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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 65-2

REPORT OF ACTIVITIES: Part II

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OF CANADA

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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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CONTENTS

CONTENTS (cont.)

CONTENTS (cont.)

INTRODUCTION

This report comprises a number of short abstract-type papers presenting the results of current scientific work of the Geological Survey. Some of the papers report complete projects, others are interim progress accounts of research that will eventually be described in full in one of the Survey's publications, or in one of the scientific journals. The papers have received little or no formal editing and include, where appropriate, illustrations prepared by individual authors. Compilation by Peter Harker assisted by Leona R. Mahoney.

Field observations properly provide the basis of most of the scientific work of the Geological Survey and no clear line can, or should be drawn between laboratory and field research. No such distinction is made in the contents of this report. Reports of activities will be issued each year in parts; the first part (already issued during the current year as Paper 65-1) deals mainly with the previous summer's field work. The other part or parts will be issued later in the year and will comprise short reports on any aspect of the Survey's scientific program that can conveniently be reported in this way. These reports, together with the index of publications, provide an annual accounting of the major scientific activities of the Geological Survey.

GEOPHYSICS

1. PALAEOMAGNETIC RESULTS ON THE MILES CANYON BASALTS, SOUTHERN YUKON

R.F. Black, A. Larochelle

The Miles Canyon Basalts are known to be the youngest consolidated deposits in the Whitehorse map-area, Yukon Territory. They are believed to be of Pleistocene age on the basis of microfossil assemblages found in the unconsolidated deposits interlayered with them. No field evidence is reported to indicate that they have been folded or faulted since their extrusion (Wheeler, 1961).

A total of 78 oriented samples was collected at 4 sites distributed along a line extending 10 miles southward from the city of Whitehorse. The sites are numbered according to their position in the stratigraphic column, the rocks at site 4 being the uppermost. Data on twelve of the samples included for site 2 were reported earlier by DuBois (1959).

Two one inch cubes were cut from each sample and the natural remanent magnetization of each cube was measured with an astatic magnetometer in the laboratory of the Geological Survey. The mean direction of magnetization of the two cubes from each sample was considered as representative of that for the sample. Two samples were selected from each of the four sites for stability tests. The cubes were submitted to alternating field cleaning treatments (Larochelle and Black, 1965) with the peak amplitude of the demagnetizing field set successively at 50, 100, ... up to a maximum of 700 oersteds. The demagnetizing curves for the two samples representative of site 1 are represented in Figure 1. The curves obtained for the other sites are also characteristic of samples whose magnetization is remarkably stable and most likely of thermoremanent origin. Only one of the 8 samples treated indicated the presence of a weak component of viscous magnetization which was effectively removed during the cleaning treatment at peak field amplitude of 150 oersteds. Accordingly the cubes of the remaining samples were exposed to an alternating field of this intensity and the directions of the residual magnetization after the treatment are represented in Figure 2. The fact that the directions of magnetization at each site are well grouped, that they are notably different from that of the present earth's field at the collecting sites and that the alternating field tests indicate good magnetic stability of the samples leads to the conclusion that the directions of magnetization plotted in Figure 2 reflect the attitude of the earth's field at the time the rocks cooled from magmatic temperatures.

It is noted that the directions of magnetization at sites 1 and 3 are almost parallel whereas those at sites 2 and 4 are almost diametrically opposed to one another and have a declination quite distinct from those of the other sites. This disparity in the directions of magnetization is difficult to explain considering that the rocks from which they were obtained are supposedly of the same age and undisturbed since the period of their cooling.

TABLE I

Summary of Palaeomagnetic Data, Statistical Parameters* and Pole Positions for the Miles Canyon Basalts

Collection Site	D	I	N	R	k	α_{95}	Pole Position		$d\psi$	$d\chi$
1 60.7N, 135.0W	71.3	-57.9	22	21.85	136	2.7	25N	170E	2.9	3.9
2 60.7N, 135.0W	191.7	-83.7	27	26.69	83	3.1	73N	126W	5.7	7.3
3 60.6N, 135.0W	71.0	-61.0	19	18.64	50	4.8	28N	172E	5.6	7.3
4 60.6N, 135.0W	319.0	+75.2	10	9.93	126	4.3	71N	158E	7.2	7.9

*Fisher, 1953

No definite explanation has been found so far for this anomalous situation although three hypotheses may be advanced temporarily:

1. The ages of the rocks at the different sites may be markedly different.

2. The structure of the area may be far more complex than the thick coverage of glacial drift allows to observe; a normal fault between sites 2 and 3 for instance could explain the parallelism in the magnetization directions at sites 1 and 3 on one hand and at sites 2 and 4 on the other.

3. The rocks dealt with may have acquired their magnetization during a period of considerable earth's magnetic field instability which was terminated by a reversal.

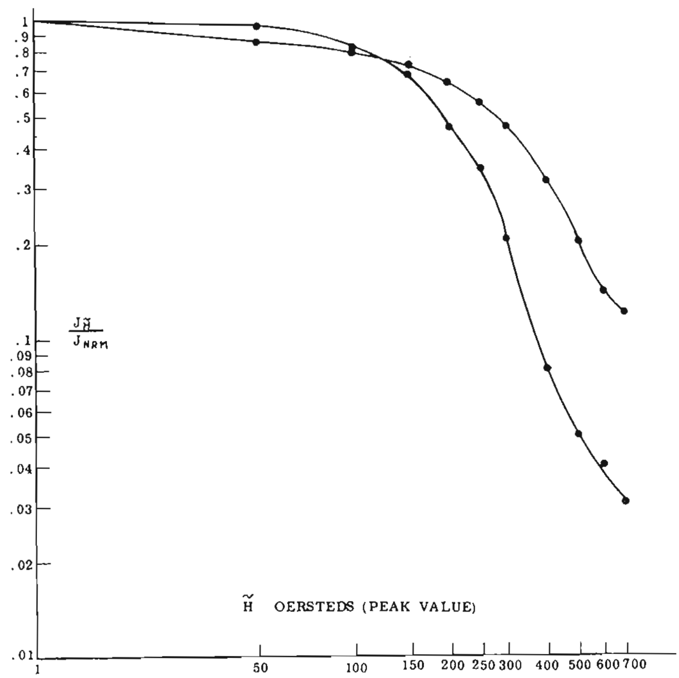

Figure 1. Demagnetization curves for two samples from site No. 1.

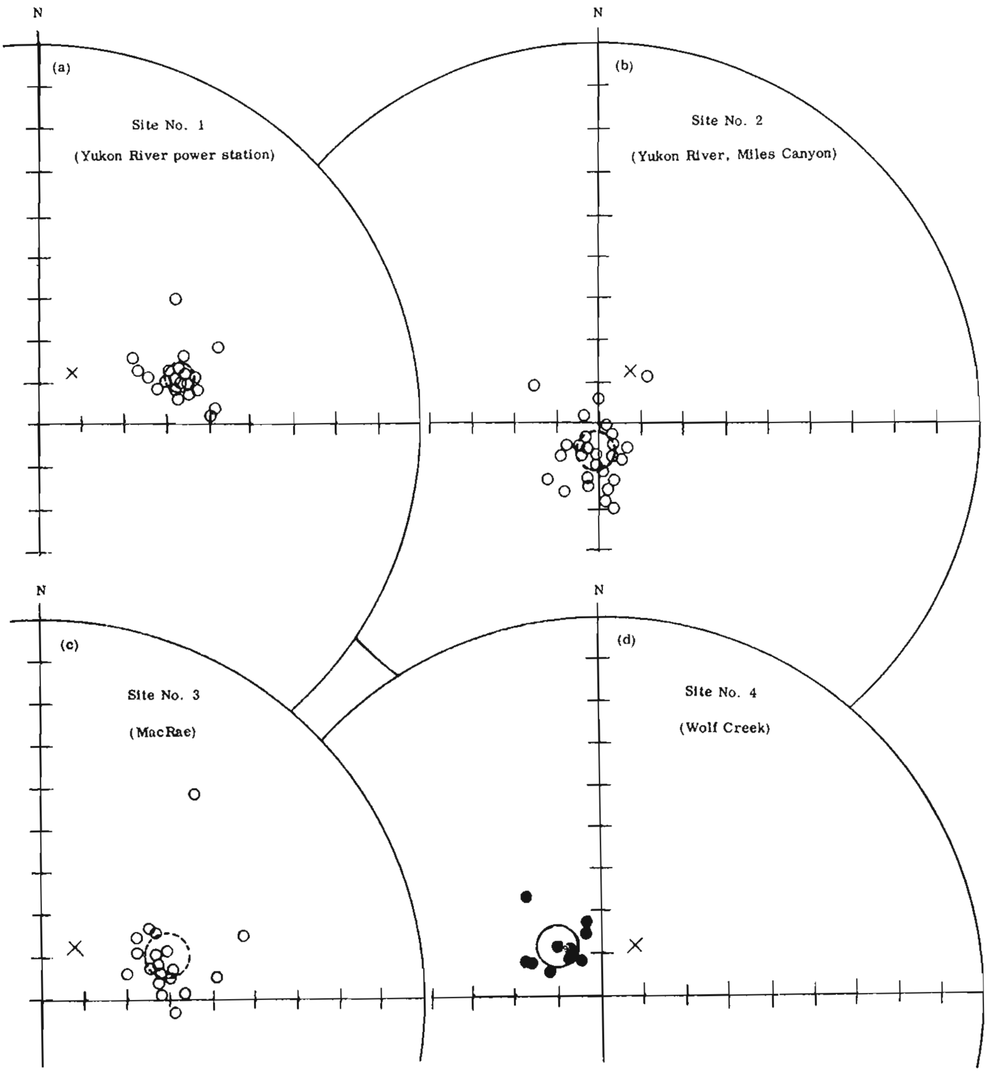

Figure 2

Equal area projections of stable magnetization directions ($J_{(\tilde{H}=150)}$) of Miles Canyon Basalts

vectors pointing upwards .... ○

vectors pointing downwards .... ●

circles of confidence ....

present local direction of the earth's field .... ×

Regardless of the plausibility of any of these hypotheses it is suggested however that the data reported here could be of some utility in correlating Pleistocene volcanic flows in the Whitehorse map-area. Radiogenic age determinations of samples from the four sites would undoubtedly help in interpreting the above data.

DuBois, P.M.
1959: Geomagnetic field in Late Tertiary time in northwestern Canada; Nature, vol. 183, pp. 16-17.

Fisher, R.A.
1953: Dispersion of a sphere; Proc. Roy. Soc. London, Ser. A, vol. 217, pp. 295-305.

Larochelle, A., and Black, R.F.
Testing of an alternating field demagnetization apparatus (in preparation).

Wheeler, J.O.
1961: Whitehorse map-area, Yukon Territory; Geol. Surv. Can., Memoir 312.

2. AUTOMATED COMPILATION OF AEROMAGNETIC DATA

M.E. Bower

An important part of the National Aeronautical Establishment's airborne magnetometer project is the development of rapid methods of compiling and analysing data. This is necessary not only because of the large amount of information being obtained, but also because it is recorded in digital form which cannot be compiled efficiently by hand. Therefore the use of high-speed electronic computers has become almost a necessity.

A rubidium vapor magnetometer is used in this project. It operates on the principle that the energy level of the electrons in a cell of rubidium gas can be made to oscillate at a frequency proportional to the magnetic field strength. The signal from the magnetometer is mixed with a known crystal frequency to produce a different frequency in the range of 5,000 to 25,000 cycles per second. The time, T, is measured for 1,000 cycles of this frequency, and recorded as a 7-digit number.

$$\text{Magnetic field (gammas)} = \frac{\text{crystal freq.} \pm 1{,}000/T}{4.66}$$

The readings are recorded on Digistore magnetic tape in 8-4-2-1 binary coded decimal format, and on printer tape as ordinary decimal numbers. Also recorded are certain codes required by the computer, and automatic and manual identification numbers.

At present a Bendix G-15 computer is used to compile the data. Connected to the computer are a typewriter, AN-1 mechanical punch tape reader, magnetic tape recorders, a Digistore tape reader, and a Calcomp PA-3 plotter. The computer's magnetic tape units use a different kind of tape than the Digistore, and record the data in a different format. The Calcomp plotter uses a continuous strip chart with a recording width of 10.24 inches; maximum plotting speed is 1.9 inches per second.

Frequently it is useful to convert the magnetic data from digital to profile form. If the Digistore tape is known to be relatively free of errors, the whole process of computing and plotting can be accomplished with one computer program. First, a constant derived from the crystal frequency is given to the computer through its typewriter. The program is then started, and several operations take place simultaneously or in rapid succession.

(1) A block of 64 readings, each a 7 digit number, is read by the Digistore and loaded into the computer memory.
(2) The readings are converted from time to gammas, and added to or subtracted from the crystal constant. The check sum is computed; this is the logical sum of all the data words in the block without regard to overflow, and serves to identify that block of data.
(3) The computed readings and check sum are stored on computer magnetic tape.
(4) The readings are plotted at a predetermined scale; the end of each block is marked.

(5) The typewriter prints the last reading of each block, and the check sum is punched on the computer's punch.

The whole cycle repeats under program control until the end of the Digistore tape.

If desired, the profiles may be replotted with corrections for drift or gradient. A punch tape is prepared which gives the amount of correction per reading and the check sums of the blocks of data between which the correction applies. This tape is read by the computer's photo-electric reader, the data are taken from the magnetic tape unit, and the corrected readings are computed and plotted.

Some experimental work has been done in simulating the conventional methods of aeromagnetic compilation. On a small test survey the only operations done manually were: plotting aircraft track, converting positions to an xy coordinate system, setting up initial control grid, and contouring. Computer programs performed the following operations.

(1) Remove drift from control lines.
(2) Calculate crossing locations of traverse and control lines, and the corrected magnetic readings at the crossings.
(3) Tie traverse lines into control lines and remove drift from traverse lines.
(4) Find 10 gamma intercept levels, highs and lows, and calculate their coordinates.
(5) Plot the above information using various symbols. The plotting was done by a Pace plotter using a punch tape produced by the computer.

This project was quite successful, but the method is not really practical unless the aircraft position can be recorded automatically in digital form.

3. A METHOD FOR CALCULATING THE MAGNETIC FIELD DUE TO A THREE DIMENSIONAL GEOLOGICAL BODY OF ASSUMED SHAPE AND MAGNETIZATION

Edwin H. Gaucher[1], P.H. Payette[2], G.D. Cameron[3]

One method of interpreting magnetic anomalies is to assume a shape and magnetization of the body causing the anomaly, calculate the field caused by the body and then compare the resultant field with the original observed field. If the "fit" is poor, changes are made in the assumption about either the shape or magnetization of the body and the field is recalculated. This process is repeated until an adequate "fit" is obtained. This method is known as the indirect method of quantitative interpretation and although the solution reached is not unique, the chances of it being so are relatively good if the geological knowledge of the area also indicates that the assumed shape is reasonable.

Hand calculations with this method are long and tedious and we attempted to eliminate them. This program may calculate the magnetic anomaly of a body of any shape, within certain limits, for any direction of the earth's field and for any direction of the total (remanent plus induced) magnetization in the body.

The general mechanism of this program is similar to that of Vacquier (1962) except that our program finds by itself the boundaries of the body, which need to be defined only by up to three mathematical equations, and that the final product of our program is a calculated magnetic anomaly whereas Vacquier obtains only the direction of magnetization of a body from its known shape and an observed magnetic survey map, the shape having been scaled previously manually point by point from a map of the body.

The total magnetization of the body under study is first decomposed in three rectangular components. One of these components is vertical and the other, X, is selected to be parallel to the horizontal component of the earth's magnetic field.

This permits us to consider the body to act approximately as three bundles of square prisms, magnetized parallel to their length. For each point in the flight plane the anomaly due to the pole at each end of the magnetized prisms is then calculated and these effects are summed up. The computer will print out the resulting net anomaly and plot the contour lines. Alternately the computer may give just a profile line along the X or Y directions as chosen.

---

[1] Geologist - Geological Survey of Canada.

[2] Engineer - Asselin, Benoit, Boucher, Ducharme, Lapointe, Ingénieurs Conseils.

[3] Programmer - Department of Mines and Technical Surveys.

There are two main parts to this program:

Geometrical Part: a rectangular cartesian coordinate system is used. The region to be considered is limited by a cube 20 units to a side, the number of units being chosen to suit the speed of our computer (IBM 1620). For example, for a plane flying at 1,000 feet the body would be limited to a cube up to 3 miles on the side. The body is defined by three equations, the Upper Boundary Function (BUF), the Sides Boundary Function (BSF) and the Lower Boundary Function (BLF). These functions can be quite general (for example a vertical body with an approximately square cross-section is represented by the side function $X^n \quad Y^n = C$, n being a large positive integer) except that for the time being only functions monotone inside the cube should be used for the BUF and BLF. For a prism bundle parallel to a given coordinate axis the poles of the prisms are located on the surfaces at integer values of the two other coordinates.

Magnetic Part: the anomaly due to each pole is then calculated for midway points between the integer coordinates. In this paper, we utilized the classical formulae for the strength of the magnetic field due to a pole (Vacquier, 1962). As illustrated on Figure 1, the precision afforded by these approximations should be sufficient considering the irregular nature of geological bodies.

A major difficulty that had to be overcome in the writing of the program was that of determining when a given point is inside or outside the geological body. This was done by the application of a Jourdain (1896) type criterion, based on signs and sign changes of boundary functions at boundaries of the body, for successive values of a running coordinate parallel to the direction of the bundle of poles under investigation (see Fig. 2 for Block Diagram).

In the present arrangement several trials with different assumed shapes of body might be necessary before satisfactory concordance with aeromagnetic maps is observed. We have found that one run might take as much as four hours on the IBM 1620 (minimum run 10 minutes). It is hoped that it may soon be possible to program a loop automatically modifying the assumed shape of the body from a test fit with the observed magnetic data. Work is also being done on ways to speed up the existing program.

As it is, the program is fully operational. Copies can be made available to interested parties.

Jourdain, Camille
1896: Cours d'analyse de l'Ecole Polytechnique; Gauthier-Villars, Editeur, Paris, 1896.

Vacquier, Victor
1962: A machine method for computing the magnitude and direction of magnetization of a uniformly magnetized body from its shape and a magnetic survey; Benedum Earth Magnetism Symposium, Pittsburgh, 1962, pp. 123-137.

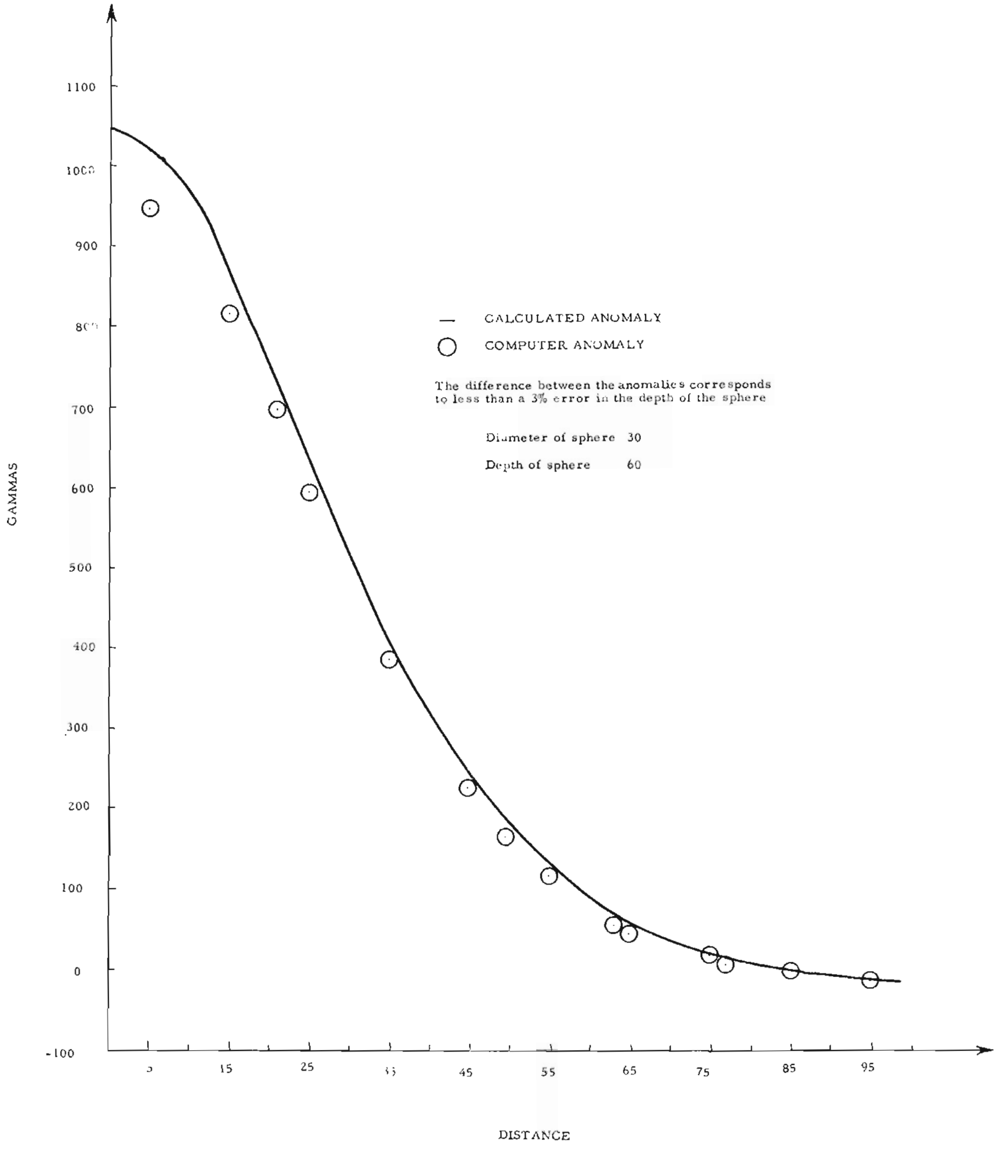

Figure 1. Calculated anomaly over a sphere by computer and by hand. The sphere has a vertical magnetization of 0.001 cgs. The earth's field is also vertical.

LOGIC OF THE GEOMETRICAL PART

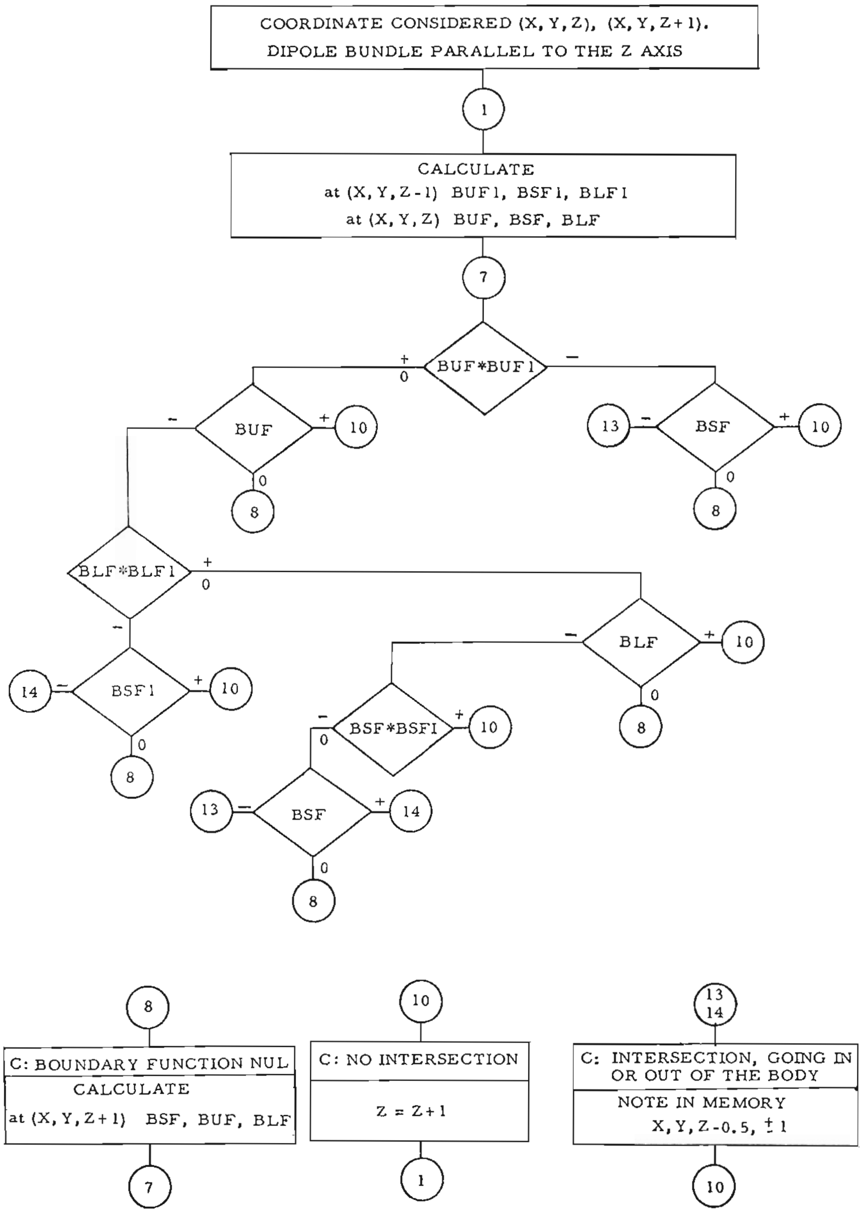

Figure 2. Flow chart of the logic of the geometrical part to determine the surface pole distribution.

