64-2

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES
AND TECHNICAL SURVEYS

PAPER 64-2

SUMMARY OF ACTIVITIES: OFFICE AND LABORATORY, 1963

Compiled by Peter Harker

Price, 75 cents

1964

GEOLOGICAL SURVEY

OF CANADA

PAPER 64-2

Summary of Activities:

OFFICE AND LABORATORY, 1963

Compiled by Peter Harker

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

Available by mail from the Queen's Printer, Ottawa,
from Geological Survey of Canada, 601 Booth St.,
Ottawa,
and at the following Canadian Government bookshops:

OTTAWA

Daly Building, Corner Mackenzie and Rideau

TORONTO

Mackenzie Building, 36 Adelaide St. East

MONTREAL

Æterna-Vie Building, 1182 St. Catherine St. West

or through your bookseller

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

CONTENTS

Geological Survey Building,
Ottawa

(Photo, D. K. Norris)

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.

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 but the report does differ from its annual counterpart (Summary of Field Activities) which gives in brief form, the results of the work of the preceding field season. These two reports, together with the index of publications, provide an annual summary of the major activities of the Geological Survey.

There is commonly some delay between submission of a report and its appearance in final printed form, especially with some of the larger and more extensively illustrated reports. In an attempt to bridge this gap the appendix consists of abstracts of reports accepted for publication but not yet ready for submission to the Queen's Printer.

STRATIGRAPHY AND PALAEONTOLOGY

STUDIES ON CARBONIFEROUS PALYNOLOGY

M.S. Barss

1. Representative sections of the Mississippian Horton Group in Cape Breton Island. A miospore study is in progress of clastic sediments collected from the type sections of the Craignish, Strathlorne and Ainslie Formations exposed on the southwest Mabou River, as well as from corresponding sections on Graham River and adjoining region. Preliminary results indicate that only a part and not the entire Cape Breton succession is of the same age as the type section of the Horton Group (along Avon River in Horton-Windsor district). Older strata with a different Mississippian spore assemblage are present.

2. The type section of the Pennsylvanian Pictou Group along River John, Nova Scotia. This study was commenced with the view of establishing a detailed correlation between the type section and strata of many other locations presently assigned to the Pictou Group. Of particular interest would be to find the possible equivalents of the three floral zones known from the comparable Morien Series of the Sydney Coalfield. From the type section, which is predominantly red, only a limited number of promising spore samples could be obtained. Preliminary results indicate that with these samples correlations can likely be made.

3. Of the many samples submitted during 1963 for a palynological age determination, two samples from northern Canada are worth mentioning, namely from Lands Lokk, northwestern Ellesmere Island (N.W.T.) and from Porcupine River (northern Yukon Territory). Both samples contain the characteristic Viséan spore assemblage that has been previously recorded from the south Nahanni River area, Axel Heiberg Island, Spitsbergen and the U.S.S.R. The new findings give additional support to the previously postulated existence of a similar Upper Mississippian floral province throughout the Arctic and northern latitudes.

DEVONIAN CORRELATIONS NEAR SUNWAPTA PASS, BANFF NATIONAL PARK, ALBERTA

Helen R. Belyea and D.J. McLaren

A carbonate reef and correlative clastic sequence is developed in the Upper Devonian of the Sunwapta Pass area, Banff and Jasper National Parks, Alberta. Sandstone and sandy dolomite

at the base of the section in the Cirrus Mountain - "Big Hill" area are overlain by dark brownish grey stromatoporoid-rich dolomites of the Cairn Formation. These are laterally continuous into the Flume Formation at Nigel Peak where they are overlain by black shales of the Perdrix Formation. The overlying fossiliferous shales and limestones of the Mount Hawk Formation of the Nigel Peak section pass southward on the "Big Hill" to light grey massive coarsely crystalline dolomite (Peechee Member of the Southesk Formation) interpreted as reef and reef detritus. These are correlative with bedded, dark and light grey, probable lagoonal dolomites on Cirrus Mountain. Dark brown coralliferous beds of the Grotto Member of the Southesk and the overlying light grey Arcs dolomite extend over the whole area. Grey, yellowish-weathering, laminated silty dolomites of the Ronde Formation close Southesk deposition and mark the end of Frasnian time. The Southesk is disconformably overlain by the sandy dolomites of the Sassenach Formation, basal Famennian, present at Nigel Peak and Parker Ridge where it is overlain by the Palliser Formation. On "Big Hill" and Cirrus Mountain the Sassenach is missing and the Ronde is directly overlain by the Palliser.

These sections are comparable with the carbonate-clastic sequences of central Alberta, the massive Peechee Member being similar to and correlative with the oil-and-gas-producing upper part of the Leduc Formation.

THE MIDDLE DEVONIAN ROCKS OF THE BEAVERFOOT, BRISCO, AND STANFORD RANGES, BRITISH COLUMBIA

Helen R. Belyea and B.S. Norford

The Middle Devonian of the Beaverfoot, Brisco and Stanford Ranges is separated into a lower, grey or light grey and locally red-weathering sandy limestone, dolomite and sandstone formation, laterally equivalent to the Burnais gypsum, and an upper fossiliferous brown limestone and dolomite, the Harrogate Formation.

The lower formation consists predominantly of cryptograined silty to sandy limestone, dolomite, sandstone and breccias. Beds 2 inches to 2 feet thick are separated by undulatory surfaces, locally channelled. The carbonates were probably deposited as ooze, some of the dolomite being primary or early diagenetic. Post-depositional changes include micro-brecciation, slump structures, burrowing in plastic carbonate, desiccation cracks filled by calcite or hematite. Advancing dolomitization is marked by growth of euhedral rhombs, commonly with a nucleus of dusty material, pyrite or spores. Increase in number and size of rhombs results in a crystalline-grain-growth mosaic. Pellets, bahamiths, detrital grains and older fabrics are

partly or completely destroyed in the process. Internal cavities and fractures are filled by crystalline (granular) cement and drusy growth. Quartz grains are extensively corroded by carbonate and late tension cracks are filled by quartz and carbonate. Ostracods and charophytes are present in some beds. This rock unit, correlative with the Burnais gypsum, is interpreted as the deposit of a shallow-water, near-shore environment, periodically exposed, that received drainage from an early Palaeozoic terrain of carbonates and clastics.

The overlying Harrogate is dark brown, mostly aphanitic limestone and finely crystalline dolomite. Post-depositional effects have resulted in development of grain-growth mosaic and drusy growth. Deposition took place in deeper water than the lower unit but subject to wave or current action; lack of oxidation due to abundance of organic growth is suggested as the cause of dark colour.

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

C.F. Burk, Jr.

Twenty correlatable electric-log marker horizons within the Dunvegan Formation were established by closed correlation loops. A widespread, prominent marker horizon at the top of the formation provides a convenient datum for cross-sections. The cross-sections suggest that sandstones of the Dunvegan represent a series of slowly regressive, deltaic deposits, separated by thin, rapidly transgressive, marine shales. This sedimentary regime was terminated by a rapid, major marine transgression and a new tectonic orientation of the basin.

NEOCOMIAN FORAMINIFERIDA FROM THE AKLAVIK RANGE, DISTRICT OF MACKENZIE

T. Potter Chamney

Samples collected by the writer while attached to Operation Porcupine have yielded abundant microfossils from the earliest Lower Cretaceous marine sediments in Western Canada. The object of the study is to systematically describe foraminifera from the Neocomian beds from the region as these are the most fully developed marine deposits of this geological age at present known in Canada.

The study includes beds designated by J.A. Jeletzky (1961) as Barremian. Eight plates with descriptions have been completed and include all of the representatives of the Textulariidae recovered to date.

Although this study has not been completed, there is sufficient evidence to indicate that there might well be some Albian sediments in the highest of the beds previously included in the Barremian. Changes in time-rock boundaries are to be expected as more detailed analyses are conducted of the gross rock-stratigraphic units erected for reconnaissance mapping.

ALBIAN FORAMINIFERIDA OF THE PEEL RIVER AREA, DISTRICT OF MACKENZIE

T. Potter Chamney

Foraminiferal recovery from Operation Porcupine sample material MJ 118-62 will provide significant palaeontological criteria for correlation of equivalent rock-stratigraphic units within the Middle and possible Upper Albian with those of northern Alaska. Globorotalites cf. G. alaskensis Tappan, 1957, and Gavelinella cf. G. awunensis Tappan, 1957, are the most distinctive calcareous forms. Numerous agglutinated, benthonic forms also indicate assemblages similar to those reported by Helen Tappan Loeblich, United States National Museum Bulletin 215, 1957. The Grandstand and Topagoruk Formations of Alaska are involved in this correlation which will be resolved with additional sample studies from the Peel River area.

Microfaunal elements in the MJ 118-62 material also indicate possible correlation with the Middle Albian of northeastern British Columbia and adjacent areas. Haplophragmoides cf. H. spissum Stelck and Wall, 1956, and "Vernevilina" aff. V. porta Stelck and Wall, 1956, are two of the fossils used in equating these two areas.

FORAMINIFERAL EVIDENCE FOR THE MOOSEBAR FORMATION EQUIVALENT IN THE CENTRAL FOOTHILLS AND ROCKY MOUNTAINS

T. Potter Chamney

Samples collected by the author while attached to D.F. Stott's field party west of Grande Prairie, Alberta, were investigated. Previous stratigraphic nomenclature applied to this area did not recognize the equivalent of the early Middle Albian, Moosebar

Formation within the interval at the base of the Commotion Formation. In spite of the silty and sandy nature of the sediments, and other indications of very shallow marine to non-marine environments, sufficient foraminifers were recovered to permit correlation with the marine Moosebar microfauna (Stelck et al., 1956).

Of special note is the species which has been compared with Vernevilina porta Stelck and Wall, 1956. It is much more triangular in the initial serial portion and a smaller variety is also present. The same species has been recorded from several similar stratigraphic equivalents in the northern Cretaceous basins. This species may thus represent one of the strongest agglutinated, and most diagnostic, benthonic elements for regional correlation of the Middle Albian.

A few of the more significant species are as follows:

CR1-62, Deadhorse Meadows

Quadrimorphina albertensis Mellon and Wall, 1956
Glomospira cf. G. charoides Jones and Parker
Marginulinopsis collinsi Stelck and Wall, 1954
Saracenaria cf. S. grandstandensis Tappan, 1957

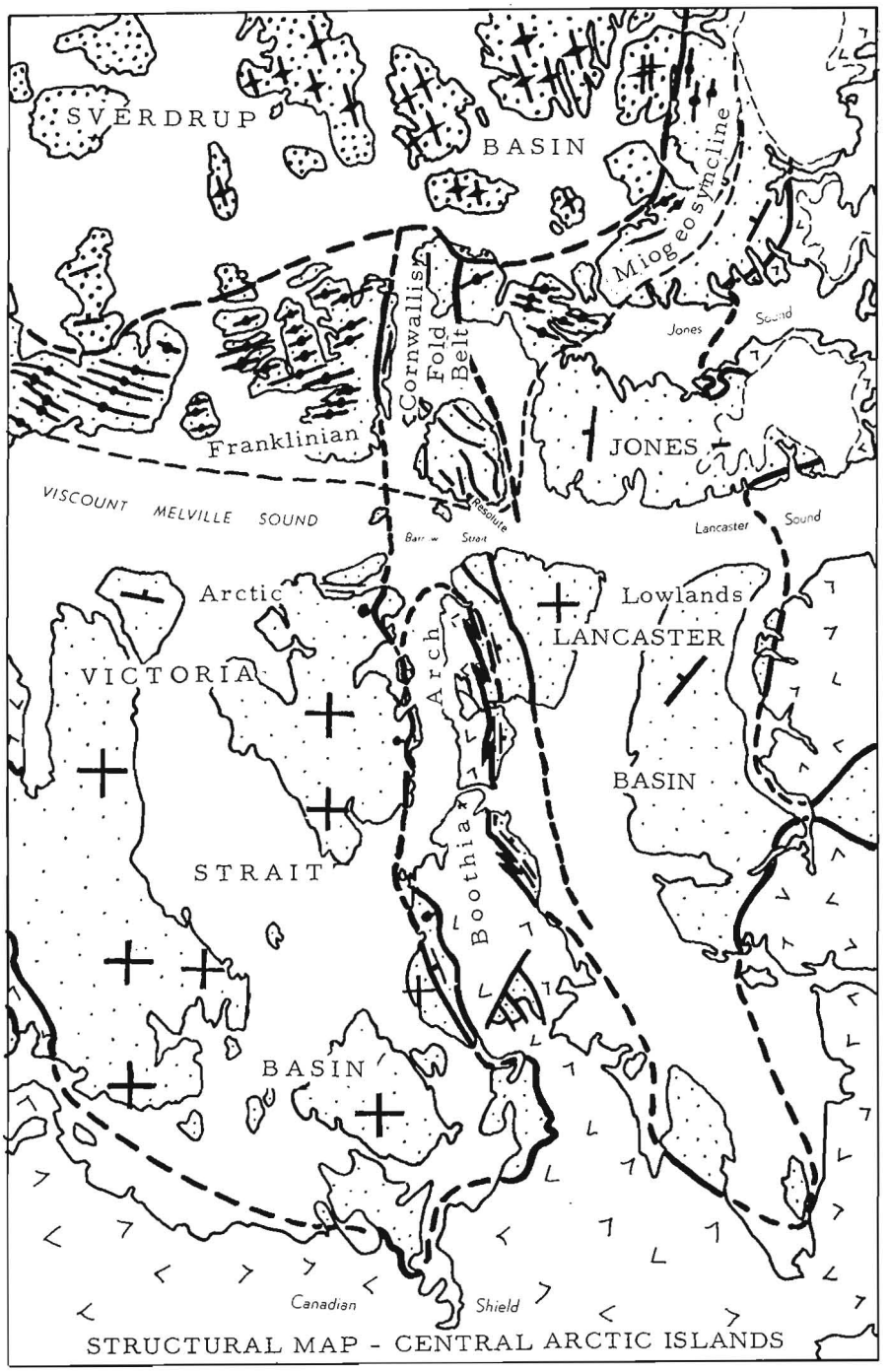
CR2-62, Mount Torrens

Ammodiscus kiowensis Loeblich and Tappan, 1950
Ammodiscus cf. A. gaultinus Berthelin
"Vernevilina" cf. V. porta Stelck and Wall, 1956
Spiroplectammina cf. S. koveri Tappan, 1957
Haplophragmoides globosa Lozo, 1944
(and similar species as recorded in CR1-62).

THE BOOTHIA ARCH

R.L. Christie and J.W. Kerr

The Boothia Arch is a north-northwesterly-trending extension of the Canadian Shield and forms the northern extremity of the North American mainland. The arch is a horst structure in which Precambrian crystalline rocks have risen at least 5,000 feet. Cambrian, Ordovician, and Silurian clastic and carbonate rocks representing a shelf environment dip gently away from the Precambrian basement complex on the east, but are abruptly juxtaposed against it along the western margin. The basement rocks appear to have been elevated mainly by vertical movement along major thrust and normal faults rather than by arch-like flexing. In general, the faults parallel the arch.



STRUCTURAL MAP - CENTRAL ARCTIC ISLANDS

A northern continuation of the Boothia Arch is indicated by the northerly trending structures of the Cornwallis Fold Belt on eastern Bathurst and Cornwallis Islands and on western Grinnell Peninsula. The Boothia-Cornwallis structures disappear northward beneath the younger Sverdrup Basin, but the northerly trends of that basin, conforming as they do with the older structures, are perhaps related in some way to them.

The history of the arch is reflected in the lower Palaeozoic sedimentary sequence of rocks. The Cambrian, Ordovician, and Silurian sediments are represented by formations that were deposited under conditions of gradual subsidence in the Arctic Lowlands and under greater subsidence in the Franklinian geosyncline to the north. Thickening of these formations to the east and west of the Boothia Arch is suggested by field studies and by geophysical data. Apparently, therefore, the arch remained relatively positive (that is, less downsinking) throughout these periods.

South of Barrow Strait, the principal movements of the Boothia Arch are dated by the syntectonic Lower Devonian Peel Sound Formation, which consists largely of conglomerates comprising detritus from Lower Palaeozoic and Precambrian rocks. The Peel Sound rocks rest variously: (a) with gradational contact on the Middle Silurian to Lower Devonian Read Bay Formation; and (b) with angular unconformity on the Read Bay and older formations. The Peel Sound beds are themselves upturned by major horst-forming faults.

On Bathurst Island the principal movement produced northerly trending structures and a westward spread of clastic sediments of the Stuart Bay Formation. A pronounced angular unconformity is bracketed by formations of Lower Devonian age on eastern Bathurst Island. Traced westerly, the unconformity passes into a disconformity, then disappears. The lithology of post-deformation of Lower Devonian and of Middle Devonian rocks and the trends of the facies belts indicate that the eastern part of Bathurst Island again subsided but that shallower water prevailed there than to the west. A second movement of the arch is indicated by a sub-Famennian unconformity on northwestern Cornwallis Island and on northeastern Bathurst Island. Faults trend along the arch and probably are related to the period of arch-formation; faulting was probably intermittent, however, and on Cornwallis Island rocks as young as Tertiary are displaced.

PRIMARY FEATURES IN CHERTY IRON-FORMATIONS

G.A. Gross

Special attention is being given in the study of iron-formations to primary textural and structural features and to what they indicate about the depositional environment of these beds. Very few primary features in cherty iron-formation have been described in existing literature and little attention has been given to their significance.

Sedimentation features studied in cherty beds include granules, oolites, various types of pisolites and nodules, microbanding, scour and fill structures, crossbedding and ripple-marks. Diagenetic features recognized include various forms of contraction cracks and syneresis patterns. Compaction phenomena recognized provide convincing evidence for deposition of silica gels and for the hydroplastic state of the silica during diagenesis. Intraformational breccias, corrugations and folds, and slump and glide structures are common. Slumpage folds are not easily distinguished from imposed folds in some areas and the two structures may be confused.

Algoma-type formations with volcanic rocks have features indicative of deposition in eugeosynclines, and primary features in Superior-type formations indicate depositional conditions found in neritic zones of continental shelves.

STRATIGRAPHY AND PALYNOLOGY OF THE UPPER CARBONIFEROUS COAL MEASURES IN THE CUMBERLAND BASIN OF NOVA SCOTIA

P.A. Hacquebard and J.R. Donaldson

Intermontane deposition in the Cumberland basin gave rise to approximately 12,000 feet of terrestrial strata of the Cumberland Group. This group has been subdivided into five units or facies, of which the lower part of the middle fine facies is coal bearing. The productive coal measures of this facies occur on opposite flanks of a major syncline in the Joggins and Springhill coal fields. Contrary to existing opinion the authors contend that the productive zones of these two fields are contemporaneous. The conclusion is based on stratigraphic distances, on rank evaluations of the coal and on palynological evidence. For the latter a study has been made of the miospore genera present in 35 coal seams.

The spore florule of the coal-bearing facies consists of 28 genera, but none of these has a restricted range within this facies. A subdivision, however, can be made from the quantitative

spore-distribution patterns represented in successive seams. In the (type) section at Joggins it is possible to recognize a lower zone (2,200 feet) with coal seams that are persistently high in Lycospora, and an upper zone (2,900 feet) with seams in which this genus occurs in variable, but usually low quantities. The productive coals at Joggins and Springhill are considered the same age, because both belong to the high Lycospora zone, and have otherwise similar spore assemblages. This age, as compared with spore florules reported from Belgium and Great Britain, is regarded as middle Westphalian B. Other coal occurrences belonging to this zone are located at Salt Springs, DeWolf Brook and Maringouin Peninsula.

The coals at Spicer Cove and a plant-bearing shale at Apple River contain a spore assemblage indicative of the Lonchopteris zone of the Morien Series, which is regarded as lower Westphalian C. As these strata can be placed immediately above the coal-bearing facies, the following age relationships of the Cumberland Group are indicated. The lower part of the group (the Joggins Formation) represents a Westphalian B, and the upper part (the Shulie Formation) a lower Westphalian C equivalent. Formerly the entire group was assigned a Westphalian B age.

Ref. Hacquebard, P.A., and Donaldson, J.R.: Contribution to the 5th Carboniferous Congress, Paris, 1963 (in press).

JURASSIC ROCKS OF THE WESTERN SLOPE OF RICHARDSON MOUNTAINS AND NORTHERN PORCUPINE PLAINS

J.A. Jeletzky

An attempt is made to describe, date, subdivide, and correlate the extremely thick (up to 7,000 or 8,000 feet), lithologically monotonous but laterally variable Jurassic rocks of the area. Although largely based on the writer's field work in the area and the identifications of fossils collected by him (by Dr. H. Frebold and the writer), this study also utilizes some other published and unpublished information. Some of the results have already been published in an outside paper.

Ref. Jeletzky, J.A.: Pre-Cretaceous Richardson Mountains Trough: Its place in the Tectonic framework of Arctic Canada and its bearing on some geosynclinal concepts; Trans. Roy. Soc. Can., vol. 56, ser. 3, sec. 3, pp. 55-84, 6 text figs. (1963).

BATHURST ISLAND GROUP

J.W. Kerr and P.G. Temple

The Cape Phillips Formation, about 1,400 feet in thickness, is predominantly a dark grey to black, non-calcareous to slightly calcareous, graptolitic shale and siltstone. At the base of this formation there is an interval in which carbonates are interbedded with the shales, and with some variation, this interval increases in thickness southward, particularly south of Driftwood Bay.

West of longitude 99° the Cape Phillips Formation is succeeded gradationally by a calcareous fine-grained rock of early Devonian age, which includes the Bathurst Island, Stuart Bay and Eids Formations. Limestone conglomerate horizons that occur in this interval mark the base of the Stuart Bay. They occur earlier and are thicker and more numerous in the east, thinning and disappearing toward the west. Within Stuart Bay, time uplift of the Boothia Arch to the southeast caused an angular unconformity to develop there; it merges into a disconformity to the north and west. The elevation was of short duration and probably confined to the middle part of Lower Devonian time. In the Driftwood Bay area the unconformity is overlain by a thin quartz sandstone, the Driftwood Bay Formation, then by a mainly dolomitic unit, which is thick and extensive in the eastern parts of the island. This dolomite unit includes rock mapped at Driftwood Bay as the Sherard Osborn Formation and the lower part of that mapped as Blue Fiord in upper Wicketts River. This dolomite grades westward into the upper part of the Stuart Bay and the Eids Formations.

Two occurrences of gypsiferous rocks northeast of Purcell Bay are large lens-shaped masses of dark grey to black gypsiferous limestone and shaly limestone with minor light grey gypsum, which follow stratigraphic horizons in which their contained faunas are anomalous. The more southerly mass occurs stratigraphically within the Lower Devonian yet yields graptolites of early or Middle Silurian age. These blocks may have slid to their present positions from highs within the Cape Phillips shale belt.

In the area of Cockscomb Peak is a new and unnamed formation which lies unconformably upon rocks as young as the Okse Bay Formation (Frasnian) and dips eastward toward Queens Channel. It is several hundred feet thick, comprising light-coloured quartzose sandstone at the base, overlain by dark green siltstone, bearing plant remains and Famennian (Latest Devonian) brachiopods. This intra-Upper Devonian unconformity is probably a late movement on the Boothia Arch — however it might possibly mark the beginning of development of the Sverdrup Basin.

Limited exposure of the Belcher Channel Formation occurs on northeast Helena Island where it rests with slight angular unconformity upon the Okse Bay Formation, and is the oldest formation of the Sverdrup Basin.

Ref. Fortier, Y.O., et. al.: Geology, Bathurst Island Group, District of Franklin, Northwest Territories; Geol. Surv. Can., Map 18-1959 (1959).

OUTLIERS ON THE CANADIAN SHIELD

B.A. Liberty

At present about 54 outliers by actual count are known, although several of these are in groups of 14, 5, 4, and 3. An additional thirteen localities are known where there is loose material 'far removed' from the nearest Palaeozoic rocks. The age of these outliers ranges from Cambrian on the Strait of Belle Isle, Ordovician at Nicholson Lake (N.W.T.), Ordovician and Silurian at Lake Timiskaming, to Cretaceous in the Hudson Bay Lowland and Tertiary near Shefferville. At two localities, Lake Timiskaming and Aberdeen Lake, both Ordovician and Silurian systems are represented. At one locality, the diatreme on St. Helen Island near Montreal, Cambrian, Ordovician and Devonian faunas are known. If one should classify the Hudson Bay Lowland as an outlier, as some authors do, then the Ordovician, Silurian, Devonian and Cretaceous systems are known. Included in the above figures are four new outliers (Clearwater Lake, and three near the Ontario-Manitoba border south of the Hudson Bay Lowland) and four localities at which loose Palaeozoic material has been found (at the southeast end of Baffin Island, and three north of the east end of Lake Superior).

The existence of these little-publicised outliers suggests that the 'post-Precambrian' formations extended far beyond the present main outcrop areas for these systems. This data is considered the best evidence, yet obtained, that is pertinent to both the relative stability of the Canadian Shield through geological time and to palaeogeography. At least the broad southern marginal areas of the Shield were covered by continental seas in Ordovician, Silurian and Devonian times. It is considered that most of the Shield was masked by Palaeozoic cover at one time or another. A minimal concept embraces wide arms of the epeiric seas extending across the Shield to connect with the Arctic marginal waters.

PALAEOCURRENTS IN THE TRIASSIC OF NORTHEASTERN BRITISH COLUMBIA

B.R. Pelletier

Triassic strata of the Rocky Mountain Foothills in northeastern British Columbia consist predominately of fine-grained clastics in the lower part, medium- to coarse-grained in the middle and lower upper parts, and fine-grained in the uppermost part. Some bioclastic carbonates and evaporites also occur in the middle and upper parts. Triassic rocks rest disconformably upon upper Palaeozoic chert, and are overlain disconformably by Jurassic shales in the southern part of the area and by lower Cretaceous shales in the north. This together with an unconformity bevelling progressively older beds northeasterly indicates uplift in the northeast. Seventy sections were measured to establish the stratigraphic facies relationships, and history of sedimentation. This work was augmented by textural studies on hand specimens from certain sections and by observations on bedding thicknesses. Generally, lower Triassic beds are thinner and finer grained than middle and upper parts except for the youngest beds. Considering also that sediments are coarser in the east than west, the following history of easterly transgression followed by westerly regression and again followed by easterly transgression, was established. Palaeocurrents based on the observations on 2,500 current structures such as planar crossbedding, festoon bedding, current and wave ripple-marks, and flow markings indicated that the probable direction of sedimentary transport was to the west and southwest. Triassic sediments deposited during a regressive phase underwent textural changes expressed as decrease in grain size and gross lithological aspect from coarse in the east to fine in the west; at a given section, younger beds are generally coarser than older beds; and axes of maximum thickness for successively younger formations occur successively westerly from those of older formations. These observations implied an apparent migration of depositional sites in the direction of sedimentary transport during the regressive phase of sedimentation. Such apparent migratory behaviour of depositional sites in a direction away from the source area, and coinciding with the direction of sedimentary transport was a response to increased erosion and consequent sedimentation arising from uplift in the northeast. It appears that palaeoslope attitude was the dominant regional control of the resulting sedimentary trends.

SUBSURFACE STRATIGRAPHY OF SILURIAN ROCKS IN SOUTHWESTERN ONTARIO

B.V. Sanford

The purpose of the present study is largely that of mapping the Silurian formations in the subsurface of southwestern Ontario, and by regional facies studies to reconstruct the historical events which contributed to the development of the Michigan Basin during the Silurian. Although some of the Basin concepts which have evolved during the process of this investigation are mainly of academic interest, they could conceivably also have far-reaching value in the future exploration for hydrocarbons in Ontario, and the adjoining Great Lakes region of the United States.

The gradation of facies which developed in Ontario during Lower Silurian (Alexandrian) time between the Michigan (carbonate) Basin on the west and a clastic basin to the south (Appalachian) is shown in Figure 1. The sandstone facies of this sequence has long been a commercial producer of natural gas. Until recent years these reservoirs were exploited only in the Niagara Peninsula region. In recent years, offshore exploration has extended several of these fields beneath the waters of eastern Lake Erie. Regional studies indicate that prospective beds are most likely present over a considerable distance also to the westward beneath central Lake Erie, and as yet remain untested.

