-1A

Thomas Frisch

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 72-1
Part A

REPORT OF ACTIVITIES,
Part A: April to October, 1971

Price, $2.00

1972

Technical editing and compilation
R. G. Blackadar
Layout
Leona R. Mahoney

CANADA

GEOLOGICAL SURVEY OF CANADA

PAPER 72-1
Part A

REPORT OF ACTIVITIES,
Part A: April to October, 1971

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Available by mail from *Information Canada*, Ottawa

from the Geological Survey of Canada
601 Booth St., Ottawa

and

Information Canada bookshops in

HALIFAX - 1735 Barrington Street
MONTREAL - 1182 St. Catherine Street West
OTTAWA - 171 Slater Street
TORONTO - 221 Yonge Street
WINNIPEG - 499 Portage Avenue
VANCOUVER - 657 Granville Street

or through your bookseller

Price: $2.00 Catalogue No. M44-72-1A

Price subject to change without notice

Information Canada
Ottawa
1972

CONTENTS

Page

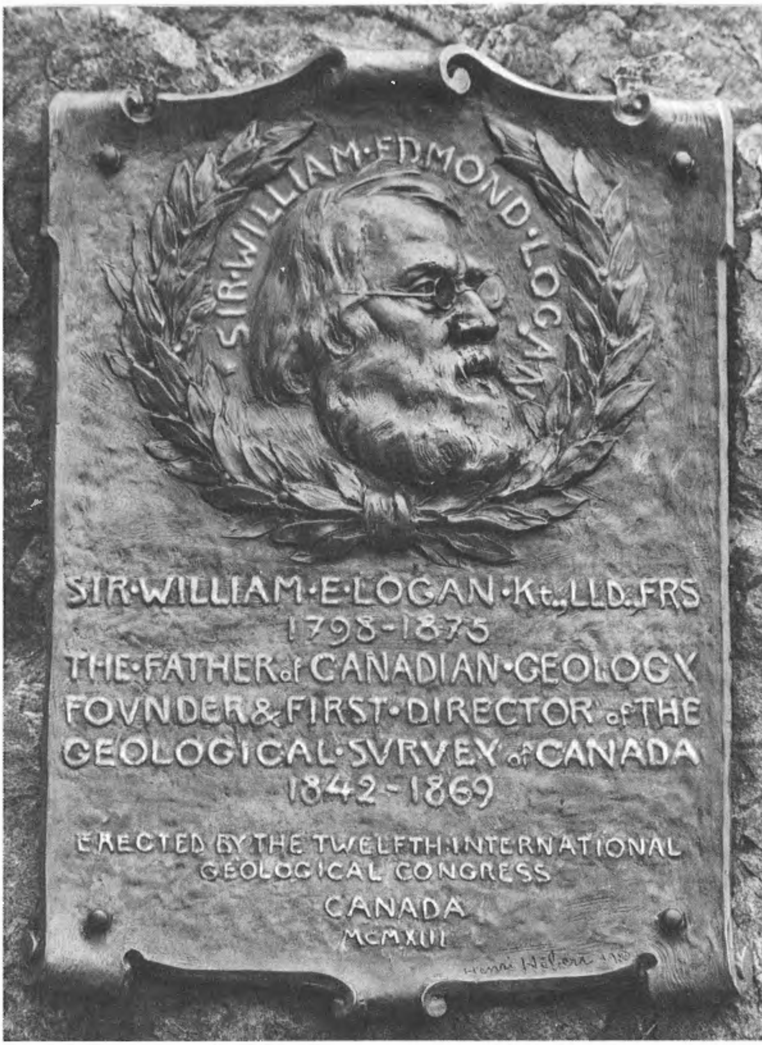
PRECAMBRIAN GEOLOGY

QUATERNARY GEOCHRONOLOGY AND PALEONTOLOGY

QUATERNARY GEOLOGY: ENVIRONMENTAL AND ENGINEERING GEOLOGY STUDIES

ABSTRACT

This report, containing 124 short papers, many illustrated by page-size maps and figures, presents the preliminary results of field work undertaken by members of the Geological Survey of Canada in 1971.



In August 1972, Canada will once again be host to the International Geological Congress. This plaque, presented by the 12th Congress, held in Toronto in 1913, commemorates our founder and is mounted on a boulder on the terrace of the Survey's Ottawa headquarters.

Le Canada sera de nouveau le pays d'accueil du Congrès Géologique International qui se tiendra en août 1972. Cette plaque, représentant l'effigie de notre fondateur, fut offerte par les pays membres du C.G.I., lors du 12e Congrès tenu à Toronto en 1913. Fixée à un boulder, elle est exposée en face de l'édifice de la Commission géologique du Canada.

INTRODUCTION

The Geological Survey of Canada, established in 1842, is one of the nation's oldest scientific organizations. Its current activities are designed to support two programs of the Department of Energy, Mines and Resources, the Mineral and Energy Resources Program (MERP) and the Earth Sciences Program (ESP).

A principal subobjective of the MERP activities is to ascertain the mineral and energy resource potential available to Canada and thus, during the period covered by this report, considerable effort was directed to such objectives as the estimation of the potential abundance and probable distribution of mineral and fuel resources. Studies were carried out to provide the necessary geological framework, to establish the geoscientific settings favourable to the occurrence of the various types of mineral commodities and fuels, to correlate the geoscientific settings favourable for mineral deposits and for pools and deposits of fuel resources, to evaluate foreign mineral and fuel resources, and to provide standards and controls to ensure consistent terminology, description and correlation. The departmental MERP activities are also concerned with improving the means of discovery, extraction, processing, transportation and use of mineral and energy resources and some of the projects carried out by the Geological Survey were designed to develop or improve methods and instruments suitable to Canadian conditions.

The Earth Science Program of the department includes activities designed to assist in effective use and conservation of resources and in the management and preservation of man's environment throughout Canada. Many of the activities carried out between April and October 1971 were part of this objective and were designed to provide geologically based information on land resources and terrain performance derived from geological, geomorphic, geophysical, geotechnical and related studies of earth and rock materials, landforms, and associated dynamic processes.

In support of these objectives the Geological Survey has 490 active projects in 1971-72; of these about 190 had a field component and the papers that comprise this publication present the preliminary results of many of these studies. Submissions for inclusion in this report were accepted until October 29, 1971. Many of the conclusions presented are based on a preliminary assessment of the data collected and are therefore subject to confirmation or revision in the light of more detailed office and laboratory studies. To expedite publication illustrations are reproduced directly from material submitted by the authors and the text has been given a minimum of editorial attention. The 124 papers that make up this publication are arranged in broad geoscientific categories. An index to geographic locations (arranged by province, territory, or district) and an authors' index, follow the text; for branch use project numbers are included with each paper. Requests for geological information, announcement cards concerning publication release dates, maps, reports, or information on specific areas should be addressed to: Geological Survey of Canada, Department of Energy, Mines and Resources, 601 Booth Street, Ottawa K1A OE8, Canada.

This publication (Paper 72-1, Part A) describes the activities of the Geological Survey between April and October, 1971. Paper 72-1, Part B to be published in mid-1972 will include brief reports on work done between November 1971 and March 1972. These reports, together with reports on isotopic and radiocarbon dating, the annual index of publications and the volume of abstracts of papers published by Geological Survey personnel in non-Survey publications, provide a comprehensive accounting of the scientific work of the organization.

APPALACHIAN GEOLOGY

1. BUCHANS AND BADGER MAP-AREAS, NEWFOUNDLAND (12 A/15, A/16)

Project 710045

F.D. Anderson

During 1971, a project was commenced by which geological maps and reports of the central mineral belt prepared by mining exploration companies were compiled, and lithology and formational contacts examined in the field. In this manner the field work in two map-areas, Buchans (12 A/15 and Badger (12 A/16), was completed using information supplied by American Smelting and Refining Company - Buchans Unit, Newfoundland and Labrador Corporation, and Canadian Javelin Limited, supplemented by field work in critical areas. The co-operation of the mining companies is gratefully acknowledged. Maps, on a scale of 1:50, 000 and an accompanying report will be published on the two areas.

In general the distribution of the rock units outlined by Williams[1] are retained with minor modifications. Ordovician and Silurian rocks west of Badger previously shown as being separated by an assumed fault are now considered to form a conformable sequence. The Middle Ordovician sediments are north-facing and grade northward into a conglomerate that is overlain by a volcanic sequence that contains the Buchans orebodies. The conglomerate contains well-rounded fragments of intrusive rocks, including granite and fossiliferous limestone; lithogically the rock is similar to Silurian Goldson conglomerate.

[1] Williams, Harold: Red Indian Lake (East Half), Newfoundland; Geol. Surv. Can., Map 1196A (1970).

---

2. REVISION OF THE ARICHAT MAP-AREA, NOVA SCOTIA (11 F/11 EAST HALF)

Project 710056

D.G. Benson

The Arichat map-area was re-examined during the 1971 field season to assist in preparing a report from the incomplete manuscript map and report by G.A. Collins.

The north and west slopes of Sporting Mountain are underlain by steeply dipping, generally sheared volcanic and sedimentary rocks of the

Precambrian Fourchu Group. Porphyritic andesite, tuff and greywacke are the most common rock types.

