66-2

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 66-2

REPORT OF ACTIVITIES

November 1965 to April 1966

Edited by

R.G. Blackadar

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ABSTRACT

This report comprises thirty-nine brief papers that describe research undertaken by members of the Geological Survey of Canada between November 1965 and April 1966.

REPORT OF ACTIVITIES, NOVEMBER 1965 to APRIL 1966

INTRODUCTION

This report consists of thirty-nine short papers that present the results of scientific studies carried out by members of the Geological Survey between November 1965 and April 1966. Many of these papers are interim reports on research that will later be more fully described either in one of the Survey's publications or in one of the scientific journals. The illustrations accompanying this report are reproduced without change from material submitted by individual authors.

The report of activities is published twice each year in order to make the results of current research available to the public as quickly as possible. The section covering the period May to October consists primarily of reports of field work whereas this section includes reports on both field and laboratory investigations. Most research is based on field observations and thus both sections form part of a whole and together with the volume of abstracts and index of publications provide an annual resume of the major scientific activities of the Geological Survey.

GEOCHEMISTRY

1. SAMPLING PRECISION IN REGIONAL GEOCHEMICAL STUDIES

E.M. Cameron

In areal geochemical studies the element content of a spot sample is usually taken to represent the composition of a much larger volume of rock at the sampled locality. This estimate will, however, differ from the true composition of a finite volume of rock surrounding the sample because of variation within the rock, sampling bias, and analytical error. Knowledge of this sampling error is most critical where geological variation is subtle and thus likely to be obscured by sampling error.

A regional geochemical study has been made of the carbonate Slave Point Formation in the subsurface of parts of British Columbia and Alberta to determine the chemical characteristics of the different sedimentary facies (Cameron, in press). The study posed severe sampling problems because the relatively slight regional variation of this rather uniform formation had to be determined using two different sample types, core and drill cuttings, the latter being far from ideal for quantitative geochemical studies.

Sampling errors were found to be smallest for those elements that are held in solid solution in the dominant carbonate mineral of the samples (calcite or dolomite). Sampling errors are much greater for elements contained in the minor terrigenous fraction or in minor secondary minerals. There are two main causes for the difference in sampling precision. First, selective preservation of certain lithologies as drill cuttings can considerably alter the content of a minor component in a sample and the elements that it contains, but will have little effect on the proportion of a major component. Thus when drilling a limestone composed of 99 per cent calcite and 1 per cent bedded chert, enrichment of the tough chert in the cuttings might double the concentration of this component to 2 per cent, but change the content of calcite to 98 per cent. The estimated Si content of the rock will thus be highly biased, but Sr contained in the calcite will hardly be biased at all. The second cause of general significance is that the major mineral components, such as calcite, show little variation within any one stratigraphic section. The elements they contain are therefore not subject to the sampling imprecision that arises from the irregular distribution of a host mineral. The terrigenous fraction is much less regularly distributed, and the minor secondary minerals sphalerite and barite are so irregularly distributed that estimates of the mean Zn and Ba content of sections are very poor. Danger of contamination of drill cuttings by cavings was shown, for the area studied, to be confined to the elements carried in the terrigenous fraction of the Slave Point. For the limestones, analytical variance for all elements except Ca does not significantly add to within-section sampling variance.

It is concluded that elements held principally in solid solution in the calcite or dolomite of this and similar units are the most suitable indicators of regional geological variation. For the other elements it is better to use ratios of elements that are contained in the same mineral fraction.

Cameron, E.M.
(in press): Evaluation of sampling and analytical methods for the regional geochemical study of a subsurface carbonate formation, J. Sedimentary Petrol.

GEOPHYSICS

2. SHORT PERIOD MAGNETO-TELLURICS

A. Becker

The successful application of long period (10-1000 sec.) magneto-telluric measurements to the determination of basement depth and topography in France, the U.S.S.R. and Canada suggested that the method could be equally well exploited for the mapping of near surface resistivity anomalies. For this application, however, higher frequencies must be used if good resolution is to be obtained.

Natural electro-magnetic radiation caused by thunder storms is unusually strong at 8 cycles per second because of favourable propagation conditions through the earth's ionosphere cavity. Measurement of the electromagnetic field at this frequency should provide information down to about one thousand feet.

A pilot model of an apparatus for the measurement of telluric currents at 8 cycles per second has been constructed. It will be tested and evaluated during the coming field season. The immediate objectives are the detection of the resistivity anomaly across the Gloucester Fault near Ottawa, Ontario, the sensing of sulphide conductors in Quebec and the outlining of resistive aquifers in Manitoba.

3. REFERENCE SIGNAL OSCILLATOR FOR TUNING RADIO RECEIVERS

J. Blanchard

Transistor radio receivers used by field personnel on geological mapping survey parties using aircraft are proving satisfactory in terms of long periods of standby service. However the inability to tune to an aircraft frequency in the absence of a signal from an aircraft is a major drawback. The operation of tuning the receiver dial back and forth across the approximate frequency of the aircraft's transmitted radio signal is time consuming. If the pilot must turn back to the main base camp or land because of weather conditions, the field officer is left wondering as to the whereabouts of the aircraft. The ground radio receiver is used for other purposes, and, as is often the case, it is virtually impossible to return it to a predetermined setting. A small hand-held signal source for accurate tuning of transistor radio receivers will overcome these difficulties (Fig. 1).

The reference signal oscillator is an accurate source of modulated R.F. energy of low intensity designed to radiate a signal for the purpose of radio receiver tuning in the field.

A crystal-controlled transistor high frequency oscillator is 30 per cent modulated by a 279 cycle audio tone. The audio tone is generated by an audio oscillator of the Hartley type (Fig. 2). The frequency of the unit can be controlled over a frequency range from 2-10 Mc by inserting the proper crystal in the holder. Power requirement is 540 micro-amps at 1.5

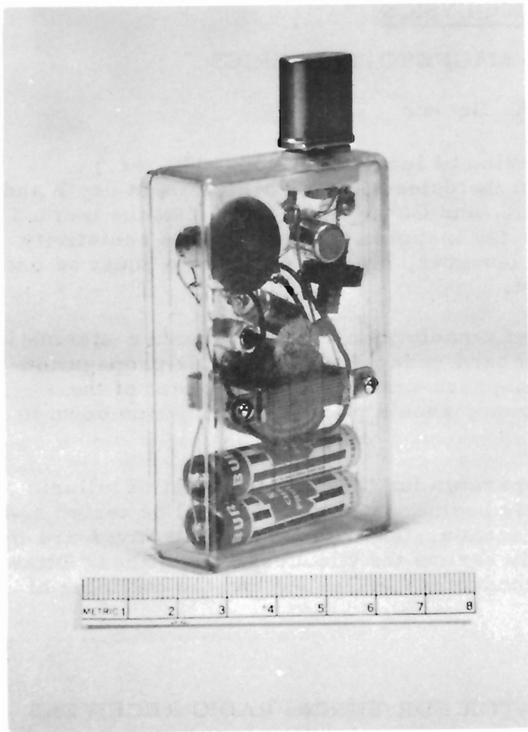
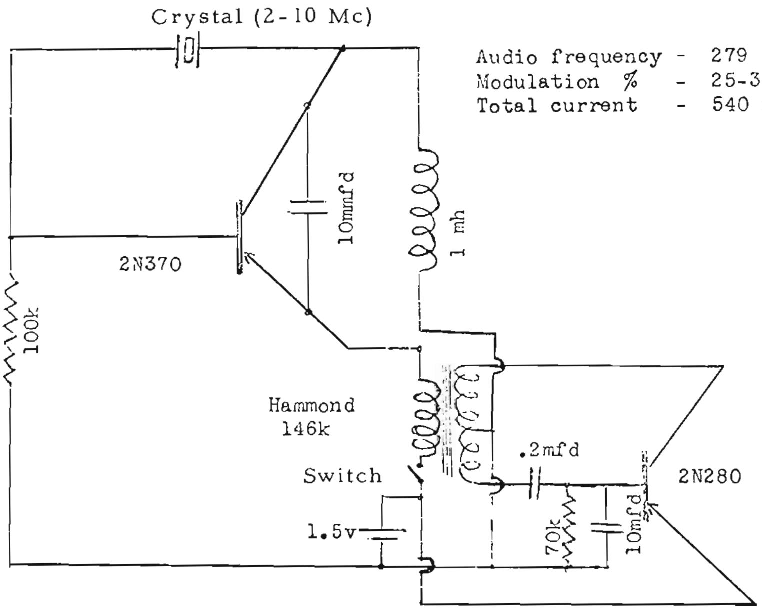


Figure 1. Reference Oscillator (Prototype model)

Figure 2. Circuit diagram



Audio frequency - 279 cycles
Modulation % - 25-30
Total current - 540 microamps @ 1.5v.

volts. The battery is adequate for an entire field season.

A crystal of the correct frequency is installed in the reference signal oscillator. The radio gain control is turned to maximum and a check is made that the receiver is switched to the correct band. The dial pointer is moved to the approximate dial frequency. With the reference signal oscillator in one hand, the radio receiver is tuned with the other. The switch on oscillator is depressed and the signal is tuned in on radio receiver. For the initial tuning the unit is held close but then the signal oscillator is moved progressively farther from the radio receiver while the receiver tuning is adjusted for maximum signal, until it is accurately tuned to a weak signal from the oscillator. Maximum deflection of the meter pointer indicates maximum signal on those receivers incorporating a tuning meter.

The reference signal oscillator as a companion unit to variable tuned radio receivers, will increase the usefulness of these receivers many times. It will be possible to use the radio receiver for receiving weather forecasts, monitoring other frequencies as required or for entertainment in the evenings. It requires just a few seconds to plug the correct crystal in the range from 2-10 Mc into the oscillator, place it in operation, tune the signal in on the receiver, switch the reference signal oscillator off and continue with other duties confident that the radio is accurately tuned. In the field, it can also be used for receiver tuning after a change of crystals, and will act as an accurate reference to check calibration of multi-band receivers.

4. DIGITAL FILTERING AS AN AID TO AEROMAGNETIC INTERPRETATION

Margaret E. Bower

One of the major problems in the analysis of aeromagnetic data has been the difficulty in isolating anomalies of various amplitudes and frequencies. A typical magnetic profile may contain anomalies with wavelengths ranging from a fraction of a mile to tens of miles, and amplitudes ranging from less than one gamma to hundreds or thousands of gammas. Therefore the anomalies with short wavelengths and small amplitudes can be completely masked by the larger ones. If they could be observed, the small anomalies might be very useful in the geological interpretation of any region.

Various means have been used to resolve the small anomalies. The data may be filtered electronically as it is obtained, removing the low frequency anomalies and amplifying the remainder. This method is commonly used in real time, so the filter can take into account only the data in past time. This introduces a phase shift into the filtered output and distorts the shape of the anomalies. Simple forms of digital filtering have been used, such as removal of regional gradient and running averages. These methods are useful in some cases, but they tend to accentuate certain frequencies and attenuate others in an undesirable manner.

Some useful methods of digital filtering are described in a report by Anders, et al. These involve a type of Fourier analysis in which a smoothing function is computed and applies to the data. One requirement is that the data be a number of equally spaced readings. The magnetic readings obtained on the National Aeronautical Establishment's North Star flights meet this requirement; they are recorded in digital form at either equal time or equal distance intervals, and can therefore be used directly in the digital filter programs. To date, programs have been written for a low pass filter, band pass filter, and first and second derivative smoothing filters. All computing and plotting is done with a PB-250 computer and Calcomp plotter.

A test area was chosen in the Scotian Shelf aeromagnetic project where the main magnetic feature is a broad anomaly of about 400 gammas. Flight line spacing is 3,000 feet, and portions of 13 consecutive lines were used. A band pass filter was used which retains only the anomalies with frequencies between 1 and 5 cycles per mile; all other frequencies are attenuated or cut off. The filtered magnetic records revealed that on 12 consecutive lines there was a group of small, high frequency anomalies. Each group contains from two to four anomalies, with wavelengths less than one mile and amplitudes of 1 to 2 gammas. These occur on the side of the main anomaly, and were practically invisible on the original profile because of the steep gradient. This same group of lines was then put through a first derivative filter, which showed that the small anomalies were at the point of steepest gradient on the original anomaly.

Further tests will be carried out on this and other areas. It is believed that this method of anomaly separation could become a very useful aid to aeromagnetic interpretation.

Anders, E.B. et al.
"Digital Filters" NASA Contractor Report CR-136.

5. AIRBORNE ELECTROMAGNETIC SURVEY OVER THE WINKLER AQUIFER, MANITOBA

L.S. Collett

In 1965, the Geological Survey of Canada embarked on an experimental program to test whether the electromagnetic method could differentiate between clays, tills, and sands and gravels with the possibility of delineating buried aquifers. The Barringer INPUT (Induced Pulse Transient) system was selected to fly over the aquifer near Winkler, Manitoba (Charron, 1964), which had previously been outlined by a ground DC resistivity survey (Wyder, 1964) and by drilling.

INPUT differs from other electromagnetic systems in that a half-sine pulse is transmitted from a loop on an aircraft and a signal is received from the ground following the termination of the pulse. Circulating currents are induced in the ground which take a finite time to decay. It is during this period after the abrupt cessation of the pulse that the receiving circuit samples these "relaxation" or transient signals. This field is detected in a vertical axis-orientated coil which is housed in a "bird" and towed about 250 feet behind and below the aircraft. Each sampling of the pulse is fed into separate amplifiers and smoothed over approximately a

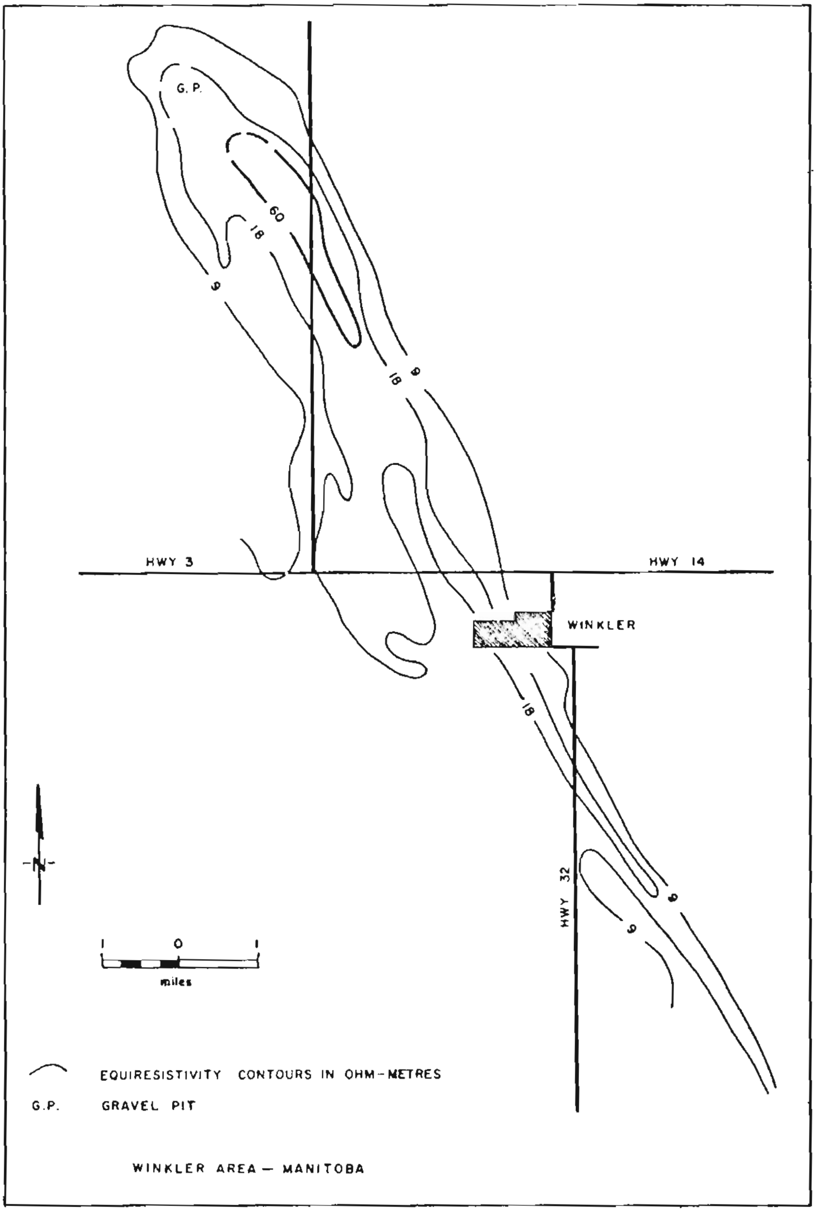


Figure 1. Equiresistivity contours.

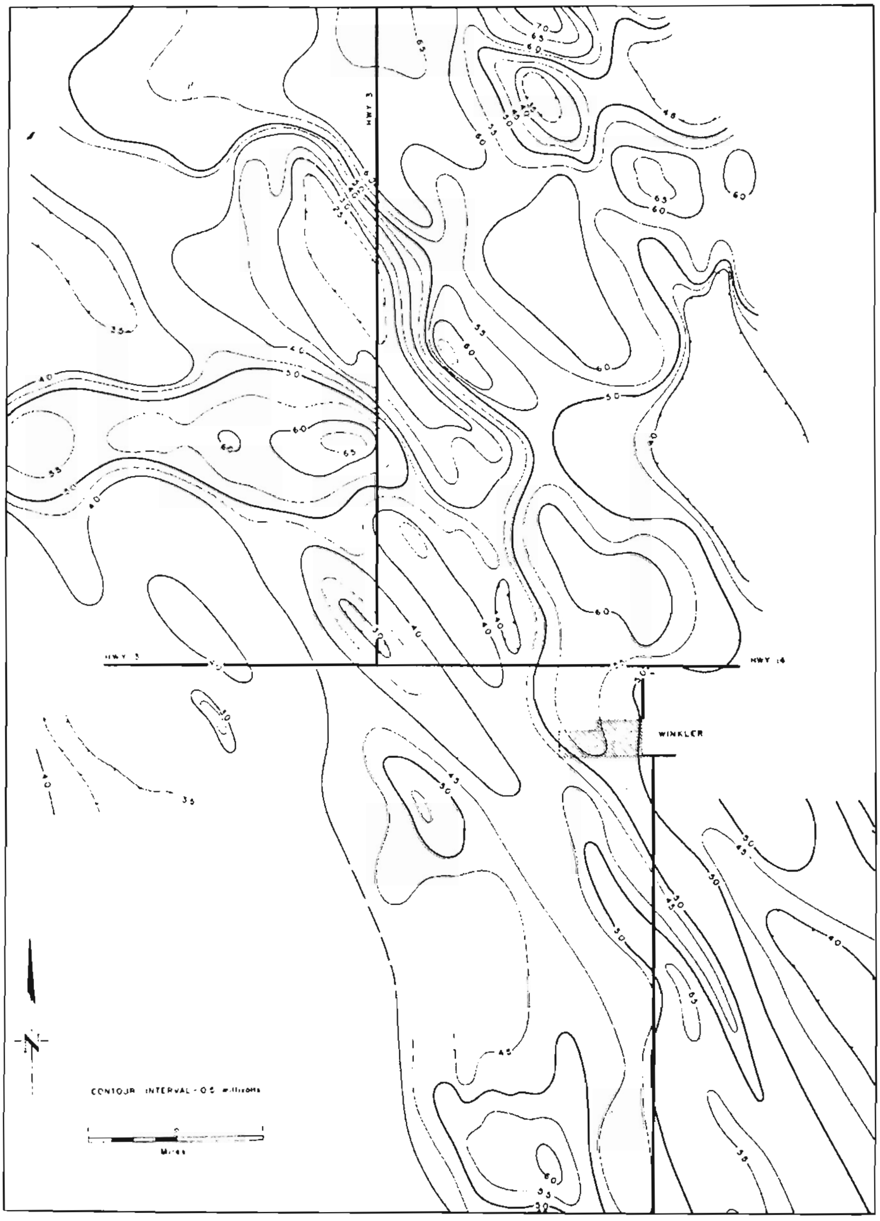


Figure 2. Input contours

three second period. The voltage output from each amplifier or channel is recorded in analogue form on a multi-channel paper chart recorder. The time-isolation principle eliminates the interference effects between the transmitter and the receiver caused by air turbulence.

The ground DC resistivity survey over the Winkler aquifer is shown in Figure 1 using a Wenner profile with an electrode spacing of 100 feet. The resistivity of clays and silty clays range between 5 to 20 ohm-meters, of tills and sandy tills from 10 to 30 ohm-metres and of sands and gravel beds from 40 to 650 ohm-meters. Bedrock shales are saline and have a resistivity of 3 to 6 ohm-meters. The depth to the top of the shale is greater than 200 feet under the aquifer.

The INPUT survey over the same area is shown in Figure 2. The contour values are in millivolts for channel No. 1 which is centred at 250 microseconds after the end of the transmitted pulse and 300 microseconds in width. The aircraft was flown at a height of 500 feet with the flight lines spaced 1 mile apart. The amplitude of the transient response is greater over good conductors such as clay and till than over poor conductors such as sand and gravel.

The airborne survey correlates very well with the ground DC resistivity survey over the aquifer. The resolution of changes in the lithology is better defined by the INPUT survey. Although the airborne method does not give the apparent resistivity values as measured by the ground DC resistivity survey, the amplitudes of the transient responses do delineate areas of different resistivity contrasts. The survey showed that the method is able to detect sand and gravel beds with thicknesses of a few tens of feet lying beneath clay and till deposits up to 75 feet in thickness.

Another important factor is the time taken to do the survey; the ground DC resistivity survey took a four-man crew 3 months whereas the airborne survey took 3 hours operating from the Winnipeg airport. Local power lines do not interfere with the measurements. High tension cross-country power lines, however, do blank out the measurements for about 200 feet on each side of the power line. Power lines over small towns and oil fields also blank out the transient pulses.

The airborne INPUT method is an important new tool for reconnaissance surveying of surficial and glacial deposits. It will aid the groundwater hydrologist and Pleistocene geologist in their mapping programs in the same manner as airborne magnetic maps are now used by the mapping geologist. It should be possible using this method to pinpoint in a direct way where to concentrate drilling programs for investigating the lithology and for exploring for local municipal and farm water supplies.

Charron, J.E.
1964: Two aquifer tests in Winnipeg and Brandon Map-Areas, Manitoba, 1962; Geol. Surv. Can., Paper 63-43, 51 p.

Wyder, J.E.
1964: Reconnaissance resistivity surveys in Southeastern Manitoba; M.Sc. Thesis, Univ. Sask., pp. 91-104.

6. A SHALLOW SEISMIC EXPERIMENT IN PERMAFROST, KLONDIKE AREA, YUKON TERRITORY

G.D. Hobson

A hammer seismograph instrument was used in the Klondike area of the Yukon Territory to test the feasibility of delineating bedrock topography favourable to the accumulation of placer gold deposits in a permafrost environment. Prior to the experiment it was appreciated that seismic wave velocities would be considerably different from those regularly observed in Pleistocene materials beyond the zone of permafrost but the benefits that might be derived through application of this geophysical tool to placer mining certainly were not anticipated.