The development of thick carbonate bank deposits consisting of high-energy crinoidal detritus characterized the lower-middle Niagaran of Ontario (see Figure 2). These shallow-water deposits representing the more stable fringe of the Michigan Basin continued to develop during Guelph time, and formed a barrier reef complex completely embracing the Michigan Basin (see Figure 3). During the deposition of the late Niagaran, subsidence inside of the carbonate bank was considerably accelerated, resulting in the development of numerous bioherm reefs. Two distinct belts of inter-reef facies are recognized within that area bordering the Michigan Basin: (1) The region immediately inside the carbonate bank where subsidence was somewhat restricted, resulting in the development of large patch reefs, and (2) a more mobile belt (bordering Lake Huron) where subsidence was more rapid and in which small but very high pinnacle reefs developed. Not all of the reefs found to date are productive of oil and gas. It has been found however that most of the successful reefs discovered to date are those in the areas above thick crinoid bank deposits shown in Figure 2, i.e. western Lambton, Kent and Essex counties. Detailed lithofacies (limestone-dolomite ratios) studies of later initial Cayugan limestones indicate an abrupt change from limestone to dolomite approaching the pinnacle reef. With the

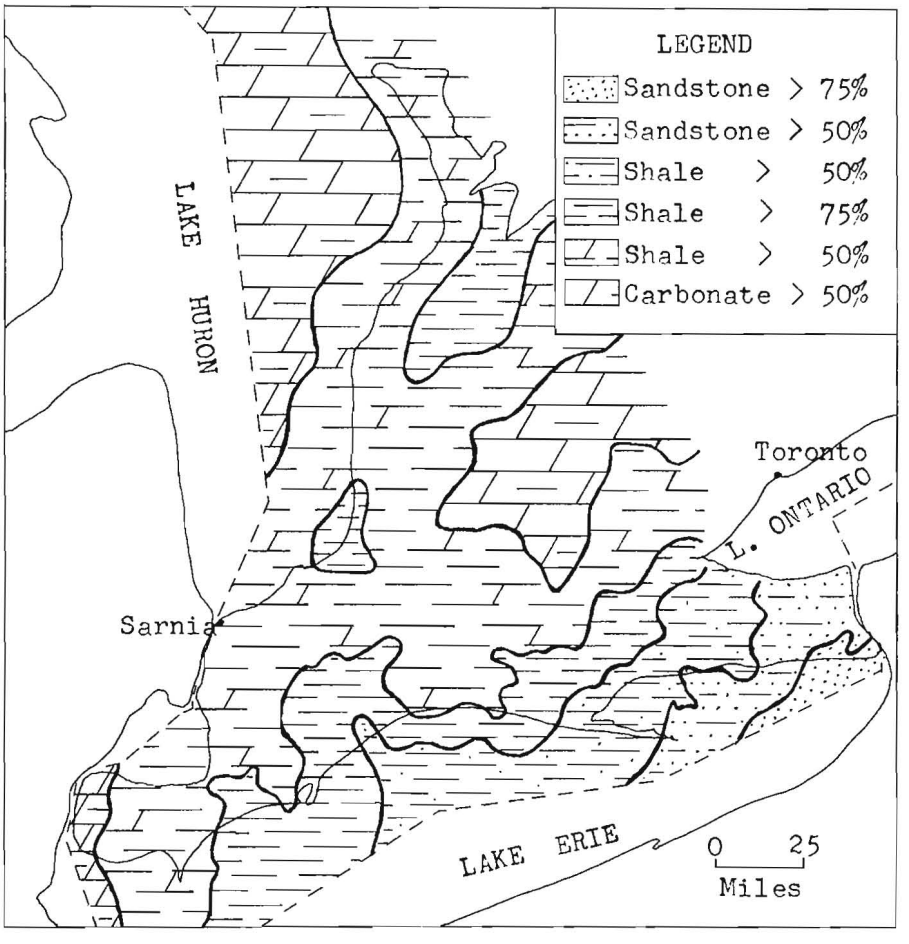


Figure 1. Lithofacies of Lower Silurian (Cataract) Rocks in Southwestern Ontario

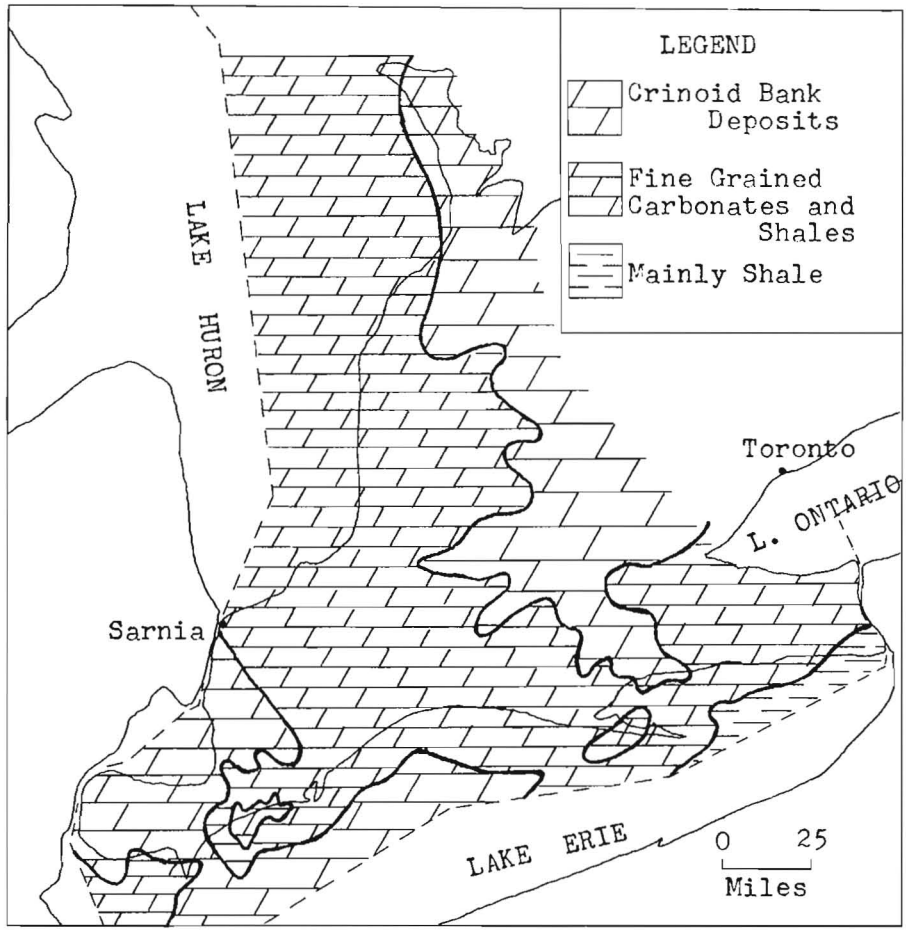


Figure 2. Lithofacies of Early Niagaran (Clinton-Lockport) Rocks in Southwestern Ontario

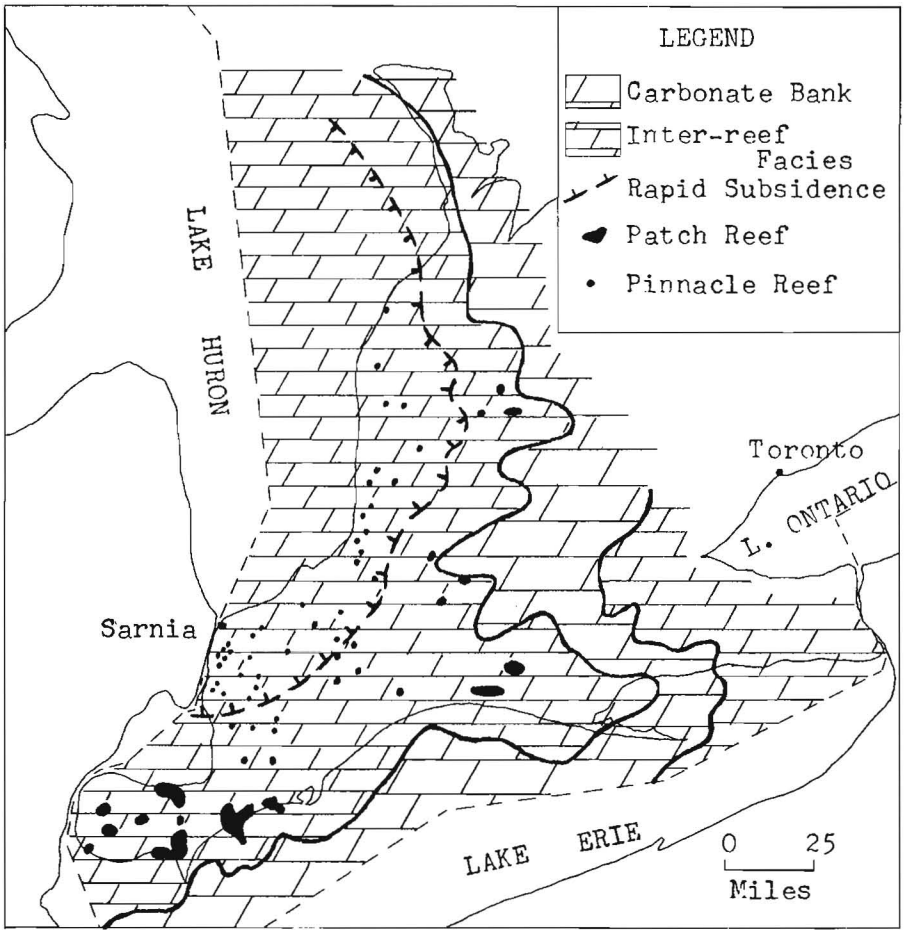


Figure 3. Lithofacies of Late Niagaran (Guelph) Rocks in Southwestern Ontario

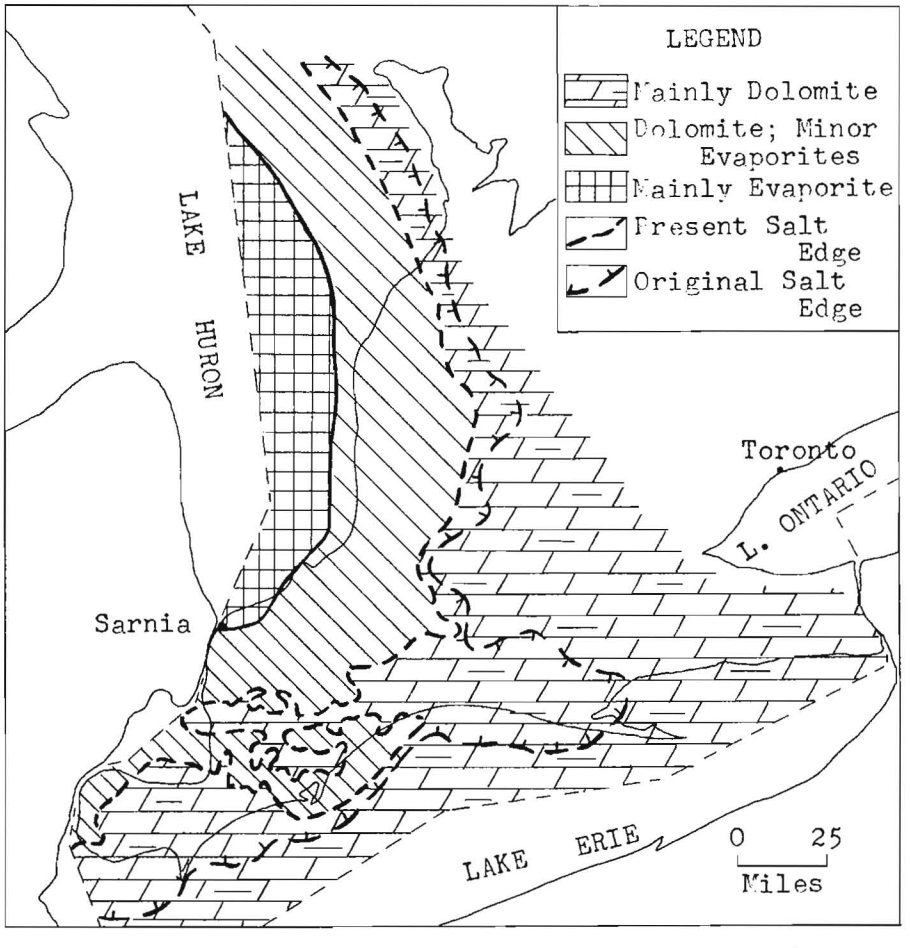


Figure 4. Lithofacies of Upper Silurian (Cayugan) Rocks in Southwestern Ontario

subsurface detail now available this constitutes an important exploration tool.

Following development of a thick Niagaran carbonate bank around the fringe of the Michigan Basin, Cayugan evaporites (salt, anhydrite and primary dolomites) along with normal marine limestones and shales were deposited within its margin (see Figure 4). From detailed stratigraphy of the uppermost beds of the Cayugan, the original area underlain by salt can be reconstructed. This is accomplished by the fact that leaching occurred late in Cayugan time in the southern part of the region, and first in the areas of local Niagaran structures or along fracture zones; this resulted in anomalous thickening of the formation being deposited at the time of initial collapse. As an exploration tool, shallow stratigraphic test drilling would have accurately established the location of a number of oil and gas fields discovered to date in Kent and Essex counties, including several fields producing from rocks of Pre-Silurian age.

SUBSURFACE STUDIES OF CRETACEOUS ROCKS IN NORTHEASTERN BRITISH COLUMBIA AND ALBERTA

D.F. Stott

The Lower Cretaceous Bullhead and Fort St. John Groups were studied in the subsurface east of the Foothills of Alberta and British Columbia between latitudes 54° and 56° as far east as the Sixth Meridian. This study establishes correlation of that succession with rocks of the outcrop belt within the Foothills. Cross-sections and isopach maps showing regional distribution patterns and relationships have been prepared.

The Gething coal-bearing sediments and Cadomin conglomerates are intertonguing facies of an alluvial-plain environment. The base of that succession is a regional erosional unconformity that bevels older Cretaceous and Jurassic strata from the Foothills into the Plains. The overlying Fort St. John Group comprises a thick succession of intertonguing marine and continental sediments. The Spirit River Formation, equivalent to the Moosebar and lower (Gates) member of the Commotion Formation, contains sediments that grade laterally southward from predominantly marine sandstones and shales into alluvial plains deposits. A similar relationship is found in the Peace River Formation and its equivalents, the two upper (Hulcross and Boulder Creek) members of the Commotion Formation.

The general regional parallelism of the lithologic units, as shown by the isopach maps, indicates that deposition was influenced by considerable tectonic control related to negative movements along the ancient Peace River "arch". That structural element was a definite factor until the end of deposition of the Peace River Formation. A distinctly different distribution of later sediments implies that movement must have ceased during Late Albian (Neogastroplites) time.

Several fields near the British Columbia-Alberta border produce petroleum and natural gas from these rocks. Trends of major sandstone bodies outlined by this study, show that stratigraphic control is important in the development of the reservoirs. Prospective reservoir rock decreases northward from Fort St. John but well-sorted marine sandstones south of Peace River are favourable as potential reservoir rock.

SUBSURFACE GEOLOGY, LOWER MACKENZIE RIVER AND ANDERSON RIVER AREA, DISTRICT OF MACKENZIE

E.J. Tassonyi

This study is based on completed core, sample and mechanical log studies of released exploratory wells north of the 65th parallel, and will lead to revision of the nomenclature and correlation of subsurface formations presented in GSC Paper 45-29 and Memoir 273. The study covers strata from Cretaceous to Cambrian, with special emphasis on the Devonian.

The lowest penetrated stratum is correlated with the Cambrian Mount Cap Formation. Within the overlying Saline River Formation two informal members are recognized, a lower, salt member and an upper, shale member. Sparse data suggest that in the Norman Wells area the centre of the Cambrian salt deposition coincides with the maximum development of the evaporitic member of the Bear Rock Formation.

The Ronning Group is reduced to formational rank in order to accommodate three informal members. The wedge-like westwardly increase of thickness and progressive truncation toward the east is indicated.

The Devonian nomenclature and stratigraphic concept is in basic agreement with H.G. Bassett's proposition, published in the Arctic Symposium[1] with the following modification or emphasis:

(a) The Bear Rock Formation is restricted to a lithology corresponding with that of the type area, with an upper, brecciated and a lower, evaporitic member. A new formational name is required for the rocks occupying the interval between the Ronning Formation and the Hume Formation west and outside of the area of the evaporitic facies of the Bear Rock Formation. This new formation can be divided into upper, pellet limestone member, a middle dolomite member, and a thin, lower limestone member.

(b) The Hume Formation may be divided into upper, middle and lower members.

(c) The basal bituminous shales of the Hare Indian Formation will be given a formal name. The distinct spore content of this member is significant for correlation.

(d) It is suggested that the term "Ramparts Formation" be used as it was originally by Kindle and Bosworth[2]. The difference in depositional environment between the lower platform member and the upper reef member and separate, but contemporaneous reef growth is emphasized.

There is evidence that the unconformity at the base of the Canol Formation cuts progressively older beds from Fort Good Hope towards Point Separation.

The study shows that an upper and lower member can be recognized in the Imperial Formation.

The Sans Sault Group and the Slater River Formation are correlated within the study area, and the uncertainty of the correlation within the Sans Sault Group is attributed to facies changes.

In the assessment of oil producing potential the primary role of broad tectonic movements is emphasized, particularly tilting and downwarping, which affected the whole shelf area and governed oil migration and accumulation in stratigraphic traps; only modifying effect and secondary importance can be attributed to Laramide structures.

---

[1] Bassett, H.G.: "Devonian stratigraphy, central Mackenzie region, Northwest Territories, Canada" in Geology of the Arctic; Proc. First Internat. Sympos. Arctic Geology, 1961, vol. 1, pp. 481-498 (1961).

[2] Kindle, E.M., and Bosworth, T.O.: Oil-bearing rocks of lower Mackenzie River valley, Northwest Territories; Geol. Surv. Can., Sum. Rept. 1920, pt. B. pp. 37-63.

PETROLOGY OF SEDIMENTARY AND VOLCANIC STRATA OF THE FRANKLINIAN EUGEOSYNCLINE

H.P. Trettin

In 1961 and 1962 in the course of a geological reconnaissance program directed by R. Thorsteinsson, the writer mapped the pre-Mississippian eugeosynclinal rocks of northern Axel Heiberg and northwestern Ellesmere Islands. Most of the time between field seasons was spent on thin-section and point-counter analysis of the sedimentary and volcanic rock specimens collected. The objectives were: 1. to establish microscopic criteria for correlation where fossils are lacking and macroscopic criteria are insufficient; 2. to learn about provenance and environment of deposition of the sedimentary rocks; and 3. to record the evolution of the volcanic rocks. Some preliminary results of these studies are summarized below.

1. Ordovician, Silurian, and Devonian clastic sediments of the Franklinian geosyncline were derived from early Lower Palaeozoic and older metamorphic, volcanic, and sedimentary rocks that appear to have counterparts in known formations such as the Cape Columbia Group, the Mount Disraeli Group, and the Rens Fiord Complex. In other words, they were probably derived from uplifted strata deposited earlier in the mobile belt itself; not from the continent to the south, probably not from a stable borderland to the north, and probably only to minor extent from possible volcanic-island arcs — as might be deduced from some of the geosynclinal theories.

2. Thick sequences of turbidites are present but seem to be confined to the early and climactic phases of orogenies. It is noteworthy that many sand-grade turbidites contain less than 10 per cent of clay matrix.

3. Thick sequences of volcanic rocks are present but appear to be confined to orogenic periods. In the Silurian and Devonian volcanic rocks there is an evolution from predominantly intermediate to increasingly basic compositions. The plagioclases are largely, but not entirely, sodic in composition.

QUATERNARY GEOLOGY

LATE PLEISTOCENE STRATIGRAPHIC CHRONOLOGY IN SOUTHWESTERN BRITISH COLUMBIA AND NORTHWESTERN WASHINGTON

J.E. Armstrong, D.R. Crandell, D.J. Easterbrook, and J.B. Noble

Stratigraphic studies undertaken between 1950 and 1963, supplemented by more than 120 radiocarbon dates, have shown a need for defining several new geologic-climate units for the late Pleistocene in northwestern Washington and southwestern British Columbia. A formal name is required for the last major glaciation during which glaciers occupied the mountains and lowlands of this area. In the past many writers have used the informal term "Vashon glaciation" to refer to this event, however, it is now proposed to restrict the use of the name "Vashon" to a stade within the last major glaciation. The discovery of non-glacial deposits in southern Puget Lowland and southwestern British Columbia directly below Vashon Drift has now been demonstrated to record a non-glacial interval that is younger than those for which pre-existing formal names are available. This interval, like the major glacial episode that followed it, merits a formal designation.

MULTIPLE GLACIATION OF SOUTHERN YUKON TERRITORY

H.S. Bostock, R.B. Campbell, J.E. Muller, and J.O. Wheeler

This study of glaciation of southern Yukon is based mainly on aerial-photograph interpretation supported by scattered field observations. The area to be investigated when the study is complete covers most of Yukon between latitudes 60° and 64° with the exception of the extreme eastern parts. The study has brought to light evidence of at least three glaciations, the oldest of greatest extent and the youngest of least extent, during which ice flowed inward from the north, east, south, and southwest into Yukon Plateau. The study is incomplete and it is not yet possible to correlate all of the glaciations of the Kluane Lake and Snag areas to those farther east and north.

The oldest discernible glaciation is distinguished by greatly modified features of glacial erosion and deposition. There are notched spurs, disrupted drainage, and a difference between glaciated and unglaciated topography. Field evidence in the Carmacks and surrounding region verifies existence of at least two, probably three, and possibly even four glacial tills.

Ice of the oldest and most extensive glaciation encroached closely on the northeast of the Klondike placer district. It moved from the east, south, and southwest down the valleys of Stewart, Yukon, and White Rivers and extended down Yukon Valley north to near Selwyn River, and down Stewart River to below Scroggie Creek.

The two younger glaciations have left much more obvious features of erosion and deposition, though those of the second are more modified and less sharply defined than those of the third. The extent of each of these glaciations is marked in many places by prominent moraines but in others the boundary is not clearly defined.

Near its margin the ice surface of the second glaciation lay 1,000 feet below that attained by the first. Ice from the east and southeast reached to about 137°15'W on Stewart, Pelly, and Yukon Rivers. Ice of the second glaciation from St. Elias Mountains flowed northeast across Shakwak Valley and projected into Ruby Range. A lobe occupied Wellesley Basin and extended down White River valley to the mouth of Donjek River.

The third, and youngest major glacial advance has left clear-cut and obvious topographical features. Toward its margin it lay about 1,000 feet below the level of the second ice-sheet. From an eastern source this ice reached to about 136°15' on Stewart and Pelly Rivers and from the southeast it extended down Yukon Valley to about 20 miles below Carmacks. The third glaciation in the western part of the region flowed northeasterly from the centre but did not pass the margins of St. Elias Mountains.

Source areas can be inferred, from flow patterns, for the third glaciation. Ice flowed westerly from Selwyn Range and was, in part, deflected northwestward by the barrier of Pelly Mountains. From a high in northern Cassiar Mountains ice flowed east, north, and west. The northerly flow was diverted northwestward by the bulk of Pelly Mountains. Ice flowed northerly toward Aishihik Lake from a high in the Coast Mountains. In general ice from the crest of St. Elias Mountains flowed downslope toward Shakwak Valley.

QUATERNARY HISTORY, KOM OMBO PLAINS, UNITED ARAB REPUBLIC

Robert J. Fulton

Early in 1963 two months were spent as geologic consultant with a Canadian archaeology party in the Aswan area, U.A.R. The work was requested by the National Museum and was part of Canada's contribution to the UNESCO archaeology salvage project necessitated by construction of the Aswan Dam.

The area of study, referred to as the Kom Ombo Plains, is a tectonic basin 30 miles north of Aswan. Sandstone escarpments bound the plain on the north and the south, the Nile forms the western limit, and to the east the plain passes into the valleys of Wadi Shait and Wadi Kharit. Tertiary limestone is faulted topographically below Cretaceous sandstone at the northern edge of the basin.

The history of the Nile River has been discussed in terms of periods of aggradation separated by intervals of degradation. Two stages of deposition and at least one phase of erosion are recorded in the Quaternary deposits of the Kom Ombo basin.

Maturely dissected hills of coarse gravel and high remnants of gravel terraces in the eastern portion of the plain are the oldest exposed Quaternary deposits in the area. The composition, the texture, and the position of the gravel remnants indicate the source was at the heads of the two large wadies entering the basin from the east. Climate was much wetter than present during gravel deposition, as the present-day runoff moves little material of any size down the wadies.

Isolated gravel patches on the sandstone desert north of Kom Ombo Plains suggest the basin was completely filled during the early period of aggradation. Absence of gravel from most of the basin indicates deposition was followed by a considerable period of erosion. A well-marked bench on the east side of the gravel hills suggests the gravel was removed in more than one period of erosion.

The silt and sand flooring the Kom Ombo Plains was deposited during the last major cycle of aggradation. This material, identical to modern deposits of the Nile, was deposited when the river was about 35 feet above its present level. A period of abnormally high precipitation is the probable cause of this phase of aggradation. A forthcoming radiocarbon date will shed light on the problem of the age of this latest major depositional cycle of the Nile.

The wide fluctuations of the regimen of the Nile, reflected in the history of the Kom Ombo Plains, require a regional explanation. The climatic fluctuations characteristic of the Quaternary are the probable answer.

STUDIES OF LAKE-BOTTOM SEDIMENTS

J. Terasmae and R.J. Mott

Field and laboratory studies of surficial deposits from many parts of Canada clearly indicate that lake-bottom sediments provide the best palynological records. Deposition in lakes is commonly more continuous than in bogs and alluvial environments. Also, such deposition begins when a lake basin is formed, for example, after retreat of the continental ice-sheet, whereas bogs often may begin to develop considerably later.

In the winter of 1963 several lakes in southern Ontario were cored through ice using a truck-mounted drill rig. A continuous 2-inch Shelby tube core of the lacustrine sediments and the rest of the surficial deposits was collected and 15 feet of bedrock was drilled. Reconnaissance studies made in the previous summer included echo-sounding, SCUBA diving, investigation of bottom sediments and water chemistry, and plant and animal life in the lakes.

In the course of these studies it was necessary to modify existing equipment and design new items, making it more lightweight and portable for air transport or back-packing to less accessible sampling sites.

The results obtained certainly warrant further application and improvement of the methods and equipment as this investigation is extended in the future.

HYDROGEOLOGY

HYDROGEOLOGICAL STUDY OF THE STEINBACH AREA, MANITOBA

J.E. Charron

After analysing all the groundwater data collected during the course of the study, three interesting phenomena could be seen.

1. One would expect the groundwater to flow from the highlands of Sandilands Forest Reserve, in a general westward direction, but instead the main flow is northwestward. This can be explained geologically. The Red River Formation (dolomite and limestone) which is the aquifer that should transmit the groundwater westward has been eroded and replaced by the Amaranth Formation (shale). This formation and the clayey till on top of it form an aquiclude and thus prevent the groundwater from flowing westward. The path of least resistance is followed, by by-passing the shale formation to the north. Consequently from the recharge area of Sandilands Forest Reserve the groundwater follows a northwestward path through Marchand, La Broquerie, Giroux, Steinbach and St. Anne.

2. A large flowing artesian zone of some 320 square miles has been established during this study and the water level in this flowing zone is lowering each year. It was assumed that the piezometric surface would be lowered in such a way that by comparing many wells, a general regression southeastward or simply eastward could be observed each year as a solid line or front. However, the study brought out by the fact that the piezometric surface of the flowing zone is being undermined bit by bit within the zone itself. The reasons for this are not quite clear yet. This means that a well in the centre of the flowing zone can stop flowing before a well situated on the northwestern edge of the zone.

3. A dry summer such as one experienced in the Steinbach area in 1961 lowered the water table 8 feet below normal, but the cold of winter will lower the same water table by as much as 6 feet. This difference of only 2 feet is much less than had been assumed previously.

MODEL STUDIES APPLIED TO GROUNDWATER INVESTIGATIONS

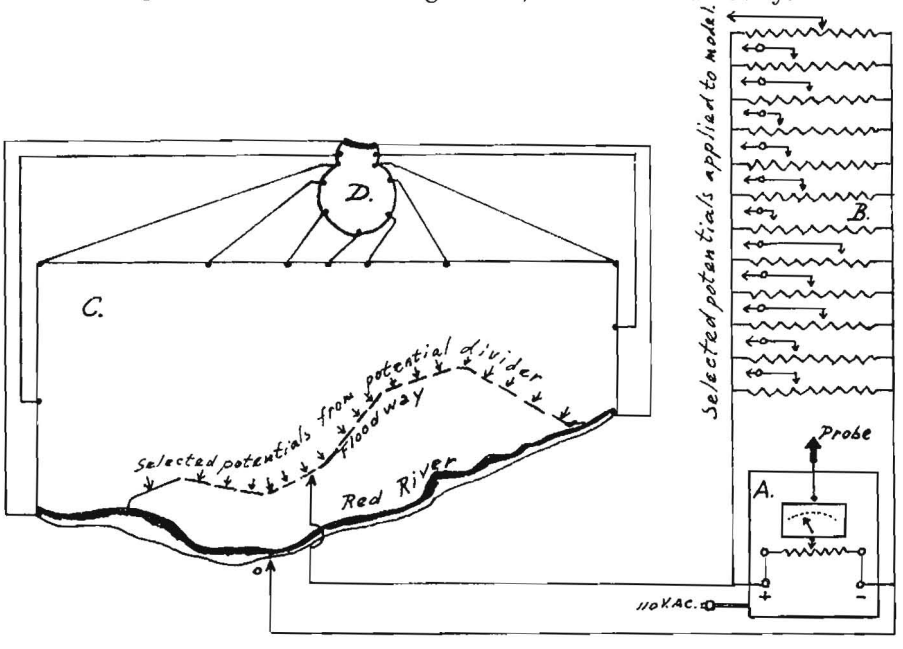
R.O. van Everdingen

The initial phase of the project has resulted in a review of groundwater model methods (GSC Paper 63-12). Practical use so far has been restricted to the Teledeltos conducting-paper model.

