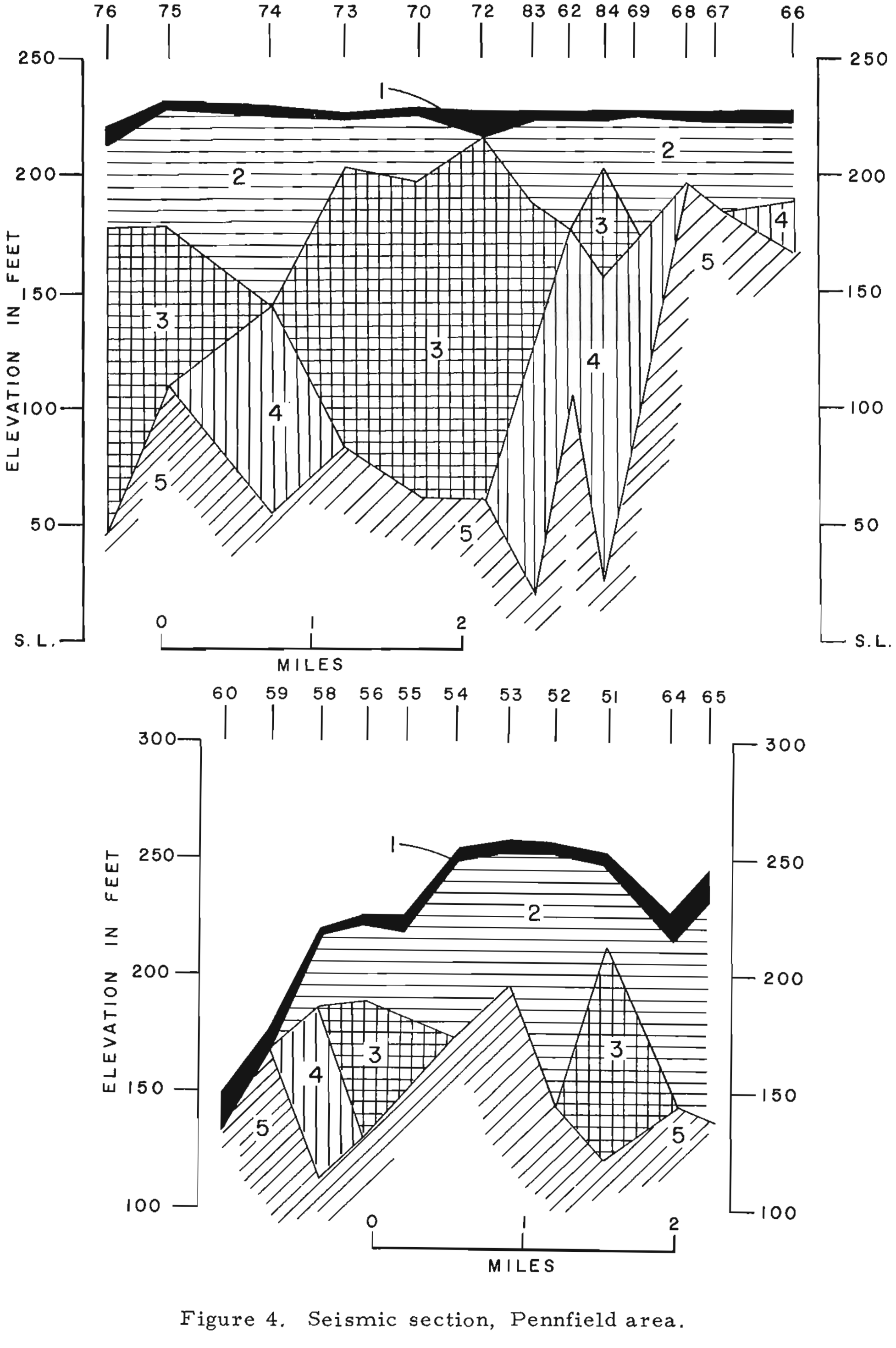

Figure 4. Seismic section, Pennfield area.

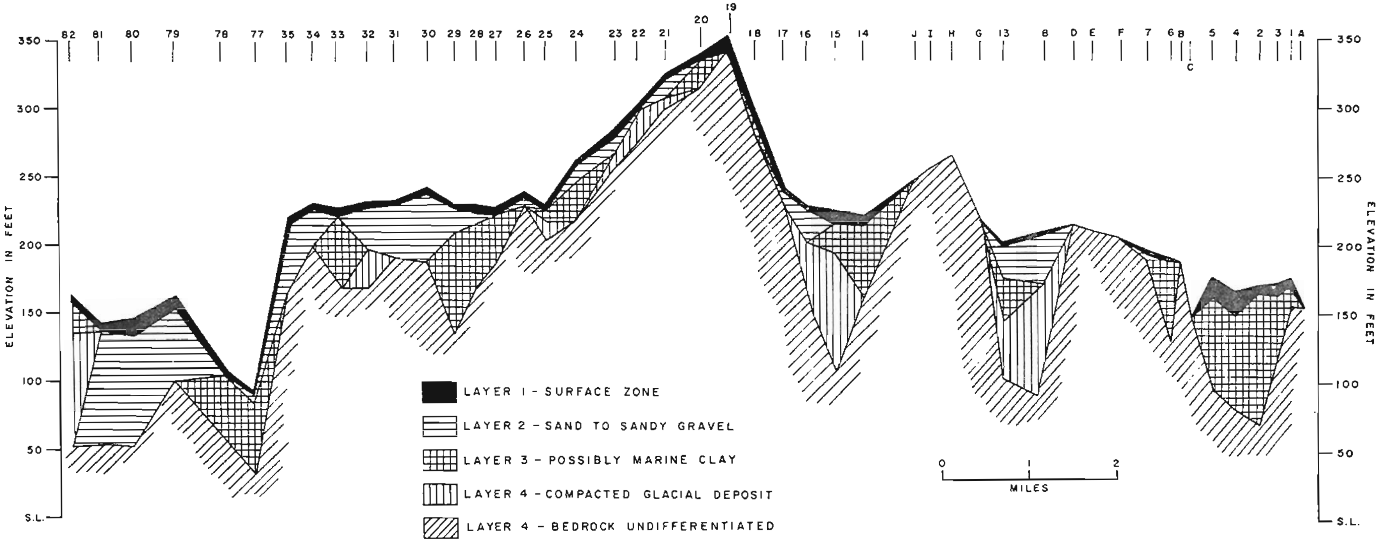

Figure 5. Seismic section, Pennfield area.

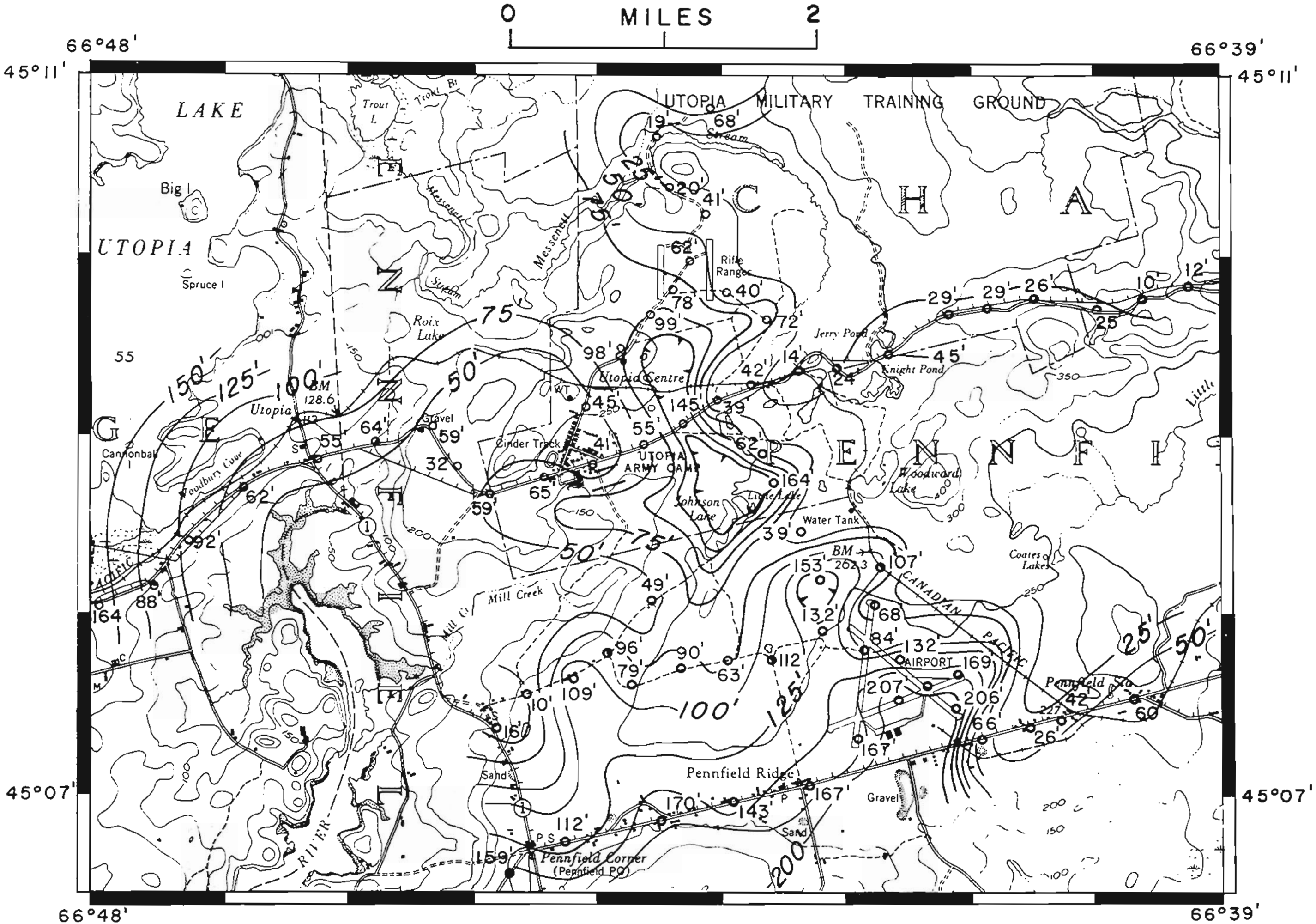

Figure 6. Thickness of overburden, Pennfield area.

however should be of considerable interest and use to those engaged in drilling wells in the area. All sections depict a very irregular bedrock topography with depressions in the bedrock being at least partly infilled with either marine clay or till. Outcrop was observed in the eastern part of the project area at locations A to L as shown on Figure 3.

In conclusion, a portable hammer seismograph is adequate to define bedrock topography in the Pennfield area and to determine subsurface velocities correlatable with Pleistocene materials. Additional seismic control would delineate preglacial basins as potential water reservoirs; these basins would probably not be contaminated by an infiltration of salt water.

---

[1] Gadd, N.R.: St. George map-area, New Brunswick (21 B, 21 C); Geol. Surv. Can., Paper 68-1, Part A, p. 161 (1968).

[2] Cumming, L.M.: Geology of the Passamaquoddy Bay region, Charlotte County, New Brunswick, 21 B, 21 G (parts of); Geol. Surv. Can., Paper 65-29 (1967).

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10. HAMMER REFRACTION SEISMIC SURVEYS OVER BIOGEOCHEMICAL PLOTS AND PROFILES, MOOSE RIVER AREA, ONTARIO

Project 650421

George D. Hobson

Seismic surveys were conducted over 10 plots and profiles in the Moose River area, Ontario to supplement biogeochemical surveys over the same locations. The area of investigation is shown in Figure 1. Access to the area was by Ontario Northland Railway out of Cochrane to Otter Rapids. Transport within the survey area was by means of helicopter.

Eighty-one seismic locations were investigated, some along straight lines while others were grouped around a plot to acquire the desired information. In all cases, unreversed refraction profiles were surveyed while at many locations seismic data were obtained in two, three and sometimes four directions from a central survey location. This latter procedure reveals additional data for deriving true velocities and dips of strata.

The project area is located in the Canadian Shield environment, all biogeochemical plots having been selected over interesting aeromagnetic anomalies. It was appreciated before commencement of the program that inliers of Cretaceous sediments may be present in the area and would exhibit anomalous values of seismic bedrock velocity. Muskeg is prevalent over much of the area interspersed with knolls of birch and poplar.

A histogram of the occurrence of observed seismic velocities is shown in Figure 2. These velocities are as observed and are uncorrected for dip. Bedrock appears to exhibit a velocity in excess of 9,000 feet per second. The histogram shows various velocity ranges associated with different Pleistocene materials.

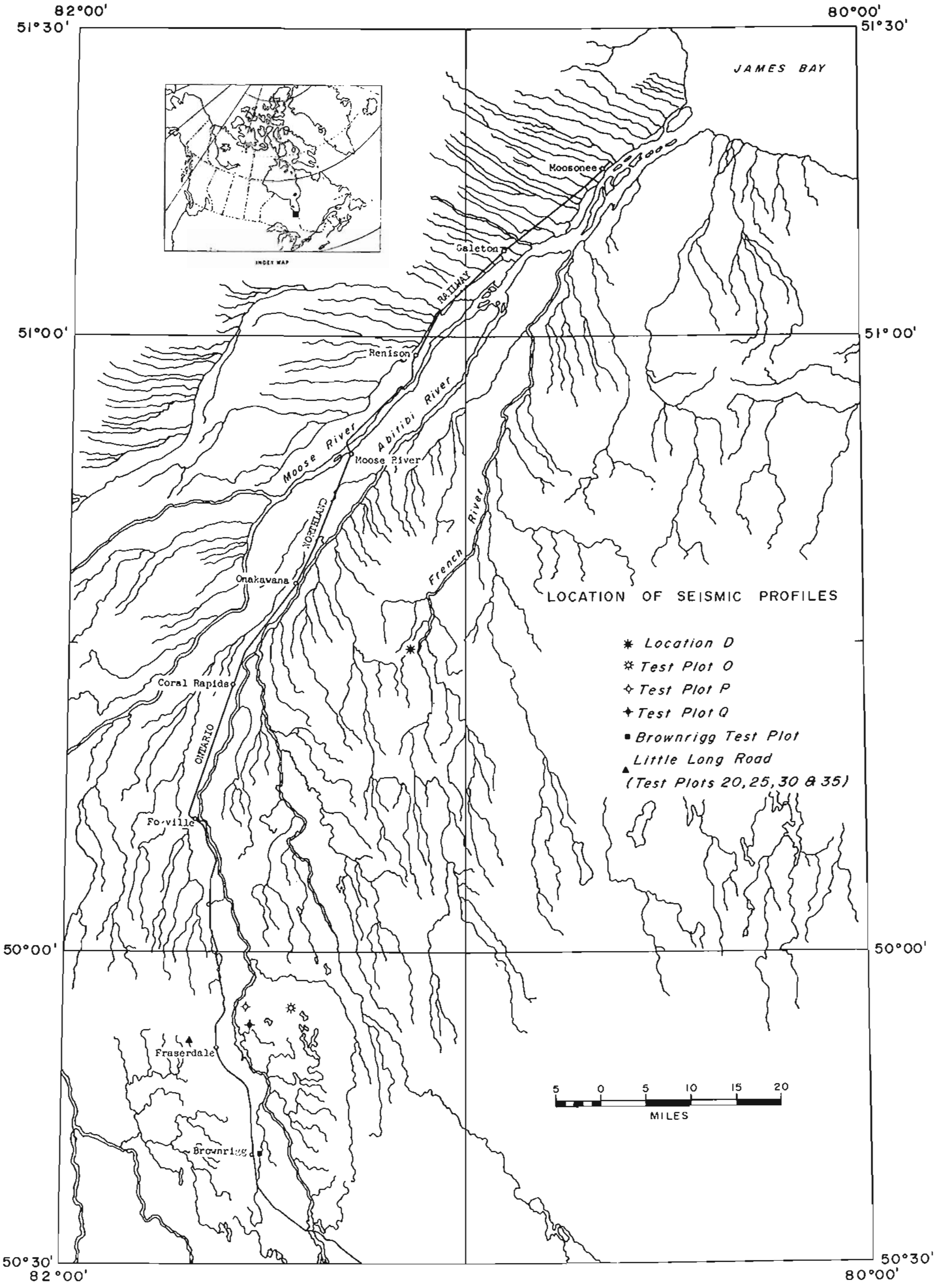

Figure 1. Location of seismic profiles, Moose River area, Ontario.

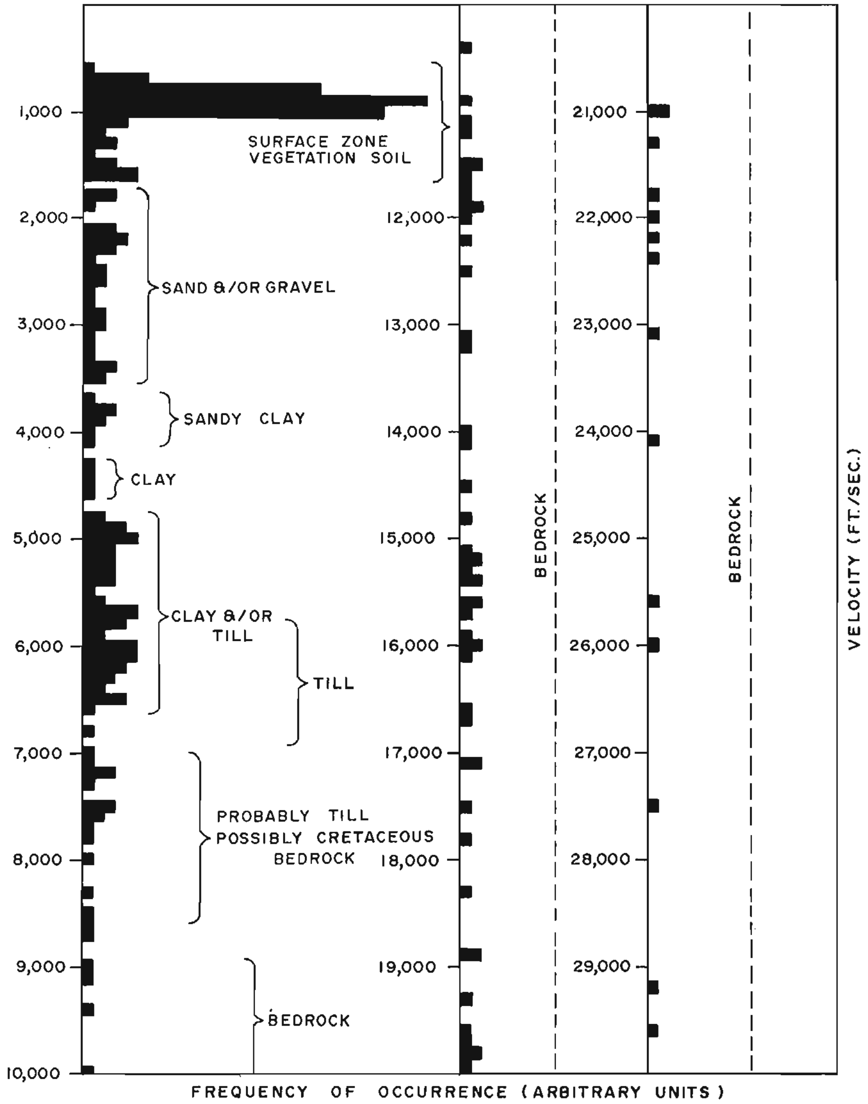

Figure 2. Histogram of observed velocities versus frequency of occurrence, Moose River area, Ontario.

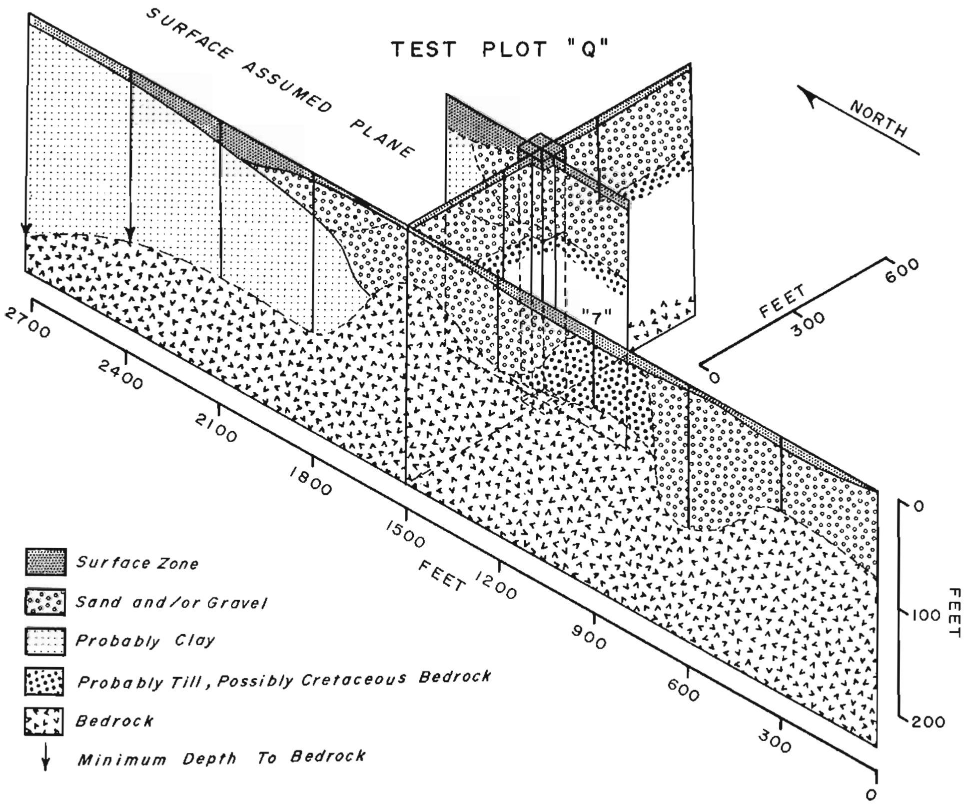

Figure 3. Isometric section, test plot 'Q', Moose River area, Ontario.