The outcrops north of Arichat, consisting of volcanic breccia, hornfels, laminated quartzite and associated rocks, are also correlated with the Fourchu Group.

The moderate red fine- to coarse-grained granitic rocks on Sporting Mountain, southeast of Rear Black River and near the north boundary of the map-area are regarded as three separate Devonian intrusive bodies. Narrow veins of granite intrude the volcanic rocks exposed on Macdonald Mountain.

The Carboniferous sediments unconformably overlie the Fourchu Group and the Devonian granite. They are less indurated, more gently dipping and less sheared than the pre-Carboniferous rocks.

The Lower Carboniferous Horton Group, exposed mainly on Isle Madame and Petit de Grat Island, comprises a lower unit of red and grey granule to boulder conglomerate, micaceous wacke and quartz arenite overlain by finer grained wacke, conglomerate and shale. The conglomerate on Petit de Grat Island is coarser than elsewhere.

The Windsor-Canso contact is transitional, and is placed above the highest marine limestone. The Canso, which is well-exposed on the west coast of Janvrin Island consists of greyish red and grey mudstone and siltstone with minor fine-grained wacke and shale.

The overlying Riversdale Group is more massive and coarser grained than the Canso. It consists generally of crossbedded and flaggy greywacke, arenite, siltstone and minor mudstone that are well-exposed on Rabbit Island and the north shores of Janvrin Island and Lennox Passage. The Riversdale-Canso contact is arbitrarily placed at the base of the oldest light grey medium-grained wacke.

Moderate red poorly consolidated pebble-conglomerate, wacke, siltstone and mudstone on Low Point is regarded as correlative with the Triassic Annapolis Group.

---

3. OPERATION STRAIT OF BELLE ISLE, QUEBEC AND NEWFOUNDLAND-LABRADOR (PARTS OF 2M, 12I, 12P)

Project 680130

L. M. Cumming

Geological mapping of Paleozoic strata on both sides of the Strait of Belle Isle was completed during a six-week field season with use of a Bell G-2 helicopter. The area lies between 50°30'N to 52° 00'N and 55° 30'W to 57° 30'W and is underlain largely by Cambro-Ordovician platformal facies autochthonous rocks which have been subdivided into formations as liste in Table I.

The general distribution of Paleozoic strata within the area is shown on Figure 1.

Large- and small-scale vertical and steeply dipping normal faults occur throughout the area. Of particular interest is a northeast trending fault in eastern Quebec and southern Labrador (see Figs. 1 and 2). This fault extends

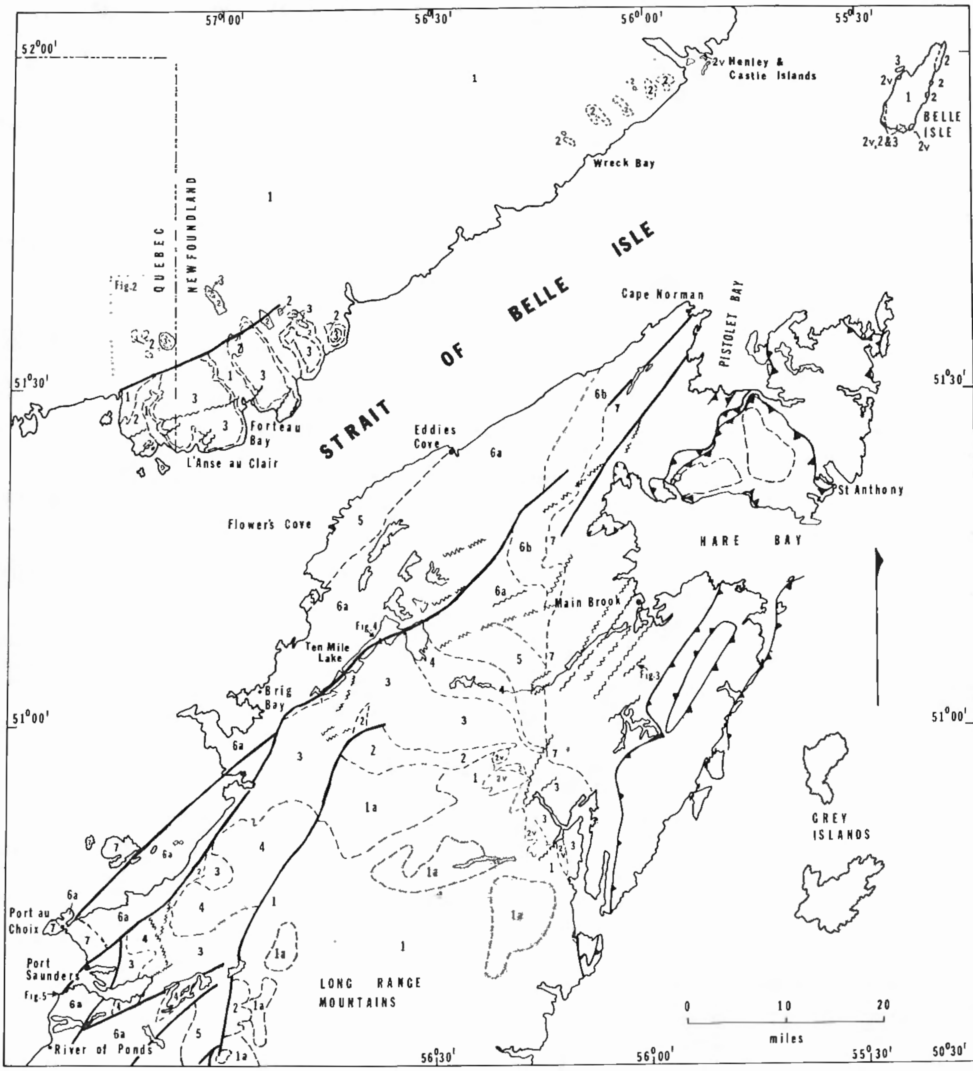


Figure 1. Geological sketch map showing distribution of Paleozoic rocks in the Strait of Belle Isle region.

for 20 miles and on the west side of L'Anse au Loup Pond the massive Bradore arkose locally displays cataclastic deformation along a network of veinlets 1 to 6 inches apart. A number of northeast-trending normal faults south and west of Hare Bay typically display coarse fault breccias (see Fig. 3). The St. George Formation throughout the area normally has a regional dip of less than one degree; however near the major fault through Ten Mile Lake, bedding is locally nearly vertical (see Fig. 4). The southern extension of this fault near Port Saunders also forms breccias composed of blocks of St. George Formation (see Figs. 1 and 5).

Figure 2. Airphoto mosaic of part of eastern Quebec and southern Labrador (see Fig. 1) showing a northeast trending normal fault and outliers of Labrador Group. GSC photo 201401-B

Figure 3. Fault breccia composed of carbonate rocks, 51°05'05"N; 56°01'33"W; Salmon River E 1/2 (see Fig. 1). GSC photo 201826

Figure 4. Carbonate rocks of the St. George Formation, Ten Mile Lake, Newfoundland (see Fig. 1). GSC photo 201827

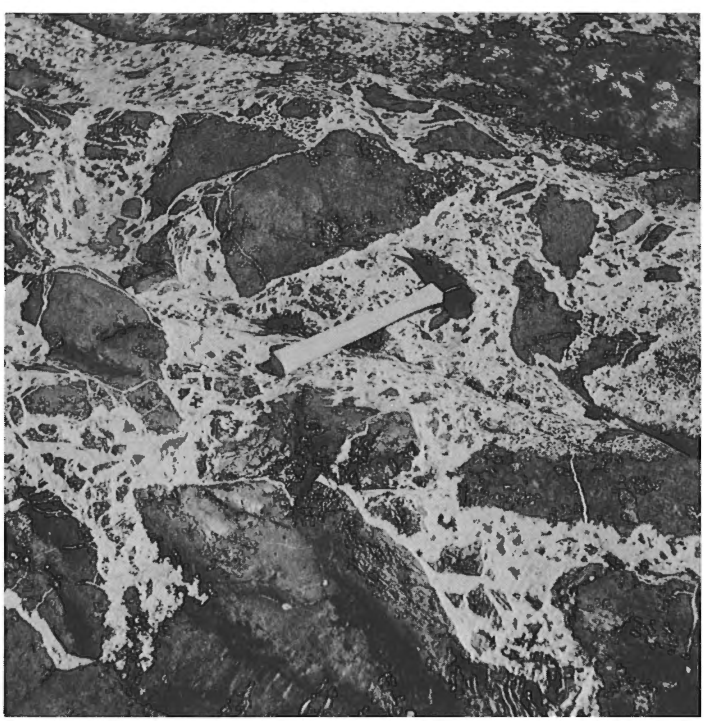


Figure 5. Fault breccia with grey dolomite blocks and white sparry dolomite, Spirity Cove, Newfoundland (see Fig. 1). GSC photo 201825

TABLE I

		Unit on Figure 1
Middle Ordovician	Table Head Formation	7
	... Disconformity ...	
Lower Ordovician	St. George Formation (shoal facies)	6b
	(platform facies)	6a
Middle Cambrian	unnamed unit	5
Lower Cambrian	Hawke Bay Formation	4
	Forteau Formation	3
	Bradore Formation (clastics)	2
	(volcanics)	2V
	... Unconformity ...	
Precambrian	granitic gneisses (1) and granite (1a)	1, 1a

Several zinc occurrences of Appalachian (Tennessee) type[1] have been found within map-unit 6b (St. George Formation, shoal facies) beneath the disconformably overlying Table Head Formation.