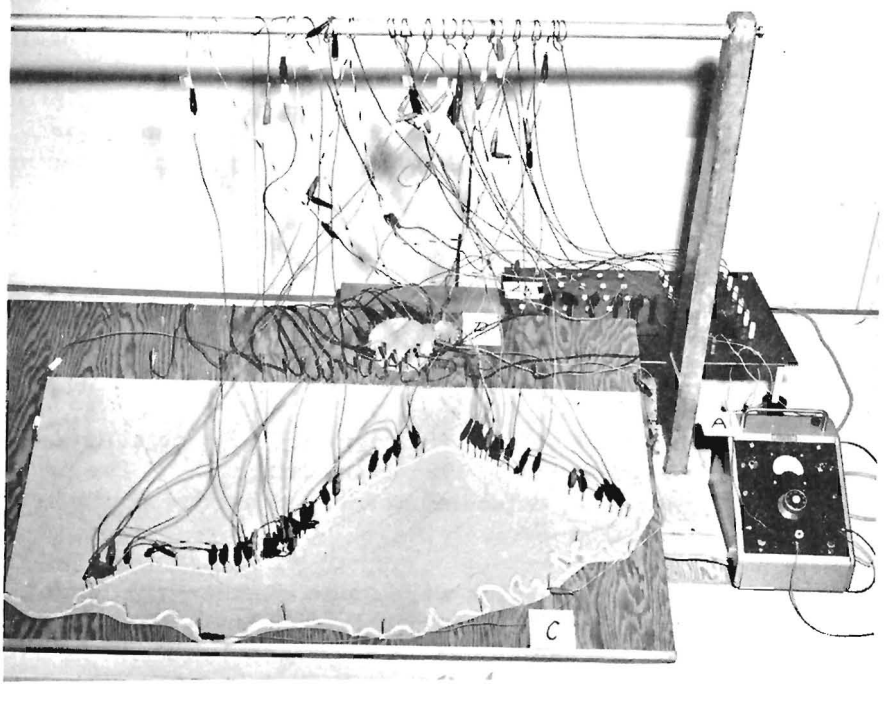
The first major model of this type was run in 1963 for the Red River Floodway, Winnipeg, Manitoba. The aim of the study was to determine drawdowns in the piezometric surface of the artesian Red River limestone aquifer, to be expected as a result of the excavation of the Floodway channel. The model was set up as a secondary flow or drawdown model, in which 'known' drawdowns along the channel were put in the model as potential electrodes. The plotted electric potential distribution then represents expected drawdown distribution. Part D (Figure 1) was attached to the main model C to reduce distortion of the field at the edges of the model. Using aquifer characteristics determined from pump tests in the area, predictions were thus made of maximum possible drawdown, time necessary to reach new equilibrium conditions, and probable amount of induced groundwater discharge into the channel.

The Teledeltos paper was also used for heat-flow studies in connection with the Upper Mantle Project.

Figure 1. Electric-analog model, Red River Floodway.



(a) Schematic circuit diagram.



(b) Actual model arrangement.

MARINE GEOLOGY

ORGANIC GEOCHEMISTRY OF MARINE SEDIMENTS - SCOTIAN SHELF

Lewis H. King

This is a continuing laboratory and field project begun in August 1963, to isolate and study the constitution of the organic fraction of the sediment. Organic matter in sediments is in general more sensitive to environmental changes than the inorganic components; therefore, an important part of the project is to study the chemical nature of the organic matter with respect to environment. A number of structural chemical parameters of the organic matter will be mapped and integrated with the data obtained by conventional mechanical analysis of sediments.

On the basis of the information provided by the distribution studies, critical samples will be chosen and studied in detail with respect to their optical, physical and chemical properties. This data in turn will be used to provide a structural assessment of the organic matter. Changes in organic matter with respect to depth of burial will also be studied.

The area chosen for the first investigation is on the Scotian shelf in the vicinity of Emerald and Sambro banks. A preliminary sampling program was carried out in August to provide samples for the development of technique. A method is being developed for separating the organic matter of a low ash content from the sediment, and the analytical section of the laboratory is being set up.

RECENT MARINE SEDIMENTS OF EXETER BAY, BAFFIN ISLAND, DISTRICT OF FRANKLIN

K.M. Kranck

See Paper 63-2, p. 23 — identical text!

Officers of the Canadian Hydrographic Service collected 127 samples of bottom sediments in 1955 from Exeter Bay. The area sampled is 5 by 16 miles, extending across the narrow continental shelf to the continental slope.

Size and shape analyses were made together with petrographic studies on thin sections of selected pebbles and heavy mineral mounts of unconsolidated sands. Charts were constructed to show the data. From this study, distribution and properties of the sediments and agents of deposition were determined. The sediments are coarse;

50 per cent of the samples are gravel and 35 per cent of these have no sand. High sand content occurs close to shore and between islands off Exeter Bay. Gravels occur from about 5 miles from shore to the continental slope, where sand is again found. Sedimentary transport is due to rivers and ice-rafting, the latter predominating; this is seen in the poor sorting and abundance of large pebbles. On the continental shelf, sediments are exposed to the Labrador current and fines are winnowed out, leaving a coarse lag deposit.

Petrographic results indicate local derivation for some coarser fragments. Igneous and metamorphic rocks correspond to rock types on Cumberland Peninsula. Limestone and sandstone fragments are probably ice-rafted from regions underlain by sedimentary rocks around northern Baffin Bay. Basaltic pebbles also occur and probably come from Tertiary volcanics between Cape Dyer and Cape Bearle. Heavy minerals show little variation, illustrating the dominant masking effect of ice-rafting over normal sedimentary processes.

FAUNAL STUDIES, POLAR CONTINENTAL SHELF PROJECT

Frances J.E. Wagner

Identification of microfaunas collected by B.R. Pelletier in 1962 from the Arctic Ocean west of the Queen Elizabeth Islands was commenced and completed in 1963. Thirty-four more species of Foraminifera were added to those previously listed from the Polar Continental Shelf Project area (Wagner, GSC Paper 61-27, 1962). An additional 16 molluscs, 8 ostracods, 3 annelids and 2 bryozoans were also found in the 1962 collections. Conclusions reached in Paper 61-27 regarding depth zonation of the faunas and indicator species are essentially unchanged. However, a finer zonation of faunas on the continental shelf now appears possible.

GEOPHYSICS

ELECTROMAGNETIC FIELDS OF A SMALL LOOP ANTENNA ON THE SURFACE OF A POLARIZABLE MEDIUM

B.K. Bhattacharyya

Studies have been made on the characteristics of the electromagnetic fields produced by a small loop antenna placed on the surface of a medium that exhibits induced polarization effects. An approximate expression for the effective impedance of a polarizable medium is used for this purpose. Both the real and imaginary parts of the impedance are appreciably frequency-dependent. Different expressions suitable for specific ranges of time and specific values

of the characteristic parameter of the medium are obtained for the fields when the antenna is excited by a step-function current source. The step-function responses show marked differences in characteristics as the parameter of the medium is increased from very small values typical of membrane polarization, to very large values corresponding to electrode polarization. In the transient decay curve, the rate of decay in the initial small portion of the curve increases, whereas in the remaining major portion of the curve it decreases with rise in the value of the characteristic parameter of the medium.

QUANTITATIVE TREATMENT AND INTERPRETATION OF AEROMAGNETIC DATA

B.K. Bhattacharyya

An accurate method for determining second and higher-order derivatives and for making upward and downward continuation of the magnetic field has been developed. The harmonic expansion of the anomalous total magnetic field simultaneously along two directions has made it possible to calculate with exceptional accuracy its pseudogravimetric potential at all magnetic latitudes for all possible directions of the polarization vector of the magnetized rock mass, free from the effect of the inclination of the earth's main geomagnetic field. These methods are very useful in delineating the magnetic bodies causing the anomalies and they have been tested for fields of theoretical magnetic sources as well as for actual field anomalies. For calculating fields produced by rectangular block-type bodies, accurately and very rapidly with digital computers, exact expressions of the fields have been analytically obtained.

In connection with the International Upper Mantle Project, aeromagnetic data over a large area in central Ontario, approximately 320 miles by 320 miles, are being analyzed to determine the depth and extent of the magnetic sources in the crust of the earth.

SCOTIAN SHELF SURVEY (MAGNETOMETER AIRBORNE DETECTOR)

Margaret E. Bower

Aeromagnetic compilation of the Scotian Shelf MAD Survey is now in the final stages. Contouring at a 10-gamma interval has been completed and the main task now is to make the corrections necessitated by erratic behaviour of the Decca navigation system.

Magnetic patterns in this area are varied and complex. Near the coast there are many strong linear trends running parallel to those on the adjacent land. One negatively polarized dyke-like structure was found; it is well defined and extends for many miles. Out to sea there are large anomalies of deep basement origin, including those rather mysterious ones that occur just at the edge of the continental shelf. Magnetic effects from the sediments have also been observed; there are fairly well defined trends of less than 1-gamma intensity. Further study of these sedimentary magnetics is planned, although a new method of handling the data will have to be devised. Some experiments with digital filtering have already been tried.

NINE REVERSED REFRACTION SEISMIC PROFILES HUDSON BAY LOWLAND, MANITOBA

George D. Hobson

Between March 26 and April 23, 1963, 38 holes were shot over nine reversed refraction seismic profiles in the Hudson Bay Lowland area of Manitoba. During this period, 10 days were lost because of weather and 5 days were required to move and set up camp at five locations. The objectives of the project were to determine the feasibility of using the seismic method to determine the thickness of the various geologic formations down to the Precambrian surface, to correlate seismic velocities with lithologic units, and to develop a technique for conducting such operations in this area. All objectives have been partially or completely achieved.

Location of Profiles

Seismic refraction profiles are indicated on the location map (Figure 1). In particular, the locations are as follows:

Location 1: Hudson Bay near mouth of Broad River on shore-fast ice.

Location 2: Hudson Bay northwest of Nelson Shoal near mouth of Rupert Creek on shore-fast ice.

Location 3: Hayes River about 1 1/2 miles upstream from York Factory.

Location 4: Hudson Bay about 20 miles east-northeast of York Factory on shore-fast ice.

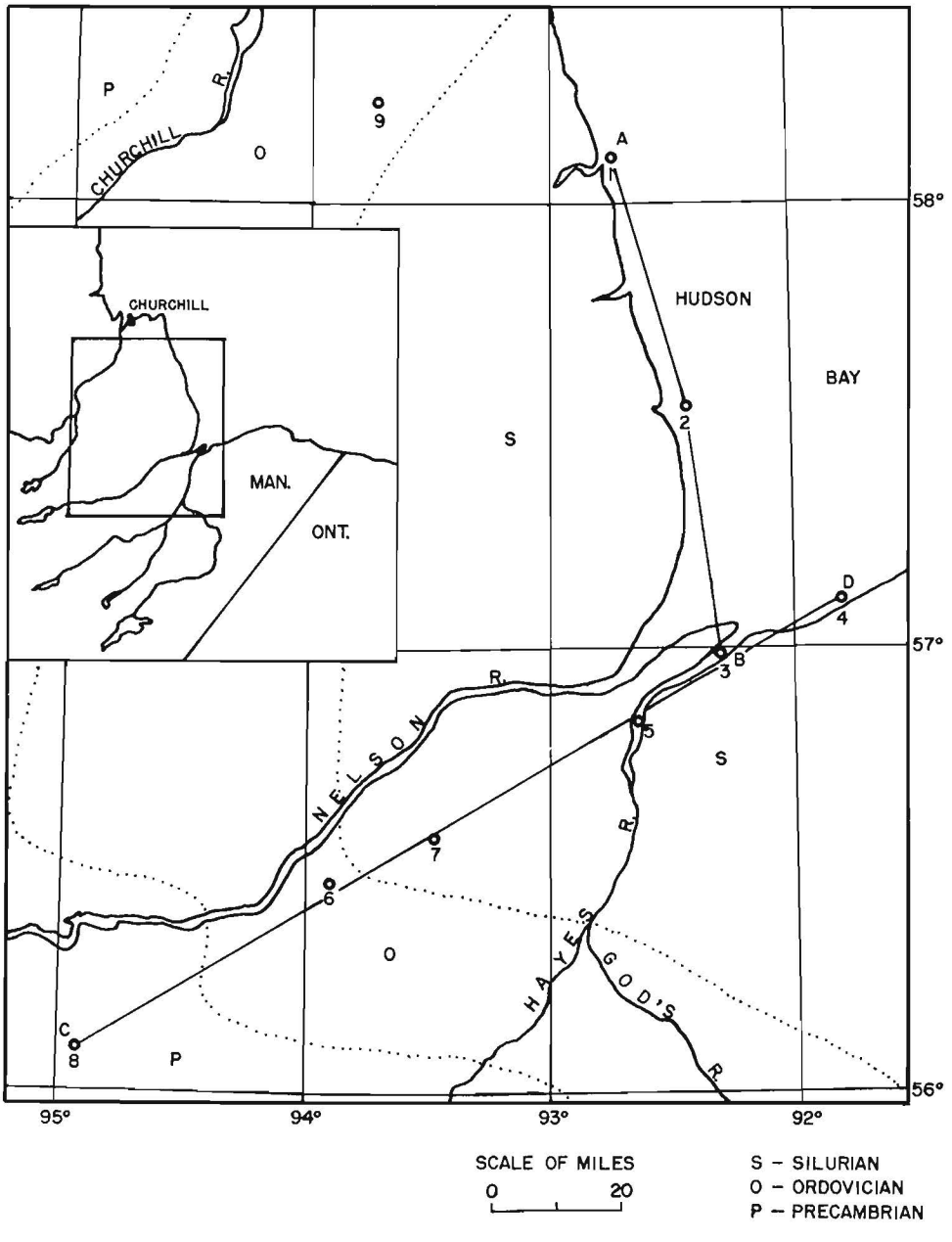

P
CHURCHILL R.
O
9
A
1
58°
CHURCHILL
HUDSON
BAY
MAN.
ONT.
S
2
D
4
57°
B
3
R.
NELSON
5
S
R.
7
6
O
HAYES
GOD'S
R.
C
8
P
56°
95°
94°
93°
92°
SCALE OF MILES
0 20
S – SILURIAN
O – ORDOVICIAN
P – PRECAMBRIAN

Figure 1.

Location 5: Hayes River about 17 miles upstream from York Factory.

Location 6: Angling Lake.

Location 7: Unnamed lake about 20 miles east-northeast of Angling Lake.

Location 8: Kettle Lake about 19 miles southwest of Gillam.

Location 9: Steele Lake about 38 miles south-southeast of Churchill.

Two sections, A-B and C-D, will be discussed.

Equipment and Procedure

All seismic data were recorded through 12-channel conventional instruments and 7.5-cps detectors. Geophone interval was 150, 300, or 600 feet varying with distance of shot-point to detector. Elevation above sea-level at each location was carried into the location from base camp by the aircraft altimeter so that elevations indicated on the sections are approximate. A theodolite was used to determine position by sun observations for those locations along the shore of Hudson Bay. All profiles were reversed.

The crew was accommodated in tents and the camp was moved by means of a casual-chartered DC-3 aircraft. A Bell G-2 helicopter was used to move crew and equipment over a profile but this technique did not prove to be the most efficient method of operation. Subsequent operations have been carried out using an Otter fixed-wing aircraft and a small motorized snow-vehicle.

A power-saw gasoline-powered engine with a transmission adapted to auger drill stem was used to drill holes through the ice so that the explosive charges could be set at the bottom of the water. This auger drilled a 10-inch hole so that no difficulty was encountered lowering the largest charges through the ice. Geogel explosive was used in the following generalized quantities:

1 1/4 lb. for distances to 1,380 feet,
2 1/2 lb. for distances to 3,300 feet,
between 2 1/2 and 20 lb., average 5 lb., for distances to 6,600 feet,
between 5 and 50 lb., average 30 lb., for distances to 13,200 feet,
between 15 and 100 lb., for distances to 17,150 feet.

The lakes and rivers are generally very shallow in the Lowland area and frequently no tamping material other than snow was available for the charge. This, of course, necessitated the larger charges at some locations.

Ice and Snow Conditions

Ice thickness during March-April 1963 on the lakes and rivers investigated varied between a minimum of 40 inches and a maximum of 72 inches. The sea-ice varied between 3 1/2 and 6 feet in thickness with an average of 5 feet. River and lake ice varied between 4 and 5 feet with an average very close to 4 feet. The ice on the lakes and rivers visited was generally smooth with some light ridging at a few locations. There were few or no cracks in the ice. Along the shore of Hudson Bay the ice was frequently ridged and cracked, presenting obstacles to laying out cables and detectors. However, some flat undisturbed areas could be found along the shore-fast ice inside the tidal leads.

Snow cover was generally less than 8 inches and averaged about 4 inches. In general, there was no snow cover on the shore-fast ice or on the lakes since high winds had blown away any accumulations of snow. The snow cover on the rivers was about 6 inches. No drifts of more than 1 foot high on ice were encountered.

A few whiteout weather conditions were encountered during the project. The ice and snow conditions during March-April 1963 may have been unusual due to the severity of the previous winter season, because operations during March-April 1964 encountered snow generally 1 to 2 feet thick overlying ice only 2 feet thick on rivers and lakes. Shore-fast ice along the west coast of James Bay was never found to be over 3 feet thick. Obviously the 1963-64 winter was a poor year for thick ice and is probably attributable to an early thick protective layer of snow.

Geology

This subject will not be discussed in detail. Davies et al. (1962) and Savage and Van Tuyl (1919) both discuss the geology of the project area and reference can be made to their publications. Jenness (1949) has pointed out that there is about 140 feet of permafrost at Churchill and none under the Churchill River at its mouth. There is probably no permafrost under the major rivers of the Lowland area and probably very little, if any, under the shallow lakes of the area. The general geologic boundaries after Davies (1962) are indicated on Figure 1.

Bedrock formations are sandstone, limestone, or dolomite of early Palaeozoic age and they dip toward Hudson Bay from the Precambrian-sediment contact. However, since both the Silurian and Ordovician formations are dolomitic or limestone in composition they may be difficult to distinguish seismically. Such is not the case in southern Ontario, and many geologists believe that the geologic sections of southern Ontario and the Hudson Bay Lowlands should be similar, where seismic velocities are generally higher in the Silurian formations than in the Ordovician, Hobson (1960). Holes have been drilled in the Weir River and Pennycutaway River areas but no seismic data was obtained at these locations. Drift thicknesses of 400 feet are known to be present in the surveyed area.

Discussion of Results

The data observed have been computed and compiled and presented in the form of two sections, Figures 2 and 3. Velocities, represented by such as 17,400'/ₛ, in feet per second, are as observed and corrected from the seismic records. Profile A-B (Figure 2) is located along the shore of Hudson Bay. At Location 1, the low

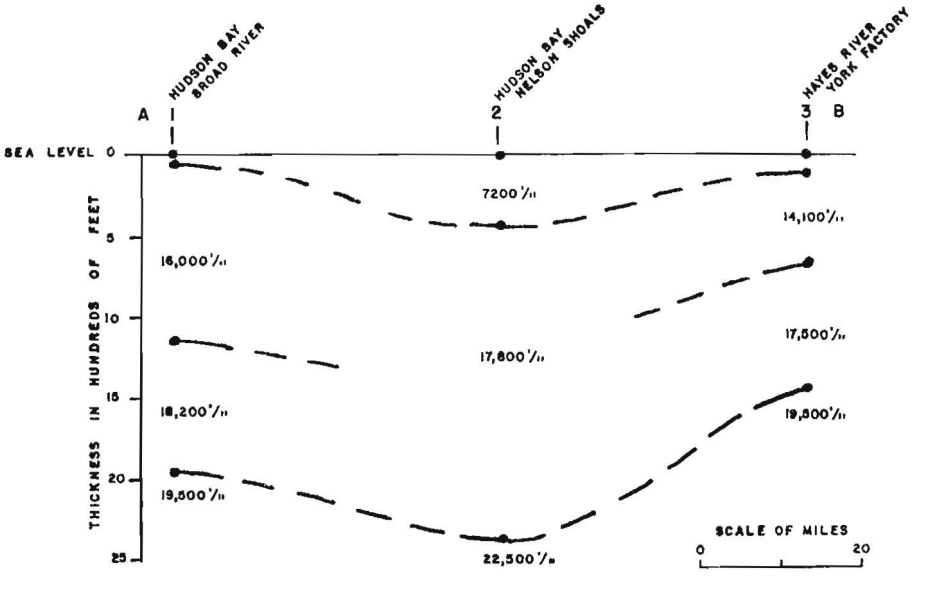


Figure 2.

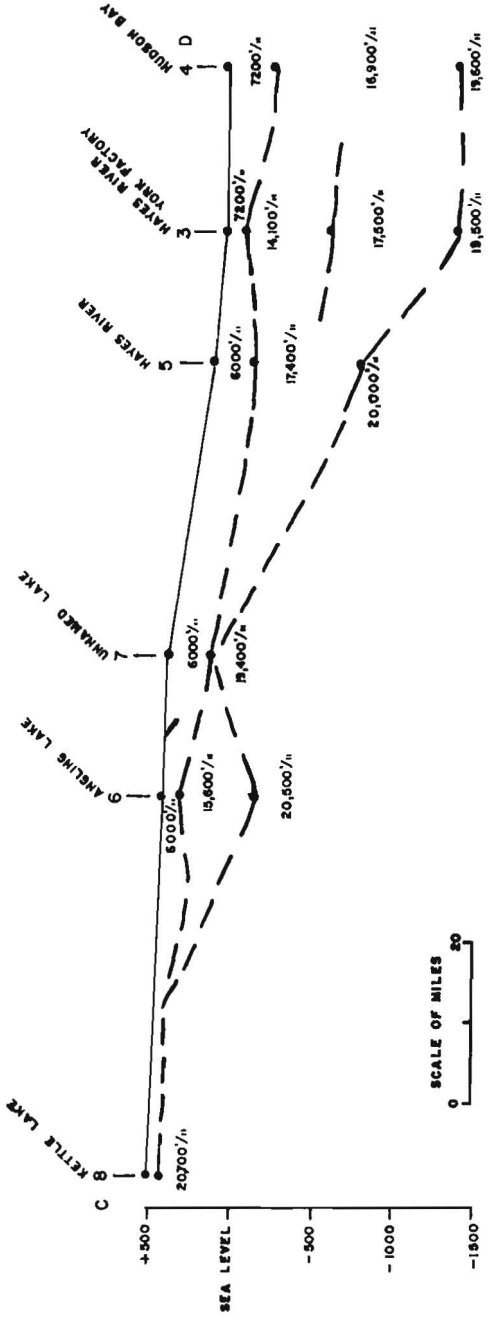

HUDSON BAY
D
4
HAYES RIVER YORK FACTORY
3
HAYES RIVER
5
UNNAMED LAKE
7
ANGLING LAKE
9
KETTLE LAKE
8
C
7200'/"
14,100'/"
17,500'/"
18,500'/"
16,900'/"
19,500'/"
6000'/"
17,400'/"
20,900'/"
19,400'/"
6000'/"
15,600'/"
20,500'/"
6000'/"
20700'/"
+500
SEA LEVEL
-500
-1000
-1500
SCALE OF MILES
0
20

Figure 3

velocity layer is only about 56 feet thick and it is about 1,964 feet to the Precambrian surface. At Location 2, the drift layer is very thick, about 488 feet. The Silurian and Ordovician formations cannot be differentiated at this location, probably due to both being of very similar limestone composition. It is at this Location 2 that the thickest section of sediments was observed in the project area. Here it is about 2,343 feet to basement. Location 3 is near York Factory and overburden is about 102 feet thick. At Locations 1 and 3 the Silurian and Ordovician formations can be differentiated.

Profile C-D extends from a site on the Precambrian Shield at Kettle Lake to a point on the shores of Hudson Bay east of York Factory. This profile is about 135 miles long. Drift at Location 8 is about 115 feet thick while at Location 6 it is about 94 feet thick. Location 6 is over Ordovician bedrock sediments and a depth to basement of 568 feet is indicated. Location 7 indicates a drift thickness of 278 feet. At this location no intermediate velocities are observed between drift and basement. Two possibilities present themselves to explain this situation. Either the Silurian and Ordovician sediments are collectively too thin to transmit refracted seismic energy or the Precambrian 'high' is present. If the latter is true — and there is absolutely no reason why this cannot be the case because the presence of these Precambrian 'highs' or monadnocks is known in the Lowland area — then the profile C-D as shown must be quite acceptable. Drift thickness at Location 5 is about 243 feet and about 295 feet at Location 4. At both of these locations the Silurian and Ordovician formations cannot be differentiated seismically. Location 3 was discussed under profile A-B. The lack of dip between Locations 3 and 4 is probably due to the profile coming on to strike with the nosing structure of Cape Tatnam.

Location 9 yielded the poorest data of the survey. Drift is about 310 feet thick and basement was not penetrated below an Ordovician velocity of 17,500 ft/sec. A charge of 85 pounds gave very poor first arrivals at this location over a spread length of 6,500 feet.

Conclusions

1. The seismic method can be used in the Hudson Bay Lowland area of Manitoba to determine the thickness of sediments to the Precambrian surface.

2. Sections can be drawn to show subsurface strata and their attitude.

3. The Precambrian surface can be detected by the observation of seismic velocity in excess of 19,400 ft/sec.

4. Silurian and Ordovician sediments cannot always be differentiated seismically, probably because of similar composition of these sediments.

5. Excessive amounts of explosives are not required to conduct seismic operations in this area.

6. Overburden thicknesses average over 200 feet and may in some localities be in excess of 500 feet.

7. There is a general agreement between depths to basement determined by seismic methods and those determined by the sea-magnetometer (Hood, in press) off Churchill and York Factory, although in both cases control must be considered to be sparse and contouring is purely conjectural.

References

Davies, J.F., Bannatyne, B.B., Barry, G.S., and McCabe, H.R.
1962: Geology and mineral resources of Manitoba; Manitoba Dept. Mines Nat. Res.

Hobson, George D.
1960: A reconnaissance seismic refraction and reflection survey in southwestern Ontario; Can. Min. J., vol. 81, No. 4, pp. 83-87.

Hood, Peter J.
in press: Geophysical reconnaissance of Hudson Bay; Geol. Surv. Can., Bulletin.

Jenness, J.L.
1949: Permafrost in Canada; Arctic, vol. 2, No. 1.

Savage, T.E., and Van Tuyl, F.M.
1919: Geology and stratigraphy of the area of Paleozoic rocks in the vicinity of Hudson and James Bays; Bull. Geol. Soc. Amer., vol. 30, pp. 339-378.

PALÉOMAGNÉTISME DES DYKES DE DIABASE

E. H. Gaucher, A. Larochelle, W. F. Fahrig

Le paléomagnétisme des dykes de diabase du Précambrien est particulièrement intéressant à étudier à cause d'un certain nombre de facteurs favorables. Les dykes de diabase sont très nombreux dans le Bouclier canadien où ils sont groupés par essaims parallèles qui s'étendent sur des centaines de milles; les dykes de chaque essaim sont vraisemblablement du même âge. Deux ou même trois essaims peuvent se croiser dans une région donnée. Le peu d'effet des mouvements tectoniques sur les régions de dykes, depuis l'injection de ceux-ci, rend leur étude particulièrement attrayante au point de vue du paléomagnétisme. L'un d'entre nous (W. F. F.) est en train de compléter une carte des dykes à travers le Canada; les âges radiogéniques d'un certain nombre d'essaims ont été déterminés. Il semble d'après ces données que les essaims ont été injectés à des intervalles presque réguliers au cours du Précambrien (Fahrig et Wanless, 1963). A l'aide de ces âges et de mesures paléomagnétiques, il nous sera peut-être possible de déterminer les positions successives des pôles au cours du Précambrien et vice versa de déterminer à quel âge appartient un dyke isolé. L'échantillonnage des dykes est relativement facile à cause de leur abondance; généralement, les échantillons orientés ont été prélevés au contact de la roche encaissante, ce qui assure, à cause du grain fin de la roche, une plus grande stabilité de l'aimantation rémanente. Les contacts des dykes offrent aussi l'avantage d'avoir été à l'abri des effets des mouvements de convection qui pourraient se produire dans la roche du milieu du dyke à des températures inférieures au point de Curie (580° C), soit après que la roche eut acquise une aimantation rémanente. L'aimantation des dykes de diabase étant forte, les mesures en sont d'autant plus faciles et plus rapides. La principale difficulté inhérente à l'étude du paléomagnétisme de ces roches précambriennes résulte de la désintégration progressive, selon le logarithme du temps, de leur aimantation acquise au moment du refroidissement, simultanément à l'acquisition de nouvelles composantes isothermes.