4. FOREUSE PORTATIVE POUR L'ÉCHANTILLONNAGE EN SURFACE

Edwin H. Gaucher, Gérald A. Meilleur

Sommaire

La présente notice décrit une foreuse à diamants dont le poids total est limité à 7 Kg. et qui permet d'effectuer dans des conditions très satisfaisantes l'échantillonnage des affleurements par prélèvement de carottes à une profondeur allant jusqu'à un mètre. Cette foreuse ultra légère qui comporte une pompe à eau incorporée, est très rapide et d'un maniement aisé. On a déposé une demande de brevet sur cet appareil.

Introduction

Il est souvent nécessaire de prélever sur le terrain des échantillons de roche non altérée pour des études de paléomagnetisme, de géochimie, etc. Les prélèvements à la masse sont difficiles, surtout dans les roches ignées ou métamorphiques, et les problèmes sont encore plus grands lorsque l'on désire des échantillons orientés, comme pour les études de paléomagnetisme. Les foreuses présentement disponibles sur le marché sont à notre avis soit trop lourdes pour être vraiment appropriées aux conditions de leur emploi par les géologues en campagne, ou alors, lorsque plus légères elles sont d'un maniement difficile. En plus ces foreuses exigent l'usage d'une pompe accessoire pour la circulation d'eau de refroidissement, ce qui ajoute à l'encombrement et au poids de l'ensemble.

Tout en nous inspirant largement de la foreuse construite vers 1955 par R. Doell (1965), nous avons construit une foreuse plus légère, à laquelle nous avons incorporé une pompe à eau.

La nouvelle "Foreg O1"[1]

La foreuse qui est l'objet de la présente notice a été mise au point à la suite de l'expérience acquise au cours de deux saisons d'exploration par des équipes de la Commission Géologique chargées de collectionner des échantillons orientés et qui ont employé avec discernement et d'une manière comparative l'échantillonnage au moyen des diverses foreuses aussi bien que l'échantillonnage à la masse. La foreuse à été conçue à la Commission Géologique du Canada plus spécialement dans le but de prélever des échantillons orientés pour l'étude du magnétisme rémanent des roches et du paléomagnétisme. Elle peut être employée également pour les relevés géochimiques et dans tous les cas où l'on désire un échantillon frais et non altéré, à condition toutefois, comme c'est généralement le cas au Canada, que l'altération ne soit pas trop profonde.

La foreuse permet d'échantillonner les affleurements par carottage de 6" à 40" (15 cm à 1 m) de profondeur, avec une pénétration moyenne de 6" à la minute dans le granite frais. Jusqu'à present, les carottes prélevées ont 1" ou 1 3/8" de diamètre (2.54 cm ou 3.5 cm).

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[1] C'est le nom que nous proposons pour cette nouvelle foreuse.

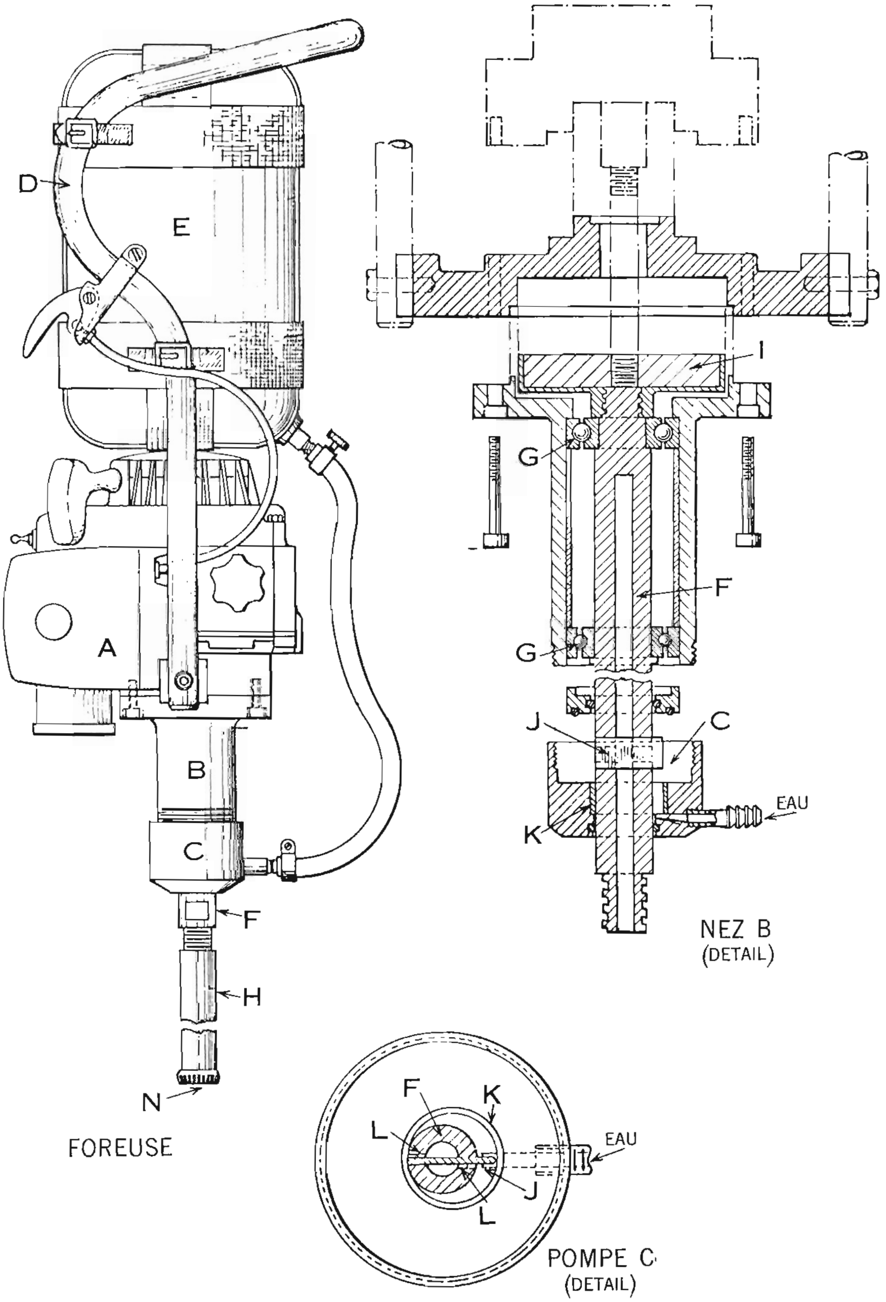


Figure 1. Plan de la foreuse.

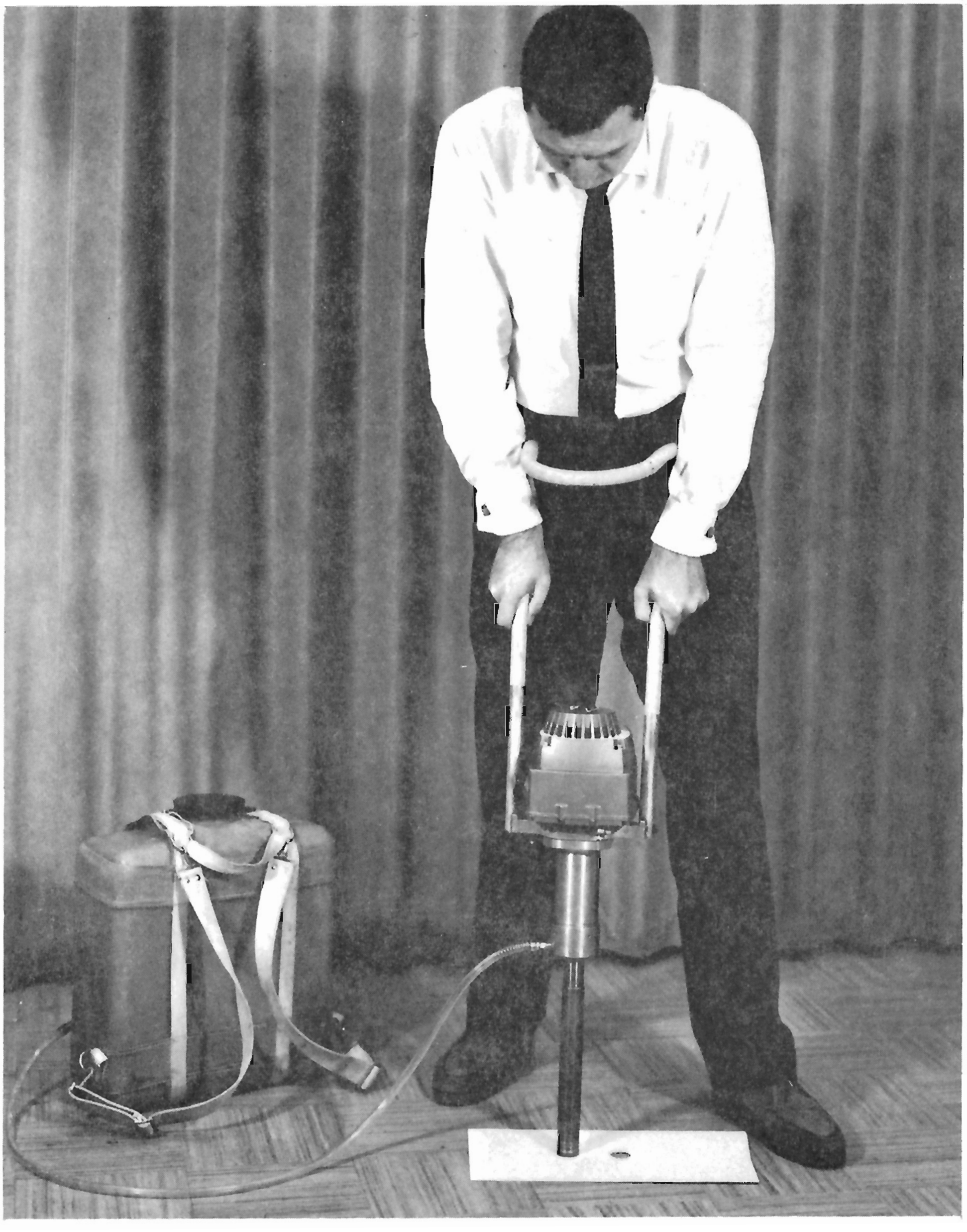
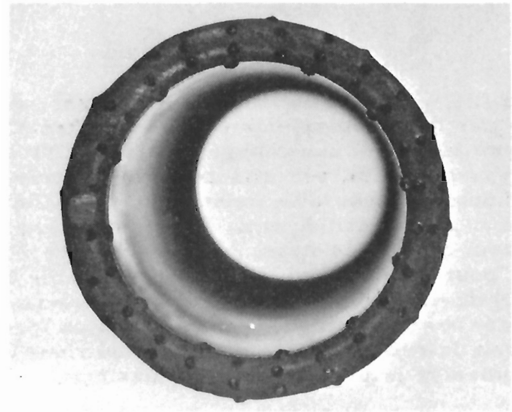


Planche I. Foreuse en état de marche. Pour forer du granite on mettrait le reservoir par-dessus la foreuse.



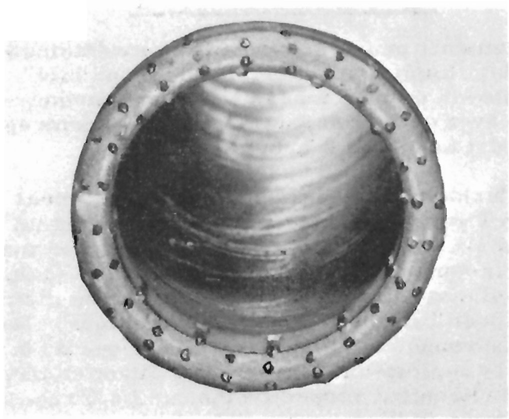


Planche II. Couronne de diamants spécialement étudiée pour notre foreuse (Canadian Longyear).

Pour faire notre foreuse nous avons adapté à un moteur de scie à chaînette (A Fig. 1, aussi Planche I) de 50 cc (3.3 po. cu.) un nez (B Fig. 1) sur lequel sont fixés une pompe (C), des poignées (D) et un réservoir à eau (E). Nous avons aussi étudié des tubes à carottes et des couronnes à diamants spéciaux pour notre foreuse.

Le nez et la pompe à eau

Le nez (B), partie principale de la foreuse, comprend un axe (F) de 1" supporté par deux roulements à billes scellés (G), distants de 3", capable de supporter aisément une charge axiale de 200 lbs. à une vitesse de 6,000 R.P.M. La couronne (H) est attachée à une extrémité de l'axe et le moteur (A), par l'intermédiaire d'un embrayage (I), à l'autre extrémité. Le bâtis du moteur est solidaire du nez. Deux poignées (D) partent du nez, font le tour du moteur pour le protéger, et s'élèvent de 20 pouces, à partir du nez du moteur, pour assurer une position confortable au foreur. Le réservoir d'eau (E) de 4.5 gallons (Imp.) en polyéthylène, qui a été prévu pour être placé entre les deux poignées par-dessus la foreuse, est facilement détachable pour le remplissage. Le poids du réservoir est destiné en même temps à augmenter le pression sur la couronne.

Une petite pompe à excentrique (G), montée dans le nez de la foreuse, fournit l'eau nécessaire pour refroidir la couronne de diamants. La pompe est opérée par un impulseur (J) en "téflon" qui glisse dans une mortaise (fente) usinée dans l'axe de la foreuse. L'impulseur tourne avec l'axe de la foreuse, tout en glissant dans sa mortaise, et ce faisant balaie le volume compris entre l'axe et l'excentrique (K) de la pompe. L'eau sous pression est injectée par deux rainures (L) de la mortaise dans le milieu creux de l'axe (F), et de là elle descend à la couronne de diamants. La quantité d'eau nécessaire pour forer un échantillon de 6" est d'environ 1 litre (un quart de gallon).

La couronne de diamants

Les diamants peuvent être montés directement sur le tube à carottes, comme les "Longyear industrial diamond bits". Cependant, nous avons préféré employer un tube à carottes avec couronne démontable vissée, le tube étant usiné avec précision pour assurer un centrage rigoureux des couronnes, ce qui est essentiel à 6,000 R.P.M.

Pour l'échantillonnage paléomagnétique, nous employons des tubes à carottes de 8 pouces de longueur (20 cm) ayant un diamètre extérieur de 1.25" (3.125 cm) en acier inoxydable, type 304, non magnétique. Les diamants sont sertis dans une matrice de tungstène, également non magnétique. Un tube de 40 cm de longueur et de 4 cm de diamètre extérieur peut être employé pour l'échantillonnage géochimique. Dans les deux cas l'épaisseur de la couronne de diamants (N) n'est que de 0.16 pouce (0.4 cm), ce qui contribue à la rapidité du forage. Les carottes obtenues sont de 1 pouce et 1 3/8" de diamètre respectivement. Le forage peut être approfondi en intercalant des tiges d'allongement (dill rods) après que la première carotte a été enlevée.

Il est préférable que les couronnes ne soient pas serties de plus de 100 diamants d'un poids total d'environ un carat (Planche II). D'après nos expériences un plus grand nombre de diamants provoque le polissage prématuré de ceux-ci car la pression de l'ensemble sur la couronne (100 lbs.) n'est alors pas suffisante pour les empêcher de glisser sur la roche au lieu de la couper, surtout à 6,000 R.P.M. Une vitesse plus lente n'est pas désirable car elle ralentit le forage.

Le prix de revient du prélèvement d'un échantillon de 6" (15 cm) dans du granit s'établit à moins de $2.00 d'usure de la couronne de diamants. Ce prix s'abaisse sensiblement pour les prélèvements d'échantillons dans des basaltes ou autres roches moins dures, et devient négligeable dans des roches tendres. Ces rendements ont été observés sur des couronnes de diamants montées spécialement suivant des spécifications particulières adaptées à la nouvelle foreuse "Foreg Ol".

Nous avons aussi essayé des couronnes imprégnées de diamants, mais comme leur vitesse de pénétration était bien inférieure, nous n'avons pas étudié leur prix de revient.

Conclusion

Cette foreuse constitue une amélioration par rapport aux foreuses pré-existantes, tant au point de vue d'allègement qui est de 40 à 100%, que de la maniabilité, et de la facilité d'emploi. Bien que conçue spécialement pour les géologues, la foreuse pourrait également servir à cause de son faible poids à d'autres usages, tels que pour le forage d'une station permanente d'arpentage dans un affleurement, le dynamitage occasionnel d'erratiques, la collection d'échantillons de chaussées de béton ou dans des tranchées d'exploration, etc. Elle sera fabriquée sans doute en série au Canada.

Doell, R.R., et Cox, Allan
1965: Measurement of the remanent magnetization of igneous rocks; U.S. Geol. Surv., Bull. 1203A, 1965, pp. 1-32.

5. AEROMAGNETIC GRADIENT SURVEYS

Peter Hood

The recent development of highly sensitive magnetometers, such as the optical-pumping varieties, has made feasible the measurement of the first-vertical derivative of the total field ($\partial \Delta T/\partial h$) in aeromagnetic surveys. This is accomplished by using two sensitive magnetometer heads separated by a constant vertical distance and recording the difference in outputs. The effect of diurnal is thus eliminated in the resultant differential output, and this is an especially desirable feature in northern Canada where the diurnal variation is usually much greater than is found in more southerly magnetic latitudes. Moreover, steeply dipping geological contacts in high magnetic latitudes are outlined by the resultant zero-gradient contour. It is also possible to obtain the depth of burial of the contact from the graph of ($\partial \Delta T/\partial h$) versus ($x\partial \Delta T/\partial x$) where x is the horizontal distance measured from the contact. Similar quantitative interpretations may be made for the point pole and dipole. The data reduction necessary to produce a vertical-gradient map is much simpler than with the total-field case because no datum levelling is necessary. Since the aircraft track will be available from the main compilation it is only necessary to plot the resultant vertical gradient values on the track map and contour. Thus two maps will be obtained for little more than the price of one but with a greatly increased gain in geophysical information concerning the geometry of the causative bodies. Actually a first-derivative map is difficult (and therefore costly) to produce by any other means. The measurement of the vertical gradient would appear to be the main advantage to using hundredth-gamma magnetometers in aeromagnetic surveys, since those types presently in service are sensitive enough for the effective delineation of total-field anomalies.

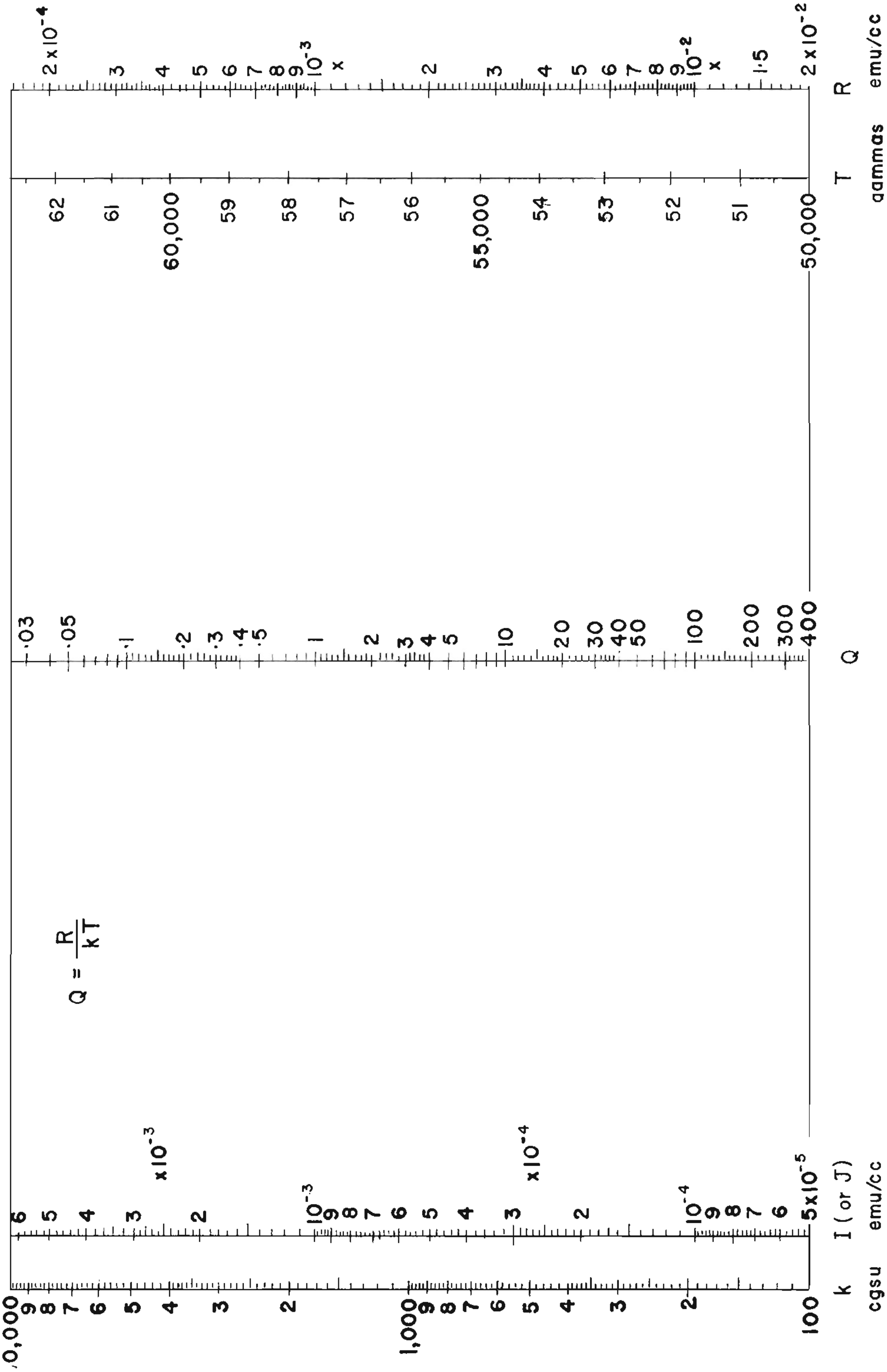
6. NOMOGRAM FOR THE KÖNIGSBERGER RATIO OF ROCK FORMATIONS

Peter Hood

The important role of remanent magnetism in producing magnetic anomalies is being realized by an increasing number of geophysicists. One of the ways to ascertain the relative contribution of the remanent magnetism is to calculate the Königsberger (1938) ratio. The Königsberger ratio (Q) is defined as the ratio of the remanent (R) to the induced magnetization (I) in the rock formation under consideration. Thus

$$Q = \frac{R}{I} = \frac{R}{kT}$$

where k is the volume susceptibility of the formation, and T is the total intensity of the earth's magnetic field in the area. The value of R may be obtained using a remanent magnetometer usually the spinner or astatic varieties. The intensities of remanent (R) and induced magnetization (I) combine vectorially to give a total intensity of magnetization (J), which is also the total magnetic moment per unit volume of the rock formation. The amplitude of the magnetic anomaly associated with the rock formation is directly proportional to the total intensity of magnetization (J).