[1] Hoagland, A.D.: Appalachian strata-bound deposits: Their essential features, genesis and the exploration problem; Econ. Geol., vol. 66, pp. 805-810 (1971).

4. STRUCTURAL HISTORY OF PRE-CARBONIFEROUS ROCKS IN PARTS OF EASTERN CAPE BRETON ISLAND

Project 710046

Herwart Helmstaedt and Subhas Tella

During the 1971 field season parts of the Boisdale Peninsula were mapped on a scale of 1 inch to 1,320 feet, and reconnaissance studies were conducted at other localities in eastern Cape Breton Island, in order to establish the deformational history of the pre-Carboniferous rocks and determine the position of the base metal sulphide bodies in the Coxheath Hills and near Stirling within the sequence of structural events.

The geological record in eastern Cape Breton Island begins with platformal sediments (quartzite, slates and limestones) of the Hadrynian (?) George River Group. Andesitic fragments in a limestone breccia in the upper parts of the George River Group on Long Island indicate nearby volcanism, most probably the beginning of the mainly subaerial Coxheath volcanism six miles to the southeast. The Coxheath volcanics consist of intermediate and acidic flows, and minor tuff and breccia.

In Hadrynian-Cambrian times the George River Group underwent low-grade regional metamorphism and was deformed into gently to steeply plunging, tight to open upright folds. A steep to vertical, northeasterly trending cleavage, axial planar to these folds, is developed regionally, but is not penetrative in all rock types. Except for tuffs and some breccias the Coxheath volcanics have no penetrative planar fabric. Large bodies of diorite, quartz monzonite, and granite intruded both the George River Group and the Coxheath volcanics, and caused widespread contact metamorphism which overprints the regional fabric in the George River Group. Brittle deformation, after emplacement of the intrusions, formed fractures which in the Coxheath Hills and to a lesser extent in the Boisdale Hills became channelways for epigenetic hydrothermal copper-molybdenum sulphide mineralizing fluids[1]. Continuing deformation caused local folding of the quartz-molybdenite veins[1] and an incipient mineral fabric. Pebbles of Long Island diorite, contact metamorphosed George River slate, and granite of unknown provenance, were found in conglomerates of the lower Middle Cambrian Bourinot Group on Long Island suggesting that the Bourinot unconformably overlies the George River and that most of the plutonic rocks were emplaced during the interval of latest Hadrynian and Early Cambrian. A late Precambrian to earliest Cambrian age for the intrusions was also proposed by Bell and Goranson (Ref. 2) and is supported by radiometric age determinations, Rb-Sr whole rock isochron date of 555 m.y.[3], and a K-Ar date on hornblende of 584 m.y.[4]. Thus the late Precambrian orogenic event in this area suggested by Weeks (Ref. 5) is supported; it may be an expression of the Avalonian Orogeny[6, 7].

The correlation of the Coxheath volcanics with the Fourchu volcanics[2, 5] remains somewhat problematic. Weeks (Ref. 5) proposed a pre-Fourchu age for the folding in the George River, whereas the present study clearly shows that the Coxheath volcanics predate the pre-Middle Cambrian intrusions and thus, at least part of the deformation. On the other hand, the Fourchu volcanics in the Mira area, 15 miles southeast of the Coxheath Hills, are in continuous succession with the Cambrian strata[5], or perhaps in disconformable relationship with them[8]. Whether the Coxheath volcanics are therefore somewhat older than the Fourchu volcanics, or the Fourchu volcanics in the Mira area were only little or not at all affected by the deformation that caused the folding of the George River Group, cannot be decided at present.

While Lower Cambrian strata were deposited in the Mira area, the Boisdale Hills and Coxheath Hills areas underwent erosion. At the beginning of the Middle Cambrian, a second volcanic cycle developed in both areas, depositing the basic lavas and pillow lavas, intermediate to acidic flows and tuffs, and interlayered sediments of the Bourinot Group. Abundant conglomerates in the Bourinot Group of the Boisdale area suggest a near-shore alluvial facies, but a marine basin existed to the southeast in the Stirling area. The base metal sulphides of the Mindamar Mine near Stirling can be interpreted as having formed as a volcanogenic deposit in this basin.

The lower part of the Middle Cambrian MacMullin Formation contains abundant volcanic debris and local flows, but the absence of readily distinguishable volcanic material in the upper parts of the MacMullin and in the MacNeil Formation indicates cessation of volcanism and the erosion of the nearby volcanoes down to sea level. Lower Paleozoic deposition in eastern Cape Breton Island ends with the Lower Ordovician slates of the McLeod Brook Formation.

Style and orientation of folds and cleavage in the Cambrian and Lower Ordovician strata in the Boisdale area resemble those of the George River Group. Folding appears to have been accompanied by high-angle faulting that dissected the area into northeasterly trending fault blocks. In the Boisdale area this deformation apparently did not produce penetrative structures in the Precambrian granites and George River Group, but caused only local interference structures.

Locally developed hornfels in Cambrian and possibly also in Lower Ordovician rocks near Barachois Harbour and Spruce Brook indicate that not all plutonic bodies of the Boisdale Peninsula are Precambrian. Cambrian strata are intruded by a granitic stock at Gillis Mountain in the Mira valley[8] and northwest of Capelin Cove[5]. According to Weeks (Ref. 5) the latter granite has intruded the Middle River Group which was thought by him to be of Silurian or Early Devonian age. The present writers concur with Kelley (Ref. 9) who decided that Weeks' age assignments to the granites as well as to the Middle River Group were tenuous and rested on circular reasoning. The age of the Middle River Group must be established by independent means in order to place an acceptable upper age limit on these granites. Also the contact relationship between the granites and the Middle River Group must be better documented. In the Boisdale area, the age of the later granites at present can be stated only as between Early Ordovician and Middle to (?) Upper Devonian McAdam Lake Formation, which unconformably rests on the older strata. The plant-bearing McAdam Lake Formation contains pebbles of most of the granitic and metamorphic rocks recognizable in outcrops nearby. At present there is thus no basis for distinguishing Taconian and Acadian orogenic and intrusive events in the Boisdale area. A K-Ar date of 364 m. y. on biotite from granite near Framboise[10] suggests Acadian intrusive activity in southeastern Cape Breton Island, but a more recent Rb-Sr whole rock isochron age on another granite body a few miles to the northwest yielded a date of 523 m. y. (Cormier, recorded in Ref. 3) indicating the possible presence of granites older than Devonian.

The Middle to (?) Upper Devonian McAdam Lake Formation is disconformably overlain by red beds of the Grantmire Member of the Mississippian Windsor Group. Locally the older rocks are in unconformable or fault contact with the marine member of the Windsor. Steep dips in parts of the McAdam Lake Formation and to a lesser extent in the Windsor Group are attributed to normal faulting.

In summary, two full cycles of sedimentation, volcanism, deformation and intrusion, and each involving sulphide mineralization of a different type, can be recognized in the pre-Carboniferous rocks of eastern Cape Breton Island. The interval of time between initiation of volcanism and orogenic activity (Late Hadrynian) and cessation of volcanism as well as active erosion of related intrusive rocks (pre-Middle Cambrian) of the older cycle was relatively short. Because the volcanics are non-marine, volcanogenic base metal sulphide deposits were not developed. Rather, the mineralization of the

Coxheath deposit is epigenetic, fracture controlled and related to intrusive activity[1]. The volcanic part of the second cycle was also short-lived and was confined to the early Middle Cambrian. The Bourinot Group in the Boisdale Hills represents a near-shore facies, and lacks sizeable mineral deposits, whereas in the Stirling area, base metal sulphide and carbonate facies iron-formation were deposited in a marine basin. Deformation of the Cambrian rocks and intrusion of granites occurred prior to Middle Devonian time, but these processes at present cannot be keyed with certainty to the Taconian and Acadian Orogenies.

Structures in eastern Cape Breton Island are the result of high-level deformation and are very inhomogeneous. Interference structures of penetrative fabrics are therefore rare. As a consequence, the correlation of fabric elements from one fault block to another remains extremely uncertain and can be attempted only if supported by independent stratigraphic evidence.

[1] Oldale, H.R.: A Centennial of Mining exploration and development - Coxheath Hills, Cape Breton; Trans. Can. Inst. Mining Met., vol. 60, pp. 1414-1419 (1967).

[2] Bell, W.A., and Goranson, E.A.: Sydney sheet, west half, Nova Scotia; Geol. Surv. Can., Map 360A (1938).

[3] Wanless, R.K. compil.: Isotopic age map of Canada; Geol. Surv. Can., Map 1256A (1970).

[4] Benson, D.G. in Wanless, R.K., Stevens, R.D., Lachance, G.R. and Edmonds, C.M.: Age determinations and geological studies, K-Ar isotopic ages, report 8; Geol. Surv. Can., Paper 67-2, Part A, pp. 129-130 (1968).