Deux cubes ont été prélevés de chacun des 650 échantillons orientés collectionnés à travers tout le Bouclier précambrien par W. F. Fahrig en 1961, 1962 et 1963, et par E. Gaucher en 1962. D'après les mesures de l'aimantation actuelle, il semble que divers essaims aient des stabilités différentes. Les grands dykes N. E. Abitibi de la région de Noranda et les dykes N. W. du district de Mackenzie sont particulièrement stables. La dispersion dans les directions d'aimantation nous a cependant convaincus de procéder à des lavages magnétiques par champs alternatifs afin d'isoler l'aimantation thermorémanente originelle des autres types d'aimantation acquise depuis. Pour déterminer l'intensité optimum des lavages magnétiques, 60 échantillons, chacun représenté par ses deux cubes, ont été traités dans des champs alternatifs de 80, 130, 200 et 310 oersteds. Ces traitements nous ont permis de constater, qu'au delà d'un champ critique, de nombreux échantillons n'étaient

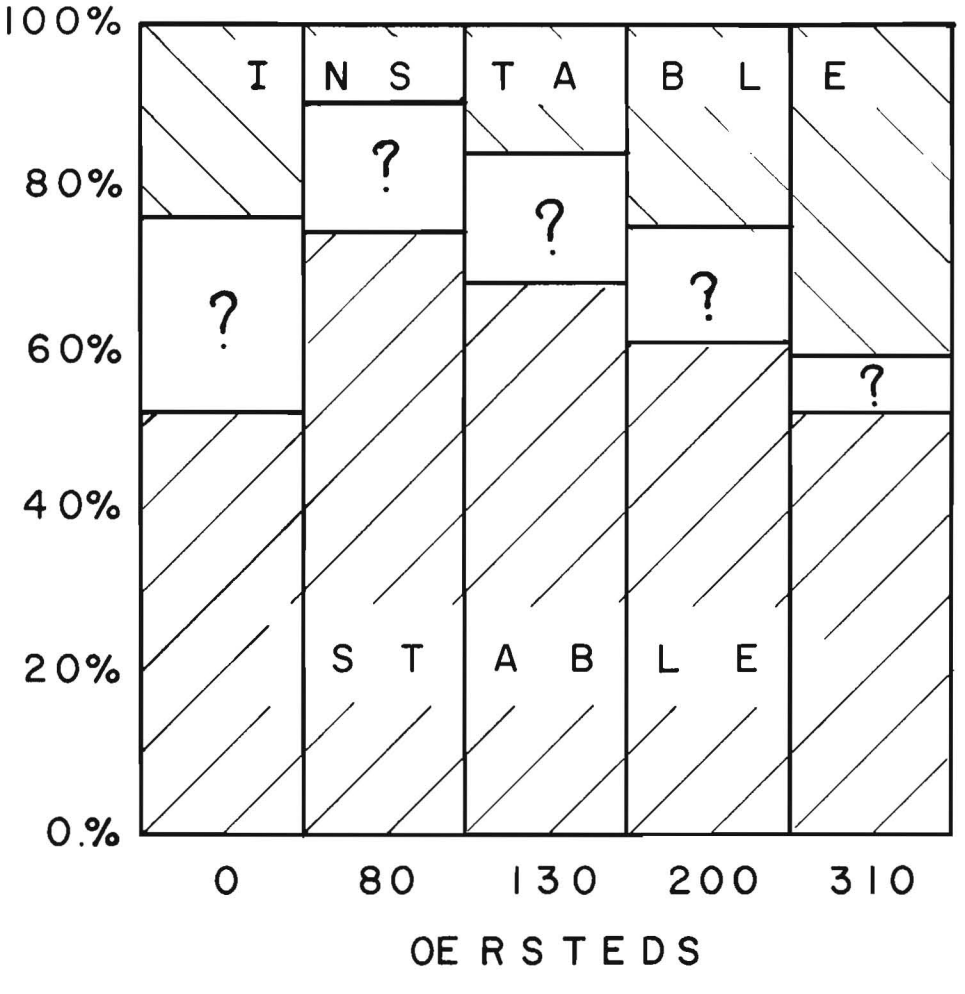


Figure 1: Stabilité de l'aimantation rémanente des dykes.

Les échantillons dont la direction d'aimantation des deux cubes diffère par moins de 20° et dont la direction moyenne d'aimantation varie de moins de 10° par traitement successif sont considérés comme stables. Cinquante-six des 650 échantillons sont étudiés ici.

plus stables et changeaient de direction de façon désordonnée. Nous avons aussi constaté que l'angle entre les directions d'aimantation des deux cubes d'un même échantillon est un bon indice de la stabilité de l'aimantation, surtout si les deux cubes sont traités dans des positions différentes. Un champ alternatif compris entre 80 et 130 oersteds semble optimum pour le traitement des dykes par lavage magnétique, tout au moins par les techniques en usage dans notre laboratoire.

Aucune donnée ne peut être fournie à ce stade-ci en ce qui concerne les implications géologiques de cette étude. Il semble toutefois établi, d'après les résultats obtenus à date, que la direction d'aimantation d'un dyke n'est pas controlée par l'attitude de ce dyke. Cette dernière conclusion vient en contradiction avec les résultats de l'étude de D. W. Strangway (1960).

Références

Fahrig, W. F., et Wanless, R. K.
1963: Age and Significance of diabase dyke swarms of the Canadian Shield; Nature, vol. 200, 7 décembre; pp. 234-937.

Strangway, D. W.
1960: Magnetic properties of some Canadian diabase dykes; these de doctorat, Univ. Toronto.

GEOLOGICAL SOLAR COMPASS

A. Larochelle

The use of an ordinary magnetic-needle compass can be significantly misleading in the collection of oriented rock samples in the field or in many other types of directional measurements. To overcome this difficulty the use of a solar compass was adopted by our laboratory some years ago and others have used sun chart compass corrections[1]. This paper describes a sun compass adapted for our use from a Mark II Astro Compass that was used extensively by the Allied Forces during World War II and is now available at relatively low cost as a war surplus item.

Figure 1 shows the converted instrument, with the latitude and horizontal dials unchanged from the original instrument. The hour dial has been redivided, each hour into 12-minute sections, to replace the 360° graduation on the original dial. To render the system a little more compact the sight was fixed directly to the hour dial and aligned with the 12-12 hour index line on it. The tripod of the original instrument was replaced by a circular aluminum plate with a segment cut off to provide a reference straight edge. The axis of the original compass was located 2 inches off the centre of the aluminum plate so as to make the rim of the horizontal dial coincide roughly with the straight edge of the aluminum plate. Parallel to the straight edge and through the vertical axis, a line was scribed on the plate as a guide to fix the azimuth pointer appropriately (to the left of the horizontal circle in Fig. 1). A round level was fixed to the aluminum base plate which was mounted on three stubs.

Determining the azimuth of a line with this compass does not take any longer than doing it with an ordinary magnetic compass. The procedure is as follows:

1. Set the vertical circle (LAT) to the latitude of the location.

2. Set the hour circle to the apparent solar time. The latter may be readily derived from the formula:

$$A = S - E + 4(T-L)$$

where S is the standard time at the location, E is the equation of time (E_{m-a}) for the day and the year of the observation, and T and L are the westerly longitudes of the time zone meridian and the location respectively. The value of E may be obtained from ephemeris tables but since its variation is very small from year to year for a specific date it may be read directly from a graph such as Figure 2. If a

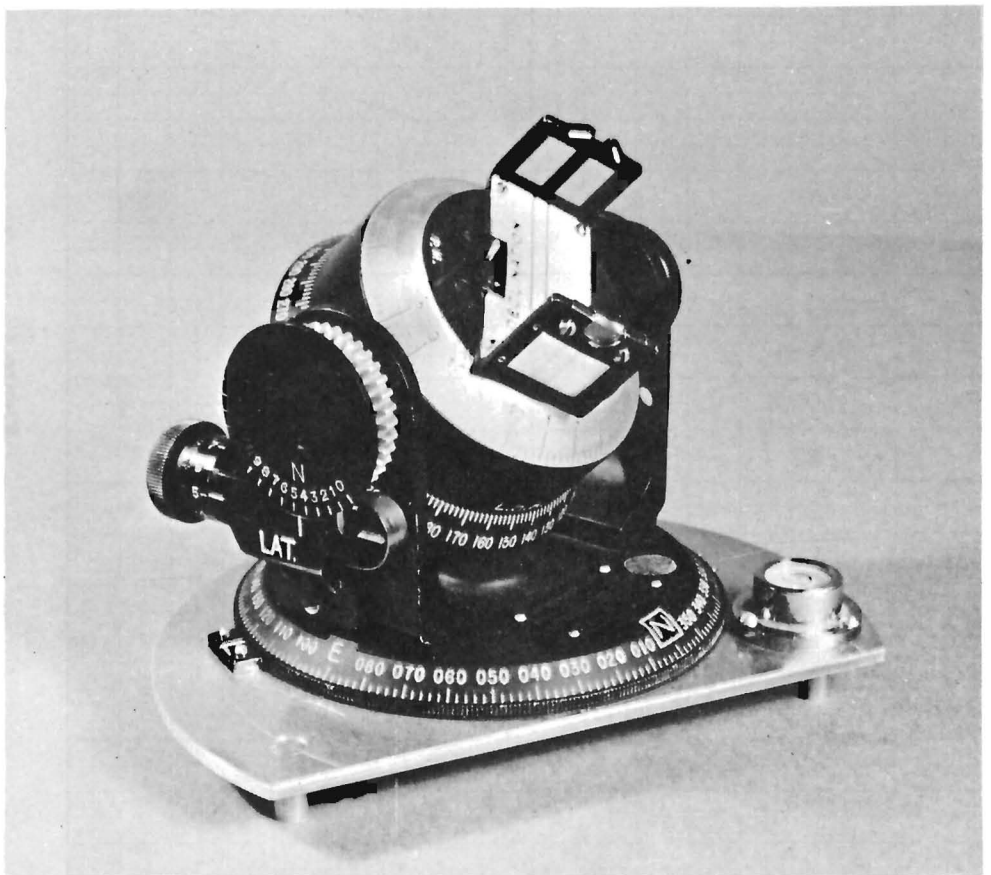


Figure 1

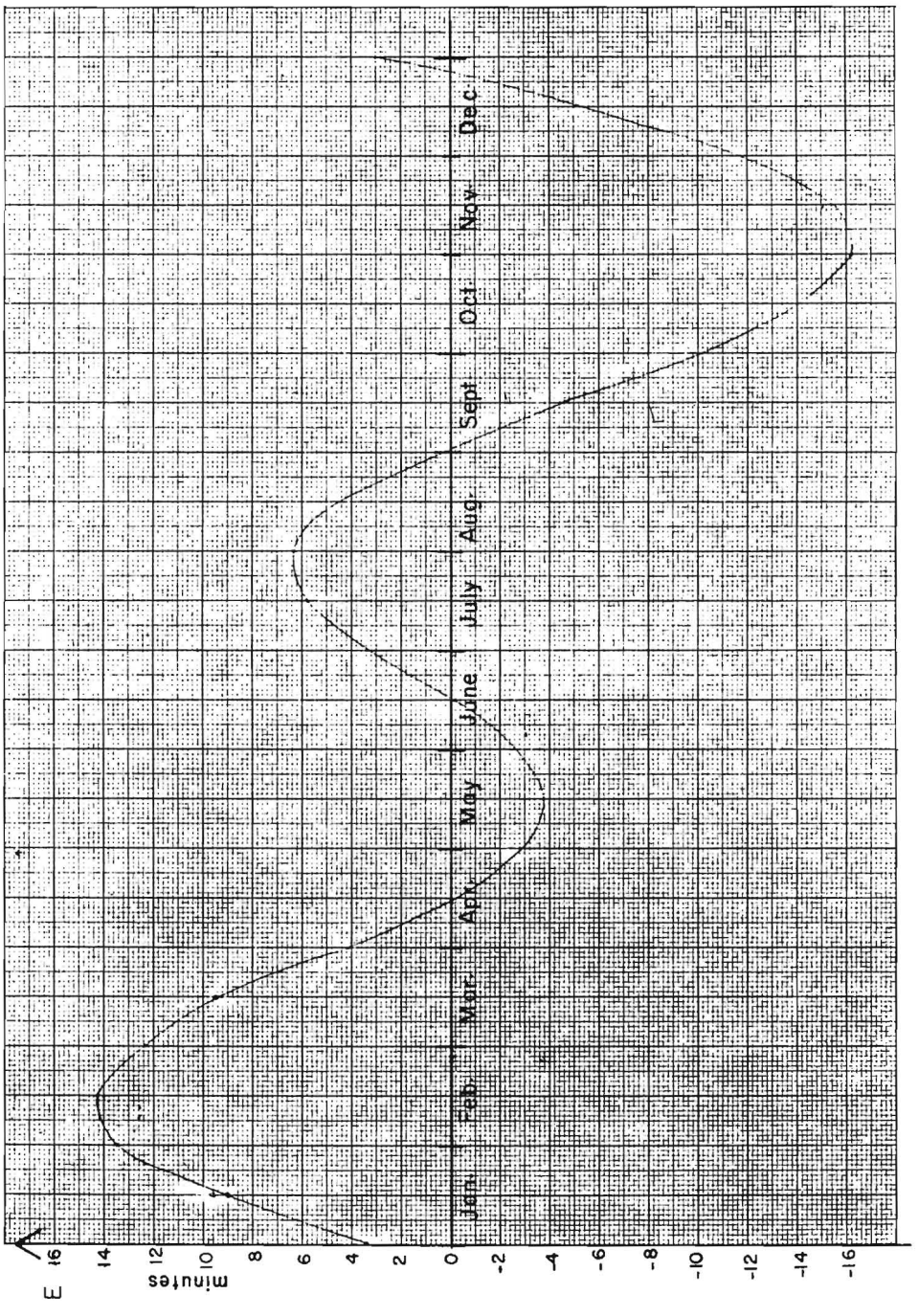

E
minutes
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 2

large number of observations are to be made in a day within a few degrees of longitude, a watch may be adjusted to the local apparent solar time in the morning and the compass hour set directly from it.

3. Hold the base plate horizontally and rotate the compass about its vertical axis until the shadow of the vertical stem on the sight is between the hair lines of the translucent screen opposite to it.

4. Read the azimuth of the line parallel to the base-plate straight edge and directed away from the round level along it (e.g. 120° in Fig. 1).

Given the standard time within an accuracy of 5 minutes and the latitude and longitude of the location to an accuracy of 1 degree, the azimuth of a line may be determined within an error of 1 degree.

---

[1] Fraser, D.C.
1963: Sun chart compass corrections for reconnaissance mapping and geophysical prospecting in areas of magnetic disturbance; Econ. Geol., vol. 58, pp. 131-137.

PALAEOMAGNETIC AGE OF THE PRE-ORDOVICIAN ROCKS NEAR INUVIK, NORTHWEST TERRITORIES

D.K. Norris and R.F. Black

Five miles south of Inuvik, Northwest Territories, lies an elongate area of approximately 20 square miles of red and grey dolomites (see Figure 1). The only fossils reported from these rocks are algal structures from near the top of the succession (Sproule, 1959). Whereas its base is covered the formation is overlain by and is in contact with Upper Ordovician, thick-bedded, grey dolomites containing Halysites sp. (Sproule, idem). On the basis of their gross lithologic similarities to parts of the Macdougal Group they had been assigned to the Cambrian system (Norris et al., 1963).

These pre-Ordovician rocks outcrop in the axial region of a major, asymmetric anticline which plunges less than 5 degrees northeast. They commonly dip about 10 degrees on the southeast flank and between 30 and 40 degrees on the northwest. The structural trend is similar to that of the Keele Range in Yukon Territory.

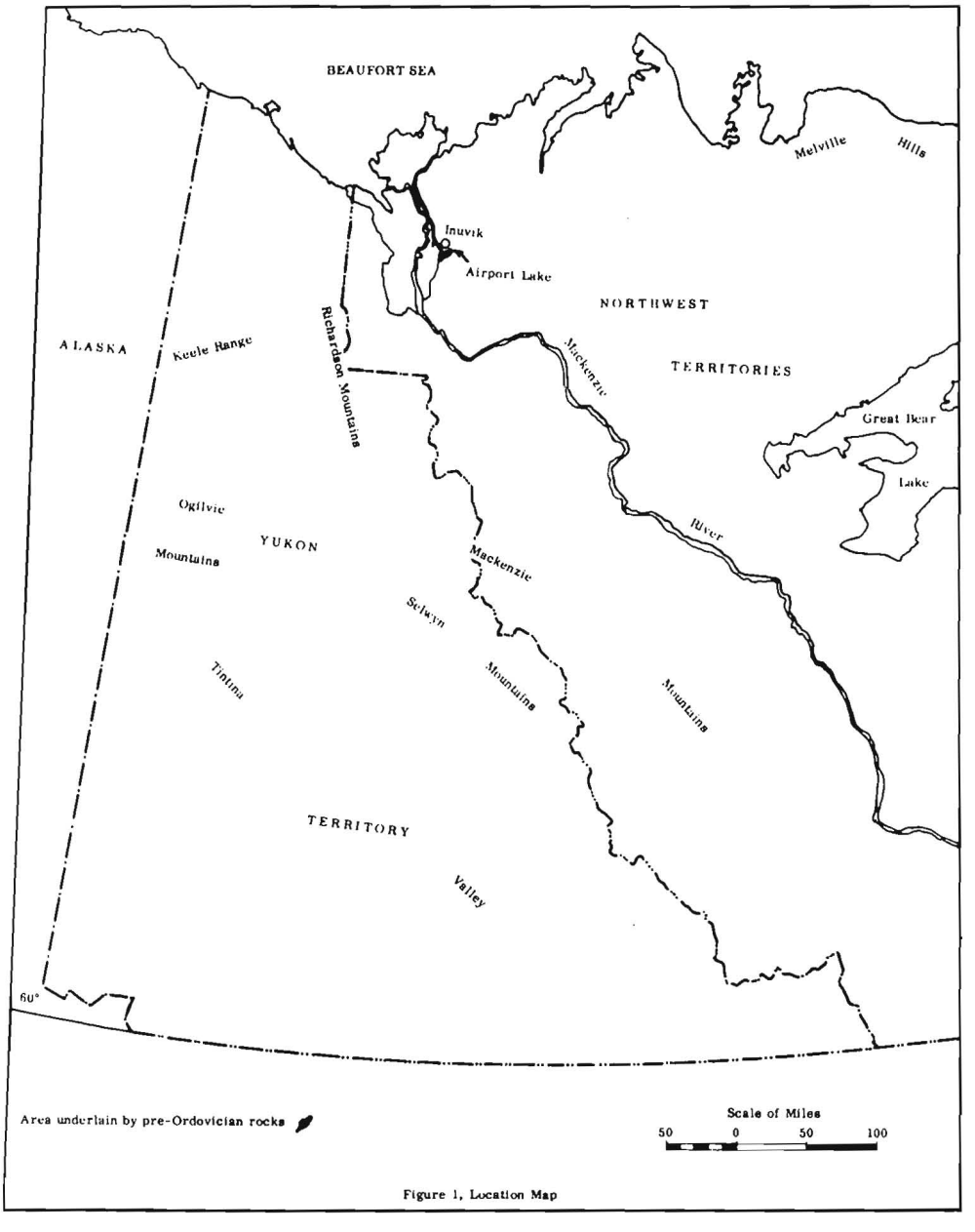


Figure 1, Location Map

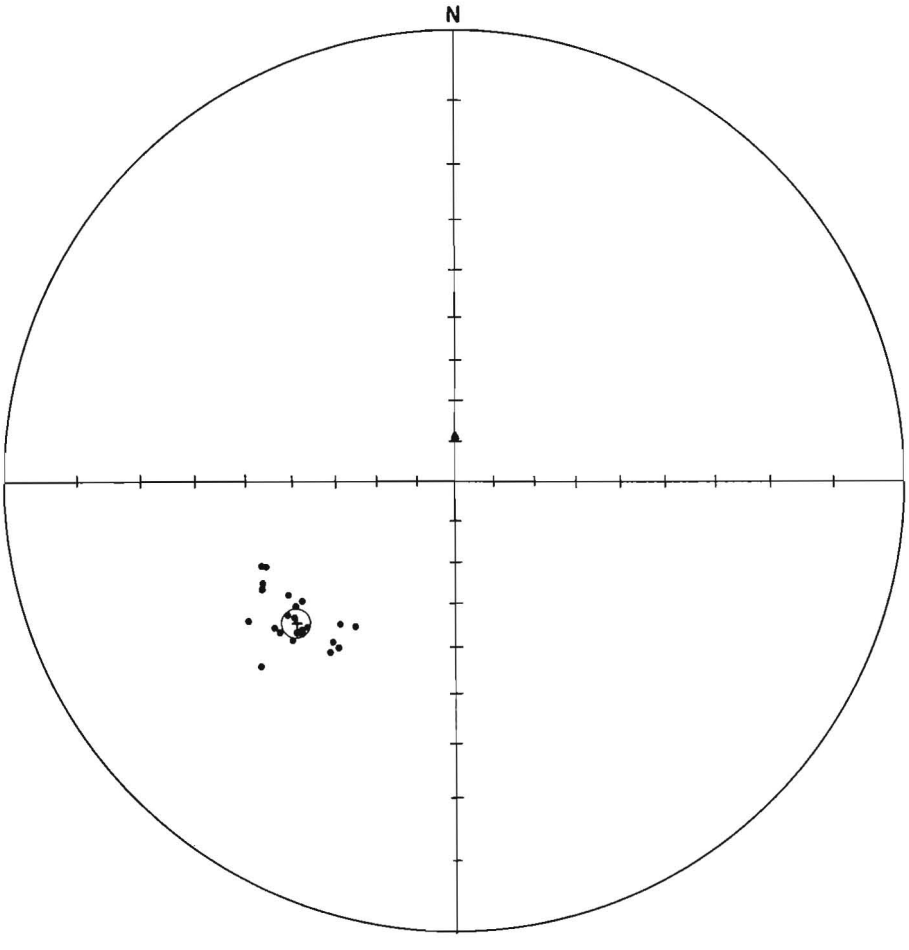


Figure 2. Stereographic projection (lower hemisphere) of the directions of magnetization for 23 samples of the pre-Ordovician rocks near Inuvik, NWT.

Vector pointing downwards.....●

Mean direction of magnetization with circle of confidence .....+

Present theoretical dipole .....▲

Fisher statistics and other basic data

D	I	N	S	R	α_{95}	K	Collection Site		Pole Position		$d\psi$	$d\chi$
228.4	+39.5	23	46	22.7906	3.0	105	68°.3N	133°.6W	7°.2N	178°.0W	2.2	3.6

In a quarry immediately north of Airport Lake (see Figure 1), 23 oriented samples of unweathered, silty, greyish red, fine-grained dolomite were collected from a 50-foot stratigraphic interval on the northwest flank of the anticline. There the strata have a mean strike of 050° and dip of 32°NW. The samples were selected as free as possible from minor faulting and folding evident in the quarry.

Two 1-inch cubical specimens were cut from each of the oriented samples and their directions of remanent magnetization were determined on an astatic magnetometer in the laboratories of the Dominion Observatory. All of the samples were found to be positively polarized. One third of them were tested for magnetic stability with a decreasing-amplitude alternating magnetic field where the maximum amplitude of the field was progressively increased after each set of measurements up to a maximum of 300 oersteds (peak value). This treatment had no significant effect on the directions of magnetization of the test samples and it is concluded that the samples used to represent these pre-Ordovician rocks are stably magnetized.

The mean direction of magnetization of these rocks (see Figure 2) differs significantly from the present field direction produced by an axial geocentric dipole. The statistical parameters computed for the group are N, θ , and K as defined by Fisher (1953), where N is the number of samples, θ is the radius of the circle of confidence calculated at the 95 per cent level of confidence and K is a measure of the dispersion.

The virtual geomagnetic pole computed for these rocks plots between the pole determined for the Duluth Gabbro (1,120 m.y.) and that for the diabase dykes in the Sudbury district (1,020 m.y.) on the mean polar wandering curve for the Precambrian rocks of North America (see Sopher, 1963, Fig. 7).

If it can be assumed that the remanent magnetization of these rocks has been preserved since diagenesis and that the strata sampled have suffered only external rotation from an initially horizontal position about an axis parallel or subparallel to their present strike, the data suggest these pre-Ordovician rocks are Late Precambrian in age, possibly slightly older than the Purcell system of the south-eastern Cordillera of Canada. The potential of these rocks as a source of petroleum and natural gas may therefore be nil.

Ref.

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

Norris, D.K., et al.
1963: Northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Map 10-1963.

Sopher, S.R.
1963: Palaeomagnetic study of the Sudbury Irruptive; Geol. Surv. Can., Bull. 90.

Sproule, J.C., and associates
1959: Geological report, Charter Oil Company Limited Petroleum and Natural Gas Holdings, northern Mackenzie Basin, Northwest Territories, pp. 14-17, December.

CONSTRUCTION OF NON-MAGNETIC OVEN

W.A. Robertson

A non-magnetic oven was constructed during 1963 to test oriented palaeomagnetic specimens. It can be used to 'clean' specimens thermally by raising them to a known temperature in a null field (Irving et al., 1961). This technique is the thermal analogy of magnetic cleaning (As and Zijderveld, 1958; Irving, Stott and Ward, 1961). It may also be used to obtain curves of magnetic intensity with heating to give the spread of Curie Points and hence some idea of the range of magnetic minerals present in the specimen, and to test for anisotropy in a known magnetic field specimens that have been heated above the Curie Points of the contained magnetic minerals.

The oven consists of a three-tier specimen stand, set inside a bronze pot which is surrounded by cylindrical heating elements contained in an insulating jacket. The temperature is measured by two chromel-alumel thermocouples inserted through the base; these may be removed during cooling to avoid causing inhomogeneities in the magnetic field. The voltage from the thermocouples is read with a potentiometer that is accurate to 0.1 mV and the temperatures are reliable to better than 2°C. A copper tube is also inserted through the base to maintain a nitrogen supply to the space within the bronze pot and thus avoid oxidation of the specimens.

The oven is set at the centre of three pairs of orthogonal square coils set in the Helmholtz position. The length of the sides of the coils ranges between 5'0" and 5'10". These coils are used to annul or control the magnetic field inside the oven. The current is taken from a power supply which maintains a constant potential difference of 40 volts. The current for each coil pair is controlled

by helipot variable resistors and read on ammeters accurate to 0.1 mA. Constantan resistances are connected in series with each coil pair to reduce current fluctuations due to temperature changes. Thus the horizontal field may be controlled to within 25 gammas, and the vertical field to within 60 gammas. The limits are comparable with the daily fluctuations of the earth's magnetic field. Greater accuracy may be obtained by using the potentiometer to measure the current.

The heating elements, which are enclosed in a four-layer aluminum radiation sheath and supported on a fiberfrax base, supply 1,300 watts. This heating sheath is lowered over the bronze pot on a pulley system to heat the specimens, and raised when the required temperature is reached, to ensure rapid cooling. This system allows twenty-seven 1-inch cube specimens to be heated from room temperature to 600°C and cooled to room temperature in 3 1/4 hours.

A. Larochelle, R.F. Black, and G. Freida assisted in assembling the oven, and the sheath unit was made by A.G. Meilleur.

Ref.

As, J.A., and Zijderfeld, Z.D.A.
1958: Magnetic cleaning of rocks in palaeomagnetic research; Geophys. J., 1, pp. 308-319.

Irving, E., Robertson, W.A., Stott, P.M., Tarling, D.H., and Ward, M.A.
1961: Treatment of partially stable sedimentary rocks showing planar distribution of directions of magnetization; J. Geophys. Research, 66, pp. 1927-1933.

Irving, E., Stott, P.M., and Ward, M.A.
1961: Demagnetization of igneous rocks by alternating magnetic fields; Phil. Mag., 6, pp. 225-241.

MAGNETOMETER DEVELOPMENT

P. Sawatzky

During the 1962 magnetometer survey conducted in the Port Hardy area of Vancouver Island, B.C., numerous faults or weaknesses were noticed in the equipment, which had been constructed rather hurriedly for this project. Most of these chassis were redesigned and rebuilt.

A special camera hatch that would accommodate either a Carl Mark VII or a Vinten 70-mm camera was designed to fit any Beaver aircraft. It had provision for rotation of the camera through 360 degrees as well as tilting of the camera $\pm$ 30 degrees.

For use in mountainous terrain, new lightweight radio equipment was purchased for the radio relay station (mobile). These units were modified to function automatically when the power is turned on.