Q = R/kT
T gammas
R emu/cc
Q
k cgsu
I (or J) emu/cc
50,000
55,000
60,000
2 x 10^-2
2 x 10^-4
5x10^-5
x10^-3
x10^-4

A double nomogram has been devised for the convenient calculation of Q (and I) using the units commonly employed by exploration geophysicists. The reader should note that as Q is a ratio, it is dimensionless. The procedure for using the nomogram is best illustrated by an example for a rock specimen collected from the micropegmatite zone of the Sudbury nickel irruptive in northern Ontario (Hood, 1961). A value of the volume susceptibility $k = 1124 \times 10^{-6}$ cgs units (or emu/cc) was obtained experimentally using a susceptibility meter, and using the value of T = 59,000 gammas obtained from the Dominion Observatory isodynamic chart (1955), the induced magnetization $I = 6.6 \times 10^{-4}$ emu/cc is obtained. Using this value of I, and the value of the remanent magnetization $R = 4.4 \times 10^{-4}$ emu/cc determined with a spinner magnetometer; the Königsberger ratio of the rock specimen Q = 0.66 is read from the nomogram. One can thus conclude that the contribution of the remanent magnetization to the production of total intensity magnetic anomalies associated with the micropegmatite is somewhat less than the magnetization induced by the earth's field. However, in any given formation both k and R are somewhat variable quantities and the procedure should be repeated for a number of rock specimens collected from the same outcrop, in order to obtain a mean value.

The effective susceptibility of a rock (k_e) may be defined as the total magnetization (J) divided by the intensity of the ambient earth's field, i.e. $k_e = \frac{J}{T}$. This may also be readily calculated using the nomogram.

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Königsberger, J.G.
1938: Natural residual magnetism of eruptive rocks; Terr. Mag. Atmos. Elec., vol. 43, pp. 119-130, 299-320.

1955: F-Isodynamic Chart, Dominion Observatory, Canada.

GEOCHEMISTRY

7. GEOCHEMISTRY OF THE YELLOWKNIFE GROUP VOLCANIC ROCKS

W.R.A. Baragar

The Yellowknife and Cameron River volcanic belts of approximately 40, 000 feet and 7, 000 feet thickness respectively were sampled in 1962 at about 500-foot stratigraphic intervals. Each sample has been analysed for the 9 major oxides by X-ray fluorescence techniques supplemented by chemical analyses. The results, obtained late this year, have not been fully processed but a preliminary assessment follows:

1. The volcanic belts are composed of the following rock types in the proportions given:
   (a) Yellowknife belt. Basalt - 49%, quartz basalt - 6%, andesite - 27%, latite - 3%, dacite - 8%, quartz latite - 7%.
   (b) Cameron River belt. Basalt - 36%, andesite - 43%, latite - 7%, dacite - 7%, quartz latite - 7%.

Geological Survey nomenclature (Brown, 1952) is used but classifications are based on normative rather than modal minerals.

2. The chemistry of the volcanic rocks shows little overall systematic change with height in the lava piles. Rather each oxide seems to vary about a mean that persists through the entire stratigraphic section. In the Yellowknife belt most of the acidic rocks are contained in two layers, one, roughly 2, 000-feet thick, is about halfway down in the section; the other of possibly 3, 000 feet thickness caps the section unconformably. The lower acidic layer represents an abrupt change in the chemistry of the lava from that of immediately preceding basalts and andesites. The upper acidic layer, on the other hand, may be heralded by a rising acidity apparent in lavas immediately below the unconformity. In the Cameron River volcanic belt an acidic layer of about 1, 000 to 1, 500 feet thick occurs about two thirds of the distance from the base to the top of the section. However, because of the higher acidity of the Cameron River belt it does not represent as abrupt a chemical change as do the acid layers of the Yellowknife belt.

3. Frequency distribution diagrams of all Yellowknife Group volcanic rocks analysed exhibit sharp peaks at the following values for each of the oxides: SiO_2 - 51%, Al_2O_3 - 15%, Total iron as FeO - 11%, MgO - 5%, Na_2O - 2.5%, K_2O - 0.5%, TiO_2 - 1.0%. Comparison of these values with those obtained by Chayes (1964) for 360 circumoceanic and 579 oceanic basalts leads to some conflict in assigning affiliation of the Yellowknife lavas to either suite. The CaO, MgO, and TiO_2 peaks coincide with those of the circumoceanic basalts, the Al_2O_3 peak with that of the oceanic basalts, and the SiO_2 peak falls between peaks of the other two suites. Peaks of the remaining oxides coincide with corresponding peaks of both oceanic and circumoceanic basalts which for these oxides are unresolvable.

4. A differentiated sill interlayered with volcanic rocks of the Yellowknife belt shows an iron-enriched differentiation trend with negligible alkali enrichment. This corresponds with one of two types of chemical variation exhibited by the lavas viz a variation dominated by an FeO - MgO exchange,

and a variation characterized by alkali enrichment with little change in the FeO/MgO ratio. Assuming the differentiated sill can be regarded as a model of the magma behaviour in high-level magma chambers the iron-enriched trend of the lavas might be attributed to crystal fractionation in such chambers. The alkali enrichment trend that produces the acidic rocks of the Yellowknife Group is not likely attributable to a similar origin.

Brown, I.C.
1952: A nomenclature of igneous rocks; Trans. Can. Inst. Mining Met., vol. LV, pp. 53-56.

Chayes, F.
1964: A petrographic distinction between Cenozoic volcanics in and around the open oceans; J. Geoph. Research, vol. 69, pp. 1573-1588.

8. COPPER, ZINC, NICKEL AND LEAD IN LOWER TILL MATERIAL COLLECTED NEAR A MASSIVE SULPHIDE OREBODY IN THE CLAY BELT OF NORTHERN ONTARIO

J.A.C. Fortescue, O.L. Hughes

During the course of geochemical investigations, carried out by the Geological Survey of Canada in the vicinity of the Dragon orebody of the Texas Gulf Sulphur Company near Timmins (Anon., 1964), the Company made available to the Survey samples of surficial material collected from sixteen drill-holes located above and around the orebody (Fig. 1). These holes were drilled to bedrock during a part of a civil engineering investigation carried out on the property by Professor E.I. Robinsky of Toronto University.

One object of the geochemical investigation was to discover whether a chemical anomaly exists in the lower till material "down ice" from the orebody. It is believed that if an extensive anomaly of this kind (for example several times the area of the suboutcrop area of the orebody) does occur at the Dragon property, chemical analysis of lower till material would be of value as a 'follow-up level' (Fortescue, 1964) method of prospecting. Such a method would be of special interest in the interpretation of geophysical anomalies in the Clay Belt of northern Ontario, and for this reason we publish these preliminary findings at this time. A more comprehensive account of these, and pending, investigations carried out in the area will be published after the current drilling program is completed.

The stratigraphy of the overburden material at the Dragon property is typical of that part of the Clay Belt overridden by a late (Cochrane) ice advance (Hughes, 1956, 1960a, b, 1961). Sandy, bouldery "lower" till lying on bedrock is overlain by varved silt and clay and by clay till on which a few feet of peaty material may occur. Where the overburden is thin (less than 35 feet) varved clay is commonly lacking and clay till lies on fresh bedrock or on the lower till. The lower till consists predominantly of material scraped from bedrock a short distance upstream in the direction of ice movement. The varved clay and silt are glacial lake deposits, whereas the overlying clay till was formed by glacial reworking of the varved clay and silt.

Complete cores of the holes were not available, hence sections shown on Figure 2 are not divided up into stratigraphic units. In order to facilitate the description of the chemical results the holes have been divided into four groups, and arranged in order of increasing depth in each group (Fig. 2).

The samples were analysed for total zinc, copper, nickel and lead by colorimetric methods due to Gilbert (1959) and Stanton and Coope (1959). One hundred milligram portions of the minus eighty mesh material from each sample were attacked by a hot hydrofluoric/perchloric acid mixture in platinum crucibles. The residue from this procedure was dissolved in dilute hydrochloric acid and colorimetric analyses carried out on separate aliquots of this solution. The nature of the occurrence of the metals in the samples was not established during this preliminary investigation.

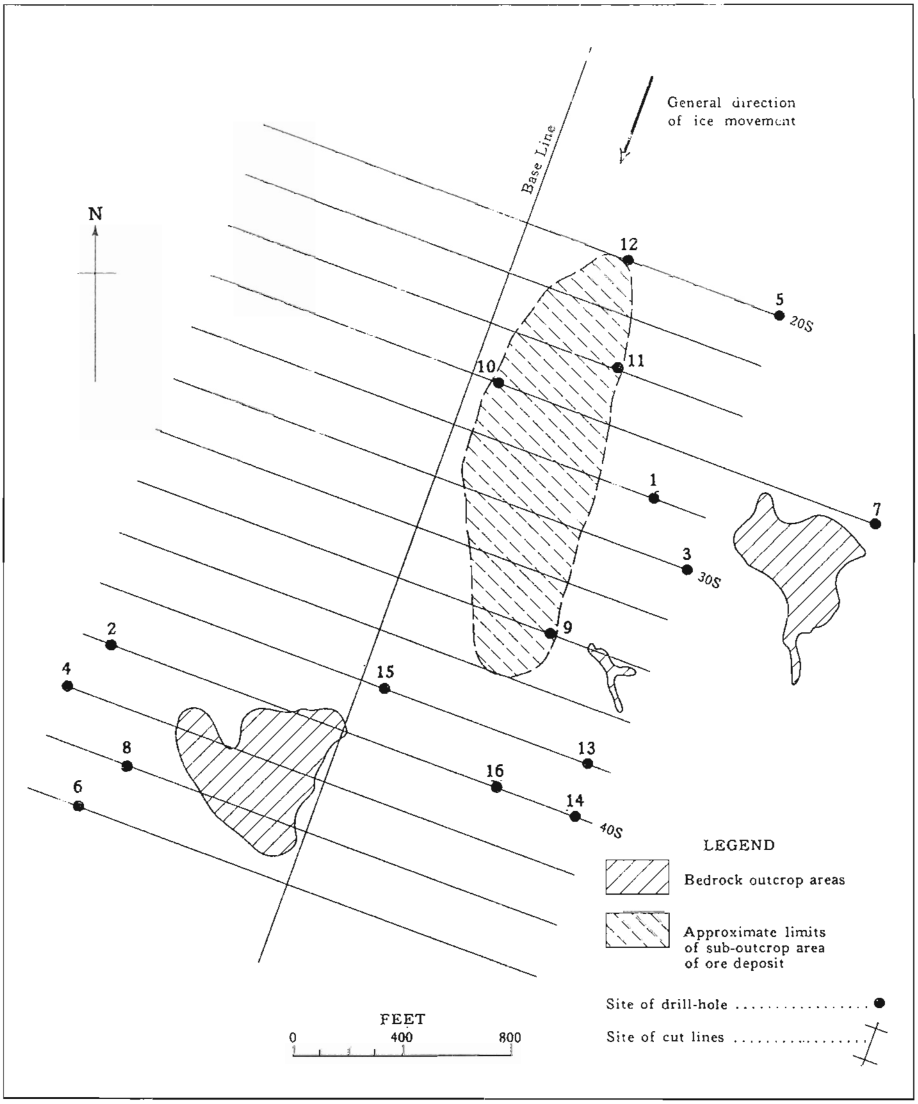
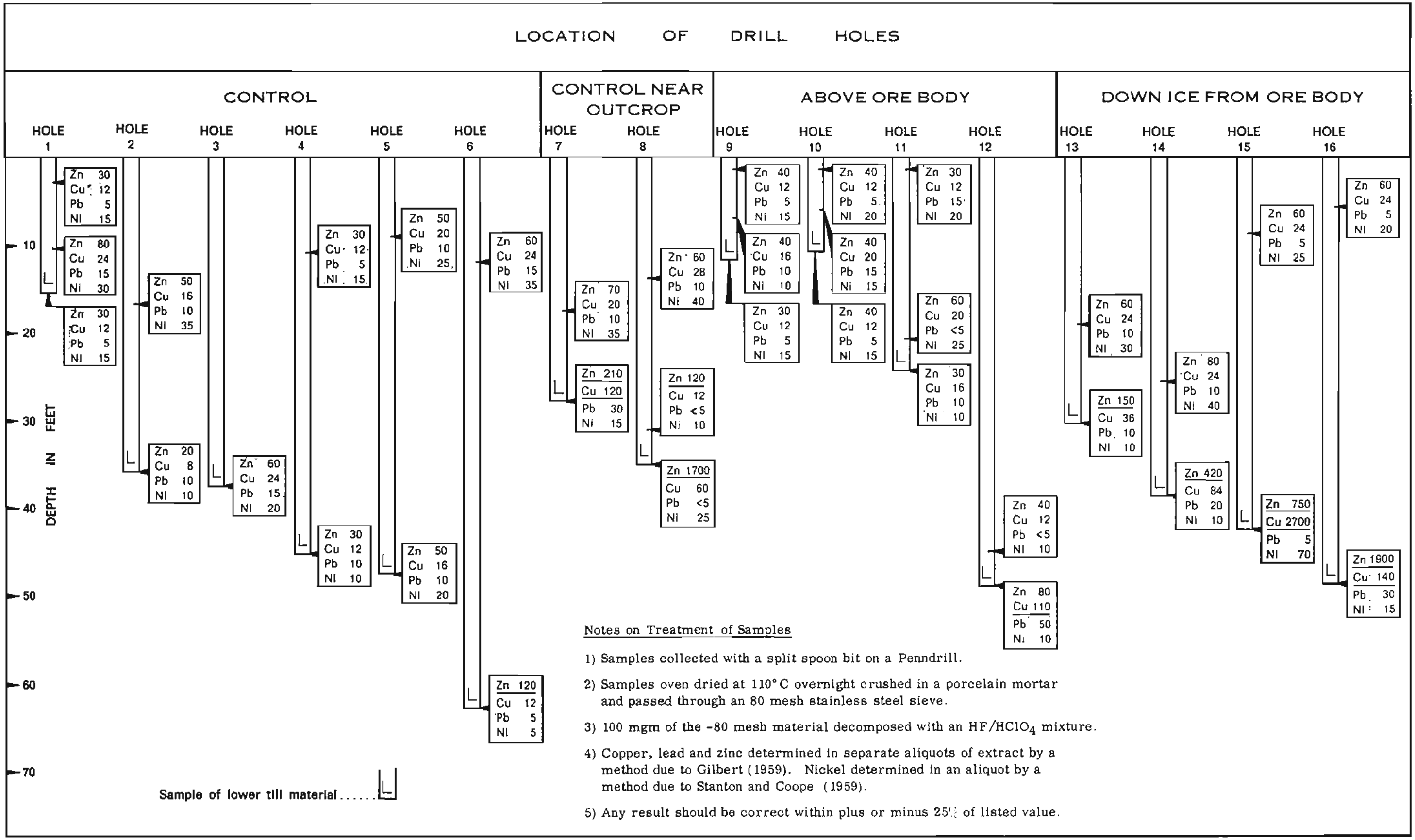


Figure 1. Sketch map of the Texas Gulf Sulphur Property showing the location of the suboutcrop area of the Dragon orebody and the sites of drill holes in surficial material.



Notes on Treatment of Samples

1) Samples collected with a split spoon bit on a Penndrill.

2) Samples oven dried at 110°C overnight crushed in a porcelain mortar and passed through an 80 mesh stainless steel sieve.

3) 100 mgm of the -80 mesh material decomposed with an $HF/HClO_4$ mixture.

4) Copper, lead and zinc determined in separate aliquots of extract by a method due to Gilbert (1959). Nickel determined in an aliquot by a method due to Stanton and Coope (1959).

5) Any result should be correct within plus or minus 25% of listed value.

Figure 2. The distribution of total zinc, copper, lead and nickel in samples collected from sixteen drill holes in the vicinity of the Dragon orebody.

In the case of lead and nickel very similar levels of concentration were found in the samples of lower till and in the material collected nearer the surface. The 70 ppm nickel value in hole 15 is an exception, and should be considered as an erratic high value of little interest in the present investigation. The copper content of upper and lower till samples in holes 1-6 and 9-12 inclusive is always below 30 ppm except in one case. The exception is in the lower till sample of hole 12 situated above the orebody where one might expect a high value. The copper values in lower till collected 'down ice' from the mineral deposit are in all cases over 100 ppm. Values of 120 ppm and 60 ppm copper were found in the lower till material taken from holes 7 and 8 situated near outcrops away from the mineral deposit. The copper content of all the upper samples in holes 7, 8, 13, 14, 15 and 16 is below 30 ppm.

The zinc values exhibit a distribution pattern similar to the copper except that the contrast in level of concentration between background samples (i.e. those taken of lower till and upper material in control areas and in upper samples where the lower till is anomalous) and anomalous ones is higher in the case of zinc. Zinc values of over 100 ppm are found in the lower till material in all four samples collected 'down ice' from the deposit as well as in the two (7 & 8) near the outcrop and in control hole 6 which is relatively deep and close to an outcrop area.

The fact that values for copper and zinc are not significantly above background level in lower till over the orebody (except for high copper in a sample from immediately above bedrock in hole 12) may at first seem anomalous. However, material deposited at the base of a moving ice-sheet must necessarily have been eroded from bedrock some finite distance upstream (with respect to direction of ice movement) from the point of deposition; hence, the source of a large part of the lower till overlying the orebody probably lies to the north of the orebody.

At the Dragon property a geochemical anomaly in lower till "down ice" from the orebody appears to be directly attributable to ice transport of material from the orebody. The results discussed are too few to give any indication of the size of the anomaly, or its uniformity within the lower till unit. A drilling program designed to provide more information on these two aspects is presently in progress by the Geological Survey.

The writers thank the Texas Gulf Sulphur Company for allowing the Geological Survey of Canada to carry out geochemical investigations on the Dragon property during 1964, for providing information and samples, and for reading this paper and allowing it to be published at this time. The chemical analyses were made at the Geochemical Laboratory of the Geological Survey of Canada by Mr. J.J. Lynch and Mr. G. Mihailov.

Note

Since going to press, we have obtained directions of N15°W and N10°W for striae exposed on the bedrock in the bottom of the open pit at the Dragon orebody. This suggests that results from holes 1 and 3 should be included in the group of holes "down ice from orebody" in Figure 2, although the interpretation of the results from these holes is similar to that for holes 9, 10 and 11.

Anon.
1964: "T.G.S. plans production for late 1965"; <u>Precambrian-Mining in Canada</u>, vol. 37, No. 6, p. 13.

Fortescue, J.A.C.
1964: "Exploration architecture"; <u>in</u> Neale, E.R.W. (1964) "Some Guides to Mineral Exploration" Commonwealth Geological Liaison Office, London, S.P. 4; also <u>Geol. Surv. Can.</u>, Paper 65-6, pp. 4-8.

Gilbert, M.A.
1959: Laboratory methods for determining copper, zinc and lead; <u>Geol. Surv. Can.</u>, Paper 59-3.

Hughes, O.L.
1956: Surficial geology of Smooth Rock, Cochrane District, Ontario; <u>Geol. Surv. Can.</u>, Paper 55-41.

1960a: Surficial geology Iroquois Falls, Cochrane District, Ontario; <u>Geol. Surv. Can.</u>, Map 46-1959.

1960b: Surficial geology of Kirkland Lake, Cochrane District, Ontario; <u>Geol. Surv. Can.</u>, Map 1-1960.

1961: Preliminary Report on borings through Pleistocene deposits, Cochrane District, Ontario; <u>Geol. Surv. Can.</u>, Paper 61-16.

Stanton, R.E., and Coope, J.
1959: Modified field test for the determination of small amounts of nickel in soils and rocks; <u>Trans. Inst. Mining Met.</u>, London, 1958-59, vol. 68, pp. 9-14.

GROUNDWATER STUDIES

9. WATER-SAMPLING EQUIPMENT

R.O. van Everdingen

The water-sampling equipment for small-diameter cased wells, developed by the Engineering and Groundwater Geology Section, consists of a sampling tube, and a stand with cable reel and pulley.

The sampling tube (see Plate I), with an outside diameter of 1/4 inch and an overall length of 33 1/4 inches, is a modified version of the standard Kemmerer sampler. Because of space limitations only the bottom opening is closed by the triggering mechanism, and the emptying valve at the bottom has been omitted.

The tube can be used in casing with an inside diameter of 1 1/2 inches or larger. Its capacity is 445 cubic centimeters.

The sampler stand (see Plate II) was constructed from angle aluminum with pre-drilled holes on 3/4-inch centres. Construction details are shown in Figure 1. The stand can be assembled in about 10 minutes. In assembled state it can be transported in a standard panel truck, and operated from the back of such vehicle.

The cable reel is mounted on the stand by way of a piece of 1/2-inch plywood. It has a long handle for easy operation, but no gears or level-winding device. The capacity of the reel is approximately 500 feet of 1/8-inch steel cable. For deep wells 1,000 feet of 1/16-inch cable can be used instead.

The pulley has a circumference of exactly one foot. The pulley shaft is coupled to a revolution counter that indicates feet-of-cable let down the well. The pulley assembly can be mounted on a wooden cross-member or on the metal cross-member at the front of the stand (see Figure 1 and Plate II).

Both the standard Kemmerer sampler and the modified one-inch sampler can be used with this sampler stand.

The operation of the one-inch sampling tube is practically identical to that of the Kemmerer sampler. The tube must be emptied through the top opening, because the bottom valve of the standard sampler has been omitted.

Very little contamination of the sample through the open top has been found so far. It should be pointed out, however, that gasses dissolved in the sample can escape through the open top. Samples obtained with this sampling tube thus will not yield a reliable CO_2 analysis.

During the summer of 1964 the sampling tube was used as a bailing tool for determinations of hydraulic conductivity in till, shales and fine-grained sandstones in southern Saskatchewan. A prerequisite for this use of the sampling tube is a fairly low hydraulic conductivity of the formation tested, because bailing has to produce at least some measurable drawdown. In cases of very low hydraulic conductivity one run of the 'bailer' will produce approximately 0.65 foot drawdown in a well with 2-inch casing. About one minute is required to run the bailer in and out of the well for each 100 feet of depth to the water. Some time can be saved, and excessive wear of the triggering mechanism can be avoided, by operating the sampling tube in the 'closed' position when used as a bailer.