A placer deposit has been described as a mass of gravel, sand or similar loose material resulting from the crumbling or erosion of solid bedrock and enriched by particles of valuable heavy minerals which have been derived from the rocks and veins. Placer gold deposits in the Klondike area are found as stream or alluvial deposits: (1) in buried bedrock channels as originally cut by an ancient stream or later cut by the present stream; and (2) on benches formed when present streams abandoned old river beds and cut down below the ancient stream levels thus leaving benches on hillsides. These benches are usually well covered by overburden. Placer gold mining was the Yukon Territory's principal industry for over 50 years but in recent years it has been displaced by silver mining.

Baird (1955) has described a venture wherein a deep shaft was sunk on claim 3A on Eldorado Creek in which four levels of pay gravel interbedded with slides of schist and muck and talus were found. It is interesting to speculate upon the economic possibilities associated with the presence of a false or second bedrock. This theory has no doubt intrigued many prospectors and more than passive consideration was given to this theory during the interpretation of the seismic data to be discussed.

In this study the standard formulae for the computation of thicknesses and dip by the seismic refraction method have been applied throughout the reduction of data. No explosives were used; the energy source generally used was a 10-pound sledge hammer struck against a steel plate on the ground.

The following tabulation of velocities is compiled from data observed in an area of limited extent along Dominion Creek. Because these refraction profiles were not reversed, the individual velocities are as observed in the field and are not corrected for dip. Permafrost extends to an unknown depth into bedrock.

Material		Velocity range, feet per second
working layer	-	900 - 6,500
frozen muck	-	9,800 - 11,500
frozen gravel	-	13,200 - 15,300
bedrock (schist)	-	$>$16,500

These velocity values are considerably higher than those for the same materials in non-permafrost areas. Muck is comparable to clay or silty

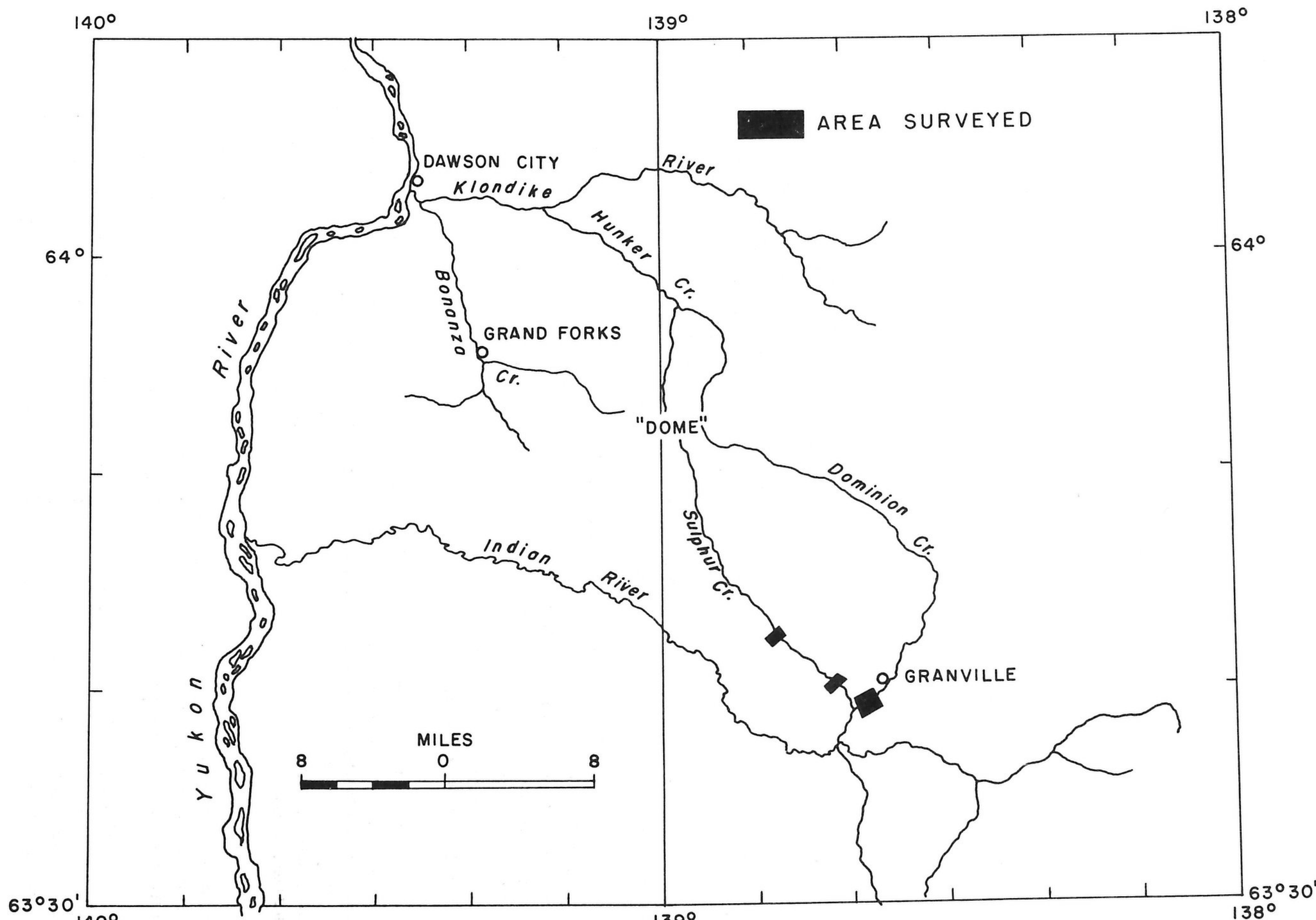


Figure 1. Area studied.

clay in which seismic velocities in general vary between 4,000 and 7,000 feet per second and unconsolidated gravels have velocities between 1,500 and 3,000 feet per second depending upon their moisture content.

Seventy-one locations were probed by the seismic method along Dominion and Sulphur Creeks, Paradise Hill, and the Klondike River, Figure 1. Drill holes along Dominion Creek and side-hill cuts on Paradise Hill provided control for correlation of seismic data with geology. Twenty-two locations were investigated within a small area on Dominion Creek adjacent to bore-holes drilled 20 or 30 years earlier. These locations provided exceptionally close control for correlation of seismic data with drift materials and bedrock surface.

There is exceptionally good correlation at 11 of the 22 bore-hole locations between drift thickness derived from seismic data and that determined by the drill. This accuracy is about two per cent which is extremely good compared to the 10 per cent accuracy generally claimed for the seismic method. However, at the other 11 locations, great discrepancies appear between the seismically calculated and the known depths to bedrock. This error may be as great as 200 per cent. Nevertheless, at these anomalous locations where percentage error is excessive, the depth to the gravel below the muck is always within the error of the instrument and the seismic method. This presents an interesting geological situation. Seismically, the phenomenon can be explained only by the presence below the frozen gravel of a layer of material which has a seismic velocity equal to or less than that of frozen gravel so that seismic energy is refracted downwards instead of upwards to the detector on surface. This lower velocity layer could be thawed gravel, highly weathered schist bedrock, or a lower density intrusive. The false bedrock theory must also be evaluated.

The Yukon Consolidated Gold Corporation Limited drilled two holes in the Granville area between the confluence of Sulphur and Dominion Creeks and Indian River at locations suggested as anomalous at the conclusion of the seismic project. In these two holes, bedrock was penetrated to a depth of 29 feet and 22 feet respectively with no evidence of gravel or muck below the schist bedrock. However, bedrock was thawed to considerable depth in both holes.

The lowest seismic refractor appeared to be very irregular over the relatively small project area indicating either an irregular interface or differential thawing within the permafrost. The two bore-holes confirmed this interpretation of the seismic data. The nearby surface workings, thawing, etc., have evidently changed the subsurface frost conditions since the earlier drilling.

It is also noted that there was no contourable pattern to the anomalous seismic locations. If these locations had shown a definite contourable trend on the bedrock surface there may have been further gravel accumulations in a deeper channel cutting through or across the valley.

Observations to date do not indicate positive criteria by which an interpreter may evaluate the validity of data acquired under differential thawing conditions. The procedure of thawing by driving "points" into the muck and gravels can have extensive effects on frost conditions within the

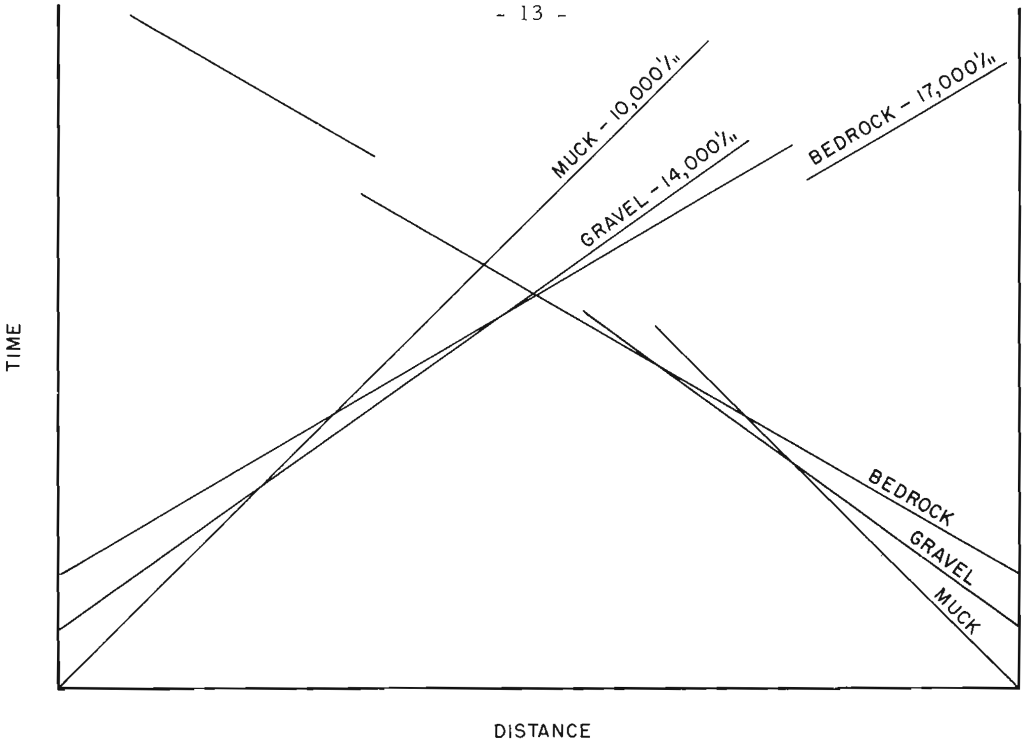


Figure 2. Typical reversed refraction profile plot showing a vertical discontinuity on bedrock, Klondike Area, Yukon Territory.

gravels. The seismologist must be aware of the effects of such conditions upon the raw data.

The active layer at Sulphur Creek during July was at a depth of 3 or 3 1/2 feet and presented operational problems. There is a high attenuation of seismic energy through the active layer making the use of hammer and plate as an energy source an almost futile exercise. Explosives are required. One innovation attempted under these conditions was to attach the geophone to a steel stake driven through the thawed surface layer into the permafrost and to strike a similarly driven stake with the hammer. This method was partially successful.

At several surveyed locations in the Sulphur Creek area, a "step-out" or offset was noted on the time-distance graphs which has been interpreted as indicative of a velocity inversion or a fault-like bedrock feature. A reversed profile confirmed the latter situation to be more plausible, Figure 2. This phenomenon on the time-distance graphs may be one method of interpreting benches on the bedrock surface particularly if such phenomena can be observed and aligned on several adjacent profiles.

Several conclusions can be drawn:

1. Bedrock surface can be detailed by the seismic refraction method unless the differential thawing of permafrost within the gravels has occurred in which case a velocity inversion occurs within or below the gravel so that

an accurate depth to bedrock cannot be calculated.

2. Regardless of permafrost conditions the thickness of the muck overlying the gravel can be determined with relatively high accuracy.

3. More interpretable time-distance graphs can be obtained if both geophone and energy source are immediately in contact with permafrost. The working layer of permafrost highly attenuates seismic energy. If necessary the detector can be attached to a metal stake driven to the permafrost and a similar arrangement can be used to introduce energy into the ground. Explosives are recommended as an energy source.

4. Benches may be interpreted from seismic time-distance graphs that indicate the presence of a vertical discontinuity on the bedrock surface.

5. The seismic method cannot detect occurrences of gold but can outline benches and channels wherein placer gold may have accumulated.

6. Seismic methods may be a complementary tool in research into thawing techniques in placer mining. It may point out those areas of differential thawing in the permafrost and thus affect considerable savings in thawing costs and perhaps influence the choice of method used to thaw the overlying mucks and gravels.

Mr. A.G. Barrett, Manager, and Mr. B. Hester, Geologist, both with The Yukon Consolidated Gold Corporation Limited, were most cooperative and understanding of the requirements of the seismic crew in the Klondike area. Accommodation was made available at the Y.C.G.C. Granville camp and they have maintained a continuing interest in all projects in that area. O.L. Hughes, Geological Survey of Canada, suggested the project in cooperation with his Pleistocene studies in the area. C. Gauvreau was in charge of the seismic crew in the field.

Baird, A.
1955: Search for a submerged channel in the Yukon; West. Miner and Oil Rev., July, pp. 36-37.

7. AEROMAGNETIC PROFILES ACROSS UNGAVA BAY

P.J. Hood and Margaret E. Bower

During June 1964 an aeromagnetic reconnaissance of the Labrador Sea was carried out in co-operation with the National Aeronautical Establishment using a North Star aircraft equipped with a rubidium-vapour magnetometer (Godby, Baker, Bower, and Hood, 1966). The aircraft was based at Frobisher Bay on Baffin Island and on ferry flights to and from Ottawa the opportunity was taken of obtaining magnetic profiles across Ungava Bay. Figure 1 shows the aircraft track (with fiducial numbers) together with the bathymetric contours (in fathoms) of the water-covered areas, and the generalized geology of the adjacent land masses. The east-west profile immediately to the south of Cape Chidley in eastern Ungava Bay was obtained during one of the flights across the Labrador Sea.

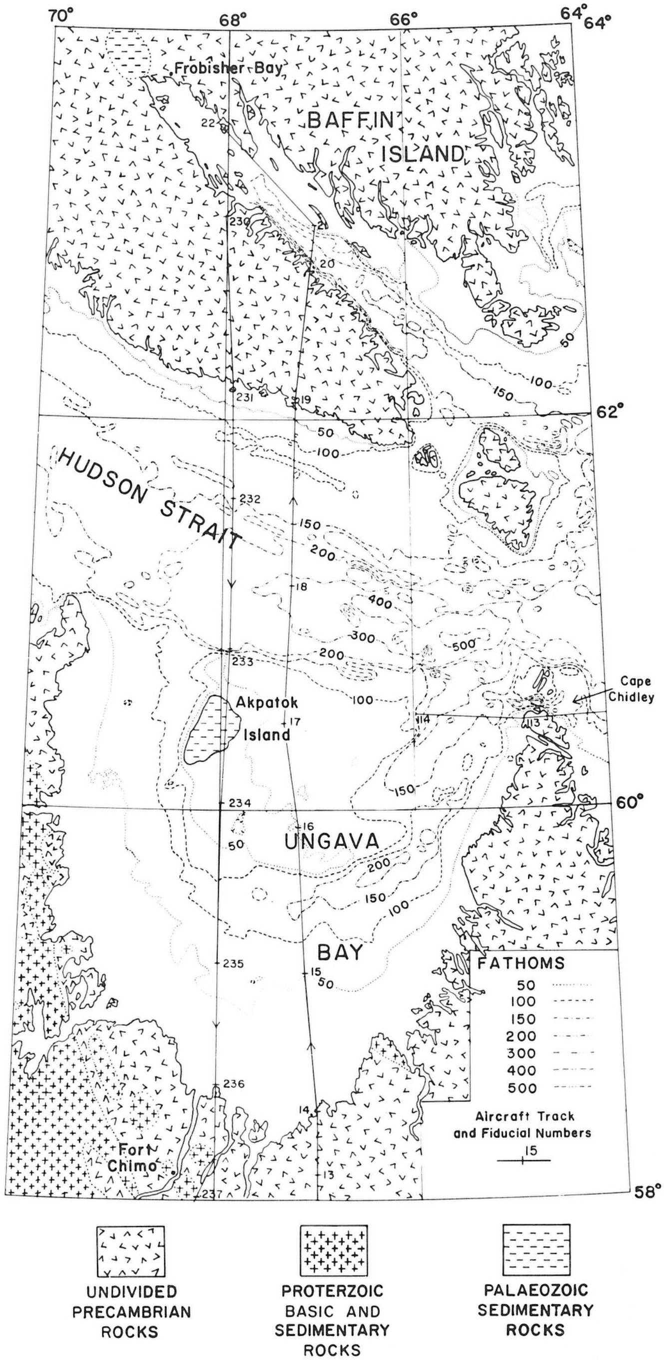


Figure 1. Geology of area studied and flight lines.

The bathymetric contours are based on Canadian Hydrographic Chart 5300. There appears to be a trough running around the central part of Ungava Bay, and Akpatok Island is located in the westernmost part of this central area. The top of this central area is relatively flat and slopes monotonously at an average rate of about 5 feet per mile from west to east which suggests that it is Palaeozoic limestone. The deepest part of the trough is on the east side of Ungava Bay where depths in excess of 200 fathoms (1,200 feet) have been recorded (Canadian Hydrographic Chart 5300).

A North Star aircraft of the National Aeronautical Establishment, equipped with a rubidium-vapour magnetometer, was used for the survey. Magnetic field values were recorded at 1/30th mile intervals on digital magnetic and printer tape and also in analogue form on an Offner chart recorder together with terrain clearance, WWV time signals, and Doppler mileage. Astro and Doppler navigation were used to position the aircraft track. A rubidium-vapour magnetometer ground station was established at Frobisher Bay to monitor the earth's magnetic field during the flights across the Labrador Sea. The magnetic diurnal records from Baker Lake were examined for the occurrence of magnetic storms during the ferry flights between Frobisher Bay and Ottawa and fortunately the period during which the flights across Ungava Bay were made was relatively quiet.

The digital magnetic tapes were used to produce the aeromagnetic profiles shown in Figures 2, 3 and 4. The readings recorded on the tapes are actually times (t) for 100 cycles of a frequency which is dependent on the magnetic field strength. Total magnetic field values are obtained by computing:

$$T \text{ (gammas)} = \frac{\text{Crystal frequency} \pm 100/t}{4.6635}$$

The Bendix G-15 computer was used to correct recording errors, compute total field and plot profiles. To simplify presentation and interpretation of the data, the regional gradient was also removed with the aid of the computer to give the residual total field (ΔT) values. The profiles were plotted with a Calcomp PA-3 plotter. This plotter operates under the control of the computer and records on a continuous strip chart. Also included with the ΔT profiles plotted in Figures 2, 3, and 4 are land elevations, depth of water, and aircraft altitude given in feet above or below sea level. On Figure 3, the diurnal variation of the earth's magnetic field recorded at Frobisher Bay during the time the profile was obtained has been inserted at the bottom of the figure using a dashed line. A number of depth determinations were carried out on the profiles using Peters (1949) half-slope method, and the resultant values are included on Figures 2 and 4 above the appropriate anomaly. The anomalies are also marked with a bar to indicate which side or whether both sides of the anomaly were used in the depth determination.

Consideration of the easterly north-south profile (Fig. 2) shows that the anomalies are sharpest, i.e. have the shortest wavelength, between Fiducials 13 and 14. In general the period of the anomalies increases in a northward direction indicating that the distance to the crystalline basement also increases in this direction. At Fiducial 18 the aeroplane climbed to 7,500 feet above sea-level so the anomalies tend to become lower in amplitude and longer in wavelength because of the higher flying height. The depth values to the southeast of Akpatok Island obtained using Peter's (1949)

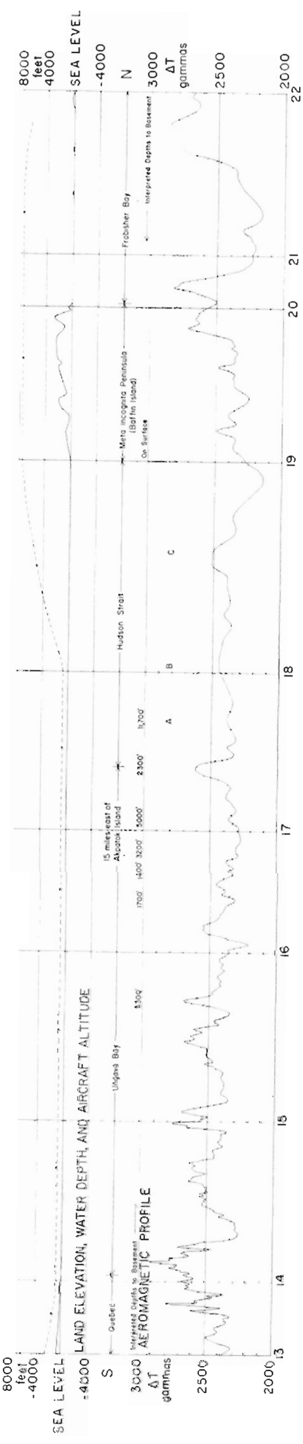


Figure 2. Aeromagnetic profiles across Ungava Bay, N.W.T.

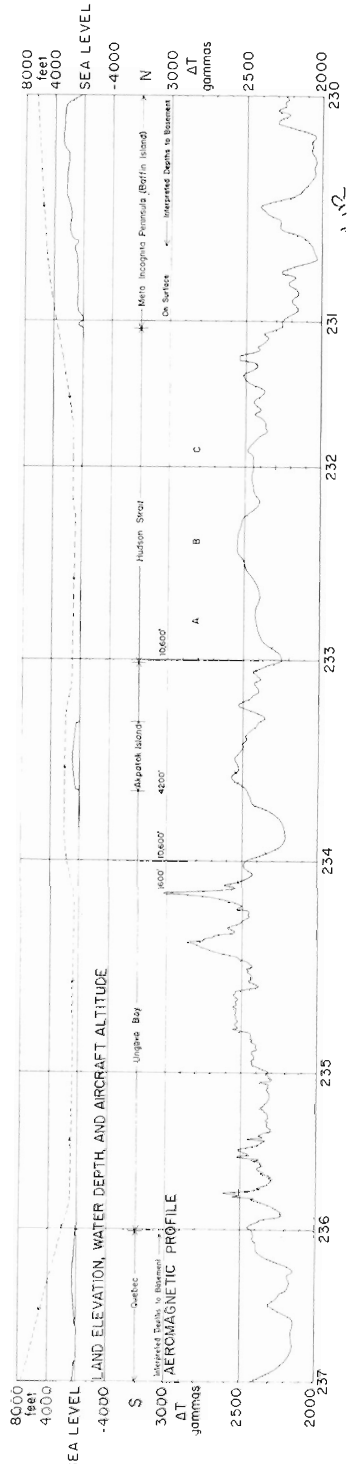


Figure 3. Aeromagnetic profiles across Ungava Bay, N.W.T.

half-slope method indicate that the depth to basement increases from about 1,500 feet to about 5,000 feet below sea-level opposite the island and then becomes shallower. However the anomalies are not well resolved in that area. The depth of water in this area averages around 350 feet. There is a distinct anomaly (reminiscent of the continental slope anomaly) where the slope of the bottom suddenly changes, which is a natural division between Ungava Bay and Hudson Strait. A depth determination on the Hudson Strait side of the anomaly gave a depth value of 2,300 feet to basement.