[5] Weeks, L.J.: Southeast Cape Breton Island, Nova Scotia; Geol. Surv. Can., Mem. 277 (1954).

[6] Lilly, H.D.: Late Precambrian and Appalachian tectonics in the light of submarine exploration on the Great Bank of Newfoundland and in the Gulf of St. Lawrence, preliminary views; Am. J. Sci., vol. 264, pp. 569-574 (1966).

[7] Hughes, C.J.: The late Precambrian Avalonian Orogeny in Avalon, southeast Newfoundland; Am. J. Sci., vol. 269, pp. 183-190 (1970).

[8] Hutchinson, R.O.: The stratigraphy and trilobite faunas of the Cambrian sedimentary rocks of Cape Breton Island, Nova Scotia; Geol. Surv. Can., Mem. 263 (1952).

[9] Kelley, D.G.: Baddeck and Whycocomagh map-areas; Geol. Surv. Can., Mem. 351 (1967).

[10] Fairbairn, H.W., Hurley, P.M., Pinson, W.H., Jr., and Cormier, R.F.: Age of the granitic rocks of Nova Scotia; Bull. Geol. Soc. Am., vol. 71, pp. 399-414 (1960).

5. JUNIPER (EAST HALF) MAP-AREA, NEW BRUNSWICK (21 J/11, E 1/2)

Project 710038

R. Skinner

Geological mapping of the bedrock of the Juniper (east half) map-area for publication on a scale of 1:50,000 was started and completed in 1971.

The map-area lies on the west flank of the Miramichi Highlands of New Brunswick about 30 miles northeast of Woodstock. The central and eastern parts of the area are underlain by mainly granitic rocks of Devonian and older age that enclose large masses of paragneiss. The granitic rocks are bordered on the west by tightly folded Silurian and/or Devonian volcanic and sedimentary rocks.

Unit 1 underlies a large area in the southern part of the map-area and smaller lens-shaped areas in the north, and consists of brownish grey medium-grained quartz-feldspar-biotite paragneiss, a rock type that is widespread to the northeast in the Tuadook Lake map-area.[1]

Unit 2 comprises Silurian and/or Devonian volcanic and sedimentary rocks and occurs along the west side of the map-area. These rocks are extensions of those mapped to the north in Plaster Rock map-area[2] and to the south in Coldstream map-area[3]. No fossils were found in unit 2 within the map-area, however, fossils found in this unit in the Plaster Rock map-area are tentatively dated Middle Silurian.

Sub-unit 2a consists mainly of greenish grey, aphanitic to fine-grained, massive basalt with intercalations of slate and siltstone. In places, the basalt is amygdaloidal and here and there contains pillows. This sub-unit occurs at or near the base of the unit, is up to 3,000 feet thick and can be traced from north to south across the map-area. It is not known whether rocks of the sub-unit in the northwest part of the map-area belong to the same horizon or are younger than those rocks that occur at Welch.

Sub-unit 2b consists of buff, red and grey, aphanitic to finely porphyritic rhyolite with minor intercalations of basalt and siltstone. It occurs as lens-shaped bodies up to 3,000 feet thick below sub-unit 2a east of Summit, and as smaller lenses above sub-unit 2a in the northern and southern parts of the map-area.

Sub-unit 2c consists of grey slate and siltstone with minor intercalations of basalts and rhyolite, and appears to overlie the volcanic sub-units. Although the siltstone is commonly graded (by which tops can be determined), attitudes are so variable that it is impossible to determine the thickness of the sub-unit.

Sub-unit 2d consists of greenish grey, medium-grained, massive diabase and occurs mainly in a small area southwest of Juniper. Similar rocks occur within sub-unit 2a and are considered to be either coarse-grained flows or their intrusive equivalents.

Unit 3 consists mainly of grey to pink, massive, medium-grained, biotite granite and granodiorite. In places these rocks are foliated. Some varieties are leucocratic and contain muscovite, others are brownish, strongly foliated and contain clots and lenses of medium- to coarse-grained brown biotite. The latter variety commonly occurs near paragneiss (unit 1),

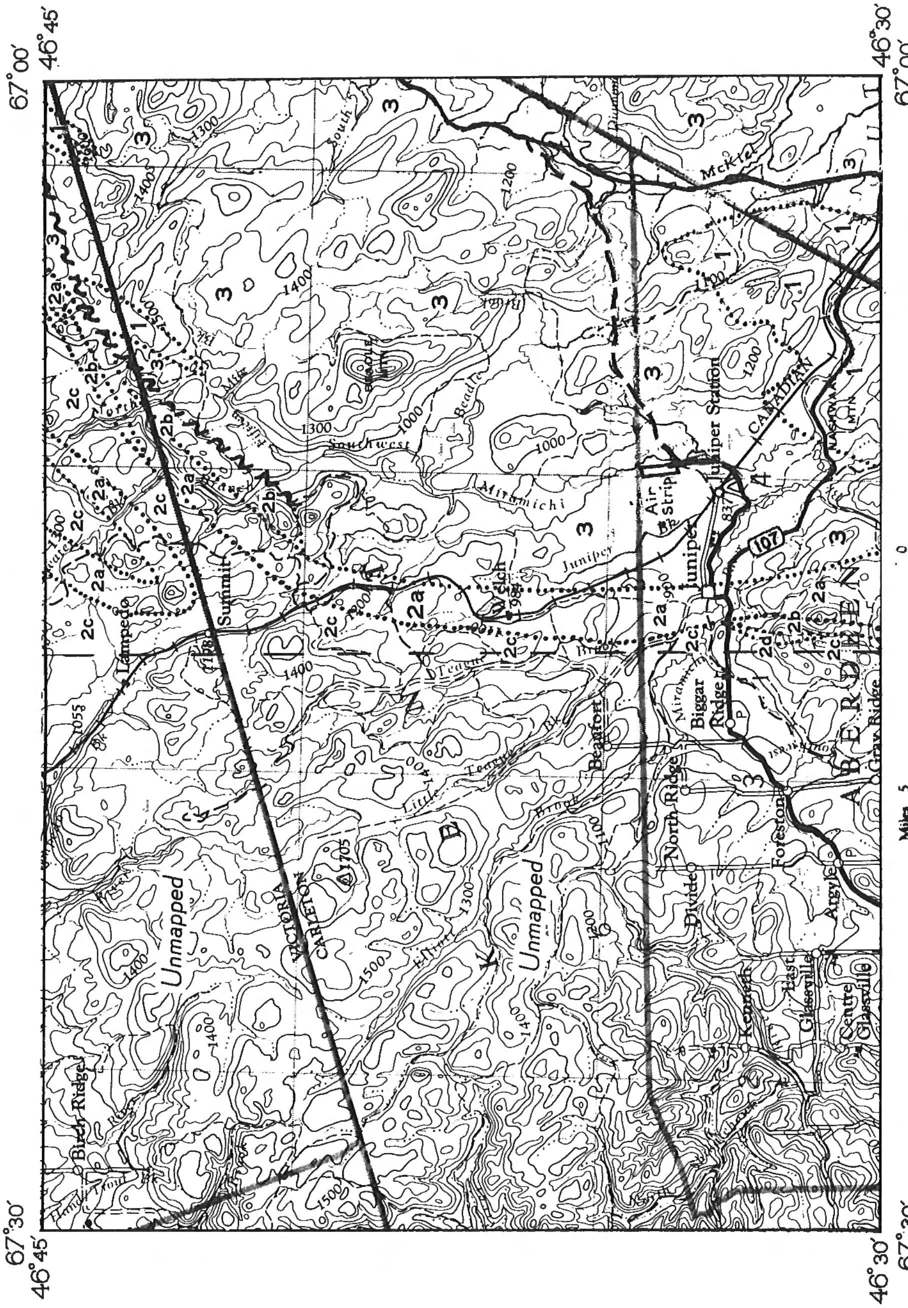


Figure 1. Sketch map of Juniper map-area.

LEGEND (Figure 1 opposite)

Devonian		
3		Granite, granodiorite, minor paragneiss
Silurian and/or Devonian		
2	2a	Basalt, minor slate and siltstone
	2b	Rhyolite, minor basalt and siltstone
	2c	Slate, siltstone, minor basalt and rhyolite
	2d	Diabase
Cambro-Ordovician		
1		Paragneiss

although, in places, grey, massive, biotite granodiorite is present near paragneiss. Rocks of this unit underlie much of the western part of the adjoining Hayesville map-area.[4]

The contact between the Siluro-Devonian rocks (unit 2) and the granitic rocks (unit 3) was not observed but appears to be mainly along a fault (Catamaran) in the northern part of the map-area. South of the fault, unit 2 probably lies unconformably on the granite (unit 3). The Siluro-Devonian rocks do not appear to have been metamorphosed or cut by the "granite". Reddish grit, about 100 feet thick, occurs at the base of sub-unit 2a, one mile north-northeast of Welch; reddish conglomerate outcrops on strike and a mile north of the grit. The conglomerate has a matrix of reddish grit and clasts of red pebbles and boulders of rhyolite and granite. If unit 2 is Middle Silurian in age the above data indicates that at least some of the granite is Middle Silurian or older.