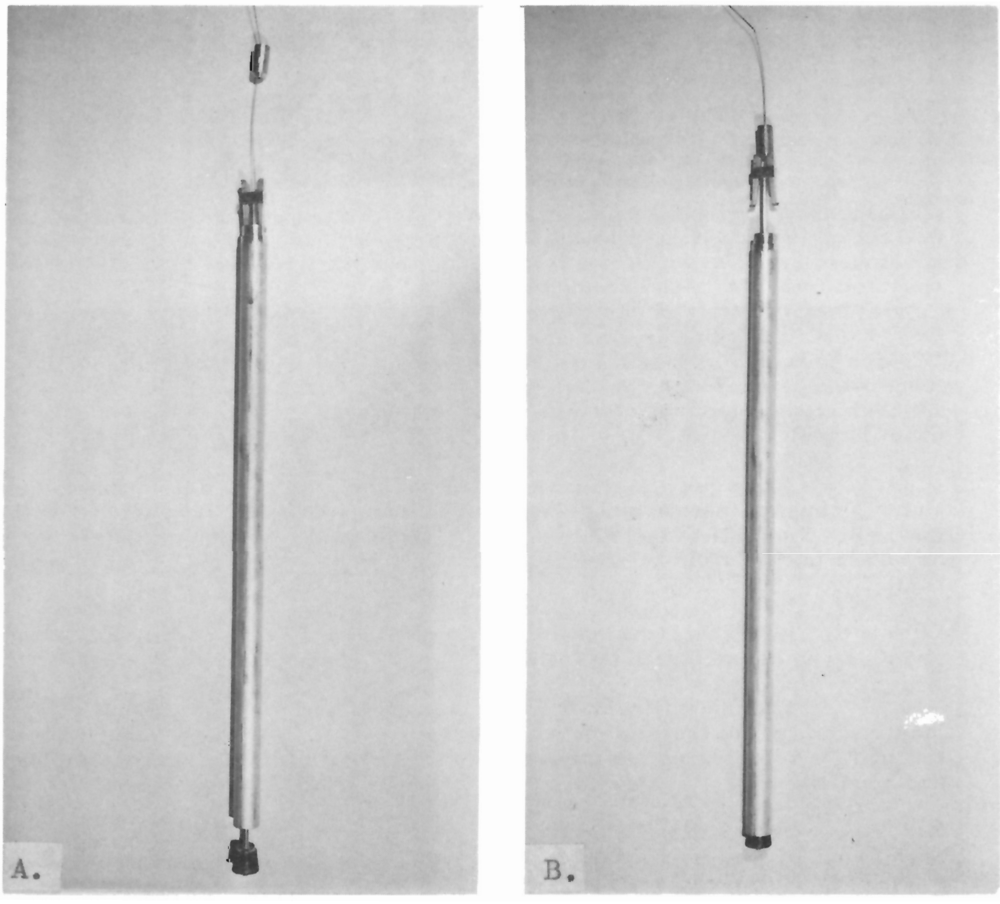
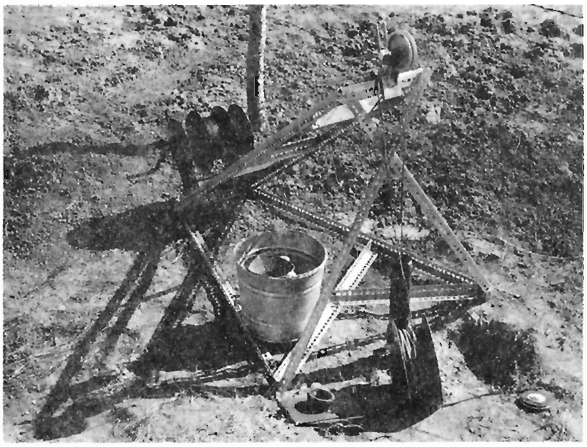
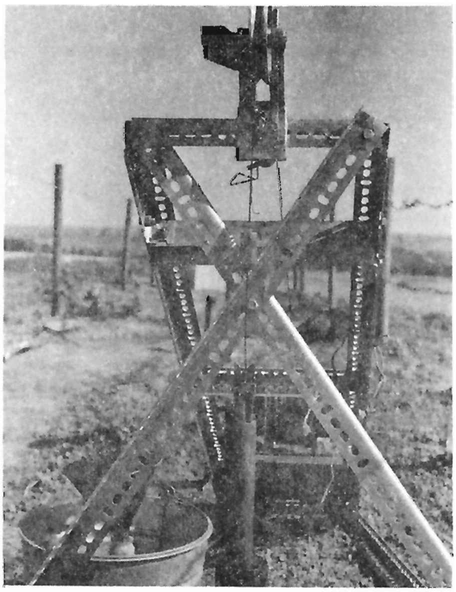


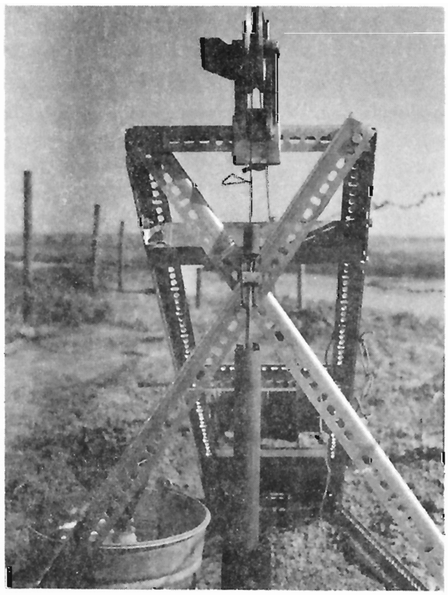
Plate I. One-inch sampling tube.
A. Open.
B. Closed.



A



B.



C.

Plate II. Sampler stand.
A. Full view.
B. Front view, with sampler in open position.
C. Front view, with sampler in closed position.

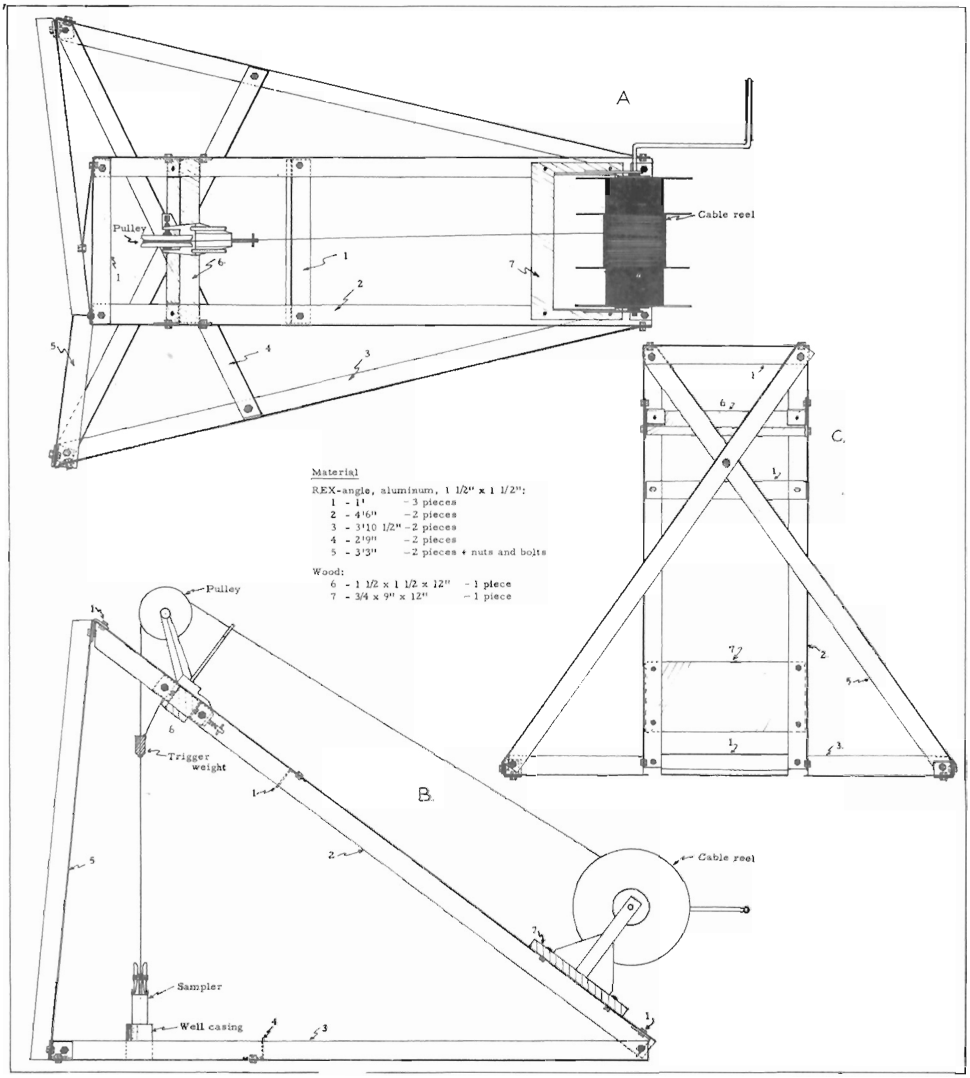


Figure 1. Construction details of sampler stand.
A. Top view.
B. Side view.
C. Front view. Cross-braces '4' omitted.

ISOTOPE AND NUCLEAR GEOLOGY

10. RADIOCARBON DATING LABORATORY

W. Dyck

The study of variations of C^{14} concentrations in Douglas Fir tree rings from Vancouver Island (part I of O.P. 338) was completed. The experimental results indicate a maximum variation of 44°/oo during the past 1,100 years. The magnitude and trend of these variations are similar to those observed by deVries in Douglas Fir from Germany and by Willis et al. in Sequoia from California, confirming earlier observations that atmospheric mixing of CO_2 takes place rapidly on a large scale.

C^{14} measurements of about ten successive annual growth rings from the piths of two firs (345 yrs. and 1,100 yrs. old) show no variations beyond those attributable to the statistical counting error of $\pm$ 6°/oo. Thus, cyclic variations in sunspot activity and/or climate, if present during these intervals, did not affect the C^{14} concentration in the biosphere appreciably.

Analyses of 1964 leaves and grass from Champlain Lookout (part II of O.P. 338) indicate an average C^{14} concentration of 86% above the level existing prior to the testing of nuclear bombs, and 21% above the 1963 level.

A 5 litre counter, with exceptionally good counting characteristics, was put into routine operation. In addition to the extension of the dating range from 40,000 years (obtainable with the 2 litre counter) to 54,000 years, the counter has made it possible to double the output of the laboratory.

The design of a 1 litre counter, for use with very small sample, has been completed. It incorporates disc-type quartz insulators instead of the conventional sleeve type, making the theoretical counter volume efficiency nearly 100%.

11. K-AR AGE OF CAMBRIAN GLAUCONITES FROM ALBERTA

R.D. Stevens

Six stratigraphically controlled glauconitic limestone samples were collected from the Cambrian succession in southwestern Alberta for K-Ar age determinations (Aitken and Stevens, 1964).

Only one of these samples (Ac-96) was considered satisfactory for age determination after petrographic examination. However, a second sample (Ac-91 E-42.5) was also selected for age determination to give a greater geographic coverage. Two clean glauconite concentrates were prepared from Ac-96, one by normal heavy liquid and magnetic separation, and the other by acid solution of the associated carbonate. Concentrate Ac-91 was cleaned by acid leaching of the carbonate impurities.

K-Ar age determinations yielded middle Pennsylvanian and late Mississippian ages of 300, 301 and 327 million years. Since the stratigraphic position of the samples is well established as being upper and middle Cambrian, the ages obtained are clearly anomalous and must be attributed to radiogenic argon loss from the glauconites since Cambrian time.

The result of this study, together with two ages reported by Folinsbee, et al. 1960, are shown in the following table:

SUMMARY OF ALBERTA GLAUCONITE AGES

Sample	Locality	Associated Fauna	Stratigraphic Position	K-Ar Age
AC-96	52°28'44"N 116°55'50"W	Cedaria Zone	Corona Fm. U. Cambrian	300 m.y.
AC-96 (Acid cleaned)	"	"	"	301 m.y.
AC-91 (E-42.5)	53°02'18"N 118°08'36"W	(?)Albertella	Low Middle Cambrian	327 m.y.
AK-9 (Folinsbee, et al. 1960)	Sunset Peak, Alta.	Olenellus	Upper Lower Cambrian	413 m.y.
AK-55	Sunset Peak, Alta.	Olenellus	Upper Lower Cambrian	396 m.y.

The reason for these anomalously low ages is not immediately apparent. It is known that the Cambrian rocks containing the glauconites have been very deeply buried, the samples in question having at some time been overlain by the entire stratigraphic section through Devonian to and including the Cretaceous. At such depths the temperature may have been high enough to cause at least partial loss of radiogenic argon until the time of tectonic or erosional "unloading".

In addition to the stratigraphic depth of burial, there is strong evidence for the stacking-up of westerly thrust sheets over the sampled rocks which, themselves, are located in a large thrust sheet. The dynamic temperature increase associated with the thrusting could have been sufficient to cause argon loss from the glauconite, even though the limestones and their enclosed fossil remains show no sign of recrystallization.

It is a point of interest that rocks of the Ice River Complex yield K-Ar ages in a similar range. Lowdon (1960) reports ages of 340 m.y. (GSC 59-7) and 330 m.y. (GSC 59-8), while Baadsgaard et al. (1961) indicates a range of 304 to 360 m.y. for the Ice River rocks. These rocks are intrusive into Ordovician, and Reesor (1964) considers 360 m.y. to be a minimum age for them. However, the glauconitic limestones of the present study are some distance from the Ice River area and show no indication of thermal metamorphism.

One additional sample of glauconitic green sand from a drill core from the absolutely undisturbed, though deeply buried, Cambrian sequence in the Plains has been collected by J.D. Aitken. An age determination will be carried out on this material to help decide whether the radiogenic argon loss from samples already studied was perhaps due to the thrust faulting or to the great depth of burial.

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1960: "Age determinations by the Geological Survey of Canada. Report 1, Isotopic Ages"; Geol. Surv. Can., Paper 60-17, pp. 6-7.

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1964: "K-Ar Age of Cambrian glauconites from Alberta"; Geol. Surv. Can., Paper 64-2, compiled by Peter Harker, pp. 59-60.

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MINERALOGY AND PETROLOGY

12. DETERMINATION OF "DIAGNOSTIC ELEMENTS" IN FELDSPARS BY FLAME PHOTOMETRY

Sydney Abbey

A combined flame photometric method has been developed for the determination of potassium, sodium and calcium in feldspars. Magnesium is used to minimize variations in the depressant effect of aluminum on calcium emission resulting from deviations from stoichiometry. Standard solutions, approximating the compositions of the sample solutions, are prepared from pure reagents. Background effects on the calcium emission and minimized by using a recording spectrophotometer, which permits scanning across the contour of each emission peak.

Analysis has been done on as little as 10 milligrams of some samples. Possible application of the method to other types of samples is being investigated.

13. PRE-CONCENTRATION OF TRACES OF HEAVY METALS

Sydney Abbey, C.J. Peters, J.A. Maxwell

Three separate procedures were worked out for chemical pre-concentration of such "heavy metals" as Ag, Pb, Si, Zn, Cd, Mo, As, Sb, Bi and some others, from samples in which their concentrations were below the limits of detection by existing spectrographic techniques.

For limestones, gypsums and barites, the trace elements were precipitated on an alumina-iron-silica carrier, by means of 8-hydroxyquinoline, thionalid and tannin. The addition of silica, in the form of a colloidal suspension, represented an improvement over earlier methods, in that it improved the texture of the ignited final concentrate, and gave it a composition similar to that of the silicate rocks for which the spectrographic method was designed.

For pyrite and similar sulphides, the bulk of the iron was removed by extraction of ferric chloride with iso-propyl ether. Trace elements were then precipitated from the sample solution by a modified version of the technique described above.

For magnetites, traces of silver and molybdenum were precipitated as sulphides, using copper as a carrier.

All of these procedures gave some good results, but all showed significant limitations, indicating the necessity for further investigation.

14. VALLERIITE AND MACKINAWITE IN THE MUSKOX INTRUSION

J.A. Chamberlain, R.N. Delabio

Mackinawite and valleriite have been observed in the dunites and pyroxenites of the central layered series of the intrusion. Electron probe measurements and X-ray powder diffraction data obtained on several specimens compare closely with those given by earlier workers. Certain optical and physical properties were found to be helpful in distinguishing the two minerals in polished section. Mackinawite occurs as a replacement in pentlandite and is invariably associated with this mineral in serpentine-bearing rocks. Valleriite occurs in serpentine where it may replace secondary magnetite and, unlike mackinawite, is not usually associated with other sulphides. Mackinawite formed before valleriite and various lines of evidence suggest that both minerals formed at sub-magmatic temperatures during, and as a result of, the serpentinization process.

15. DIFFUSION IN GEOLOGICAL PROCESSES

K.L. Currie

1. Determination of the solubility of albite in super-critical water was completed between temperatures of 400 and 625°C, and water pressure from 500 to 3,000 bars. The data may be summarized in the equations

$$\ln X_1 \quad 106/V - 5495/T - 4.60$$
$$\ln X_2 \quad 10.62 - 5495/T - 4 \ln V$$
$$\ln X_3 \quad 10.49 - 5495/T - 4 \ln V$$

where X_1, X_2, X_3 refer respectively to the mol fractions of silica, soda and alumina in solution, V is the mol volume of water at the given pressure and temperature and T is the temperature. This formula is correct within 1% in the measured range.

2. Determination of solubility of orthoclase is in progress. It appears to be similar to that of albite.

3. Preliminary experiments on the leaching of rocks by super-critical water were begun and indicate some startling differences in the composition of the solutions depending on rate of passage of the water over the experimental material. These differences cannot be due to incomplete solution of some components, because the absolute concentration of SiO_2 in the solutions rises by a factor of two at the most rapid rate of passage of water.

4. A theoretical investigation of the motion of water during metasomatism indicates that water lost from crystals during metamorphism may be concentrated in areas of high temperature, and hence be available for anatexis and/or hydrothermal activity. Experiments are being designed to test the mechanism involved.

5. Measurement of the Hf/Zr ratio in rocks of the Crow Lake dome seems to indicate influx of Hf and Zr into the granitoid rocks, with preferential motion of Zr.

16. NATIVE METALS IN THE MUSKOX INTRUSION

J.A. Chamberlain, C.R. McLeod, R.J. Traill, G.R. Lachance

The following native metals have been identified in the Muskox Intrusion: native iron; native nickel-iron (awaruite); native cobalt-iron (wairauite) and native copper. Mineral distributions and textures indicate that the native metals formed at roughly the same time, during the period of serpentinization of the host dunites and related rocks.

Conditions during serpentinization must have been extremely reducing in the central and lower parts of the layered series, and less so toward the margins and upper parts of the intrusion. This is indicated by the fact that most native metals are abundant in the central regions and are essentially lacking elsewhere, even in strongly serpentinized zones. This zoning suggests that reducing conditions may have been generated internally, possibly as a result of the serpentinization process itself. The composition of the primary olivine of Fo_{80-85} together with the presence of abundant secondary magnetite in equivalent serpentinites suggest that a redox reaction, olivine + water = serpentine + magnetite + hydrogen, contributed to the development of a progressively more reducing, or hydrogen-rich, fluid phase.

Natural phase relations indicate that each native metal formed primarily in situ as a result of the decomposition of specific earlier-formed minerals that had become unstable in the reducing environment. Native iron appears to have been formed by the reduction of magnetite; awaruite by the reduction of pentlandite; wairauite by the reduction of an unknown phase, possibly cobalt pentlandite or cobaltian pyrite; and native copper by the reduction of chalcopyrite. The feasibility of most of these reactions was confirmed by experimental studies carried out in systems open to moist hydrogen.

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

W.H. Champ

(1) The fractional distillation method for volatiles in silicates, developed in 1963, has been put into routine use. Analytical working curves are available for determining eleven elements, as follows:

Ag	.05 - 10	ppm	Pb	.5 - 500	ppm
B	.7 - 200	"	Sb	10 - 1000	"
Bi	.5 - 150	"	Sn	.4 - 200	"
Cd	2 - 500	"	Tl	.2 - 30	"
Ge	.5 - 100	"	Zn	10 - 1000	"
Mo	.5 - 200	"			

Curves are in preparation for Ga (.2-200), In (.2-200) and Te (30-1000 ppm). Difficulties of element distribution in the samples at low concentrations, in preparing synthetic standards, and in avoiding ubiquitous Cu contamination, have prevented establishment of reliable curves for As, Au, Cu and Hg to date. The method is applicable to a wide range of alumino-silicate rocks and minerals, including some low grade sulphide ores, but basic and ultrabasic rocks and high-grade ores are excluded. On a routine single exposure basis results are reported with an expected accuracy of 30% of the concentration stated.

(2) Optinum operating conditions were experimentally determined and a revised and extended routine analytical method was put in use, employing air-jet controlled D.C. arc excitation and Ilford Special Rapid photographic plates. This replaces earlier methods using the now discontinued Kodak type SA11 plates.

This procedure is of broad applicability and can be used for practically all silicate rocks and minerals, plus Ca-Mg carbonates, various iron ores and sulphide ores, etc., including mixtures of these sample types. Concentration ranges covered are from approximately .002 to 5%, depending on the element considered.

Twenty-four analytical working curves are available for determining 19 elements: Ag, As, B, Ba, Be, Bi, Ca, Co, Cr, Cu, Ge, Mg, Mn, Mo, Ni, Sr, Ti, V and Zr. In preparation are another 25 curves which will cover an additional 15 elements (Al, Cd, Ce, Fe, La, Nb, Pb, Sb, Si, Sn, Sc, Th, Y, Yb, Zn).

Intensity ratios determined from replicate exposures of standard test samples gave coefficients of variation between 4-12% for most trace elements. On a routine single exposure basis, results on samples are reported with an expected accuracy of 15% of the amount stated.

(3) Installation and preliminary alignment of a direct-reading optical spectrometer (the Jarrell-Ash company "Atom counter" with 10 analytical channels) has been completed. Analytical calibration for trace element determinations will be carried out in 1965.

In conjuction with this, new gas-flow regulating equipment has been installed. This will enable us to excite samples with the D.C. arc under controlled conditions in environments other than air.

18. RAPID ROCK ANALYSES BY X-RAY SPECTROGRAPH

S. Courville

Emphasis is now being placed on the improvement of the accuracy and precision of this routine procedure. In order to establish necessary basic guidelines for such a study, numerous factors are being investigated, among which are those external factors affecting the stability of the samples discs, the effect of X-rays on the sample surface, the dilution factor and the sample to flux ratio.

The statistical data required for this investigation were obtained with the proposed laboratory reference rock sample (picrite). Those factors which affect routine sample processing, such as replicate analyses and homogeneity of the sample were considered also and this work is still in process.

Another aspect presently under investigation is the choice of the most suitable heavy absorber to use in conjunction with the lithium tetraborate flux. The present absorber, lanthanum oxide, gives a very high background which interferes with the magnesium determination and, the use of cerium oxide was investigated, with very favourable results. This latter heavy absorber is now in routine use.

An attempt was made to improve the sensitivity of the light elements Al, Si and Mg by using a sealed detector (exatron) instead of the present gas-flow detectors (minitron). A decrease in sensitivity was found for Mg; the results with the Al channel were no better than those obtained with the minitron under the conditions being used. Further study is planned.

A very different approach to obtaining increased senitivity is now being investigated. This involves the use of the rock powder without fusion. The problems inherent in this approach are numerous and complex in nature but the potential saving of laboratory time, if this method is put on a routine basis, makes its investigation very worth while.

19. MAJOR ELEMENT ABUNDANCES IN A PART OF THE CANADIAN SHIELD

W.F. Fahrig, K.E. Eade, J.A. Maxwell

Rapid analysis, for major elements, of groups of hand specimens collected during the reconnaissance mapping of some 200,000 square miles of New Quebec presented a unique opportunity to compare the chemical composition of granulite facies and amphibolite facies rocks. These analyses have provided a direct determination of the bulk composition of a large area of Shield. In addition the regional variation in chemical composition over this large area was defined.

The rocks consist chiefly of faintly to strongly foliated Archaean granodioritic gneisses that are probably of metasedimentary origin. Two major metamorphic facies, granulite and amphibolite, are prevalent. The study area was divided into fifteen unit areas and in each unit area hand specimens of each rock unit as determined by the geological mapping were grouped together. The composite sample of each rock unit in each unit area was analysed. To determine average compositions, the data were weighted in proportion to the area occupied by each rock unit.

The analytical results indicate that TiO_2, MgO, CaO, P_2O_5, Al_2O_3 and total Fe as FeO are higher and K_2O, SiO_2 and H_2O lower in rocks of granulite facies than in surrounding rocks of the amphibolite facies. The indicated loss of K from rocks of granulite facies is of particular interest because it is a major contributor of crustal radiogenic heat.

This part of the surface of the crystalline Shield probably represents an area of deep continental crust. There are significant differences between the average composition which we have determined for this region and previously published estimates of continental shield composition.

Within New Quebec there are marked regional variations in the distribution of some major elements. Mg in particular shows pronounced variation.

20. PLATINUM IN THE TULAMEEN ULTRAMAFIC COMPLEX, B.C.

D.C. Findlay

One hundred and ten assays of rocks and minerals of the Tulameen complex have been done at the Mines Branch to determine the distribution of platinum in the body. In rocks, Pt. is confined to the principal ultramafic units, dunite (65 to 340 parts per billion, mean 85 p.p.b.), olivine pyroxenite (65 p.p.b. to 170 p.p.b., mean 59 p.p.b.), and hornblende pyroxenite (detected in only 2 of 10 samples, mean 45 p.p.b.). Platinum group metals were not detected in the gabbroic rocks of the complex. In minerals, Pt. occurs mainly in massive chromite of dunite (100 to over 8,000 p.p.b.) and in lesser amounts in magnetite of hornblende pyroxenite (130 to 520 p.p.b.). In chromite, Pt. is concentrated in magnetic fractions of samples up to 20 times that of non-magnetic fractions.

21. PREPARATION OF AN ULTRABASIC REFERENCE ROCK SAMPLE FOR LABORATORY USE

J.A. Maxwell

The picrite, crushed and ground to pass through a 150-mesh screen, was split into fourteen approximately 10-pound lots and each lot was mixed thoroughly in a Patterson-Kelley dry blender. Each lot was then split with an automatic revolving splitter into 100-gram quantities.

One 100-gram split was taken from each 10-pound lot, and nine 100-gram splits from one 10-pound lot. These were analyzed in replicate for Si, Al, Fe, Ca, Mg, K, Ti and Mn with the ARL X-ray spectrograph. Statistical treatment of the data showed that the material was homogeneous within the 10-pound lot but not from lot to lot.

The splits were combined again and, with the assistance of the Mines Branch, the whole was rolled in a large drum and split this time into 16 lots. A similar series of homogeneity tests were made and the material found to be satisfactorily homogeneous, at least as concerns the distribution of the major and minor elements.