The westerly north-south profile (Fig. 3) is generally similar in magnetic character to the first profile discussed. The aircraft ascended to 2,000 feet in flying over Akpatok Island because of low cloud. There is a distinct trough in the aeromagnetic profile to the south of Akpatok Island immediately to the north of Fiducial 234 which is not apparent on the first profile. A 600-gamma anomaly also occurs to the south of the feature, but unfortunately the aircraft descended from 2,500 to 800 feet at this point and the character of the aeromagnetic profile was adversely affected. However the character of the profile does suggest a lithologic change immediately to the south of Fiducial 234. Cox (1933) postulated the existence of a fault which bifurcated south of the island to give two subsidiary faults. One fault parallels the west coast of the island with the downthrow to the west; the second bifurcation is parallel to the east coast with the downthrow to the east making the island a small horst. It may be that the large depression in the profile is the magnetic expression of a graben but this speculation is not really warranted from a single profile.

Depth determinations over Akpatok Island itself indicate that the thickness of sediments is relatively shallow, probably less than 5,000 feet.

There is a noticeable change in the character of the profile at the edge of Hudson Strait. The anomalies in the strait have been labelled A, B, and C. A similar set has been labelled on the first profile and it is inferred that the anomalies are continuous between the profiles, i.e. that the anomalies in Hudson Strait strike about northwest. Depth determinations carried out on anomaly A on both profiles gave an average value of about 11,000 feet indicative of the fact that Hudson Strait is downfaulted on its southern side.

The profile on the eastern side of Ungava Bay (Fig. 4) was flown at an elevation of about 2,000 feet. Anomalies in excess of 500 gammas occur along its length and are highest near Cape Chidley. The anomalies in the vicinity of Fiducial 114 indicate that the crystalline basement is at a shallow depth being less than a thousand feet below the bottom of the bay. A marked depression in the aeromagnetic profile between Fiducials 113 and 114 seems to be associated with the trough running around Ungava Bay. The greatest depth of water below the profile was about 1,500 feet.

No definite conclusions can be drawn from a pair of profiles separated by some 18 miles and the following results must be considered tentative and will be subsequently modified by additional geophysical data. Depth determinations carried out on the profiles indicate that the crystalline basement surface slopes gently to the south from Baffin Island and reaches its greatest depth on the south side of Hudson Strait where the water is deepest. The depth estimates indicate that the thickness of sediments is

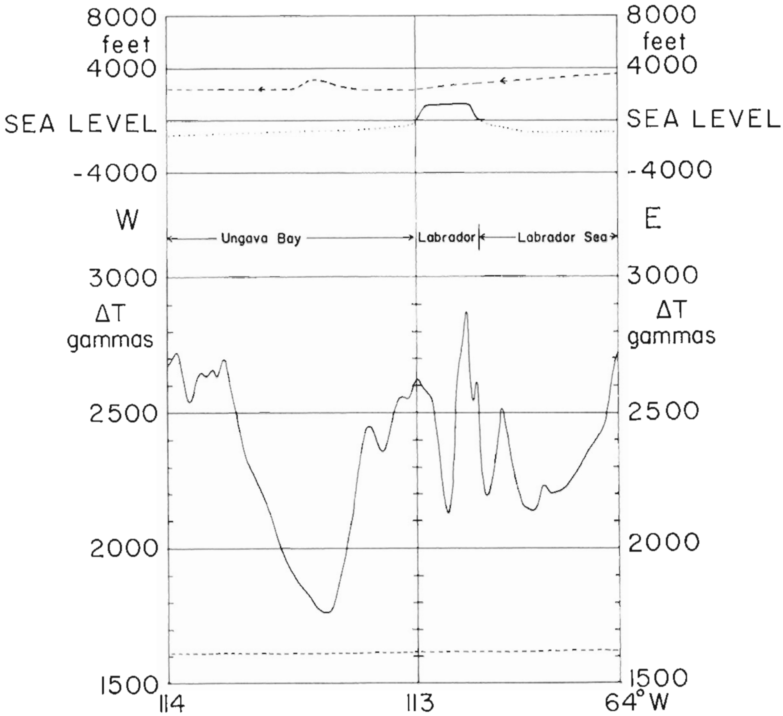


Figure 4. Aeromagnetic profiles across Ungava Bay, N.W.T.

greater than 5,000 feet at this point. In the vicinity of Akpatok Island there would appear to be somewhat less than 5,000 feet of sediments.

The central part of Ungava Bay comprising some 3,500 square miles does however appear from the bathymetry to be covered with flat-lying sediments; this elevated region is separated from the Precambrian sequence outcropping on the shores of Ungava Bay by a trough-like depression in the bottom topography.

The authors wish to acknowledge the cooperation of E.A. Godby, R.C. Baker, W.M. Strome and other members of the National Aeronautical Establishment who designed and built the airborne magnetometer system used in recording the profiles over Ungava Bay. The North Star aircraft was flown by R.C.A.F. aircrew under Flight Lieutenant N. Paul. Clarence Lyster of N.A.E. aided in the data reduction process and K.H. Owens compiled the geological map and drafted the final figures. Canadian Hydrographic Service supplied the echo-sounding data upon which the bathymetric contours in the figures are based. The magnetic diurnal records from Baker Lake were supplied by the Dominion Observatory through the courtesy of E.I. Loomer.

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8. SEISMIC REFRACTION SURVEYS, WESTERN QUEEN ELIZABETH ISLANDS AND POLAR CONTINENTAL MARGIN

A. Overton

During 1964 and 1965, explosion seismic studies were conducted in an area centring on Prince Patrick Island, N.W.T. (see Fig. 1). The work was an extension of the seismic investigations of sedimentary thicknesses by Hobson (1962, 1966) and similar studies extending to the crust and upper mantle by Sander and the writer (1965).

More than usual interest has been aroused in the area by the high incidence of local tremors at the Mould Bay seismograph (station G, Fig. 1), and the anomalous behaviour of the geomagnetic field reported by Whitham (1963, 1964).

Tozer and Thorsteinsson (1964) and Thorsteinsson and Tozer (1960) have described the geology of the area.

The data disclose seismic velocities for sedimentary rocks ranging from 2.7 km/sec. on the surface at station H to 6.23 km/sec. for the Cornwallis Formation between stations I and K and at stations E, F and G. An integrated sonic log from the Dome et al. Winter Harbour bore-hole (station K) indicates velocities as high as 7 km/sec. for the Cornwallis Formation. Depths computed for the seismic event ascribed to the Cornwallis Formation range from zero at McCormick Inlet (shotpoint 73) to 4 km at shotpoint 78. This seismic event appears as a weak high frequency (15 cps) pulse. In the area bounded by stations D, E and I, centring on Emerald Isle, these high frequency events are not seen suggesting that the Cornwallis Formation has become too thin to transmit perceptible seismic energy, or that the formation has undergone a facies change with an attendant reduction in velocity. The predominant sedimentary event in the Emerald Isle area represents a well defined 5.5 km/sec. velocity layer at depths of 3 to 4 km.

Between shotpoints 7 and 15 on the ocean profile northwest from Brock Island, another weak, high frequency event is observed with a velocity of 6.1 km/sec. and depths ranging from 2.5 to 4.5 km. This event may represent a sedimentary layer or a diabase sill (Blackadar, 1964).

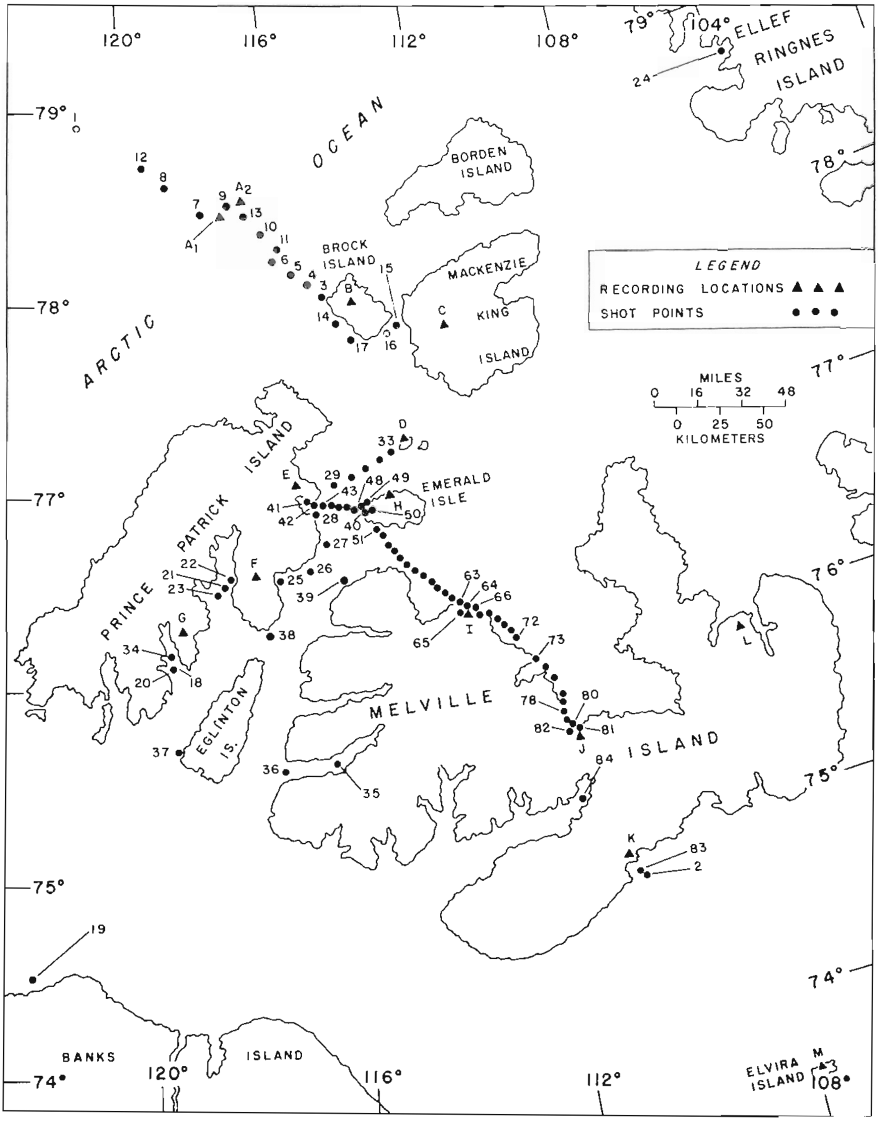

Figure 1. Shotpoint and recording station locations.

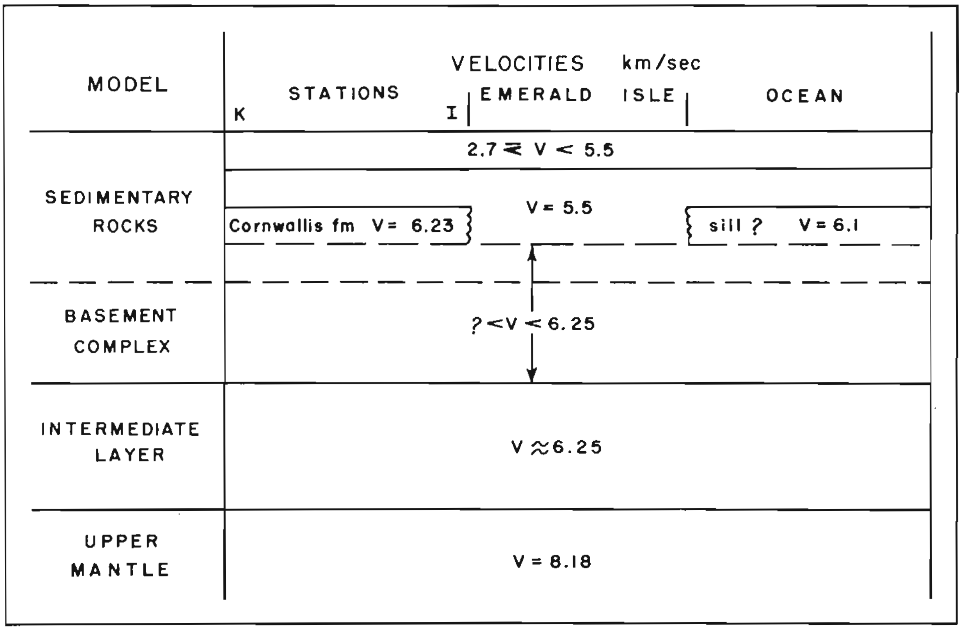

Figure 2. Generalized velocity model.

Deeper in the section a velocity layer characterized by strong, low frequency (2.5 to 5 cps) events appears to persist over most of the project area. These events are frequently seen as secondary arrivals and occasionally as first arrivals. The layer has a poorly defined velocity of 6.25 km/sec. and is the only layer, other than those within the sedimentary column, observed with a velocity comparable to values published for granitic rocks of the Canadian Shield (Hodgson, 1953b). However, depths to the top of the layer vary from 10 to 20 km using any reasonable velocity function. This layer, called the "intermediate layer" on Figure 2, implies the presence of about 5 to 15 km of rock ("basement complex" Fig. 2) below the sedimentary column for which no measure of velocity is apparent.

In general, accurate depth calculations from refraction seismic data require that the velocities of layers increase with depth and that the velocity of each layer can be measured. If one or more layers exists with lower velocity than overlying layers (velocity inversion), conditions are not conducive to the measurement of the lower velocities. The basement complex could represent a velocity inversion problem.

Geological implications of the basement complex and intermediate layer are conjectural at this time and may not be resolved without drilling at least into the basement complex. Two interesting possibilities are suggested:

Firstly, if the intermediate layer represents the granitic crust, then the basement complex could represent a considerable thickness of Precambrian rocks.

Secondly, if the basement complex represents the granitic crust at reasonable depth, then the intermediate layer may be a low velocity expression of the basaltic crust, referred to in previous work to the east (Sander, Overton, 1965) with velocity measured at 7.3 km/sec.

The depths and thicknesses of the intermediate layer compare with those prescribed by Whitham (1963, 1964) to account for the Mould Bay geomagnetic anomaly. The low velocity of the assumed basaltic crust could be related to the high conductivity required by the anomaly.

About 17 per cent of upper mantle (Pn) events show time delays ranging from 1.2 to 3.0 seconds, and an analysis for Pn velocity exhibits a wide degree of scatter for this parameter.

Most of the delayed paths are oriented in a northwest-southeast azimuth. The analysis shows that the wide variation in Pn velocity is due to the delayed travel times and can be explained by an upper mantle with a well defined velocity of 8.18 km/sec., containing an anomalous zone localized near Eglinton Island and the northwest coast of Melville Island. Numerous physical conditions in the upper mantle can cause delays in Pn events. The important consideration is that if theoretical time-distance curves are drawn for any of these conditions, the path of minimum time is the diffraction curve originating from the southeast boundary of the anomaly into points to the northwest. Further discussion of the anomaly is unwarranted until events which have actually travelled through the anomaly are recognized.

Estimates of crustal thickness from time-terms would have been somewhat questionable in view of the unmeasured velocity of the basement complex and the poorly defined velocity of the intermediate layer. However, an opportunity to check the average crustal velocity was provided by reflections from the upper mantle near critical incidence. These reflections, observed at station K from shotpoints 80 to 82, indicate an average velocity of approximately 6.00 km/sec. from the surface to the upper mantle, and a time-term to depth conversion factor of 9.67 km/sec. The time-distance curves suggest little reliable basis for changing this conversion factor over the area and the value of 9.67 km/sec. is thought to be representative except for the ocean profile and shotpoints 19 and 24.

Time-terms to the upper mantle range from 2.51 sec. at shotpoint 19 to 4.63 sec. at station D with an average of 3.70 sec. for the project area. On the ocean profile shotpoints 1 and 12 show time-terms of 3.11 sec. and 4.26 sec. respectively; the average of 3.65 sec. is not significantly different from the average for the entire area. The only suggestion of crustal thinning toward the Arctic Ocean is indicated by the smaller time-term at shotpoint 1 compared with that of shotpoint 12. This statement could be modified by more extensive crustal velocity information. The average time-term of 3.70 sec. for the entire area represents a crustal thickness of 35.8 km. Care must be exercised in interpreting the time-term of shotpoint 19 (2.51 sec.) as a thin crust (24.27 km), since the small time-term could be the result of a Pn velocity in excess of 8.18 km/sec. not revealed in the velocity analysis for paths involving shotpoint 19.

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9. A BALLISTIC MAGNETOMETER

E.J. Schwarz

This versatile instrument allows the measurement of various magnetic properties of single minerals and of rocks in external fields up to 600 oe and at temperatures up to about 700°C. Instruments of this type were described previously by, for instance, Thellier (1938) and Nagata (1961).

The change in magnetic flux due to the displacement of a magnetized specimen induces an electric current in a detection coil. The induced current is sensed by a ballistic galvanometer. The charge induced in a detection coil placed around the specimen is given by:

$$q = \frac{ns\ J}{R} \int_a^b \left(4\pi - \frac{2\ L\ A}{r^3}\right) dr,$$

in which n represents the number of turns per cm, s is the cross-sectional area of the specimen, J is the total magnetization of the specimen, R is the resistance of the detector coil circuit, a and b are the distances between the centre of the specimen and the nearest and the farthest winding of the detector coil, L is the length of the specimen, and A is the area of effective cross-section of the coil.

In the present instrument (see Fig. 1), two detector coils are used. Both are connected in series opposition. The advantage of using two detector coils is that most changes in the ambient field do not produce a significant electromotive force in the detector circuit. The specimen is moved by hand from the centre of one of the detection coils to that of the other (a distance of nearly 4 inches). The deflection of the galvanometer is read with a scale. The sensitivity is about 10^{-3} emu per gram.

The cylindrical specimens are 1/4 inch in diameter and 2 inches in length. The specimen is mounted on a rod (usually quartz glass) for easy manipulation, and is placed inside a 12 inch long cylindrical electric oven. The oven is surrounded by a glass cooling jacket. The detector coils (about 33,000 turns each) are mounted on the cooling jacket. This assemblage is placed inside a 10-inch-long coil. The coil produces a magnetic field (H) of up to 600 oe. Heating of the specimen may be carried out in any type of atmosphere.

The instrument allows measuring of the following quantities at various temperatures:

1. The total magnetization as a function of H (magnetization curve) and of T (Curie temperatures).

2. The remanent magnetization (including thermal demagnetization).

3. Acquisition of remanent magnetization under various conditions (pTRM, CRM).

4. Coercive force (of remanent magnetization).

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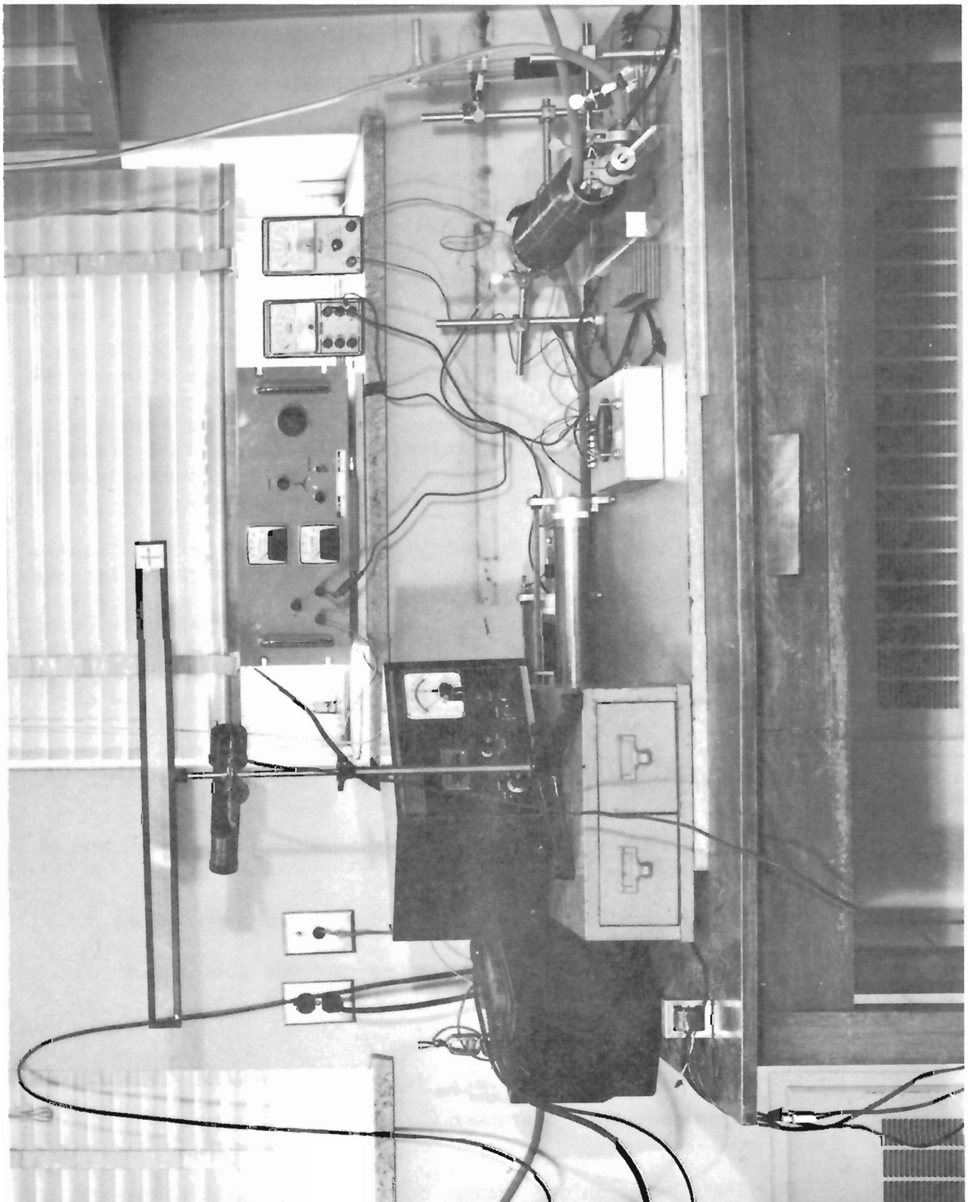

Figure 1. The ballistic magnetometer.

(Schwarz 9)

10. A MAGNETIC BALANCE

E. J. Schwarz

The instrument may be used in the investigation of magnetic properties of minerals, in the identification of ferromagnetic minerals in rocks, and in the investigation of magnetochemical changes during heating of rocks in neutral, oxidizing or reducing atmospheres. Various types of somewhat similar magnetic balances are described by, for instance, Selwood (1956) and Nagata (1961).

The instrument allows measuring of the translational force acting on a specimen suspended in an inhomogeneous magnetic field. This force is given by:

$$F_z = v.\ J\,(H).\ \delta H/\delta z,$$

in which v represents the volume of the specimen, J (H) is the total magnetization as a function of the magnetic field H, and $\delta H/\delta z$ is the gradient of H (z is the direction of translation of the specimen). The most advantageous position of the specimen was selected by careful sampling of the applied magnetic field with a small Hall effect probe. F_z may be measured in 0.1 mgram at temperatures up to 800°C.