The Catamaran fault which cuts southwesterly across the northern part of the map-area, was not observed in the "granite" (unit 3) in the western part of the area, although it apparently cuts the Siluro-Devonian (unit 2) 2 miles north of Welch[5].

No significant metallic mineral occurrences are known within Juniper (east half) map-area. However, traces of molybdenite are present in quartz veins cutting paragneiss within the "granite" (unit 3), 2 1/2 miles northeast of Juniper Station and disseminated sulphides (mainly pyrite) have been found in small pegmatite dykes cutting paragneiss along Highway 107, 2 and 3 1/2 miles east of Nashwaak Mountain. A stream geochemical sediment survey was made of the North Branch of the Southwest Miramichi River and some of its tributaries and analyses were made for zinc, copper, lead, manganese and silver. No significant anomalies were found.

[1] Skinner, R.: Tuadook Lake map-area, New Brunswick; in Report of Activities, Part A: April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 12-14 (1970).

[2] Skinner, R.: Plaster Rock map-area, New Brunswick; in Report of Activities, Part A: April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 13-16 (1971).

[3] Anderson, F.D.: Woodstock, Millville, and Coldstream map-areas, Carleton and York counties, New Brunswick; Geol. Surv. Can., Mem. 353 (1968).

[4] Poole, W.H.: Geology, Hayesville, New Brunswick; Geol. Surv. Can., Map 6-1963 (1963).

[5] Anderson, F.D.: Catamaran Fault, New Brunswick; in Report of Activities, Part A: April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 2 (1970).

---

6. BAY OF ISLANDS MAP-AREA, NEWFOUNDLAND (12 G)

Project 710040

Harold Williams, John G. Malpas, and R. Comeau

The geology of the Bay of Islands area was mapped suitable for publication at a scale of 1 inch to 2 miles. In the context of west Newfoundland geology all rocks in the map-area are transported and form a succession of structural slices that overlie an autochthonous Cambrian-Ordovician carbonate succession[1]. The general relationships are shown in Figure 1.

The transported rocks can be broadly subdivided into two groups: a Cambrian-Ordovician clastic succession (the Humber Arm Group) that structurally overlies autochthonous carbonates, and an Ordovician and older group of plutonic and volcanic rocks (includes the Bay of Islands Complex) that constitutes higher structural slices above the transported clastic rocks. Five units of formational status are recognized in the clastic succession and the present mapping, augmented by local paleontological data, supports the subdivisions of the Humber Arm Group earlier proposed[2,3,4]. The clastic succession is interpreted as an offshore, more easterly facies of the autochthonous carbonate succession at deposition[1,5]. Repetitions and omissions of strata, combined with the occurrence of thick mélange zones within the succession, clearly indicate that, in its present position, the clastic succession is a composite structural unit composed of a number of separate transported slices.

Present mapping allows subdivision of the transported plutonic-volcanic rocks into a number of structural slices, each sharply bounded by thrust faults or mélange zones. In most cases the plutonic-volcanic slices form isolated detached masses (klippen) that lie directly upon clastic sedimentary rocks. In a few places, e.g. Trout River, several plutonic-volcanic slices are juxtaposed and separated by east-dipping thrusts. Recognition of individual slices is simplified because each contains a contrasting succession of igneous rock units.

The main transported massifs of Blow Me Down Mountain, North Arm Mountain, and Table Mountain are made up of a typical ophiolitic succession, which in ascending order is as follows: (a) tectonic base marked by a thin zone of mylonitized peridotite grading outwards into garnetiferous amphibolite and greenschist, (b) layered ultramafic rocks, (c) layered gabbroic rocks, (d) massive gabbroic rocks with local amphibolite inclusions, (e) sheeted dykes and dyke breccias, and (f) mafic pillow lavas. The ultramafic and gabbroic rocks are interlayered in the contact zone. The sheeted dykes cut the gabbros at higher levels, pass upwards, and locally cut

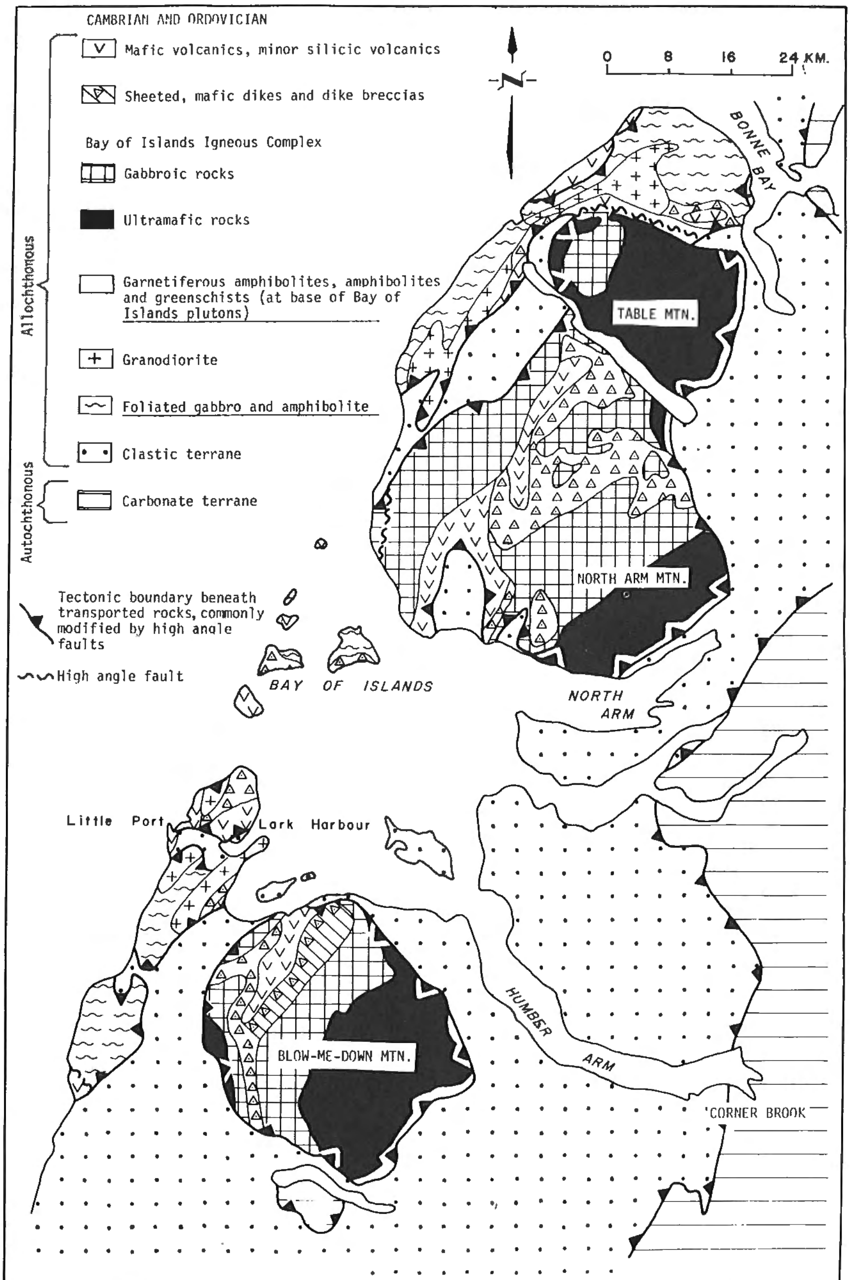


Figure 1. Geology in vicinity of Bay of Islands Complex.

overlying mafic volcanic rocks. The northwestern leading edges of these transported massifs are marked by southeast-dipping serpentinite mélange zones the sides of which are marked by southeast-trending high-angle transcurrent faults, e.g. Table Mountain pluton. Base metal mineral deposits in the Blow Me Down Mountain and North Arm Mountain plutons occur at or near the contact between the dyke complex rocks and overlying mafic volcanic rocks.

An almost continuous northeast-trending slice of plutonic-volcanic rocks can be traced from south of Little Port to Bonne Bay. It consists of well-foliated amphibolites, mainly of gabbroic derivation, and massive to well-foliated grey to pink granodiorite. Both of these rock types are much more deformed than the rocks in the main ophiolite massifs, i.e. Blow Me Down Mountain, North Arm Mountain, and Table Mountain. The granodiorites cut the amphibolites and all are locally cut by massive sheeted dykes that grade upwards into relatively undeformed mafic volcanic rocks. Both the dykes and volcanic rocks are identical to those of the main ophiolite massifs but the well-foliated amphibolitic gabbros and granitic rocks are probably older than gabbros and ultramafic rocks of the massifs.

The Little Port-Bonne Bay slice is underlain to the west by a thin slice made up of polyphase deformed greenschists at Trout River. The latter, in turn, overlies still another slice composed of unaltered pillow lavas, well-layered agglomerates, and pink porphyritic flows. The latter, in turn, structurally overlies transported clastic sedimentary rocks. Within this succession of slices at Trout River, it is clear that if Table Mountain massif had moved westward a few additional miles, it would have overridden the Little Port-Bonne Bay slice to form the highest structural slice.