Figures 3 to 9 are isometric projections of seismic data over and associated with the various biogeochemical plots; Figure 10 shows sections along two roads near which biogeochemical prospecting techniques were attempted. It must be remembered that the surface over all the plots is irregular and not planar as shown in these figures. Also, all velocities are apparent except for that associated with the surface zone.

Test plot 'Q' is shown in Figure 3. Sixteen seismic stations located within 1,500 feet of the biogeochemical plot indicate that overburden thickness varies between 52 and 207 feet. The plot is located over overburden of indeterminate thickness unless velocities of 7,500 to 8,650 feet per second are considered to be bedrock of Cretaceous age. This may be a method of locating this type of inlier beneath the overburden. The till indicated beneath station '7' however is probably as shown, that is a till, and not Cretaceous bedrock. If the bedrock beneath the plot and immediately adjacent locations is Cretaceous in age then overburden varies between 70 and 80 feet in thickness beneath the biogeochemical plot. The plot is underlain by an east-west trending bedrock ridge.

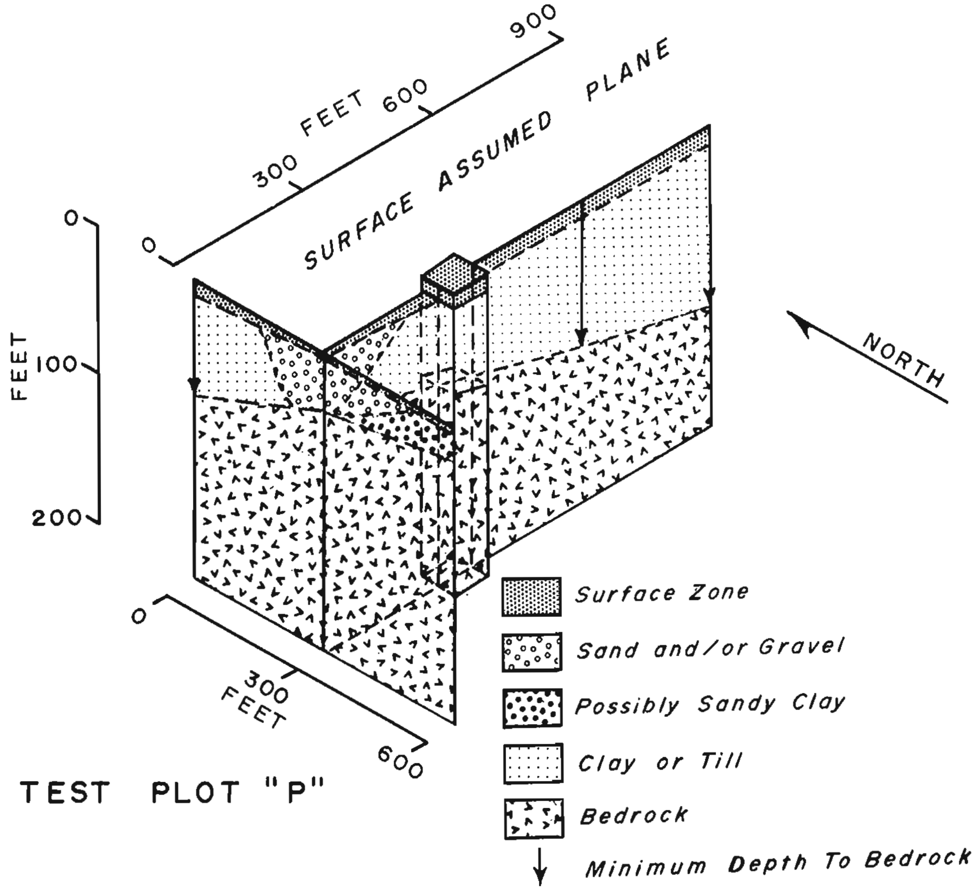

Figure 4. Isometric section, Test plot 'P', Moose River area, Ontario.

Test plot 'P' is shown in Figure 4. Seven seismic stations located within 600 feet on the plot indicate that the bedrock surface dips to the northeast. Depth to bedrock beneath the plot is 70 feet, as shallow as 21 feet to the southwest of the plot and in excess of 119 feet to the east of the plot. The sandy clay shown under stations to the southwest of the plot may be sand although the velocity of 3, 800 feet per second indicates the presence of some clay material within the sand.

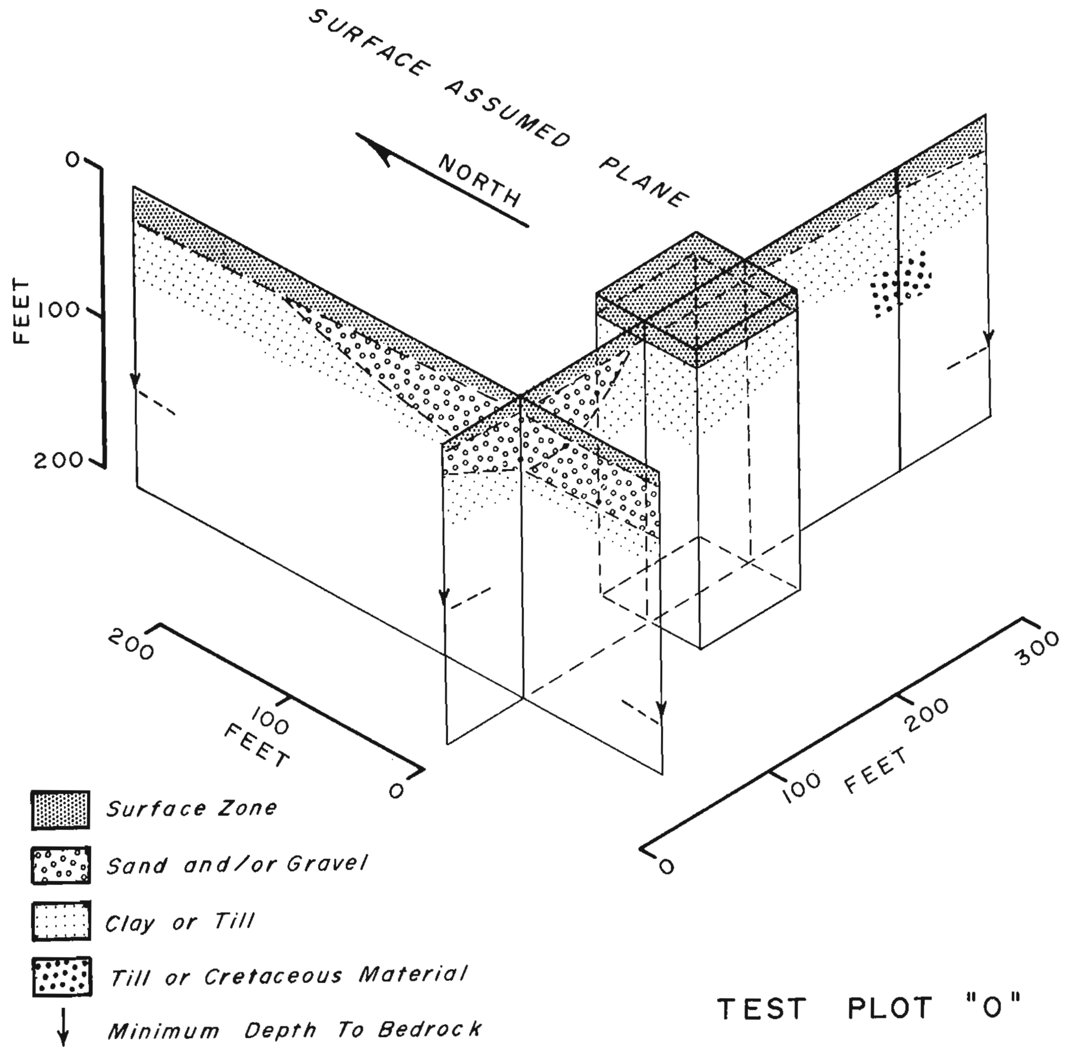

Figure 5. Isometric section, Test plot 'O', Moose River area, Ontario.

Test plot 'O' is shown in Figure 5. Six seismic stations are located within 600 feet of the plot; no seismic station is located on this plot. Bedrock may have been observed only beneath the station immediately east of the plot at a depth of 63 feet and is possibly of Cretaceous age since a velocity of 9,250 feet per second was recorded. Elsewhere at this plot the final velocity recorded was less than 8,000 feet per second resulting in minimum depths to bedrock being calculated as shown.

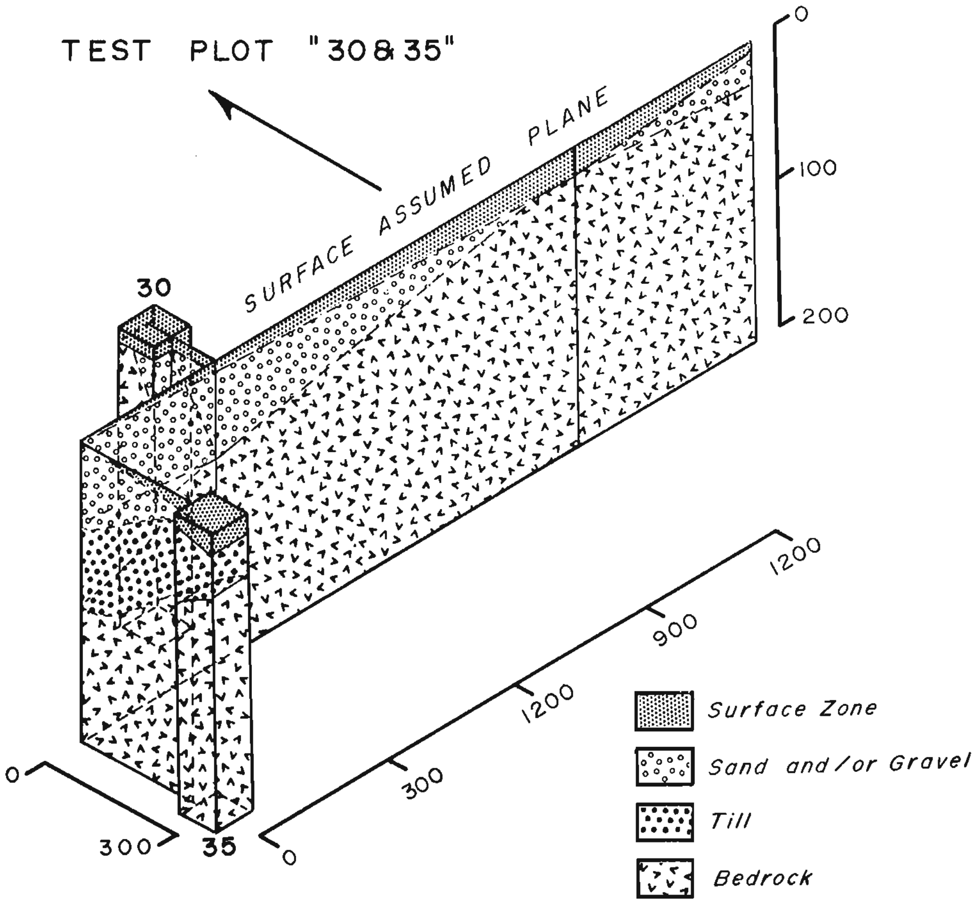

Figure 6. Isometric section, Test plot '30 and 35', Moose River area, Ontario.

Test plots 30 and 35 are shown in Figure 6. Plot 30 is populated with poor quality black spruce while plot 35 is covered with poplar trees. Bedrock is at a depth of approximately 7 feet beneath plot 30 and approximately 35 feet at plot 35. The first plot is completely covered by muskeg. Bedrock was penetrated beneath all stations on these plots.

Test plot 20 is shown in Figure 7. This plot is covered by birch trees where approximately 69 feet of overburden overlies bedrock. Bedrock dips slightly to the east and west beneath the plot. Good till velocities were recorded to the east and west of the plot but not immediately beneath it.

Test plot 25 is shown in Figure 8. Bedrock beneath the plot is at a depth of approximately 86 feet; bedrock to the southeast is about 157 feet deep and in excess of 133 feet to the southwest. Overburden may be relatively homogeneous clay beneath this plot.

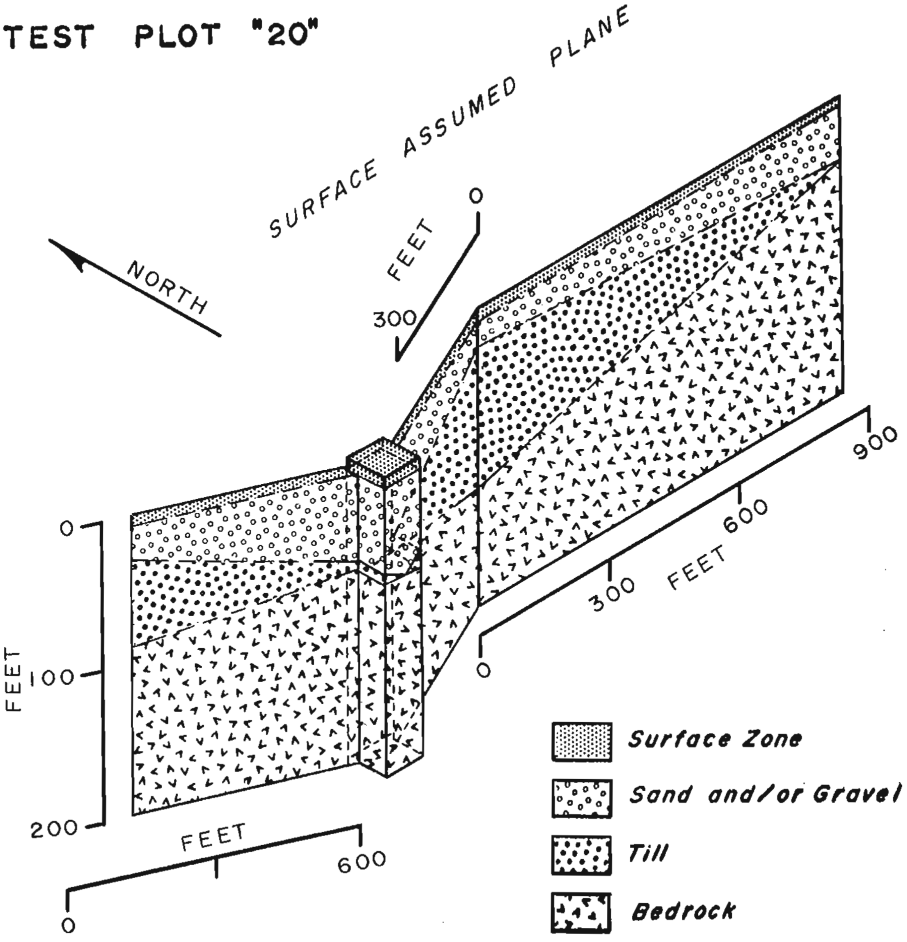

Figure 7. Isometric section, Test plot '20', Moose River area, Ontario.

Brownrigg test plot is shown in Figure 9. Bedrock under the plot is about 53 feet deep and appears to dip away to the north, south and east of the plot. It is interesting to note that for this plot a study of air photographs indicates that seismic station '75' is the most favourable test location from a biogeochemical aspect but the seismic data show bedrock to be at a depth of 82 feet and therefore undesirable as a sampling location.

The lower section of Figure 10 is located along the Hydro or Little Long Road. Twenty-one seismic stations were surveyed within a distance of three miles west of milepost 21. Four biogeochemical plots, that is plot 20 or birch, plot 25 or black spruce, plot 30 or poor black spruce and plot 35 or poplar, are located along the Little Long Road; as above, seismic assessments of these four plots were obtained in the course of the survey. Three types of overburden materials can be distinguished over this profile. The

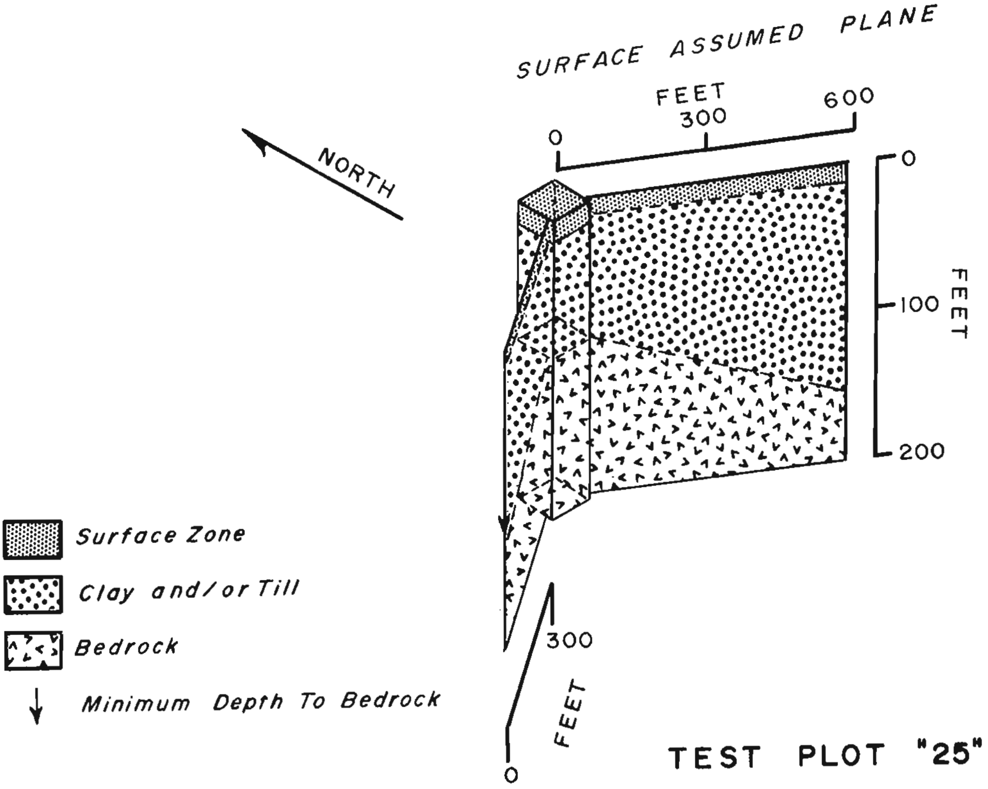

Figure 8. Isometric section, Test plot '25', Moose River area, Ontario.

low-velocity surficial material is underlain by a clay and/or till perhaps interbedded. It is suggested that the sandy material with velocity of about 2,000 feet per second may be associated with the Cochrane advance while the underlying clays and/or tills may have been deposited during the previous glaciation since this latter material appears to be concentrated in the bedrock 'lows'. Although the Little Long Road is generally of low topographic relief over its surveyed length, there is local relief of about 40 feet near seismic stations 44 and 45 at the birch plot; however the bedrock depression beneath this plot on the section of Figure 10 cannot be completely accounted for by surface relief.

Nineteen seismic stations were surveyed to yield the upper profile of Figure 10. This profile traverses a bog or muskeg area located about 32 miles northeast of Otter Rapids. The profile is about three miles long extending from the French River westward along a cut township line. In general, this section indicates a surficial layer of muskeg and peat from one to

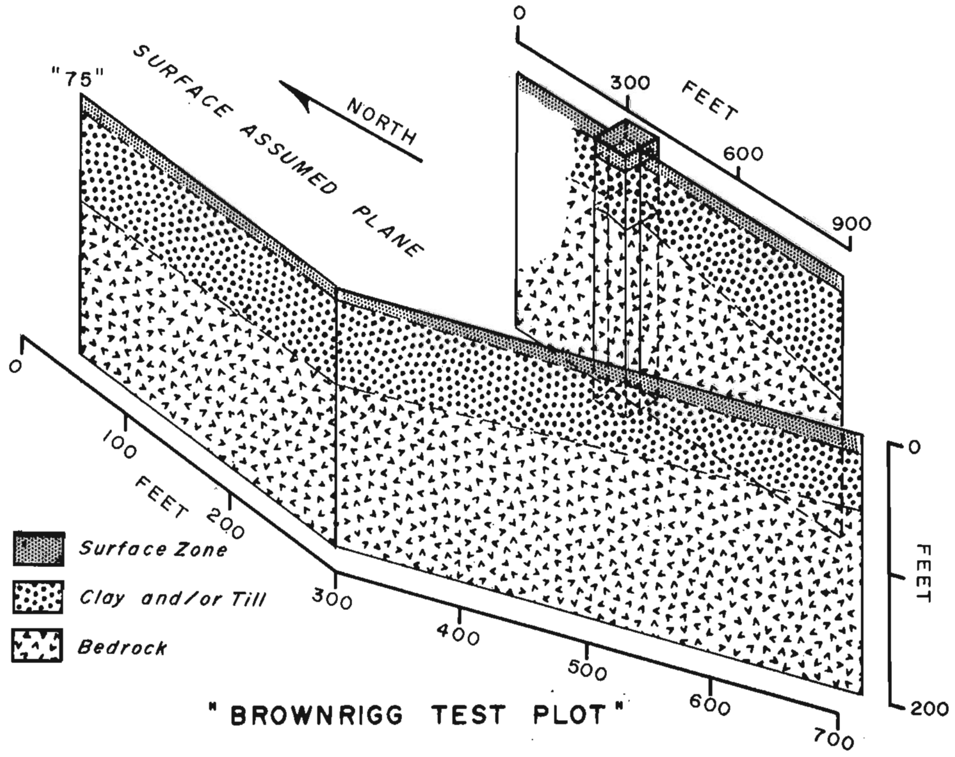

Figure 9. Isometric section 'Brownrig' Test plot, Moose River area, Ontario.

10 feet thick overlying clay and till of variable thickness overlying bedrock. Beneath seismic stations 72 and 73 bedrock is very shallow and loose gravel can be observed immediately beneath the reindeer moss.

There are no drillholes within the project area for the correlation of seismic velocities with bedrock or overburden materials.