The main parts of the instrument are a 6 inch electromagnet and a chain-type chemical balance (see Fig. 1). The magnetic field produced by the electromagnet is variable between 70 and 6000 oe (at the centre of the sample). The instrument is easily converted into an automatic recording one by replacing the chemical balance with an electrobalance.

The specimens used are rod-shaped and of maximum diameter 1/4 inch and length 1/8 inch. For each specimen the following information may be obtained:

1. The magnetization curve at various temperatures.

2. Thermal change of the (saturation) magnetization and Curie temperatures.

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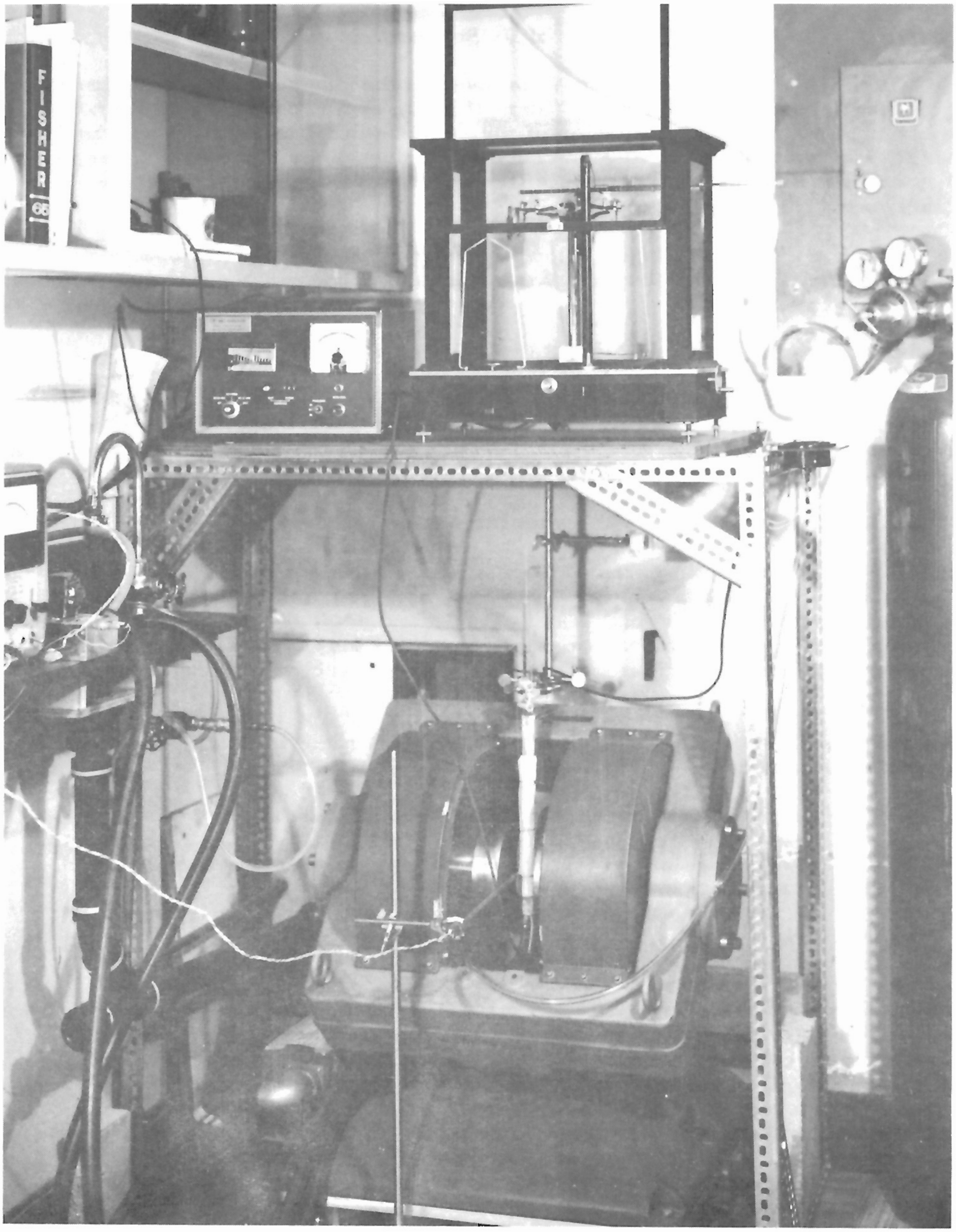

Figure 1. The magnetic balance. (Schwarz 10)

11. A MASER PROTON PRECESSION MAGNETOMETER

S. Washkurak

A continuous self oscillating proton precession magnetometer has been developed for the measurement of the earth's total magnetic field to a sensitivity of 0.01 gamma.

The instrument utilizes dynamic nuclear polarization to increase the signal to noise ratio of the precessing nucleus. The interaction between the nuclear and electron moments affects the spin lattice relaxation time, and if the electron or hyperfine structure (at low magnetic fields such as the earth's) is saturated, the difference of the normal Boltzman population of the nuclei between their levels is greatly increased.

Since polarization (enhancement) is realized by saturating the electronic line of a paramagnetic free radical dissolved and ionized in a solvent, this frequency being far removed from the precession frequency of a proton a continuous recording of the total magnetic intensity of the geomagnetic field can be measured by counting the Larmorprecession frequency of the proton on a ratemeter.

Dynamic nuclear polarization also provides a method for investigating magnetic relaxation, molecular motion and liquid structure.

A solution of 250 cm^3 of water and 0.25 gram of potassium nitro sodisulfonate ($NO(SO_3)_2K_2$) is subjected to an R.F. polarizing field of 10 watts at 56.5 megacycles, saturating the hyperfine structure of the electron resonance line. The precessing frequency of the proton is detected with a low "Q" pick-up coil. The signal is amplified with a low noise, broad band amplifier with flat phase characteristic. To sustain oscillation at the Larmor precession frequency it is necessary to provide regenerative coupling at right angles to the pick-up coil reducing all non-nuclear coupling between the two coils. With this nuclear filter technique frequency pulling of the absolute value of the precessing protons is reduced to $\pm$ 0.5 gamma over a range of $\pm$500 gamma with a fixed tuning position of the detector coil.

To obtain maximum enhancement of the signal the double distilled de-ionized water or ammonia solution (0.880) should be thoroughly degassed of dissolved oxygen by a freeze thaw cycle under vacuum. The aqueous solutions were maintained at a ph = 11.5 with a phosphate buffer. The solution of the free radical was most stable under these conditions and would last for several days.

The pick-up coil number 1 of Figure 1 consists of two axially opposing coils of 2,000 turns each of #22 wire on a 2.5 inch diameter by 4 inch long form. The R.F. polarizing coil #2 has 4 turns of #12 wire wound directly on the 250 cm^3, two inch diameter sample container. The feedback coils #3 consist of 200 turns each of #20 wire wound on a 12 inch diameter form spaced 10 inches apart.

The four stage differential broad band amplifier has a gain of about 70 db. A portion of the amplified signal is feedback at right angles to the detector coil with the amount of feedback adjusted by a ten turn helipot.

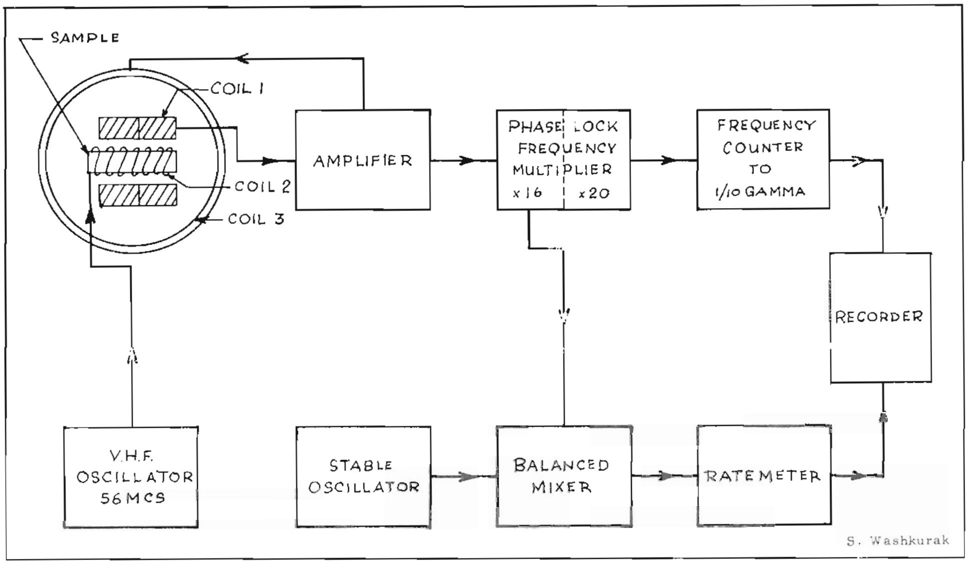

Figure 1. Continuous free precession magnetometer

The signal is also fed on through a cathode follower to a digital and analogue frequency measuring circuit.

The Larmor precession frequency of about 2,500 cycles is multiplied 320 times with a Serson type frequency multiplier. The multiplied frequency when counted for a period of 0.734 second gives a digital total magnetic field value directly in gammas to an accuracy of 0.1 gamma.

A continuous analogue presentation of the total magnetic field is obtained by tapping into the Serson multiplier at the times sixteen point and comparing this multiplied frequency to a stable crystal oscillator or variable frequency oscillator in a balanced mixer. The difference beat frequency is amplified and counted on the Hewlett Packard ratemeter. With the expand multiplier set at times ten a sensitivity of 0.05 gamma can be read on a Leeds and Northrup 9 inch strip chart recorder showing 10 gammas full scale.

A continuous self-oscillating nuclear precession magnetometer has been realized with an absolute accuracy of 0.5 gamma in a ± 500 gamma range with an ultimate sensitivity of 0.05 gamma. A stable free radical solution that will last indefinitely is in the process of being selected and transistorizing the instrument for field use is in progress.

GROUNDWATER

12. HYDROCHEMISTRY OF MOOSE MOUNTAIN AREA, SASKATCHEWAN

A. Rozkowski

The purpose of this study is to investigate the development and origin of the surface and groundwater chemistry and their interrelation in an area of hummocky moraine. The preliminary investigations are based on the results of chemical analyses of water samples collected by P. Meyboom in 1965.

The Moose Mountain region, situated in southeast Saskatchewan, consists of an isolated group of hills (Fig. 1). It is an area of typical hummocky moraine with knob-and-kettle topography with a number of sloughs and lakes without outlets. The permeability of glacial deposits is very low. Groundwater flow is under investigation by P. Meyboom, who has observed the downward direction of groundwater flow in the till deposits. Lateral flow and upward leakage in permeable zones occur in the vicinity of discharge areas.

The conductivity measurements and chemical analysis of water show considerable differences in hydrochemistry.

The mineralization of surface water varies from 240 to 16,500 ppm, and groundwater from 470 to 4,700 ppm.

There are two basic types of surface and groundwater with respect to their chemical content. The first one consists mainly of HCO_3^- or SO_4^{--} - HCO_3^- anions, and Ca^{++} or Ca^{++} - Mg^{++} cations, and is low in mineralization.

The second type of water consists mainly of SO_4^{--} - Mg^{++} ions. These are waters of high mineralization.

Figure 2 shows the relation between the ions and total mineralization of water. We observe the increase of concentration of ions, especially SO_4^{--}, Mg^{++} and Na^+ with the increase of total mineralization.

The high mineralization of water in shallow aquifers in moraine deposits is typical for semi-arid regions where infiltration of rain and percolation of soluble salts is low.

The observed differences in the chemistry of groundwater and its concentration changes from the area of recharge to the area of discharge are dependent on the following factors:

1. different velocity of groundwater flow through the strata,
2. the length of flow,
3. the time of contact between the water and tills,
4. the rate of evaporation in the zone of discharge.

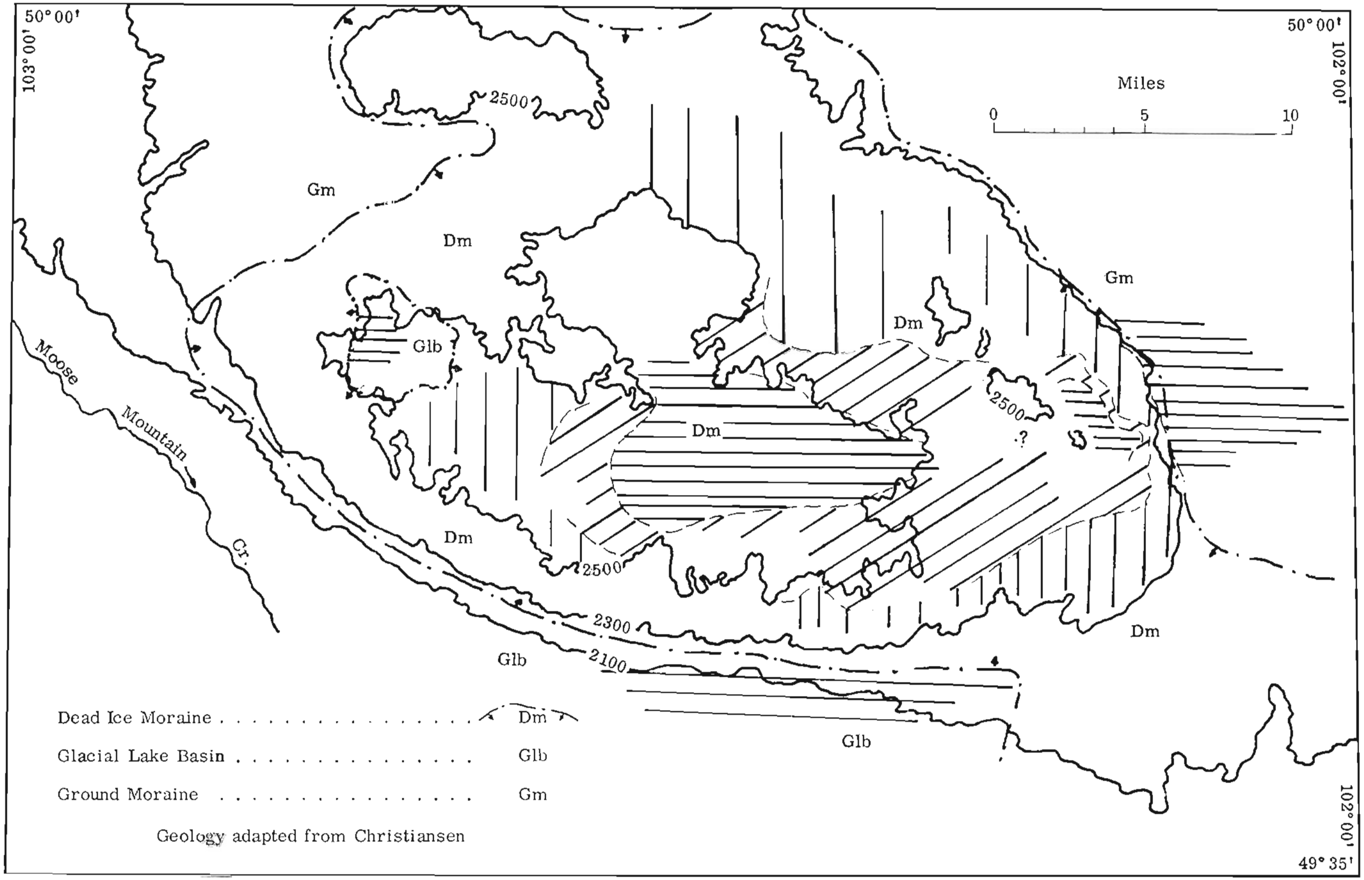

Figure 1. Sketch map of hydrochemistry of Moose Mountain area.

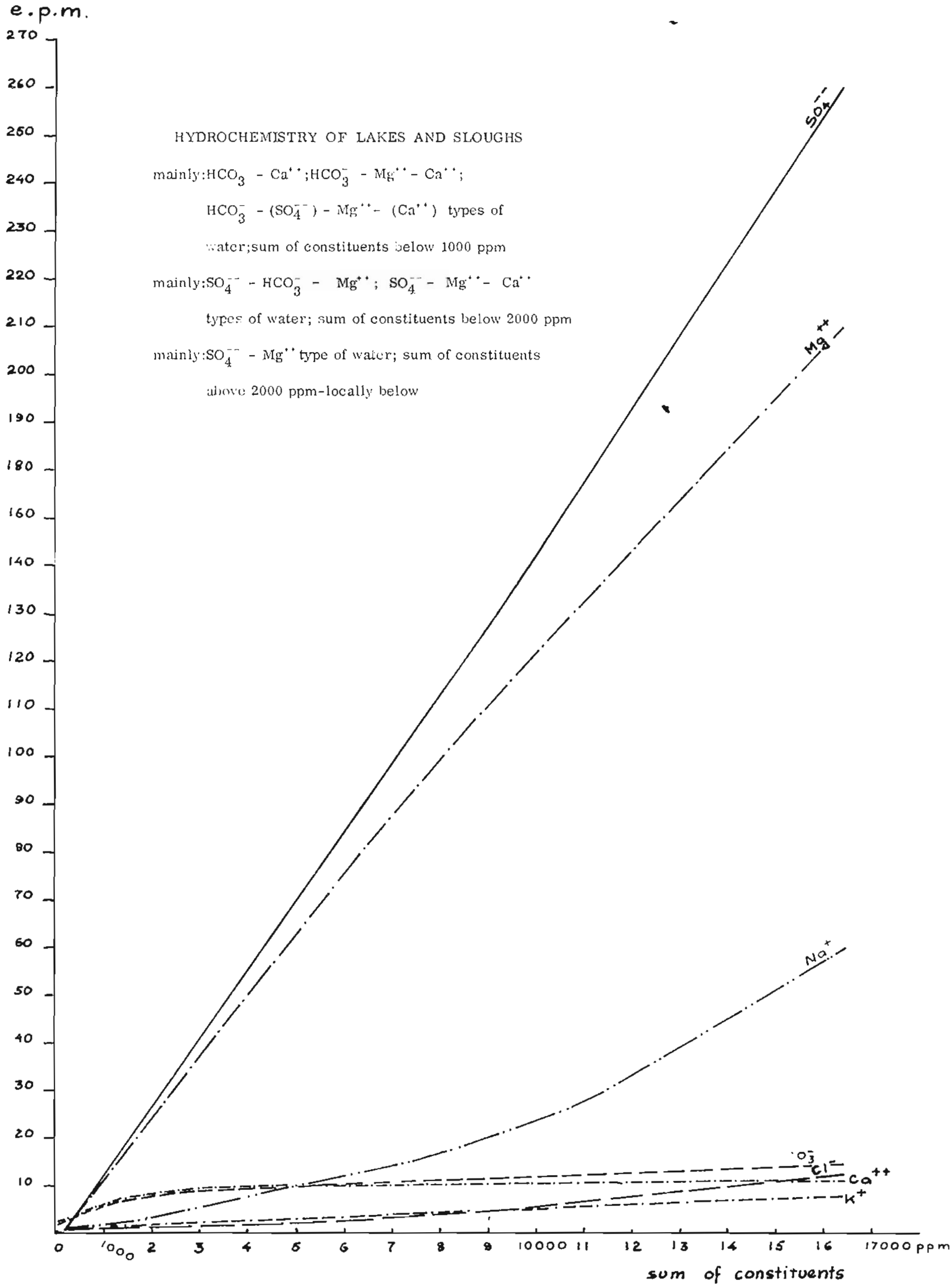

Figure 2. Relation between ionic concentrations and total sum of constituents

These observations of chemical changes permit us to classify the hydrochemical zones:

$$HCO_3^- - SO_4^{--} \rightarrow SO_4^{--} - HCO_3^- \rightarrow SO_4^{--}$$

The high evaporation of surface water results in:

1. the general increase of water mineralization,
2. the concentration of easily soluble salts mainly $MgSO_4$ and Na_2SO_4,
3. the precipitation of carbonate salts.

There is an increase in mineralization from the top of the hills downward to the 2,400 foot contour. Below that level the mineralization of sloughs is low again (see Fig. 1).

The changes of chemistry of water suggest the appearance of hydrochemical zones in the sequence

$$HCO_3^- \rightarrow HCO_3^- - SO_4^{--} \rightarrow SO_4^{--} - HCO_3^- \rightarrow SO_4^{--}$$

The results of analyses of surface and groundwater indicate the existence of a hydraulic interrelationship.

Both ground and surface water show similarities with respect to their chemical types.

The presence of corresponding hydrochemical zones in both cases confirms this hypothesis.

The lack of $HCO_3^- - Ca^{++}$ type of water in the groundwater can be explained by previous percolation of rain water through the soil.

The low mineralization and HCO_3^- type of surface water as well as the increasing concentration of groundwater with depth indicates that the recharge area of the moraine aquifers consists mainly of the upper part of Moose Mountain. On the other hand the region of sloughs with high mineralization shows the area of discharge of groundwater. In the latter area the mineralization of surface water is higher than groundwater. This phenomenon can be explained by the influence of evaporation. The explanation for the limited area of lakes and sloughs with high mineralization can be attributed to the different permeabilities of glacial deposits. Further detailed investigations based on geochemical and hydrochemical methods are planned in the near future.

ISOTOPE AND NUCLEAR GEOLOGY

13. ATOMIC ABSORPTION SPECTROSCOPY

Sydney Abbey

In this new technique, developed as a method of chemical analysis during the last ten years, a solution of the sample is dispersed in a flame. Light from a source emitting the line spectrum of the desired element is passed through the flame, and the attenuation of one spectrum line of that element, resulting from the absorption of "resonant" energy by "ground-state" atoms of the element, is measured by means of a monochromator and a photo-multiplier tube.

In atomic absorption, selectivity originates in the light source, rather than in the flame (as in flame photometry) or in the chemical pre-treatment (as in molecular spectrophotometry, or colorimetry). Inter-element effects are much less pronounced than in other methods.

Although atomic absorption was first considered for work at the Geological Survey as early as 1960, it was not until the summer of 1965 that refinement of the equipment had reached the stage where a decision was reached to proceed. The equipment was received at the beginning of 1966 and work began in February.

So far, excellent results have been obtained for up to 15 per cent of Mg0, much more rapidly and accurately than by other methods. Incomplete work indicates that lithium can be determined down to about 2 ppm in rocks, with little or no inter-element effects. Further work is planned on zinc, cadmium and other trace metals.

14. CARBON-14 AGES OF DOUGLAS FIR TREE RINGS FROM VANCOUVER ISLAND

Willy Dyck

To calibrate the apparatus in the Radiocarbon Dating Laboratory of the Geological Survey it was essential to obtain materials whose age is known accurately. There are only two sources of such materials: museums and trees. Curators as a rule, are reluctant to part with artifacts especially if they cannot be returned. Even very old living trees are difficult to find but through the diligent efforts of Rayonier Canada (B.C.) Limited, the Forest Products Laboratory of Canada, and the director of the Geological Survey, an old tree was discovered and shipped to the Ottawa laboratories where its age was determined, firstly, by counting the annual growth rings and secondly, by measuring the $carbon^{14}$ disintegration rate in these rings using the so-called "radiocarbon clock" method.