Further analyses, by different methods, are being made, including the determination of the trace elements by emission spectrography.

22. THE CONTACT METASOMATIC MAGNETITE DEPOSITS OF SOUTHWESTERN BRITISH COLUMBIA

D.F. Sangster

Ore zones, skarn, host rocks, and associated intrusions of twelve magnetite deposits were studied in both field and laboratory to determine their mineralogical and geochemical characteristics, origin of the iron, and factors controlling emplacement of iron-bearing minerals. The study seeks a better understanding of the origin and mode of occurrence of contact metasomatic magnetite deposits which in turn may provide better guides to their exploration and evaluation.

Skarn in the coastal British Columbia region is composed mainly of garnet (andradite-grossularite), pyroxene (diopside-hedenbergite), epidote, and magnetite. Conformity to Gibbs Phase Rule and the non-appearance of incompatible phases is strong evidence that equilibrium was attained during skarnification. Magnetite is the major metallic mineral but chalcopyrite, pyrite, pyrrhotite, and arsenopyrite are locally abundant.

The temperature of intrusion is estimated to be in the range 800-900°C and stability relations of coexisting minerals indicate a temperature of 700-550°C during skarnification. The pyrite-pyrrhotite geothermometer applied to eight specimens shows that ore deposition took place within the temperature range 400-550°C. The composition of arsenopyrite coexisting with pyrite and pyrrhotite in one orebody indicates a confining pressure of 2,600 $\pm$ 1,000 bars during ore formation.

A majority of deposits have replaced volcanic rocks near a contact with limestone. Several orebodies have formed entirely in limestone or, rarely, in an adjacent intrusion. Stocks adjacent to the magnetite deposits are generally of intermediate composition but range from gabbro to quartz monzonite. Local folds and faults are important physical ore controls; the presence of limestone is a major chemical control.

The immediate source of iron in these deposits is believed to be nearby intrusions. The ultimate source, however, is very probably underlying volcanic rocks which have been assimilated, in part, by an advancing pluton. Iron is considered to have been derived from plutons adjacent to the orebodies and to have been carried to the sites of deposition as aqueous supercritical solutions of iron chloride. Magnetite was precipitated from the ore-forming fluid by an increase in pH brought about by reaction with limestone.

Changes in the chemical and physical nature of the ore-forming fluid during ore deposition are discussed in terms of temperature, density, pH, partial pressures of oxygen and sulphur, and composition. Hydrothermal processes operative in formation of the deposits were solvate apposition, metasomatism, and cavity filling.

The author proposes that the process by which skarn is formed be called skarnification i.e. the replacement by, conversion into, or introduction of skarn. The term would include all processes by which skarn may be formed such as contact metamorphism, contact metasomatism, or regional metamorphism.

23. DETERMINATION OF THE PLATINUM METALS AND THORIUM IN METEORITES

J.G. Sen Gupta

Arsenazo III has been used as a very sensitive and selective reagent for the colorimetric determination of palladium in mixtures of palladium, platinum, rhodium and iridium separated from meteorites by ion-exchange technique. The use of the reagent has also been extended to the determination of trace amounts of thorium in stony meteorites after separating the element from the other base metals by ion-exchange.

In order to determine the relative abundances of the platinum metals and thorium in meteorites two iron and five stony meteorites were decomposed by distillation with perchloric acid in a distillation apparatus. Osmium and ruthenium were determined in the distillate by colorimetric methods. The perchlorates remaining in the distillation flask were evaporated in presence of nitric acid and then converted to chlorides with hydrochloric acid. Work is now in progress on the separation of the remaining platinum metals and thorium from the other base metals in these solutions by ion-exchange procedure for subsequent determinations of these trace elements using appropriate colorimetric reagents.

24. DEFORMATION OF STRAIN SLIP CLEAVAGE BY BEDDING SLIPPAGE IN BAY D'ESPOIR GROUP, NEWFOUNDLAND

F.D. Anderson, D.K. Norris

The Bay d'Espoir Group consists largely of slate and siltstone and their metamorphic equivalents. The strata are of Mid-Ordovician (?) age and best exposed around Bay d'Espoir in southern Newfoundland.

Structurally the Group may be divided into three zones: (1) a northern zone characterized by folded strata and subhorizontal cleavage, (2) a central, relatively undisturbed zone, and (3) a southern faulted and metamorphic zone.

Studies in the northern zone indicate that the rocks have undergone several stages of deformation. The strata are intensely folded and everywhere transected by a subhorizontal cleavage along which there has been subsequent movement.

Plate I is a photograph of an outcrop of slate and siltstone displaying subhorizontal cleavage about 1 1/2 miles southwest of Milltown on the east side of Bay d'Espoir. The outcrop illustrates a probable history of: (1) folding, (2) development of subhorizontal cleavage, and (3) subsequent movement parallel to the cleavage, with the detachment of the siltstone bed from the enclosing slate.

Truncation of the cleavage in the siltstone at its interfaces with the slate would suggest that these interfaces served as deformation discontinuities separating two mechanically distinct forms, a shear fold in the slate and a flexural-slip fold in the siltstone. The folds appear to have formed simultaneously and after the cleavage was imposed on the rock.

Measurements were made of the rotation of the cleavage in the siltstone as a function of the corresponding rotation of the bed in the axial region of the fold (see Fig. 1). The fundamental reference line for bed rotation is the projection into the photograph (Plate I) of the upper limb of the fold and the zero point is arbitrarily chosen as the point at which the bed deviates from this planar position. Cleavage rotation is measured by the acute angle between the two cleavages in the two media. Counterclockwise rotation (as viewed) is considered positive.

The measurements of the rotation were then plotted (Fig. 2). The results show that the relation between bedding and cleavage rotation is apparently linear in the axial region of the fold, has a slope of 0.67 there and intersects the cleavage rotation axis at -5 degrees. The data would suggest that in this region cleavage rotation is therefore proportional to bed rotation and had an initial value of about 5 degrees measured in the opposite sense (clockwise) from parallelism with the cleavage in the slate.

The cleavage rotation appears to be the net result of external rotation of the bed (counterclockwise as viewed in Plate I) and internal rotation (clockwise) within the bed. However, cleavage rotation due only to external rotation (in response to shear folding in the slate) should be equal

Plate I. Strain slip cleavage in interbedded slate and siltstone of the Bay d'Espoir Group.

in magnitude and sense to bed rotation and the relation between them should be a straight line with a slope of one. But the slope of this relation is less than one, indicating that the cleavage rotation at any point is smaller than anticipated for simple external rotation. The difference in ordinates for a given bed deflection is therefore a measure of the magnitude of the internal rotation.

The data are therefore consistent with the two types of folds formed contemporaneously in the same rock mass. The cleavage surfaces in the slate was actively involved in shear folding, those in the siltstone were passive and served only to facilitate rotation of successive cleavage plates.

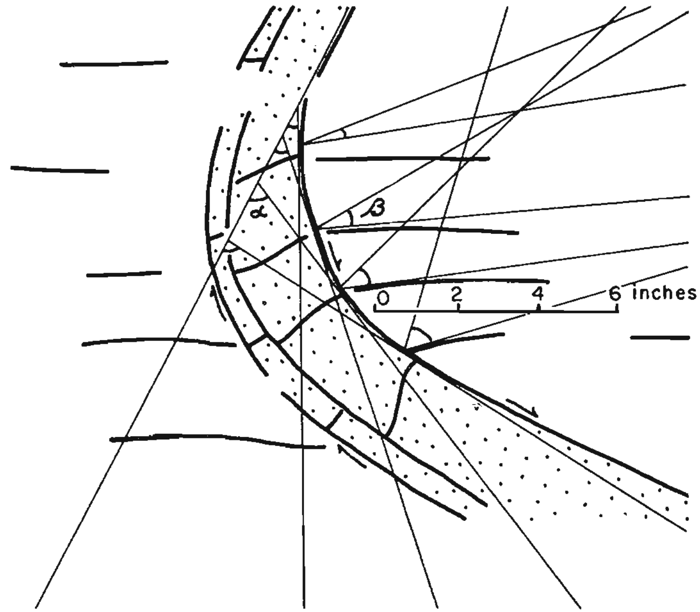


Figure 1

Sketch of Part of Fold, Showing Points where Bed Rotation (α) and Cleavage Rotation (β) were Measured

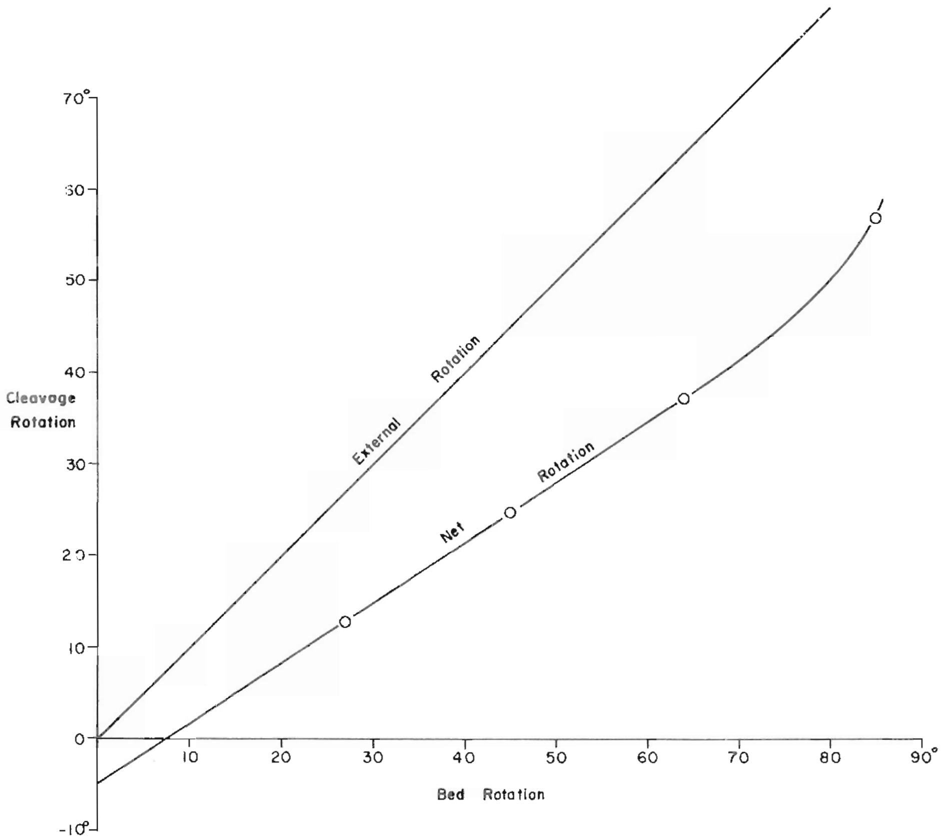


Figure 2

Relation between Cleavage and Bedding Rotation

REGIONAL AND STRUCTURAL STUDIES

25. CANOE RIVER WEST HALF (83 D W 1/2) MAP-AREA, BRITISH COLUMBIA

R.B. Campbell

A section of an earlier report dealing with the geology of the Canoe River area (see Campbell in Jenness, 1965, pp. 43-46) was unintentionally omitted. The following is supplementary to the earlier report and should be read in conjunction with it.

As mentioned in the earlier report the region may be divided into two systems in terms of structural geology; the Shuswap Metamorphic Complex and the folded Kaza and Cariboo Groups. The contacts between the two systems are not clear cut and require further study. The Shuswap Metamorphic Complex, irrespective of the age of the rocks within it, displays a unique structural style featuring recumbent folds and approximately east-west axial trends. In the second system folds vary from isoclinal to relatively open structures mainly with distinct northwesterly axial trends.

The structure of the Kaza and Cariboo Groups, exclusive of that part east of North Thompson River, can be discussed in relation to three major structural axes, two "fan axes" and an antiformal axis. The term "fan axis" signifies an axis or zone in which foliation and fold axial planes are vertical and on either side of which the foliation and axial planes dip inward; that is, the foliation on one side dips toward the axis, steepens and becomes vertical at the axis, and assumes the opposite dip beyond it.

Northeast of the "fan axis" along North Thompson and Raush Rivers the strata of the Kaza Group are isoclinally folded and become progressively more metamorphosed toward the northeast until they reach the kyanite zone. Both the foliation and axial planes are warped across the antiformal axis north of Canoe River and both pass through the more northeasterly "fan axis" beyond which they maintain a southwesterly dip to the edge of the Rocky Mountain Trench.

On the "fan axis" along North Thompson and Raush Rivers folds in the Kaza Group are nearly isoclinal and have a strong axial plane cleavage. To the northeast in the isoclinal folds foliation and compositional layering are parallel. To the south folds have northeast dipping axial planes, one steep limb and one flat limb, and well developed axial plane cleavage. Still farther south strata of the Cariboo Group are deformed into much attenuated isoclinal folds with northeast dipping axial planes and here again foliation and compositional layering tend to be parallel.

In the Kaza Group east of North Thompson River folding is isoclinal and locally recumbent.

The direction of tectonic transport in the folded rocks between the two "fan axes" could not be determined. It seems, however, that one or other of the axes, or the general area between them, is an important structural axis that marks a zone across which the direction of tectonic transport changes on a regional scale. To the west tectonic transport in the Kaza and Cariboo Groups is to the southwest whereas on the opposite side structures, including those in the Rocky Mountains, are directed to the northeast.

LEGEND

MESOZOIC CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

9 Glacial deposits; alluvium

TERTIARY, PLEISTOCENE, AND RECENT

8 Basaltic flows, cinder cones, and fragmental deposits

CRETACEOUS OR EARLIER

7 7a, biotite quartz monzonite; 7b muscovite-biotite granite

PALAEOZOIC

CAMBRIAN OR LATER

LOWER CAMBRIAN OR LATER

CARIBOO GROUP (4 to 6)

6 YANKEE BELLE FORMATION: slate, phyllite, and quartzite

LOWER CAMBRIAN

5 CUNNINGHAM LIMESTONE: grey and buff marble; may include some carbonate units of Isaac Formation

LOWER CAMBRIAN OR EARLIER

4 ISAAC FORMATION: 4a, phyllite, schist, marble, quartzite, slate, and limestone; 4b, garnet, staurolite, and kyanite mica schist, quartzite, and marble; may include undifferentiated Yankee Belle Formation

PRECAMBRIAN

WINDERMERE

KAZA GROUP (equivalent to Miette Group)

3 3a, quartzite, micaceous and garnetiferous quartzite, garnet, staurolite, and kyanite mica schist; minor marble and metaconglomerate; 3b, micaceous marble, minor schist (may be equivalent to units 4 or 5); 3c, quartzite, commonly feldspathic and gritty, phyllite, schist, and minor conglomerate

MIETTE GROUP (equivalent to Kaza Group)

2 Phyllite (locally garnetiferous), slate, quartzite, grit, conglomerate, and limestone

AGE UNKNOWN

SHUSWAP METAMORPHIC COMPLEX

1 1a, quartz-feldspar-biotite gneiss, quartzite, amphibolite, mica schist (locally garnetiferous) marble, lime-silicate gneiss; includes much pegmatite; 1b, grey and buff marble; 1c, quartz-hornblende gneiss, amphibolite, quartzite; minor staurolite and garnet mica schist

Geological contact (defined, approximate or assumed)

Foliation (approximates axial planes of folds) (inclined, vertical)

Lineation (approximates fold axes) (plunging, horizontal)

Fault (approximate or inferred)

Thrust fault, approximate

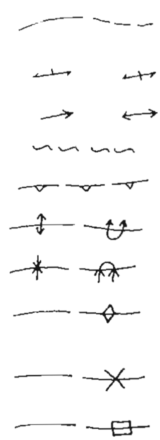
Anticline (upright, overturned)

Syncline (upright, overturned)

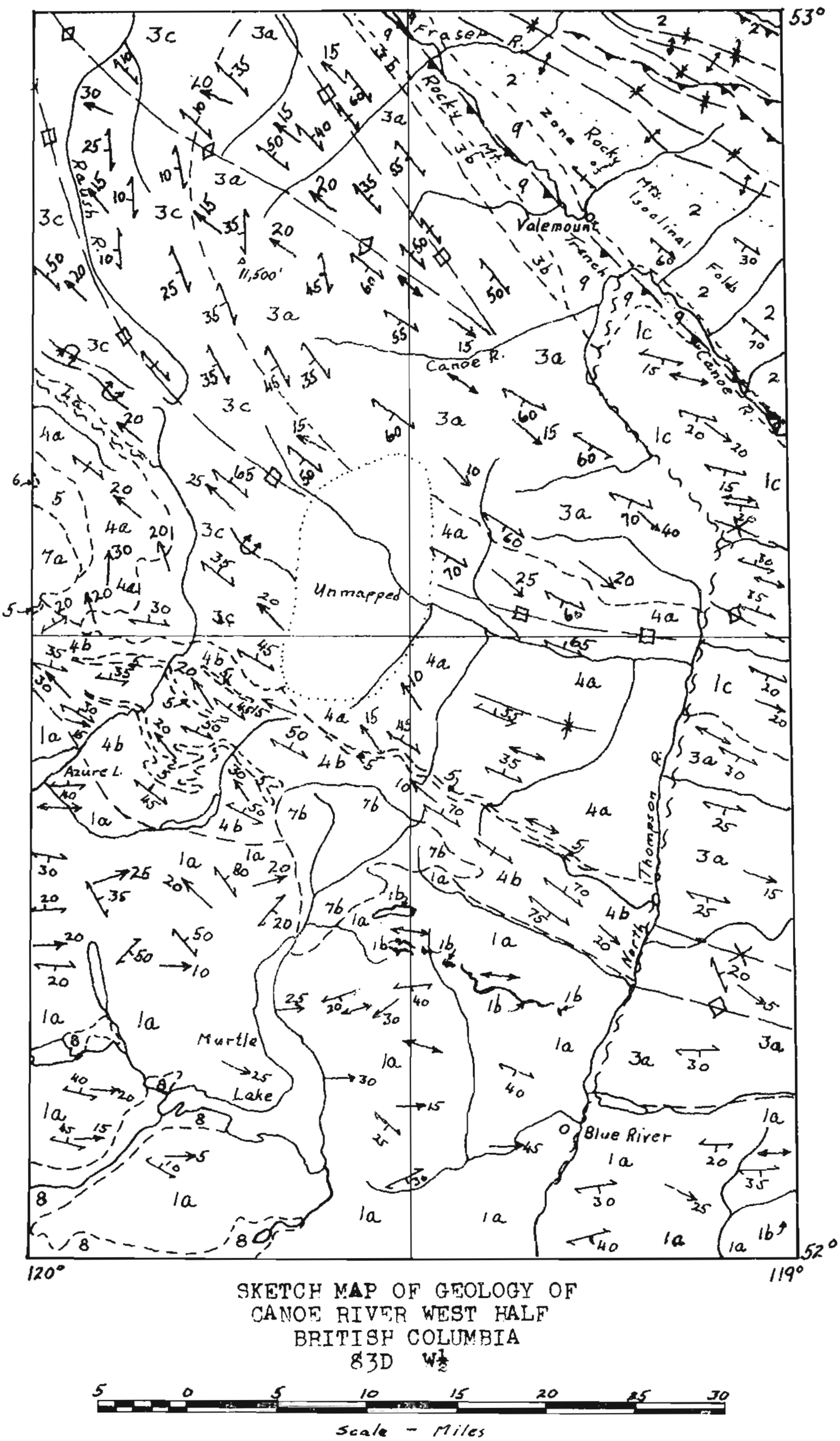
Antiform (fold in foliation and axial planes of older folds)

Synform (fold in foliation and axial planes of older folds)

Fan axis



Geology by R.B. Campbell, 1963 and R.B. Campbell and E.W. Mountjoy, 1964



SKETCH MAP OF GEOLOGY OF
CANOE RIVER WEST HALF
BRITISH COLUMBIA
83D W½

Scale - Miles

The part played by the gneisses of the Shuswap Metamorphic Complex in the regional structural development is not understood. The unique structural character of the gneisses suggests that they were in their present condition prior to the deformation of the Kaza and Cariboo Groups but nevertheless they were involved in younger deformation at least to the extent that they were thrust eastward across the Rocky Mountain Trench and over the Miette Group and younger rocks in the Rocky Mountains east of the map-area. Miette Group strata adjoining the thrust are intensely deformed and altered to staurolite schist.

Within the map-area and in the map-area to the east (Canoe River E 1/2) the Rocky Mountain Trench marks, approximately, the locus of a fault along which rocks on the southwest are thrust northeastward. In the map-area to the east the fault locally leaves the Trench. No evidence was noted which would suggest extensive lateral movement.

Jenness, S.E.
1965: Report of Activites: Field, 1964; Geol. Surv. Can., Paper 65-1.

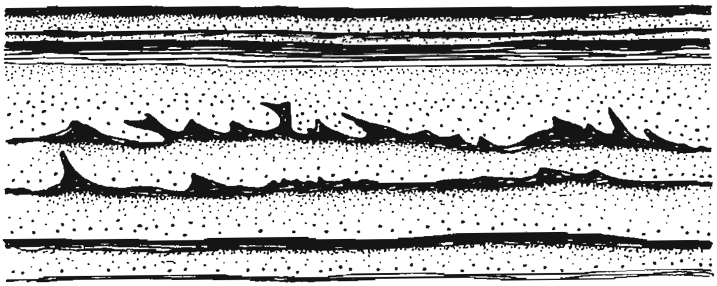
26. ARCHAEAN SEDIMENTARY ROCKS OF NORTHWESTERN ONTARIO

J.A. Donaldson, G.D. Jackson

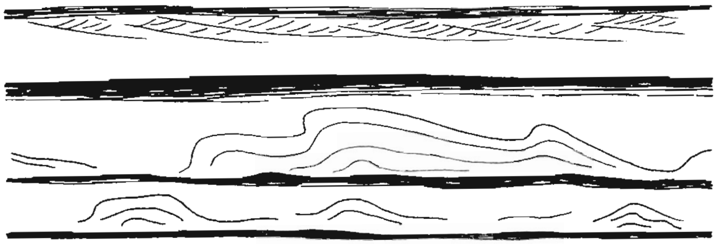
This study was initiated to evaluate provenance for Temiskaming-type clastic sediments in Archaean metasedimentary-metavolcanic belts of the Superior Province. Most attention was directed to arenaceous sediments that form about 60 per cent of the Archaean sedimentary sequence at North Spirit Lake, but additional data were collected for other areas between Red Lake and Lansdowne House. Most of the arenites are interbedded with argillites in thick sequences characterized by grain gradation. Primary structures in the graded beds suggest turbidity current origin, and hold promise for palaeocurrent determinations (Fig. 1). Phenoclasts in conglomerates were studied in some detail because, representing large samples of source rocks, they yield textural and structural information not obtainable from a study of the finer-grained clastic rocks. In an effort to stress quantitative rather than qualitative data, the concept of modal analysis was extended to megascopic determination of volumetric abundances for glacially-smoothed outcrops of conglomerate.

Many sandstones in the North Spirit area can best be termed quartz greywackes on the basis of a matrix content greater than 15 per cent and abundance of clastic quartz grains in the framework (Plate IA). Relatively calcareous sandstones are locally abundant, and textural data for such rocks supports primary origin for the carbonate rather than "carbonatization". Sand-sized clastic quartz composes more than 30 per cent of the total sequence of Temiskaming-type sediments and similar abundances hold for clastic sediments of nearby belts. Much of the silt-sized quartz in the sandstones and associated argillites may have been derived by comminution of larger quartz grains.

These data have implications with regard to geologic history in the Archaean. Temiskaming-type sediments commonly are characterized as the products of rapid erosion of rising volcanic arcs, and belts of Keewatin-type volcanic rocks have been regarded by some workers as relics of proto-continents. It has been recently argued that granitoid rocks of batholithic dimensions were non-existent prior to deposition of "Temiskaming" sediments, and the scarcity of phenoclasts of granitoid rocks in Temiskaming-type conglomerates has been cited in support of this concept. Our study has substantiated scarcity of granitoid phenoclasts in conglomerates of the North Spirit area, but we regard this merely as the outcome of proximity of source rocks to the site of deposition. We propose a model consisting of a depositional basin flanked by volcanics, with granitoid rocks (and probably older sedimentary rocks) exposed in abundance beyond the proximal volcanic terrain. For such distribution, volcanic rocks would provide coarse detritus, and the granitoids (plus older sedimentary rocks?) would contribute large volumes of sand- and silt-sized detritus, but, following Sternberg's law, relatively few cobbles and boulders. This model satisfactorily explains our petrographic data, whereas a source terrain consisting essentially of volcanic rocks does not. Basic volcanics, the most abundant Keewatin-type rocks, contain virtually no quartz, and the less abundant associated acid volcanics could have supplied significant amounts of quartz sand only under conditions of extremely rigorous weathering (quartz-phenocrysts of sand size compose less than 10 per cent of the porphyritic volcanics which in turn



A. Flame structures in the upper parts of graded greywacke - argillite couplets. Asymmetry indicates transport towards the left.