In this area, overburden materials can be identified in general by the seismic velocities associated with them. In many cases this correlation has been verified by digging shallow holes with a shovel. In other cases these materials have been identified by velocity ranges and peaks on the histogram of Figure 2. There is generally a good velocity contrast between overburden materials and bedrock at any particular location thus greatly simplifying the interpretation.

The contrasts in velocity also permit identification of areas under which bedrock may be Cretaceous in age thus localizing inliers of these formations within the Shield environment.

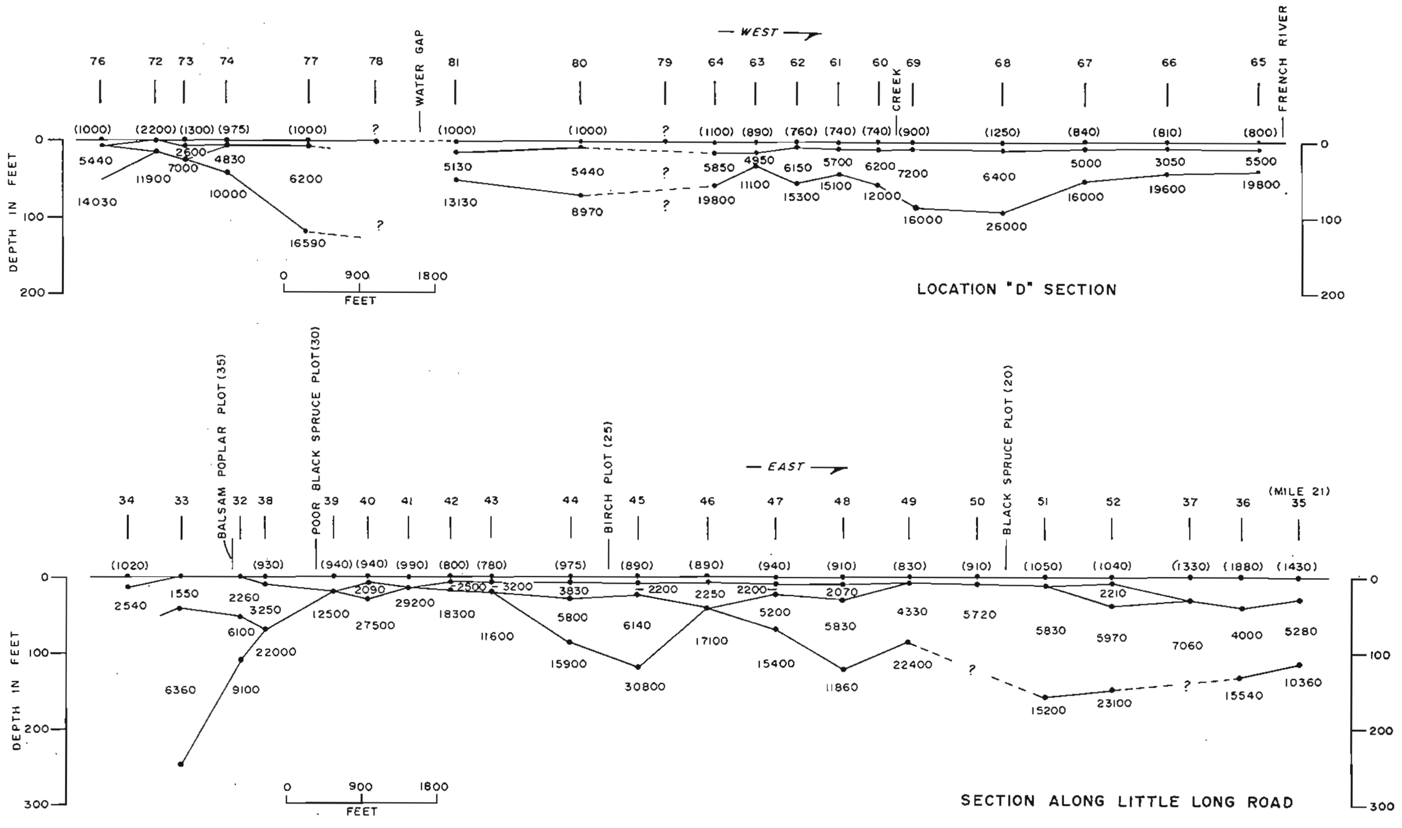

Figure 10. Seismic sections, Moose River area, Ontario.

11. A MAGNETIC INTERPRETATION OF THE EASTERN PORTION OF THE ATHABASCA FORMATION

Project 660042

L. J. Kornik

A preliminary interpretation of the area of northern Saskatchewan east of longitude 106° W which is overlain by the Athabasca Formation was deemed worthy of study in view of the intense prospecting currently taking place in that area for uranium. Depth determinations of magnetic anomalies in the Athabasca Formation area were undertaken using an automatic computer method of analyzing thick dyke anomalies. This program was written

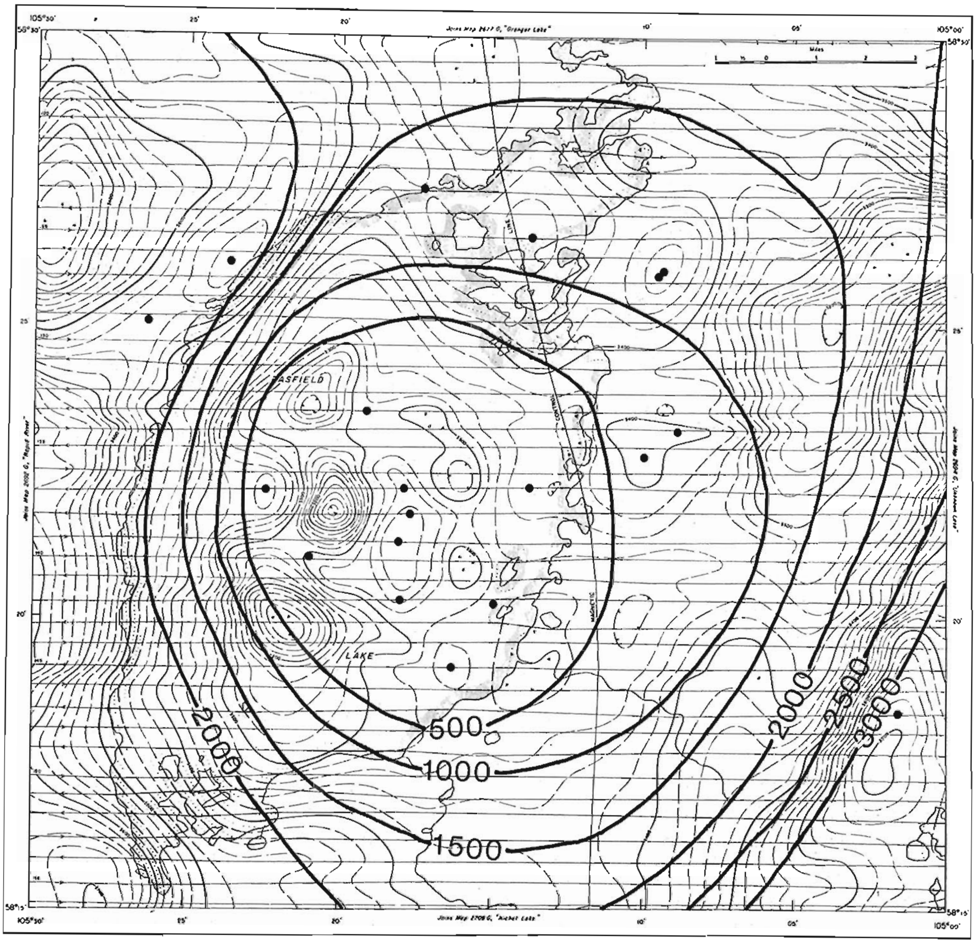

Figure 1. Thickness of Athabasca Formation in Pasfield Lake area, contour interval 500 feet, full circles indicate location of magnetic depth determinations.

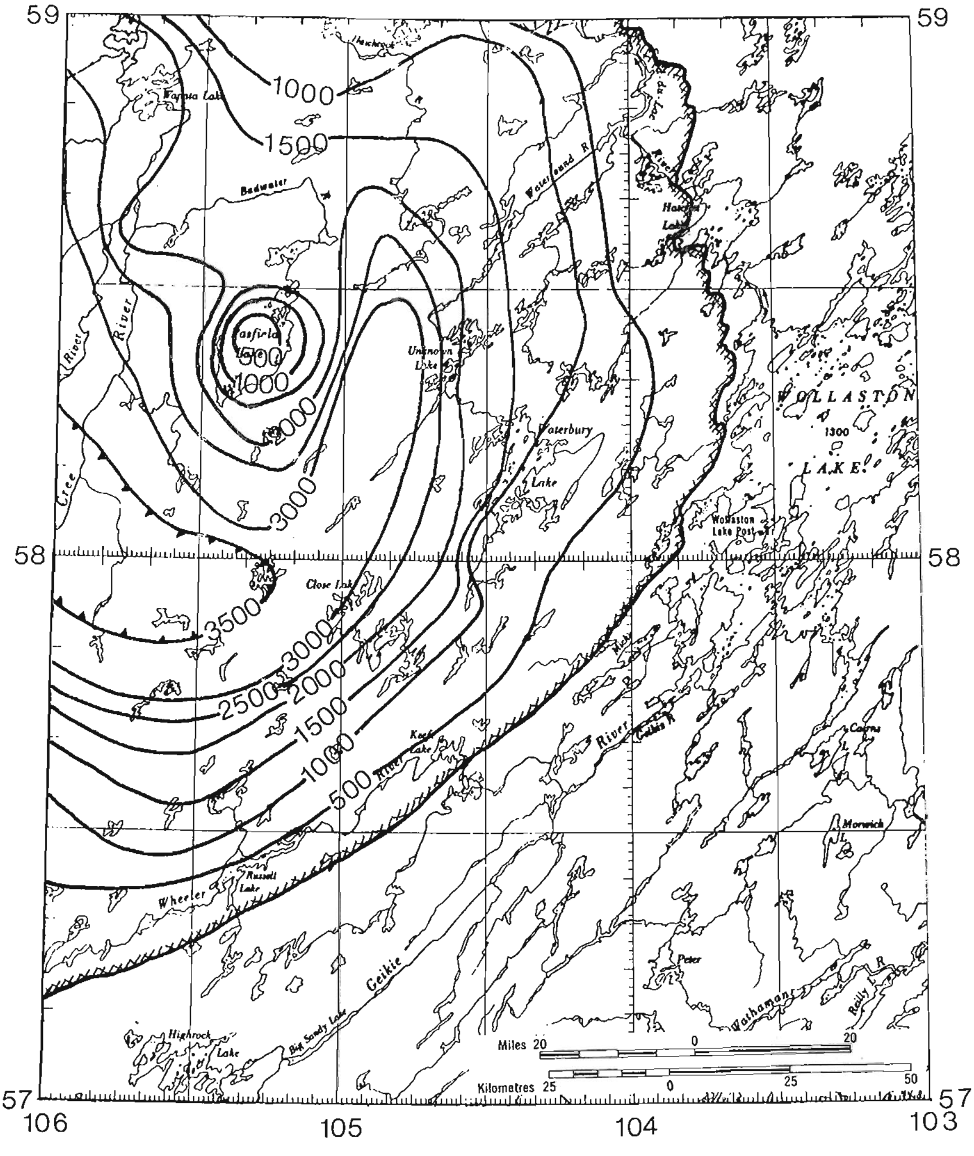

Figure 2. Thickness of the Athabasca Formation.

by P. H. McGrath of the Geological Survey of Canada. Lack of reliable depth control other than unproven seismic depth determinations and errors inherent in the magnetic method necessitate that this interpretation be considered tentative until more concrete evidence, that is drillholes to basement, becomes available.

The computer program for the thick dyke anomaly determines the depth of burial, dimensions, dip and effective magnetic susceptibility contrast of the causative body. Approximately 150 anomalies were analyzed in the study area.

Shallow depths to causative magnetic bodies were obtained in the Pasfield Lake area (Fig. 1). These depths were not determined from an isolated feature but from several elongated magnetic anomalies which have trends consistent with the regional pattern of magnetic anomalies present in surrounding aeromagnetic maps. The pattern of the magnetic anomalies in the Pasfield Lake area, their frequency and distribution, indicate relatively shallow magnetic bodies. Two explanations for these shallow depths appear to be possible. Either the bodies intrude the nonmagnetic Athabasca Formation, which seismic evidence[1] suggests is more than 5,000 feet thick in this locality, or the magnetic basement rises under Pasfield Lake and the seismic depths in this locality are incorrect. The present preferred interpretation is that the magnetic basement rises to within a shallow depth under Pasfield Lake as shown in Figure 1. This basement feature is probably similar to the Carswell Lake structure which occurs near the western boundary of the Athabasca Formation. Outcrops of magnetic basement have not been reported in the Pasfield Lake area, but the pattern of magnetic anomalies would suggest the basement is near surface.

A contour map of the thickness of the Athabasca Formation using values derived from a quantitative interpretation of the aeromagnetic maps is presented in Figure 2. This is a tentative interpretation and may be modified as drillhole depths become available for reliable checks on the thickness of the Athabasca Formation.

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[1] Hobson, G. D., and MacAulay, H. A.: A seismic reconnaissance survey of the Athabasca Formation, Saskatchewan; Geol. Surv. Can., Map 2-1969 (1969).

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12. AEROMAGNETIC EXTENSION OF THE CHURCHILL-SUPERIOR BOUNDARY IN MANITOBA

Project 660042

L. J. Kornik

Recent Federal-Provincial aeromagnetic maps extend the aeromagnetic coverage southwards between Lake Winnipeg and the Manitoba-Saskatchewan boundary and allow an extension of the Churchill-Superior boundary under the Paleozoic rocks[1, 2].

The position of the Churchill-Superior boundary, based on aeromagnetic trends, is shown in Figure 1. This figure utilizes the Bouguer gravity anomaly map of this area[3] as the base map for this extension. This proposed extension marks the position of the change from recognizable east or northwest magnetic trends present in the Superior Province to the strong northeast magnetic trends present along the eastern edge of the Churchill (structural) Province. This boundary is essentially based on the magnetic expression of the upper layer of the basement rocks.

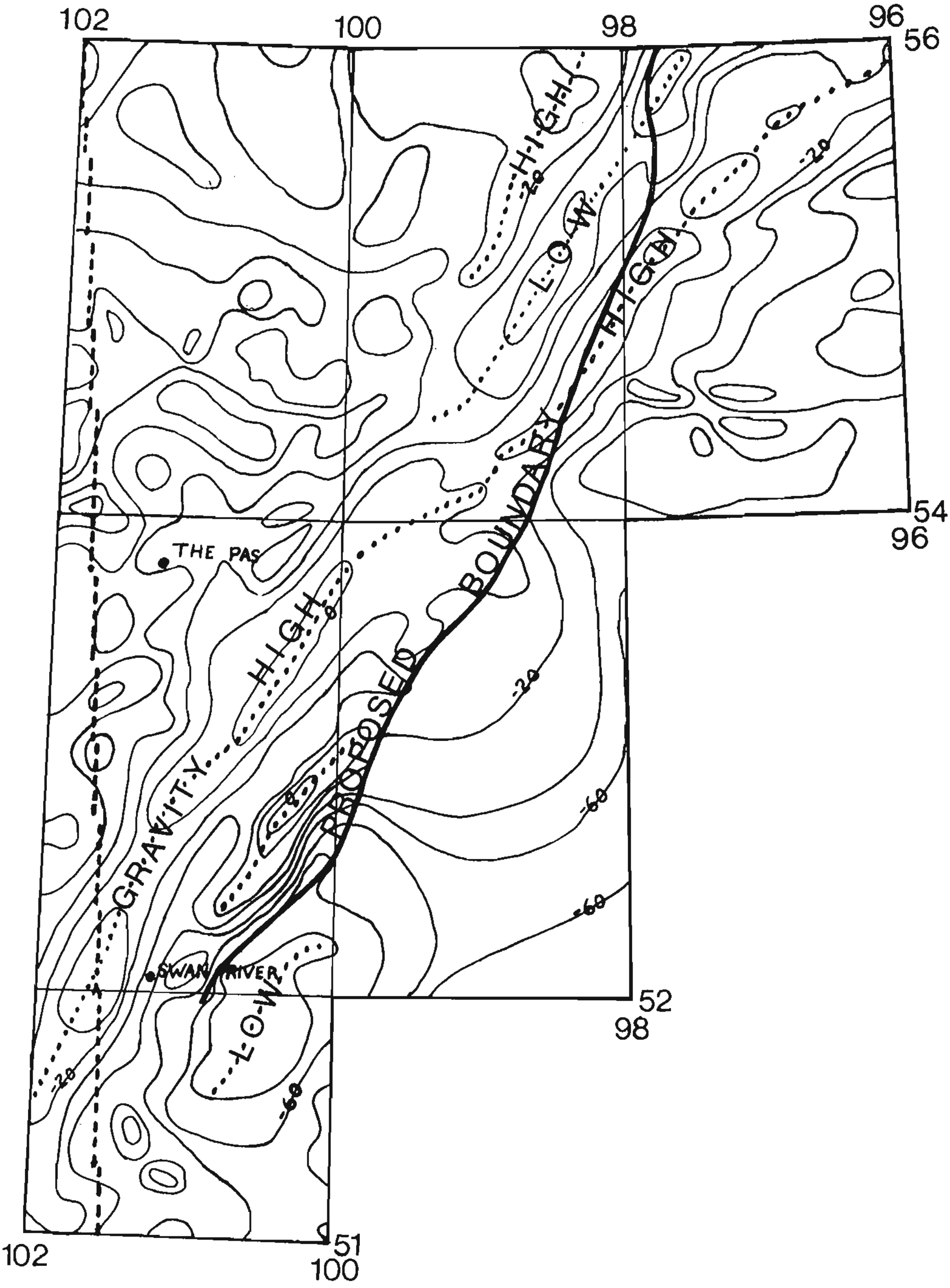

Figure 1. Bouguer Gravity Anomaly Map showing the extension of the Churchill-Superior boundary based on aeromagnetic data.

An obvious feature in Figure 1 is the lack of correspondence between this proposed boundary and the major Bouguer gravity anomalies. At the top of Figure 1 at latitude 56° N the Churchill-Superior boundary is on the west flank of the gravity low anomaly that is so prominent in the region of Manitoba's nickel belt. However by 55° N latitude this proposed boundary has crossed this gravity low and is on the western flank of the well-developed gravity high anomaly which is present east of the nickel belt. By 54° N latitude the proposed Churchill-Superior boundary has crossed this gravity high and occurs along the extreme eastern flanks of the extension of this gravity high to 52° N latitude, the southern limit of aeromagnetic coverage.

The gravity and aeromagnetic data in this area do not appear to correlate and continuous gravity anomalies cross the boundary between the Churchill and Superior (structural) provinces. These features suggest that the gravity anomalies do not have a simple relationship to the near-surface magnetic basement. Two possible explanations are suggested, first that the gravity anomalies are not related to shallow basement rocks but have sources deeper within the crust, or secondly, that the gravity anomalies are produced by density changes within the shallow basement rocks which are not controlled by the boundary between the structural provinces. In other words, these density patterns must have existed before the boundary between the two structural provinces existed. If shallow basement rocks produce these gravity anomalies then these anomalies must have existed before the Churchill (structural) Province was formed. This feature warrants a further study and a fuller treatment in the near future.

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[1] Kornik, L. J., and MacLaren, A. S.: Aeromagnetic study of the Churchill-Superior boundary in northern Manitoba; Can. J. Earth Sci., vol. 3, pp. 547-557 (1966).

[2] Kornik, L. J.: An aeromagnetic study of the Moak Lake-Setting Lake structure in northern Manitoba; Can. J. Earth Sci. (in press).

[3] Bouguer Gravity Anomaly Map of Canada; Observatories Branch, Dept. Energy, Mines and Resources (1967).

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13. A RE-EVALUATION OF THE PALEOMAGNETIC DATA FROM THE MANICOUAGAN GROUP OF LOWER TRIASSIC IGNEOUS ROCKS

Project 630029

A. Larochelle

A set of paleomagnetic directions from the Manicouagan Group of igneous rocks was recently reported by Larochelle and Currie[1] and a mean position of the geomagnetic pole for part of the Lower Triassic was estimated from these data. The latter were analyzed through standard statistical methods but, because the reliability of two of the eleven site means considered as valid in the analysis cannot be clearly established, it is of interest to verify whether the final result would have been the same if only data of closely controlled reliability had been considered.

Quite independently from the above data, Robertson[2] has also estimated the position of the Manicouagan Group paleomagnetic pole, but because he arrived at a somewhat different result, it seems pertinent to find an explanation for this discrepancy and to establish the relative reliability of his result.

The reader is referred to the original paper of Larochelle and Currie (op. cit.) for a description of the sampling and measuring procedures used to obtain their basic data and to assess the precision of their individual measurements. The latter are summarized in Table 1 as site means, the angular standard errors of which are defined by

$$\delta_{\bar{R}} = \sqrt{\frac{2\,(N-R)}{N\,(N-1)}} \qquad \text{radians}$$

where, for each site, N refers to the number of core mean directions of magnetization and R is the modulus of their vectorial sum, each core being represented by a vector of unit length. The angle θ_{av} in Table 1 refers to the average value of the angle θ between the two magnetization vectors yielded by the pairs of cylindrical specimens cut from most cores. An estimate of the angular standard error ($\delta_{\bar{c}}$) of a core mean direction can be obtained by replacing N by 2 and R by $2\cos(\theta_{av}/2)$ in the above equation. It may be verified that the value of $\delta_{\bar{c}}$ rarely exceeds 2.5 degrees and it may thus be considered that the core mean directions are practically freed from the effects of measurement errors and of within-core magnetization inhomogeneities. On the same basis, the few core magnetization directions derived from only one cylinder may be considered reliable to within 2.5 degrees.

It was demonstrated in the previous analysis that the natural remanent magnetization of the cores from site 11 bears a strong secondary component which persisted even after these cores had been cleaned in an alternating field of 800 oe. (peak). For this reason the paleomagnetic directions from this site were not included in either this or the previous analysis.