The tree, a 60 inch diameter Douglas Fir, grew on the west coast of Vancouver Island near San Simon Point (Long. 124°04'W, Lat. 48°27'N) and was cut alive late in 1960. An approximately 8 inch rectangular section, cut about 20 feet up the bole from the stump and from periphery to periphery through the pith was sent to the Geological Survey for analysis. A preliminary ring count showed 1,127 growth rings. A careful count by Mr. J.D. Hale at the Forest Products Laboratory revealed 1,143 annual growth rings. His count was used for reference in all subsequent comparisons.

Carbon^{14} analyses of samples consisting of 4 to 20 growth rings and taken at approximately 100 year intervals were converted to radiocarbon ages and compared to the tree ring ages. The results are listed in the table. If ideal conditions had prevailed throughout the lifetime of the tree and beyond, all the points if plotted graphically would have fallen on a 45 degree line. However, the forces of nature seldom remain constant long enough to permit the establishment of equilibrium. In addition to the deviations from the ideal state each measurement has associated with it an error which is due to errors in the preparation and measurement of the sample and the randomness of radioactive decay. Statistical theory predicts and practical experiments verify that with random phenomena measurements occasionally can be far removed from the true value and still be quite valid. But errors alone cannot explain the deviations observed in this particular case. Similar observations have been made on Sequoias from California and Oak and Douglas Fir from Germany by other scientists. There is no doubt that the variations are real and are due to variations in the carbon^{14} concentration of the air from which the trees drew their carbon. The reasons for this however, are complex and not fully understood as yet.

Although the principles behind the dating method are relatively simple in practice considerable effort is required to determine the age of a sample. This is so mainly because the carbon^{14} concentration is so very small (10^{-10}% i.e. 0.0000000001%). Samples are converted to pure carbon dioxide gas. The gas is pumped into a radiation detector (Geiger counter) where the disintegration rate of carbon^{14} in the sample is measured. From the disintegration rate the age of a specimen can be calculated.

In addition to many events which have been dated, considerable information on the circulation patterns of the atmosphere and ocean is gained by tracing carbon^{14} through these reservoirs.

A word of caution may be in order. From tree ring measurements and well-dated historical artifacts, it is known that the carbon^{14} age scale has deviated from the solar scale by as much as 200 years during parts of the last millennium and by as much as 600 years during parts of the past five millennia. Although arguments favor a more or less steady state over long periods of time there is no absolute guarantee that the radiocarbon year has not deviated from the solar year by more than that during the distant past. However, even if that were so, it would not invalidate the effort and time spent on the radiocarbon clock, for events could still be correlated on the radiocarbon age scale.

Table of
Carbon^{14} Ages and Tree Ring Ages of Douglas Fir

Growth, A.D. From - To	Aver. Ring Age A.D.	Aver. Carbon^{14} Age A.D.
830 - 834	832	740 ± 80
914 - 934	924	880 ± 100
1014 - 1034	1024	870 ± 100
1126 - 1136	1131	1150 ± 90
1228 - 1238	1233	1200 ± 60
1330 - 1340	1335	1300 ± 60
1432 - 1442	1437	1530 ± 50
1524 - 1544	1534	1700 ± 70
1626 - 1646	1636	1690 ± 60
1728 - 1748	1738	1850 ± 70
1830 - 1850	1840	1860 ± 90

15. URANIUM-LEAD AGES AND LEAD ISOTOPE RATIOS IN GALENAS AND CLAUSTHALITES OF THE BEAVERLODGE AREA, SASKATCHEWAN

V. Koeppel

A new attempt is being made to determine the history of the metallic mineral deposits of the Beaverlodge area. The isotopic composition and elemental concentrations of lead and uranium in small samples of pitchblende (1-2 mg) have been determined with a solid source mass spectrometer.

The main purpose of the investigation is to determine whether the formation of the mineral deposits took place during only one period, or whether they are the product of repeated mineralization occurring at widely separated intervals. The study should also help to solve the age relations between the pegmatitic and the hydrothermal uranium deposits, the metamorphic event recorded by the potassium-argon ages of micas, and the volcanism occurring in the Martin Formation.

Special attention is being paid to the selection of pitchblende and uraninite samples for isotopic analysis. Ideally a sample should consist of only one type of pitchblende, it should be free of any alteration products, and it should not be intergrown with lead minerals, except in cases where microscopic evidence suggests that the lead mineral was formed by exsolution of lead from the surrounding pitchblende. Whenever possible samples were chosen from pitchblende occurrences where an upper or lower relative age was established on field evidence.

Prior to removing the sample from the polished section the selected surface was examined with an electron microprobe in order to make a preliminary estimate of the uranium-lead ratio and to study the lead distribution within the selected area.

Several concordant, or closely concordant, ages have been obtained on pitchblende from hydrothermal deposits suggesting a time of deposition of 1780 my. On the other hand, the pattern of discordant ages of some pitchblendes suggests a first lead loss between 1050 and 1100 my, and further lead losses between 0 and 300 my. The lead isotope ratios of galenas and clausthalites support the conclusions drawn from the interpretation of the apparent pitchblende ages. Apparent ages obtained from pitchblende samples of the same pitchblende veinlet of a given hand specimen do not support the theory of continuous lead loss by diffusion as the sole mechanism of lead loss.

The presence of one or two distinctly younger generations of pitchblende is indicated by the apparent pitchblende ages combined with a possible interpretation of the lead isotope ratios of galena occurring in veins which are cut by pitchblende bearing veins.

Uraninite of pegmatitic deposits was formed 1900 my ago.

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1953: Goldfields - Martin Lake Map-area, Saskatchewan; Geol. Surv. Can., Mem. 269.

Eckelmann, W.R., Kulp, J.L.
1956: Uranium-Lead Method of Age Determination, Part I: Lake Athabasca Problem; Bull. Geol. Soc. Am., vol. 67, No. 1, pp. 35-53.

Robinson, S.C.
1955: Mineralogy of Uranium Deposits, Goldfields, Saskatchewan; Geol. Surv. Can., Bull. 31.

MINERAL DEPOSITS

16. THE ORIGIN OF HIGH GRADE IRON DEPOSITS ON BAFFIN ISLAND, N.W.T.

G.A. Gross

The discovery of high grade iron deposits near the north end of Baffin Island is of major significance. The deposits are part of a new region in Canada that can supply iron ore of exceptional quality for export, and production of ore from this area would be a major advance in pioneering Arctic development. The iron deposits are of special geological importance because of the exceptionally high grade and structural quality of the hematite and magnetite ore zones and the unusual sequence of geological events which produced them.

The iron deposits were discovered in 1962 and have been explored by Baffinland Iron Mines Limited who carried out comprehensive studies during 1965 of the feasibility of mining and shipping iron ore from the Mary River area. The Geological Survey of Canada did reconnaissance geology along the coast of Baffin Island prior to 1960 and of the adjacent area west of the iron ranges in 1963. Detailed geological investigation of the iron deposits was carried out in 1964 and 1965 by the writer.

The largest iron deposit occurs in Archaean rocks about 60 miles southeast of the head of Milne Inlet at lat. 71°20'N and long. 79°16'N on the east side of a major structural break that extends northwest from Pilik Lake to Milne Inlet. The topographically low area west of this structural lineament is underlain by Palaeozoic rocks and the highland plateau to the east is underlain by highly metamorphosed Precambrian rocks. A group of rocks composed of acid and basic metavolcanics, iron-formation and metasediments has been infolded and faulted within the granitoid massif. This group of rocks is granitized in local areas and intruded by basic dykes, now amphibolite masses, and by ultrabasic rocks now largely serpentinized. Erosion of complex steeply plunging fold structures has left numerous small isolated belts of metasediments, iron-formation and metavolcanics distributed in the granitoid rocks of the plateau area.

The iron-formations form conspicuous lenticular masses in the volcanic-sedimentary sequence and are of general Algoma type. Typical thin layered quartz magnetite and quartz hematite facies are most common. A distinctive feature in the iron-formation is the occurrence of beds of nearly pure magnetite and occasionally hematite, which range in thickness from a few inches to tens of feet that are interlayered with the thinly laminated quartz magnetite beds.

The Number 1 Deposit in the Mary River area is a folded steeply dipping zone of porous hard specular hematite that grades to zones of dense hard magnetite at both north and south ends. The magnetite zones grade to thin banded magnetite and quartz-magnetite or iron-silicate quartz iron-formation. The iron-rich zone varies in thickness from 350 to 500 feet over a strike length of 8,200 feet and pinches to less than 50 feet in the most southerly outcrop. The typical composition of this deposit indicated by diamond drilling is 69.65% iron, 0.72% silica, and 0.026% phosphorus. The

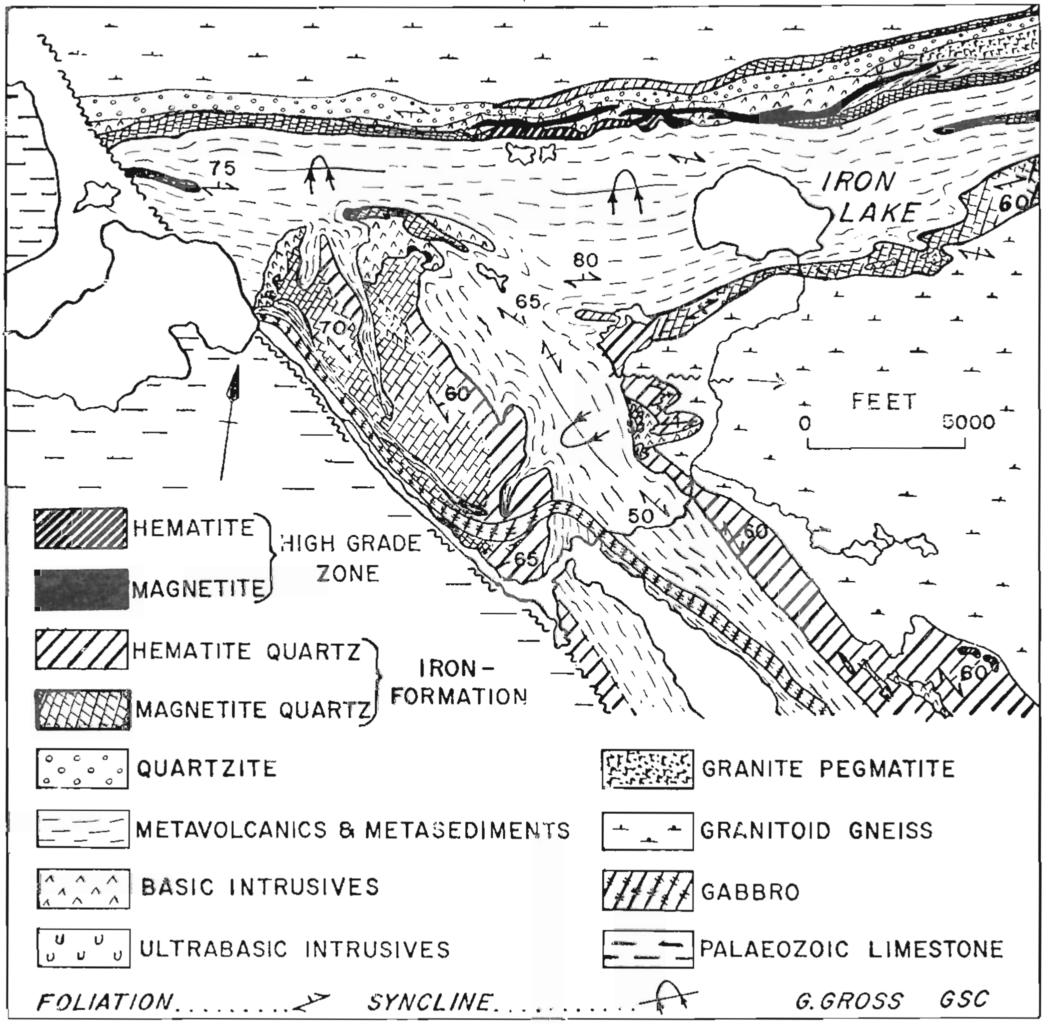

Figure 1. Geology of the Iron Lake area, Baffin Island.

average iron content is more than 68% and the silica content is less than one per cent.

The Iron Lake deposit consists of a lenticular bed composed of magnetite and hematite that forms part of the iron-formation on the north limb of a complex syncline. The iron-rich zone is 7,800 feet long and its maximum width is 250 feet. Surface channel samples indicate an average composition of 66.84% iron, 2.06% silica, and 0.081% phosphorus.

Other deposits in the Mary River area are part of a stratigraphic zone within the iron-formation that is composed of specular hematite and

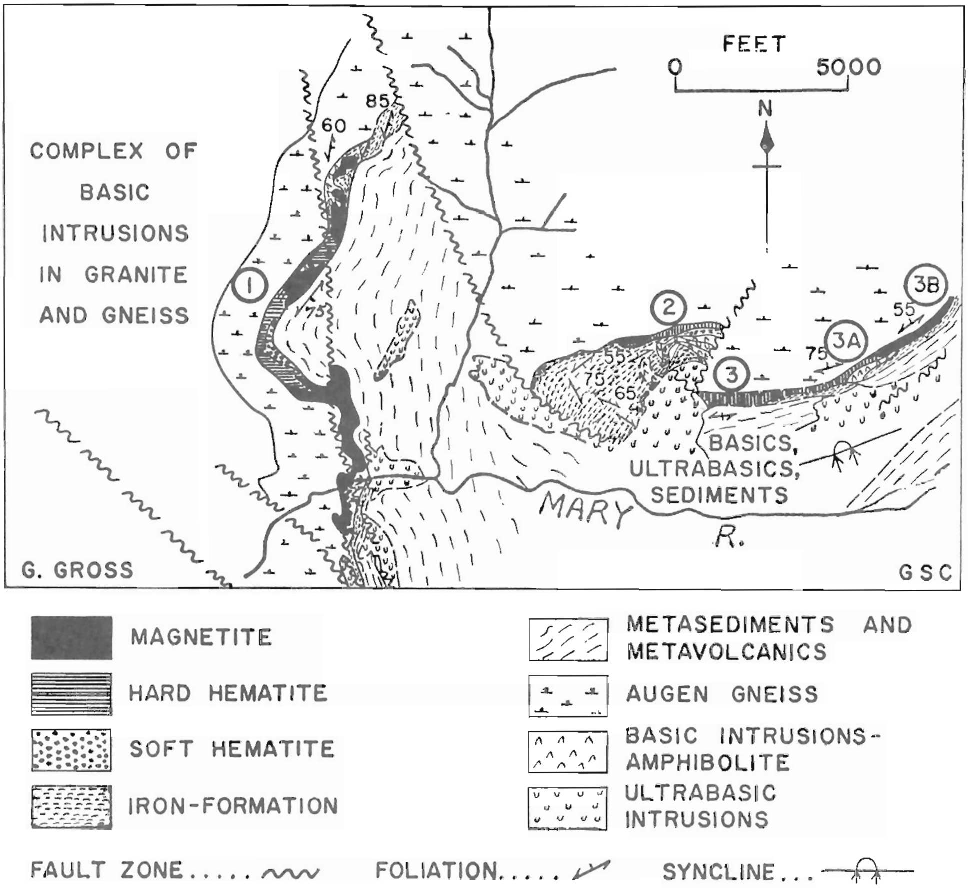

Figure 2. Geology of the Mary River area, Baffin Island. High grade magnetite and hematite zones are numbered 1 to 3B.

magnetite. This zone was traced eastward for more than a mile and its thickness varies from 100 to 300 feet. The exceptional high grade and structural quality of most of the potential ore in the Baffin deposits is rare if not unique, and their mode of origin is of special interest. The main period of iron enrichment in the deposits was during early Precambrian time when predominantly oxide facies of iron-formation were oxidized, silica was leached by groundwater, and supergene enrichment of iron took place, leaving vuggy lenticular cavities and streaky porous zones in the hematite. The deposits were deeply buried and extensively recrystallized during a period of metamorphism that reached amphibolite rank. Hematite formed at the expense of magnetite, much of the porosity in some of the deposits was preserved and many relict sedimentary features are preserved in the magnetite and quartz magnetite iron-formations. Evidence was not found to suggest any appreciable amount of migration of iron during metamorphism.

Some alteration and enrichment of iron has taken place in parts of the Number 1 Deposit after metamorphism and prior to glaciation.

It is doubtful whether leaching and enrichment processes alone were the principal factors in producing such pure iron oxide although they appear to have been an essential part of the genetic process. It is believed that much of the iron-formation that is now host or protore for the rich deposits was originally rich in iron oxide and composed mainly of magnetite

Figure 3. The Number 1 magnetite-hematite deposit, Mary River area, exposed along the crest of the ridge viewed from the southeast.

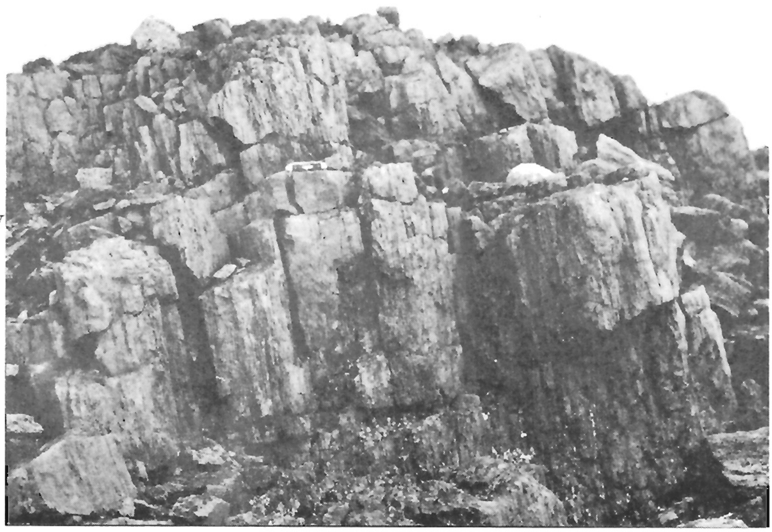

Figure 4. Typical porous grey hard hematite in the Number 1 deposit, Mary River area. Bedding, foliation and streaky porous zones dip steeply.

beds, and only a small amount of impurity had to be removed in the ore-forming process. Enrichment of the iron-formations extends to depths greater than one thousand feet and the processes that led to the formation of high grade ore may have been widespread throughout the region.

Variations in the texture and composition of the high grade iron oxide zones are reflected in the existing topography, and areas of low relief and drift covered iron-formations must be sampled before iron-ore potential in the area can be adequately assessed. Magnetometer surveys alone will not serve to distinguish either high grade magnetite or hematite zones from low grade iron-formation. The existence of nearly pure magnetite and hematite beds of sedimentary origin within the iron-formations greatly enhances the possibility of finding other high grade iron deposits, or of finding iron-formations of unusually high iron content that can be beneficiated easily. Minor zones in the iron-formation containing pyrite and pyrrhotite suggest that more extensive and significant sulphide facies of iron-formation may be present.

17. COPPER DEPOSITS, CORDILLERAN REGION

E.D. Kindle

Library research relating to the study of copper occurrences in the Cordilleran Region of Canada was carried out during the winter months. All copper properties lying within N.T.S. map-areas 92G, 92J, 92H, 82F, 82G, 82J, 82K, 82L and 82N were located, classified and described in summary form. In these areas the copper deposits are commonly found in Precambrian and Palaeozoic sedimentary rocks and in Triassic sedimentary and volcanic rocks. They also occur in intrusive rocks of Precambrian age, Jurassic age and Cretaceous or later age. Copper minerals in the different localities are associated with one or more of the following: gold, silver, platinum, molybdenum, iron, vanadium, tin, lead, zinc, antimony, and bismuth minerals.

Two magnetite samples from deposits 10 miles west of Kamloops collected by the writer in 1965 were found to contain very little copper, but spectrographic analyses show a vanadium content of 0.20 and 0.30 per cent respectively.

MINERALOGY AND PETROLOGY

18. MIGMATIZATION IN THE CORE OF A SHUSWAP GNEISS DOME

P. Blattner

During a 10-day period in summer 1965 the migmatite complex, forming the deepest exposed part of Thor-Odin gneiss dome, was studied in detail, as represented by an area of about 200 square yards. Within 200 feet the rocks are overlain by a sequence of mostly metasedimentary gneisses, including a conglomerate-like layer (Reesor, 1966).

The complex consists mainly of hornblende bearing "augen-granodiorite-gneiss" (Reesor) and, in the area studied, broadly concordant pegmatoid veins or layers several inches in thickness, and inclusions of amphibolite; the original relationship of the latter is not easily recognized but they may be former dykes. In addition massive, granitic material is distributed in dyke-like fashion along late-kinematic shear-planes (also termed flexure zones, or strain-slip cleavage) of irregular spacing. Many of the shears are free from granitic material, some show a bare beginning of its development, and there are transitions to one occurrence, where angular pieces of wall-rock are incorporated in a three-foot-wide granitic dyke, forming an agmatite.

On the structural projection the normals to the shear-planes are scattered about the π-circle, and the complex can be regarded as a B-migmatite, as defined by the writer (1965). The shears do not necessarily follow axial planes of folds.

In classical descriptive terminology the rocks are most nearly veined gneisses with regard to the pegmatoid material, and dictyonites[1] with regard to the granitoid material. Agmatites are of limited occurrence as mentioned.

In dealing with the formation of migmatites a convergence of the rock-forming processes themselves ("transitiveness", Smulikowski, 1958) must be considered in addition to the experimental results on "granite-systems". It is important, then, to search for relatively simple processes of migmatite genesis first, which thereafter may be considered "end-members" of hypothetically more complex cases of migmatization. An example of essentially isochemical "granitization" on a regional scale has been given by Mehnert (1953, 1957, 1962, 1963).

In the present case attention was paid mainly to the granodiorite-gneiss host rock, to the pegmatoid layers or veins, and to the granitic material, emplaced along shears. The results of chemical analyses so far have shown that the formation of the granitic material has probably been an isochemical process, involving both granodiorite-gneiss and pegmatoid veins in their previous proportions. Both Or/Ab and Ab/An of the pegmatoid veins are high with respect to granodiorite-gneiss as well as the granitic material, suggesting an increase in temperature between the time of formation of the pegmatoid veins and of the granitic material. However, there are no signs of dark constituents being enriched at boundary surfaces of the veins.

An unexpected result has been the behaviour of Ba/K values. At any one of three localities, which are about 100 yards apart, values of the weight ratio $Ba/(K_2O - \frac{FeO}{3})$[2] were found constant, irrespectively of whether measured in granodiorite-gneiss, or in pegmatoid veins. However, at two places they are .025 and .028, while at the third locality they are distinctly higher, namely .042. The uneven distribution of Ba on the 100 yard scale could be either relic or superimposed on the complex, but it does not seem to be directly related to the migmatite formation.

Several of the mineral assemblages involved in the complex are now being studied. The grant of a National Research Council Postdoctorate Fellowship is gratefully acknowledged.

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[1] Sederholm's term "dictyonite" has not been used commonly in the English language. The term, however, is of some significance for the description of migmatites, notably since defined and illustrated by Holmquist, 1920.

[2] $(- \frac{FeO}{3})$ is a correction for biotite. Biotite can be shown to contain relatively little Ba as compared to alkali-feldspar.

Blattner, P.
1965: Ein anatektisches Gneissmassiv zwischen Valle Bodengo und Valle di Livo, Prov. Sondrio und Como. Schweiz. Min. Petr. Mitt. 45, 973-1072.