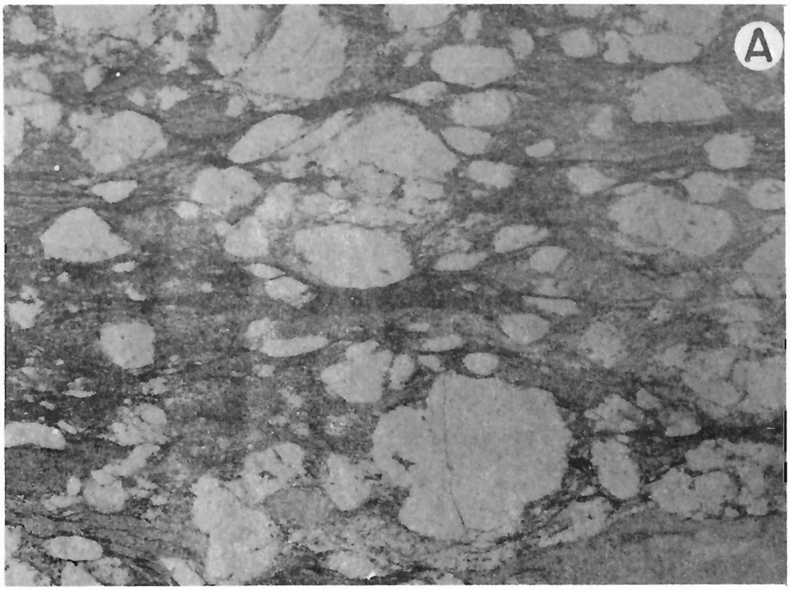


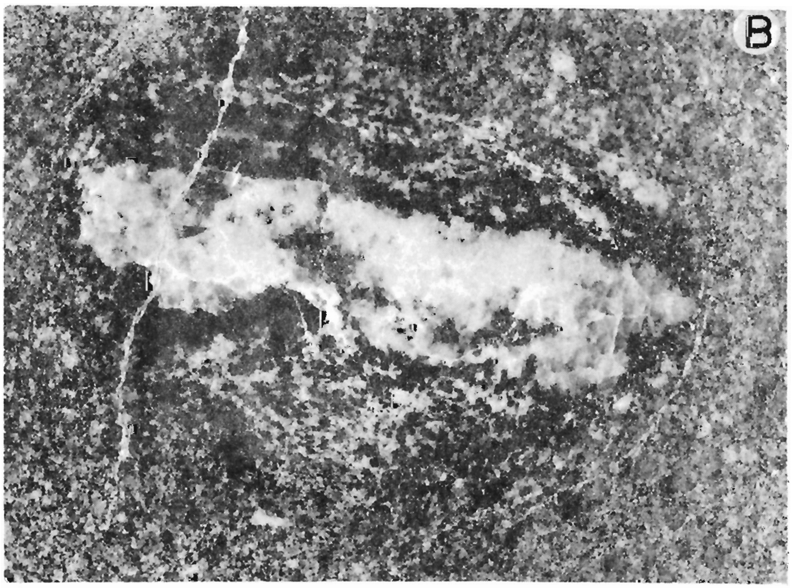
B. Two successive beds showing convolute lamination, capped by a bed showing ripple-drift crossbedding. Both types of structure indicate transport towards the left.

C. Graded bed showing sole marks (probably groove casts) and festoon crossbedding. The section is transverse to the direction of transport.

1 METRE

Figure 1. Primary structure in outcrops on the shore of South Bay. North Spirit Lake. All sections are perpendicular to bedding.


A


B

compose less than 10 per cent of the acid volcanic rocks). The chemical analysis of a typical argillite shows a potash content of 3.4 per cent and a magnesia content of only 0.5 per cent, suggesting that even the fine-grained sedimentary detritus was not derived primarily from basic volcanic rocks.

A few distinctly layered migmatite pebbles were found in some conglomerates (Plate IB). Regardless of their scarcity, the presence of such pebbles indicates earlier orogeny. The "Laurentian" problem, centring around the premise of major unconformity between the volcanic and sedimentary rocks, is resolved by rejecting the premise in favour of a volcanic-sedimentary sequence with orogeny (and granite emplacement) preceding volcanism. The concept of multiple orogenies involving and separating successive "Keewatin-Temiskaming" pairs appears more acceptable than the classical concept of post-"Keewatin", pre-"Temiskaming" (i.e. "Laurentian") orogeny.

27. GEOLOGY OF NORTHWESTERN PICTOU COUNTY, NOVA SCOTIA

J.W. Gillis

The main purposes of this study were 1) to map and describe the field occurrence, and 2) determine the mineral composition of the Upper Palaeozoic sedimentary rocks of northwestern Pictou county, and 3) use the results in deciphering the details of the stratigraphy and geological history of the map-area[1]. Geological mapping, at a scale of one inch to one mile, and laboratory work were included in the investigation. Samples were collected from the detrital units of the map-area, and the mineral composition was measured by point-count techniques.

The metamorphic and igneous rocks of the pre-Carboniferous Cobequid Complex constitute the oldest rocks of the map-area (Fig. 1). The overlying Upper Palaeozoic section consists of the Devonian and Mississippian (?) River John Group[2], the Mississippian Windsor Group, the Mississippian and (or) Pennsylvanian Canso Group, the Millsville Conglomerate and the Boss Point Formation of the Pennsylvanian Riversdale Group, the New Glasgow Conglomerate of the Pennsylvanian Cumberland Group, and the Pennsylvanian Stellarton and Pictou Groups. Minor felsite and diabase dikes, which are intrusive into the Upper Palaeozoic strata, comprise the Carboniferous and (or) post-Carboniferous intrusive rocks.

The dominant structural features of northwestern Pictou county are the eastern end of the Cobequid massif, the broad northeast-plunging Scotsburn anticline, and two high-angle faults, the West River fault and the Loganville fault.

The detrital units below the Millsville Conglomerate are low rank greywackes, whereas the Millsville is a typical arkose, and the units above the Millsville are impure arkoses.

The change in mineral composition from the River John and Canso Groups, which contain abundant sedimentary and metasedimentary rock fragments and minor quartz-feldspar rock fragments and feldspar, to the Millsville and younger units, which contain relatively abundant granitic rock fragments and feldspar and less common sedimentary and metasedimentary rock fragments, reflects the unroofing of a plutonic igneous source area. The mineral composition of the Upper Palaeozoic strata, particularly the arkosic Millsville Conglomerate and the feldspathic younger units, and the abundance of coarse detrital rocks are typical of the sedimentary rocks derived from a post-geosynclinal terrane.

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[1] Gillis, J.W.: Geology of northwestern Pictou county, Nova Scotia, Canada; unpub. Ph.D. thesis, The Pennsylvania State Univ., University Park, Pennsylvania (1964).

[2] Kelley, D.G.: Cobequid Mountains; in Jenness, S.E., Compiler, Report of activities: Field, 1964; Geol. Surv. Can., Paper 65-1, pp. 125-127 (1965).

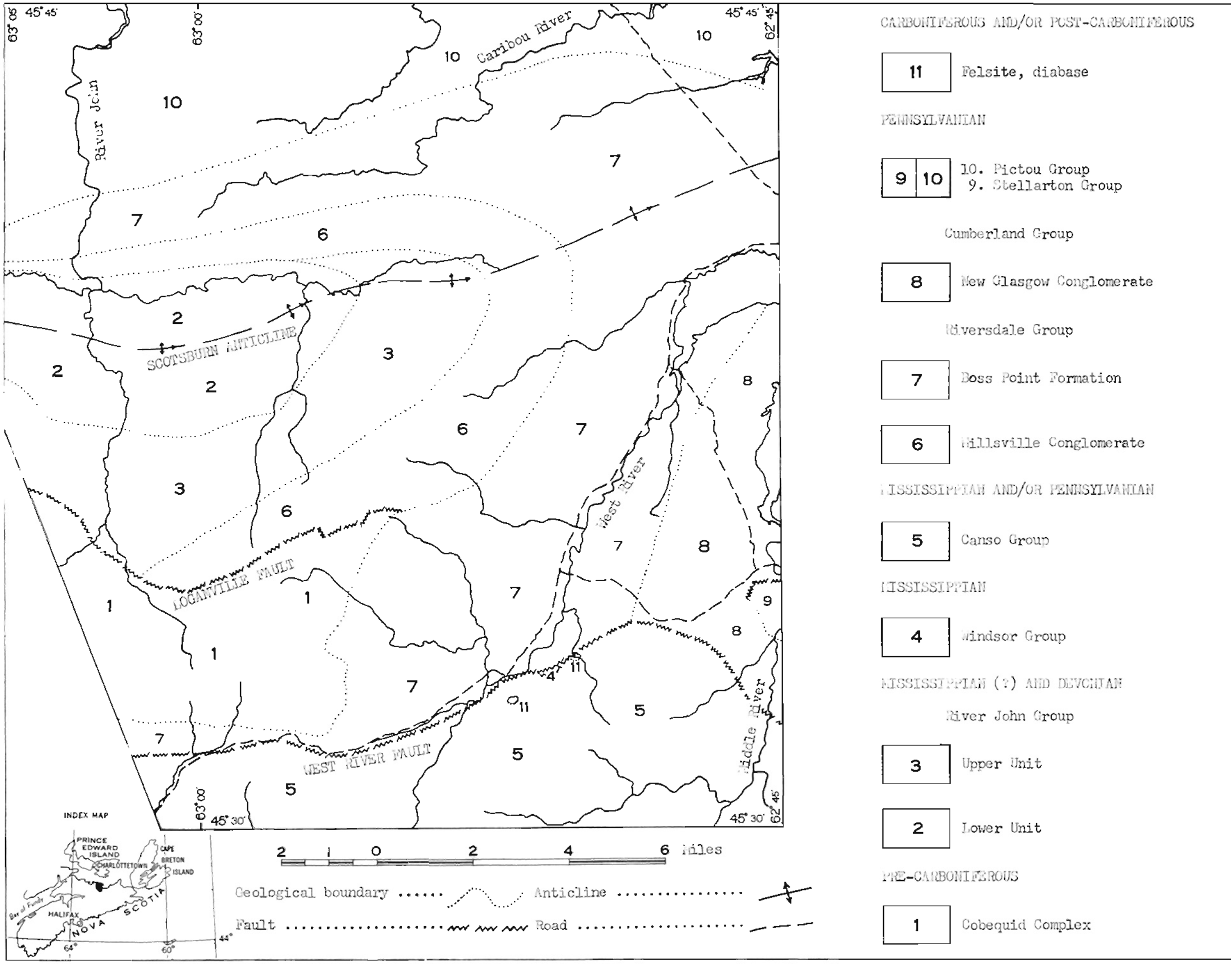

River John
Caribou River
West River
Middle River
SCOTSBURN ANTICLINE
LOGANVILLE FAULT
WEST RIVER FAULT
63°05'
45°45'
63°00'
62°45'
45°30'
INDEX MAP
PRINCE EDWARD ISLAND
CHARLOTTETOWN
CAPE BRETON ISLAND
HALIFAX
NOVA SCOTIA
Bay of Fundy
64°
60°
44°
2 1 0 2 4 6 Miles
Geological boundary
Anticline
Fault
Road
CARBONIFEROUS AND/OR POST-CARBONIFEROUS
11 Felsite, diabase
PENNSYLVANIAN
9 10 10. Pictou Group
9. Stellarton Group
Cumberland Group
8 New Glasgow Conglomerate
Riversdale Group
7 Boss Point Formation
6 Millsville Conglomerate
MISSISSIPPIAN AND/OR PENNSYLVANIAN
5 Canso Group
MISSISSIPPIAN
4 Windsor Group
MISSISSIPPIAN (?) AND DEVONIAN
River John Group
3 Upper Unit
2 Lower Unit
PRE-CARBONIFEROUS
1 Cobequid Complex

FIGURE 1

The development of coarse conglomerates near the Loganville fault indicates that the eastern end of the Cobequid massif was tilted up along the Loganville fault in Middle to Late Devonian or Early Mississippian time, and that movement recurred in Early Pennsylvanian time. The most recent displacement on the fault was post-Early Pennsylvanian. Unconformable relations between some of the units involved in the Scotsburn anticline indicate that the structure was growing during sedimentation. The structure was active in pre-Early Pennsylvanian time and movement recurred in pre-Middle Pennsylvanian time. Latest activity was post-Middle Pennsylvanian. The West River fault is of post-Early Pennsylvanian age; there is no evidence for earlier movement.

28. RIGHT-LATERAL MOVEMENT ALONG THE TINTINA FAULT

J.A. Roddick

A study of the major geologic units bordering Tintina Trench, made as part of a memoir on the Pelly River area, Yukon Territory, indicates a right-lateral movement of from 240 to 260 miles. The conclusion is based mainly on the apparent offset of a distinctive, thick, late Proterozoic (and Cambrian?), clastic formation, the Yukon Group, a band of greenstone of uncertain age, and with less certainty, on several lesser units. The postulated movement is further supported by the matching offset of different regional trends across Tintina Trench. The age of movement is bracketed by the youngest rocks truncated by the trench (Middle Jurassic shales) and gently deformed, Paleocene rocks that lie in the trench. Poor additional evidence indicates that the movement took place more probably in the upper Cretaceous than earlier.

STATISTICAL ANALYSIS

29. STATISTICAL TECHNIQUES

F.P. Agterberg

During 1964, work was done on the following subjects:

1. Methods of trend analysis
2. Analysis of frequency distributions for trace elements
3. Compilation of statistical techniques for geologic data
4. Development of a stochastic prediction model for mineral deposits.

1. Methods of trend analysis: The reliability of polynomial trend surfaces for mineral composition data and specific gravity of the Mount Albert Peridotite Intrusion, Gaspé, Quebec, was tested in several ways:

A. Method of partial correlation coefficients
B. Duplicate trend surface analysis
C. Confidence intervals on trend surfaces
D. Experiments on an artificial trend surface with autoregressive residuals
E. Three dimensional trend analysis for specific gravity data.

These methods were reported on the 4th International Computer Symposium at Golden, Colorado, in April, 1964 (Transactions, Col. School Mines, Quart., vol. 59, pp. 111-130).

2. Frequency distributions: About 1,000 determinations for each of nine trace elements from the Muskox Intrusion were statistically analysed.

A. Regression curves were computed for the relationship between rock type means and standard deviations for the elements.
B. One-way variance analysis to test the equality of sub-group means for the rock types was applied using two independent classifications for the sub-groups.
C. Information statistics such as the entropy and the discriminator I were computed for two configurations of frequency class interval. This is similar to techniques recently applied by Vistelius method.
D. Part of the problem of analyzing truncated frequency distributions was approached by using maximum entropy estimators as developed by Tribus.
E. Experiments with random normal numbers generated by an IBM Monte Carlo method were made to simulate the growth of frequency distributions with time.

These techniques were reported at the Computer Symposium at Tucson, Ariz., in March 1965 (Transactions, vol. 1, pp. G1-33).

3. Statistical Techniques: Table 1 represents some methods for analyzing geologic data. Explanatory notes are given in a paper entitled: 'Statistical techniques for geologic data' (Tectonophysics, vol. 1, pp. 233-255, 1964).

4. Stochastic prediction model: Figure 1, left hand side, shows elements which are randomly distributed throughout a matrix. Figure 1, right hand side, represents elements which are subject to a certain amount of clustering (autoregressive Poisson Model). In many instances, Figure 1B will provide the more realistic model. The clustering can be studied by

autocorrelation functions. Formulas for the relationship between the variance of the number of elements to be expected in a certain volume V and the size of V have been developed. This model was presented on the 8th Commonwealth Mining and Metallurgical Congress, Melbourne, Australia in March, 1965 (Transactions No. 2, pp. 23-28).

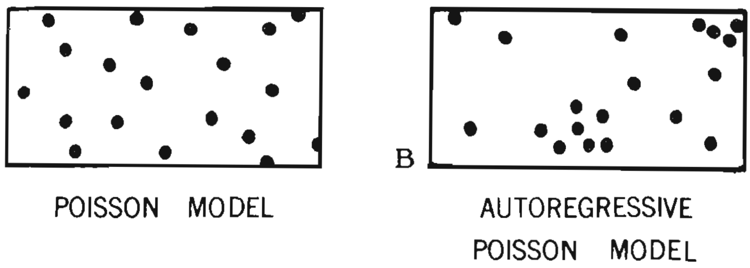
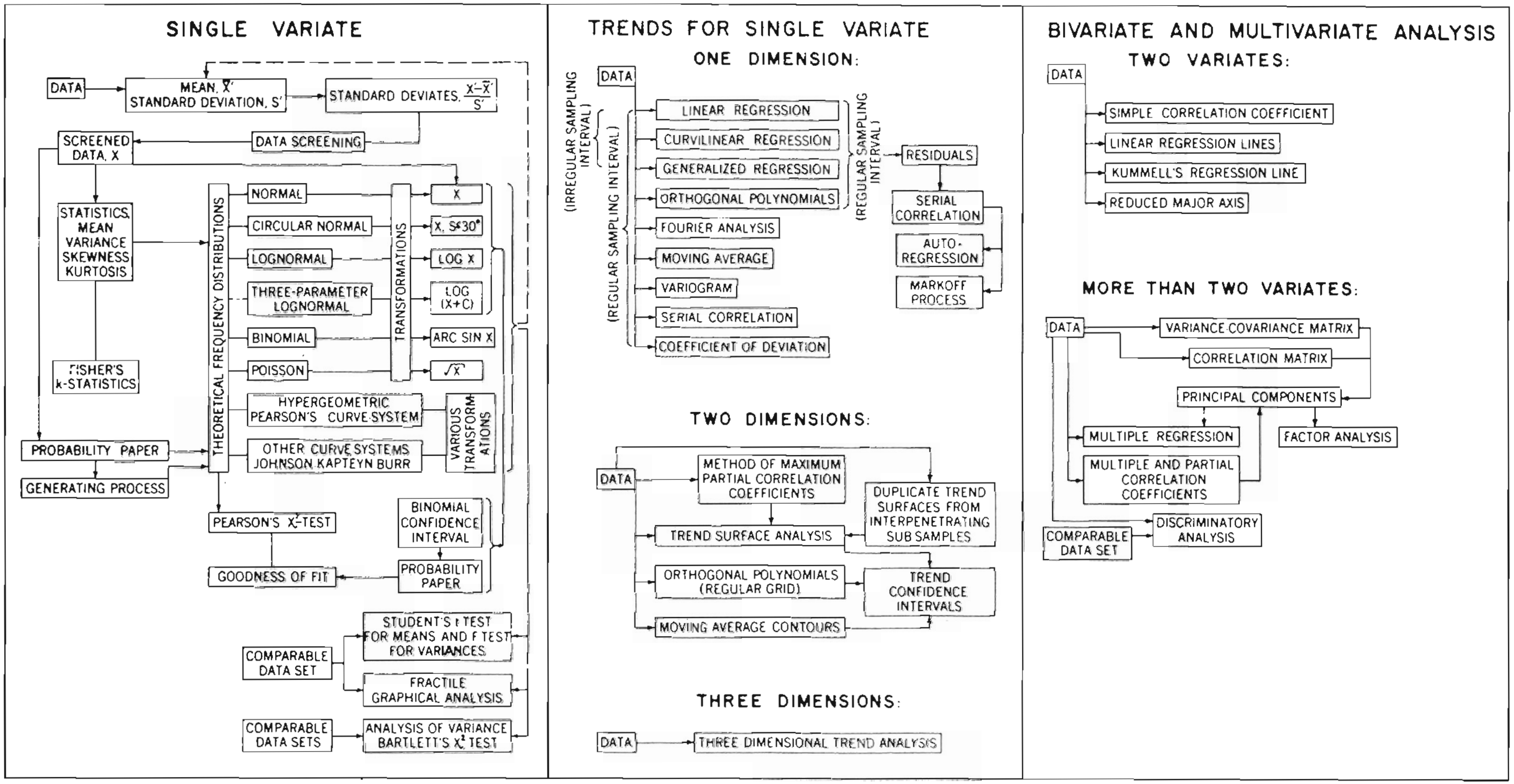


Figure 1. The Poisson model (1A) represents elements randomly distributed throughout a matrix. The elements are clustering in case of the autoregressive Poisson model (1B).

TABLE I

Some statistical techniques for geological data



STRATIGRAPHY, PALAEONTOLOGY AND COAL PETROGRAPHY

30. CAMBRIAN STRATA OF THE EASTERNMOST SOUTHERN ROCKY MOUNTAINS AND THE ADJACENT SUBSURFACE, ALBERTA

J.D. Aitken

The Cambrian of the easternmost Rocky Mountains and adjacent Plains comprises five depositional cycles, each commencing with fine clastic rocks and ending with carbonate rocks. With one exception, the carbonate facies belt for each successive cycle shifted progressively northeastward, following the general Cambrian marine transgression.

Lithologic analogues of the Lower Cambrian Gog Group of the Mountains, encountered in the subsurface, are younger than the Gog, and are assigned to the basal sandstone unit. The Mt. Whyte Formation is recognized only where the Cathedral Formation can be delineated; beyond the facies edge of the Cathedral carbonate rocks, the lower fine clastic unit, similar in lithology to the Mt. Whyte and Stephen Formations, is equivalent to the sequence Mt. Whyte - Cathedral - Stephen (Fig. 1). Carbonate rocks of the Eldon Formation extend beyond the Cathedral limit to the northeast, but eventually pass into the lower fine clastic unit. The Pika Formation, youngest of the Middle Cambrian formations, is remarkable for its uniform and widespread development; carbonate rocks of the Pika extend beyond the limit of the Eldon.

The Arctomys and Waterfowl Formations are clearly recognizable in Foothills wells, but no lithologic equivalents are known in the Plains subsurface, and time-equivalents are thought to be missing, as illustrated in Figure 1. Lithologic and at least partial time-equivalents of the Sullivan Formation in the Plains subsurface are assigned to the upper fine clastic unit. The Sullivan and the upper fine clastic unit are overlain by mainly carbonate rocks of the upper division of the Lynx Group. The upper Lynx is overlain nearly everywhere by basal Devonian rocks, except in eastern Alberta, where thin Lower Ordovician deposits may be present.

Aitken, J.D.
(in press): Sub-Fairholme Devonian rocks of the Eastern Front Ranges, southern Rocky Mountains, Alberta; Geol. Surv. Can., Paper 64-33.

Aitken, J.D., and Greggs, R.G.
(in press): Upper Cambrian Formations, southern Rocky Mountains of Alberta, an interim report; Geol. Surv. Can., Bulletin.

van Hees, H.
1964: Cambrian, Part I - Plains, in Geological History of Western Canada; Alta. Soc. Petrol. Geol., Calgary, pp. 20-28.