It is noted in Table 1 that the angular standard error of site 8 is not defined whereas that of site 10 is 12 degrees. On the basis of reliability norms adopted by the writer in more recent studies[3, 4] the data obtained from these two sites (unit 5) would be regarded as unreliable. On the other hand, as the standard errors of the other 9 site means are about 4 degrees, it may be considered that the site means are largely freed from the effects of orientation errors and of within-site magnetization inhomogeneities.

Among the 5 units sampled, unit 2 is the most widely distributed and also was the most extensively sampled. The geographic distribution of its site means is such that the ratio of the between-site to the within-site angular variances (δ_b^2/δ_w^2) should provide a reliable indicator of whether the angular dispersion of the 24 core mean directions obtained from this unit reflects the effects of between-site relative displacements. The results of a variance-ratio test[5] show that the site means are in fact significantly different (Table 2) and thus suggest that differential tilting of the sites may be an important factor of angular dispersion of the individual core mean directions.

Table 1

SITE MEAN DIRECTIONS OF MAGNETIZATION (RM$_{200\ \mathrm{oe.}}$)

UNIT No.	SITE No.	n	N	$\theta_{av.}$ (deg)	D (deg)	I (deg)	R	δ_R (deg)
1	1	-	5	5.2	19.2	46.7	4.985	2.2
2	2	-	3	4.7	11.6	41.1	2.969	5.9
2	3	-	6	2.2	353.6	45.7	5.912	4.4
3	4	-	2	1.6	359.7	33.2	1.993	4.9
1	5	-	4	4.7	20.0	39.6	3.888	7.8
2	6	1	6	1.3	11.3	39.7	5.966	2.7
4	7	-	6	3.8	15.6	38.0*	5.994	1.2
5	8	1	1	-	24.3	39.8	-	-
2	9	2	3	2.1	16.6	34.3	2.987	3.8
5	10	2	2	-	0.9	44.4	1.956	12.0
2	11	2	6	11.4	90.5	50.7	5.966	2.7
2	12	-	6	4.0	18.8	44.3	5.978	2.2

n: number of core mean directions based on the measurement of only one cylindrical specimen

N: total number of core mean directions

D, I: declination and inclination of site mean direction

*: originally transcribed erroneously as 40.0

other symbols explained in the text

Table 2

RESULTS OF VARIANCE-RATIO TESTS

UNIT(S) No.	N	B	D (deg)	I (deg)	δ_b^2 rad.^{2}	δ_w^2 rad.^{2}	δ_b^2/δ_w^2	F	δ_n (deg)
2	24	5	9.8	42.2	.11373	.01980	5.74	2.19	8.5
1, 2, 3, 4	41	9	12.2	41.6	.09319	.02048	4.55	1.80	8.4

N: total number of core mean directions considered

B: total number of site means considered

D, I: declination and inclination of the weighted site means resultant

F: theoretical statistic $F_{2(B-1),\ 2(N-B),\ .05}$

other symbols explained in the text

A second variance-ratio test extended to the 41 core means from the 9 reliable sites confirms the above indication that the site means are significantly different within the group (Table 2). As minor tectonic disturbances have been noted in the field[1], it appears that the 8.4 degrees of angular standard deviation (δ_n) of the 9 normalized site means would in fact be an exaggerated estimate of the sole paleomagnetic field angular standard deviation. Noting further that the δ_n of the only site means within unit 2 is essentially the same (8.5°), it is suggested that either the non-dipole component of the Manicouagan Group paleomagnetic field was considerably more stable than that of the present field or that the formation of the 4 units considered in this analysis was a relatively rapid succession of short duration events.

An insufficient number of sites were sampled from units 1, 3 and 4 to establish by the variance-ratio test whether the unit means (resultants of the normalized site means within units) are significantly different.

The standard error of the resultant of the normalized site means ($\delta_{\bar{n}} = \delta_n/\sqrt{9}$) and that of the resultant of the weighted site means ($\delta_{\bar{m}} = \delta_b/\sqrt{41}$) are respectively equal to 2.8 and 2.7 degrees. The corresponding values of α'_{95}, the radii of confidence at the .95 probability level about these resultants, are then respectively 4.8 and 4.7 degrees.

The computation on the basis of the resultant of the 9 weighted site means (which is in practice equivalent to that of the 41 core means) with an average sampling position of 68.7°W and 51.4°N yields a paleomagnetic pole position at 87.8°E and 61.0°N. This pole and its limits of confidence at the .95 probability level (5.8° and 3.5° respectively) are essentially identical to those previously reported (88°E, 60 1/2°N, 6° and 3 1/2° respectively) but the pole is 4 degrees north of that reported by Robertson[2]. Out of the 7 sites that he sampled, the data that he obtained from 6 were considered reliable. The angular standard deviation of these 6 normalized site means is 11.6 degrees, which is appreciably larger than the corresponding statistic of the present analysis (8.4°). The difference is however not statistically significant at the .05 probability level. It may lie in the fact that Robertson's study was based on samples collected with 'standard geological techniques' and/or that the number of independently oriented samples representing each of his sites (not specified by Robertson) is too small to allow the sampling error to be averaged out of the site means. The pole derived in the present study has this added element of reliability over Robertson's pole in that it is based on more site means. The end result is that the ellipse of confidence surrounding it covers an area less than 1/3 of that surrounding Robertson's pole, which it does not quite encompass.

In summary, the above analysis confirms the position and the limits of confidence of the Manicouagan Group paleomagnetic pole as reported by Larochelle and Currie previously, that is when the data obtained from unit 5 were not discounted as unreliable. Nevertheless, it can be said that since the present result is based exclusively on closely controlled data, a clearer separation can be made of the various factors which may have contributed to their angular dispersion. In the present perspective, the sampling of units 1, 3 and 4 no longer appears adequate to justify deducing on the basis of the variance-ratio test that the unit means are not significantly different. This hypothesis still appears plausible, however, judging from the fact that the angular dispersion of the site means remains the same either within or beyond the scope of unit 2. Finally, the small differences noted between the position and the relative reliability of Robertson's pole with respect to that reported by Larochelle and Currie appear to be related to the different sampling techniques and patterns adopted in both studies.

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[1] Larochelle, A., and Currie, K. L.: Paleomagnetic study of igneous rocks from the Manicouagan structure, Quebec; J. Geophys. Res., vol. 72, 4163 (1967).

[2] Robertson, W.A.: Manicouagan, P.Q., paleomagnetic results; Can. J. Earth Sci., vol. 4, 641 (1967).

[3] Larochelle, A.: Paleomagnetism of the Monteregian Hills: Further new results; J. Geophys. Res., vol. 73 (in press).

[4] Larochelle, A.: Preliminary results on the paleomagnetism of the Sudbury Irruptive; Geol. Surv. Can., Paper 69-19 (1969).

[5] Larochelle, A.: L'application de la statistique au paléomagnétisme; Geol. Surv. Can., Paper 68-59 (1968).

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14. SEISMIC REFRACTION SURVEY, LOUVICOURT TOWNSHIP, QUEBEC, 32 C/4

Project 670097

H.A. MacAulay

A seismic study was conducted in December 1968 to provide an estimate of drift thickness in advance of a drilling program associated with geochemical studies (see R.G. Garrett, report 18, this publication). The area surveyed is about 12 miles east of Val d'Or, Quebec, on the Louvicourt Township property of Naganta Mining and Development Co., and presently under option to Soquem.

Eight, reversed refraction profiles, each 1,100 feet long, were obtained over cut lines that were 200 feet apart in a north-south direction. Geophones were spaced every 100 feet along the profiles. In addition, short profiles 160 or 220 feet in length and generally reversed, with close geophone spacing were shot at both ends of the 1,100 foot control lines to provide data for velocity determinations in the overburden. Small dynamite charges were detonated in holes about two feet deep to provide the energy source for all profiles.

The apparent seismic velocities observed in the drift range between 600 and 8,300 feet per second. Every time-distance graph for the project reveals a velocity segment of about 5,000 feet per second. The delay times associated with this velocity segment indicate that the Pleistocene material transmitting energy at or near this velocity forms the greater part of the drift. Borehole data indicate that wet sand and silt is the predominant drift

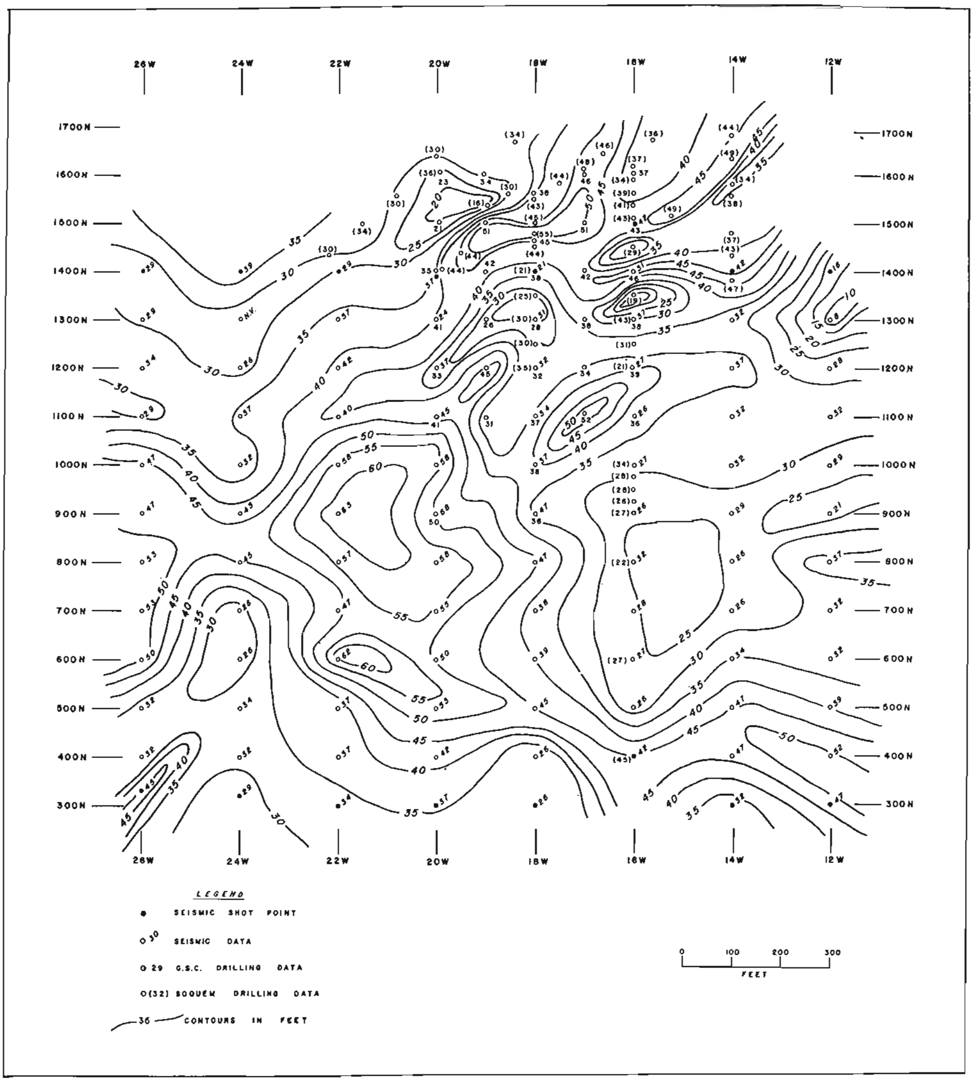

Figure 1. Thickness of overburden, Louvicourt Project.

material. Velocities ranging between 600 and 3,000 feet per second are probably associated with this same material in a dryer state.

At the southern end of profile 20 W and at the northern end of profile 18 W, velocity layers of 7,550 and 8,200 feet per second respectively overlie bedrock. These higher velocities in the drift were interpreted at first to indicate till; subsequent drilling has confirmed the presence of till in the drift section at the north end of line 18 W. However, the failure to observe similar velocities elsewhere in the area does not preclude the presence of till.

Seismic velocities through bedrock vary from 15,000 to 17,000 feet per second, variations occurring both along the profile and from profile to profile.

Delay time under each geophone position was calculated and converted to depth using a velocity of 5,000 feet per second. A preliminary isopach map, based on the seismic and then existing borehole data, was prepared prior to the geochemical study drilling program. The map, Figure 1, is an altered version of the preliminary map. Borehole data arising from the geochemical study have been incorporated and the contouring adjusted accordingly.

Depths from all sources are indicated on the map with the most confidence given to depths obtained during the geochemical study. At each site drilled by the Geological Survey, approximately three feet of bedrock core was taken to verify that bedrock had been penetrated. Sixteen direct comparisons can be made between depths obtained seismically and those from the geochemical drilling program; this sampling gives a standard deviation of 24 per cent for the discrepancies.

Many factors can contribute to error in seismic depth estimates; in this case, the failure of the selected velocity function to be uniformly appropriate is probably the main cause of error.

Since the topography of the project area is virtually flat the isopach map depicts the bedrock configuration as well as the drift thickness. The most notable features of the bedrock surface are the rapid changes in relief with a generally east-northeast trend in the northern part of the map-area and the broader features in the rest of the area. The former may be related in some way to the mineralized zone or may be a function of the greater density of control.

Estimates of drift thickness are considered to be valuable preliminary data for geochemical studies; these can be made rapidly and economically by the seismic refraction method.

15. A COMPUTERIZED METHOD OF MAGNETIC INTERPRETATION FOR DYKE ANOMALIES

Project 680121

P.H. McGrath and Peter J. Hood

A self-adjusting least squares curve-matching method of magnetic interpretation for the dipping dyke case has been designed and programmed using the CGE-265 Time Sharing System[1]. Given a two-dimensional magnetic anomaly, the computer program automatically obtains the set of dyke parameters yielding a best-fit model anomaly curve. Thus with this method a best-depth estimate to the top of a dyke-like body may be determined. For cases of induced magnetization the effective susceptibility contrast and the dip of the dyke may also be calculated. For instance, using this program a depth of 1,900 feet below ground level was obtained for the Precambrian basement underneath the Phanerozoic cover of the Hudson Bay Lowlands at 91°20.0'W longitude and 56°51.4'N latitude. The causative body strikes

N 80° W, dips 76 degrees to the north, is 6,000 feet wide and possesses an effective susceptibility contrast of 3.3×10^{-3} c.g.s. units. This magnetic depth determination agrees with estimated basement depths for this area based upon (1) regional mapping of surface exposures[2], and (2) a reconnaissance seismic refraction survey[3].

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[1] McGrath, P.H., and Hood, Peter J.: The dipping dyke case: a computer curve-matching method of magnetic interpretation (in preparation).

[2] Cumming, L.M.: Personal communication.

[3] Hobson, G.D.: A reconnaissance seismic survey in Hudson Bay, Canada; Panel discussion No. 9, 7th World Petroleum Congress, Mexico City, April (1967).

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16. SEISMIC DATA EVALUATION, ELLIOT LAKE AREA, ONTARIO (41 J/2 7)

Project 660055

A. Overton

The seismic data for the feasibility assessment[1] in the Quirke Lake syncline have been subjected to exhaustive digital processing techniques. All available seismic velocity information from velocity profiles and the 'common depth point' profile have been scrutinized and analyzed for geological and statistical significance.

The conclusions are now clear:

(1) Seismic velocities for each formation may be expected to vary laterally as much as from one formation to another.

(2) Differences in seismic velocity between formations need not maintain a constant relationship in an areal sense, but may vary haphazardly.

(3) On the average, seismic velocities may vary by only a few hundred feet per second between formations.

These conditions are manifest on the processed 'reflection' sections by a general absence of coherent seismic events, but with occasional coherent bursts which may be attributed to a random velocity disparity between formations. It is sometimes possible to follow coherent lineups on the sections which can be rationalized as having geological significance, but the choices are numerous and can be found to fit nearly any preconceived geological structure. Thus one finds himself rationalizing seismic events in terms of assumed structure rather than the reverse process which must be possible for an effective exploration tool.

It has already been stated[2] that the seismic refraction method is of no use in the area for delineating structure at depth (it is an excellent method for determining depths to bedrock). It may now be stated that the seismic reflection method using the Texas Instruments Model 7000 B seismograph system for the survey, the most up-to-date processing techniques, and the most successful of field technology applied in other difficult areas, yield nothing but the most uninterpretable data. The seismic method must therefore be considered to be of no avail in delineating the basement features which are favourable to the concentration of uraniferous ores in the Quirke Lake syncline.

The author realizes the disappointment this conclusion will hold for those who were most optimistic at the outset of the experiment. He also recognizes that some will not (and certainly need not) accept this conclusion. Those wishing to continue experiments of this nature would be well advised to pursue the technique of surface energy sources in the form of either gas exploding devices or, perhaps preferably, swept frequency sources with signal cross-correlation capability.

The final report for this project is in preparation.

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[1] Overton, A.: Seismic reflection surveys, Elliot Lake, Ontario; Geol. Surv. Can., Paper 68-1, Part A, pp. 86-87 (1968).

[2] Overton, A.: Seismic studies, Elliot Lake area; Geol. Surv. Can., Paper 67-1, Part A, pp. 155-157 (1967).

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17. THERMOMAGNETICS OF PYRRHOTITE

Project 660525

E. J. Schwarz

The variation of magnetic properties with temperature of pyrrhotites ($Fe_{1-x}S$, $0 < x \lesssim 0.125$) is known to be abnormal in several respects due to the occurrence of crystallographic changes, ordering effects, and inhomogeneity in chemical composition.

The general shape of a thermomagnetic curve giving the change of the magnetization (J) acquired by specimens with vacancy contents $0.08 \lesssim x \lesssim 0.11$ in a constant magnetic field of several koe is shown on Figure 1. Recent work[1] shows that the curve must be interpreted as a hybrid curve indicating the coexistence of two phases (1 and 2) which differ in vacancy content. Moreover, a method was developed to calculate the chemical composition and the relative abundance of each of these phases from such curves.

The cation lattice sites of each of the $Fe_{1-x}S$ phases form two magnetic sublattices (A and B on Fig. 1). Each sublattice contains one-half of the total number of cation lattice sites in a crystal whether such sites are vacant or not. The total magnetization of each of the sublattices is indicated by an arrow in Figure 1, and it is composed of the cation magnetic moments. The total magnetizations of the sublattices of each phase are antiparallel. If the difference between the opposing sublattice magnetizations within each

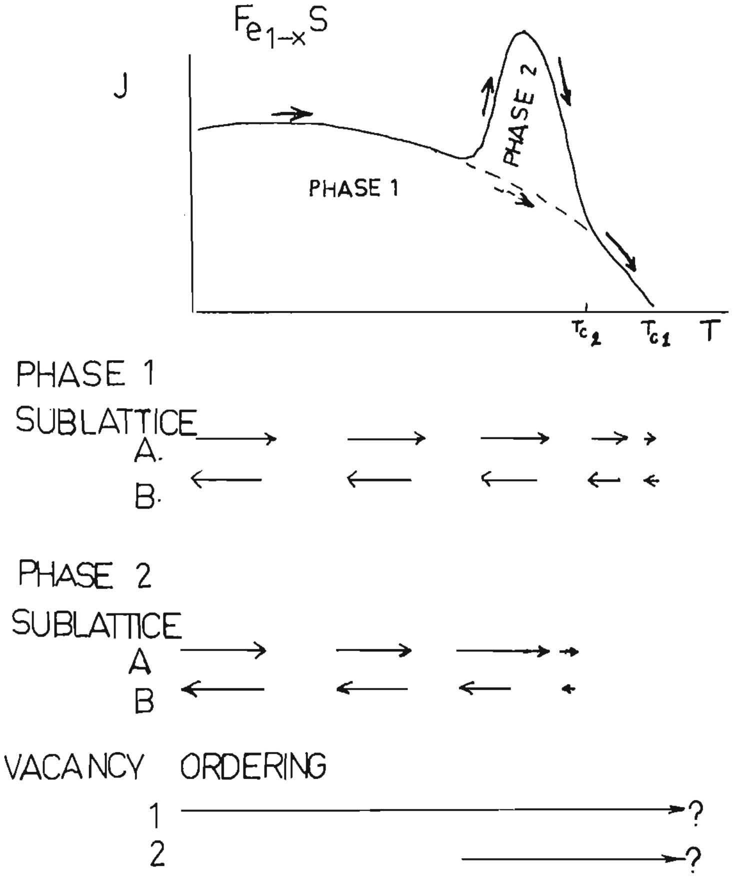

Figure 1. Thermomagnetic curve and the interpretation diagrammatically represented. For explanation see text.

phase equals zero (x = 0; or vacancies, Fe^{2+}, and Fe^{3+} equally distributed over both sublattices) we speak of antiferromagnetism; otherwise we deal with a ferrimagnetic structure. The total magnetization of each sublattice normally decreases with increasing temperature due to the breaking up of the coupling between the magnetic moments of the cations composing the sublattice. At the Curie point (T_{c1} and T_{c2} on Fig. 1 for phases 1 and 2), the magnetic coupling in relatively extensive volumes has disappeared. Phase 1 can be considered as a normal ferrimagnetic case due to a stable pattern of the vacant cation sites (no magnetic moments) in such a manner that these vacancies are concentrated on one sublattice while the other sublattice is filled up with Fe ions which possess an appreciable magnetic moment. The chemical composition of this phase corresponds to that (x = 0.125) for which such a vacancy ordering pattern was established[2]. On the other hand, the vacancy content of phase 2 is much smaller and it appears that the vacancies are equally divided over both sublattices giving rise to an antiferromagnetic structure up to about 100° C below T_{c2}. However, there is evidence[1, 3, 4] that at (T_{c2}-100)° C the vacancies tend to order in a somewhat regular pattern