Holmquist, P.J.
1920: Om pegmatitpalingenes och ptygmatisk veckning; Geol. Fören. Förhandl., 42, 191-213 (English summary).

Mehnert, K.R.
1953: Petrographie und Abfolge der Granitisation im Schwarzwald.
1957: Neues Jahrb. Mineral. Abh. 85/1, 59-140; 90/1, 39-90;
1962: 98/2, 208-249; 99/2, 161-199 (English summaries).
1963:

Reesor, J.E.
1966: The Thor-Odin Gneiss Dome, Monashee Mountains, Southern British Columbia; Geol. Surv. Can., Paper 66-1, 78-80.

Smulikowski, K.
1958: Problem of Genetic Classification of Granitoids; Studia Geol. Polon. I, 59-115.

19. ROCK ANALYSIS BY X-RAY SPECTROMETRY

S. Courville and G.R. Lachance

The feasibility of using the ARL multi-channel X-ray fluorescence unit in a dual capacity is being investigated. Two separate procedures have been worked out for: (a) the ultra-rapid analysis of most rocks for the eight constituents MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, MnO and total Fe as Fe_2O_3 with fair accuracy, and (b) the more accurate but rapid determination of the same eight constituents in rocks. The procedures are being assessed for precision and accuracy by comparing the X-ray results with values obtained by classical chemical methods.

For ultra-rapid analysis, a pellet is prepared from a 1.7 gm portion of a rock to which 0.3 gm of boric acid has been added (to act as a binder) and the mixture ground for 4 minutes. The characteristic intensities for the eight constituents are measured for 3 one-minute periods and the intensities found are converted to concentrations with little or no inter-element corrections. Under normal operating conditions, two experienced technicians can analyze approximately 50 rock samples per day.

For those samples requiring greater accuracy, pellets are prepared in triplicate by the lithium borate-lanthanum oxide fusion method and the characteristic intensities of the eight constituents are measured for 3 three-minute periods. The measured intensities are converted to concentrations by direct comparison using primary standards which are analyzed together with the unknowns. It has been found preferable that the whole analysis be carried out by one person. Under normal operating conditions, two experienced technicians (working on an "alternate day schedule") could analyze 3 rock samples a day.

20. PETROLOGICAL STUDIES OF THE THOR-ODIN GNEISS DOME, SOUTHERN BRITISH COLUMBIA

E. Froese

An area, approximately 15 by 24 miles, surrounding the Thor-Odin gneiss dome, in the Shuswap metamorphic terrain, has been mapped by J.E. Reesor (1965, 1966) and J.M. Moore. Structural studies of the area by J.E. Reesor and an investigation of metamorphic zoning by J.M. Moore are in progress. P.B. Blattner is examining selected problems of migmatization. The writer is concerned with further detailed petrological studies.

Structurally, the area can be divided into a core of migmatized gneisses, surrounded by a mantle of metasedimentary gneisses grading into a fringe of supracrustal rocks. The rocks of the fringe zone belong to the greenschist facies and lower almandine-amphibolite facies. Mineral assemblages from rocks of the core migmatites and of the mantling gneisses are typical of the sillimanite-almandine-orthoclase subfacies of the almandine-amphibolite facies. The mineral assemblage quartz + plagioclase + K-feldspar + biotite + garnet + sillimanite is common in pelitic rocks from both structural zones and, therefore, this assemblage is suitable for studying

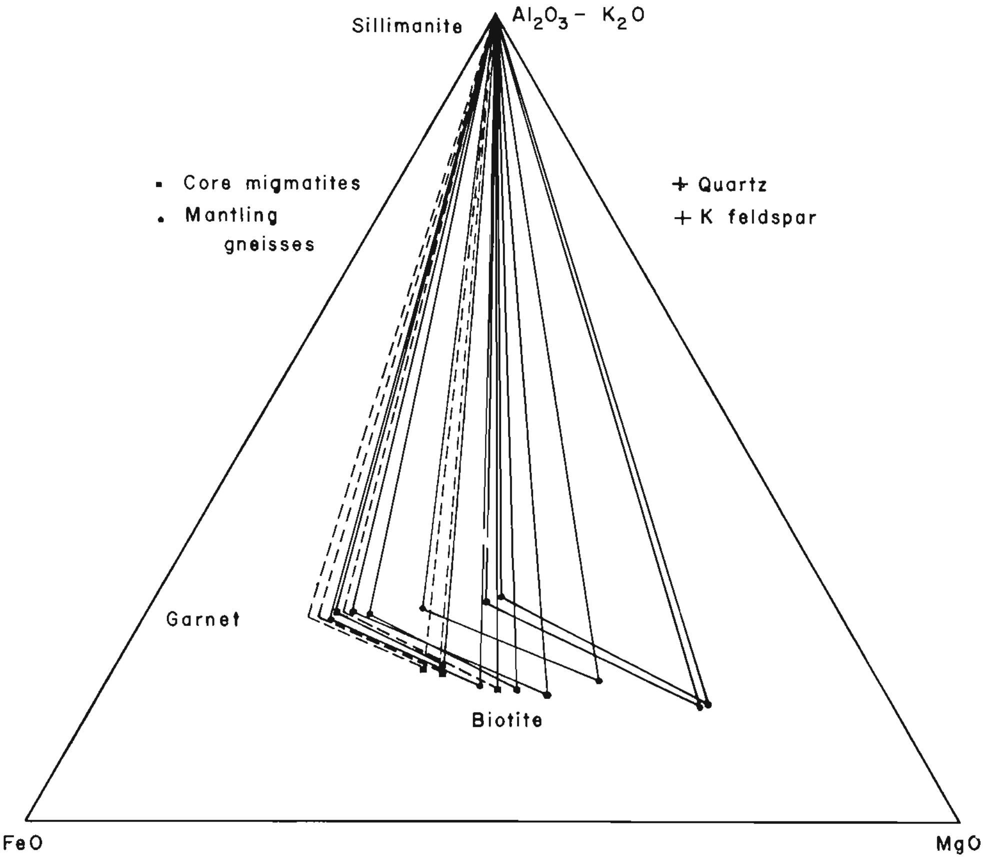

Figure 1. The composition of biotite and garnet from the mineral assemblage quartz + K-feldspar + biotite + garnet + sillimanite, common in pelitic rocks from the Thor-Odin area, southern British Columbia.

possible differences in metamorphic conditions between the two zones.

In this mineral assemblage, magnetite is absent in many cases, particularly if graphite is present. The Fe_2O_3 content of biotite and garnet is very low and can be neglected. In the presence of quartz, the minerals K-feldspar + biotite + garnet + sillimanite may be regarded as belonging to the system $K_2O - Al_2O_3 - FeO - MgO$, if the content of TiO_2, MnO, CaO, and Na_2O in these minerals is neglected, and they may be represented within a tetrahedron. Because K-feldspar is present in most rocks, the composition of biotite can be projected through K-feldspar onto the $Al_2O_3 - FeO - MgO$ plane of the tetrahedron. This projection is accomplished by subtracting K_2O from Al_2O_3 (both expressed as molecular proportions). Figure 1 shows coexisting minerals of some rocks from the Thor-Odin area plotted on such a diagram.

It is obvious that biotite and garnet from this assemblage show an appreciable variation in composition, reflecting possible differences in P_{total}, P_{H_2O}, and T from rock to rock. Considerable variation is observed, even if different specimens come from the same outcrop, in which case the P_{total} and T must be practically the same, suggesting that the variation in composition is largely a reflection of differences in P_{H_2O}. Because mineral assemblages from the core migmatites and from the mantling gneisses indicate the same metamorphic grade, it is assumed that temperature differences were slight and that variations in mineral composition again indicate mainly differences in P_{H_2O}. An increase in P_{H_2O} would favour the formation of biotite (+ sillimanite) at the expense of garnet (+ K-feldspar), both minerals becoming enriched in iron. It is observed that biotite and garnet from the core migmatites have a higher iron content than those from the mantling gneisses, indicating a higher P_{H_2O} (see Fig. 1). At present, the FeO/FeO + Mg ratio of biotites from other rocks, having the same mineral assemblage, is being determined, in an attempt to substantiate the observation based on a few samples only. The observation is, of course, consistent with the fact that an increase in P_{H_2O} favours the melting of granitic constituents, which is one possible mechanism of migmatization.

Reesor, J.E.
1965: The Thor-Odin gneiss dome, southern British Columbia; Geol. Surv. Can., Paper 65-1, pp. 63-64.

1966: idem; Geol. Surv. Can., Paper 66-1, pp. 78-80.

21. TIN-BEARING GARNET AND PYROXENE FROM SKARN IN THE CASSIAR DISTRICT, B.C.

R. Mulligan and J.L. Jambor

Coarsely crystalline brown garnetite, found just north of the pass at lat. 59°17 1/2N, long. 130°31W, yielded 1.1 per cent tin on spectrographic analysis. The garnetite occurs among crystalline limestone and garnet, pyroxene, and vesuvianite skarns near their contact with granodiorite (Watson and Mathews, 1944), but occupies only a single small area and may be exotic. Dark pyroxene-rich and garnet-free skarn from a boulder a few hundred feet south of the pass contains 0.78 per cent tin. A green pyroxene-rich skarn contains 0.04 per cent tin and other vesuvianite-pyroxene-garnet skarns in the area yielded up to 0.026 per cent tin. A vesuvianite sample contains 0.012 per cent Be.

The tin-rich garnetite is composed of about 65 per cent interlocking crystals of deep green garnet up to 25 mm across and about 35 per cent finer brownish-green pyroxene. The garnet is finely banded in concentric zones parallel to the crystal outlines, the bands showing distinct but variable optical anisotropy. The pyroxene, near augite in optical properties, is mainly in anhedral interstitial masses and in thin bands along the zone boundaries within the garnet crystals.

Tin distribution in the co-existing skarn silicates has been studied by electron probe and spectrographic techniques. Analysis of the garnet indicates that it is virtually a pure stannian andradite end-member in which the depth of green coloration in the zones can be correlated with tin content.

Watson, K. DeP., and Mathews, W.H.
1944: The Tuya-Teslin area, Northern British Columbia; B.C. Dept. Mines, Bull. No. 19.

22. NEGATIVE AEROMAGNETIC ANOMALY ASSOCIATED WITH OCCURRENCE OF HEMOILMENITE IN ANORTHOSITIC GABBRO

E.R. Rose

About 16 miles north of the village of Mont Tremblant, near Lac Rossi, in the Grenville geological province of Quebec, as reported by Dr. E.H. Gaucher[1], a negative aeromagnetic anomaly is associated with a body of dark, weakly magnetic rock, that is in part surrounded by a mass of granitic rock with which positive magnetic anomalies are associated. Microscopic examination of polished thin sections, by the author, of samples submitted by Dr. Gaucher, indicates that the dark rock is anorthositic gabbro and the light coloured rock is quartz monzonite. Both rock types carry accessory fine-grained, disseminated, opaque, magnetic iron-titanium oxides, mainly hemoilmenite (ilmenite with exsolved blades of hematite), and titanomagnetite (magnetite with more than 1 per cent titanium in solid solution). The magnetic oxides are more abundant in the anorthositic gabbro than in the quartz monzonite, and whereas hemoilmenite predominates over titanomagnetite in the former, titanomagnetite predominates over hemoilmenite in the latter.

The presence of hemoilmenite and titanomagnetite in rocks of both types suggests either close contemporaneity of the two intrusions or partial assimilation of one by the other. The negative anomaly associated with the gabbroic phase of the intrusions appears to be related to the relative abundance of hemoilmenite in this rock, this mineral intergrowth having apparently imparted a reversed polarity to the rock.

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[1] Personal communication, Dr. E.H. Gaucher, Geophysics Division, Geological Survey of Canada, now Geophysicist, SOQEM, Quebec.

23. SYSTEMATIC REFERENCE SERIES, NATIONAL MINERAL COLLECTION

H.R. Steacy

The Systematic Reference Series is the research portion of the National Mineral Collection and is the responsibility of the Geological Survey of Canada. A major reorganization of the Series – undertaken in the summer of 1965 – was completed in March, 1966. This involved the re-grouping and re-indexing of the approximately 7,500 specimens on file, representing some 1,400 mineral species and varieties. Significant progress was also made in the acquisition of unrepresented species. The Series is maintained as an active working collection that is available to qualified scientists in all fields of research. Enquiries and applications for the loan of specimen material should be addressed to the Curator, H.R. Steacy.

PLEISTOCENE AND QUATERNARY GEOLOGY

24. AURIFEROUS TILL IN THE EASTERN TOWNSHIPS, SOUTHEASTERN QUEBEC

B.C. McDonald

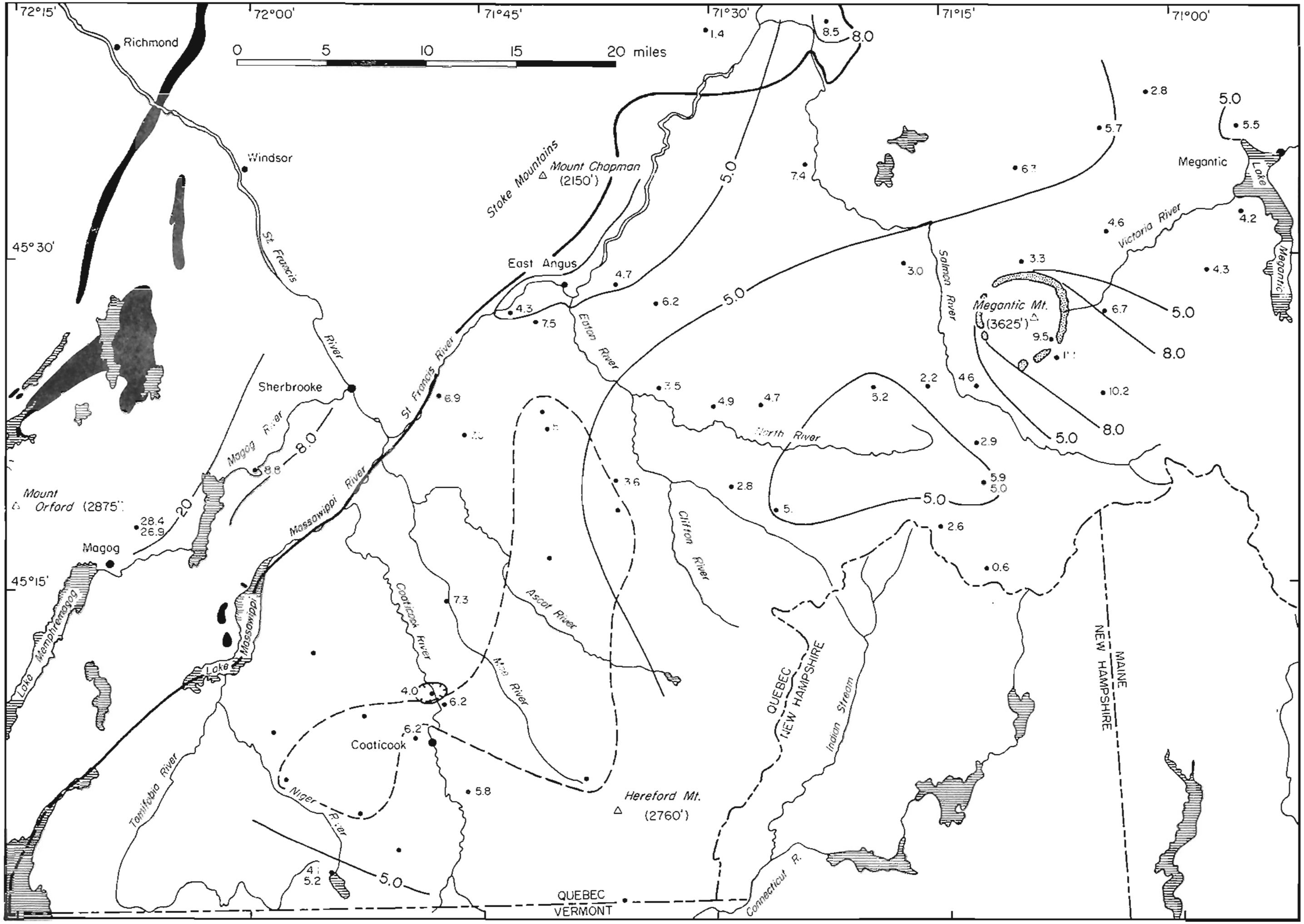
Placer gold has stimulated interest in the Appalachian region of Quebec since 1823 when alluvial gold was discovered in Beauce County. Regional studies of gold distribution (Chalmers, 1898; McGerrigle, 1936) have emphasized gold occurrences in recent stream alluvium.

During the course of glacial geologic field work in the Richmond-Sherbrooke area (McDonald, 1965, 1966) 56 samples of surface till were collected for heavy-mineral study (Fig. 1). The samples, weighing 50 to 650 grams (approximately 500 cu. cm., or 30 cu. in.) were taken from depths of 1 to 7 feet below the ground surface in both natural and artificial exposures. The tills at this depth are leached of carbonate and are oxidized. Disaggregation of most samples was facilitated by soaking them overnight in 0.01 M solution of $NaPO_3$. After wet sieving, heavy minerals were separated from the fine sand fraction (0.125 to 0.250 mm.) with bromoform (S.G. = 2.85).

Gold and minor amounts of silver were present in nine samples (Fig. 1). Typically, the gold is present as angular and ragged, thin, highly contorted flakes. The flake surfaces are commonly finely grooved. Although gold was restricted mainly to the fine sand fraction, grains as large as 0.5 mm. diameter were noted. About 25 per cent of the grains were slightly tarnished, and the remainder were free of tarnish. The concentration of gold, where present, ranged between approximately 5 and 25 grains per gram of heavy mineral concentrate. Fine sand heavy minerals constituted between 0.1 and 2.5 per cent of the original till sample. Reliable determination of weight per cent of gold in the till would require detailed field sampling and large samples. Preliminary tests with a superpanner failed to concentrate gold from the auriferous samples.

Silver grains were present in three of the gold-bearing concentrates and were also found in lacustrine sandy silt on the Ascot and Eaton Rivers. These silt deposits antedate the last two glacial episodes and are correlated with a nonglacial interval during which through-flowing streams existed in southeastern Quebec. Like the gold, the silver grains are highly contorted and angular but are untarnished. Identification of the grains as silver is based on their dissolution in 1:1 HNO_3, the subsequent addition of a saturated $BaCl_2$ solution giving a milky white precipitate, presumably AgCl.

The segments of the Moe and Ascot Rivers where McGerrigle (1936) reported gold in recent alluvium are those segments along which the till is auriferous (Fig. 1). McGerrigle did not find gold in recent alluvium of either the Coaticook or Massawippi Rivers. It seems likely that gold in recent alluvium is being washed from the till through which the streams flow. Angular gold nuggets, although suggesting little stream transport, need not indicate proximity to a bedrock source as inferred by several workers in the past. The nuggets may have been transported several miles in the glacier with little or no rounding. In contrast with the above relationship between gold in till and in overlying alluvium, at the well-known placers of Mining


72°15'
72°00'
71°45'
71°30'
71°15'
71°00'
45°30'
45°15'
0 5 10 15 20 miles
Richmond
Windsor
St Francis River
Sherbrooke
Magog River
Mount Orford (2875')
Magog
Lake Memphremagog
Lake Massawippi
Massawippi River
St Francis River
Stoke Mountains
Mount Chapman (2150')
East Angus
Eaton River
North River
Clifton River
Ascot River
Moe River
Coaticook River
Coaticook
Niger River
Tomifobia River
Hereford Mt. (2760')
Salmon River
Megantic Mt. (3625')
Victoria River
Megantic
Lake Megantic
Indian Stream
Connecticut R.
QUEBEC
NEW HAMPSHIRE
MAINE
NEW HAMPSHIRE
QUEBEC
VERMONT
5.0
8.0
20
1.4
8.5
2.8
5.5
5.7
6.7
7.4
4.6
4.2
4.7
4.3
3.3
3.0
6.2
7.5
6.7
9.5
3.5
4.9
5.2
2.2
10.2
6.9
2.9
5.9
3.6
2.8
2.6
0.6
8.8
28.4
26.9
7.3
4.0
5.8
5.2

Brook (10 miles south-southeast of Mount Megantic), where gold occurs in the alluvium, no gold has been found in the surface till.

The ultimate source of the gold is unknown, although very small amounts are almost ubiquitous in the pyritic bedrock. Pyrite cubes, derived from local bedrock, were collected from till along Ascot River, 3 miles upstream from its confluence with Moe River. Assays showed 0.0034 and 0.0037 oz. gold a ton, and 0.015 and 0.025 oz. silver a ton. After dissolution of duplicates of each of these samples in concentrated HNO_3, a small, black, fine-grained residue remained in which no gold was visible under a microscope. (Assays were conducted by the Mineral Sciences Division of the Mines Branch, Department of Mines and Technical Surveys, Ottawa; test report AC-65-86).

Magnetic minerals (principally magnetite) are derived from rocks of the Green Mountain anticlinorium, especially the ultrabasic rocks (peridotite, serpentinite, pyroxenite (Fig. 1)), and from the nordmarkite surrounding Mount Megantic (Fig. 1). Southeastward decrease in concentration of the magnetite in the till supports abundant evidence from till fabrics, striations, and other indicators that the last glacier in the area flowed from northwest to southeast. Late-glacial lobation around the Stoke Mountains probably produced the low values near East Angus. Relatively high magnetite concentrations in till from areas near Mount Megantic and the apparent shadow trending southeastward from the mountain are further support of southeastward glacial transport during the last glacial episode. There is considerable evidence that ice flowed from east-northeast during part of the penultimate glacial episode.

Figure 1. Principal bedrock sources of magnetic minerals and distribution of magnetic fraction and gold in heavy minerals of fine sand fraction in surface till.

- Peridotite, serpentinite, pyroxenite outcrop
- Nordmarkite outcrop
- Contact between Green Mountain Anticlinorium (to northwest) and Connecticut Valley-Gaspé Synclinorium (to southeast)
- 5.0 Isopleths showing weight per cent of magnetic fraction in heavy minerals in till
- Depression isopleth
- Boundary of area in which gold is present in till
- • 5.1 Figure refers to magnetic content; all dots (with or without number) show sites checked for gold

Although the present study shows a reliable relationship between pattern of magnetite concentration and direction of flow in the last glaciation, it has not been possible to establish any relationship between concentration of magnetite and presence of gold in tills. The gold distribution may have other heavy mineral associations as yet unknown, or may be dependent upon other factors such as reworking of older placers by the last glaciation. The discovery of the origin of the gold will depend upon more intensive studies than those undertaken to date and probably will require an analysis of the complete heavy mineral suite.

Chalmers, Robert
1898: Report on the surface geology and auriferous deposits of southeastern Quebec; Geol. Surv. Can., Ann. Rept. for 1897, vol. X, part J, 149 pp.

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1936: Gold placer deposits of the Eastern Townships; Que. Bureau Mines, Ann. Rept. for 1935, part E, 65 pp.

25. PALYNOLOGICAL STUDIES

J. Terasmae

A drilling project at Niagara Falls, Ontario, was carried out to investigate the history of the buried St. Davids gorge, a former Niagara River valley, and the stratigraphy and chronology of the surficial deposits filling this valley.