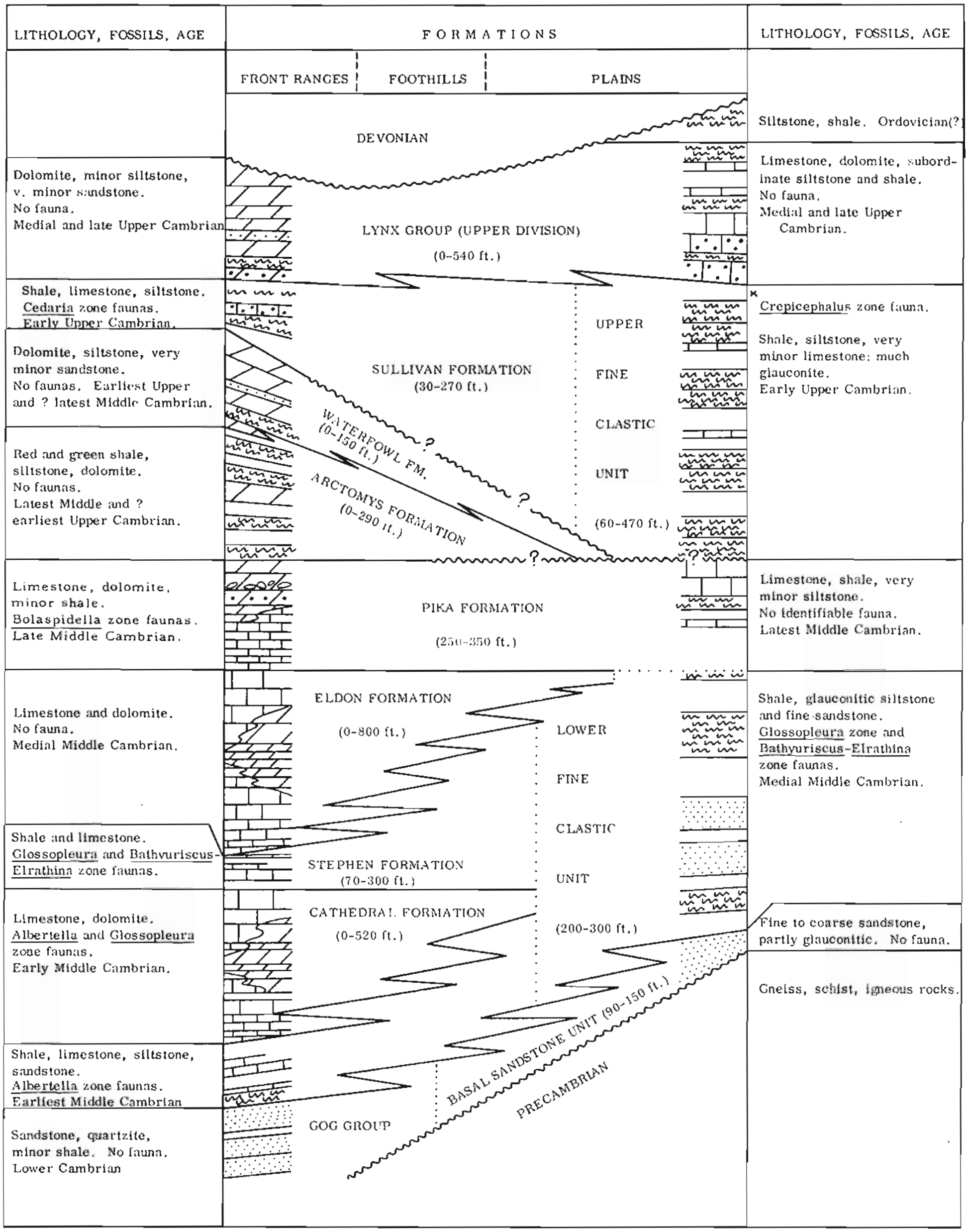


Figure 1. Table of Cambrian formations for the eastern Front Ranges, Foothills, and Plains of southern Alberta.

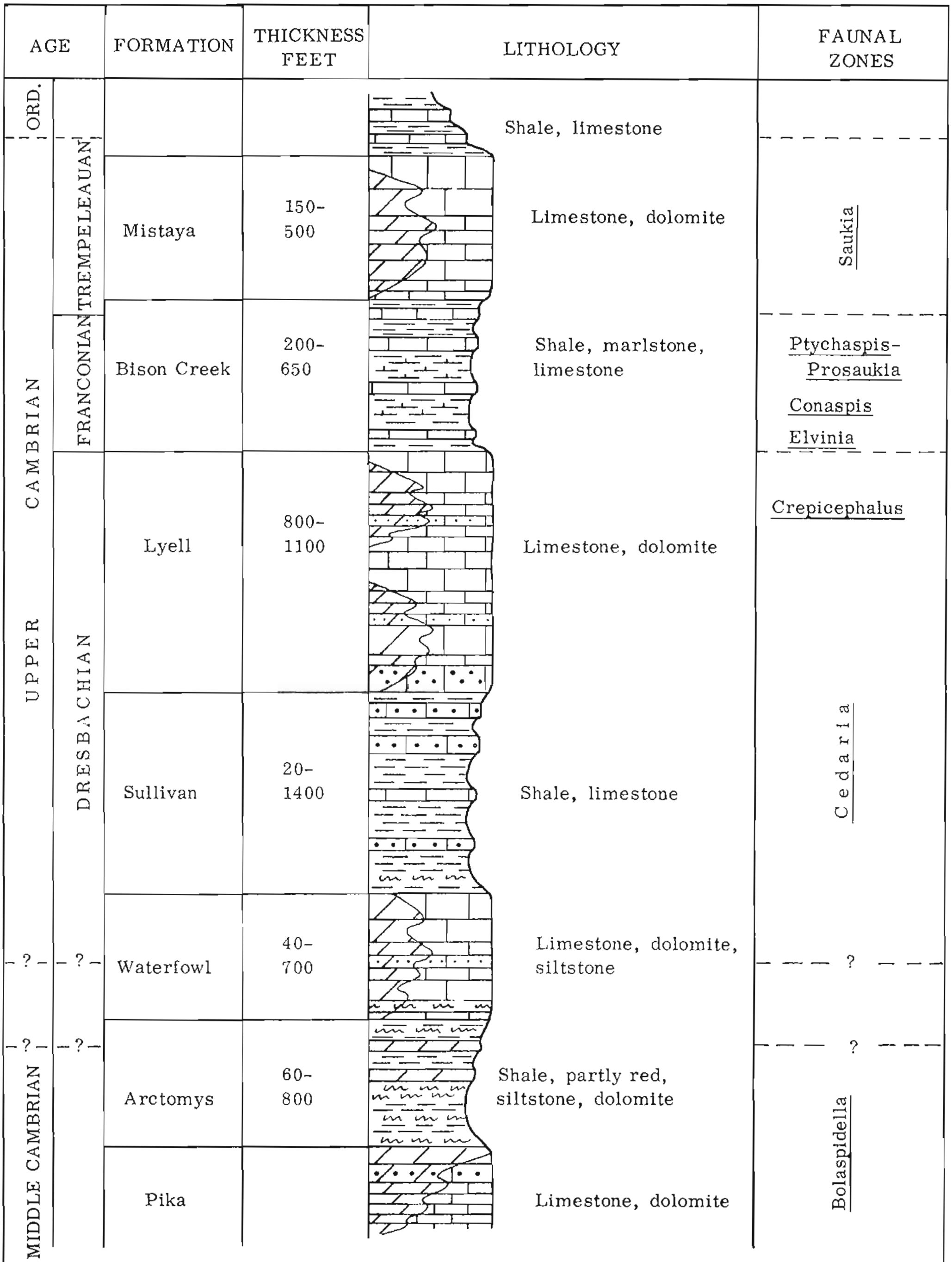


Fig. 1. Upper Cambrian sequence, Southern Rocky Mountains, Alberta

31. UPPER CAMBRIAN FORMATIONS, SOUTHERN ROCKY MOUNTAINS OF ALBERTA

J.D. Aitken, R.G. Greggs

The revised Upper Cambrian Series of the southern Rockies of Alberta is summarized in Figure 1. The series comprises three cycles of deposition (Arctomys-Waterfowl, Sullivan-Lyell and Bison Creek-Mistaya). Each cycle begins with the sudden appearance of shales above a thick carbonate interval. The interbedded shales, limestones and subordinate siltstones of the first half of the cycle grade upward into the carbonate rocks with minor siltstones and sandstones of the second half. Evidence of deposition in very shallow water, such as mud-cracks, ripple-marks, algal stromatolites, pebble conglomerates, oolites and well-sorted calcarenites, is widespread in both shaly and carbonate half-cycles.

The shaly Sullivan and Bison Creek Formations grade northward into carbonate intervals indistinguishable from the bounding Waterfowl, Lyell, and Mistaya Formations. The sequence Waterfowl-Sullivan-Lyell-Bison Creek-Mistaya thus passes into an equivalent, thick, undivided carbonate unit, the Lynx Group (elevated from Lynx Formation). The Lynx Group is divisible into Upper and Lower divisions in the region in which the Sullivan Formation is present but the Bison Creek Formation is unrecognizable (Fig. 2).

The Bosworth, Paget, and Sherbrooke Formations of the Kicking Horse Pass area, the Mons Formation of the Glacier Lake area, the Tangle Ridge Formation of the Sunwapta Pass area and the Ghost River Formation of the eastern Front Ranges are considered obsolete and invalid.

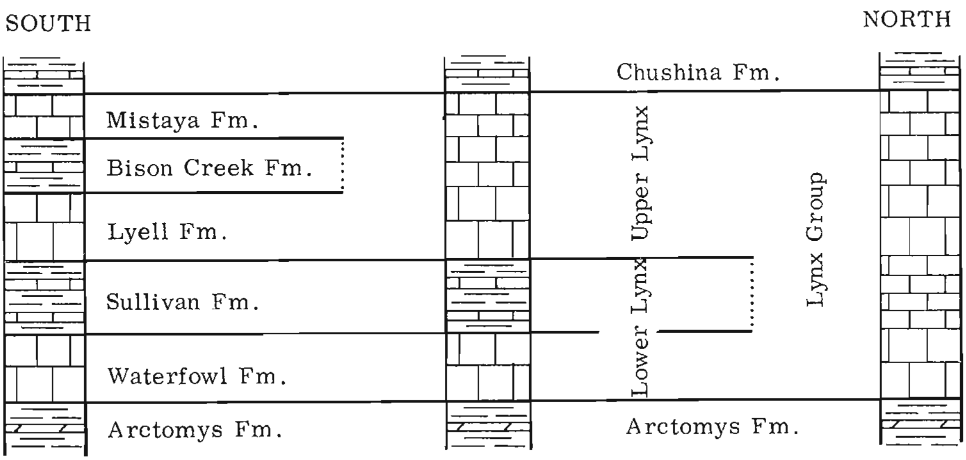


Fig. 2. Stratigraphic relationships of the Lynx Group.

32. STUDIES ON CARBONIFEROUS PALYNOLOGY

M.S. Barss

The miospore studies of the type sections of the various Carboniferous formations in the Maritime Provinces has been continued. Samples examined from the Pennsylvanian Pictou Group indicate that the type section is younger in age than previously considered; it may even extend into the Permian.

Of the many samples submitted during 1964 for a palynological age determination, one sample is worth mentioning. A bore-hole sample from near Walton, N.S. from the Scotch Village Formation, revealed a Westphalian D age for this formation, which was previously considered to be Westphalian A (Riversdale Group).

33. SUBSURFACE STRATIGRAPHY OF DUNVEGAN FORMATION (UPPER CRETACEOUS), WEST-CENTRAL ALBERTA AND ADJACENT BRITISH COLUMBIA

C.F. Burk, Jr.

A widespread electric-log marker horizon equivalent to the top of the Doe Creek sandstone member (Stelck and Wall, 1954, Fig. 4) was correlated throughout the report-area. This marker horizon, located a few feet above the Dunvegan Formation, provides a convenient datum for cross-sections.

The isopach map of the marker-defined interval between the Fish Scales and Doe Creek markers, which embrace sandstones of the Dunvegan Formation, has a dominant north-northeast trend with a minor trend superimposed at right angles. The minor trend is most strongly expressed in the eastern third of the report-area and diminishes westwardly. Possibly it reflects the presence of a surface of erosion near the level of the Fish Scales marker. The overlying marker-defined interval between the Second and First White Specks markers, which has a dominant northwest trend, lacks any such superimposed minor trend.

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

A.R. Cameron, S.K. Babu

For this continuing project two column samples of a low volatile coal seam have been examined. As the seam is over 50 feet thick, its petrographic study required the preparation and microscopic examination of several hundred polished sections and grain mounts. Based on detailed megascopic and microscopic examinations, twenty-two petrographically distinct zones could be recognized. These zones show prominent differences in maceral composition and reflectance values of the vitrinite component. In view of the established relationship between petrography, including reflectance measurements, and coke stability, the present columnar study permits a selection of those parts of the seam which will likely produce the strongest coke. Interesting differences between the fluidity and swelling properties of pure vitrain and whole coal samples have been observed, which will play an important part in the preparation of the most suitable coal blends for coking purposes.

35. PETROGRAPHY AND CARBONIZATION CHARACTERISTICS OF SOME WESTERN CANADIAN COALS

A.R. Cameron, J.C. Botham

In this joint investigation between the G.S.C. and the Mines Branch, a number of samples from two seams in the Crowsnest Pass area of British Columbia were studied with respect to correlation between petrography and coking properties. Physical tests included measurement of swelling by the free swelling index test, measurements of fluidity by the Gieseler test, and measurement of strength on coke from the 500 lb. capacity, movable wall test oven. Petrographic data include results in terms of both macerals and microlithotypes. Of interest is the somewhat anomalous distribution of opaque components, especially the fusinitic constituents, in the various size fractions of one of the seams examined. Fluidity is shown to have a better correlation with the content of the microlithotype vitrite than with the total vitrinite. Calculated stability factors on six cokes suggest that a textural variety of vitrinite, described as mylonitized or pitted, has a deleterious effect on coke strength.

Cameron, A.R., and Botham, J.C.
(in press): Contribution to the First American Conference on Coal Science, Pennsylvania State University, State College, 1964.

36. STRATIGRAPHY OF THE WEST COAST OF NEWFOUNDLAND

L.M. Cumming

Portions of two contrasting tectono-stratigraphic regions dominate the geology of the west coast of Newfoundland - 1. the Anticosti-Strait of Belle Isle Platform composed of Lower Palaeozoic carbonate deposits; 2. a late Palaeozoic belt of deep subsidence represented by marine and non-marine Carboniferous strata; the NW margin of this Carboniferous fold belt is preserved around the head of St. George Bay.

The southeastern part of the Anticosti-Strait of Belle Isle Platform lies near the edge of an enormous gravity slide mass which was emplaced during Middle Ordovician time. Once emplaced, rocks of this klippe[1] acted as a thick stratigraphic unit that was accommodated into the carbonate succession by localized additional subsidence of the platform edge.

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[1] Rodgers, J., and Neale, E.R.W.: Possible "Taconic" Klippen in western Newfoundland; Am. J. Sci., vol. 261, pp. 713-730 (1963).

On Port au Port Peninsula klippe rocks of the Humber Arm Group are sandwiched between platform carbonates. The succession from east to west across Port au Port Bay is: St. George Formation (Cambro-Ord.); Table Head Formation (Mid. Ord.[2]); Humber Arm Group (Lower Ord.); Long Point Formation (Mid. Ord.); Clam Bank Formation (Sil. ? - Lower Dev.). To the west and unconformably overlying this succession, are undisturbed red conglomerates composed of rhyolite cobbles. These Red Island strata are interpreted as a remnant of the sedimentation bordering a northeast trending, graben-like, Carboniferous trench (aulacogene[3]) occurring between Anticosti Island and Newfoundland.

37. TRIASSIC DISCONFORMITY IN THE TANQUARY FIORD-YELVERTON PASS REGION, ELLESMERE ISLAND, N.W.T.

R.L. Christie

Stratigraphic sections were measured in 1963 in a northeastward extension of the Sverdrup Basin; the following remarks provide a partial accounting and interpretation of relationships observed there.

The basal beds of the Sverdrup Basin at the head of Tanquary Fiord are limestones of Pennsylvanian age, and locally, sandstones of unknown age. Overlying the basal beds is a generally conformable sequence of Permian, Triassic, Jurassic, and Cretaceous Formations. However, at various localities a thick, late Triassic Formation, the Heiberg Formation, rests directly on late Palaeozoic beds, on the undated basal beds, and on the basement rocks underlying the Sverdrup Basin.

The undated basal formation noted above is an unfossiliferous arenaceous clastic sequence nearly 2,000 feet thick exposed at Yelverton Pass. The sequence is divisible into two map-units more or less equal in thickness: the lower unit, red-weathering and thin-bedded shale and sandstone; and the upper, white-weathering medium- to thick-bedded sandstone and conglomerate. This unnamed formation is overlain with apparent slight angular discordance by the Heiberg Formation.

The Permo-Carboniferous beds include: basal, red-weathering conglomerate and sandstone, nearly 400 feet thick but only locally developed; coral-rich limestone and limy sandstone beds aggregating at least 500 feet; and, uppermost, about 600 feet of massive, strikingly pure white sandstone, in most places with a carbonate cement. Tentative correlation is: the basal clastic beds, Canyon Fiord Formation; the coralline limestones, Belcher Channel Formation; and the white sandstones, uncertain, or 'Permian (?) sandstones'.

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[2] Whittington, H.B.: Trilobites of the Ordovician Table Head Formation, western Newfoundland; Bull. Mus. Comp. Zool., Harvard University, vol. 132, No. 4, pp. 277-441; 68 plates (1965).

[3] Nalivkin, V.D.: Graben-like trenches in the east of the Russian Platform; Defence Research Board of Canada, translated by E.R. Hope, T400R (1965).

The Triassic Bjorne and Schei Point Formations are represented by grey- and yellow-weathering sandstone units respectively 120 to 300 feet thick and 50 to 80 feet thick.

The Heiberg Formation comprises two distinct members: the lower, interbedded sandstone, siltstone, and shaly siltstone in about equal proportions, and minor shale; the upper, massive, fine-grained grey to white sandstone. Igneous sills form up to one-third of sections in the lower member. The thinnest section is measured at 1,700 feet, and the thickest estimated to be about 3,500 feet. Although 'coalified' plant remains occur scattered throughout the lower member, almost none are sufficiently well preserved for plant identification. A collection of larger and better-preserved plant fossils from a bed in the upper half of the lower member was submitted to W.A. Bell, Geological Survey of Canada, who reports as follows:

> Neocalamites hoerensis (Schimper) Halle (GSC Loc. 6873, 6876)
> Pterophyllum sp. cf. nathorsti (Schenk) (non Seward) (GSC Loc. 6874)

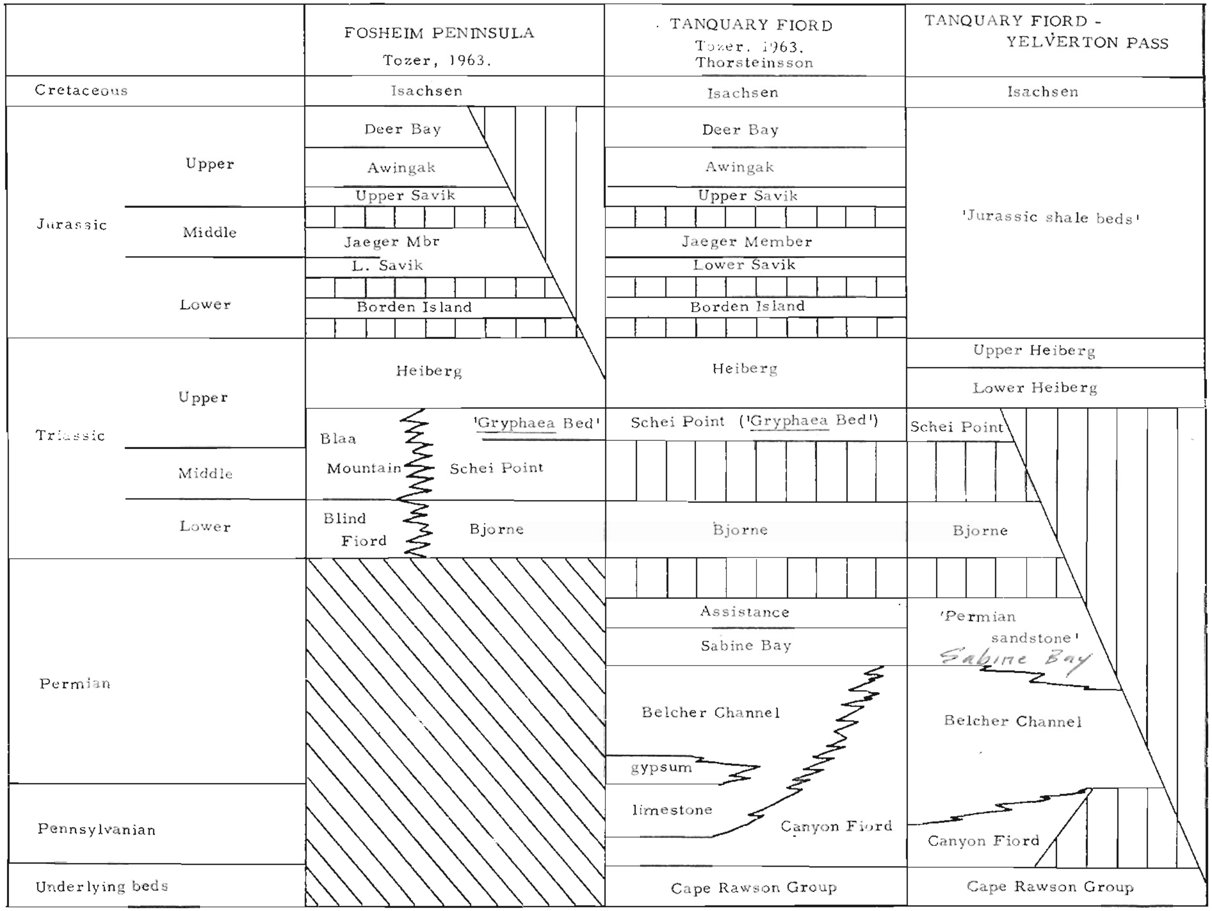
Of Neocalamites hoerensis, Dr. Bell remarks that the species was long considered restricted to Rhaetic (latest Upper Triassic) floras, but that specimens from Liassic (Lower Jurassic) beds have recently been assigned to it, and that the enclosing Heiberg beds therefore could be either late Triassic or early Jurassic in age.

Recessive black, crumbling shales, siltstones, and grey-brown sandstones of Jurassic age overlie with structural conformity the strikingly competent upper sandstone member of the Heiberg Formation, and are overlain similarly by the Isachsen Formation, also of competent sandstone.

The Sub-Heiberg Disconformity

The Heiberg Formation in the Tanquary-Yelverton regions rests upon an eroded terrane comprising various older formations. The relationships between the Heiberg and underlying formations, not everywhere precisely determined, are evidently as follows: either conformably or disconformably upon the Schei Point Formation (the known immediate predecessor of the Heiberg Formation); disconformably, or perhaps with slight angular unconformity upon the Permo-Carboniferous coral beds; nearly disconformably, but with slight angular unconformity upon the undated white sandstones and conglomerates of Yelverton Pass; and with great angular unconformity upon the pre-Carboniferous basement rocks. Evidently an episode of tectonism and erosion immediately preceded the deposition of the Heiberg Formation. From present evidence only a limited area was affected, but further exploration may show the event to be a significant one in the stratigraphic history of the region.

Although the Heiberg Formation rests in places directly upon the pre-Carboniferous basement, only a few miles away the stratigraphic section appears normal and complete, the Heiberg Formation resting without apparent discordance upon the Schei Point Formation. There is little or nothing in the measured sections to suggest either a thinning of the pre-Heiberg Formations or progressive truncation of them. Had a tectonic arch,



Formation names and correlatio...

RLC

or broad upwarp, risen in pre-Heiberg time, one or both of these relationships would be expected to obtain. The abrupt disappearance of the entire pre-Heiberg section, on the other hand, could be due to pre-Heiberg faulting; a basement fault of considerable vertical displacement would have elevated a welt of Permo-Carboniferous and Lower Triassic deposits, exposing them to erosion while allowing the preservation nearby of a complete, or near-complete section. The local vertical component of fault movement required would be at least the thickness of the pre-Heiberg section, which is about 1,500 feet. Upper Triassic movement of this order on a nearby branch of the Lake Hazen fault zone, which was a locus of major post-Cretaceous faulting, would explain the relationships observed.

Tozer, E.T.

1961: Triassic stratigraphy and faunas, Queen Elizabeth Islands, Arctic Archipelago; Geol. Surv. Can., Mem. 316.

1963a: Mesozoic and Tertiary stratigraphy, pp. 74-95, in Fortier, et al., Geology of the north-central part of the Arctic Archipelago, N.W.T. (Operation Franklin); Geol. Surv. Can., Mem. 320.

1963b: Mesozoic and Tertiary stratigraphy, western Ellesmere Island and Axel Heiberg Island, District of Franklin; Geol. Surv. Can., Paper 63-30.

38. CARBONIFEROUS COAL DEPOSITION ASSOCIATED WITH FLOOD-PLAIN AND LIMNIC ENVIRONMENTS IN NOVA SCOTIA

P.A. Hacquebard, J.R. Donaldson

This investigation was carried out to present factual data and possible explanations on the origin and deposition of coal measures in two distinctly different basins. The basins are those of the Sydney and Pictou coalfields in Nova Scotia of which much information was available for study, due to their long mining history.