Some time was also spent on transistorizing the survey equipment. Units such as counters and recorders were obtained commercially and modified to fit our special requirements. The magnetometer itself is not yet commercially obtainable. A start was made on building a transistorized magnetometer during the early part of 1963. Those parts which have been completed appear to be more satisfactory than the older units that were built using vacuum tubes.

CONTINUOUS READING (MASER) MAGNETOMETER

S. Washkurak

A continuous reading Overhauser effect magnetometer has been constructed and successfully tested as a laboratory prototype.

The prototype magnetometer consisted of a detector coil (2,500 cycles), "Q" multiplier and audio amplifier for the detection of the proton precession signal. A Heathkit VHF (56 Mcs) power oscillator in conjunction with an R.F. polarizing coil saturated the electron resonance line of nitro-sodisulfonate dissolved in deoxygenated water. A continuous precession signal is produced by the coupling between the magnetic moments of the proton and the electron. At present the free radical solutions of nitrosodisulfonate has an active life of only 2 hours. Other solutions are available that last for 2 weeks.

The range of magnetic field that can be detected is limited to 250 gammas due to the "Q" multiplier. Circular polarization should eliminate the need of a "Q" multiplier, increasing the range to 7,500 gammas.

Equipment is being designed and built to record the continuous signal on an analogue recorder and to evaluate circular polarization.

GEOCHEMISTRY

STUDIES IN CARBONATE GEOCHEMISTRY

E.M. Cameron

Preliminary chemical determinations have been made on samples taken from core of the upper part of the Slave Point Formation, penetrated by wells drilled for oil and gas in northeastern British Columbia. Analyses show that minor zinc mineralization is widely distributed in this carbonate formation, with samples ranging up to 2.7% Zn. Both limestones and dolomites have been mineralized. Small amounts of lead accompany the zinc in some samples, to a maximum of 250 ppm Pb. The copper content of all samples is very low.

It seems probable that this mineralization is related to that of the distant Pine Point lead-zinc deposit where the main ore-bearing unit, the Presqu'ile Formation, underlies the Slave Point. Thus the presence of widespread mineralization in the Slave Point Formation bears on considerations of the genesis of the Pine Point ore.

GEOCHEMICAL STUDIES OF GRANITIC BODIES

E.M. Cameron, R.F. Emslie, and R.H.C. Holman

With the development of rapid methods of analysing rocks there arises the intriguing possibility of providing field geologists with geochemical data which they may use to map geological units. One such application would be in the mapping of seemingly homogeneous granitic bodies. The data may further be used to help interpret the origin of the rocks.

During the mapping[1] of large areas of the Canadian Shield in northwestern Ontario on the scale of 1 inch to 4 miles, rock samples were collected for a regional trace-element study. Later a direct-reading emission spectro-chemical method of determining the major-element components of rocks was developed. This method was used to analyse several hundred samples, from granitic bodies in the mapped area, for Si, Al, Fe, Ca, Mg, Ti, and Mn. The elements Na and K were determined by flame-photometry.

At a sampling density of 1 to 2 samples per square mile the chemical data does reveal structures within the granitic bodies. A third-order trend surface analysis[2] of the data was made for each element in the different bodies. The generalized chemical trends

provided by this analysis showed no consistent relationship to the boundaries of the bodies or to the country rocks. The trend surface contours are, however, generally parallel to the tectonic trend of the area in which the body lies.

Further statistical and geological interpretations are in progress.

---

[1] Duffell, S., MacLaren, A.S., and Holman, R.H.C., 1963: Red Lake - Lansdowne House Area, Northwestern Ontario; Geol. Surv. Can., Paper 63-5.

[2] Krumbein, W.C., 1959: Trend surface analysis of contour-type maps with irregular control-point spacing; J. Geophys. Res., vol. 64, pp. 823-834.

STUDIES ON THE GEOCHEMICAL CORRELATION OF SEDIMENTS

E.M. Cameron

The Lower Cretaceous series has been sampled at close stratigraphic intervals throughout the western Plains and Foothills, and these samples have been analysed for soda and potash. The data shows that this series can be divided into three stratigraphic divisions, each of distinctive soda content.

The lower soda division is of low soda content and in different localities comprises such units as the Gething and Bluesky Formations, the McMurray Formation, the lower Blairmore, lower Mannville, Dina Member, and Ellerslie Member.

The middle soda division is principally made up of sediments rich in soda and includes the Spirit River Formation, middle Blairmore, upper Mannville, and the Grand Rapids and Clearwater Formations. The sediments of this division derive their sodic character from volcanic detritus which they contain. In east-central Alberta the high-soda strata intertongue with low-soda sediments, and thin out eastwards. The alternating tongues of high- and low-soda sediments correspond to Nauss's members of the Mannville Formation in the Vermilion area. In the southern Foothills the middle soda division rests directly on the "Calcareous" member - Ostracod zone horizon. Under much of the Plains the lower boundary of the middle soda division is some distance above this horizon and the intervening sandy, glauconitic strata are called the Bluesky Formation, the Wabiskaw Member, or the "Glauconitic" sand.

The upper soda division is composed of sediments generally intermediate in soda content to the sediments of the underlying divisions. The sampled units of this division include the Joli Fou and Viking Formations in central Alberta, the Peace River and basal Shaftesbury Formations of the Peace River area, and the upper Blairmore of the southern Foothills.

Although the sands, silts, or shales of a division do not contain the same amount of soda, each has a content that is distinctive to the division. Thus the different interdivisional and intradivisional boundaries may be drawn irrespective of the local lithology. This is an important attribute of the chemical method of correlation since much of the Lower Cretaceous series, made up of interbedded mixtures of detrital sediments of different grain size, shows rapid vertical and lateral facies changes. The chemical boundaries are sharp, and do not everywhere correspond to the existing formation and member boundaries.

ROLE OF SUPER-CRITICAL WATER IN GEOLOGICAL PROCESSES

K. L. Currie

Measurement of the solubility of albite in water, between temperatures of 400 and 650°C, and 500 to 3,500 bars pressure was completed. 'Solubility' of each oxide can be represented by a Frank equation, but each oxide has a different equation, and that for silica is qualitatively different from those for soda and alumina. Nepheline is produced by prolonged action of water at the lowest temperature and pressure, but at the highest pressures used, free quartz is produced. The results show that 'solubility' in this context is meaningless. Parts of the molecule react with water, probably with formation of stable hydrated complexes.

Experiments on the Belleoram granite, Newfoundland, show that the curious silica-poor assimilation zone surrounding this intrusion could have been produced by rapid degassing of the magma. Results show that the solubility of silica under non-equilibrium flow conditions is substantially higher than the equilibrium value, while solubilities of other components are lower by several orders of magnitude. The results also show that (a) the mobility of Ca and Mg in granitoid rocks is negligible in the presence of water, and (b) solubilities obey Frank equations of the theoretically derived form, even in rather complex rocks.

Further progress was made on the 10-kilobar apparatus, and this equipment is now in working order, except for the intensifier. An internal filtering system was introduced into the 3,500-kilobar apparatus, but had no systematic effect on results.

NEW LABORATORY TECHNIQUES IN GEOCHEMISTRY

John J. Lynch

In connection with geochemical studies conducted by A. Y. Smith, it was necessary to determine trace amounts of zinc, nickel and cobalt in copper-bearing minerals (chalcopyrite, malachite etc.). Since the methods used in this laboratory are unsuitable in the presence of percentage amounts of copper, a rapid means of separation was devised. This method was first applied to solutions of copper sulphate with trace amounts of zinc, nickel and cobalt added. Recovery of these added metals ranged from 95 to 110 per cent, with an average recovery of 101 per cent.

A method for determining silver in rocks was developed. On applying this method to rock samples, good agreement with spectrographic values was obtained. Interferences however have not yet been established and the sensitivity of the method (1 ppm) is only fair. This project will be continued in 1964.

A rapid decomposition procedure was devised for determining arsenic in coal. Due to the volatile nature of arsenic, these samples could not be dry-ashed and hence a wet-oxidation procedure was used. A mixture of perchloric and nitric acid was successfully employed although several precautions had to be observed to avoid explosive hazards.

To determine zinc, copper, lead and arsenic in graphite, several decomposition procedures were investigated. The most rapid method was found to be a fusion with a mixture of potassium hydroxide and potassium nitrate. The sizing of the sample, however, was found to be a very important factor in this method; the best mesh size was the -100 to +150 fractions; +100 mesh samples were attached very slowly and -150 mesh samples tended to deflagrate.

The silver diethyldithiocarbonate method for determining arsenic was applied to samples where abnormally high values were encountered. Since this method is not as sensitive as the conventional Gutzeit test as employed in the trace-element laboratory, it was found to be very useful for these types of samples. The method was first applied to a standard ore (Sulphide Ore -1, obtained from Dr. G.R. Webber of McGill University). An average of four

determinations yielded a value of 440 ppm arsenic, which compares quite well with the preferred value of 420 ppm. The glassware recommended for this procedure was costly (about $16 per unit) and in some cases quite inadequate. A new type of unit was built at a much reduced cost (about 90 cents) and was found to be very satisfactory.

ADSORPTION STUDIES

R.A. Washington

Apparatus was designed, built, and calibrated to measure the surface area of powdered rock samples, in connection with studies of adsorption of trace elements by minerals. The apparatus is based on one described by Ringqvist. It employs the principle that the force required to withdraw a given volume of liquid from a bed of powder (which is wetted by the liquid) is proportional to the surface tension of the liquid relative to the solid and to the surface area of the solid.

A flow-type apparatus was also designed and tested for studying adsorption from liquids by powdered mineral samples. Some initial difficulties were eliminated by minor changes in design and adjustments in operating technique, and preliminary runs then indicated that the flow technique should prove more satisfactory as to speed, accuracy, and reproducibility than the batch technique used previously. The experiments are continuing.

COPRECIPITATION STUDIES

R.A. Washington

A preliminary study was made of the coprecipitation at room temperature of trace amounts of Co with hydrous ferric oxide, using Co^{60} radiotracer. The pH of precipitation was varied from 4 to 10, and the proportion of Co remaining in solution was measured. The Co carried by the precipitate increased from 0 at pH 4 to 95 per cent pH 7.5 and remained relatively constant at 95 per cent to pH 10. However, when ammonia was used to form the precipitate, the amount of Co carried decreased appreciably at pH values above 9, probably due to the complexation of the Co by the ammonia. Further experiments are being planned to examine the coprecipitation mechanism in greater detail.

ACTIVATION ANALYSIS

R.A. Washington

A method was developed for determination of Au in glacial till, etc., by neutron activation. Approximately 150 determinations were made on samples submitted by H.A. Lee from the Kirkland Lake area. The sensitivity limit was estimated to be ca. 0.001 ppm for a 4-day irradiation of a 100-mg sample at a flux of ca. 10^{13} cm^{-2} sec^{-1}. Further determinations are to be made to establish the complete pattern of Au distribution in the Kirkland Lake area. A modification of the method has been proposed, consisting of concentration of the Au in a Ag bead by the technique employed in fire assay and subsequent activation of the bead. The feasibility of this procedure is being tested.

A small amount of development work has been done on the method for determining Cd by activation analysis, but several problems in the radiochemical separation of Cd from rock samples remain to be solved.

ISOTOPE AND NUCLEAR GEOLOGY

K-Ar AGE OF CAMBRIAN GLAUCONITES FROM ALBERTA

J.D. Aitken and R.D. Stevens

Six glauconitic limestones were collected from various parts of the Cambrian section of southwestern Alberta by J.D. Aitken for K-Ar age determination and verification of the Cambrian part of the geological time scale.

All six samples are accurately located in stratigraphic position by associated trilobite faunas as follows:

Sample AC-81 M-1-1A Corona Formation (Cedaria Zone). Upper Cambrian.
Sample AC-91 E minus 42.5 feet (?Albertella). Low Middle Cambrian.
Sample AC-91 E minus 42 feet. Same.
Sample AC-91 328-329. Same
Sample AC-94 1,736 feet Stephen Formation (post-Glossopleura Zone). Mid-Middle Cambrian.
Sample AC-96 1,352 feet Corona Formation (Cedaria Zone). Upper Cambrian.

A preliminary examination has shown that samples AC-91 E-42.5, AC-91 E-42, AC-94 and AC-96 contain sufficient glauconite for the mineral separation and possible duplicate argon extractions and analyses.

Thin sections were made from these four samples and examined petrographically with the following observations:

AC-96. Coarse, grey, clastic limestone with fine glauconite pellets and grains. Carbonate 75 per cent, glauconite 20 per cent, hematite 3 per cent, quartz 2 per cent. Glauconite is fresh-looking, with clastic texture — more angular than sample AC-91 E-42, but not as many composite grains.

AC-94. Grey limestone with abundant glauconite pellets and grains. Carbonate 60 per cent, glauconite 25 per cent, collophane 5 per cent, hematite 3 per cent, quartz 2 per cent. The relation between the collophane and glauconite is obscure, however some green material does replace collophane and this could be glauconite. There has been advanced alteration of glauconite to hematite and replacement by $CaCO_3$.

AC-91 E-42. Clastic-textured, fine-grained grey limestone. Carbonate 88 per cent, glauconite 10 per cent, opaques 1 per cent, less than 1 per cent quartz. Glauconite is in grains 0.2 to 0.6 mm in diameter. Individual grains are composed of scaly aggregates of glauconite crystals. Some grains have colourless centres and blue interference colours. The rock is a calcarenite and the glauconite could be detrital, in that some grains show evidence of rounding, and at least one compound grain of carbonate contains glauconite.

AC-91 E-42.5. Fine-grained, grey limestone. Carbonate 63 per cent, glauconite 20 per cent, quartz 7 per cent, collophane 5 per cent, pyrite 2 per cent, hematite 3 per cent. Glauconite is fresh-looking and a few grains have bleached cores.

On the basis of petrographic study, only sample AC-96 was judged to be satisfactory for age determination, and a glauconite concentrate is now being prepared from this specimen.

VARIATION OF THE RADIOCARBON CONCENTRATION WITH TIME

Willy Dyck

The C^{14} analyses of nine successive annual-growth rings from the pith of the 1,100-year Douglas Fir were completed in 1963. The C^{14} concentration in these rings varied from $+0.05 \pm 0.67\%$ to $1.93 \pm 0.60\%$ relative to the National Bureau of Standards, oxalic acid standard. The average concentration was $1.02 \pm 0.22\%$ with respect to the standard.

The analyses of four modern grass and leaf samples collected July 1, 1963 from Champlain Lookout gave average C^{14} concentrations 64.6 per cent above that of the pre-thermonuclear bomb testing era. This is 31.7 per cent above the 1962 C^{14} concentration.

THE DETERMINATION OF ISOTOPIC ABUNDANCES OF LEAD IN SULPHIDE MINERALS

W.D. Loveridge

Galenas may be analyzed without chemical extraction of lead. Roughly a milligram of galena is required; this is crushed and analyzed directly in the mass spectrometer.

A series of fourteen analyses were made on a standard galena sample. The isotopic abundances of each of these analyses differed from the mean by less than the experimental error inherent in the determination: Pb^{204}, $\pm$ 1.0%; Pb^{206} and Pb^{207}, $\pm$ 0.25%; Pb^{208}, $\pm$ 0.15%. Our value for the isotopic abundances of this sample agrees well with those published by other workers in the field.

Lead must be chemically extracted from sulphides other than galenas, for mass spectrometric analyses. During developmental work on chemical extraction procedures, poor reproducibility was obtained on lead isotopic abundances in two pyrite samples. It was found that these pyrites contained two phases of lead which differed markedly in isotopic composition. These phases could be separated by leaching the pyrite in hot hydrochloric acid and then extracting the lead separately from the leach solution and the residue. Reproducibility of the same order as that obtained for the galena was obtained on each of the two phases of lead. The poor reproducibility on analyses of lead extracted from the unleached sample was due to unequal portions of the two phases being included in the lead being analyzed.

Present techniques permit reproducible isotopic analyses on 1-gram portions of sulphide minerals containing more than 50 ppm lead. Below this level, analyses may be conducted, but contamination begins to become a problem and mass spectrometric analyses become considerably more difficult.

The techniques described have been applied to a preliminary reconnaissance investigation of the lead isotope distribution in a number of ore deposits in Ontario and Quebec.

SULPHUR ISOTOPE STUDIES OF THE MUSKOX INTRUSION

A. Sasaki

Sulphides in the Muskox Intrusion occur (1) along the lower contact as massive and disseminated nickeliferous pyrrhotite, chalcopyrite and cubanite, (2) within a chromite horizon as pyrrhotite and chalcopyrite, (3) disseminated through the upper gabbros as pyrite and chalcopyrite, and (4) in the roof and country rocks as pyrite. About one hundred samples from these different spatial environments were chosen to investigate whether sulphur isotopic fractionation has occurred, and if so, to interpret the trends in relation to the known chemical and petrographic differentiation patterns. The analyses are being made on each different mineral species separated from co-existing sulphide aggregates.

The results obtained to date indicate a discernible enrichment in S^{34} and a fairly wide spread in S^{34}/S^{34} ratio, ranging from about 0 per mil to +17 per mil in $\delta\ S^{34}$ (compared with Canyon Diablo troilite) in the Muskox sulphides, compared with those of other similar basic intrusive bodies. A distinct correlation between the sulphur isotope data and the type of country rocks has been found in sulphides from the lower contact of the intrusion. Along the gneiss region the $\delta\ S^{34}$ is around +6 to +9 per mil and rarely exceeds +10 per mil, while along the metasedimentary rock region it is generally more than +10 per mil and has a much wider spread coming up to +17 per mil. The cause of this peculiar pattern and a possible sulphur isotope fractionation which might have occurred in the course of magmatic differentiation are now under investigation, and it is hoped that the samples collected from a continuous drill-core specimen from the top of the intrusion to the basement complex obtained in 1963 will be good for these purposes.

EXPERIMENT ON WHOLE-ROCK PHYLLITE K-Ar AGE DETERMINATION

R.D. Stevens

A sample of fine-grained phyllite from an area between the McTavish Arm of Great Slave Lake and Coppermine River, N.W.T., (65°44'N, 114°59'W), was selected as a suitable Precambrian sediment of low-grade regional metamorphic character for whole-rock age determination. The sample was provided by J.A. Fraser. Results of the experiment are as follows:

K-Ar age = 1835 m.y.
K = 4.70%
Ar^{40}/K^{40} = 0.18139
Radiogenic Ar = 97%
Weight of sample = 9.1241 gm.

Ages ranging from 1,700 to 2,500 m.y. are very common in this general area and it is concluded that the phyllite age of 1835 m.y. indicates satisfactory radiogenic argon retention.

COOPERATIVE STUDY OF LEAD ISOTOPES IN HUDSON BAY BOTTOM SEDIMENTS

R.D. Stevens

A cooperative study between this laboratory, B.R. Pelletier of the Bedford Institute of Oceanography, and T.J. Chow of the Scripps Institution of Oceanography, University of California, was carried out to investigate the isotopic composition of lead in widely distributed sediment samples from the bottom of Hudson Bay.

Dr. Pelletier collected the samples and Dr. Chow carried out the isotopic analyses at the University of California. The results of the study are shown in the table below:

Isotopic Composition of Lead in Hudson Bay Bottom Sediments

Sample No.	Theta Sta.	Lat.	Long.	$\frac{Pb^{206}}{Pb^{204}}$	$\frac{Pb^{206}}{Pb^{207}}$	$\frac{Pb^{206}}{Pb^{208}}$
1 (S-135)	173	62°30'N	90°34'W	25.00	1.5230	0.5339
2 (S-139)	178	61°45'N	90°02'W	24.39	1.4925	0.5241
3 (S-162)	224	58°35'N	92°08'W	24.15	1.4822	0.5261
4 (S-160)	222	58°00'N	91°00'W	23.42	1.4429	0.5200
5 (S-159)	221	57°30'N	89°34'W	23.49	1.4364	0.5219
6 (S-130)	166	63°02'N	87°49'W	22.36	1.3826	0.5007
7 (S-155)	217	56°54'N	86°18'W	22.07	1.3687	0.5168
8 (S-123)	158	61°48'N	81°58'W	21.63	1.3516	0.4987
Average lead isotope composition				23.31	1.435	0.518

U-Pb AGES OF PITCHBLENDES FROM BEAVERLODGE, SASKATCHEWAN

R.D. Stevens

Lead isotope analyses have been made on 56 pitchblende samples from the Beaverlodge district of Saskatchewan. Ages have been calculated from the isotopic ratios Pb^{207}/Pb^{206}, Pb^{207}/U^{235} and Pb^{206}/U^{238}.

The minerals investigated were true pitchblendes as defined by Robinson (1955) and Cohen (1953), differing from distinctly crystalline uraninite in that they are cryptocrystalline aggregates of tiny (less than 10^{-3} cm) crystallites with consequent uniformity and broadening of the lines on an X-ray powder pattern, and in that they carry a negligible (less than 0.1%) content of thorium and rare earths.

Geological and mineralogical evidence demonstrates that there are several generations of epigenetic pitchblende ores in very close association, so that many samples may be of a composite nature, containing two, and sometimes three, generations of pitchblende. Robinson also shows that opening and re-working of the mineral-bearing veins is indicated by structural and textural relationships.

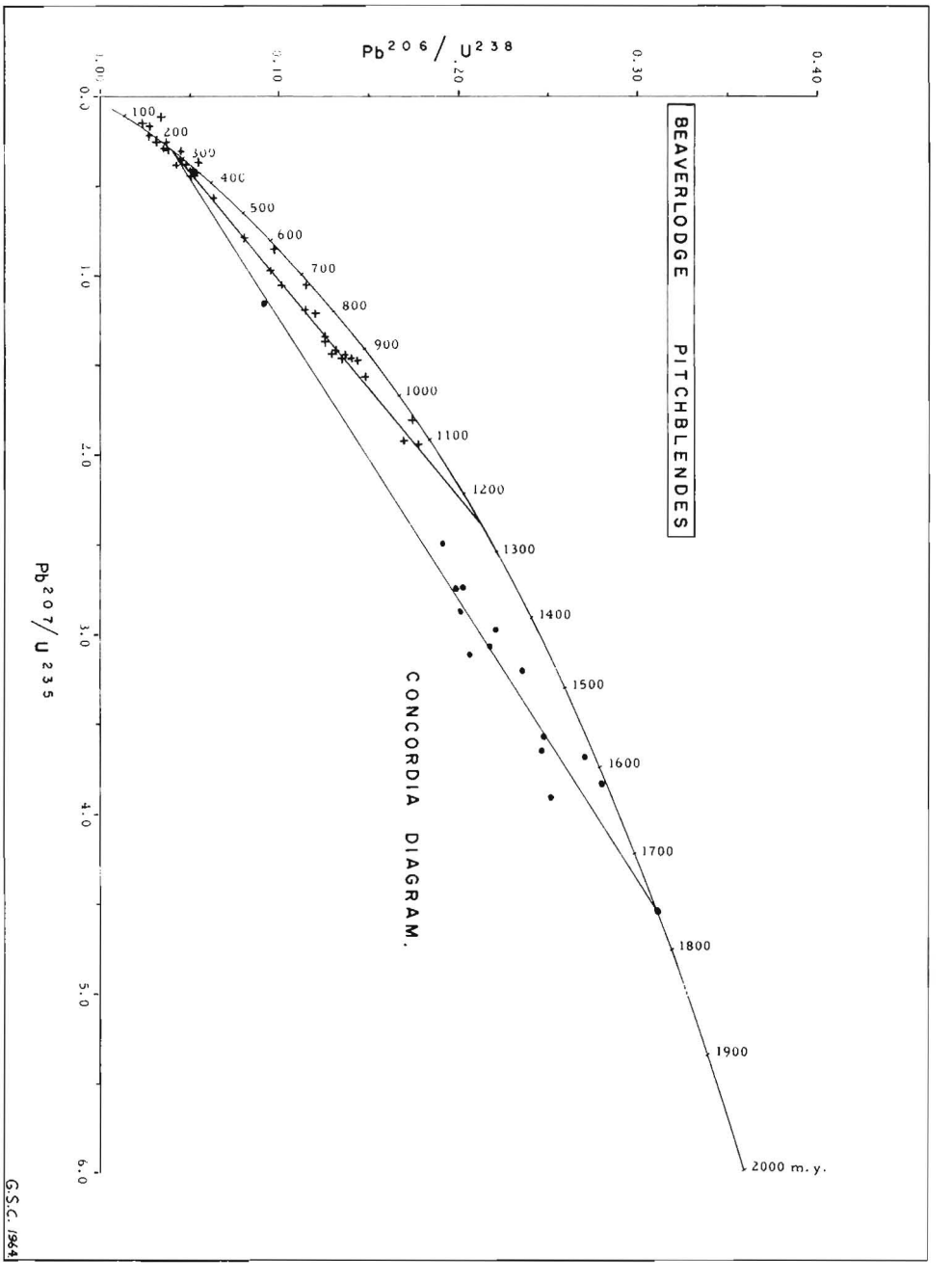
Most of the calculated ages are highly discordant, with a general pattern such that the Pb^{207}/Pb^{206} age is highest, Pb^{206}/Pb^{235} intermediate, and Pb^{206}/U^{238} lowest.

Only the three listed samples in the following table yielded concordant ages:

Sample No.	Pb^{207}/Pb^{206} Age (m.y.)	Pb^{207}/U^{235} Age (m.y.)	Pb^{206}/U^{238} Age (m.y.)
AD-111	1,755	1,750	1,780
R-631	1,680	1,610	1,620
AD-108	1,610	1,590	1,560

One highly discordant sample (pitchblende R-636) gave a Pb^{207}/Pb^{206} age of 1,905 m.y.

Earlier work had indicated three fairly distinct age groups on the basis of their Pb^{207}/Pb^{206} ages at 0-800 m.y., 1,040-1,280 m.y., and 1,570-1,905 m.y. A plot of all present data on a Concordia Diagram relating the Pb^{206}/U^{238} and Pb^{207}/U^{235} ratios indicates only two distinct groups on this basis (Fig. 1).


BEAVERLODGE PITCHBLENDES
CONCORDIA DIAGRAM.
Pb 206 / U 238
Pb 207 / U 235
0.40
0.30
6.0
5.0
4.0
3.0
2.0
1.0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000 m. y.
G.S.C. 1964

The line of best fit through one group of points intersects the Concordia Curve at 1,750 m.y. and about 250 m.y., while the line of best fit through the other group intersects the Concordia Curve at 1,200 m.y. and about 250 m.y.

Such a pattern might be taken to indicate a primary mineralization at about 1,750 m.y. ago, followed by another (perhaps secondary) mineralization at about 1,250 m.y. The lower point of intersection of both lines between 200 and 300 m.y. ago may indicate an episodic lead loss at that time. On the other hand, the whole pattern may have a significance of a more obscure nature.

The difficulty of interpretation is compounded by the composite character of many of the samples. In order to elucidate this problem, future work will be carried out on material of individual generations of pitchblende separated from the composite samples.

Evidence obtained by other workers, and by this group on other problems, tends to indicate that the ages obtained from this study are too low. For example, the GSC group has reported a K-Ar age of 1,795 m.y. on biotite from the Donaldson Lake gneiss (Lowdon, et al., 1963, Sample GSC 61-108), while a rather higher age of 1,815 m.y. has been obtained on a muscovite from pegmatite cutting the ore zone at Gunnar Mine (Lowdon, 1961, Sample GSC 60-65). Robinson (1955) reports on syngenetic monazites with a probable age between 1,700 and 1,800 m.y. Additional supporting data from syngenetic minerals includes a uraninite average age of 2,000 m.y. on Sample R-700 from the Viking Lake pegmatite, an average age of 2,045 m.y. on uraninite from Laird Island, and two average ages on uraninite from the Sure Group of 1,950 and 1,985 m.y.

Eckelmann and Kulp (1956) studied samples of pitchblende, clausthalite and galena from various mines in the Lake Athabaska area and found apparent isotopic ages ranging from 220 to 1,860 m.y. They postulate that the diverse ages can all be accounted for on the hypothesis of a single period of pitchblende deposition at 1,900 m.y. ago.

The data of Russell and Ahrens (1957) indicate an original age of 1,800 m.y., while Aldrich and Wetherill (1958) obtained an age for the primary mineralization of 1,900 m.y. Aldrich, et al. (1958), studying the age of the uraninite and biotite from the Viking Lake pegmatite, obtained a K-Ar age on chloritized biotite of 1,780 m.y., and a Rb/Sr age of 1,970 m.y. From the associated uraninite they obtained concordant U-Pb ages at 1,790-1,850 m.y. and a Th-Pb age of 1,600 m.y.

Syngenetic uraninite and monazite, being distinctly crystalline, are less likely to have lost lead and therefore should, and do, yield older ages than the cryptocrystalline epigenetic pitchblendes. The latter give highly discordant, younger ages which appear to reflect a more active mobility of lead in this environment.