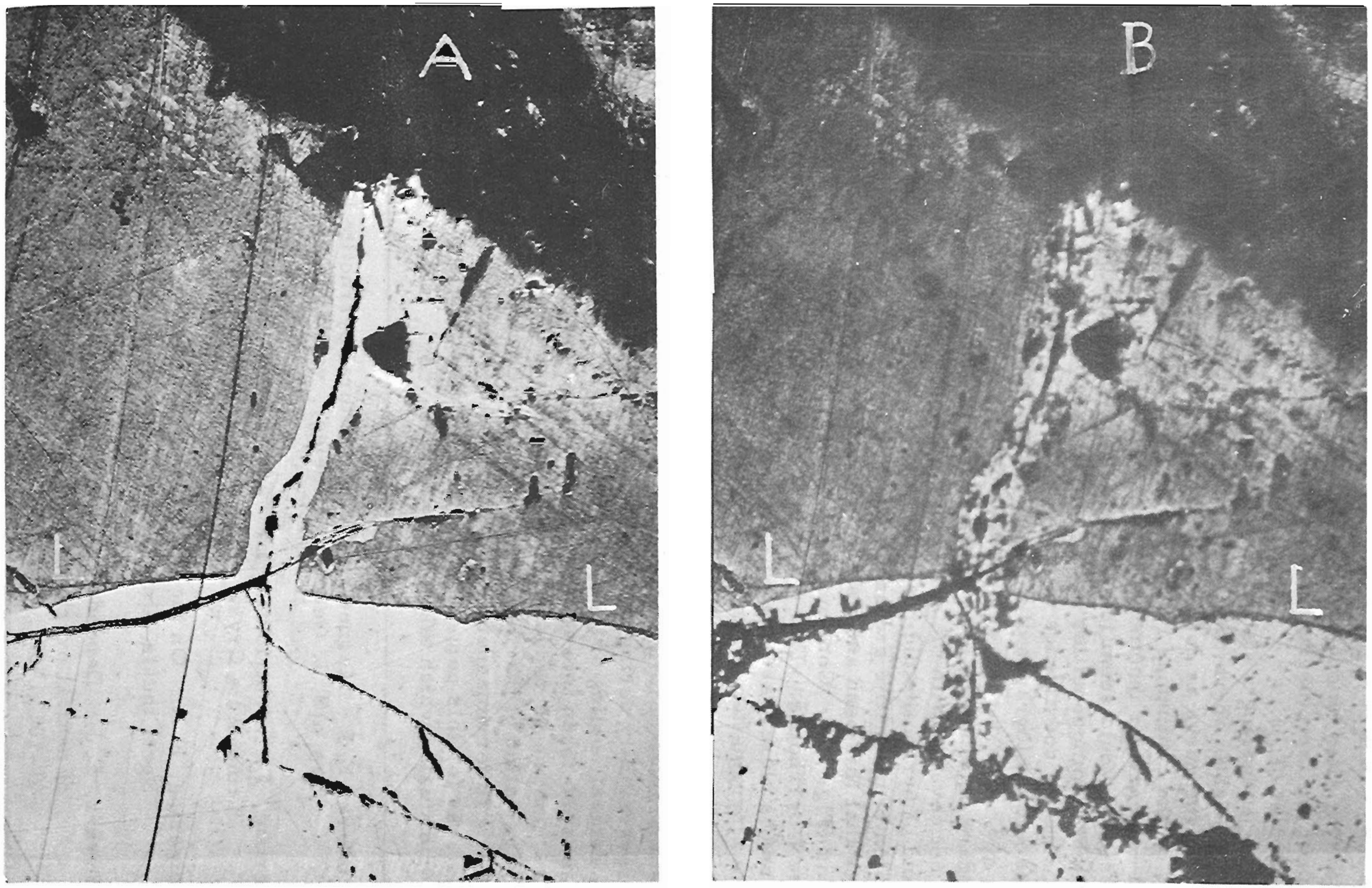

Figure 2. Photographs of polished section of $Fe_{0.91}S$ after etching of upper part only (boundary L-L) before (A) and after magnetization and application of the colloid containing magnetite grains.

preferring sites on one of the sublattices only. In that case, we have a transition of antiferromagnetism to ferrimagnetism which prevails up to the Curie point (T_{c2}).

Lotgering's statement[3] that ordering of the vacancies disappears on heating slightly above the Curie point is based mainly on slight variations in slope of the curve as determined by spot readings. We have found no indications on the continuous records for vacancy disordering. However, we have good evidence for inhomogeneity of the samples due to the coexistence of phases. It would seem that Lotgering's results can be explained on the basis of slight inhomogeneities of his synthetic samples.

The coexistence of phases 1 and 2 is illustrated on Figure 2 A and B. These are photographs of a polished section of pyrrhotite of bulk composition $Fe_{0.91}S$. The dark-grey areas reacted with the etching fluid (HI, 47%), the boundary between the area covered (upper part of illustration) with HI and that not covered with the acid running transversely across the photographs. A band of pyrrhotite did not react with the fluid. Application of a colloidal solution of magnetite grains in a soap solution to the surface of the specimen shows that this band and its continuation downwards attracts the magnetite grains (Fig. 2 B). Consequently, this band is ferrimagnetic corresponding to phase 1 pyrrhotite. This phase is formed by relatively sulphur-rich pyrrhotite and is closely associated with cracks. The rest of the area is formed by phase 2 pyrrhotite. Present work indicates considerable changes of this pattern after heating of this specimen.

Variations in magnetic properties of natural pyrrhotites can be used as temperature of formation indicators if these variations show no tendency for reversibility during heating and subsequent cooling. Furthermore, the slow natural cooling of many pyrrhotites, their thermal history, and their age must be taken into account in theoretical considerations as these conditions cannot be reproduced in the laboratory. Of several phenomena operative in the variation of thermomagnetic properties of pyrrhotites, the antiferromagnetic to ferrimagnetic transition of phase 2 pyrrhotite can be discarded as useless for this purpose because this transition is probably caused by cation diffusion which takes finite time.

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[1] Schwarz, E. J.: Magnetic phases in natural pyrrhotite $Fe_{0.89}S$ and $Fe_{0.91}S$; J. Geomag. Geoelec., vol. 20, pp. 67-74 (1968)

[2] Bertaut, F.: Contribution à l'étude des structures lacunaires: la pyrrhotine; Acta Cryst., vol. 6, pp. 557-566 (1953).

[3] Lotgering, F. K.: On the ferrimagnetism of some sulphides and oxydes; Doct. thesis, University of Utrecht, 87 pp. (1956).

[4] Schwarz, E. J.: Dependence of magnetic properties on the thermal history of natural pyrrhotite $Fe_{0.89}S$; J. Geomag. Geoelec., vol. 19, pp. 91-101 (1967).

GEOCHEMISTRY

18. GEOCHEMICAL STUDY, LOUVICOURT TOWNSHIP, QUEBEC (32 C/4)

Project 670097

R. G. Garrett

As part of a study to investigate the application of geochemical prospecting methods in the environment of the Canadian Shield a six-week (January-February) field program was undertaken on the Louvicourt Township property of Naganta Mining and Development Co., presently under option to Soquem, approximately 12 miles east of Val d'Or, Que.

The glacial overburden, consisting of glaciolacustrine sediments overlying a till of local origin, was sampled at 100-foot centres over, and in a down-ice direction from, the suboutcrop of a pipe-like orebody. The pipe is composed of a chalcopyrite-sericite assemblage and subcrops over an area some 250 feet by 75 feet. The pipe lies within a sphalerite-bearing pyritiferous zone approximately 1,400 feet long which trends at 060 degrees.

A screw-feed diamond-drill was used to sink 34 holes to an average depth of 38 feet. The holes were NX cased and samples were taken ahead of the casing with a split-spoon sampler. At each site an AXT core of approximately 3 feet was taken to verify that bedrock had been reached. Prior to drilling a shallow seismic survey had been undertaken in order to estimate the probable thickness of overburden (see also H. A. MacAulay, this publication).

A mobile laboratory was established in Val d'Or and the minus 80 mesh fraction of all samples was analyzed colorimetrically for Cu and Zn after a potassium pyrosulphate fusion. It is of note that a microwave oven was used for sample drying and proved very satisfactory. Batches of 12 wet samples each weighing approximately one half pound could be dried ready for sieving in 12 minutes.

The glaciolacustrine sediments overlying the deposit have a uniformly low metal content, 10 ppm Cu and Zn. However, marked dispersion patterns exist in the underlying till. A threshold of 30 ppm Cu was established for the area. An anomalous pattern overlies the cupriferous pipe and extends some 300 feet in the down-ice direction in the minus 80 mesh fraction of the till. There is evidence that the anomalous values climb through the till and that 300 feet down-ice the maximum values in the minus 80 mesh fraction are some 3 feet above bedrock, whilst at the bedrock interface values are of background level. Both clastic and saline dispersion patterns are present, the former being related to the glacial history of the area, and the latter being related to the present hydrologic regime. A limited number of heavy mineral concentrates made of casing washings revealed the presence of pyrite, chalcopyrite and sphalerite.

Further laboratory studies are planned in which the geochemistry of the heavy mineral and other fractions will be studied in detail.

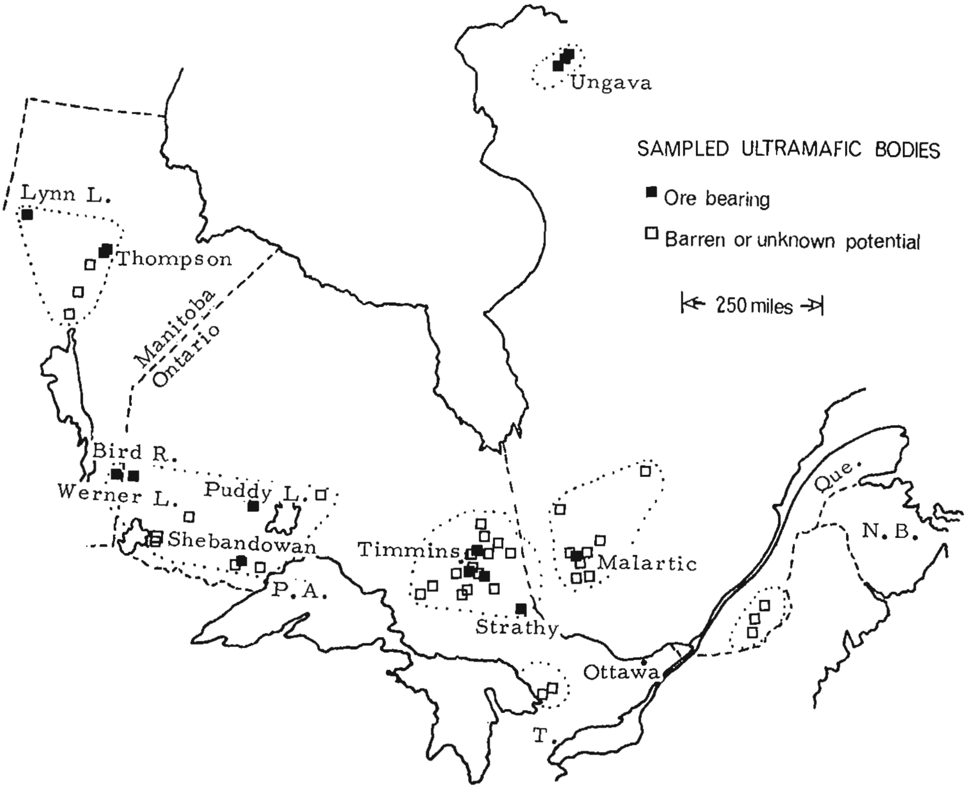
The detection of anomalous geochemical patterns in basal till could become a more widely used detailed exploration tool. The method might have great applicability in ranking geophysical anomalies before expensive diamond drilling programs are commenced. However, the ultimate success of the method depends greatly upon the design and manufacture of a portable and cheap (< $2.50/ft) sampling tool.

19. THE GEOCHEMICAL COMPOSITION OF ULTRAMAFIC ROCKS AND ITS RELATION TO THEIR CONTAINED MINERAL DEPOSITS

Project 680061

G. Siddeley

This study is being undertaken to determine ore-bearing potential in ultramafic rock bodies on the basis of their geochemical content. Over 50 ultramafic bodies (Fig. 1) are represented by 830 samples which have been individually analyzed for up to 23 major and trace elements. The data are presently being processed. Preliminary findings show that the most



favourable ore indicators in ultramafic rock are Ni, Cr, Cu, S, and possibly Zr, these elements generally being enriched throughout an ultramafic body associated with ore, though their greater statistical variability may also help to distinguish between ore-bearing and barren types. Different enrichment 'levels' of the above elements are present in individual ore-bearing bodies; thus, at Werner Lake, nickel in peridotites away from ore averages 0.35 per cent (this project), but elsewhere average nickel values for ore-associated ultramafics may approach the average for ultramafic rock as a whole (0.24%).

Several ore-bearing bodies have significant chemical differences from those considered barren for this project. In cases where there is no apparent difference, an explanation may lie with the mechanism of ore deposition (fault control or very local marginal reactions). Several bodies with unknown potential were also sampled, and the resultant data suggest that in perhaps three cases, there is more of a chemical affinity to the ore-bearing type rather than the barren type. Further exploration in these areas may be warranted.

Statistical treatment (multiple discriminant analysis and Bayesian decision theory) will be applied for more vigorous testing.

GEOMATHEMATICS

20. GEOMATHEMATICS AND DATA PROCESSING SECTION

Project 640426

K. R. Dawson

The Geodat Databank is basically a file of analytical results as reported by the Branch laboratories without modification or adjustment. The Databank has progressed rapidly enough so that the 30,000 rock and mineral analyses produced by GSC laboratories since December, 1956 were updated and written on the master tapes by the end of March, 1969. A complex retrieval program is in operation that will enable one to have data retrieved in a variety of ways and which will provide output on scratch tapes ready to serve as input to an index map plotting routine data or to a set of petrographic computation programs.

The 1956-1966 backlog of analyses was written on magnetic tape by November, 1966 and 18 batches had been advanced through the system to the update stage when the complex update program was found to be faulty. The resulting pause in master tape production lasted until May, 1968 when updating was started again.

The master tape is written to include all chemical analyses (reported as oxides) and quantitative emission spectrographic analyses of rocks and minerals produced by the Analytical Chemistry Section since 1956. All of the C^{14} and K-Ar ages, and a large number of size analyses of sediments produced by Branch laboratories, are also on file. The file has been partly edited by the software and corrected, and a more detailed manual verification of the data against the original laboratory reports is now in process.

The user is cautioned that the file is only as complete as the individual scientist who collected specimens was prepared to make it. Geographic retrievals, for example, are possible only when the necessary co-ordinates have been filed. The system is well provided with the procedures for deletion and correction of errors or omissions and these will be corrected as they become apparent.

21. THE CANADIAN INDEX TO GEOSCIENCE DATA (FORMERLY THE NATIONAL DATA INDEX)

Project 660505

B.A. McGee

The first index publication was given a limited distribution in July, 1968. A second edition, printed in eleven volumes, was distributed in December, 1968. An updated computer information system with the acronym SIS II (Streamed Information System II) is presently being tested and was producing indexes by April, 1969.

Each printing run of the Index project had two products – an index of the geological material that had been processed and a thesaurus of the terms used for indexing. The system allows for the printing of special indexes by provinces, discipline, geological age and other relevant divisions. Eleven such special indexes or volumes were printed.

The body of documents indexed represents, with trivial exceptions, the entire publications of the Geological Survey of Canada. Also included are a number of maps published by the Quebec Department of Natural Resources. In total numbers there are 8,000 Geological Survey documents and 200 from the Quebec Department of Natural Resources.

The thesaurus of terms used in indexing has grown to about 25,000 unique geological, geographical and author terms.

One of the functions of the project is to induce other agencies to contribute indexed source documents. For this purpose the Index Project trains indexers from other agencies. Our trainees thus far have been from provincial Departments of Mines. Quebec is the only province contributing material to the project. It is hoped other provinces will contribute in the future.

Future publication and distribution of the Canadian Index to Geoscience data will be the responsibility of C.F. Burk Jr., National Coordinator, Secretariat for Geoscience Data.

MINERAL DEPOSITS

22. FREQUENCY DISTRIBUTION OF MICRODEPOSITS AS A SUGGESTED INDICATOR OF MINERAL POTENTIAL

E.M. Cameron

Several investigators[1, 2] have noted that the frequency distribution by size of oil or of metallic mineral deposits within an area or rock unit is approximately lognormal (care must be taken in interpreting some published distributions since a lognormal distribution may be simulated by the mixing of data from several non-lognormally distributed populations).

One of the important consequences of this observation is that probability decision methods may be applied to exploration for mineral deposits. With a reasonable knowledge of the distribution function for a homogeneous group of deposits, the exploration strategy required to find further deposits of this type in the particular area or rock unit may be optimized. This is of particular importance in attempting to locate ore deposits at depth, for it may be possible to establish, with a known probability of success, an optimum drilling pattern.

The difficulty of this approach is that it is not possible directly to establish the frequency distribution for deposits within an area or rock unit that has not been explored in some detail and where the size and number of deposits has not been evaluated. However, it would seem feasible, in many cases, to estimate the distribution by chemical analysis of rock samples. This possibility arises because the observed frequency distribution of a group of related deposits is likely to be only the upper, low frequency, 'tail' of a much more general frequency distribution function for ore mineral(s) in an area, zone or rock unit. The majority of processes that give rise to ore deposits of economic size and grade must also produce a greater number of subeconomic 'showings' and an even greater number of yet smaller 'microdeposits', which are defined as an accumulation of ore mineral(s), one or more of which may be substantially contained within a normal fist-sized rock specimen. Kaufman[2] has noted that the decreasing frequency of oil deposits smaller than the mode for that distribution is an artificial condition caused by small, uneconomic oil accumulation not being reported.

Chemical analysis of rock samples for ore metals will reveal the distribution of these microdeposits within an area, zone or rock unit. Partial extraction is preferable in order that the metal contained within the ore minerals is measured rather than the total metal. The number of samples required adequately to characterize the distribution will vary considerably for different distribution functions. Comparison of the distribution function for microdeposits in areas or for rock types of known ore potential with the distribution function for microdeposits for areas or for rock types of unknown potential, should substantially aid in evaluating the probable mineral potential of the latter and allow the exploration strategy to be optimized. Departures from a lognormal or other regular distribution for microdeposits may be of value for interpreting ore genesis. For instance, truncation of the distribution curve above a given metal content may indicate the absence of geological processes capable of forming large deposits.

It is important to distinguish this suggested approach to the use of rock geochemistry in exploration from that where an attempt is made to locate, as potential targets, rock units simply richer in metal than the average for that rock type or area. Many ore-forming events have a negligible effect on the average abundance of the particular metal in the host rocks.

It is suggested that studies be made of the distribution of ore metals in areas and rock units of known mineral potential in order that the relationship between the distribution function for microdeposits may be related to the distribution function for ore deposits. This is being done for nickel in ultramafic rocks (see report by Siddeley, this publication).

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[1] Allais, M.: Method of appraising economic prospects of mining exploration over large territories; Algerian Sahara Case Study. Management Science, vol. 2, pp. 285-347 (1957).

[2] Kaufman, G.M.: Statistical decision and related techniques in oil and gas exploration; Prentice Hall, 307 pp. (1963).

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23. CONTINUING STUDY OF ALGOMA-TYPE IRON-FORMATIONS

Project 570029

G.A. Gross

Three aspects of the study of Algoma-type iron-formation in volcanic rocks were emphasized in the project work.

A study of the siderite-sulphide facies of iron-formation in the Michipicoten district, Ontario by Professor A. Sugaki* has defined nine prominent mineral assemblages and mineral phase relationships under relatively low-rank metamorphic conditions. The recognition of numerous primary sedimentary features on both the macro and the micro scale in these iron-rich beds, and a systematic study of alteration and recrystallization of these features in various stages of metamorphism, has provided valuable criteria for understanding their geological history and genesis. These established criteria, and new information on the genesis of these beds, provide a valuable guide for understanding and interpreting the origin of many other stratiform polymetallic sulphide deposits in volcanic rocks, the genetic history of which has been left obscure or poorly defined because of intense metamorphism and recrystallization.

Studies of the mineralogy, texture and mineral paragenesis of a number of Algoma-type iron-formations were continued by C.R. McLeod as part of a comparative study of different facies of this type of iron-formation in various sedimentary and metamorphic environments.

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* Research Associate, 1968-69.

Considerable progress has been made in plotting the distribution of iron-formation facies in the Superior Province of the Canadian Shield on a scale of 1 inch = 4 miles. This information on the iron-formation will be used in conjunction with information on types and distribution of volcanic rocks to interpret the depositional environment of the iron-formation and related areas favourable for the occurrence of polymetallic sulphide deposits.

24. A STATISTICAL ANALYSIS OF 1,700 COPPER DEPOSITS, CORDILLERAN REGION OF CANADA

Project 600009

E. K. Kindle

Summary tables prepared during a study of Cordilleran copper deposits indicate the presence of 8 principal types of copper lodes. Quartz veins, breccia fillings and stockwork deposits (733 listed) form the most numerous group and make up about 42 per cent of the total. Replacement deposits are not far behind (506 listed) and comprise about 30 per cent of the lot. Skarn lodes (309 listed) comprise about 18 per cent, and porphyry coppers (134 listed) form about 8 per cent of the deposits. Records of only 13 copper-bearing pegmatites, 4 supergene copper lodes, 4 sedimentary copper lodes and 6 copper-bearing placer deposits were found.

Statistical evidence discloses that the copper deposits are found in almost equal numbers in sedimentary rocks, in volcanic rocks and in intrusive rocks. The figures show that 36 per cent of the copper lodes occur in sedimentary rocks; 26 per cent are found in volcanic rocks (mostly andesites and basalts) and about 19 per cent occur in intrusive rocks, with granitic and dioritic types more favoured than basic intrusives. Nearly 13 per cent are found in intercalated sedimentary and volcanic rocks and 6 per cent occur in mica schists, gneiss and hornfels.