The similarities between the rocks in the plutonic-volcanic slices of Bay of Islands and rocks in Notre Dame Bay of northeastern Newfoundland are pronounced. The main ophiolite massifs of Bay of Islands resemble the Lower Ordovician Snooks Arm-Betts Cove ophiolitic succession of Notre Dame Bay[6] and probably represent transported oceanic crust that originated in that general area of central Newfoundland. If so, one may walk on a well-exposed Lower Ordovician "Moho" for mile after mile in western Newfoundland. Similar relationships to those displayed in the Little Port-Bonne Bay slice are evident in eastern Notre Dame Bay where the well-foliated Twillingate granite and associated amphibolite are cut by sheeted dykes related to Lower Ordovician Lushs Bight volcanic rocks. In this case the deformed granitic and amphibolitic rocks are basement to Lower Ordovician volcanic rocks. Finally, the greenschist at Trout River resemble the Birchy Schist of the Fleur de Lys Supergroup of the Burlington Peninsula[7].

An understanding of the geological evolution of the area requires an integrated model involving the development of a continental margin and the generation of oceanic crust in Cambrian and Early Ordovician time, then ocean closing, deformation, and westward transportation of continental margin clastic deposits and ocean crust in Early and Middle Ordovician time. Transported metamorphic rocks of the Little Port-Bonne Bay slice and their equivalents in Notre Dame Bay (Twillingate granite) most likely represent basement remnants that lay within the oceanic domain.

[1] Williams, Harold: Mafic ultramafic complexes in western Newfoundland Appalachians and the evidence for their transportation; Geol. Assoc. Can., Proc., vol. 24, pp. 9-25 (1971).

[2]Stevens, R.K.: Geology of the Humber Arm, west Newfoundland; M. Sc. thesis, Memorial Univ. of Newfoundland (1965).

[3]Bruckner, W.D.: Stratigraphy and structure of west-central Newfoundland; in Poole, W.H. (editor) Guidebook - Geology of parts of Atlantic Provinces, Ann. Meeting, Geol. Assoc. Can. and Mineral. Assoc. Can., pp. 137-151 (1966).

[4]Lilly, H.D.: Some notes on stratigraphy and structural style in central-west Newfoundland; in Neale, E.R.W. and Williams, Harold (editors) - Geology of the Atlantic Region, Geol. Assoc. Can., Spec. Paper No. 4, pp. 201-211 (1967).

[5]Stevens, R.K.: Cambro-Ordovician flysch sedimentation and tectonics in west Newfoundland and their possible bearing on a Proto-Atlantic Ocean; in Lajoie, J. (editor) - Flysch Sedimentology in North America, Geol. Assoc. Can., Spec. Paper No. 7, pp. 165-177 (1970).

[6]Upadhyay, H.D., Dewey, J.F., and Neale, E.R.W.: The Betts Cove ophiolite complex, Newfoundland: Appalachian Oceanic Crust and Mantle; Geol. Assoc. Can., Proc., vol. 24, pp. 27-34 (1971).

[7]Kennedy, M.J.: Structure and stratigraphy of the Fleur de Lys Supergroup in the Fleur de Lys Area, Burlington Peninsula, Newfoundland; Geol. Assoc. Can., Proc., vol. 24, pp. 59-71 (1971).

COAL RESEARCH

7. STUDIES BY THE COAL RESEARCH SECTION

Projects 610269, 680102, 680105, 710089, 710091

P.A. Hacquebard

Field work by the Coal Research Section in 1971 involved the collection by A.R. Cameron and J.R. Donaldson of coal samples from active mines and exploratory openings in the Upper Elk River and Crowsnest areas of southeastern British Columbia and the Sukunka River area south of Chetwynd, British Columbia. Collections were also made in the Blairmore, Canmore, Mountain Park and Smoky River areas of Alberta. The samples collected in many cases serve two purposes, they provide material for studies under the rank variation project (680102) as well as for the petrographic composition studies (projects 610269 and 680105). A total of 285 samples were taken, many of which were incremental samples; that is one seam at a given site might be represented by a number of samples, each collected from a different level within the seam. Approximately 40 different coal seams were sampled, considering all the localities.

In addition some 320 samples of clay bands or "tonsteins" were collected from coal seams in the Crowsnest-Upper Elk River area by E. Meriaux under project 710089. These are being studied petrographically to evaluate their use in the correlation of coal seams.

Finally a series of approximately 600 samples of coal and clastics were collected from Sparwood and Natal Ridges in the Crowsnest area for palynological studies. These were collected by A. Sweet under project 710091. In the course of collecting these samples the Kootenay sections on both ridges were measured and described.

Project Titles

610269	Petrographic Examination of Coking Coals from the Crowsnest Coalfield, Alberta and B.C.
680102	Rank Studies of Coal and Carbonaceous Matter
680105	Petrography of Coal Seams in the Rocky Mountain Foothill Belt, north of the Crowsnest Area
710089	Study of Tonstein Bands in Coal Seams of Kootenay Formation
710091	Palynological Studies of Upper Jurassic and Cretaceous Coal Measures in Western Canada

CONTINENTAL MARGINS

8. GEOLOGICAL AND GEOPHYSICAL STUDIES ON THE PACIFIC CONTINENTAL MARGIN, AND BEAUFORT SEA

Projects 710048, 710049

D.L. Tiffin

In 1971, two cruises on C.H.S. Parizeau obtained continuous seismic reflection and magnetometer data, bottom photographs and sea floor samples from areas west of Vancouver Island, in Hecate Strait, Dixon Entrance and west coast of the Queen Charlotte Islands. A magnetometer was also placed aboard Parizeau for her hydrographic voyage to the western Arctic.

Continuous seismic data west of Vancouver Island indicates that buried Pleistocene drainage channels cross the shelf in the south. Also, northwest-southeast folding occurs in Tertiary sediments under the shelf. Southwest of Cape Flattery there is evidence of diapirism. Diapirs are exposed at several points along the shoreline of the Olympic Peninsula.[1]

West of Brooks Peninsula, the southern part of Winona Basin[2] at the base of the slope is severely faulted, with faults trending obliquely to the continental slope and possibly related to faults on the slope and shelf. Considerable vertical movement is apparent. Bottom samples obtained from the continental shelf and slope are under study by B.E.B. Cameron.

A single reconnaissance profile through Hecate Strait revealed flat-lying sediments to a depth equivalent to a reflection time of 0.65 second over most of the area. These overlie an angular unconformity below which sediments dip northward at a low angle.

In Dixon Entrance, a sedimentary prism under the shelf has truncated reflectors which dip westward off Learmouth Bank. The shelf edge is abrupt, with probable slump deposits resting on the upper slope.

West of the Queen Charlotte Islands the shelf is in places almost nonexistent. The slope is tripartite, with a steep upper and lower section and a mid-slope plateau, with a reverse slope toward the continent. Oceanic seismic basement can be traced to the base of the slope within 30 kilometres of the shoreline. The Queen Charlotte fault is thought to extend over a zone including the Queen Charlotte Trough, the continental slope and possibly into the Queen Charlotte Islands themselves.[3]

Approximately 8,000 miles of magnetometer data was obtained in the Beaufort sea north of Tuktoyaktuk in an area bounded by latitude 69° to 71°N and longitude 130° to 139°W.

[1] Rau, W.W.: Foraminifera, stratigraphy and paleoecology of the Quinault Formations, Pt. Grenville-Raft River Coastal area, Washington; Washington Division of Mines and Geology, Bull. 62 (1970).

[2] Tiffin, D.L., Cameron, B.E.B. and Murray, J.W.: Tectonics and depositional history of the Continental Margin off Vancouver Island, British Columbia; Can. J. Earth Sci. (in press).

[3] Chase, R.L. and Tiffin, D.L.: The Queen Charlotte Fault: Oceanic-Continental Boundary; 24th Internatl. Geol. Congress (in press).

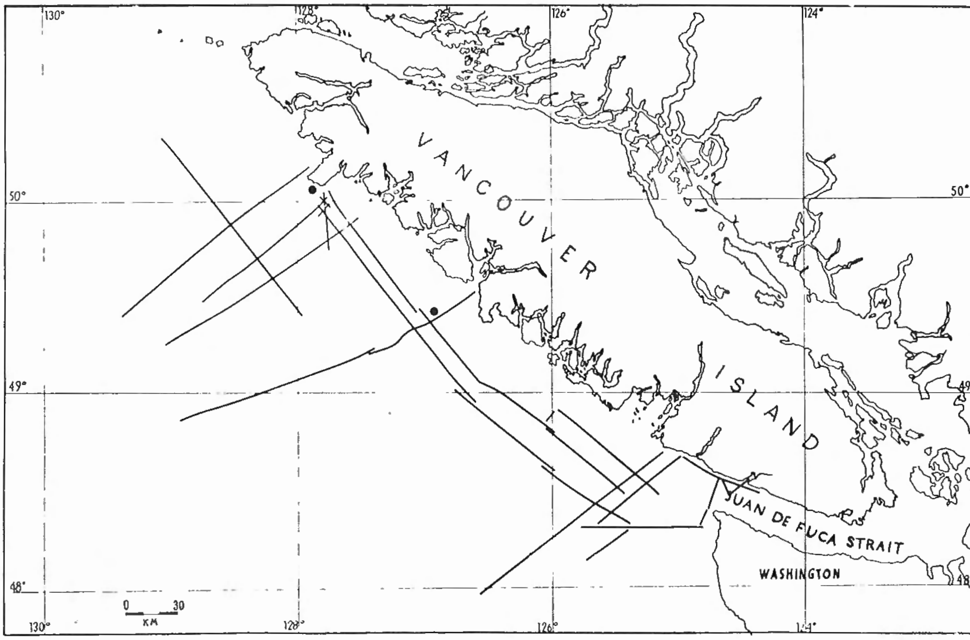


Figure 1. Location of 1971 track lines west of Vancouver Island along which C.S.P. and magnetometer data were obtained. Dots are bottom photograph stations.