Kanasewich (1962), in a more general study of anomalous leads, reports on a sample of apparently ordinary lead from the Goldfields region, on which he calculates an age of 2,015 m.y. Also with respect to isotopic analyses on ore leads from the area investigated, it is interesting to note that Robinson (1955, p. 85) lists ten analyses of galena and clausthalite. All of those from pitchblende-bearing veins are highly anomalous, but a galena (R-100) from a pegmatite and another (R-653) from a non-radioactive vein have nearly normal isotopic composition.

This is another point in support of the hypothesis that the syngenetic systems have remained closed, while the epigenetic systems have suffered from considerable mobility of lead.

Ref.

Cohen, W.
1953: A note on pitchblende and uraninite; U.S. Atomic Energy Comm., Tech. Inf. Serv., RME-3046, p. 58.

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

Eckelmann, W.R., and Kulp, J.L.
1956: The uranium-lead method of age determination. 1. the Lake Athabaska problem; Bull. Geol. Soc. Amer., vol. 66, p. 267.

Russell, R.D., and Ahrens, L.
1957: Additional regularities, etc.; Geochim. et Cosmochim. Acta, vol. 11, p. 213.

Aldrich, L.T., and Wetherill, G.W.
1958: Geochronology by radioactive decay; Ann. Rev. Nuclear Sci., vol. 8, p. 257.

Aldrich, L.T., et al.
1958: Radioactive ages of micas from granite rocks by Rb-Sr and K-Ar methods; Trans. Am. Geophys. Union, vol. 39, p. 1124.

Lowdon, J.A.
1961: Age determinations by the Geological Survey of Canada, Report 2 - isotopic ages; Geol. Surv. Can., Paper 61-17.

Kanasewich, E.R.
1962: Approximate age of tectonic activity using anomalous lead isotopes; Geophys. J., vol. 7, No. 2, p. 158.

Lowdon, J.A., et al.
1963: Age determinations and geological studies, including isotopic ages - Report 3; Geol. Surv. Can., Paper 62-17.

DEVELOPMENT OF MASS SPECTROMETRIC APPARATUS

R.K. Wanless and A.G. Meilleur

Assembly of a 6-inch-radius gas source mass spectrometer has been completed. The instrument embodies many new design features which facilitate servicing of the internal components. The increased sensitivity realized as a consequence of the installation of an electron multiplier has been found to be most valuable in the analysis of small samples of radiogenic argon.

A new type of all-metal high-vacuum valve, designed by Meilleur, has been incorporated into the gas-handling line associated with the instrument. This innovation has removed the necessity of employing mercury-filled valves in the sample vacuum line.

Good progress has been made on the assembly of a 6-inch-radius solid-source mass spectrometer. At year's end the analyzer tube was undergoing vacuum tests and the final electronic assembly was nearing completion.

MINERALOGY AND PETROLOGY

THE CHEMICAL AND SPECTROGRAPHIC ANALYSIS OF ROCKS AND MINERALS

Staff of Analytical Chemistry Section

This is the general project that covers the regular work of the Section, including the investigation, adaptation and development of new methods and techniques. A detailed account of the productivity of the Section is given in the annual report; the following is a brief summary of the development work done in parallel with sample analysis.

An Applied Research Laboratories Multichannel Vacuum X-ray Spectrometer was installed and the quantitative determination of Si, Al, Fe, Ca, Mg, K, Ti and Mn in rocks was begun, using an established procedure which was modified to suit our facilities and needs. Intensive calibration led to the establishment of working curves for the analysis of samples ranging in composition from granites to limestones; although certain long-term factors have yet to be fully evaluated, the new procedure has been operating on a routine basis since May 1963.

The use of Arsenazo III, a highly selective and sensitive colorimetric reagent for thorium in rocks, was studied. The sample is sintered with sodium peroxide, the thorium collected on calcium oxalate, and the coloured complex measured in a perchlorate medium.

Four possible methods for the extraction of lead in microgram quantity from various sulphide minerals were investigated, including extraction, electrolysis and ion-exchange separation. Best results were obtained by leaching the sample with acid and extracting the lead, with dithizone, from both fractions.

Because available methods for the separation and determination of the rare earths in thorium-bearing britholite proved unsatisfactory, a procedure which utilized ion-exchange separation and final measurement of the rare earth fraction by X-ray fluorescence was developed.

The reporting of results by an improved semiquantitative spectrographic method has been changed from the use of percentage ranges to specific figures over a range of 0.002 - 20 per cent.

The collaborative investigation into the application of infrared spectroscopy to mineralogical analysis, started in 1962, was completed.

A new fractional distillation spectrographic procedure for the determination of volatile trace elements (Ag, Cd, Bi, Sn, etc.) has been established with lower detection limits, and greater precision. Similar development work was done on the improvement of the semiquantitative procedure now in use and on the quantitative trace element analysis of sulphides; in connection with the latter, preliminary work on the preconcentration of trace elements was started.

The application of the laser microprobe, which utilizes a laser beam as a spectrographic source, to the microanalysis of minerals in situ was investigated.

Complete analyses were made of two minerals for which about 100 milligrams of sample was available for each, and of a series of chromites. The analysis of two meteorites is in progress.

A new procedure for the determination of ferrous iron was put into routine use, and the method for the separation and determination of fluorine has been revised. Apparatus for the simultaneous determination of water and carbon dioxide was constructed and used.

PREPARATION OF SAMPLES FOR INFRARED ANALYSIS

Sydney Abbey

Finely ground samples were prepared from three synthetic mixtures of quartz, plagioclase, microcline and muscovite, of each of the pure minerals, and of a rock on which both modal and chemical analyses were available. The samples were sent to four manufacturers of infrared spectrometers for determination of the contents of the four minerals in the three mixtures and in the rock.

One firm failed to report. Another provided some data, but no analytical results could be calculated. The third firm reported fair results on the three mixtures, but poor results on the rock (relative to modal and normative data). The fourth firm reported values which agreed closely with the known values in the three mixtures, but their results on the rock disagreed with both the modes and the norms.

Chemical analysis of the three synthetic mixtures provided results from which normative values were calculated. These values served to confirm that infrared results can be closer to the truth than norms. No explanation is available for the poor results on the rock samples, although they may have resulted from differences in composition between the feldspars in the sample and those in the pure minerals.

LABORATORY INVESTIGATION OF ROCKS FROM CLEARWATER LAKE, QUEBEC

H.H. Bostock

The rocks at Clearwater Lake are tentatively divided into six main units in order of decreasing age:

(1) Basement (Precambrian) intruded by small diabase bodies of uncertain age found only on the island ring

(2) Ordovician limestone

(3) Friable volcanic breccia locally glass-bearing

(4) Coherent volcanic breccia

(5) Massive dacite

(6) Sedimentary rocks, found only in drill core from the 'east' lake – from published information.

K-Ar Whole-Rock age Determinations

Two samples of massive dacite have been dated at 300 and 285 million years.

Drill Core Log

Details withheld pending full investigation by Dominion Observatory staff.

Glasses

Plagioclase in the rocks of the central islands in 'west' Clearwater Lake is largely converted to glass. In antiperthitic crystals, blebs of alkali feldspar maintain their birefringence and parallel optical orientation within the plagioclase glass. Such blebs are, however, surrounded by a thin selvedge of glass of low refractive index (1.490). The texture and birefringence of pyroxene remains unaltered, biotite shows slight alteration, and quartz shows development of parallel fractures suggesting cleavage.

Where both unaltered plagioclase and plagioclase glass from the same rock have been examined, refractive indices of the latter were found to be slightly higher than expected for glass of composition corresponding to that determined for unaltered plagioclase (An_{55}). Fragments of plagioclase glass re-fused in an electric arc yielded a new glass of refractive index about 0.004 lower than the original glass.

Some thin sections of deeply altered basement rocks from the island ring contain similar glasses in more or less advanced stages of devitrification and alteration, chiefly to montmorillonite. A dark brown to black vitreous glass of refractive index 1.551, and specific gravity 2.61 was found as coatings on breccia fragments and as distorted blebs in one exposure of friable breccia. This glass contains corroded fragments of clear colourless glass with refractive indices ranging between 1.511 and 1.461. The latter value suggests that some lechatelierite may be present.

Zircon Concentrate

Zircon has been concentrated from the massive dacite in which it is present to approximately 10×10^{-6} weight per cent. The crystals examined appear similar to zircon in some plutonic rocks.

RELATIONSHIP OF ANTHOPHYLLITE, CUMMINGTONITE AND MANGANO-CUMMINGTONITE IN THE METAMORPHOSED WABUSH IRON-FORMATION, LABRADOR

K.L. Chakraborty and G.A. Gross

Chemical and optical properties show that anthophyllite and cummingtonite belong to different series and have limited isomorphism. Mangano-cummingtonite has monoclinic crystal symmetry, but its chemical composition and optical properties are more similar to anthophyllite, with orthorhombic symmetry, than to the cummingtonite-grunerite series. The anthophyllite - mangano-cummingtonite relationship is suggested to be a case of inversion where Mn plays a critical role. The unusual chemical and optical properties of mangano-cummingtonite are also investigated here.

STUDIES OF WOOD TIN IN THE KLONDIKE AREA, YUKON TERRITORY

C.F. Gleeson and G.M. Archibald

Thin-section and polished-section studies have been made on 'wood' tin pebbles from various parts of the Klondike area, Yukon. The pebbles are made up of very fine bands of cassiterite that vary in width from 0.05 to 1.0 mm. Some samples exhibit regular concentric banding but in others the banding is more irregular and coarse needled textured cassiterite is present. One specimen had a nucleus of fluorite, but generally only cassiterite was visible at the centre of the bands. Inclusions of hematite, fluorite, quartz, feldspar and zircon have also been found in the pebbles.

Spectrographic analyses show that the pebbles contain 5 to 7 per cent Fe, less than 1 per cent Al and Si and trace amounts of Mn, Mg, Be, Ca, Ba, W, Cu and Sr. Mercury was determined with a mercury detector. The 'wood' tin pebbles averaged 0.55 ppm Hg, however cassiterite pebbles from Dublin Gulch had 12 ppm Hg. The latter cassiterite is brown, sugary textured and crystalline (Thompson, 1945). These results suggest that mercury might be a valuable pathfinder element in prospecting for cassiterite deposits in Dublin Gulch area.

Studies are continuing on the Klondike 'wood' tin in order to determine if it is genetically related to the rhyolite porphyries of the district. In addition, X-ray studies are being made on the crystal structure of the 'wood' tin.

Ref.

Thompson, R.M.
1945: An occurrence of cassiterite at Dublin Gulch, Yukon Territory; Econ. Geol., vol. 40, No. 2.

MINERALOGY AND BENEFICIATION OF QUEBEC IRON ORES

G.A. Gross

A special study and review of the mineralogy and beneficiation characteristics of Quebec iron ores was carried out in preparation for a symposium held by the Canadian Institute of Mining and Metallurgy. Five major types of ore include hematite-goethite masses within iron-formation, taconites, metataconites, replacement magnetite and titaniferous magnetite deposits. Properties affecting beneficiation of each type of ore that pertain to mineralogy and texture were evaluated and the significance of these features in estimating potential ore reserves was indicated. It was concluded that in view of rapidly changing technology in the steel industry the metataconites will constitute the largest and most important iron ore reserve, but the value of these ores in future depends on further research on their geology and on beneficiation methods.

INVESTIGATION OF MINERALOGY AND PETROLOGY OF IRON-FORMATIONS

G.A. Gross and W. Nash

Mineralogical and petrological studies were carried out on Algoma type iron-formations from ten major iron ranges in the Superior structural province. Further evidence concerning the origin of these sediments has been gained from study of primary sedimentary and compositional features. Continuing study of metamorphic features in these beds has contributed to evaluation of potential iron ore deposits, and certain textural features coincide in distribution with tectonic subdivisions in this part of the Precambrian Shield.

PREPARATION OF AN ULTRABASIC ROCK STANDARD FOR ANALYTICAL USE

J.A. Maxwell, W.H. Champ, C.H. Smith and
Staff of Analytical Chemistry Section

The picrite sample, weighing approximately 200 pounds, which is to serve as a reference sample for the chemical and spectrographic analysis of basic and ultrabasic rocks, is in process of preparation. The material, in the form of hand specimens, was trimmed and broken into approximately 1-inch pieces under the supervision of C.H.R. Gauthier, and then sorted by hand to exclude weathered and non-representative material. J.C. Paris supervised the crushing and grinding of the material, now weighing about 150 pounds, to pass through a 150-mesh screen. The final product, in approximately 10-pound lots, was mixed thoroughly in a Patterson-Kelley dry blender and homogeneity tests on these lots will be made to determine the next step in the preparation of the sample aliquots.

BARITE-FLUORITE STUDY

W.D. McCartney

Major and trace element study of hand-picked, seemingly pure barite and celestite was undertaken to investigate possible variations in (a) trace element content with associated, possibly hidden sulphides, (b) content of calcium possibly related to temperature of formation, and (c) strontium content of barite and barium content of celestite in Canada as related to the formerly accepted isomorphous series between barite and celestite.

Semi-quantitative spectrographic analyses failed to detect lead, zinc and other significant elements, in part because new, sensitive procedures are in the development stage and spectrographic results available to date depend on a less sensitive method than was used in GSC laboratories a few years ago.

Copper was detected in about one half the sixty samples analyzed to date, varying from less than 0.001 to 0.07 per cent. Results suggest that where copper was not detected in any one of several samples from the same deposit, there is little likelihood of associated sulphides; but the converse is not necessarily true. In southeast British Columbia, for example, only two thirds of the barite from such lead-zinc-barite deposits as the former Giant Mascot and the Mineral King mines contained variable amounts of detectable copper, as did the barite-quartz veins (Brisco, Parson, etc.) in the district with which no significant sulphide mineralization

is known. Further analyses by sensitive methods for mercury, lead and zinc are planned.

Calcium content varies appreciably within individual deposits, and no relation either to temperature of filling of liquid inclusions in associated fluorite or to geological environment of the deposit was discerned.

Natural specimens of barite and celestite from Canadian occurrences are restricted to compositions approaching the end members of the formerly accepted isomorphous barite-celestite series. Some apparent exsolution textures faintly observed in thin section by normal methods are being investigated by phase-contrast microscopy as time permits, and some exsolution(?) specimens will be submitted for X-ray probe study.

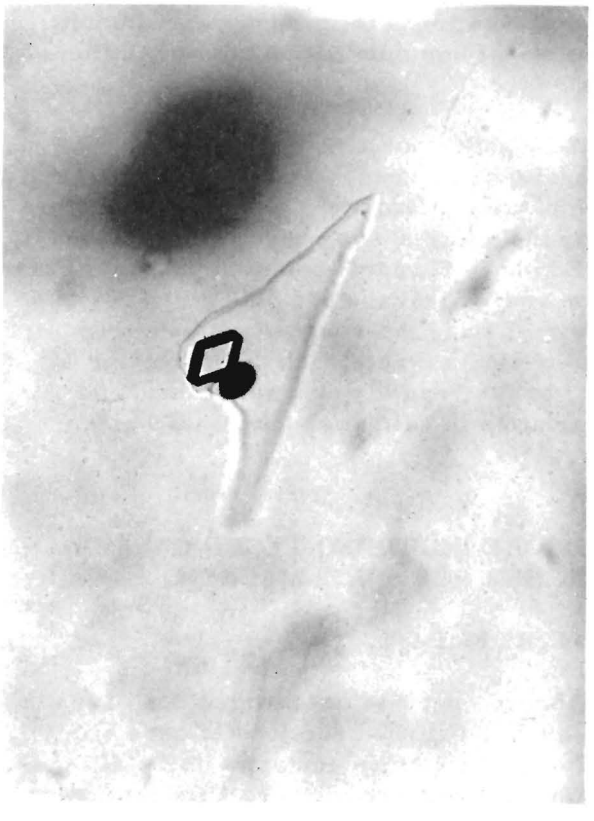
Using a microscope equipped with a heating stage, measurements of the temperature of homogenization and filling of liquid inclusions in fluorite were completed. Fluorite from some pegmatitic deposits near Bancroft contained inclusions which could not be homogenized at temperatures below their explosion point around 500°C. The highest reproducible temperatures of inclusion filling, at 270° to 273°C, were given by fluorite from the outer fringe of copper-molybdenum mineralization of west C zone, Needle Mountain, Gaspé Peninsula.

A strong tendency for inclusions filled at high temperatures (150° to 260°C) to occur in fluorite of octahedral habit was observed (Rock Candy mine, Okanagan Lake and Parson, British Columbia). However, some cubic crystals of fluorite from Mount Pleasant, New Brunswick, showed filling temperatures of 183°C. Some cubes modified by octahedral faces contained inclusions showing filling temperatures of 122° to 132°C (Madoc, Ontario), but all other inclusions which were filled at temperatures below 150°C were contained in fluorite of unmodified cubic habit.

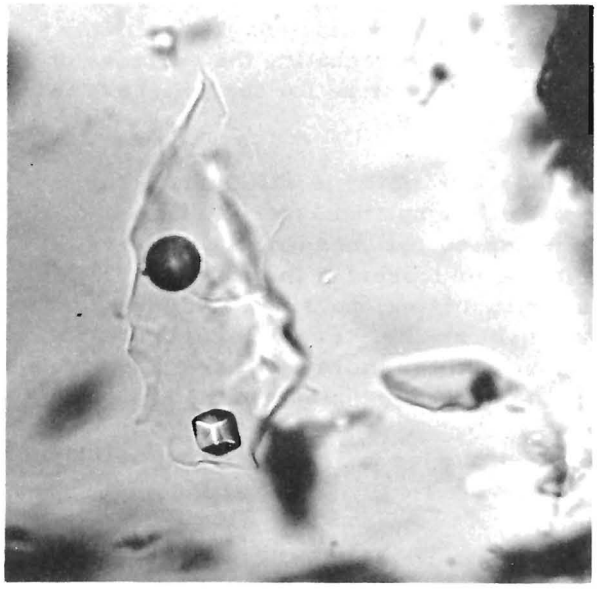
Three-phase inclusions were most common in those that homogenized and filled at high temperature, but fluorite from the Kane and Detamac veins, Madoc, contained inclusions of liquid, gas and a cubic crystal (halite?). The crystals dissolved at 85° and 105°C and the gas phase disappeared at 124-127°C and at 122°C, respectively.

Sulphur isotope studies of barite and associated sulphides were begun in coordination with this project by J. van Peteghem at McMaster University as a Ph.D. thesis problem.

Three-phase inclusions in fluorite.



A. Pegmatitic inclusion. Specimen explodes at 500°C before inclusion is homogenized. From Harcourt, Ontario.



B. Inclusion from Madoc, Ontario. Halite (?) crystal dissolves at 80° to 90° C and gas bubble disappears at 124° to 127°C.

Professor D.J. McDougal, Loyola College, agreed to measure thermoluminescence in a series of closely spaced GSC samples from a fluorite-celestite deposit at Birch Island, B.C., and found that thermoluminescence tends to increase with fluorite content (D.J. McDougal, personal communication). Correlation of his and GSC data continues.

B.A. Edmund kindly undertook a number of decrepitation tests on barite at the University of Toronto. The barite samples were sent from specimens containing fluorite of known temperature of inclusion filling, however the decrepitation results were not readily interpreted (B.A. Edmund, personal communication). Prior to these tests, decrepitation and/or leakage of liquid along cleavage planes in barite were observed during the study of inclusions on the heating stage. Thus efforts to find a direct, reliable indicator of temperature of formation of barite, namely decrepitation, fluid inclusion and a proposed variation in calcium content have given negative results.

DEVELOPMENT OF ORE POLISHING TECHNIQUES WITH THE DURENER POLISHING MACHINE

C.R. McLeod

A Durener Polisher was put into operation during 1963 in an attempt to produce high-quality polished sections of ores and related minerals. The writer kept in close contact with P. O'Donovan, operator of a similar machine for Mineral Sciences Division, Mines Branch, and spent two weeks studying under Dr. G. Aletan, Nova Scotia Technical College, Halifax. Four processes relevant to producing good polished sections were investigated: (1) media for mounting slices; (2) epoxy resins for impregnating the surfaces of sections; (3) grinding laps to prepare sections for the polisher; and (4) polishing techniques with the machine.

1. A plastic resin such as "Araldite" is satisfactory for mounting sawn slices in the bakelite rings necessary to hold the sections on the machine. It is dense, polishes well, and shows little or no tendency for shrinking or loosening in the rings. It does require rather careful attention to mixing, pouring, and curing temperatures, and needs overnight curing. For quick mounting an epoxy glue can be used. Although this is more expensive, sections can be lapped 1 hour or less after being mounted if curing is accelerated with heat.

2. The Dure "E-POX-E" is the most satisfactory of about ten epoxy resin glues tested for impregnating the surfaces of sections after mounting. This impregnation fills pits and crevices in the slice and helps avoid plucking of grains.

3. After surface impregnation, the sections are levelled with a 62-micron lap which has a surface of diamond particles held in a nickel bond. The sections are further smoothed on similar laps with 30- and 9- micron diamond particles. These laps are fast cutting and clean, with no loose abrasive present.

4. On the machine, standard lead-antimony laps of various hardnesses are used. For hard minerals, diamond powder currently seems to be the most efficient abrasive. Research is continuing on this phase, with special attention to the most effective means of polishing the softer minerals.

DETAILED STUDY OF WHITE CREEK BATHOLITH, B.C., - A ZONED INTRUSIVE

G. Mursky

The White Creek Batholith, located near the Sullivan lead-zinc mine at Kimberley, is one of those granitic intrusives in southeastern British Columbia that show considerable variation in physical and chemical character but share a similar structural pattern. The batholith has been unroofed only slightly. At the exposed levels it consists of five compositionally different, zonally arranged shells which range from leucocratic quartz monzonite in the centre to granodiorite at parts of the margin. Through differential erosion the batholith has been exposed to a depth of some 5,000 feet from the presently exposed "cupola".

Partially completed study of this batholith reveals that biotite K-Ar ages in various shells are discordant and range from 18 to 81 million years. Rubidium-strontium dating on the whole rock (a few more determinations are needed to define the concordia better) is more consistent but indicates a definite break — marginal rocks about 400 million years and interior about 130 million years. This break strongly contrasts with the chemistry of the rocks since whole rock analyses (to date 26 samples) display a pattern which suggests that the interior rocks lie on the normal course of descent from a melt that gave rise to marginal units. Mineralogically there is a progressive increase of quartz, K-feldspar and muscovite towards the core and a decrease of hornblende, biotite, chlorite and plagioclase. Biotite (6 analyses) becomes richer in Fe towards the core whereas, optical properties of hornblende (20 samples) indicate

similarity in composition. Optically, K-feldspar does not vary and indicates a consistency of triclinic form whereas R.I. of K-feldspar glass and chemical analyses indicate shortcomings in determination of Na in K-feldspar by means of R.I. The composition of plagioclase changes rather gradually from an average An 35 at the margins to An 25 in the core. There is fair uniformity in An content within individual units with depth of the intrusive. Plagioclase also shows a progressive increase in structural ordering towards the core with an average ordering index of 71 per cent for contact rocks and 88 per cent for core rocks. On the other hand, plagioclase twin laws (represented by 9 varieties) have similar frequency distribution in all units.

Accessory minerals vary in different units. Those ascertained to date consist of magnetite, sphene, apatite, ilmenite, epidote, clinozoisite, allanite, zircon, zoisite, goethite, hematite, garnet, anatase, rutile, molybdenite, euxenite, pyrite, thorite, scheelite, bismutite and pyrochlore. The major minerals and the accessories were concentrated and purified from fifty-three samples and presently are under intensive mineralogical and geochemical study. Partially completed study on the trends of the accessories within and between different rock units shows little variation in epidote, allanite, zircon and thorite. The first two appear to be antiperthitic and their abundance related to the depth of the intrusive. Apatite increases and sphene decreases towards the core; the latter is more pronounced.

The pattern of some of the minor elements determined on whole rock samples indicates distinct increase in Mo, Ni, and Pb and a decrease in Zn towards the core. Little variation is seen in the distribution of Co, and Cu, whereas As, Sb, and W are generally below the limits of detection.

Geothermometry studies are not sufficiently advanced to warrant elaboration at this time, however, the distribution of Na in K-feldspar and plagioclase indicates variation and work on Ti content in magnetite is just beginning.

FELDSPAR MINERALOGY

G. Pouliot

Systematic study of feldspars from the Muskox Intrusion, N.W.T., a project initiated in 1962 in connection with the Upper Mantle Project, was continued during 1963. The writer was assisted during the period of June to September, 1963, by R. Trischuk, a summer student.

Composition of Plagioclase Feldspars

Work in this phase of feldspar mineralogy was directed at: (1) providing a determinative method for routine determination of plagioclase compositions; and (2) outlining the distribution of plagioclase compositions within the intrusion.

An X-ray determinative curve involving the separation $[2\theta(131) + 2\theta(220) - 4\theta(1\bar{3}1)]$ was constructed from data obtained in 22 chemically analyzed plagioclase specimens, 17 of which were prepared during the current year. A first-order equation relating composition of the plagioclase with the X-ray data has been calculated. The curve is applicable for the composition range An_{60}-An_{90} and although statistical analysis of the data is not yet complete, an accuracy of the order of 4 per cent is anticipated.

The composition of some 220 plagioclase specimens from various groups or units of the intrusion was determined using X-ray and optical methods as necessary. The recent acquisition of a multiple Guinier powder camera will accelerate X-ray diffraction work on feldspars and permit a greater number of specimens to be investigated.

Structural State Investigation of Plagioclase Feldspars

Study of the structural state (disorder) of plagioclase feldspars from the marginal series and feeder group is largely complete. Changes in the degree of order have been studied by comparing the separation $B = 2\theta(1\bar{1}1) - 20(2\theta\bar{1})$ of Muskox plagioclase of known composition with that of "low" and "high" plagioclase of corresponding composition listed in the literature. The relative structural state or relative disorder, expressed by the ratio:

$$\frac{B_L - B_M}{B_L - B_H} \times 100,$$

where subscripts M, L, H respectively stand for Muskox plagioclases and "low" and "high" plagioclases, was shown to increase as the country rock or chilled contact is approached.

Studies on Alkali Feldspars

The construction of an X-ray determinative curve based on the measurement of $d_{(400)}$ of analyzed alkali feldspars from the

granophyre and upper border group of the Muskox intrusion was completed. Linear or first-order best fit were calculated relating $d_{(400)}$ of systematically heated feldspars to composition expressed as:

(1) $Or/Or + Ab + An + Cs$ and (2) $Or/Or + Ab$ Mole %.

The method permits determination of composition for feldspars located in the composition interval of Or_{100} or Or_{80} with an accuracy of 2 per cent.

Structural work on alkali feldspars consisted in tridinicity measurements and universal stage optical work. This work has characterized the potassic feldspars from the granophyre as being principally monoclinic high orthoclases with subordinate structural modification extending from low sanidine to low orthoclase.

ROCK-FORMING MICAS

J.Y.H. Rimsaite

Summary results of some recent studies are as follows:

None of the concentrates is entirely homogeneous. Individual flakes differ in chemical composition, state of oxidation of iron, in morphological features, and in degree of alteration.

In most of the dehydrated micas the content of ferric iron is too low to account for the excess of oxygen. It is concluded that the deficiency of the (OH) group is a result of partial loss of water as H_2O. The excess oxygen in dehydrated micas is placed in the deficient (OH) group.

The relations between physical properties and chemical composition, determined on the basis of present experimental data, are:

(a) colour of mica is a factor of the octahedral proportions of Ti, Fe''' and Fe''.
(b) the effect of different ions on the physical properties of pure Mg-mica are as follows:

Al raises the refractive indices and the specific gravity but lowers the intensity ratio (004)/(005) and reduces the spacing (010).

F lowers the ratio $I_{(004)}/I_{(005)}$ and the refractive indices and also reduces the spacing $d_{(010)}$.
Fe'' raises the refractive index, the intensity ratio (004)/(005) and specific gravity.
Fe''' and Ti raise the refractive indices.

The interrelations of physical properties can be conveniently applied for practical purposes, such as concentration and separation of various mica types from one rock, homogeneity tests, etc.

The layer structure of micas provides adequate spacings for the accommodation of a great variety of cations in the tetrahedral, octahedral and twelvefold coordination. The chemical composition of micas is a result of the composition of the source material and of physical-chemical conditions of crystallization.

The relationship between the chemical composition of mica and the stage of crystallization of the host rock explains the wide range variation in composition of micas from similar rock types. The difference in mineral (and mica) composition of the early, main and late stages of crystallization depend on the degree of differentiation. Mica can occur at either stage or at more than one stage of crystallization of the host rock. Early and late mica differs in iron content and in proportion of alkali metals.

Chemical composition of micas from metamorphic rocks is a result of chemical composition of the source material and of metamorphic grade.

Biotites from paragneisses and biotites associated with muscovites contain relatively high octahedral aluminum.

Degree of alteration of micas results from environment and chemical composition. Muscovites are stable at lower grades of metamorphism, while the stability of biotites depends on chemical composition.