Palynological studies of two sediment cores from western Lake Erie were completed. The obtained pollen record, supported by radiocarbon dates, extends back to late-glacial time and provides a means for correlation of sediment sequences within the Lake Erie basin, and with pollen diagrams from the surrounding region.

A preliminary palynological study of 18 bottom sediment samples from Georgian Bay, Lake Huron, indicated the presence of sufficient pollen in these deposits to permit further studies to be made. A comparison of the pollen assemblages obtained with the vegetation of the surrounding region was made and it will be helpful in interpretation of the pollen record from sediment cores to be taken during future studies in Georgian Bay.

Complete cores of post-glacial and glacial deposits in three lakes north of Belleville, Ontario, were obtained in February and March by using a drill rig on the lake ice. Palynological and sedimentological studies, coupled with radiocarbon dating, will be made of these cores and related to the history of the Lake Ontario basin.

26. A REPORT ON CIRCULAR FEATURES IN ORGANIC TERRAIN

Lily Usik

Certain circular terrain features discernible on aerial photographs were brought to the attention of the writer by Dr. A. MacLaren, while she was working with the Geological Survey of Canada in the Moose River District of Ontario in the summer of 1965.

Examination of other aerial photographs revealed that the features also occurred elsewhere in the area as well as in other areas of northern Ontario. Stereoscopic examination indicated that the rings were features of organic terrain and that form and tone differences in vegetal cover gave rise to the ringed appearance.

The predominant trees of the dark areas are black spruce (Picea mariana (Du Roi) K. Koch) whereas those of the light zones are tamarack (Larix laricina (Mill.) B.S.P.). These observations relate to the writer's experience and considerations developed elsewhere (Radforth and Usik, 1964; Usik, in press). The rings are located within the Precambrian Shield in a region of basic and ultrabasic Archean rocks (Stockwell, 1957) where an aeromagnetic survey has revealed numerous and extensive anomalies.

Recently biogeochemical methods of investigating plant and soil relationships have been introduced and use "... a group of natural phenomena; ... increased content of metals in the ash of land plants above ore deposits; biogenic accumulation of metals in the humus layer of soil and changes in the ratios of these metals; and the restriction of biocoenoses to the zones of mineralization and the variability of vegetation (endemic forms) under the influence of the elevated contents of ore elements in the environment" (Malyuga, 1964).

When these observations and factors are considered with the high ion mobility conferred by humic and fulvic acids found in abundance in peat, it would seem logical to suggest that the rings may provide visual evidence of the existence of localized ionic diffusion phenomena. It is reasonable speculation that these phenomena might be manifestations of what Malyuga has termed 'dispersion halos' (Malyuga, 1964).

Secondarily it is proposed that investigation also be made of the possibility of biogenesis of the rings.

In the course of summer survey the writer had noted circular islands, entirely constituted of vegetation occurring in ponds within organic terrain. They varied from 5 to 200 feet in diameter and supported a black spruce-ericoid-moss community.

The circular form of the islands possibly derives from the mode of growth of plants of certain species which characteristically appear at the island edges and colonize peripherally.

There is evidence to support the view that eventually islands and pond margins may merge in the occurrence of distinct patches of vegetation (islands) each outlined by a conspicuous rim of plants within areas with a relative excess of free water suggestively reminiscent of the pond in which the islands developed.

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1964: Biogeochemical methods of prospecting. Authorized translation from Russian; Consultants Bureau, New York, p. 5.

Radforth, N.W., and Usik, L.
1964: Airphoto interpretation applied to a study of tree growth on bogs. Proc. 9th Muskeg Res. Conf., Tech. Mem. 81, Ottawa, 1964.

Stockwell, C.H. (ed.)
1957: Geology and economic minerals of Canada; Geol. Surv. Can., Econ. Geol. Ser. No. 1, 1957.

Usik, L.
(in press): Percentage of latewood and rate of growth of black spruce of organic and mineral soil sites; Proc. 11th Muskeg Res. Conf.; (in press) Ottawa, 1965.

STATISTICAL ANALYSIS

27. ANALYSIS OF MULTIVARIATE SERIES BY MARKOV SCHEMES

F.P. Agterberg

Multivariate observations in a series may be related to each other by a transition matrix. In this way, systematic variations of the multivariate system with distance or time can be described. From the transition matrix, a trend factor may be extracted which denotes the linear combination of the variates which shows 'most' trend.

The method has been applied to a set of 77 samples from Home Swan Hills 4-28-67-10, an oil well which penetrates the limestones of the Swan Hills reef of west-central Alberta (Fig. 1). These samples have been collected and chemically analyzed by E.M. Cameron.

The first trend factor of Figure 1 has the following equation:
$t'_1x = 1.42Si - .49Al - .49Ti + .11Fe - .00Mg - .24Mn + .42Sr + .00Ba.$
It represents the linear combination of the eight elements which shows most trend. A second trend factor t'_2x can be computed when the effect of t'_1x is eliminated. The following table shows the computed coefficients by which the individual elements describe the variation patterns of Figure 1.

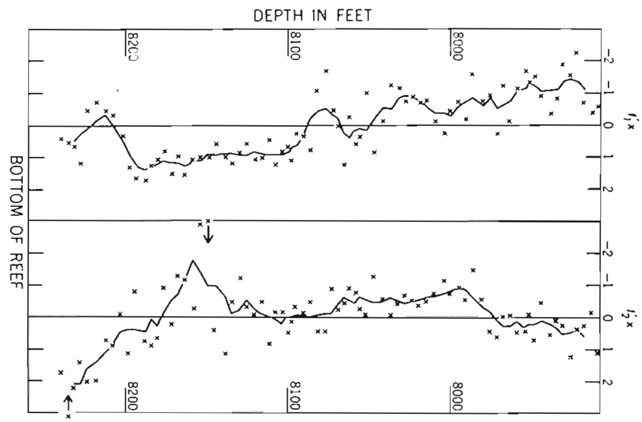

Figure 1. Home Swan Hills 4-28-67-10. First two trend factors; both the individual t'_1x -values and a five-point moving average line are shown.

	Si	Al	Ti	Fe	Mg	Mn	Sr	Ba
t'_1x	.69	.46	.42	.16	.02	-.22	.20	.33
t'_2x	-.05	-.15	.07	.51	.75	.42	.18	-.47

These results indicate that, to a first approximation, the first trend factor represents the variation of the group Si, Al, and Ti, whereas the variation pattern of the group Fe, Mg, and Mn is described by the second trend factor.

28. COMPUTER PROGRAM FOR PROCESSING SUBSURFACE STRATIGRAPHIC DATA

C.F. Burk, Jr.

A computer program is being developed to assist individual subsurface stratigraphers in processing and analyzing some of their quantitative stratigraphic data. The main functions include: a) calculating subsea elevations, b) calculating isopachous values, c) geographical sorting of control points, d) machine plotting of data, e) trend-surface analysis, and f) printing of comprehensive data tables for appendices to published reports.

Input to the program consists of three cards, a "location" card (including latitude-longitude, legal survey location), "basic well history" card (including well name, elevation, total depth, date completed and schedule of wells reference), and a "tops" card (including log tops and qualifying remarks).

Output comprises two cards, a "subsea tops" card and an "isopach" card. These are further processed for functions d), e), and f). All five cards, when interpreted, can be used by the stratigrapher in his manual files.

The program is being tested by utilizing data on the Dunvegan Formation of the west-central Alberta region, taken from 731 wells and 10 outcrops. Up to six "tops" are picked for each control point, from which up to six "subsea tops" and up to seven isopachous values per control point are calculated.

STRATIGRAPHY, PALAEONTOLOGY, COAL RESEARCH

29. STUDIES ON CARBONIFEROUS PALYNOLOGY

M.S. Barss

The miospore studies of the various Carboniferous formations in the Atlantic Provinces have been continued. As this work progresses it is becoming more and more evident that excellent zoning of these formations can be achieved by means of fossil spores.

The typical spore assemblages present in the Carboniferous and Lower Permian successions of both eastern and northwestern Canada will be illustrated in a forthcoming contribution to the Geological Survey of Canada series, "Illustrations of Canadian Fossils". In this publication, which is approaching completion, the microflora of fifteen distinct subdivisions will be illustrated in about forty plates with approximately 850 photomicrographs.

A study of several samples from a section on Tatonduck River, Yukon, revealed the great value of fossil spores in determining the age and the origin of a redeposited sedimentary sequence. Due to the small size of plant spores they can withstand transportation in fossilized form without any great deterioration, which is normally not the case with megafossils. The samples examined contain not only Lower Permian spores, signifying a corresponding age, but also perfectly preserved Viséan spores, indicating that these sediments were originally formed during Upper Mississippian time, and redeposited during the Lower Permian. A joint paper with E.W. Bamber is being prepared on this interesting material.

30. PETROGRAPHIC EXAMINATION OF COKING COALS FROM MICHEL, BRITISH COLUMBIA

A.R. Cameron and S.K. Babu

A series of samples representing the upper 46 feet of a 56 foot thick low volatile seam in the Michel area were collected during the field season of 1965. This series, along with the two column samples of this seam previously studied, constitute the material upon which a report on the petrography of this seam is to be prepared. The new samples represent the lateral extension of 17 of the 22 petrographic zones set up as a result of the data on the two original columns.

Reflectance and maceral data were determined on each of the new samples and these data were used to calculate coke stabilities for each zone. In summary the data suggest that a 10 to 12 foot thick section in the upper third of the seam has the most favourable coking characteristics. Two thinner sections in the lower half of the seam also have favourable petrographic characteristics for coking. The data from the three sets of samples also suggest that in general the petrographic zones can be traced over a distance of two miles.

Fluidity and swelling characteristics of each zone as well as chemical analysis have been determined by the Mines Branch. Determination of the microlithotype composition of each zone remains to be completed and an attempt will be made to relate the data from this type of analysis to information from the chemical and physical tests. Dr. Babu, who was associated with this project, has since returned to India.

31. PALAEOECOLOGICAL AND ENVIRONMENTAL STUDIES OF THE MINTO COALFIELD, N.B.

P.A. Hacquebard

This study was undertaken to interpret the nature and extent of the original coal swamp from coal petrological, palynological and sedimentological data. The purpose is to outline blocks of good quality mineable coal in the areas presently under exploitation and to evaluate the possibilities of finding additional reserves on the Minto seam.

Another objective, in the realm of fundamental research, is to examine the relationship between the petrographic composition of the coal and the geological and environmental conditions that controlled the specific type of basin in which the Minto seam was laid down.

From the information acquired to date it is apparent that the present boundary of the Minto coalfield coincides with the original margin of the coal swamp, except in the southwest corner where the true boundary has not yet been established. This may be regarded as a unique feature, because in all other coalfields of the Maritime Provinces the present boundary is due to erosion or to structural dislocations.

The petrographic composition of the Minto coal seam is surprisingly variable. In a maximum seam thickness of only 3 feet, there are no less than eleven successive intervals of different petrographic composition. This points to frequent changes in the ecological conditions of the swamp, due to pronounced changes in the level of the groundwater. The effect this had on the type of vegetation has yet to be determined from the palynological examinations.

As regards the type of basin and its origin, more data on the clastic sediments are required before it can be adequately interpreted.

32. THE VALUE OF FOSSIL SPORES IN EVALUATING THE REMAINING RESERVES OF THE PICTOU COALFIELD, N.S.

P.A. Hacquebard and M.S. Barss

Continuous mining has been carried out in the Pictou coalfield since 1818, and the more readily accessible coal reserves are nearing depletion. In view of this and the fact that there exists a continuing and increasing demand for coal in the area, the Nova Scotia Department of Mines requested a geological outline on the remaining coal reserves of this field.

In the Pictou field there are three separate coal mining districts, of which the most easterly one is stratigraphically the youngest. The relationship between the other two districts has been a matter of much conjecture. Either the coals of both districts are equivalent and brought to their present position by thrust-faulting, or they are stratigraphically separated, with the one underlying the other at depth.

In an attempt to solve this important correlation problem, detailed spore studies were carried out on seven coal seams of the two districts involved. The result shows that not only the spore histograms of the seams are different, but also that they belong to two separate stratigraphic zones. Those of the Westville district can be correlated with the Lonchopteris zone of the Morien Series of the Sydney coalfield. The Stellarton or Albion coals on the other hand, contain the spore assemblage that is typical of the overlying Linopteris obliqua zone of that series.

The authors are therefore of the opinion that there is good evidence to support the view that there may exist a substantial reserve of Westville coal underneath the Stellarton district, at a depth of between 2,000 and 3,500 feet. It is an engineering problem to determine the feasibility of extracting coal at this depth and of finding access to the reserve area, which lies downdip from old workings.

33. STRUCTURAL PROBLEMS IN RELATION TO COAL MINING AT SPRINGHILL, N.S.

P.A. Hacquebard and J.R. Donaldson

In view of the increasing demand for coal for industrial and power consumption, the remaining reserves in the Springhill area have obtained a new significance. The reserves lie in the disturbed northern flank of an anticline, which may have its origin as a diapiric structure. High angle normal faults, predominantly of the hinge and scissors type, occur in the area where active mining is presently in progress. One of these faults completely cuts off the underground workings and a geological understanding of the nature of the dislocations was essential to advise on continued mining operations. A detailed underground geological survey was carried out by the authors upon request of the Nova Scotia Department of Mines. The survey has resulted in the compilation of a contour plan at a scale of 1 inch equals 100 feet with contour intervals of 10 feet. The plan shows the position and displacement of several faults and their projection into the virgin coal area. This plan is by no means final, but requires revision as data become available from the advancing underground workings.

It should be noted when mining a coal seam in a disturbed area, that faults of even minor displacement can seriously curtail operations. Geologic mapping of the structure with very close control is therefore required.

34. STUDIES OF THE MOUNT HEAD FORMATION (MISSISSIPPIAN), ALBERTA ROCKY MOUNTAINS AND FOOTHILLS

R.W. Macqueen

As a part of continuing studies of the Mississippian of the Rocky Mountains and Foothills of Alberta, the Mount Head Formation (Rundle Group) has been studied in detail between Blairmore and the North Saskatchewan River.

Subdivision of the formation into Wileman, Baril, Salter, Loomis, Marston, and Carnarvon Members (ascending order) as established by Douglas in the Mount Head map-area (see Douglas, 1958) is easily accomplished in the southern Foothills and first range of the Rocky Mountains between Blairmore and the Lake Minnewanka area. Important facies changes occur westward; these are summarized in a generalized northwest-southeast stratigraphic cross-section (Fig. 1). Of particular interest is the westward disappearance of the lower members of the type Mount Head Formation through facies change to Livingstone Formation lithologies, and the thickening and facies change of most of the type Marston Carnarvon interval in ranges west of the type sections (i.e. Misty, Opal, Kananaskis, Rundle, and Fairholme Ranges). A new name will be proposed for this interval. North of the Lake Minnewanka area the individual members lose their identity as the formation changes facies to predominantly pale greyish-orange weathering microcrystalline dolomites with minor interbedded limestones.

Limestones of the formation are subdivided into skeletal and non-skeletal types. Skeletal particles include detritus of echinoderms, bryozoans, brachiopods, molluscs, and calcareous algae, and whole foraminifera, calcispheres, and echinoid spines. Non-skeletal particles include ooids, pellets, intraclasts, and compound grains. Some calcarenites have lime-mud (micrite) matrix, whereas others are cemented by sparry calcite. Quartz of silt and clay size, illitic clays, pyrite, and kerogen (insoluble organic matter) also occur as matrix constituents. Skeletal and oolitic limestones dominate the Baril and Loomis Members; pelleted micritic limestones dominate the Carnarvon Member.

Two main types of dolomite are recognized. The most important characteristics of the first type are: 1) association with evaporite minerals, or evidence of such association in the form of solution breccias or pseudomorphs after earlier evaporites, 2) local association with crinkly, algal-mat type lamination, and with oncolites or "algal biscuits", 3) light colour, especially pale yellowish-orange or greyish-orange, indicating low organic content, 4) absence or rarity of invertebrate fossils, considered to be a primary feature, 5) moderately uniform crystal size, with average range from under .005 mm to about .1 mm (.030-.050 mm most common), 6) association with strand-line features such as flat-pebble or edgewise conglomerates, mud-cracks, and rain(?) prints, 7) association with micritic limestones, including local vertical (and probably lateral) gradation to micritic limestones, 8) predominance of quartz silt and light-coloured illitic clays in insoluble residues, 9) Ca:Mg ratios close to 1:1 (by X-ray analysis), 10) frequent occurrence as units of well-developed lithological cycles. This type of dolomite is considered to be a product of penecontemporaneous dolomitization processes analogous to those operating at present within the

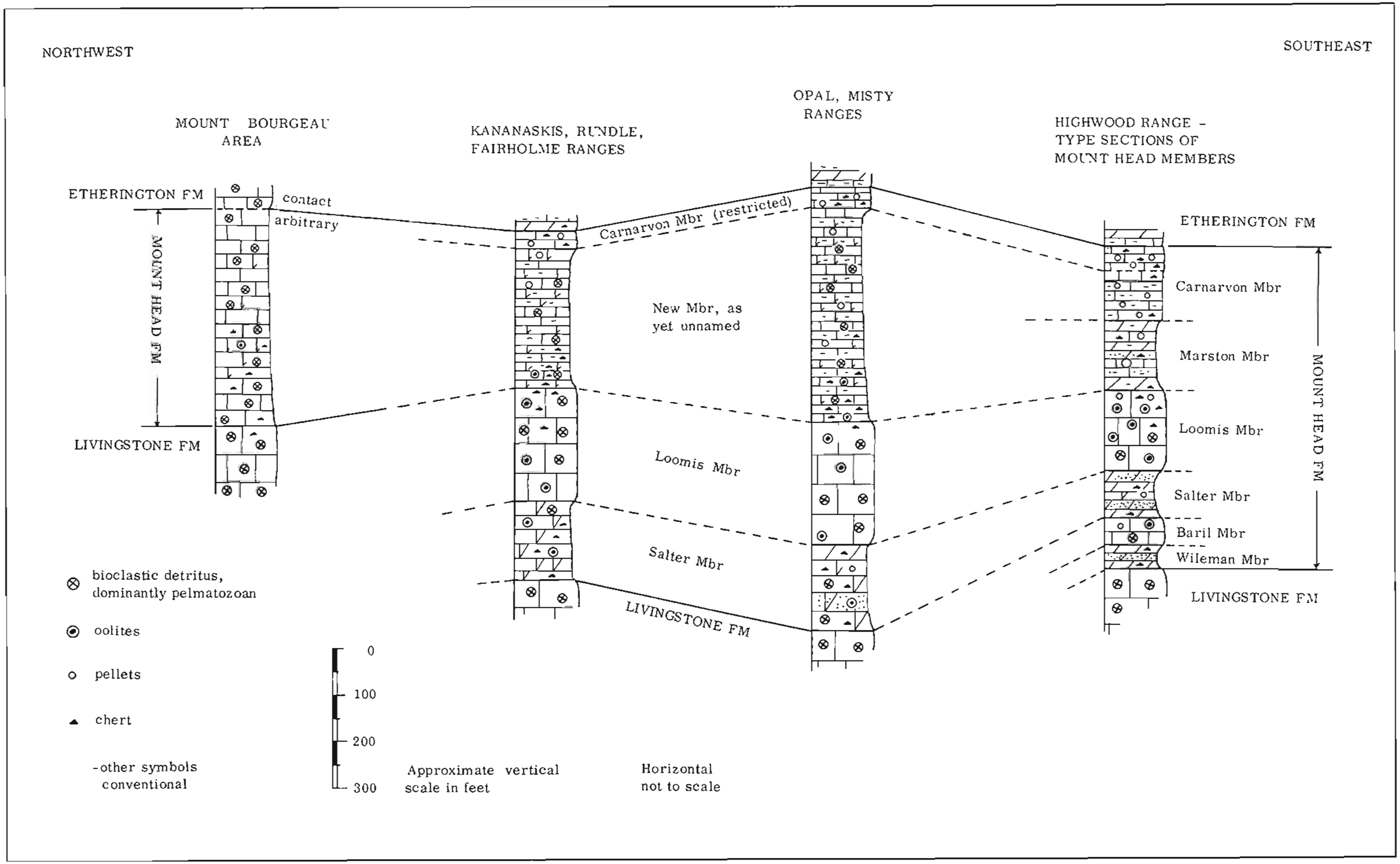

FIGURE 1. GENERALIZED NORTHWEST-SOUTHEAST STRATIGRAPHIC DIAGRAM OF MOUNT HEAD FORMATION, SOUTHERN ROCKY MOUNTAINS, ALBERTA.

supratidal carbonate-flat environment in the Persian Gulf, Bahamas, and island of Bonaire. This variety of dolomite is most abundant in the Wileman, Salter, and Marston Members.

The most important characteristics of the second type of dolomite are: 1) it occurs as a replacement of limestone, with all gradations present from scattered euhedral rhombs in limestones to porous, sucrosic dolomite with relict skeletal grains or vugs representing leached skeletal grains (lateral and vertical gradations to more or less dolomitized limestones occur), 2) crystal size is variable, ranging on the average from .050 to .5 mm, 3) insoluble residue content is consistent in amount and type with associated limestones, 4) silicified or dolomite-replaced invertebrate fossils are commonly abundant, 5) this type of dolomite tends to be deficient in Mg, 6) such sedimentary features as mud-cracks, fine lamination, edgewise conglomerates, etc. are absent. Dolomite with these characteristics is interpreted to have formed after burial (subsequent or secondary dolomite of many authors).

Within the Mount Head Formation some bedded dolomites are known which are not easily assigned to either of the foregoing groups. These constitute a third relatively minor group which may have originated by diagenetic modification (e.g. recrystallization) of previously formed dolomites, or by erosion and redeposition of lithified dolomites.

Shales containing quartz, illite, chlorite, and varying amounts of calcite or dolomite are locally important, especially in more westerly sections.

Three types of sedimentary cycles are present. Megacycles are alternations of distinct lithological types over several intervals up to several hundred feet in thickness. Mount Head Formation member-pairs Wileman-Baril, Salter-Loomis, and Marston-Carnarvon form three megacycles. Short cycles are alternations of four (most common) to as many as seven distinct lithological types over eight- to fourteen-foot intervals. Excellent examples occur in the Marston and Carnarvon Members. Microcycles are alternations of lithologic types of several millimetres to several centimetres in thickness. Examples occur in the western equivalent of the Marston-Carnarvon interval. All cycles are related to changes in water circulation and depth relative to wave base.

Many exposures of the Mount Head Formation, especially west of the first range of the Rocky Mountains, are richly fossiliferous. About 230 collections have been studied by E.W. Bamber of the Geological Survey. Ten species of rugose corals (including four lithostrotionid species) and one species of brachiopod appear to have short vertical ranges and widespread distribution. These support correlations outlined above, which were independently established on stratigraphic and lithological grounds.

The Mount Head Formation is of Meramec age; the Osage-Meramec boundary occurs within the underlying Livingstone Formation.

Study of the carbonate lithofacies and their lateral and vertical distribution permits delineation of lithofacies belts that are roughly parallel to present structural strike, and close comparison with modern carbonate sediment environments. The succession and position of the lithofacies belts records fluctuations of the strand-line over a broad epi-continental shelf throughout deposition of the formation.