Triassic rocks are found to constitute the most favourable host rocks for the copper lodes, with 465 deposits or 27 per cent of the listed properties. Jurassic rocks contain 386 copper lodes or 22.6 per cent of the total, whereas Paleozoic rocks are host to 374 deposits or about 21 per cent of the total number. Cretaceous and Tertiary host rocks contain a combined total of 308 copper deposits or about 18 per cent of the total, and so are also very favourable host rocks. Precambrian strata contain 169 of the deposits or about 10 per cent of the total number of copper lodes.

Those copper lodes found in, or close to, intrusive rocks numbered 994 out of a total of 1,703 cases. Basic intrusions are present in 266 cases and acidic intrusives in 728 cases. These observations do not include numbers of occurrences where granitic, dioritic or gabbroic rocks may lie concealed close to the copper deposits or outcrop some distance away. It is concluded that copper deposits should first be looked for in the vicinity of igneous intrusions.

25. METALLOGENIC MAPS OF NORTH AMERICA AND CANADA

Project 640125

G. B. Leech

The Metallogenic Map of North America, scale 1:5,000,000, is one of a series of continental maps initiated by the International Geological Congress and carried forward through the Commission for the Geological Map of the World, an international association affiliated with I. U. G. S. The Canadian contribution to it is a co-operative project of the Canadian Metallogenic Map Committee composed of members from Provincial Departments of Mines and the Geological Survey, co-ordinated at the Geological Survey.

The first draft of the Metallogenic Map of North America formed part of the unfortunately brief display of maps at the 23rd International Geological Congress at Prague. This draft consists of a geological (s.l.) base and a metals-display whose Canadian part contains nearly 700 coloured symbols and district outlines. Each symbol denotes 4 to 8 geological characters of the mineral deposit or district it represents and each is keyed by number to a table of additional and verifying information.

The geological base provides the following information about the regional settings of the mineral districts:

1. ages of stratified rocks (10 classes)
2. whether they are sedimentary and/or volcanic
3. whether they are deformed or undeformed

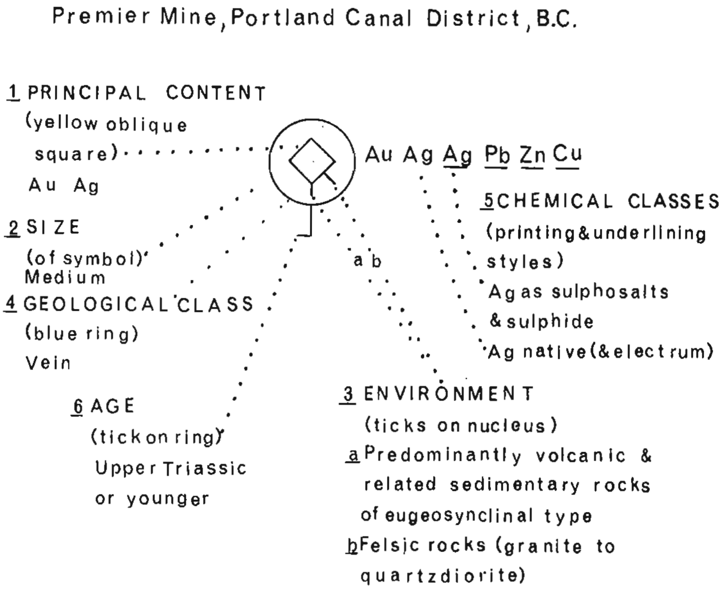
Premier Mine, Portland Canal District, B.C.

Figure 1. Representative symbol, metallogenic map.

4. degree of metamorphism (3 classes)
5. types of intrusive rocks (5 classes)
6. relative ages (3 classes) of granitoids ('orogenic' ages in Shield)
7. major regional structural and geophysical features.

The metals legend provides for representing the following features of each mineral deposit or district:

1. principal metal or metal-group or nonmetallic mineral (55 classes, represented by combinations of 5 shapes and 11 colours)
2. size (3 classes, ranges of metal tonnages dependent on the metal(s) concerned)
3. geological environment
   a. depositional environment of the stratified local country rocks (8 classes)
   b. compositions of intrusive rocks enclosing or associated with the deposit (7 classes)
4. geological class (11 classes, partly genetic, that is 'pegmatite' and partly morphological, that is 'more or less stratabound massive sulphides').
5. chemical class(es) (6 classes, e.g. sulphides, oxides).
6. age(s) of mineralization (8 classes, ranges dependent on tectonic region, plus provision for 'older than', 'younger than').

The sketch of a representative symbol (not to scale) shows how this is achieved.

Work is in progress on a related multiscale (with insets) Metallogenic Map of Canada.

26. GEOLOGY OF LEAD AND ZINC DEPOSITS IN CANADA

Project 650056

D. F. Sangster

As a result of recognizing that a disproportionately large number of lead- and zinc-bearing sulphide deposits of the Cordillera occur in Lower Cambrian strata, work was begun, in co-operation with other members of the Geological Survey of Canada, on the compilation of Lower Cambrian stratigraphy in the Canadian Western Cordillera together with associated lead-zinc deposits. Compilation, on a scale of 1 inch = 4 miles, consists of up-dating published maps as well as including new data. Final publication will consist of a series of maps on a scale of 1 inch = 8 miles together with a short text describing Lower Cambrian geology and the contained lead-zinc deposits. This study, which is only part of a continuing project on the geology of Canadian lead and zinc deposits, has the following main objectives: (1) to emphasize the importance of the Lower Cambrian to mineral exploration in the Western Cordillera; (2) to show the known distribution of Lower Cambrian rocks and their lithologies; (3) to show the distribution of known lead-zinc mines, prospects, and occurrences in the Lower Cambrian and briefly to describe the main geological features of each type of deposit; (4) to be a contribution to future, more comprehensive, metallogenic studies of the Canadian Cordillera.

27. NAKINA GEOLOGICAL-MAGNETIC STUDY

Project 630028

D. F. Sangster

Work on this project entered the final stages of completion of a manuscript describing the detailed relationships between geology and magnetic parameters of a metamorphosed Archean magnetite-quartz iron-formation. Such properties as volume susceptibility, vertical magnetic force, remanent magnetism, and other, were either measured in situ or in the laboratory on oriented drill core samples.

One of the main results of the survey is a semiquantitative measure of the contribution of remanent magnetism to vertical-force magnetic anomalies. The effects of deformation and intrusion of the iron-formation on its magnetic properties were also studied in detail.

MINERALOGY

28. STUDY OF MICA GROUP MINERALS AND HOST ROCKS

Project 590309

J. Y. H. Rimsaite

(1) Relationship Between Chemical Composition of Mica and the Host Rocks

Distribution of ionic proportions of Si, Al, Fe''', Fe'', Mg, Ca, Na, O, OH, F, Mn, Ti, Rb, Sr, Ba, Ni and Zn was studied between the micas and the host rocks. In most specimens studied, Fe'', Mg, K, OH, F, Mn, Ti, Rb and Zn are higher in the micas, and Si, Ca, Na, O and Sr are higher in the host rocks, whereas Al, Fe''', Ni and Ba may be higher either in the mica or in the host rock.

In lamprophyre, eclogite and carbonatite rocks studied, silica is either higher in the mica or equally distributed between the mica and the host rock; aluminium is usually higher in the mica and manganese is higher in the host rock.

Paragneisses and schists contain more water, magnesium, iron, titanium and strontium, and less silica and sodium than do orthogneisses and silicic magmatic rocks.

(2) Evolution of Zoned Micas and Associated Silicates in the Oka Carbonatite

Zoned minerals of the Oka carbonatite were studied by means of electron probe line scans and the relationships between the optical zoning and chemical composition was established. Zoned micas were studied in more detail by means of optical, X-ray, classical chemical, spectrographic and electron probe point counting analyses. The results indicated two- to ten-fold variations in ionic proportions of titanium, iron and aluminium, and lesser variations in concentrations of magnesium, silicon and potassium in six optically different mica zones.

Distribution coefficients of Si, Al, Fe''', Fe'', Ti and Mg in adjacent mica zones indicate the following relationships between the major constituents and trends in chemical evolution of the zoned crystals. With the exception of ferrous and ferric iron which show a straight line relationship, the relation between the other major constituents is more complex. Iron and magnesium exhibit opposite trends, modified by prominent variations in aluminium and titanium. Gradual variations within the zones are accounted for by gradual differentiation of the magma. The abrupt changes in chemical composition between the zones, coinciding with optical boundaries, indicate sudden changes in the environmental conditions, resulting from crystallization of associated minerals and periodic emplacement of certain elements into magma.

High Fe and high Ti-Al zones are used as markers for correlating cogenetic zones in pyroxene, amphibole and mica, and for establishing periods of crystallization of Fe-Ti minerals.

The zoned micas are dominant silicates and the principal carriers of Si, Al, Ti, Fe'', Mg, K, and OH in the Oka carbonatite. They represent the entire crystallization history of the host rock: mica varieties forming inner zones of the phenocrysts are cogenetic and correlative with the phenocrysts of olivine, zoned pyroxene and amphibole; the fine-grained zoned phlogopite is correlative with the associated carbonates and disseminated Fe-Ti ore minerals in the groundmass; the pleochroic biotite adjacent to quartz-alkali feldspar vugs represents the latest phase of crystallization of residual magma.

(3) Structural Formulae and Process of Oxidation and Dehydration of Biotite, Phlogopite, Muscovite and Lepidolite

Unit cell contents of 26 natural and laboratory dehydrated and/or oxidized micas were calculated applying a proposed method based on '44 + z' valencies, where 'z' is the charge difference between the original (or ideal) and altered mica. By comparing the proportions of oxidized iron and the anionic contents of the mica, the process of decomposition of the hydroxyl group and relative stabilities of hydroxyl and fluorine in the mica lattice were established. Calculated proportions of lost components of the hydroxyl group through processes of oxidation and dehydration, and changes in the charge balance of mica layers resulting from oxidation of iron were obtained for chemically analyzed biotite, phlogopite, muscovite and lepidolite.

Results of this study are summarized below:

(1) Natural and laboratory dehydrated biotite, phlogopite, muscovite and lepidolite retain the mica structure. Partly dehydrated phlogopite and biotite are stable at 1000° C, and oxidized biotite retains its structure with only 10 per cent of the original fluorine and hydroxyl remaining in the hydroxyl group.

(2) Fluorine has a higher thermal stability in the mica lattice than does hydroxyl. Biotite and phlogopite retain a larger proportion of fluorine than do muscovite and lepidolite heated under similar conditions.

(3) Phlogopite, lepidolite and muscovite lose less hydroxyl through the process of dehydration than biotite which loses hydroxyl also through the process of oxidation.

(4) Iron-rich biotite containing a large proportion of fluorine and insufficient oxygen in the hydroxyl group for oxidation of the whole of the iron, on heating remains either in a semi-oxidized state or oxidizes at the expense of atmospheric oxygen.

(5) An increase in the positive charge of the octahedral layer, resulting from oxidation of a large proportion of iron, decreases the stability of cations in the interlayer (K) and in the tetrahedral layer (Si).

(6) Biotite heated in an oxygen-free atmosphere (argon) loses a larger proportion of hydroxyl through the process of dehydration than does the biotite heated in air.

(7) Micas heated in an argon atmosphere adsorb atmospheric argon.

PRECAMBRIAN GEOLOGY

29. THE FLACK LAKE DEPRESSION, ELLIOT LAKE AREA, ONTARIO (41 J/10)

Project 680025

G. H. Eisbacher and H. U. Bielenstein

Renewed interest in uranium exploration in the Elliot Lake region has led to drilling activity in the Flack Lake structural depression, 15 miles north of Elliot Lake.

Rocks in this area have recently attracted attention because of peculiar corrugated spindles found in the Bar River Formation[1], and because of the area's significance in the regional correlation of the sedimentary rocks of the Cobalt Group[2].

During the fall of 1968 three holes were logged to obtain stratigraphic and structural data (holes A, C, D on Fig. 1); only fragmentary information was obtained for a fourth hole (hole B on Fig. 1).

Holes A and B reached the Archean basement at 2, 510 feet and 3, 900 feet respectively. Holes C and D went to depths of 2, 780 feet and 3, 900 feet respectively, without reaching basement.

Holes A and B intersected the Lorrain Formation and the Gowganda Formation. Holes C and D intersected the Bar River Formation, Gordon Lake Formation, and Lorrain Formation. The complete core of hole D was stored at the Mining Research Centre, Elliot Lake, to serve as reference section for the Bar River Formation and the Gordon Lake Formation in the Flack Lake depression.

The Gordon Lake Formation was found to be 940 feet thick in hole D and about 1, 000 feet in hole C. These values agree well with the thickness of the Gordon Lake Formation in its type area[3], 50 miles west of the Flack Lake depression. Three units could be recognized in both holes: a lower unit consisting of reddish, mottled quartz-sandstone and siltstone, intraformational breccias, and nodular aggregates of anhydrite; a middle unit consisting of dark green argillite and chert; an upper unit consisting of reddish buff mudcracked siltstone, argillite, and occasional chert.

The Bar River Formation in the area is made up of crossbedded quartz-sandstones with a minimum thickness of 1, 500 feet (intersected by hole C).

The thrust shown in Figure 1 was possibly intersected by hole D where it could be responsible for a zone of quartz veining and disturbed bedding within the Gordon Lake Formation. The thrust plane dips only slightly steeper than bedding, and is expressed by numerous northerly trending bedding-plane slip linears.

The basement contours in Figure 1 suggest that the depth to basement immediately north of the Flack Lake Fault probably exceeds 5, 000 feet.

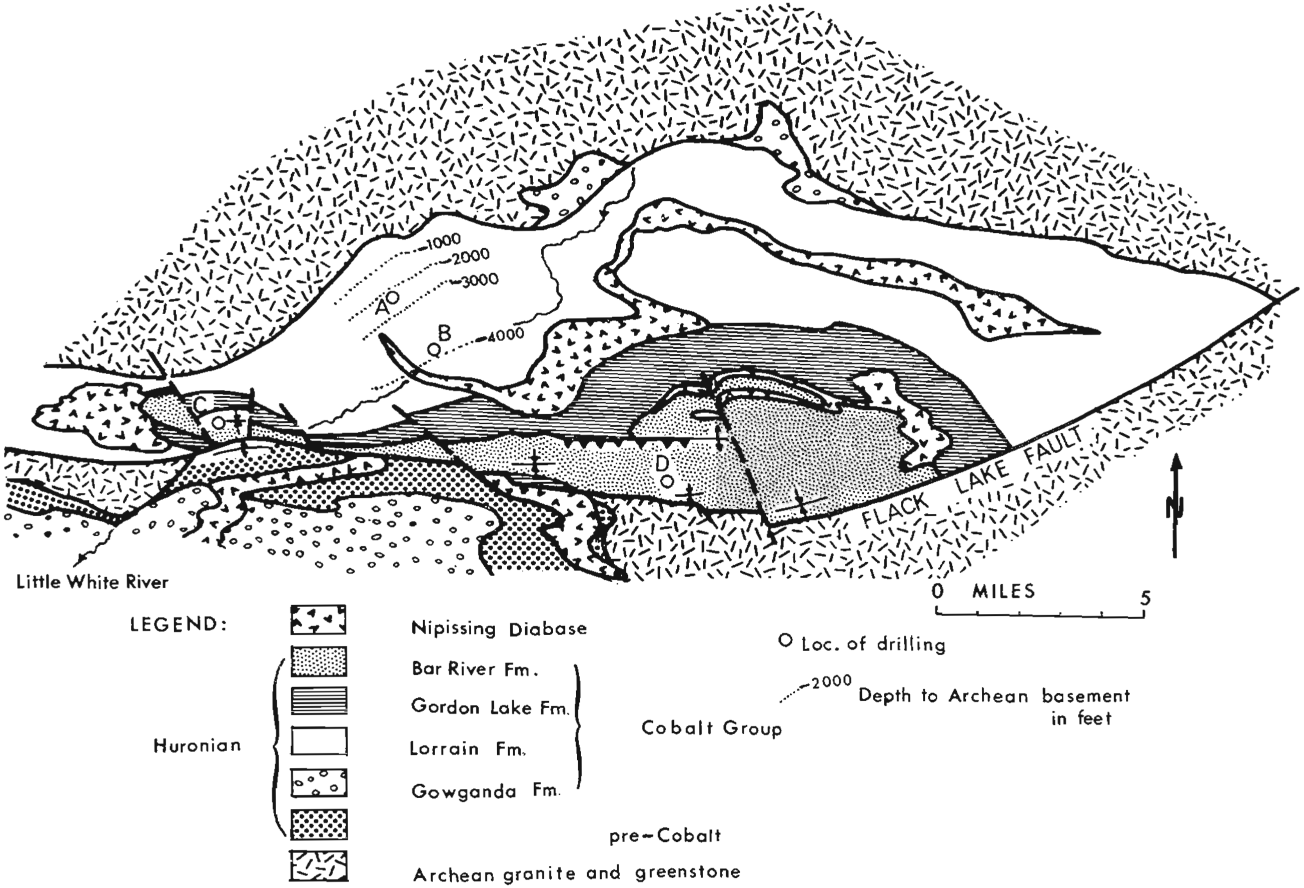

Figure 1. Sketch map of the Flack Lake depression.

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[2] Young, G. M.: Huronian stratigraphy of the McGregor Bay area, Ontario: Relevance to the paleogeography of the Lake Superior region; Can. J. Earth Sci., vol. 3, pp. 203-210 (1966).

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QUATERNARY RESEARCH AND GEOMORPHOLOGY

30. SEDIMENTOLOGY OF AN ESKER NORTH OF PETERBOROUGH, ONTARIO

Project 670036

Indranil Banerjee

A well-developed esker ridge, approximately 10 miles long, north of Peterborough, was chosen for a detailed sedimentological investigation. Eleven gravel pits along the esker were examined. These provided a large

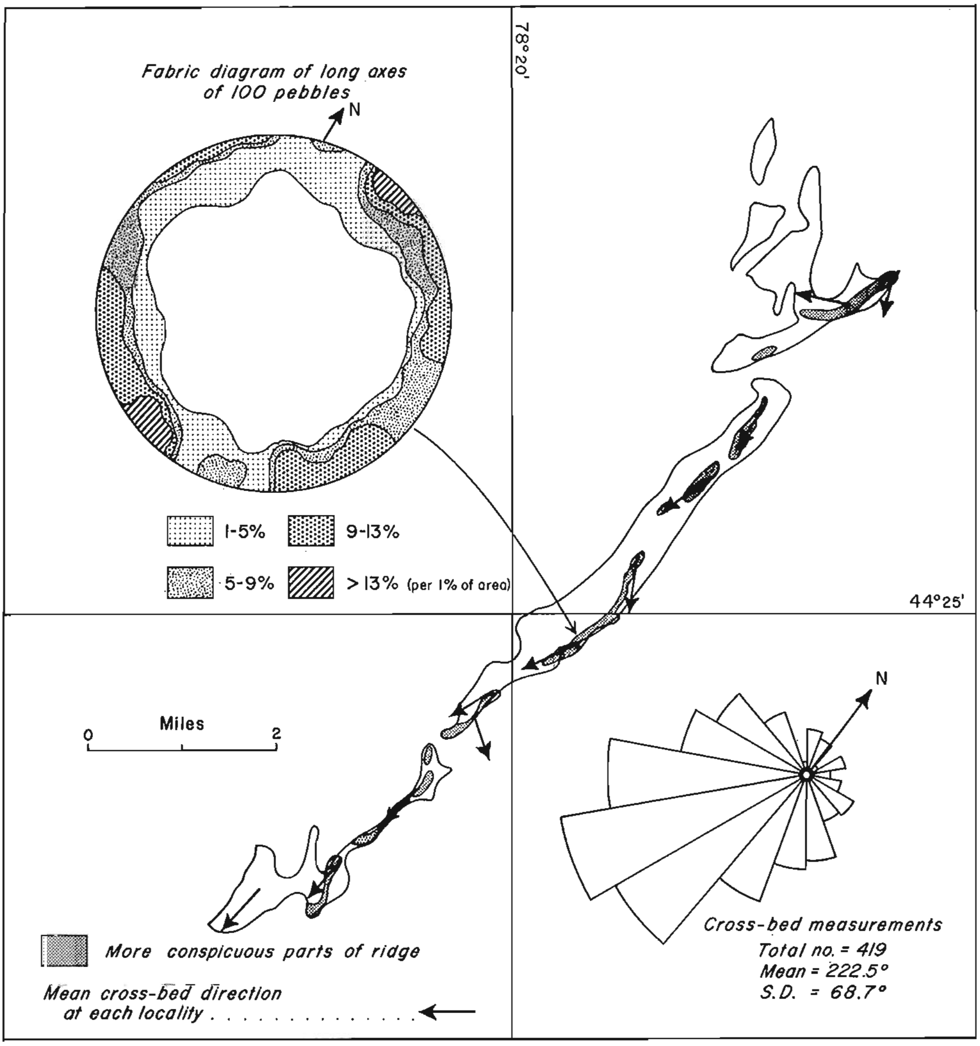

Figure 1. Paleocurrent data from the Peterborough esker.

number of cross-sections which were used to outline the stratigraphy of the esker. Five facies of sediments are common to the esker.

Arranged in stratigraphic order these basic units are:

		Maximum thickness (feet)
5	Silty rhythmites (varves)	10
4	Small-scale crosslaminated or graded very fine sand and silt	20
3	Large-scale crossbedded medium sand	40
2	Massive gravel with lenses of crossbedded coarse sand	80
1	Giant crossbedded gravelly coarse sand with lenses of silty rhythmites	30
	Total thickness	180 feet

In some localities the units occur in the order shown; in others, units 3, 4 and 5 interfinger.

A gentle fold pattern was reconstructed from a number of dip data and a provisional correlation of the stratigraphic units at the north end with those at the south end of the esker. Other structures exposed in the esker are subvertical gravity faults with throws of 5 to 10 feet, and a few thrusts, particularly in unit 4.