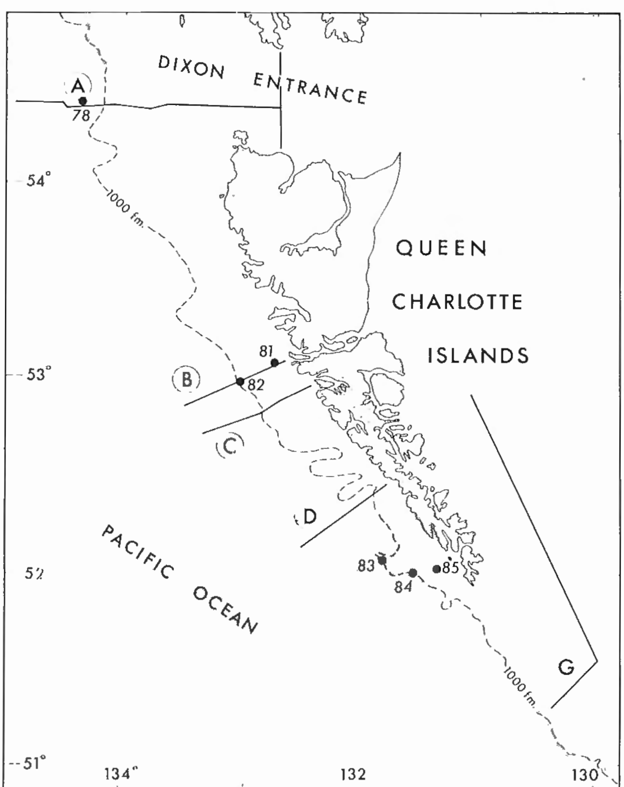


Figure 2.

Location of 1971 C.S.P. track lines in Queen Charlotte Sound, Hecate Strait, Dixon Entrance and west of the Queen Charlotte Islands. Numbered dots are dredge locations.

CORDILLERAN GEOLOGY

9 BUTE INLET MAP-AREA, VANCOUVER ISLAND BRITISH COLUMBIA (92 K)

Project 680038

Donald Carlisle*

Geological mapping at a field scale of one-half mile to one inch in the Quadra Island (92 K/3), Salmon River (92 K/4), southern half of Sayward (92 K/5), and southwestern portion of Sonora Island (92 K/6) sheets, supported in part by the University of California and the National Science Foundation, was completed in July of 1971 as a part of Project 680038 of the Geological Survey of Canada (see J.E. Muller, this publ.). The area includes the western margin of the Coast Crystalline Complex and several related plutons (Island Intrusions), but it is underlain mainly by the Vancouver Group (Fig. 1), a thick succession of pre-batholithic rocks which has long been known to characterize most of central and northern Vancouver Island. Since its base is not exposed in this area, the thickness of the lowermost unit of the Vancouver Group and its conformable relation with the underlying siliceous and tuffaceous sedimentary rocks and basalt sills is taken from earlier mapping by the writer and colleagues in the Upper Campbell (92 F/13) and Schoen Lake (92 L/1) areas.

The Karmutsen Subgroup, a "deep oceanic" (low potash) tholeiite basalt mass of remarkably consistent structure and thickness, constitutes the lower three-quarters of the Vancouver Group in this area. The lower 8,000 to 9,000 feet invariably consists of classical closely packed pillow lava. The next 2,000 to 3,300 feet consists of pillow breccia and aquagene tuff, typically with well developed but unsorted beds 1 to 5 feet thick, in the lower part. The upper 9,000 to 10,000 feet is composed of amygdaloidal and non-amygdaloidal basalt flows intercalated within which, particularly in the upper third of the unit, are sporadic and commonly incomplete sequences 10 to 600 feet thick consisting of thin, discontinuous bioclastic, micritic, cherty, or tuffaceous limestone ("intervolcanic sedimentary beds") overlain by closely packed pillows which are overlain in turn by pillow breccia[1]. Several of the sedimentary layers contain an Upper Triassic ammonoid fauna characteristic of the Dilleri Zone[2].

The Quatsino Limestone[3, 4, 5] is a coarsely bioclastic limestone, light grey, indistinctly bedded and non-fissile, resting conformably on Karmutsen flows. Textures, structures, and fauna indicate a very shallow-water, high-energy environment. Thin, dark, evenly spaced interbeds of micritic limestone appear in the upper 100 feet or so and increase in abundance upward. It is here that the Dilleri fauna is best developed. The boundary with the overlying Parson Bay Formation[7] is taken where dark micritic layers exceed 50 per cent of the rock.

The lower two-thirds, approximately, of the Parson Bay Formation is thinly laminated, alternating fissile and non-fissile, black carbonaceous limestone with an extremely fine-grained siliceous matrix. Halobia in the

---

*Department of Geology, University of California, Los Angeles, California 90024.

lowest part and Monotis above this are very abundant, especially in the lime-shales. Rocks containing or spanning eight ammonoid zones (Karnian Welleri to Norian Lower Suessi) are included in roughly 1,000 feet of strata. This contrasts markedly with the occurrence of but one zone, Dilleri, in all of the upper Karmutsen and Quatsino Limestone. The lower Parson Bay Formation is lithologically comparable with the thinly bedded member of Jeletzky[6] on western Vancouver Island.

The upper third of the Parson Bay Formation consists of thin, alternating, very fine grained, pyritic tuff-wacke and medium-grained calcarenite, showing both syngenetic sedimentary structures and secondary redistribution of silica. It is probably a facies equivalent of the Arenaceous member (Lower Suessi) of Jeletzky[6], even though finer grained and entirely above beds containing Monotis. A single small coralline reef, some 75 feet thick with lateral talus and overlying micritic limestone, has been found in the upper Memekay River drainage directly above Monotis shales and takes the place of the upper Parson Bay. This and a unique intraformational conglomerate containing reefoid cobbles within Monotis shales at Iron River (map-area 92 F/14 west) are the only known indications on northeastern Vancouver Island of late Norian shoaling and reef development (Sutton Limestone?) apparently precursory to Bonanza volcanism.

Following Crickmay[7], the base of the overlying Harbledown Formation (Sinemurian) is taken where calcareous beds no longer occur and the rock becomes light to medium grey colour-laminated, rusty weathering (pyritic), very fine grained tuff-wacke with a brittle, very angular fracture. In its upper part, commonly either not deposited or eroded away, the Harbledown Formation is a thinly bedded calcareous siltstone or wacke. The Parson Bay and Harbledown Formations described here are lithologically similar and faunally comparable with those defined by Crickmay a few tens of miles to the northwest. They are applied here to rocks formerly assigned tentatively and ambiguously by the writer and others to both the Bonanaza Subgroup Sedimentary Division, for which no type section was ever specified, and to the Quatsino Limestone.

The volcanic division of the Bonanza Subgroup is represented in this area by coarse subrounded but unsorted tuff conglomerate with sparsely bedded layers and containing, in a few places, eroded Harbledown clasts. The writer believes that the basal unconformity results from slumping of pyroclastic debris on the flanks of volcanic highs rather than from deformation of the underlying formations. In the western and southern parts of the map-area, andesitic and dacitic sills, thought to be co-magnetic with Bonanza effusives elsewhere, intrude the Parson Bay, Harbledown, and Bonanza rocks. In some places they constitute more than 50 per cent of the section. It is suggested that the abundance of these co-Bonanza hypabyssals may be related to the localization of subsequent granitic bodies.

Evidence has been presented earlier[8] that localized recurrent folding of parts of the Quatsino Limestone along north-northwesterly axes, accompanied by emplacement of andesitic sill-dykes and by shearing subparallel to fold axes, preceded slightly the emplacement of quartz diorite plutons on the western margin of the Coast Crystalline Complex. Additional evidence of pre-granitic folding and faulting of the Vancouver Group along the northwesterly trend has been found. There is some tendency for satellitic plutons or cupolas on a larger granitic mass to lie in synclinal areas and along northwesterly shear zones. A large quartz diorite body underlying much of the northern Salmon River valley has a nearly horizontal roof of upper Karmutsen flows.

Post-granitic faults have been mapped on three main sets and separations established on most. Slickensides commonly suggest horizontal slip. Along the White River fault, belonging to the late north-trending set, it has been possible to actually determine the net slip. This is apparently the first opportunity to approach directly the kinematics of a moderately large fault in the coastal region.