Pre- and syn-metamorphic micas are partly dehydrated. Dehydration has a more significant effect on loss of argon than does chlorite alteration, when potassium is also lost.

Micas in anorthosite rocks are frequently associated with alkali feldspar, which usually forms "antiperthitic" inclusions in plagioclase (Figs. 1 and 2).

Small compact mica flakes retain argon better than coarse non-compact flakes (Fig. 3).

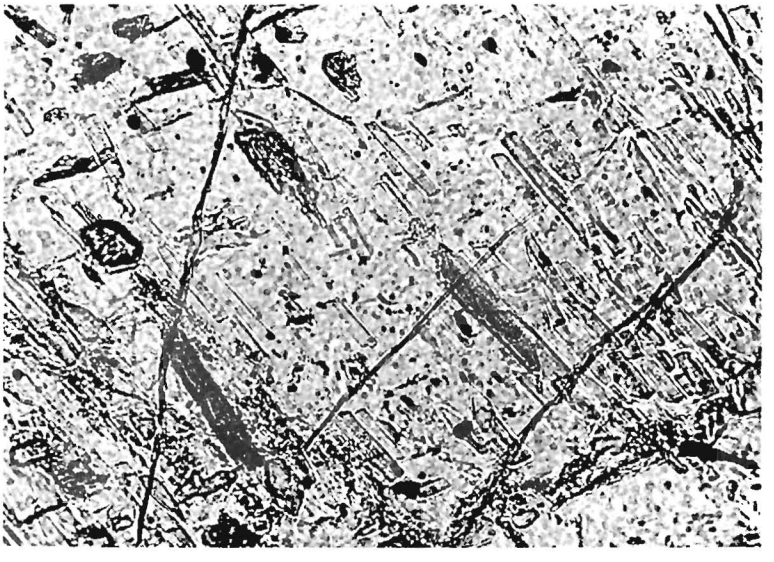


Figure 1. (x 100)
"Antiperthite" An_{45} with inclusions of biotite and muscovite.

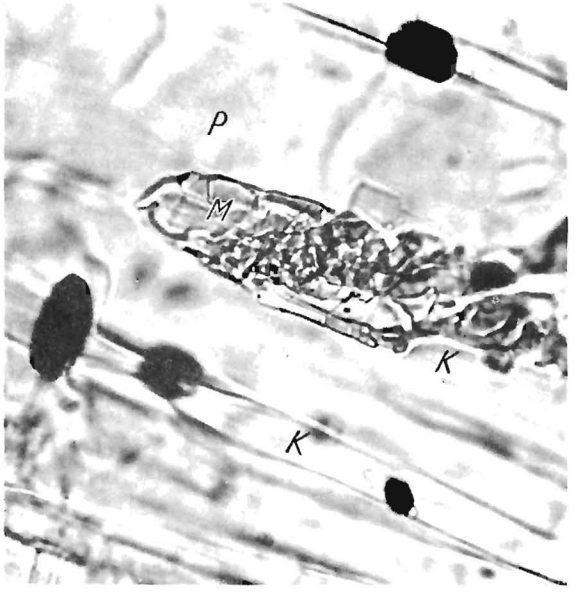


Figure 2. (x 600)
Muscovite (M) replaces K-feldspar (K) in plagioclase An_{45} (P).

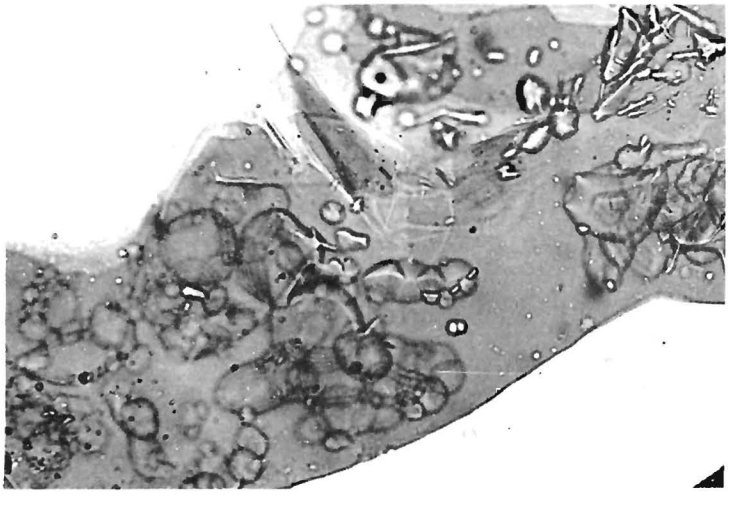


Figure 3. (x 600)
Blistered, non-compact mica.

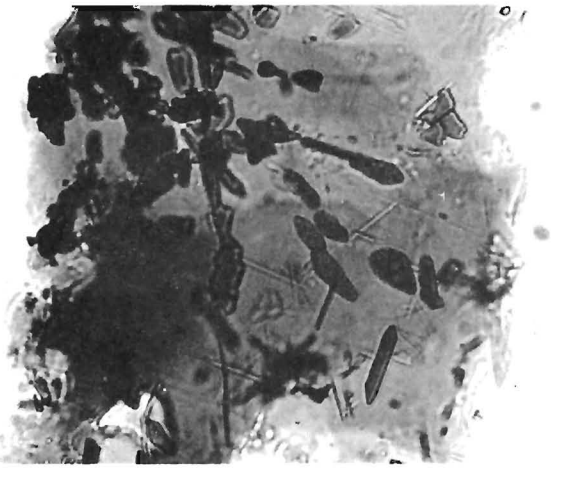


Figure 4. (x 100)
Intergrowths of primary and of secondary biotite.

Intergrowths of primary and of secondary mica is a common phenomenon (Fig. 4).

A STUDY OF GOLD-BEARING AMPHIBOLITES FROM THE CONTWOYTO LAKE AREA, NORTH-CENTRAL MACKENZIE DISTRICT

E.A. Schiller and E.H. Hornbrook

A petrographic study supported by chemical and X-ray analyses was done on a suite of amphibole-bearing rocks from the Contwoyto Lake area. The amphibolites are host to gold deposits found in a large area in north-central District of Mackenzie.

The amphibolites occur as lenticular bodies, generally hundreds of feet long and few tens of feet wide, interbedded within metasedimentary rocks of the Yellowknife Group. The sequence has been subjected to probably two or more periods of folding in which the last deformation culminated with the intrusion of granite. The important gold deposits are related to secondary crossfolds superposed on earlier isoclinally folded rocks. The Yellowknife Group rocks are slate and greywacke and their metamorphic equivalents that extend up to the almandine-amphibolite and hornblende-hornfels facies.

The amphibolites are composed of hornblende and/or 'grunerite-cummingtonite', quartz and minor garnet (almandine?). 'Grunerite-cummingtonite' in part is altered to hornblende. Chloritic alteration of the amphibole is not uncommon. Magnetite is present in amounts up to a few per cent. Individual bands of 'grunerite-cummingtonite' or hornblende containing subordinate amounts of quartz are interbedded with quartz-rich bands containing only minor amphibole minerals. 'Grunerite-cummingtonite' is colourless to neutral with Z C = 19°. Hornblende is X - pale greenish brown, Y - olive green, Z - dark green, Z C = 22°. The quartz is of both clastic and vein origin. The former consists of mosaic bands in what appears to have been a fairly well sorted sand. The vein quartz generally parallels the sedimentary bands, but some veinlets cut the bedding. The amphibolites are interbedded with rocks that range in grade from greenschist to amphibolite facies and appear to be a manifestation of low-grade metamorphism. Gold is found in the amphibolites associated with arsenopyrite, pyrrhotite, pyrite and minor lollingite and chalcopyrite. The disseminated and nearly massive bands of sulphide are a few inches wide and parallel the bedding. Of interest, the grunerite-cummingtonite rocks and their associated mineralization are comparable to the rich gold deposits of the Homestake Mines, South Dakota (Noble and Harder, 1948).

The Contwoyto Lake and Homestake deposits are similar in lithology, mineralization, structure and age of host rocks.

Amphibolites taken from a major gold prospect containing two separate beds in which one was barren and the other contained gold were found to contain the following: the barren bed contained only hornblende and the gold-bearing bed contained hornblende, and 'grunerite-cummingtonite', in part peripherally altered to hornblende. In three other smaller gold prospects the amphibolites consist of 'grunerite-cummingtonite' and hornblende.

Chemical analyses of the above amphibolites are as follows:

	H-63-1 (barren amphibolite)	H-63-2 (gold-bearing amphibolite)
SiO_2	53.3	48.0
Al_2O_3	11.0	6.0
Fe_2O_3 + FeO	26.2*	41.3*
CaO	6.2	4.6
MgO	0.6	1.4
Na_2O	0.4	0.2
K_2O	0.1	0.1
TiO_2	0.3	0.2
P_2O_5	0.1	0.2
MnO	0.2	0.1
CO_2	0.1	0.1
Total H_2O	1.6	2.1

* Magnetite, arsenopyrite and pyrite content about 5 per cent in 63-2 and about 1 per cent in 63-1.

From the chemical data it can be seen that these amphibolites are iron-rich siliceous rocks, and from the character of the clastic quartz can be ascribed a sedimentary origin.

In summary it appears that 'grunerite-cummingtonite' may be a necessary constituent of the gold-bearing amphibolites, however its control on gold deposition is not known. Other factors (e.g. folding, proximity to granite, etc.) are undoubtedly just as important, if not more so. Further mineralogical studies of this nature are definitely warranted.

Chemical analyses were made by Rapid Methods Analysis by the staff of the Analytical Chemistry Section; X-ray analysis by B. Delabio.

Ref.

Noble, J.A., and Harder, J.O.: Stratigraphy and metamorphism in a part of the northern Black Hills and the Homestake Mine, Lead, South Dakota; Bull. Geol. Soc. Amer., vol. 59, pp. 941-975.

FUELS

PETROGRAPHIC INVESTIGATION OF THE SUBBITUMINOUS COALS OF THE EDMONTON FORMATION, ALBERTA

T.F. Birmingham

A method was developed to permit examination of these high-moisture coals under reflected light by means of polished sections. A study of several complete column samples has revealed that the banded nature of these coals is due to variable concentrations of fusinite, micrinite and finely divided mineral matter in a groundmass of vitrinite. Exinite in the form of pollen and spore exines is generally a subordinate component. It was observed that different seams have different petrographic distribution patterns. The lateral variations within one coal seam are now being examined, in order to establish the distances over which individual seam correlations can be made.

PETROGRAPHIC EXAMINATION OF COKING COAL BLENDS FROM MICHEL, BRITISH COLUMBIA

A.R. Cameron

This continuing project involves the evaluation of coking properties and petrography of coals from the Fernie-Michel area of British Columbia. Two 900-pound samples of the Balmer seam collected for carbonization were analyzed in terms of microlithotypes. Each of these samples had been screened into nine size fractions and microlithotypes were determined for each fraction. As was the case with the macerals, the overall microlithotype analysis of the two bulk samples showed little differences. However, the size fractions of each sample differed from one another. In general the bright character, as exemplified by the vitrite content, declined regularly from the largest size fraction to low values in the intermediate fractions, then climbed to its highest values in the 1/8-inch by 0 fraction. The fluidity and swelling indices appeared to follow a similar trend.

In the summer of 1963 two 1,000-pound samples of the No. 1 seam at Michel were collected for carbonization. They were each screened into size fractions, and comparative studies on these samples, similar to those undertaken on the Balmer seam, are now in progress.

A DEPOSITIONAL STUDY OF THE HARBOUR SEAM, SYDNEY COALFIELD, NOVA SCOTIA

P.A. Hacquebard, A.R. Cameron and J.R. Donaldson

The objective of this study was to learn more about the depositional characteristics of a Carboniferous peat bog in both its vertical sequence and lateral variations. For this purpose an attempt has been made to correlate data on the sedimentation of the Harbour coal seam with that obtained from coal petrological and palynological examinations.

The sedimentation data were derived from detailed descriptions of cliff sections present along the shoreline and from the logs of bore-holes. The results have been expressed in a lithofacies map of the interval between the main Harbour seam and a seamlet designated as the Lower-Bench Coal.

For the coal petrological investigations both megascopic and microscopic observations have been made. The former are portrayed in a cross-section of the seam through almost the entire extent of the Sydney Coalfield. This cross-section is based on detailed megascopic examinations of polished sections representing 18 column samples. For the microscopic study the microlithotypes of one "type" column have been analyzed in order to record the vertical variations. For an insight into the lateral variations of microlithotypes, a cross-section through one selected petrographic interval of the Harbour seam is presented. These studies were carried out on polished grain mounts under reflected light with a 25X oil immersion objective.

Also discussed are some of the results obtained by a thin-section examination of prominent dull bands. These bands are a characteristic feature of the Harbour seam, which permit its subdivision into time-equivalent intervals.

Palynological data, based on a quantitative evaluation of the miospore genera present in the 15 subdivisions of the "type" column were used to establish the vertical changes in vegetation. The regional changes were recorded only on the same petrographic interval that was used to study the lateral microlithotype variations. This required a statistical analysis of 14 samples.

A map showing the regional distribution of the genus Torispora in one particular layer of the Harbour seam is also presented. This distribution is expressed as spore density per square mm, and was obtained from microscopic examinations of polished and thin sections.

Ref.

Hacquebard, P.A., Cameron, A.R., and Donaldson, J.R.: Contribution to anniversary volume in honour of Prof. R. Potonié's 75th birthday, to be published in 1964 in "Fortschritte der Geologie von Rheinland und Westfalen".

APPENDIX

FELDSPAR AND QUARTZ PHENOCRYSTS IN THE SHINGLE CREEK PORPHYRY

H.H. Bostock

Abstract

The Shingle Creek porphyry is exposed within an area some 4 1/2 by 1 1/2 miles immediately southwest of Penticton, British Columbia. It is intruded into a basement complex composed chiefly of andesine-rich granodiorite and is bordered on the south by tuff and agglomerate that may form remnants of a volcanic cone. These rocks are in part overlapped by basic volcanic rocks of the Marron Formation.

The Shingle Creek porphyry is coarsely porphyritic with sanidine, plagioclase, quartz, and minor mafic phenocrysts in a fine-grained matrix. It is differentiated into an earlier albite-bearing phase followed by an oligoclase-bearing phase. Plagioclase in the range An_8 to An_{19} is largely missing. The two plagioclase phases are essentially similar except that the mean lime content is slightly higher in the oligoclase phase.

Petrographic and mineralogical features of the broad eastern part of the intrusion, herein called the "neck", are compared with those of dykes to the north and west. Rock forming the dykes is chemically similar to that forming the neck. Regions of low phenocryst concentration are found in the albite phase of the neck and in the oligoclase phase of part of the dykes adjacent to the neck.

Albite from the neck shows higher negative optic angles than albite from the dykes. No difference between optic angles of oligoclase from the two regions was demonstrated. Alpha refractive index measurements suggest that the range in plagioclase composition is much the same in both the dykes and the neck.

Large sanidine phenocrysts show oscillatory zoning with compositions chiefly in the range Or_{60} to Or_{80}. Oscillation photographs indicate that some crystals are unmixed and that crystals not unmixed have average optic angles less than 30°. A thin-section fragment of a zoned sanidine heated for 20 minutes at 800°C retained its zoned texture; however, cryptoperthitic unmixing was homogenized by similar treatment. The lowest optic angles in sanidine are found in the neck.

Quartz phenocrysts show rounded to embayed outlines and are commonly surrounded by haloes of matrix quartz or chalcedony(?).

GROUNDWATER HYDROLOGY AND WATER SUPPLY IN THE DISTRICT OF MACKENZIE, YUKON TERRITORY, AND ADJOINING PARTS OF BRITISH COLUMBIA

L.V. Brandon

Abstract

Groundwater is effluent in regions of discontinuous permafrost in the Interior Plains and the Cordillera. Groundwater flow in the Precambrian Shield is considered to be negligible. Winter baseflow records, chemical analyses of river waters, the presence of springs, and the local occurrence of halophytic flora provide evidences of groundwater movement in regions where no piezometric data from borings are available. Quantitative information on the groundwater contribution to the Upper Liard basin is obtained from the relation between discharge and specific conductance. This relation could be used elsewhere if more data were available.

Several thermal springs in the Cordillera derive their heat from deep circulation of meteoric waters. The heating of meteoric waters by an exothermic reaction with sulphides in rock may contribute heat to water in two springs discharging sulphate waters.

Groundwater is available for domestic and community supplies in the glaciated valleys in the Cordillera and in alluvium in other regions. It is used or can be used in many settlements and towns. Whitehorse and Dawson are the largest towns with well fields.

A GEOCHEMICAL METHOD OF CORRELATION FOR THE LOWER CRETACEOUS STRATA OF ALBERTA

E.M. Cameron

Abstract

This study attempts to evaluate the use of chemical methods for subdividing and correlating detrital sediments. Lower Cretaceous strata in southwestern and central Alberta were sampled at close vertical intervals in nine outcrop and subsurface sections. Na_2O and K_2O were determined by flame photometry and these oxide values were corrected to a carbonate-free basis.

These determinations show that the Lower Cretaceous rocks may be divided into three stratigraphic divisions, each of distinctive soda content, which may be traced throughout the area studied. The mean corrected Na_2O content of the lower division is 0.21 per cent,

and of the upper division 0.87 per cent. The middle division, principally composed of sediment rich in sodic volcanic detritus, has a mean corrected content of 2.37 per cent. This high-soda facies, derived from the west, begins to pass into low-soda sediments in east-central Alberta. Potash is found to be less useful than soda for correlation, but $Na_2O + K_2O$ shows the distribution and development of clean sandstones, which, in places, contain oil and gas.

The geographic distribution of the alkalis is discussed, and the main chemical boundaries are compared to the existing palaeontologic and lithologic correlations. Trends in the alkali content of the rocks may be helpful in detecting stratigraphic traps.

FERROMAGNESIAN SILICATE MINERALS IN THE METAMORPHOSED IRON-FORMATION OF WABUSH LAKE AND ADJACENT AREAS, NEWFOUNDLAND AND QUEBEC

K.L. Chakraborty

Abstract

The Wabush iron-formation is a metamorphosed Precambrian ferruginous sediment in the southern part of the Labrador geosyncline. The whole formation is divided into three main lithological units (oxide iron-formation, silicate iron-formation, and carbonate iron-formation) on the basis of mineral assemblage. A large number of ferromagnesian and lime silicate minerals, such as anthophyllite, cummingtonite, manganoan-cummingtonite, hypersthene, diopside, actinolite, and garnet have been formed in these rocks by metamorphic reactions. The chemical and optical properties and modes of occurrence of these minerals have been studied, and their identifications confirmed by X-ray studies.

Siderite and dolomite are the predominant types of carbonate in these rocks. Variations in chemical composition of cummingtonites in different iron-formations apparently indicate differences in primary chemical composition of the sediments. The relationship of the anthophyllite, cummingtonite, and manganoan-cummingtonite minerals is established. Anthophyllite and cummingtonite are proven to be two different series with limited isomorphism. Manganoan-cummingtonite has monoclinic symmetry, but its chemical composition and optical properties are more similar to anthophyllite with orthorhombic symmetry than to the cummingtonite-grunerite series. Paragenesis of the silicate minerals was deduced from their chemical composition and textural relationship.

Results of this study suggest that the iron-formation was metamorphosed isochemically with a minimum possible migration of material and has reached the epidote-amphibolite facies or garnet-staurolite zone of metamorphism. Manganese-bearing anthophyllite and manganoan-cummingtonite are evidently the source of secondary manganese in the iron ores of this region.

SURFICIAL GEOLOGY OF NORTHEASTERN ELLESMERE ISLAND, ARCTIC ARCHIPELAGO

R.L. Christie

Abstract

Glacial features and deposits such as erratics, grooves and till are abundant in northeastern Ellesmere Island. Distinctive erratics and striae indicate a general outward movement of ice from the high mountains of the island with a limited incursion of Greenland ice onto the eastern shores. Glaciofluvial gravel and sand is widespread, and certain enigmatic 'boulder gravel hills' may be related. Thick marine and lacustrine silt deposits form conspicuous benches and badlands. A post-glacial marine inundation of at least 250 feet is indicated by marine shells. Some interesting permafrost and ground-ice structures and the existing glacial ice and ice shelves are described. A synthesis of the glacial retreat for the region is attempted: most of the deposits formed during a period of rapid deglacierization and marine incursion; a relatively warm period, the Climatic Optimum, followed in which beds bearing vegetal matter were deposited; and the glaciers advanced slightly and the ice shelves formed during a succeeding, fairly recent cold period.

THE SERSON DIRECT-READING PROTON-FREE PRECESSION MAGNETOMETER – SHIPBORNE USE

L.S. Collett and P. Sawatzky

Abstract

The value of the magnetic field is displayed directly in gammas. A digital-to-analogue converter is designed to be used with a pen recorder, although a digital printer or punch-tape recorder can directly program a digital counter. Sensitivity of $\pm$ 0.1 gamma is attainable with an accuracy of $\pm$ .5 gamma with a magnetic field range from 43,000 to 67,500 gammas. Since 1960 over 50,000 line miles have been surveyed using this instrument on board ship.

GLACIAL LAKE McCONNELL AND THE SURFICIAL GEOLOGY OF PARTS OF SLAVE RIVER AND REDSTONE RIVER MAP-AREAS, DISTRICT OF MACKENZIE

B.G. Craig

Abstract

The area was completely glaciated during Wisconsin time by the Laurentide ice-sheet, which extended westward into Mackenzie Mountains. There is no evidence that Cordilleran ice entered from the west.

A vast glacial lake, Glacial Lake McConnell, which extended from Great Bear Lake through Great Slave Lake to Lake Athabasca, was formed during deglaciation because of differential isostatic depression downward to the east. This lake originated as three separate lakes in the three basins and became one vast lake as the topographic low between Great Bear Lake and the northwest arm of Great Slave Lake, and the Slave River Lowland, became ice-free. Elevations of lacustrine features formed during the maximum stand of the lake are about 925 feet above sea-level along its eastern boundary and decrease westward. Subsequent isostatic readjustment lowered water levels until the large glacial lake separated into smaller lakes, one of which was ancestral to Great Slave Lake. The minimum amount of readjustment indicated in this basin is slightly over 2 feet per mile.

During the earliest phases of ice-retreat, flow was diverted to the north and south by the mountain barrier along Mackenzie and Liard Rivers. Subsequent marginal thinning and eastward retreat produced a radial pattern of flow features in the western part of the area. Stagnation on Horn Plateau while ice was flowing actively on either side of it formed two lobes in the east-central part of the map-area. During the last phases of deglaciation flow was to the southwest and the ice-margin was almost parallel with the edge of the Precambrian Shield.

THE GEOLOGY OF THE NEW QUEBEC CRATER

K.L. Currie

Abstract

The New Quebec Crater is a circular depression in the acid Archaean gneisses of northern Quebec, approximately 2 miles in diameter and 1,300 feet deep. The regional structure is a complex series of north-trending isoclinal folds cut by four systems of faults.

The elevated crater rim shows deflection of curviplanar structure elements, demonstrating that a dome previously existed over the crater. Significant hydrothermal alteration occurs in the wall of the crater but not elsewhere in the region. There is no evidence that the shape of the crater has been substantially modified by erosion. No evidence of meteorite impact, or catastrophic violent origin was found. The evidence is quantitatively consistent with an origin by collapse of a fluid-supported dome. The time of origin of the crater is thought to be late Pleistocene.

THE PREISSAC-LACORNE BATHOLITH, ABITIBI COUNTY, QUEBEC

K.R. Dawson

Abstract

The Archaean Preissac-Lacorne batholith, which consists of the Preissac, La Motte, and Lacorne massifs and smaller stocks, intrudes Archaean sedimentary and volcanic rocks and is cut by Proterozoic gabbro dykes near the south side of the Superior structural province of the Canadian Shield. The adjacent wall-rocks are part of the gold and base-metal-bearing greenstone belt that outcrops in northwestern Quebec, between Val d'Or and Amos.

The field relationships exhibited by the granitic rocks suggest that the Preissac-Lacorne batholith is an intrusive body that has shouldered aside the Archaean sedimentary and volcanic rocks. The dynamo-thermal metamorphic aureole, the attitudes of primary foliation and lineation, the absence of 'ghost strata' demonstrated by anomalous concentrations of the minerals magnetite, staurolite, or sillimanite, or the elements iron and silicon, and the distribution and orientation of xenoliths, collectively indicate the magmatic origin of the batholith.

The rocks of the batholith, which have the weighted average composition of granodiorite, range from intermediate monzonite and syenodiorite to granodiorite and leucoadamellite with associated dykes of granodiorite, feldspar porphyry, pegmatite and aplite, and mineralized quartz veins. The intermediate facies, which are mineralogically and chemically heterogeneous and contain abundant xenoliths, are attributed to contamination of the granodiorite magma. The leucoadamellite, which is mineralogically and chemically homogeneous and which is associated with both pegmatites and quartz veins, is attributed to the continued differentiation of the granodiorite magma. Deposits of beryl, spodumene, molybdenite-bismuthinite-pyrite, and pyrite and/or pyrite-gold are zonally arranged outwards from the centres of the massifs.

The occurrence of three massifs and smaller stocks with outward-dipping contacts, the mineralogical homogeneity of the leucoadamellite, the chemical homogeneity of the granodiorite regardless of distribution, and the gravimetric evidence suggest that the batholith is a continuous body at a shallow depth. It is elongated in the east-west direction and has several unroofed cupolas along its top. Gravimetric data suggest the body is saddle shaped in the north-south section and that the highest point is on the hypothetical eastward projection of the axis of the La Pause anticline. Gravimetric data also suggest a total thickness of 16,000 feet for the granitic rocks and less than 1,000 feet thickness for the wall-rocks of the intermassif septa. Potassium-argon ages for the micas of the granitic rocks and pegmatite fall in the range between 2,300 and 2,800 m.y., with the most probable age at 2,630 m.y.

MARION LAKE MAP-AREA, QUEBEC-NEWFOUNDLAND

J.A. Donaldson

Abstract

Marion Lake map-area is in the eastern plateau region of the Canadian Shield. Schefferville, centre of the Quebec-Labrador iron range, is about 35 miles west of Marion Lake.

The eastern third of the area is underlain by amphibolites and quartzo-feldspathic gneisses. The western two thirds is underlain by metabasalt, metagabbro, serpentinite, and slightly metamorphosed sedimentary rocks of the Labrador Trough, a narrow belt of Proterozoic rocks that extends approximately 450 miles northwest and 125 miles southeast of the Marion Lake area.

The gneisses and amphibolites form an eastern block that truncates northwest-trending folds and faults in the western block. The north-trending contact is a reverse fault, along which the gneissic block moved up relative to the western block. The gneisses and amphibolites are either part of the Archaean basement or metamorphosed rocks of the Labrador Trough.

Sedimentary strata of the Knob Lake Group, with a possible total thickness of more than 20,000 feet, have been mapped in the southwestern corner of the area. A northwest-trending fault separates these rocks from the volcanic belt in the central part of the area. Greenschists of the Murdock Group crop out immediately east of the fault. The overlying Doublet Group includes 3,500 feet of sedimentary rocks, and more than 10,000 feet of metavolcanic rocks.

Remarkably conformable basic sills underlie much of the area. The volcanic and intrusive rocks were probably derived from the same magma. The sills, which are as much as 5,000 feet thick, were intruded prior to and during the early stages of folding.

Most sedimentary rocks in the area show evidence of deposition on a stable shelf, which was, at most times, covered by shallow water. Graded beds interpreted as varves are exhibited by many of the fine-grained sedimentary rocks. Crossbedding attitudes in sandstone beds west of Marion Lake indicate sediment transport from the west.

The Denault Formation of the Knob Lake Group, which was studied in detail, is composed of approximately 30 per cent finely laminated siliceous dolomite, 20 per cent massive dolomite, 5 per cent intraformational conglomerate, and 45 per cent stromatolitic dolomite. Five zones of distinctive stromatolites were correlated in sections more than 2 miles apart. Algal activity was important in trapping sediment, and may have played a dominant role in primary precipitation of dolomite.

FORT GEORGE RIVER AND KANIAPISKAU RIVER (WEST HALF) MAP-AREAS, NEW QUEBEC

K.E. Eade

Abstract

This report is based on the results of reconnaissance geological mapping carried out by means of helicopters.

The area is largely underlain by rocks of Archaean age, granites, gneisses and schists, with some smaller masses of metamorphosed volcanic and sedimentary rocks. Scattered occurrences of Proterozoic cover rocks are also present; Manitounuk Group on the Hudson Bay coast, Kaniapiskau Supergroup of the Labrador 'trough', the Otish Mountains Group, and a hitherto undescribed formation.

The Archaean rocks in the western and central parts of the region are almost wholly of the amphibolite facies of metamorphism, but in the eastern region large areas of granulite facies rocks are present.