Cross-stratification is ubiquitous. The following types have been recognized:

- Giant (thickness: 124-234 cm)
- Large-scale (thickness: 22 to 48 cm)
- Small-scale (thickness: 2-8 cm)

A total of 419 measurements from all over the esker, representing all of the above three types show that the grand mean direction is approximately parallel to the axis of the esker ridge (Fig. 1). At one gravel pit, 100 pebble-orientations were measured from the massive gravel (unit 2). The pebbles show a strong preferred orientation in the current direction, but show no tendency for imbrication.

A model of esker sedimentation based on De Geer's views explains the facies relationship and paleocurrent patterns.

Laboratory study of the sediments is in progress.

31. DIFFERENCES IN TALUS FORMS IN THE OGILVIE AND WERNECKE MOUNTAIN, YUKON TERRITORY

Project 670033

J. T. Gray

Research has been conducted since the summer of 1966 on talus forms developed below steep bedrock slopes in two field areas in the Ogilvie and Wernecke Mountains, Yukon Territory. One of these field areas is the

Tombstone district, 35 miles northeast of Dawson City; the other is the Bear River district, 160 miles east of Dawson (Fig. 1). Structurally, the Tombstone area consists of a stock of igneous intrusives (predominantly quartz monzonite and syenite) surrounded by metasedimentary rocks (mainly quartzites and slates)[1, 2]. The Bear River area lies in a zone of metasediments consisting of dolomites and slates, with minor quartzite[1].

The features may be grouped into the following three categories.

Talus cones. These are developed below gullies in the bedrock walls, and are the principal colluvial debris forms below the metasedimentary escarpments in both field areas. The metasediments, being bedded and fissile, are readily eroded. The rock walls are, therefore, seamed at frequent intervals with deeply incised gullies and shallow chutes and there is a high degree of surface rugosity. Talus cones are rare in the zone of igneous intrusives in the Tombstone area, where gully networks are infrequent and poorly developed owing to the widely-spaced rock joints. A few cones occur below narrow joint-controlled gullies and chimneys.

Talus aprons. These are the most common depositional forms below the rock walls in the Tombstone intrusives. As indicated above, the smooth walls prevent concentration in cones except at infrequent intervals. The talus aprons usually consist of a thin veneer of coarse blocks spread over a narrow zone at the base of the walls.

Protalus debris forms. These occur as horizontal or nearly horizontal extensions of many cones, projecting outward over a low-gradient, valley floor, and are termed by the writer 'protalus rock glaciers'. In some cases they extend 200 to 400 yards from the sharp concavity at the base of the cone (Fig. 2). In other cases there is only a slight basal bulge.

Angular profiles along the fall line of thirty-one talus cones were obtained by incrementing hand level measurements over intervals of twenty-five metres. The mean and maximum angles for the eight cones in the zone of igneous intrusives are greater than those for the twenty-three in the zone of metasedimentaries. The eight cones in the igneous intrusives are built up mainly by processes of rockfall. Avalanches are of only secondary importance because the walls are too steep to act as gathering grounds for large masses of snow. There should, therefore, be minimal external disturbance of the debris on the slopes and, hence, the slope angle should be close to the maximum angle of repose for talus. This angle has been found by several researchers to lie between 35 degrees and 40 degrees; Melton[3] gives the figure 35.5 degrees to 36.5 degrees for talus slopes in Arizona, and Rapp[4] (p. 46) gives the figure 35.9 degrees for one of the cones he examined in Spitsbergen. For the group of eight cones in the Tombstone area of igneous intrusives, the mean maximum angle is 33.9 degrees.

In the metasediments, by contrast, avalanches have an important influence on the talus cones. The rock walls lie at a much gentler angle and support large snow fields. In the spring, avalanches are released in various parts of the gully network at different times. This means that several avalanches may affect the same talus cone each spring. In many cases the talus cones are bare of snow by the time the late avalanches occur. These late avalanches have, therefore, a considerable erosive effect on the cones, which are indeed transitional between the avalanche boulder tongues described by Rapp[5] in Northern Sweden and the talus cones produced purely by rockfall.

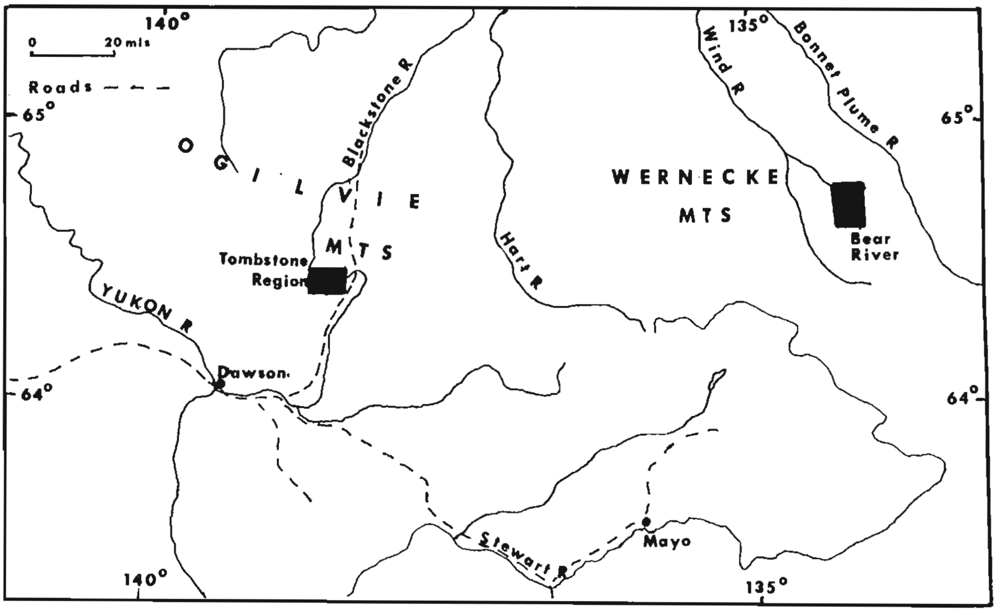

Figure 1. Location of field areas, central Yukon Territory.

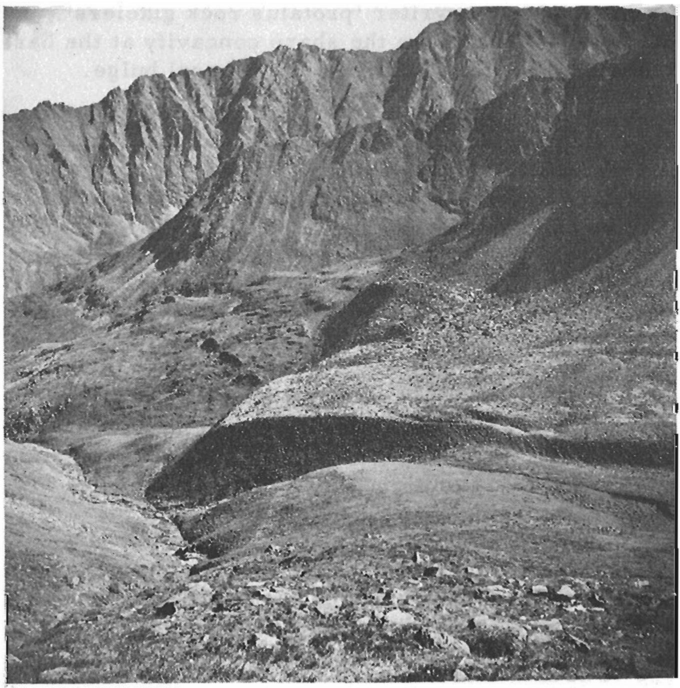

Figure 2. 'Protalus rock glacier' in the Bear River area. Its movement has caused a stream to be diverted to the near side of the main valley.

Rapp suggested that the reduction of angle in the avalanche boulder tongues was due to the erosive effect of avalanches. The mean maximum angle for the twenty-three cones in the metasedimentary zone in the Tombstone and Bear River areas is 31.7 degrees, which indicates similarly important avalanche influence on these slopes.

The concavity of all thirty-one cones, both those affected by avalanches and those produced by rockfall, is of importance. In Spitsbergen, Rapp[4] (p. 52) related this concavity to avalanche erosion and indicated that cones not affected by avalanches tend to be rectilinear or slightly concave in profile. The present writer considers that the concavity of the profiles may be the result of segregation of particle sizes on different parts of the slopes by the mechanism of fall-sorting.

This is a process, described by Bryan[6] among others, whereby the large rockfall particles bound, roll or slide to the base of the slope, whereas the small particles come to rest near the top. Experiments conducted with a small-scale, rockfall-simulation model with a mixture of dry gravel and dry sand indicated, however, that, despite the occurrence of fall-sorting, a concave slope profile was not developed. Indeed, a slight convexity was noted, the sand on the upper part of the slope lying at a lesser angle than the gravel below.

Other reasons must, therefore, be found to explain the slope concavity. In a case where the talus slope is concave in its upper part and convex in its basal part, it is possible that internal mass movement of the accumulated debris is responsible for the form. Such movement may eventually lead to the development of a large basal bulge that may gradually move out toward the centre of the valley in the form of a 'protalus rock glacier'. In the case of a concave slope with no basal convexity, it is difficult to visualize mass movement as the agent responsible. In such cases it will be necessary to determine, by statistical measurements, the degree of concavity present, and to determine whether the maximum concavity occurs near the base, middle or top of the talus slope.

Examination of the significance of variation in the cone profiles is continuing.

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[1] Green, L.H., and Roddick, J.A.: Dawson, Larsen Creek and Nash Creek map-areas, Yukon Territory; Geol. Surv. Can., Paper 62-7 (1962).

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[3] Melton, M.A.: Debris covered hillslopes of the southern Arizona Desert – consideration of their stability and sediment contribution; J. Geol., vol. 73, pp. 715-729 (1965).

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32. SOURCE OF ANDRADITE GARNET IN THE MUNRO ESKER

Project 620035

Hulbert A. Lee

The bedrock sources of two important varieties of garnet, pyrope and andradite, that occur in the Munro esker are of particular interest. The pyrope has already been shown to have a source in kimberlite from the Upper Canada Mine[1, 2].

TABLE 1

Chemical Analyses, Physical Properties of Andradite from Adams Mine and Pyrope from Upper Canada Mine of Gauthier Township

	1	2
SiO_2	ca. 38	40.2
TiO_2	0.03	0.1
Al_2O_3	0.70	21.7
Cr_2O_3	-	3.4
Fe_2O_3 } FeO }	30.1	7.7
MnO	0.05	0.5
MgO	0.16	19.8
CaO	30.9	5.6
Total	-	99.0
n	1.885	1.745
a (Å)	12.042	11.541
colour**	10R 5/6	10P 5/5

[1] Andradite garnet, Adams Mine, Ontario. Fe_2O_3, MgO, and CaO analyzed by atomic absorption. All other data except SiO_2 determined by a quantitative spectrographic method and results are expected to be accurate to within 15 per cent of values reported. New analysis by Analytical Chemistry Section, Geological Survey of Canada.

[2] Pyrope garnet in kimberlite from Upper Canada Mine, Ontario, from Lee and Lawrence (1968).

** Colour from: Munsell Book of Colour, Library edition, vol. 1, Munsell Colour Company, Baltimore, Maryland, 1929. Measurement is made on crushed mineral fragments under reflected light.

An iron-formation well-exposed in the Adams Mine of Boston Township, extends for some distance to northeast into Lebel Township, marginal to the esker and was examined as a source for the andradite. The iron-formation is a typical banded volcanic-sedimentary deposit chiefly composed of magnetite and chert with minor hematite derived from local oxidation of magnetite, and contains considerable garnet concentrated in lenses and pods. Chemical and physical characteristics of garnets collected from the Adams Mine and Upper Canada Mine are given in Table 1.

Based on the analytical data, the garnet from the iron-formation is andradite. Therefore, it is reasonable to infer that the andradite garnet in the Munro esker was derived from the iron-formation.

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[1] Lee, H. A.: An Ontario kimberlite occurrence discovered by application of the glaciofocus method to a study of the Munro esker; Geol. Surv. Can., Paper 68-7 (1968).

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33. DENDROCHRONOLOGICAL INVESTIGATIONS IN CANADA

Project 680026

M. L. Parker

A dendrochronology laboratory has been established for the purpose of providing chronological and climatological information on postglacial events through analysis of tree-ring chronologies. The first phase of this research has been focused on two major objectives: (1) to collect samples of most coniferous species throughout the forested regions of Canada for the purpose of building master chronologies; and (2) to develop laboratory techniques and instruments for rapid and specialized processing of tree-ring data.

Master tree-ring chronologies for a network of living tree sites throughout Canada will provide a basis for site and species dendrochronological quality evaluation, a foundation for dating dead wood specimens, and a means of observing climatic change through time and space. A typical master chronology consists of tree-ring indices, derived from ring measurements of two increment cores from each of ten trees of the same species from a single site. Master chronologies have been built for the following species and sites: Douglas-fir (1310-1967) from Banff, Alberta; Engelmann spruce (1680-1967) from the Peyto Glacier area, Alberta; white spruce (1870-1967) from the Cypress Hills, Alberta; black spruce (1911-1968) from the Calling Lake area, Alberta; eastern hemlock (1810-1968) and eastern larch (1900-1968) from the Petawawa Forest Experiment Station, Ontario; eastern larch (1918-1968) from the Acadia Forest Experiment Station, New Brunswick; eastern white cedar (1850-1968) from the Wawieg River area near St. Stephen, New Brunswick; eastern hemlock (1860-1968) from Amherst Point, Nova Scotia; and white spruce (1640-1966) from six different sites near Dawson, Yukon Territory.

Laboratory studies can be divided into two main aspects: (1) analyses utilizing ring-width measurements; and (2) analyses utilizing intraring density measurements. Techniques of data processing, dating, and climatic analysis of ring-width measurements developed at the Laboratory of Tree-Ring Research, University of Arizona, are being used. The Arizona laboratory has supplied the Geological Survey with a number of electronic computer programs for standardizing, summarizing, and comparing tree-ring chronologies. K. Shimizu and J. L. MacFarlane of the Division of Quaternary Research and Geomorphology, have written a tree-ring digital plotting program and a digital filtering program that standardizes tree-ring series by removing either long-term or short-term fluctuations.

Utilization of intraring density measurements has been made possible through the development of X-ray techniques by K. Meleskie (Non-Destructive Testing Laboratory, Mines Branch), and through the development of an X-ray and wood specimen scanning and measuring instrument by F. W. Jones of the Geological Survey. The tree-ring scanning and measuring instrument produces a plotted graph of intraring density measurements from a radiograph of a tree-ring specimen. The instrument also obtains ring-width measurements from the X-ray negatives of wood samples or from actual wood specimens. These measurements are automatically punched on paper tape for electronic computer analysis. Intraring density measurements provide information not obtainable from ring-width measurements alone. This additional information will improve the dating potential for many of the Canadian tree species that lack sufficient ring-width variability for cross-dating purposes.

A portable power-driven increment borer which takes a three-quarter inch wood core has been developed by G. A. Meilleur by modifying a rock sampling device. This instrument is useful for rapidly sampling dead wood specimens. The wood core produced is large enough to be used for several purposes: radiocarbon analysis, microscope examination and measurement, intraring density analysis, and species identification.

Approximately one hundred submerged wood specimens were collected from the intertidal zone in the Bay of Fundy area with the assistance of D. R. Grant. Wood samples were also taken from historical structures. The purpose of this field work was to determine the feasibility of using present dendrochronological techniques for building tree-ring chronologies to date submerged forests in that area. Analysis of living hemlock and submerged dead wood tree-ring series indicates that the material is potentially datable.

STRATIGRAPHY

34. ABNORMALLY THICK TERTIARY-CRETACEOUS SEQUENCE, MACKENZIE DELTA, DISTRICT OF MACKENZIE

Project 670068

T. P. Chamney

Upon completion of the first 'Delta' borehole, Reindeer D-27 Gulf-Shell - IOE, 69° 10'N, 134° 30'W, to a depth of 12,668 feet, several new stratigraphic problems were encountered. Although some valuable data on the economic potential for hydrocarbon source and entrapment has led to the drilling of two additional test holes, namely, Tununuk K-10, IOE-Gulf-Shell and Tuk F-18 IOE, many of the early stratigraphic problems of the abnormally thick Tertiary-Cretaceous sequences still remain to be satisfactorily explained. An approach to part of such explanation has been forwarded by first indicating the mode of deposition and sketching the geometry of these sediments[1].

The purpose of this report is to present a possible explanation for the abnormal thickness of the combined Tertiary-Cretaceous sequence penetrated by the Reindeer D-27 borehole. In all of these interpretations it has been necessary first to interpret the age of the strata which, in the contributions presented to date, has been based on the recovery of microfossil organisms, in particular the Foraminifera. Based on the author's estimate of the regional thicknesses of the major geological units compared with the provisional interpretation of comparable units in the Reindeer D-27 borehole, a striking anomaly for the Upper Cretaceous unit appears to be present.

Major Geological Units	Estimated thickness (in feet)		
	Regional	Reindeer D-27	Anomaly
Tertiary	3,500+	4,500+	near regional
Upper Cretaceous	2,000 (max.)	5,500+	3,500±
Lower Cretaceous Albian Neocomian	2,500 ?penetration	2,900	near regional

The Tertiary-Cretaceous boundary is tentatively placed at 4,730 feet with the first appearance in the borehole of Cretaceous Foraminifera whose tests are composed of calcium carbonate or represent complex chambering such that they are sufficiently fragile not to withstand attrition from

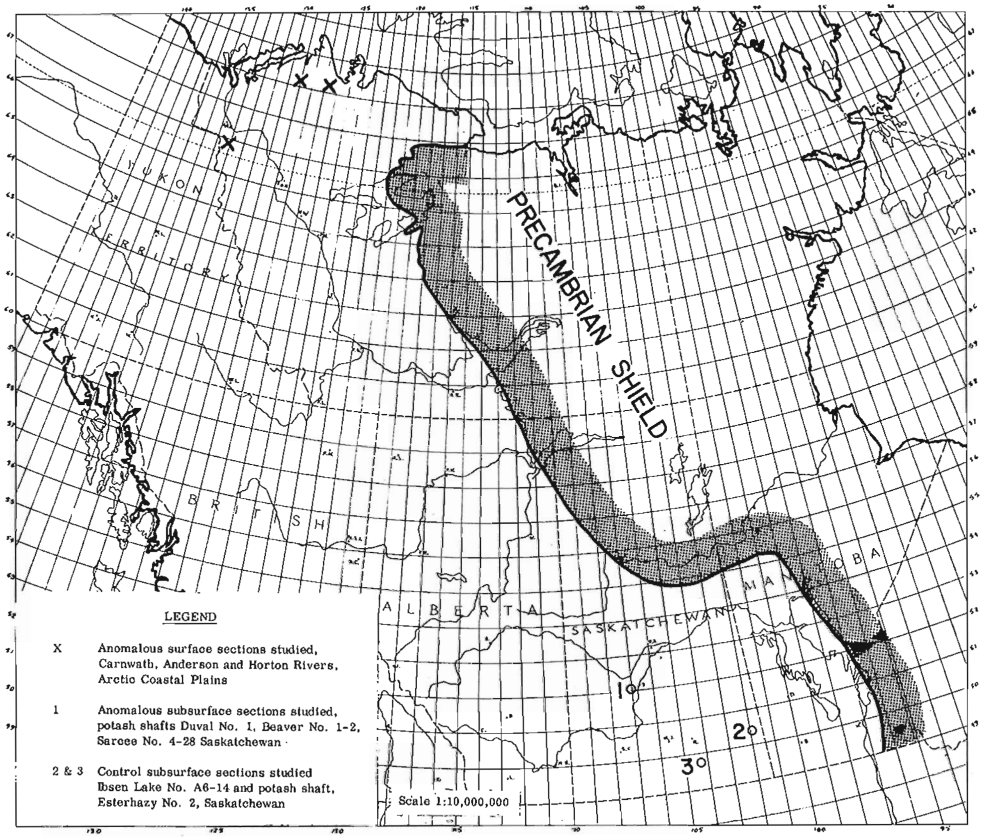
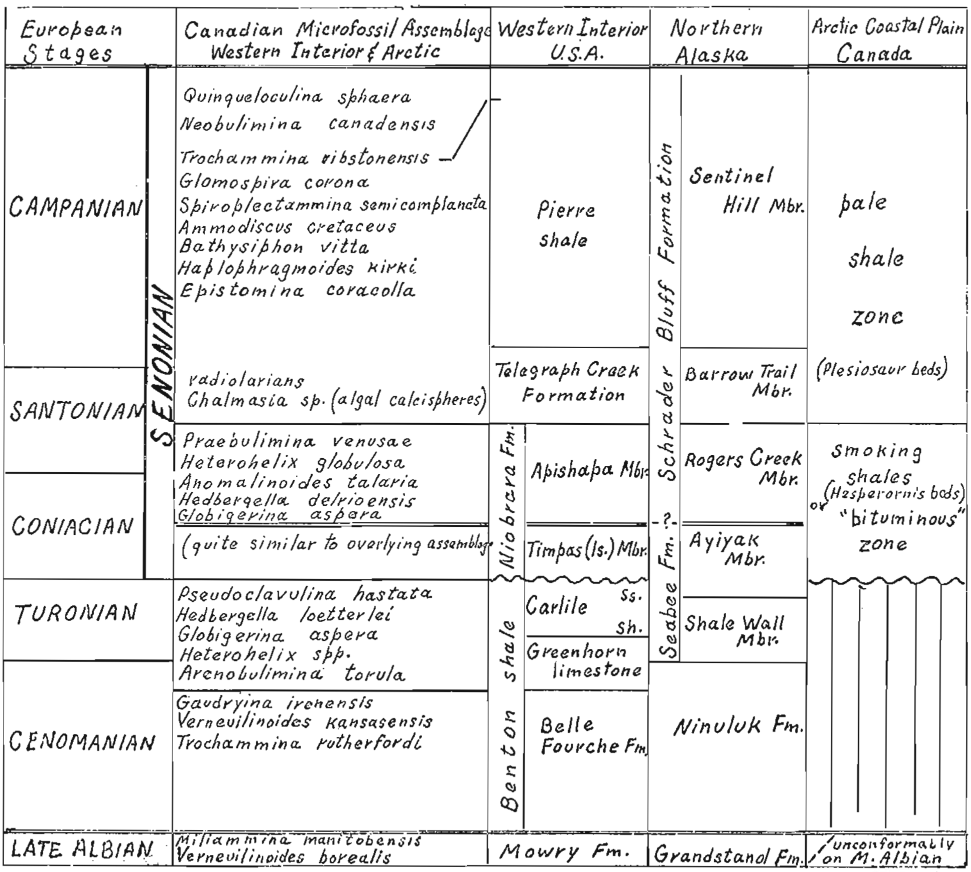


Figure 1. Regional aspect.

transportation. Other Cretaceous foraminifers were noted above this well depth but were considered to be derived microfossils from pre-existing, Cretaceous sediment source rocks, in that their tests were composed of large quantities of silica cementing the quartz grains. The following microfossil assemblage is a composite established from the boundary 4,730 feet down to 5,350 feet:

Anomalina ex. gr. A. monilithiformis
Haplophragmoides ex. gr. H. gigas minor
H. Haplophragmoides sp. .34 x 7
Thurammina-Hippocrepina sp.
Miliammina sp.
Verneuillinoides ex. gr. V. fischeri
Trochammina sp.