A generalized facies-belt sequence from east to west passes from a) microcrystalline penecontemporaneous dolomite (supra-tidal carbonate flats) through b) pelleted micritic limestones and fine-grained skeletal sands (tidal flats and shallow lagoons) to c) oolitic and skeletal calcarenites (open sea sub-tidal area of complex bars, shoals, and deltas), d) pelmatozoan and bryozoan calcarenites, in part dolomite-replaced (pelmatozoan and bryozoan banks), and e) micritic limestones with fine- and medium-grained skeletal detritus and terrigenous clastics (offshore area).

This pattern is perhaps best developed within the Salter Member and its time-equivalent in the Livingstone Formation in westernmost localities, but it seems to apply in general to any given time (as delineated by fossils) in the sequence.

During sedimentation of the upper part of the Mount Head Formation there appears to have been a westerly barrier (probably bars and shoals; present position in the Bourgeau thrust block) which defined broad, shallow, stagnant lagoons to the east in which the pyrite- and kerogen-bearing skeletal limestones of the second, third, and fourth ranges accumulated.

Douglas, R.J.W.
1958: Mount Head map-area, Alberta; Geol. Surv. Can., Mem. 291, 241 pp.

35. MISSISSIPPIAN SUBSURFACE GEOLOGY IN THE PEMBINA AREA, ALBERTA

H.L. Martin

Mississippian rocks in the Pembina map-area are more than 1,000 feet thick in the west but disappear eastward mainly because of erosion in Late Palaeozoic, Triassic, Jurassic, and Cretaceous times. Thus progressively older Mississippian formations underlie the sub-Mesozoic unconformity from west to east. Hydrocarbons are trapped in porous carbonate rocks at the erosional edges of the producing formations in the Brazeau River, Minnehik-Buck Lake, and Wilson Creek gas fields.

Mississippian rocks disconformably overlie Late Devonian limestones; in ascending order they comprise the Exshaw, Banff, Pekisko, Shunda, and Turner Valley Formations. The black radioactive Exshaw shale is overlain by the Banff which consists of three units: lower silty and argillaceous limestone, medial bioclastic limestone, and upper silty unit. Resistant, light-coloured bioclastic limestones and dolomites of the Pekisko form a low palaeotopographic ridge that separates the relatively recessive Banff and Shunda Formations. Dolomitized Pekisko crinoidal limestones with vuggy and intercrystalline porosity form the reservoir rock of the Minnehik-Buck Lake Field. Two facies are recognized within the Shunda Formation: an eastern breccia facies, and a western anhydritic carbonate facies. The uppermost Mississippian beds, the porous dolomites of the Elkton Member of the Turner Valley Formation, form the reservoir rock of the Brazeau River Field.

36. NOTES ON PENNSYLVANIAN AMMONOIDS FROM NORTHERN ELLESMERE ISLAND

W.W. Nassichuk

Pennsylvanian ammonoids from northern Ellesmere Island in the Canadian Arctic Archipelago have been systematically described and this study is being prepared for publication. Twenty-one species, twelve of which are new are assigned to seventeen genera, three of which are new. All are from an unnamed formation in the vicinity of Hare Fiord and are associated with local biohermal complexes. The Hare Fiord goniatites show remarkable affinities with forms some three thousand miles to the south in the Mid-continent Region of the United States. Particularly, the occurrence of Winslowoceras can be utilized for a precise correlation of these strata with the Winslow Formation of Arkansas. The general aspect of the Hare Fiord ammonoid fauna indicates an Atokan age as defined in North America.

The morphologically unique genus, Christioceras (Nassichuk and Furnish, 1965) was recovered from one of the Hare Fiord bioherms. On the basis of its mode of ontogenetic development, Christioceras is considered to be an offshoot from a rapidly evolving schistoceratid stock.

Another new genus, found directly associated with Christioceras is being studied and prepared for individual publication. This genus, assigned to the Homoceratidae, exhibits a morphologic character previously unrecorded for ammonoids. Primary deposits, helical in gross aspect, formed on the surface of the penultimate whorl in the dorsolateral portion of the body chamber and closed the umbilicus during adolescence. Another important feature of this new homoceratid is the excellence of preservation that permits comment on an apparent homologous relationship between particular shell layers of fossil and living cephalopods.

Nassichuk, W.W., and Furnish, W.M.
1965: Christioceras, A new Pennsylvanian Ammonoid from the Canadian Arctic; J. Pal., vol. 39, No. 4, pp. 724-728.

37. DEVONIAN STRATIGRAPHY OF NORTHEAST BRITISH COLUMBIA

G.C. Taylor and W.S. MacKenzie

This report is based on field work by the senior author during the summers of 1960-61 and 1963-65, and by MacKenzie during the summer of 1965. Some 27 Devonian sections, supplemented by numerous outcrop observations were studied within the area of Operation Liard (Taylor, 1966). Five formations of Devonian age were recognized. New names, with the exception of Muncho-McConnell (restricted) and Besa River, are to be proposed for these formations.

Strata of Early Devonian age are subdivided into two formations. The earlier Muncho-McConnell Formation, a sequence of fine crystalline dolomite and argillaceous dolomite disconformably overlies Silurian rocks. The Muncho-McConnell is recognized throughout the area. The formation ranges in thickness from 165 feet in the east to 1,160 feet in the northwest. Fossil recovery from the Muncho-McConnell has been sparse, but fish remains collected at Long Mountain and north of Keily Creek have been dated as Early Devonian by R. Thorsteinsson. A new formation, comprising 90-401 feet of yellow-brown weathering sandstone, dolomitic sandstone, and argillaceous dolomite, conformably overlies the Muncho-McConnell Formation. It approximates the lower member of Laudon and Chronic's (1949, p. 192) Ramparts Formation of the area, and is a distinctive stratigraphic marker within the Devonian succession. This formation has been recognized and described from near the Sikanni Chief River, northwards to the British Columbia–Yukon boundary where it plunges under younger Devonian covering formations. Although no fossils have been recovered from these strata, the stratigraphic relationships indicate an Early Devonian age.

Middle Devonian strata unconformably overlie the Early Devonian formations. The middle Devonian succession is subdivided into three formations, the lower two of which are composed of carbonate rocks. The earliest formation is a sequence of dolomite, dolomite breccias, argillaceous dolomite and minor limestone. The thickness of the formation ranges from 459 feet in the southeast to 1,935 feet in the northwest. Fossil control is sparse, but a collection low in the succession has been dated as Eifelian by A.W. Norris. Overlying the dolomites, locally disconformably, is a succession of argillaceous limestones. This formation ranges in thickness from 712 feet in the east to 1,200 feet in the west. The top of the formation is diachronous. Rich faunas from the top of the formation have indicated an early Middle Devonian (Givetian) age from the northern exposures, but, a late Middle Devonian age from the southern exposures. Conformably overlying the limestones is the Besa River Formation. It is composed entirely of black shale. The Besa River ranges in thickness from 1,000 feet in the west to not less than 3,000 feet in the east. Sparse faunas of Middle and Late Devonian, and in the westernmost exposures, Mississippian age, have been recovered. Both top and bottom contacts are diachronous.

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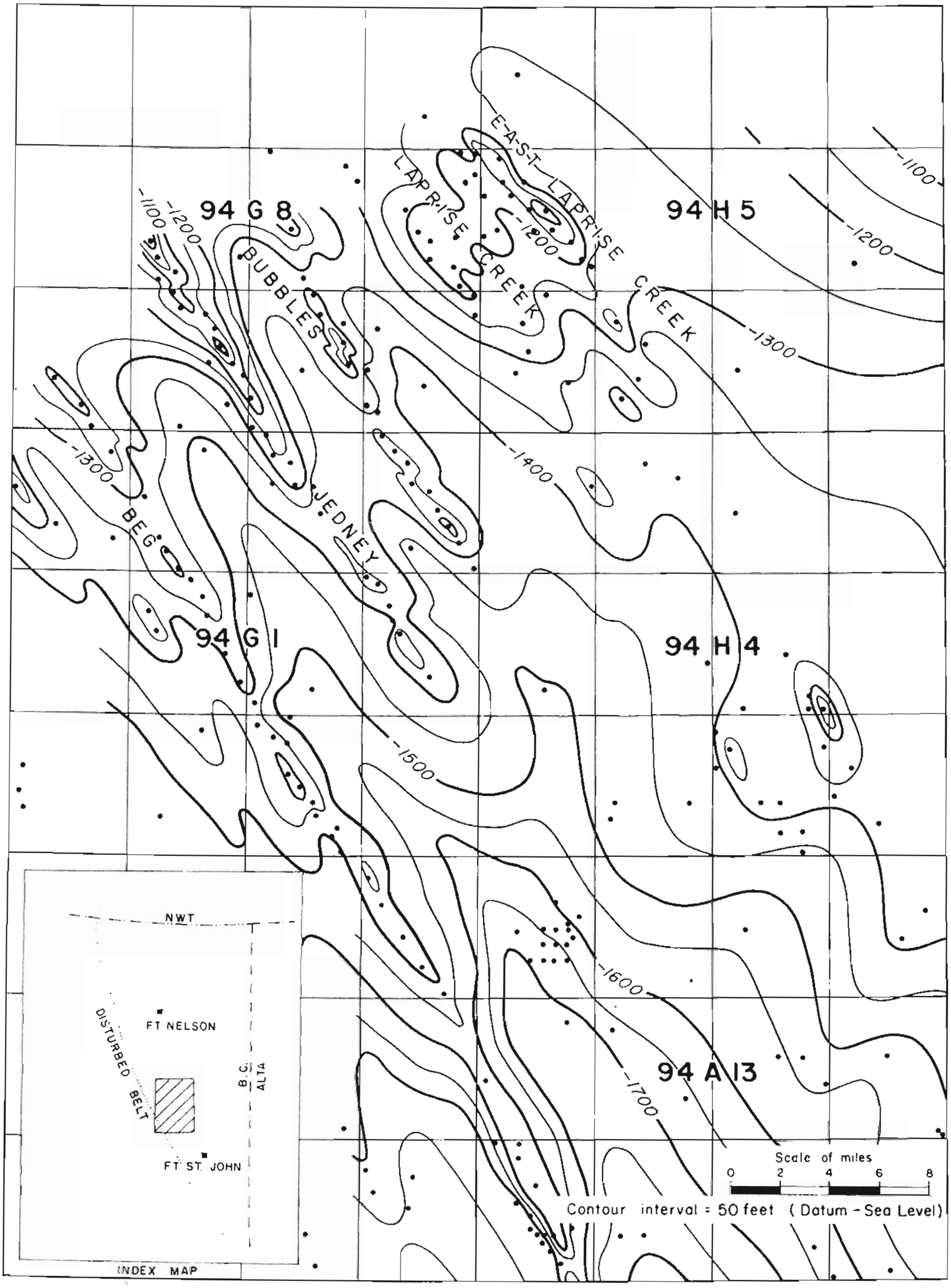

Figure 1. Structure contour map on top of the Baldonnel Formation.(Procter 38)

38. TRIASSIC BALDONNEL FORMATION IN THE JEDNEY-LAPRISE CREEK AREA, NORTHEASTERN BRITISH COLUMBIA

R.M. Procter

In conjunction with a regional subsurface stratigraphic study of the Triassic of northeastern British Columbia, which is in preparation for publication, the distribution and petrology of the Baldonnel Formation have been the subject of detailed study. This formation is the major natural gas reservoir in the Beg, Jedney, Bubbles, and Laprise Creek fields (see Fig. 1).

The Baldonnel Formation consists of light brown and brownish-grey microcrystalline to fine-crystalline dolomite which is silty and cherty in part. The lower boundary of the formation appears gradational with the underlying Charlie Lake Formation. Locally, an interfingering relationship of Baldonnel dolomites and Charlie Lake evaporites makes identification of the boundary arbitrary. For purposes of this study the boundary has been placed at the top of a thin but extensive siltstone which underlies the dolomites. Locally, minor anhydrite beds occur above the siltstone and have been included in the Baldonnel Formation. The upper boundary of the Baldonnel Formation is the erosional contact with overlying Jurassic or Cretaceous strata, except in southwesternmost wells where it is conformably overlain by a thin remnant of beds tentatively assigned to the Pardonet Formation. As shown on the isopach map (Fig. 2) the Baldonnel Formation has its greatest thickness of about 275 feet in the western part of the area and has been thinned by erosion to a zero edge near the north and east edges of the area.

Severe erosion at the end of the Triassic and Jurassic produced an irregular pattern of channels on the upper surface of the Baldonnel Formation (Fig. 2). This pattern was subsequently complicated by Laramide folding with a pronounced northwesterly trend (Fig. 1). A series of anticlines, which forms the traps for natural gas in the area, extends eastward from the Foothills to the East Laprise Creek Field. Entrapment of hydrocarbons, although primarily controlled by structure, is limited by the distribution of porous Baldonnel dolomites.

In order to investigate the magnitude of post-Triassic channelling, and the relationship of porosity development to either structure or primary carbonate texture, an informal three-fold subdivision of the Baldonnel Formation has been made. The three members are defined largely by their gamma-ray log characteristics (see inset, Fig. 2), and each consists of dolomite. The lower member consists of very fine-crystalline dolomite, containing rare relicts of skeletal material, and includes minor anhydrite. The middle member is light brown, very fine- to fine-crystalline dolomite, and is silty and argillaceous in the upper part. The upper member consists of light to medium brown, fine- to medium-crystalline dolomite which apparently has replaced a bioclastic limestone. Brecciation is common throughout the formation. Vuggy porosity, observed in all members, results primarily from removal of skeletal material.

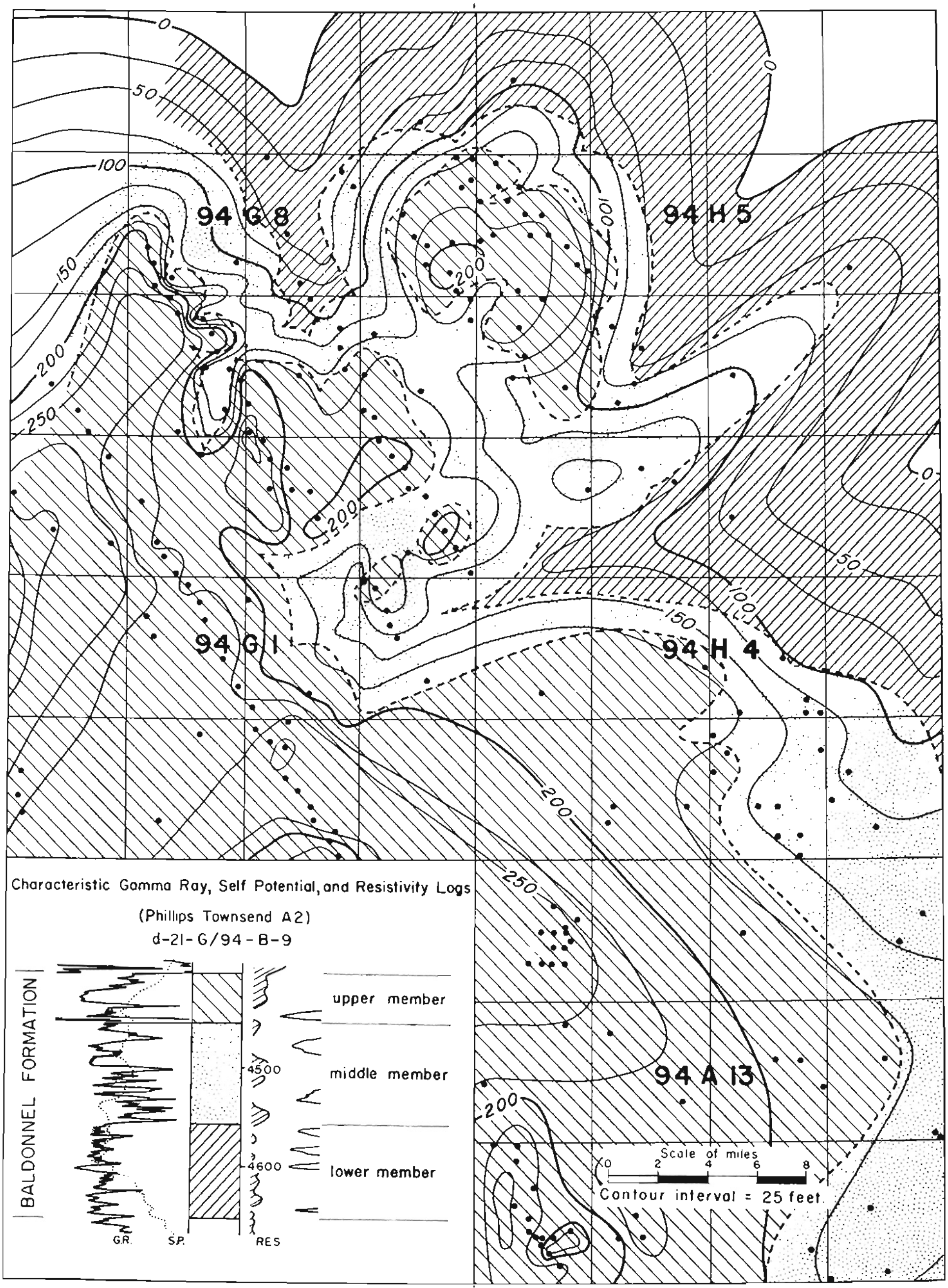

Figure 2. Isopach map of the Baldonnel Formation showing subcrop distribution of members. (Procter 38)

39. LOWER TRIASSIC "TAR SANDS" OF NORTHWESTERN MELVILLE ISLAND, ARCTIC ARCHIPELAGO

H.P. Trettin (See Paper 66-3A)

Bitumen deposits discovered in 1962 in the Bjorne Formation of Melville Island are the first reported major showing of petroleum in the Arctic Islands (Jenness, 1963; Sproule et al. 1963, 1964; Sproule and Lloyd, 1963; Trettin and Hills, 1965). This is a summary of a terminal report on a coordinated investigation, involving structural field mapping, sedimentology, chemistry, and isotope determinations (Trettin and Hills, in preparation). The analyses of the bituminous specimens were made, under the supervision of D.S. Montgomery, mainly in the laboratories of the Mines Branch.

On northwestern Melville Island, the Bjorne Formation rests unconformably on Ordovician to Pennsylvanian strata, and disconformably on Permian beds, and is overlain disconformably by Lower and Middle Jurassic formations. The early Jurassic erosion surface on the top of the Bjorne Formation probably has a relief of several hundred feet. The Bjorne Formation dips gently northeast, into the Sverdrup Basin, and its overall homoclinal structure is broken by minor faults.

The Bjorne Formation is the Lower Triassic marginal facies of the Sverdrup Basin (Tozer, 1961, 1963). On northwestern Melville Island, the isopachs of three subunits, based on 140 sections, trend generally parallel with the regional strike, and indicate that the Lower Triassic series, which in the central parts of the basin attains thicknesses up to 4,000 feet, wedges out less than two miles southeast of the outcrop belt and most "tar sands" – a typical setting for heavy petroleums. The prismatic depositional geometry is modified by minor northerly to northeasterly plunging sedimentary troughs, probably related to negative segments of a differentially sinking basement, fractured along northerly striking surfaces. These troughs were important for the localization of the petroleum.

In the area studied, the Bjorne Formation consists mainly of quartz-chert sandstones – multicycle deposits with an impoverished zircon-tourmaline heavy mineral suite – and lesser proportions of pebble to boulder conglomerate, and silty clay, composed of kaolinite and illite with minor chlorite. Red-beds occur at several levels.

Three members and several subunits have been distinguished, mainly on the basis of the proportion of interbedded clay, which appears to be independent from lateral variations in the grade of the conglomerates.

The lower member includes extensive units of silty clay, limonitic bog iron deposits, and beach sands, and probably represents a non-marine paralic environment. Concentric lithofacies, and radiating palaeocurrent determinations indicate that the middle and upper members were laid down on the flood plain of a prograding, fan-shaped delta. It is concluded from petrographic and palaeontological evidence that the delta received sediments from the Ordovician to Permian, mainly Middle and Upper Devonian formations of western Melville Island.

Although it is well known that deltas are a favourable habitat for petroleum, and although the assignment of many reservoir sands to this environment is probably correct, this is one of the few cases where the existence of an ancient delta can be demonstrated by palaeocurrent directions radiating systematically within a sector of about 157 degrees. This conclusion is based on 667 determinations of foreset dip azimuths and scoop axes made at 58 stations. Correlation between the two features used is satisfactory, but the scoop axes, having an overall standard deviation of 27 degrees are more significant than the foreset dips with their standard deviation of about 32 degrees. The average limits of confidence of the local means are plus or minus 17 degrees.

Asphaltic oil occurs in four major and two minor deposits or groups of deposits scattered over a narrow forty-mile belt. A precise estimate of reserves would require drilling; however, the order of magnitude of the deposits, and their economic significance can now be appraised. Outcrop mapping, some forty sections, and twenty-two bitumen analyses suggest that between 50 and 100 million barrels are present with only 30 million barrels or less in concentrations of 6 per cent by weight or more, which is the present lower economic limit for the processing of the Athabasca sands. Clearly, then, the present reserves would not support a mining operation of Athabasca type, but, considered as an exhumed oil field, they are encouraging for exploration.

A problem of particular interest in connection with "tar sands" is whether the high specific gravity and viscosity of the petroleum in them is original or the result of alteration. The API gravity of the bitumen in the surficial samples collected is generally less than 7°, but the high oxygen content of this material (up to 8 per cent O_2), and the fact that correlation between oxygen and specific gravity is good, and between sulphur and specific gravity poor, indicates that the surficial oil has polymerized upon exposure to the atmosphere.

Good correlation between nickel and sulphur, on the other hand, suggests that the concentration of these two elements has not been changed. Oils from Western Canada with the same sulphur concentrations (3.02 to 0.88 per cent) and nickel content (20 to 5 ppm) range in gravity from about 19° to 31° API, with a mean near 26° API, i.e. are heavy petroleums produced from conventional wells.

The sulphur and nickel content, and inferred original gravity of the oil decrease regionally from northwest to southeast, and locally from the base to the top of the deposits. The regional variation may be related to differences in the distance of migration, source material, or depth of burial, and the local vertical variations to an upward decrease in the original gas content.

The percentages of total carbon, and aliphatic carbon atoms in the surficial material are similar to those in the Athabasca bitumen.

The oil occurs mainly in highly porous sands and sandstones, which are only partly saturated, and also in conglomerates. It is concentrated: 1) invariably in the upper part of the formation beneath the disconformably overlying, rather impermeable Jurassic strata; 2) commonly near the depositional limit of the formation; 3) commonly in basement controlled sedimentary troughs. Regionally, it occurs within an inclined wedge of arenaceous strata, near its upturned edge. On the blunt end of the wedge, the fluviatile sandstones and conglomerates probably grade to paralic and marine argillaceous strata, which are the most obvious potential source, although the possibility that fluids from other shales of the Sverdrup Basin were channelled, down-dip, into the Bjorne Formation, cannot be dismissed. Migration must have taken place in Middle Jurassic or later time, probably under the influence of heavy sedimentary loading.

Derivation of the oil from clays interbedded with the reservoir beds in the present outcrop belt is precluded by the low organic content and oxidizing environment of deposition of the argillaceous strata. Evidence for a derivation from the Palaeozoic strata underlying the "tar sands" by upward migration through fractures has not been seen.

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