Folds trend east in the western part of the map-area, gradually changing to east-northeast in the eastern part. In the east, superimposed northwest-trending folding complicates the structural pattern. Faults are widespread throughout the map-area. It is suggested that a major zone of disruption, extending from James Bay almost to the Labrador 'trough' accounts for preservation of most remnants of Proterozoic rocks in down-dropped blocks.

In two localities development work has been carried out on quartz-magnetite iron-formation occurring with basic volcanic rocks. Sulphide minerals, chiefly pyrite with some chalcopyrite, were observed in the basic volcanic rocks in a number of places. Sphalerite-galena occurrences in some beds of limestone of the Manitounuk Group had been explored prior to the present survey.

GEOLOGY OF SOUTHEASTERN PRINCE EDWARD ISLAND

L. Frankel

Abstract

Southeastern Prince Edward Island is a rolling lowland composed of redbeds that show rapid horizontal and vertical facies change. The 5,425 feet of exposed sediments are divided into three informal rock-stratigraphic units, designated units A (oldest), B, and C (youngest). Units A and B probably are disconformable, and a regional (angular) unconformity apparently separates units B and C.

The diverse sediments and rare fossils of unit A show the progressive change from a deltaic-lacustrine environment to a flood plain - alluvial fan environment. Unit B, characterized by sharpstone conglomerates and lithic sandstones containing pebbles of many rock types, is an alluvial fan deposit, which indicates rapid uplift and erosion in the source area. The well-rounded orthoquartzitic conglomerates, characteristic of unit C, are alluvial plain sediments, which suggest low relief and slow erosion in the source area.

Unit A is dated as Early Permian because an Ophiacodon tibia, Xenacanthus teeth, and spores suggestive of this age were found in its sediments, and it is correlated, on the basis of lithology, with the rocks in the French River area, in which Bathygnathus borealis Leidy was discovered. The ages of the overlying unfossiliferous sediments of units B and C are not known.

The post-Early Permian (post-unit A) tectonic history of the area involves at least two episodes of minor folding, the earlier, after the deposition of unit B, and the later, after the deposition of unit C, which may indicate more intense deformation on the mainland at these times.

GROUNDWATER RESOURCES OF THE COASTAL LOWLAND AND ADJACENT ISLANDS, NANOOSE TO CAMPBELL RIVER EAST COAST OF VANCOUVER ISLAND

E.C. Halstead and A. Treichel

Abstract

Permeable sand and gravel constitute adequate recharge areas and storage reservoirs for large volumes of good-quality groundwater within the map-area. Water-transmitting properties of certain permeable sand and gravel aquifers permit rates of movement of groundwater ranging from 1,000 gallons per day per foot of aquifer to more than 40,000 gallons per day per foot of aquifer.

Groundwater is obtained from the underlying bedrock where the unconsolidated surface deposits are thin or lacking or consist of impermeable clay or till. Shale, sandstone, and conglomerate constitute the bedrock underlying much of the area, and in them groundwater is transmitted along bedding planes or fractures; only wells that encounter such openings are successful.

Precipitation occurs mostly as rain and provides adequate annual recharge. However, seasonal variation in rainfall complicates the problem of maintaining sufficient supplies in shallow dug wells and does not provide ample moisture for growing crops. A table presents data on those soils with considerable agricultural importance and the possibilities of developing groundwater for irrigation use.

GEOLOGY AND STRUCTURE OF YELLOWKNIFE GREENSTONE BELT

J.F. Henderson and I.C. Brown

Abstract

The greenstone belt includes an almost continuously exposed section of 22,000 feet of nearly vertical Archaean meta-andesites and meta-basalts which have been studied and mapped in detail on the scale of 1 inch to 500 feet. Pillow lavas make up about 50 per cent of

the volcanic assemblage and the conclusion is reached that volcanic breccia (pillow breccia) and pillow lavas formed in much the same way, and that the key to the origin of pillow structure is to be found in the breccias. Dyke swarms and irregularly shaped bodies of meta-diorite and meta-gabbro in the volcanic assemblage similar to those found in many greenstone belts of the Canadian Shield have been mapped and studied in detail and it is concluded that the irregular bodies probably formed in place by recrystallization or dioritization of the meta-basalts and meta-andesites. The sedimentary phase of the Yellowknife Group rocks overlies the volcanic rocks apparently conformably. It comprises mainly greywackes of a flysche assemblage. The volcanic rocks are also overlain disconformably in places by a molasse assemblage of subgreywacke and conglomerate of uncertain age.

The Giant-Campbell shear zone system has been mapped over a length of more than 12 miles and is up to 2,000 feet in width. It is made up of interlacing schist zones between horses of unsheared greenstone and is believed to have formed along an early zone of faulting. The development of gold deposits in the schist took place after or during the late stages in the development of the shear-zone system, the orebodies forming by diffusion of material from the schist to dilatant low-pressure zones related structurally to noses of massive unsheared country rock within the shear-zone system, or at flexures in the shear zones.

A system of late tear faults that rank with the largest dislocations in the earth's crust, displace the Yellowknife Group rocks and the early shear-zone systems. The fault pattern, which is well developed, is a typical shear system formed by nearly horizontal strain or shear with lateral rather than upward relief. It includes two sets of near vertical shear faults striking at nearly right-angles to each other and a third set developed along tension cracks at right angles to the direction of elongation or lateral relief.

THE UPPER VOLGIAN (LATEST JURASSIC) AMMONITES AND BUCHIAS OF ARCTIC CANADA

J.A. Jeletzky

Abstract

The completed study of the palaeontology and stratigraphy of the latest Jurassic (latest Lower and Upper Volgian Stages) rocks of Arctic Canada revealed the presence of the following ammonite and Buchia (=Aucella) faunas (in ascending order):

1. Late Lower Volgian (=Portlandian s. str.) beds with Buchia piochii var. russiensis, B. piochii var. mniovnikensis, and B. aff. fischeriana s. lato.

2. Early Upper Volgian (=Purbeckian = Upper Tithonian) or (?) latest Lower Volgian beds with Buchia richardsonensis n. sp. This Buchia volgensis-like species may locally occur in association with index fossils of (1) or (3) and may range upward into (3). These beds may, thus, be but a faunal facies either of the upper part of Buchia piochii zone or of the basal part of Buchia fischeriana s. lato zone.

3. Early Upper Volgian. Buchia fischeriana s. lato zone characterized by the predominance of large and typical representatives of this species. Other important but rare and/or poorly preserved fossils of this zone include: Dorsoplanites cf. gracilis Spath, D. n. sp. aff. crassus Spath, Laugeites? sp. indet. and other dorsoplanitid ammonites.

4. Late Upper Volgian beds with Craspedites (Taimyroceras?) canadensis n. sp., Buchia unschensis, and B. aff. subinflata.

All ammonites and Buchias of above-mentioned faunas are described and figured. The Craspedites (Taimyroceras?) canadensis n. sp. beds are believed to be overlain by yet another latest Jurassic fauna consisting of a new craspeditid ammonite and Buchia ex gr. uncitoides which will be described in another report. This fauna occurs only 28 feet stratigraphically below the basal Berriasian beds with B. okensis s. lato, Tollia (Subcraspedites) aff. hoeli, and T. (S.) aff. suprasubditus.

JURASSIC AND(?) TRIASSIC ROCKS OF THE EASTERN SLOPE OF RICHARDSON MOUNTAINS

J.A. Jeletzky

Abstract

This completed project (GSC Bulletin is in hands of the editor) is based largely on the writer's field work in the area but also uses some other published and unpublished information. The area is characterized by thin and incomplete development of the Jurassic System, which is largely represented by shallow-water, marine to non-marine(?) clastics (sandstones and more or less sandy siltstones with greater or lesser interbeds of coarser clastics). Within the area the Jurassic shallow-water sandstones and siltstones gradually become replaced laterally by the neritic to(?) non-marine sandstones,

grits, and conglomerates toward the south. Westward (on the western slope of the Richardsons) the above-described shallow-water facies is replaced by the deep-water facies (predominantly pure shales and various siltstones). The same probably happens at the northern end of the range (between Fish Creek and Blow River). The thicknesses of all Jurassic isochronous units (palaeontological zones) increase markedly westward and (?) northward. The southern shoreline of the Jurassic sea must have been situated closely south of Vittrekwa River basin because of the observed facies changes and apparently complete absence of marine Jurassic rocks south therefrom.

The predominantly sandy lower part of the Jurassic System [late Sinemurian, late to(?) mid-Bajocian to(?) early Oxfordian] north of Vittrekwa River basin was formally named Bug Creek Formation. The presence of a pronounced disconformity within this formation and the apparently erosionally-caused absence of its lower Jurassic part in the Rat River area indicate the flexing and uplift of the Aklavik arch at that time. The predominantly silty to shaly upper part of the Jurassic System [Upper Oxfordian(?) to Upper Tithonian] of the same area was formally named Husky Formation. This formation also includes basal Cretaceous rocks.

The Bug Creek Formation thins out on Stony Creek and at Teeweechee Mountain and presumably wedges out completely south of these localities. The Husky Formation becomes laterally replaced by the predominantly coarse clastics (named North Branch Formation) between Stony Creek and the North Branch of Vittrekwa River. The North Branch Formation is underlain by the undated, Jurassic(?) to(?) Palaeozoic shale unit.

The Triassic(?) rocks were only found in the Rat River Gorge and adjacent parts of Aklavik Range. Their upper part is represented by coaly shales tentatively named Coaly Shale Division. This unit is underlain by pebble-conglomerates and coarse, pebbly sandstones with interbeds of finer-grained clastics, formally named the Bug Creek Formation. These conglomerates disconformably overlie the early Permian sandstones and siltstones in at least one section. The palynological data suggest Triassic age in preference to the also possible Permian (late Permian only?) age. A number of important sections measured by the writer and others is appended to the report.

WHITBOURNE MAP-AREA, NEWFOUNDLAND

W.D. McCartney

Abstract

Late Precambrian and Palaeozoic sedimentary, volcanic, and plutonic rocks of west and central Avalon Peninsula, Newfoundland, are described. Major facies changes in late Precambrian sediments are most pronounced across the regional north-northeasterly structural trends. Precambrian rocks in the west, in order of decreasing age, comprise the Connecting Point Group (siltstone and greywacke) and the Musgravetown Group. The latter group comprises the Bull Arm Formation (volcanic rocks) overlain by four separate formations of arkosic sediments. Precambrian rocks in the central and eastern part of the map-area comprise the Harbour Main Group (volcanic rocks) unconformably overlain by the Conception Group (siltstones and greywackes) overlain in turn by the Hodgewater Group (arkosic sediments). The Hodgewater Group is divided into four formations: Carbonear slate, Halls Town arkose, Whiteway red siltstone, and Snows Pond arkose and siltstone. Lithostratigraphic correlations are proposed. Various rock types in the Crown Hill and Snows Pond Formations are overlain by the Random Formation (white quartzite). This formation is disconformably overlain by fossiliferous shale, slate, and limestone of Cambrian age. Lower Ordovician beds comprise shales, siltstones, sandstones and oolitic iron ores. The Harbour Main Group is intruded by the Holyrood granitic rocks, which include granite, quartz monzonite, and gabbro. A potassium-argon date of 910 $\pm$ 91 m.y. has been obtained on the quartz monzonite. Post-Cambrian plutonic rocks form three small stocks: the Iona Islands intrusions, Northern Bight granite, and Powder Horn diorite complex.

A major system of tear faults near the Isthmus of Avalon was formed in post-Lower Ordovician time, but major movements on north-trending faults occurred in Precambrian (post-Conception) time. Folds are upright and open over most of the map-area and the rocks are practically unmetamorphosed.

Low-grade Middle Cambrian manganiferous carbonate and slate beds discovered in southern Trinity Bay are less likely to be of future value than equivalent beds in Conception Bay. Lead, lead-zinc-silver, and barite deposits in the map-area are of doubtful economic value.

GROUNDWATER STUDIES IN THE ASSINIBOINE RIVER DRAINAGE BASIN

Part I. THE EVALUATION OF A FLOW SYSTEM

P. Meyboom

Abstract

Discernible groundwater phenomena of a typical prairie drainage basin have been related to a common flow system,which can be used as a model in quantitative groundwater studies. This model has been called the Prairie Profile. The Prairie Profile consists of a central topographic high bounded at either side by an area of lower elevation. Geologically, the profile is made up of two layers of different permeability, the upper layer having the lowest permeability. Through the profile is a steady flow of groundwater from the area of recharge to the area of discharge. The ratio of permeabilities is such that the groundwater flow is essentially downward in the poorly permeable layer and essentially lateral through the underlying permeable layer. The potential distribution in the Prairie Profile is governed by the differential equation of Laplace.

The various parts of this flow system can be mapped in a classical geological fashion; that is, by means of a large number of individual outcrops. In this report a groundwater outcrop is defined as any area where groundwater emerges at the surface. Geobotanical field investigations indicate that in a prairie region the following features may be classified as groundwater outcrops: willow rings, saline river valleys, playas, saline soils, springs, and seepages. Once the various parts of the flow system have been mapped, their importance in terms of a groundwater balance can be established quantitatively.

STRATIGRAPHY OF THE DEVONIAN MIETTE REEF COMPLEX AND ASSOCIATED STRATA, EASTERN JASPER NATIONAL PARK, ALBERTA

E.W. Mountjoy

Abstract

A small limestone reef complex of Upper Devonian age occurs in the Front Ranges of eastern Jasper National Park. As reconstructed from exposures in three separate thrust sheets, the reef has a subrectangular outline with a present area of about 30 square miles. The reef complex is of comparable size and stratigraphy to the

moderate sized Devonian reef complexes in the Alberta subsurface. It is about 1,400 feet thick and is surrounded by a slightly thinner succession of shales and argillaceous carbonates. It occurs on a central part of the pre-Devonian arch that parallels the trend of the Front Ranges.

Several sections were measured, of which fifteen are included in the appendix. The stratigraphy of the reef complex is described and illustrated in detail. Several figures and photographs illustrate the units, facies changes and correlations.

The depositional history of the reef complex is interpreted from the spatial form, reef-margin relationships, internal stratigraphy and carbonate petrography. The initial Upper Devonian transgression occurred over a relatively flat erosion surface on Cambrian rocks. Deposition of calcarenites and stromatoporoidal carbonates, locally forming biostromes, followed (Flume). In areas favourable to organic growth, slightly thicker accumulations of stromatoporoidal carbonates were deposited. These areas probably formed patch reefs or mounds above the level of the surrounding parts of the carbonate platform. With increasing depth of water and subsequent drowning of much of the stromatoporoidal platform, these higher areas acted as sites around which organic growth continued. Stromatoporoidal biostromal growth above these areas was able to keep pace with changes in sea-level, forming between 300 and 500 feet of carbonates (upper Cairn). Fine argillaceous calcarenites (Maligne) deposited above the platform and adjacent to the biostrome probably represent detritus eroded from the reef. Greater depth of water induced the growth of local small bioherms along parts of the margin of the reef complex, which were later dolomitized to massive structureless dolomite containing coarse breccias. Black, pyritic terrigenous muds (Perdrix) deposited in the surrounding basin during biostrome and bioherm development are indicative of stagnant, poorly circulated waters. The environment above the reef complex was changed to one of very shallow water bank conditions reflecting a gradual change from a rising sea-level to one of general stability. The change in environment is reflected in the sediments by a progressive change from organic to lime sand carbonates (lower Southesk, Peechee). Bank conditions persisted for a long time as evidenced by the thick sequence of lime sands above the former biostrome. Somewhat deeper waters followed for a short time permitting the formation of a thin coral Amphipora carbonate (Grotto) and temporarily ended bank conditions. During the latter two stages, basin relief was gradually decreased by influx of terrigenous muds and fine carbonate mud and detritus (Mount Hawk) derived from the reef complexes. Small coral biostromes developed locally on the flanks of the bank and in the immediately adjacent shale basin. Further shallowing and basin filling permitted lateral extension of the bank environment and

widespread deposition of the lime sands (upper Southesk, Arcs). Quartz silts were introduced and mixed with lime sands during the final stage of regression (Ronde).

It is concluded that eustatic changes in sea-level or epeirogenic movements of the craton have exerted the dominant control on development of the Miette reef complex. Differential subsidence within the positive pre-Devonian arch also influenced reef evolution. Remnants of the stromatoporoid biostromes of the basal platform carbonates surviving the gradually increasing depth of water, formed the sites of later, more prolific reef growth.

Some of the stratigraphic relationships of the Miette reef may be useful in locating similar reefs in the adjacent subsurface to the northeast. Most important are: (1) thickening and greater organic content of the platform (Flume) and overlying argillaceous calcarenites (Maligne) towards the reef; (2) a gradual increase in carbonate content of the basin shales (Perdrix and particularly the Mount Hawk) in a 2- to 4-mile zone around the reef; and (3) presence of a lime sand carbonate (upper Southesk) above the basin shales (Mount Hawk).

STRATIGRAPHY OF THE ROCKY MOUNTAIN GROUP IN THE SOUTHEASTERN CORDILLERA OF CANADA

D.K. Norris

Abstract

The Rocky Mountain Group in its fullest development in the southeastern Cordillera of Canada is composed of four distinct lithologic units. At its base is a sandstone assemblage of Lower Pennsylvanian age in gradational contact with Mississippian Rundle Group. The sandstones are overlain with apparent conformity by dolomites of early Middle Pennsylvanian age. These in turn are overlain unconformably by late Lower or early Upper Permian siltstones. The uppermost unit of the succession is chert of Upper (?) Permian age. Triassic Spray River Group unconformably overlies the Rocky Mountain succession in all but Livingstone and Blairmore Ranges where Jurassic Fernie Group forms the basal beds of the Mesozoic succession.

The sandstones forming the lower unit of the Rocky Mountain Group are termed the "Misty Formation" (new name), and the dolomites are assigned to the Kananaskis Formation (McGugan and Rapson, 1961), the siltstones to the Ishbel Formation (restricted), and the chert to the Fantasque Formation (Harker, 1961).

The formations thin eastward through a combination of non-deposition and erosional truncation so that all four formations are commonly present in the west whereas only the lowermost units occur in the east or all are absent. Within the area the group ranges in thickness from somewhat in excess of 2,000 feet west of Elk River, British Columbia, to about 40 feet in northern Livingstone Range, Alberta, to zero at the surface on Moose Mountain, Alberta, and in the subsurface east of the Highwood and Livingstone Ranges.

STRUCTURAL EVOLUTION AND PLUTONISM IN VALHALLA GNEISS COMPLEX, BRITISH COLUMBIA

J.E. Reesor

Abstract

Granitic and gneissic rocks in Valhalla Range are a part of the Shuswap Metamorphic Complex in southeastern British Columbia. Valhalla Complex consists of a succession of low-dipping, gneissic rocks of heterogeneous texture and composition ranging from granodiorite and leucogranite gneiss, to quartzite, marble, biotite-quartz-plagioclase paragneiss and pelitic schist. These rocks have been evolved in the deep zones of the mountain belt, and regional metamorphism everywhere reaches the sillimanite-almandine sub-facies.

Gradationally outward from the gneissic core, massive granitic rocks are found about the periphery of the complex, ranging in composition from granodiorite to leucoquartz monzonite. The latest granitic intrusions range in composition from syenodiorite to monzonite, with minor quartz monzonite and syenite.

The overall pattern of regular foliation outlines two roughly domal masses, the Valhalla and Passmore domes. The principal axes of these domal masses are oriented east-west, and in common with much of the Shuswap Metamorphic Complex, minor fold axes and mineral lineation are oriented east-west, normal to the general regional Cordilleran trend. Minor folds are principally concentrated on the north and south slopes of the domes and in Passmore dome indicate relative vertical upward movement in the core of the mass. Mineral lineation has undergone a spectacular development in the eastern part of the complex and there involves all rock units. In contrast, the lineation in western Valhalla dome affects no corresponding layer. The eastern limit of Valhalla Complex is terminated by a complex crushed and mylonitized leucoquartz monzonite.

The evolution of Valhalla Complex is considered to have taken place in two principal structural episodes with many minor associated impulses. Deformation and progressive associated petrogenic evolution was initiated by the horizontal emplacement of the 'veined granodiorite gneiss' in the core of Valhalla dome. Overlying 'hybrid gneiss' was synchronously forced into the depressions on the flanks of this initial uplift. Concurrent emplacement of the augen granodiorite-gneiss now lying above the 'hybrid gneiss' in Passmore dome took place at this time. There then followed a progressive evolution of leucocratic granitic rocks ranging from fine granodiorite to coarse leucogranite, through partial melting in situ and partly through further emplacement of material of granitic composition, probably from a western source. Probably also massive granitic rocks of a similar range of composition were emplaced late in this period in the western and northern parts of the complex.

Only with the stagnation of this plutonic evolution within the complex did the second phase of deformation begin. In contrast to the essentially constructional evolution of the first phase, the second phase is primarily destructional, and deforms, in the eastern part of the complex, all layers of all rock types built up in the first episode. Similarly, in contrast to the first phase in which greatest ease of movement was essentially horizontal, ease of relief of stress at this stage was vertically upward and movement within the domes became diapiric in the final stage of deformation. As a result of horizontal tectonic confinement in all directions, movement within the domes was such that minor folds further evolved and developed along the north-south flanks of the domes, but a spectacular lineation developed along the eastern slopes of the domes, that is parallel to the direction of movement within this part of the mass. A study of the microfabric and statistical plots of lineation and foliation in this zone shows the character and symmetry of the fabric resultant upon the late diapiric movement.

The contrast in the response of an initially heterogeneous fabric in the gneisses and the essentially homogeneous fabric in the leucoquartz monzonite, along the eastern boundary during this period of deformation, is well demonstrated by the development of the intense east-west directed fabric in the gneisses, and by crushing and mylonitization in the massive rock.

Late structural events and low-temperature retrograde metamorphic effects are largely confined to the 'crushed zone' along the eastern boundary of the complex.

The latest plutonic activity within the region appears to reflect an entirely new sequence of plutonic events, in which a succession from syenodiorite to monzonite has been emplaced along the east and west boundaries of the complex.

Throughout the evolution of Valhalla Complex a close interdependence of structural evolution, metamorphism, migmatization, and granite emplacement is clearly evident.

THE STRUCTURE AND METAMORPHISM OF MESA LAKE MAP-AREA, N.W.T.

J.V. Ross

Abstract

Mesa Lake area is underlain by two groups of rocks — the Yellowknife Group, believed to be Archaean in age, unconformably overlain by the Snare Group, whose age is set at Proterozoic.

Rocks of Yellowknife age consist of a monotonous sequence of graded sub-greywackes and slates with one marker horizon of volcanic rocks. These Yellowknife rocks have been deformed into close folds whose trend is northeasterly with a shallow plunge to the south. Metamorphism at the time of deformation is characterized by the development of chlorite.

Snare rocks lying unconformably above the Yellowknife rocks, have at their base a limestone, which is overlain stratigraphically by thin-bedded well-sorted sandstones and shales. Deformation of these Snare rocks has resulted in the formation of folds that trend in two distinct directions, northeasterly and northwesterly, with shallow plunges to the southwest and northwest, respectively; the northeasterly set of folds are the dominant set and the earlier of the two directions. This Snare deformation has also affected the underlying Yellowknife rocks and has resulted in the production of steeply plunging folds that are superimposed upon the limbs of the earlier Yellowknife structures.

Metamorphism accompanying this Snare deformation gave rise to a widespread development of andalusite and cordierite with local sillimanite.

Bodies of white foliated microgranite were intruded during the last stages of folding. These intrusions have zones of inclusions at their margins; they had little or no thermal effect on the country rocks.

Several faults occur within the map-area. All strike easterly and dip vertically, and are characterized by a right-hand tear component with some vertical displacement.

THE CRETACEOUS SMOKY GROUP, ROCKY MOUNTAIN FOOTHILLS, ALBERTA AND BRITISH COLUMBIA

D.F. Stott

Abstract

Marine sandstones and shales of the Smoky Group, originally described in the Peace River Plains, extend westward and southward into the Foothills of northeastern British Columbia and northern Alberta. Lithology, palaeontological data, and palaeogeography are discussed.

The Kaskapau Formation, containing the Sunkay, Vimy, Haven, and Opabin Members of Cenomanian and Turonian age, thickens westward from the type region and grades laterally into epineritic sandstones. The Cardium Formation, containing late Turonian regressive deposits included in the Ram, Moosehound, and Baytree Members, persists along the Foothills but grades eastward into shale. The Muskiki Formation, representing latest Turonian(?) to Coniacian transgression, is overlain by early Santonian regressive deposits included in the Bad Heart Formation. The Puskwaskau Formation includes another major transgressive-regressive sequence of Santonian to possibly Campanian age. It contains the Dowling, Thistle, Hanson, Chungo, and Nomad Members.

SURFICIAL GEOLOGY OF CORNWALL AND THE ST. LAWRENCE SEAWAY PROJECT AREAS, ONTARIO

J. Terasmae

Abstract

Evidence of three different movements of glacier ice (Malone, Fort Covington, and a post-Fort Covington readvance) has been found in the map-area. The Champlain Sea covered the area some 10,000 to 11,000 years ago and fresh-water organic sediments began to accumulate more than 9,430 $\pm$ 140 years B.P., as shown by radiocarbon dating.

As indicated by palynological studies, the early forest of the area, about 9,500 years ago, was composed of spruce, balsam fir, jack pine, and birch, with a minor component of hardwood species. An improvement in climate followed and the early boreal forest was replaced by a mixed hardwood forest with pine and hemlock. The clearing of land in historic time was marked by a sudden increase in weed pollen abundance.

SURFICIAL GEOLOGY, DAWSON, LARSEN CREEK, AND NASH CREEK MAP-AREAS, YUKON TERRITORY

P. Vernon and O.L. Hughes

Abstract

The area mapped during Operation Ogilvie includes physiographic elements ranging in character from the moderately high but rugged Wernecke and Ogilvie Mountains through parts of the deeply dissected Yukon Plateau, to low broad valleys such as that part of Tintina Trench lying southeast of the junction of Rock Creek and Klondike River.

Glacial deposits record at least three advances of a large transection glacier in the eastern part of the area, and independent valley glaciers in the west. High north-facing cirques of Ogilvie and Wernecke Mountains are occupied now by rock glaciers and debris-covered glaciers; the latter seemingly persist only by virtue of the protection afforded by their thick debris-covers.

GEOLOGY AND MINERAL DEPOSITS OF THE CHISEL LAKE AREA, MANITOBA

H. Williams

Abstract

The Chisel Lake area of northern Manitoba, comprising 10 square miles within the Churchill structural province of the Precambrian Canadian Shield, has been mapped in detail. Information is provided on the lithology, structure, relationships, and origin of the rocks. Metamorphic features of the Amisk Group are described and chemical analyses presented. Metasedimentary rocks of Amisk age have been distinguished.

Quartz-eye gneiss (formerly quartz-eye granite) is a characteristic rock type in the area. Metamorphic features of the rock do not point to an obvious origin for the parental material in most exposures and controversy has been expressed regarding its origin and age. For the Chisel Lake area, field relationships, petrographic investigations, and chemical and micrometric analyses combine to indicate that the rock is in part, if not entirely, of pyroclastic origin. The author considers the rock to have been originally a crystal tuff. Quartzo-feldspathic rocks that are related to quartz-eye gneiss are likewise controversial and are also considered to be of pyroclastic parentage.

The occurrence of a differentiated basic intrusion, and base-metal mineral deposits, within the metamorphic environment of the area, are of special interest.

INDEX OF AUTHORS

Publications issued by the Geological Survey of Canada comprise maps and printed reports. Maps include basic geological maps and special maps such as those dealing with mineral areas, geophysical observations, groundwater, oil and gas, and geochemical studies. Reports are of several categories:

Memoirs—Comprehensive reports on the geology of specific areas.

Bulletins—Detailed scientific studies on any geological or related subject.

Economic Geology Reports—Comprehensive studies of economic interest on a broad regional basis.

Preliminary Series—Designed for the prompt publication of geological information of immediate practical interest.

Requests for geological maps or information on specific areas or topics should be addressed to:

The Director, Geological Survey of Canada,
Department of Mines and Technical Surveys, Ottawa.

Requests for specific reports should be addressed to the Geological Survey as above, or to The Queen's Printer, Ottawa.

Branch offices of the Geological Survey in Vancouver, Calgary, Whitehorse and Yellowknife maintain limited stocks of reports for the convenience of local residents.

Lists of publications showing geological maps and reports for each province are available without charge.

Notification service—Regular users of Geological Survey publications who wish to receive announcement cards of all publications as issued may do so by writing to the Geological Survey. Please state clearly your name and permanent mailing address when requesting this free service.

A complete index of all reports and maps with references and geographic area covered by each publication according to the National Topographic System is provided in:

Index of Publications, Geological Survey of Canada (1845-1958). ($4.00)

Supplements for (1959-60), (1961-62), (1963) (.35)

ROGER DUHAMEL, F. R. S. C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1964

Price 75 cents Cat. No. M44-64/2