The Trochammina cf. T. ribstonensis zone appears in the borehole at 6,115 to 6,116 feet and is then present in a few of the underlying samples associated with Saccammina ex. gr. S. lathrami and numerous species of Haplophragmoides. The lower portion of the Upper Cretaceous is represented by Praebulimina cf. P. seabeensis with a very distinctive slightly asymmetrically chambered, coiled? Haplophragmoides sp. with more than



European Stages		Canadian Microfossil Assemblage Western Interior & Arctic	Western Interior U.S.A.		Northern Alaska		Arctic Coastal Plain Canada
CAMPANIAN	SENONIAN	Quinqueloculina sphaera Neobulimina canadensis Trochammina ribstonensis Glomospira corona Spiroplectammina semicomplanata Ammodiscus cretaceus Bathysiphon vitta Haplophragmoides kirki Epistomina coracolla		Pierre shale	Schrader Bluff Formation	Sentinel Hill Mbr.	pale shale zone
SANTONIAN		radiolarians Chalmasia sp. (algal calcispheres)		Telegraph Creek Formation		Barrow Trail Mbr.	(Plesiosaur beds)
CONIACIAN		Praebulimina venusae Heterohelix globulosa Anomalinoides talaria Hedbergella delrioensis Globigerina aspera	Niobrara Fm.	Apishapa Mbr.		Rogers Creek Mbr.	smoking shales (Hesperornis beds) or "bituminous" zone
		(quite similar to overlying assemblage		Timpas (ls.) Mbr.	-?- Seabee Fm.	Ayiyak Mbr.	
TURONIAN		Pseudoclavulina hastata Hedbergella loetterlei Globigerina aspera Heterohelix spp. Arenobulimina torula	Benton shale	Carlile Ss. Sh. Greenhorn limestone		Shale Wall Mbr.	
CENOMANIAN		Gaudryina irenensis Verneuilinoides kansasensis Trochammina rutherfordi		Belle Fourche Fm.	Ninuluk Fm.		
LATE ALBIAN		Miliammina manitobensis Verneuilinoides borealis	Mowry Fm.		Grandstand Fm.		unconformably on M. Albian

Figure 2.

two coils, slightly evolute. This form has been referred by some workers to the genus Cyclammina but they have failed to demonstrate the multiple aperture although all the other major Cyclammina taxonomic criteria are present. The author would prefer to place this form in Trochamminoides because of the slight trochoid coiling attested to by the slight asymmetrical coiling of the chamber arrangement. This assemblage persists down the hole from approximately 9,000 feet to approximately 9,900 feet. Additional evidence of Upper Cretaceous for this interval is the Miliammina awunensis recovered from the sample 8,160 feet.

The first significant Foraminifera which might indicate the Lower Cretaceous are to be found at the microfaunal facies change at 10,160 feet. The assemblage is represented by Ammobaculites cf. A. fragmentarius and numerous Hyperammina spp.; also present is a significant plant megaspore Microcarpolithes ex. gr. M. declivatus. A rather distinctive microfaunal assemblage appears at 11,416 feet, tentatively designated as the zone of ?Schizammina sp. with species of Ammodiscus, Reophax and Hippocrepina. Identifications are not completed to the bottom of the borehole and this latter zone of ?Schizammina sp. is thought to be still in the Albian stage of the Lower Cretaceous.

It is proposed that the very significant anomaly in the thickness of the Upper Cretaceous can be explained, in part, as the result of a major unconformity within the Upper Cretaceous over the continental portion of the Arctic Coastal Plains. Near the time of the Coniacian/Turonian transition there appears to have been a regional unconformity extending from the type section of the Colorado Group in Colorado to Arctic America. Owing to this period of erosion, strata are missing in the vicinity of Saskatoon, Saskatchewan as reported from the potash mine shafts (Fig. 1, and ref. 2). The unconformity is obvious in the Kugaluk, Anderson and Horton rivers drainage areas of the Arctic Coastal Plains region where more than one thousand feet of strata are missing. There, the Chalmasia sp., radiolarians, and rare globigerinids of the Coniacian rest unconformably on the glomospirellid assemblage of the Middle Albian (Fig. 2, and ref. 3). Evidence from the comparable horizon in parts of Alaska indicates that the Upper Cretaceous there is resting unconformably on even older strata (?Neocomian from personal communication with Mr. I. Tailleur, U.S.G.S., January, 1969).

The great volume of detritus resulting from the Coniacian erosion of the land on the east and west flanks of the ancient Mackenzie River Delta[1], was dumped into the Beaufort Sea Basin. Thus, abnormally thick Upper Cretaceous sequences were deposited in the marine basin, as most of the early Upper Cretaceous and much of the late Lower Cretaceous was removed from the present continental land areas. Preliminary examination of the microfossil recovery from samples of the Reindeer D-27 borehole supports this hypothesis because of the following facts.

(1) Extreme 'stretching' of the vertical range of Senonian index species of Foraminifera.

(2) Successively older index species are scattered upward in the late Cretaceous and the Tertiary depositional intervals. These are interpreted as 'derived' microfauna from successively older strata as they were eroded from the sediment source areas by both the Coniacian unconformity and 'Laramide', late Cretaceous and Tertiary erosion.

(3) Very common slickensiding on the core surfaces might attest to the rapid loading of detritus in an aqueous media and subsequent gravitational slip off the edge of the Continental slope.

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35. ORDOVICIAN LITHOFACIES, GODS RIVER, MANITOBA

Project 670014

L.M. Cumming

An unusual and distinctive carbonate facies, examined during mapping of the Hudson Bay Lowlands (Operation Winisk[1,2]) is a possible guide-lithology for basemetal prospecting within the Lowlands.

This burrowed carbonate mud facies (Fig. 1) occurs in the northern part of the Upper Ordovician exposures of the Churchill River Group on Gods River, Manitoba (Fig. 2). A somewhat similar burrowed carbonate mud facies is of economic importance as a guide to ore in the lead-zinc district of Missouri[3], where the facies is restricted to sites peripheral to ridges and knobs of Precambrian basement rocks.

The Upper Ordovician burrowed carbonate mud facies exposed on Gods River is only a few feet thick, and is not known to be mineralized. However, it may represent the wedge edge of thicker developments of the same facies which would be expected to occur near topographic highs in the Precambrian basement.

Figure 1. Burrowed carbonate mud facies of the Chasm Creek Formation, Churchill River Group ('Shamattawa Formation' of Savage and Van Tuyl[4]) Gods River, Manitoba; 6.9 miles northwest of latitude 56° 00'N; (GSC photo 142909).

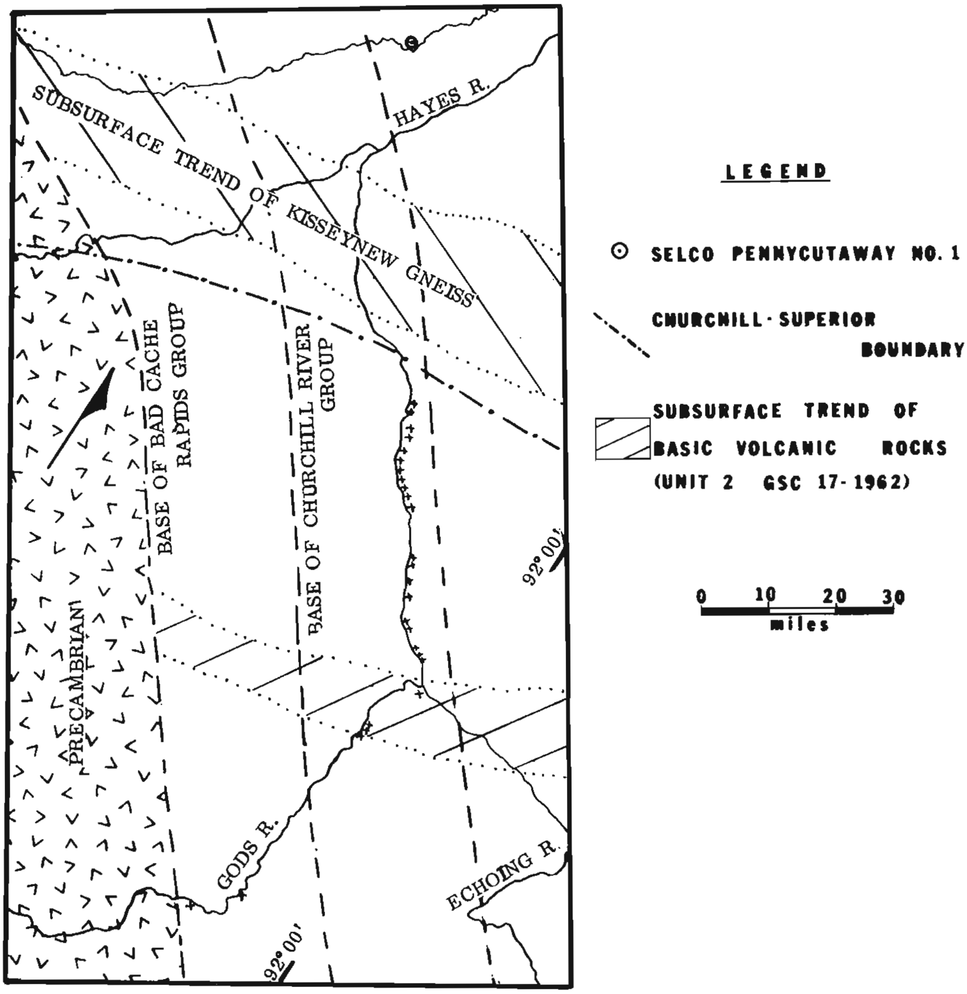

Figure 2. Geological sketch map, showing Ordovician outcrops along Gods River, Manitoba and the position of basement features related to the Churchill-Superior boundary.

An east-trending basement ridge (delimited by magnetic anomalies) occurs beneath the Phanerozoic cover, six miles north of the Ordovician exposures on the Gods River (Fig. 2). The facies of Ordovician strata on Gods River appear to reflect the position of this ridge, which marks the southern boundary of the Churchill (structural) Province.

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36. JURASSIC-CRETACEOUS BOUNDARY, NORTHWEST MELVILLE ISLAND

Project 680068

W. S. Hopkins, Jr.

Three formations, ranging in age from Early Jurassic to Early Cretaceous are exposed on northwest Melville Island, District of Franklin. Older and younger formations are also present, but these are not considered here. Palynologic examination of samples acquired from three Panarctic Oil seismic shothole lines through these formations demonstrates that a Jurassic-Cretaceous boundary can be readily determined using palynology.

Data presented here, on the three formations, pertains only to northwestern Melville Island, which lies on the southwestern margin of the Sverdrup Basin. Lithologies vary throughout the archipelago, and formation thicknesses increase markedly to the north and northeast.

The lower of the three formations is the Wilkie Point, about 450 feet thick, composed essentially of sand and sandstone. On Melville Island the unit is marine in the lower part, nonmarine in the upper. The age of the formation, based on marine invertebrates, is Bajocian to lower Bathonian.

Above the Wilkie Point lies the Mould Bay Formation, a marine unit about 450 feet thick. The lower quarter of this formation consists of shale, while the upper three-quarters is made up of sand and sandstone. Marine invertebrates indicate an Oxfordian or lower Kimeridgian to upper Valanginian age.

Conformably overlying the Mould Bay is the Isachsen Formation, made up of approximately 400 feet of arenaceous, nonmarine sediments. No diagnostic fossils are found in this area, but the Isachsen can be dated by marine beds above and below. Conclusions drawn on this basis indicate that this formation ranges in age from upper Valanginian to possibly Aptian.

A more complete discussion of stratigraphy, as well as numerous references, can be found in Tozer and Thorsteinsson[1].

It has been demonstrated by several workers that palynology can be used to reliably determine the Jurassic-Cretaceous boundary in various parts of the world (<u>see</u> especially references 2, 3). This boundary is marked by the appearance of several diagnostic genera of spores.

The Mould Bay Formation apparently represents a period of continuous deposition and the majority of spores and pollen comprising the microflora range through the entire formation without noticeable change in morphology or frequency. However, approximately 300 feet above the base and 150 feet below its top, a number of new and diagnostic genera simultaneously make their appearance. These include the genus *Cicatricosisporites* which, in various parts of the world, makes its first appearance at the base of the Cretaceous; the species *Acanthotriletes varispinosus* Pocock, 1962, (*see* ref. 4) which marks the basal Cretaceous in Western Canada; and the genera *Trilobosporites* and *Aequitriradites* which occur first in lowest Cretaceous rocks around the world. *Schizaeoisporites*, also a common constituent of Neocomian floras, is present in small numbers.

Other, but less impressive changes occur in the flora in this zone, but are not discussed here. A more lengthy and detailed presentation of the microfloras of the Jurassic-Cretaceous on Melville Island will be forthcoming in a future paper. However, evidence to date points to the fact that palynology may prove to be an excellent tool to define a Jurassic-Cretaceous boundary in the Canadian Arctic, both in marine and nonmarine sequences.

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[1] Tozer, E. T., and Thorsteinsson, R.: Western Queen Elizabeth Islands, Arctic Archipelago; Geol. Surv. Can., Mem. 332, 242 pp. (1964).

[2] Hughes, N. F.: Palaeontological evidence for the age of the English Wealdon; Geol. Mag., vol. 95, pp. 41-49 (1958).

[3] Pocock, S. J.: The Jurassic-Cretaceous boundary in Northern Canada; Rev. Paleobotan. Palynol., vol. 5, pp. 129-136 (1967).

[4] Pocock, S. J.: Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canada plains; Paleontographica, Abt. B, vol. 111, pp. 1-95 (1962).

GENERAL

37. PHOTOGRAPHY OF ALPHA TRACKS

F. J. Cooke

Introduction

Having acquired a properly exposed nuclear track plate by the due process of correct exposure and adequate development, it only remains to get an equally satisfactory negative from which a reproducible print can be made to complete the cycle of events.

The best alpha track plate is pathetically low in contrast, and as the tracks are often microscopically small, we have found that a magnification of about 200x is the most satisfactory for reproduction purposes. When viewed through the microscope it is immediately apparent that the normal film will not suffice, the important detail in the outer perimeter is so delicate, and is mixed in with the enlarged grain of the plate which creates an eerie mass of scars, blotches, and a sand-like interference which under normal photographic methods would obliterate the fine detail where it is needed most, since the tracks are much weaker in the outer area, they would be completely lost. How to get rid of this background is the subject of this article.

Ideally we would like to show the tracks as black lines on a clear, white background. We started our experiments with contrast process ortho film and a dark green filter, processing was done in DK 50 full strength; this combination produced a print suitable for laboratory investigation, but the dark background would not be suitable for reproduction (see Fig. 1). Our next test was done on Kodalith film and the dark green filter, and processed in Kodalith developer. This test, after some process refinement, produced the ideal negative, we could now show the alpha tracks as black lines on a clear white background (see Fig. 2).

The Kodalith negative offers another great advantage in that it can be easily spotted or opaqued in the needed areas, thus we can cover those ugly spots and scars and leave a clean white background; the softness of other film types prevents this sort of negative repair. The illustrations shown are contact prints from 4 x 5 negatives, magnification is 200x.

Tips for the 35 mm Worker

There are no doubt many 35 mm workers who cannot benefit from this article since Kodalith film is not presently made in that size, however there is always a second best if we look around for it. I do very little work in the 35 mm area so I have not done any research in this size, related to track plate work. However I would suggest the use of Adox K I4 film, a film noted for its extremely fine grain, and capable of very high contrast, especially when processed in a contrast developer similar to D II. Handled in this way I think a quite satisfactory result would follow.

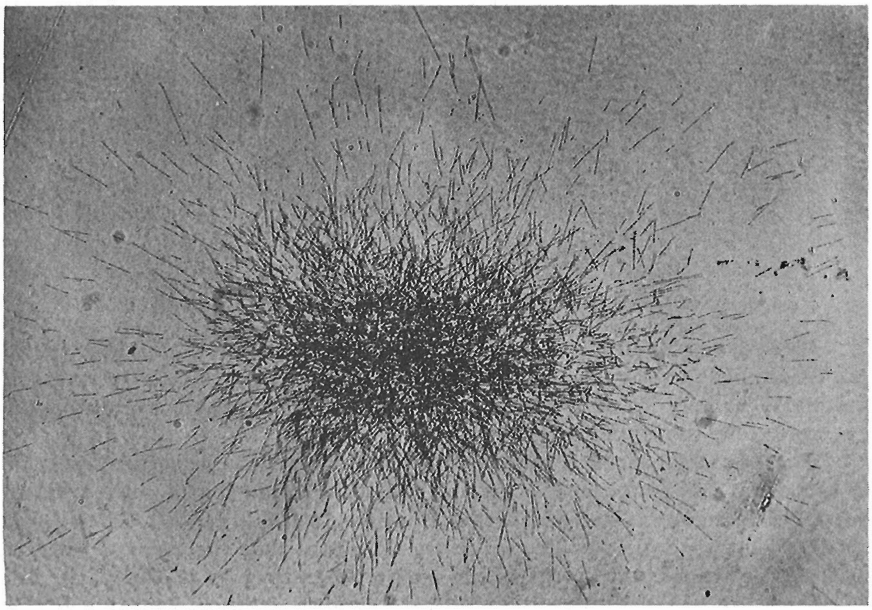

Figure 1. Photograph of alpha tracks from process ortho film.

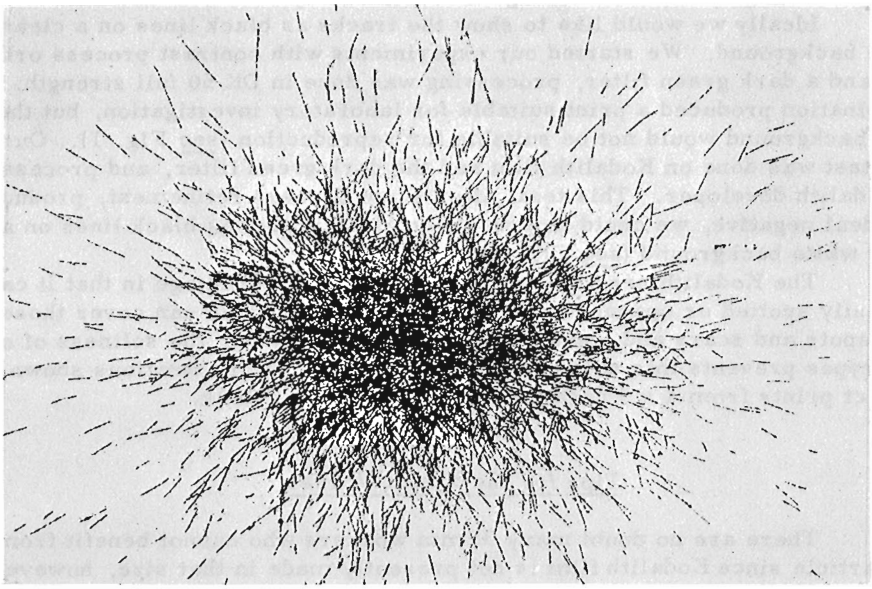

Figure 2. Photograph of alpha tracks from Kodalith negative.

Adjusting the Microscope

Kodalith film is especially sensitive to the slightest variation in light intensity at the focal plane. The microscope with its very small point source illumination may give some trouble if it is not exactly centred. A slightly off centred lamp may not show in ordinary film exposures, but the Kodalith negative would be useless, so don't be disappointed if you have to make a few trial runs before perfection is attained. In setting the microscope for this type of operation, it will be necessary to use the highest power achromatic objective lens combined with the lowest power ocular to obtain the desired magnification and only in this way will the very delicate tracks at the periphery be correctly recorded (see Fig. 2).

Development

Processing the Kodalith film is also an exacting stage of the work, however, since this can be done in red light, the time-honoured inspection method can be used to advantage. The critical period is when the emulsion side of the film turns a good strong black, at this stage the film should be viewed from the back, it will be much lighter in colour on this side. Development may continue until the reverse side is a good dark colour (but not black) there is danger that the very fine lines in the outer areas will fill in at this stage, however, a little practice will produce the skill and alertness needed for success. The entire method is quite simple, it requires the same serious care you would give to any important project.

38. MINERAL DISPLAY

H. R. Steacy

H. R. Steacy, Curator, shows C. H. R. Gauthier one of the 300 species of minerals on display in the Geological Survey of Canada headquarters building, Ottawa. This display, systematically arranged in eighteen lighted wall cases, was installed during the year as a project of the Mineralogy Section to provide Survey officers with a convenient reference collection of the more common minerals. Typical, rather than unique, specimens are displayed, using Canadian examples where appropriate. The display is also open to the public during office hours.