In the Sydney coalfield, normal-banded autochthonous coals accumulated in a flood-plain environment. Lithofacies maps show the existence of two main river channels in this plain. The interaction between fluvial sedimentation and peat deposition, which caused the splitting and digitation of seams, is illustrated with a chart showing eleven cross-sections through the major seams of the coalfield. The environmental changes in the peat swamps have been interpreted from petrographic variations within the coals. By arranging the latter in "facies triangles", it was possible to plot these changes in cross-sections of eight seams. These sections are based on previous petrographic studies carried out over several years on fifty-one column samples, which together total 253 feet of coal. The cross-sections show that forest-moor and reed-moor environments predominated throughout, but were interrupted occasionally by open moor conditions. Changes in environment were accompanied by changes in vegetation. This was concluded from variations in the spore florules within seams, particularly in the ratios of *Punctatosporites* and *Lycospora*. Rapid subsidence with early burial of peat beds is indicated for Sydney Basin, by type of clastics and excellent preservation of coal macerals.

In the Pictou coalfield, micro-banded hypautochthonous coals accumulated in a narrow intermontane lake basin. Lithofacies maps show lacustrine sediments, with coal seams up to 44 feet thick, in centre of basin, and more fluviatile deposits at margin. The rapid megascopic changes between coal and detrital sediments, which caused lateral "lithification" rather than digitation of seams is illustrated in a chart showing twelve cross-sections through the major seams of the western part of this field. Uniform ecological conditions are indicated by uniformity in petrographic composition and by constancy of the spore florule within each seam. A slowly subsiding basin, with simultaneous accumulations of peat and clastic materials, is postulated by the type and preservation of the coal macerals and the presence of numerous, minute quartz grains.

Due to the entirely different environments of coal deposition in the two basins examined, greatly different sets of sedimentological, coal petrological and palynological characteristics resulted. These are listed in a table, which shows that of the twenty-eight features compared, nearly all are dissimilar.

Hacquebard, P.A., and Donaldson, J.R.
(in press): Contribution to G.S.A. Symposium on "Environments of Coal Deposition", Miami Beach, 1964.

39. STRUCTURE AND STRATIGRAPHY OF THE STONY CREEK FIELD, NEW BRUNSWICK

R.D. Howie

The Stony Creek Gas and Oil Field located about 9 miles south of the city of Moncton, New Brunswick is the only productive field in Canada east of the province of Ontario. Production is from 6 sand zones in the Albert Formation of Mississippian age. Each of the sand zones, composed of a number of lenticular sands that vary from well to well, are separated by non-bituminous to bituminous shales. Because of the lenticular nature of the sands and the absence of good marker horizons, the detailed stratigraphy of the field has never been worked out.

In recent studies of the area it is apparent that the field is located in a deltaic deposit. A series of facies maps now in production show the movement of the stream channel across the delta. Post depositional uplift, erosion and considerable faulting can also be illustrated.

40. PLAINS OF SOUTHERN ALBERTA AND SASKATCHEWAN

E.J.W. Irish

A preliminary study of the Edmonton Formation between Red Deer and Bow Rivers indicates that the most reliable marker is the zone that includes the equivalents of the Whitemud and Battle Formations. No diagnostic fossils have been found in these units so that correlation is made, so far, only on their distinctive lithology. A tentative division of the Edmonton Formation is based on this zone. Beds up to and including the Battle equivalent are referred to as Lower Edmonton and those above the Battle equivalent, as Upper Edmonton.

So far, the Whitemud and Battle equivalents have been traced southward as far as Bow River. Upper Edmonton strata have been traced as far east as Sheerness, Alberta where only a few feet of beds separate the Whitemud equivalent from the underlying Bearpaw Formation.

Geochemical results suggest that the Bearpaw Formation may be divided into an upper and lower part on the relative amount of Na_2O in the shale. Whether or not such a division is applicable over extensive areas is as yet unknown.

41. AGE AND TECTONIC NATURE OF THE STRAIT OF GEORGIA SEAWAY

J.A. Jeletzky

The early to mid-Lower Cretaceous (Berriasian to Aptian inclusive) marine rocks of Spiden Island, western Vancouver Island and Queen Charlotte Islands are neritic, fine to coarse clastics derived from the east. An extensive tectonic highland built of the strongly dislocated and metamorphosed pre-Cretaceous sediments and volcanics invaded by the presumably mid-Jurassic Coast Intrusions was their source area. This tectonic land erected by the Jurassic (late?) tectonic movements occupied the place of the present Georgia and Queen Charlotte Straits and possibly extended northward and southward therefrom; it probably extended eastward almost to the Tatlayoko and Harrison Lake areas. The Cretaceous marine to non-marine troughs west and east of this tectonic land remained separate until mid-Upper Cretaceous (Coniacian or Santonian) faulting or (?) down-warping submerged large tracts of the highland forming the late Upper Cretaceous (late Santonian to early Maestrichtian) ancestral Georgia Strait seaway. The predominantly marine sediments of the Nanaimo Group were deposited in this graben (or trough?). This northwest trending structural depression remained a negative structural element receiving non-marine Tertiary sediments at intervals ever since.

42. TAXONOMY AND PHYLOGENY OF FOSSIL COLEOIDEA (=DIBRANCHIATA)

J.A. Jeletzky

The earliest known primitive, belemnite-like representatives of subclass Coleoidea (=Dibranchiata=Endocochlia) belong to at least two lineages which arose independently out of presumably bactritid ancestors in the late Devonian or (?) earliest Carboniferous time. Two new orders are here proposed for these lineages. The new order Aulacocerida (=Protobelemnoidea Erben, 1964[1]) is the more primitive of these lineages. This most primitive Coleoidea order known is characterized by almost achoanitic to achoanitic early (the structure of the earliest septal necks is insufficiently known) and more or less distinctly prochoanitic (aulacochoanitic) adult septal necks, tubular essentially nautiloid living chamber, absence of a proostracum and hyperbolar zones, and a loosely built predominantly to completely organic (in Chitinoteuthididae) guard. The predominantly organic concentric lamellae of the aulacocerid guard are characteristically considerably thicker than the intervening predominantly calcareous lamellae. In some forms (Aulacoceratidae) the sculpture of the conotheca is visible on the surface of the alveolar part of the guard because of its "imprinting" on surface of all successive guard's layers so long as they parallel the surface of the conotheca. Muscular mantle and arm hooks are unknown and probably absent. Aulacocerida must have been relatively inactive animals as compared with all other Coleoidea; they are believed to be essentially similar to orthoconic nautiloids and bactritids in the degree of mobility, life habits, and general organization level. The order appears to be unrelated either to the Phragmoteuthida and Belemnitida s. restr. or to any other known Coleoidea. When the genetic relationships are fully worked out it may be necessary to divide the Coleoidea into two superorders, one of which will consist only of Aulacocerida while the other will include all other orders.

The order Aulacocerida includes the following families: Aulacoceratidae (ex Aulacoceratinae Mojsisovics, 1885) Mojsisovics, 1885 s. restr.; Atractitidae new family; and Chitinoteuthididae (ex Chitinoteuthidae Müller-Stoll, 1936) Müller-Stoll, 1936. A new genus Buelowiteuthis (based on Dictyoconites planus Bülow-Trummer, 1915) is proposed for the predominantly Indonesian representatives of Aulacoceratidae with strongly depressed and flattened rostra and a new genus Mojsisovicsteuthis (based on Atractites convergens v. Hauer, 1847) is erected for the breviconic (apical angle 15°-20°) representatives of Atractitidae. The Chitinoteuthididae are believed to be relatively little changed descendants of the root stock of Aulacocerida because of their unusually large and cup-like, essentially nautiloid-like protoconch and exceptionally small apical angle of the phragmocone.

The other new order Phragmoteuthida is a less primitive belemnite-like lineage characterized by an extremely wide, fan-like proostracum consisting of a long and wide, anteriorly convex median field and two almost equally long and wide, anteriorly convex lateral fields (wings) which are separated from the median field by narrow and shallow zones of backward convex growth lines (incipient hyperbolar zones). Phragmoteuthida possessed belemnitid-like muscular mantle and arm hooks. Their breviconic phragmocone has closely spaced septa and so is essentially belemnitid in its structure. The guard is feebly developed or absent which appears to be a primitive feature. The Phragmoteuthida appears to be a direct offshoot of the bactritids ancestral to all other known Coleoidea, except for the Aulacocerida; it is believed to be directly ancestral to the Teuthida and probably also to Belemnitida s. restr.

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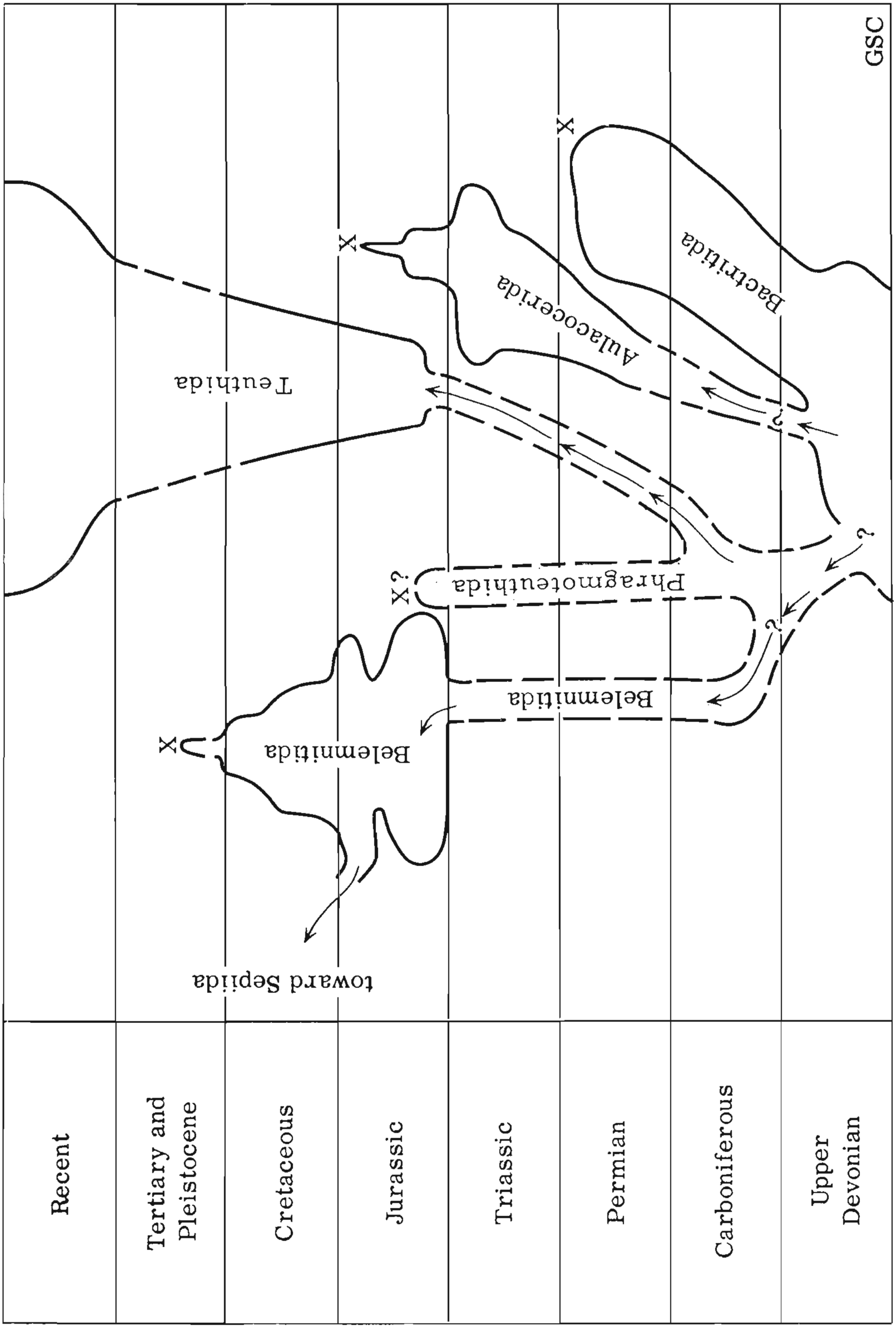
[1] Bactritoidea; in: Treatise on Invertebrate Palaeontology. Part K-Mollusca 3. Nautiloid Cephalopods; Geol. Soc. America & Univ. Kansas Press, Lawrence, pp. K491-505, text-figs. 352-361.



Recent
Tertiary and Pleistocene
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Upper Devonian
GSC
Teuthida
Aulacocerida
Bactritida
Phragmoteuthida
Belemnitida
Belemnitida
toward Sepiida
X
X?
?

The Teuthida Naef, 1916 (nomen correctum, ex Teuthoidea Naef, 1916) is characterized by a greatly reduced shell normally lacking a chambered phragmocone and guard, except for insignificant vestiges retained by some forms. The conotheca is only represented by a rudimentary conus at the posterior end of a well developed gladius (=proostracum). The gladius of the oldest known, most primitive Teuthida (Loligosepiina new suborder; typified by Loligosepia Quenstedt, 1839) exhibits wings and shallow hyperbolar zones essentially similar to those of Phragmoteuthida. Some of the younger and more advanced Mesozoic teuthids typified by Plesioteuthis (Prototeuthidina Naef, 1921 s. restr.) lack these re-entrant-like hyperbolar zones and wings and acquire an essentially Belemnitida-like gladius. Others typified by Palaeololigo (Mesoteuthidina Naef, 1921; nomen correctum, ex Mesoteuthoidea Naef, 1921) became Loligo-like.

The exclusively recent teuthid suborders Vampyromorphina Robson, 1929 (transfer of Vampyromorpha Robson, 1929 emend. Pickford, 1936 to the Teuthida was broached by Mr. L. Bairstow, British Museum Natural History, unpublished), Oegopsina d'Orbigny, 1839, and Myopsina d'Orbigny, 1839 cannot be reliably related to the fossil teuthids and a completely independent subordinal nomenclature must be maintained for them. The fossil Teuthida appear to be, at any rate, more primitive than their recent analoga and morphologically transitional between the recent Oegopsina and Myopsina on the one hand and the hypothetical, strongly vampyromorph- and octopid-like root stock of the Teuthida on the other. The Prototeuthidina s. restr. lacks, for example, the arm hooks, horn rings and large rhomboidal adult fins of its presumed oegopsid descendants while possessing large arm web, paired cirrae, and (?) uniserial suckers. The poorly understood arm crown of Loligosepiina was apparently even more vampyromorph- and octopid-like, although this suborder already possessed tentacles. The recent Vampyromorphina apparently separated from the teuthid main stem very early (in the Triassic?) before it developed the characteristic tentacles common to all other teuthid suborders known.

The Belemnitida Naef, 1912 s. restr. (nomen correctum, ex Belemnoidea Naef, 1912) is unknown in pre-Jurassic rocks, except for the still somewhat stratigraphically doubtful Eobelemnites Flower, 1945. The order is characterized by a narrow, spatulate to spear-like sharpened proostracum corresponding only to the median field and inner halves of the hyperbolar zones of the phragmoteuthid proostracum. The breviconic phragmocone is closely septate and has retrochoanitic (ortho- to hemichoanitic) early and adult septal necks. The calcareous lamellae of densely built, usually well calcified guard are characteristically thicker than the intervening predominantly organic lamellae. The guard is characteristically well developed, which is believed to be a secondary modification of the feebly developed (or completely absent?) guard of the phragmoteuthid ancestors of the Belemnitida s. restr. Muscular mantle is well developed. Paired arm hooks are present in all suitably preserved representatives but suckers and horn rings are unknown. The order is believed to be ancestral only to the Sepiida, its similarity to Teuthida being due to homoeomorphy and retention of the primitive characters derived from their common phragmoteuthid-like ancestors.

The Belemnitida s. restr. is subdivided into three suborders:

1. Belemnitina Stolley, 1919, s. restr. (nomen correctum, ex Belemnoidea Stolley, 1919) (=Acoeli auctorum) which includes families: Belemnitidae d'Orbigny, 1845 s. restr. (=Passaloteuthinae Naef, 1922); Hastitidae Naef, 1922 non Hastatidae Stolley, 1919; Cylindroteuthididae Stolley, 1919 emend. Naef, 1922; Oxyteuthididae Stolley, 1919; Bayanoteuthididae Naef, 1922; Belemnoteuthididae Zittel, 1885 emend. Naef, 1922; and Chondroteuthididae, new family.

2. Belemnopsina, new suborder (=Gastrocoeli auctorum plus Notocoeli auctorum) with the families: Belemnopsidae Naef, 1922 emend. Jeletzky, 1946 (=Hastatidae Stolley, 1919), Duvaliidae Pavlow, 1914; Belemnitellidae Pavlow, 1914; and (?) Dimitobelidae Whitehouse, 1924; and

3. Diplobelina, new suborder with the only family Diplobelidae Naef, 1926. Diplobelina differs from Belemnitina and Belemnopsina in its extremely narrow, anteriorly sharpened proostracum, more deeply incised suture line with a dorsal saddle and ventral lobe, and more or less strongly ventralward incurved axis of the phragmocone. These features ally it to the Sepiida to which it appears to be directly ancestral. A new genus Greenlandibelus is erected for "Belemnoteuthis" rosenkrantzi Birkelund, 1956.

Sepiida Naef, 1916 (ex Sepioidea Naef, 1916) is represented by fossil forms retaining all principal morphological elements of the Belemnitida shell. However, its phragmocone is either strongly incurved or coiled ventralward. Sepiida is not definitely known to occur in the Mesozoic rocks and is probably an offshoot of the Diplobelus-like belemnitids. This suggestion may, however, be subject to a revision if the still doubtful occurrence of Sepia-like forms in the Jurassic and Triassic rocks should be confirmed.

Octopida Leach, 1818 (ex Octopoda Leach, 1818) sensu Naef, 1922 is an extremely specialized taxon almost unknown in the fossil state. It is believed to be an offshoot of the same hypothetical, strongly vampyromorph-like teuthid root stock that produced Vampyromorphina. Like Vampyromorphina, the Octopida must have separated from the main teuthid stem very early (in the Triassic?) before it developed the tentacles. Among the Octopida, the recent Cirromorphina are believed to be less specialized descendants of the octopid root stock than the Incirratina. The Upper Cretaceous Palaeoctopus is probably a specialized representative of Cirromorphina.

Figure 1 illustrates the writer's proposals for revision of the taxonomy and phylogeny of the sub-class Coleoidea.

43. LOWER AND MIDDLE DEVONIAN SPORES OF EASTERN GASPÉ

D.C. McGregor

Trilete spores and acritarchs occur through most of the coastal section of Lower and early Middle Devonian rocks of the Forillon Peninsula and Gaspé Bay, Quebec. Acritarchs are abundant and usually well preserved in the limestones of the Cape Bon Ami and Grande Grève Formations, but become extremely rare in the York River Formation (which marks the beginning of non-marine deposition in the area) and in the overlying Battery Point and Malbaie Formations. Trilete spores occur at certain levels in the limestones, but they are abundant only in the overlying non-marine York River, Battery Point and Malbaie Formations.

The spore assemblages indicate that a distinct change in the terrestrial flora occurred during the time of deposition of the Battery Point Formation. The upper assemblage is characterized by zonate and (?) saccate spores and spores with bifurcate processes. The lower assemblage lacks spores with bifurcate processes, contains few zonate or (?) saccate types, and contains a greater abundance and variety of Emphanisporites spp. and several new species of azonate spores.

The Cape Bon Ami, Grande Grève and York River Formations of eastern Gaspé contain invertebrates which indicate upper Gedinnian, Siegenian, and Siegenian or lower Emsian ages respectively (A.J. Boucot, oral communication). The Battery Point and Malbaie Formations, which constitute the upper part of the apparently continuous succession, are not datable by invertebrates, but the upper spore assemblage which first occurs in about the middle of the Battery Point Formation south of Bois Brulé Brook, is clearly similar to Middle Devonian assemblages of Scotland and the USSR. For this reason an Eifelian age is suggested for the upper Battery Point and the lowermost Malbaie rocks. However, there is as yet no evidence to indicate whether or not the floral change within the Battery Point Formation coincides with the Emsian-Eifelian boundary.

Illustrations and systematic descriptions of approximately 150 species of spores from the Battery Point Formation and the lower, plant-bearing part of the Malbaie Formation are being prepared for publication.

Series	Stage	Formation	Member	Spores
Middle Devonian	Eifelian	Malbaie		
--- ? ---		Battery Point		
	Emsian	York River		
Lower Devonian	Siegenian	Grande Grève	Indian Cove Shiphead	
	Gedinnian	Cape Bon Ami	Forillon Cape Road Quay Rock	

44. UPPER DEVONIAN SPORES FROM THE GRIPER BAY FORMATION, PARRY ISLANDS, N.W.T.

D.C. McGregor

Well preserved spores occur in the Griper Bay Formation of Bathurst and Helena Islands. On Bathurst Island, spores of late Frasnian or early Famennian age occur 920 feet from the base of the formation, and early Famennian spores occur about 380 feet higher in the section. Marine invertebrates, assigned an early Famennian age by D.J. McLaren, also were identified at the latter locality. On Helena Island about 60 miles northwest of the Bathurst Island localities, spores of probable late Frasnian age were identified at a height of 2,675 feet in the formation.

The spores compare most closely with Upper Devonian species of the western USSR. Several species are also common to Upper Devonian rocks (Imperial Formation) of the Mackenzie Basin. Further study of the spores of the Griper Bay Formation and other Devonian rocks of the Parry Islands is being conducted by Dr. B. Owens, who was a National Research Council Post-Doctorate Fellow with the Geological Survey in 1964.

Kerr, J.W., McGregor, D.C., and McLaren, D.J.
(in press): An unconformity between Middle and Upper Devonian rocks of Bathurst Island with comments on Upper Devonian faunas and microfloras of the Parry Islands; Bull. Can. Petrol. Geol.

45. RECONNAISSANCE DEVONIAN STRATIGRAPHY OF THE NORTHERN YUKON TERRITORY AND NORTHWESTERN DISTRICT OF MACKENZIE

A.W. Norris

This report which is to be published in full as a GSC bulletin is based on field work by the writer and other members of Operation Porcupine in 1962 covering an area north of latitude 65° and west of longitude 132°. Some 36 Devonian sections are presented of which 32 are described in the Appendix accompanied by tentative fossil lists.

Ten formations are recognized of which five are new. With the exception of the Ramparts (Kee Scarp) and the Bear Rock (restricted), all of the formations typically developed in the central Mackenzie River region to the east can be recognized in the report area.

A new unit consisting of orange weathering fossiliferous limestone, dolomite and shale ranging in age from Lower (?) to lower Middle Devonian is locally developed in the Hart-Ogilvie Rivers area. It disconformably (?) overlies the graptolitic Road River Formation. Banded aphanitic dolomites and limestones to be named by J. Tassonyi (in press) that are roughly coeval with the Bear Rock evaporites and breccia, are widely distributed in the Mackenzie and Ogilvie Mountains and the Campbell Lake uplift. These beds range in age from Lower to lower Middle Devonian, and in the northern part of the area beds of Silurian age are present also in the formation. A new formation consisting of dark shale, argillaceous limestone and chert, ranging in age from Lower to upper Middle Devonian is confined roughly to the Richardson Mountains uplift. In places it contains a rich coral, brachiopod and goniatite fauna in its lower and middle parts. This unit transitionally overlies the graptolitic Road River Formation. A new unit consisting of resistant limestone and calcareous shale of lower Middle Devonian age is locally developed in the Snake River area. A new unit of resistant grey weathering carbonates ranging in age from Lower to upper Middle Devonian is widely developed in the Ogilvie and White Mountains and in the Campbell Lake uplift. Within the report area the upper Middle Devonian Hume Formation changes character westward and is not developed west of Flyaway Creek. An unusually thick Hare Indian Shale occurs in the Snake River area, but pinches out rapidly to the south and west. The Canol Shale occurs mainly in the eastern part of the area where it marks the base of Upper Devonian sediments. In places this shale disconformably overlies beds as old as the Middle Devonian Hume Formation. An unnamed interval of poorly exposed shales ranging in age from Middle to Upper (?) Devonian is present in the Ogilvie Mountains. The Upper Devonian Imperial Formation consisting of clastic rocks in places over 5,000 feet thick was deposited throughout the southeastern half of the report area and beyond.