Metallic mineral occurrences, mainly marginal and subeconomic to date, include:

1. Disseminated native copper and copper sulphides in Karmutsen volcanic rocks.
2. Copper and vanadium minerals in interlava sedimentary rocks.
3. Copper-bearing sulphides and pyrrhotite in flat shears and steep fractures in Karmutsen flows.
4. Gold- and copper-bearing massive sulphides in metasedimentary and metavolcanic rocks.
5. Magnetite skarns in interlava and Quatsino limestones.

[1]Carlisle, D.: Pillow breccias and their aquagene tuffs, Quadra Island, British Columbia; J. Geol., vol. 71, pp. 48-71 (1963).

[2]Givens, C.R. and Susuki, T.: Late Triassic fauna from interlava sediments of east-central Vancouver Island; Geol. Soc. Am., Spec. Paper No. 76, p. 203 (1963).

[3]Dolmage, V.: Quatsino Sound and certain mineral deposits of the west coast of Vancouver Island, B.C.; Geol. Surv. Can., Sum. Rept. 1918B, pp. 30-38 (1919).

[4]Gunning, H.C.: Preliminary report on the Nimpkish Lake Quadrangle, Vancouver Island, B.C.; Geol. Surv. Can., Sum. Rept. 1931A, pp. 22-35 (1932).

[5]Hoadley, J.W.: Geology and mineral deposits of the Zeballos-Nimpkish area, Vancouver Island, British Columbia; Geol. Surv. Can., Mem. 272 (1953).

[6]Jeletzky, J.A.: Some salient features of Early Mesozoic history of Insular Tectonic Belt, Western British Columbia; Geol. Surv. Can., Paper 69-14 (1970).

[7]Crickmay, C.H.: The stratigraphy of Parson Bay, British Columbia; Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 18(2), pp. 51-70 (1928).

[8]Carlisle, D. and Susuki, T.: Structure, stratigraphy, and paleontology of an Upper Triassic section on the west coast of British Columbia; Can. J. Earth Sci., vol. 2, pp. 442-484 (1965).

10. TECTONIC FRAMEWORK OF SUSTUT AND SIFTON BASINS, BRITISH COLUMBIA (94 E, 104 H)

Project 690032

G.H. Eisbacher

Six weeks were devoted to mapping, sampling, and basin analyses of the Sustut Group. Field work was carried out in conjunction with Operation Finlay (see Gabrielse, this publ.).

Sustut Basin

Continental Upper Cretaceous-Lower Tertiary Sustut Group and underlying marine Upper Jurassic Bowser Group and Upper Triassic-Lower Jurassic Takla-Hazelton Groups were mapped in part of the Spatsizi Plateau (104 H and 94 E). The twofold stratigraphic subdivision of the Sustut Group (Tango Creek Formation, Brothers Peak Formation) recognized in the Toodoggone map-area[1,2] was found to be useful in the Spatsizi map-area as well.

The Sustut Group, about 6,000 feet (2,000 metres) thick in the southwestern part of the basin, thins markedly towards the northeast where it wedges out onto a pediment cut on Takla volcanics and volcanoclastics, and on granitoid intrusives.

Of particular significance for the timing of tectonic events within the north-central Cordillera is the discovery of a klippe of Bowser Group conglomerate resting on intensely folded and thrust-faulted Upper Cretaceous Tango Creek Formation. Both units have supplied debris to the Eocene Brothers Peak Formation (see Fig. 1).

From this relationship and evidence gathered in neighbouring areas it appears that three pulses of deformation have affected the underlying Upper Jurassic Bowser Group:

1. A pre-Cenomanian pulse, documented by the angular unconformity between Sustut and Bowser Groups;

2. An Eocene pulse, documented by the clastic wedge of Brothers Peak Formation containing clasts of Tango Creek Formation and Bowser Group;

3. A post-Eocene pulse, documented by tilting and thrust-faulting of Eocene Brothers Peak Formation.

The paleocurrent patterns for Tango Creek and Brothers Peak Formations are compatible with this model of tectonic evolution.

Sifton Basin

Probable Upper Cretaceous-Lower Tertiary continental Sifton Formation[3] was mapped by H. Gabrielse in the Rocky Mountain Trench and on the western slopes of Cormier Range and Mount Bennett (see Gabrielse, this publ.).

Clastic sedimentary rocks of the Sifton Formation include dark red, very coarse colluvium and mountain stream conglomerates, alluvial fan deposits, alluvial plain channel sandstones and mudstones, and thinly laminated calcareous lacustrine siltstones. The source of these sediments, as inferred

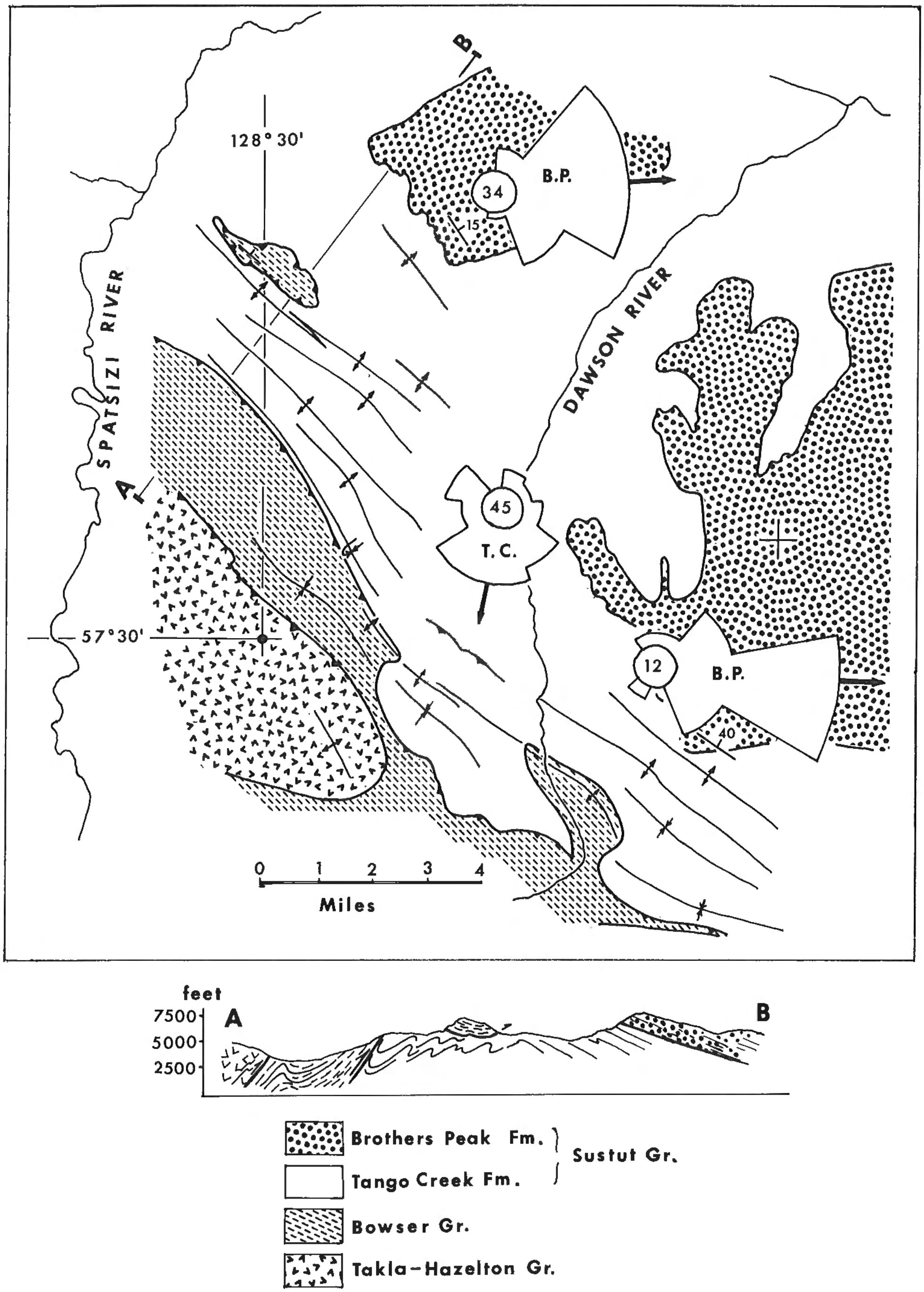


Figure 1. Structural relations and paleocurrents of Upper Cretaceous Tango Creek Formation (T.C.) and Eocene Brothers Peak Formation (B.P.), southwestern Spatsizi Plateau.

from crossbedding, slump structures, and clast size was close to the present outcrop belt of Sifton Formation. It comprised muscovite granite, chlorite-sericite phyllite, carbonate, and quartzite west of the Trench and carbonate, quartzite, and chert east of the Trench.

The depositional base of the Sifton Formation has been tectonically vertically displaced by at least 2,500 feet (800 metres) along the western boundary of the Rocky Mountain Trench. Small scale structures in the Proterozoic Ingenika Group and Good Hope Group below the Sifton Formation suggest that Sifton strata were passively deformed during the development of penetrative kink folds and discrete faults in the underlying low-grade metamorphic rocks. This late kinking and faulting is superimposed upon a pre-Sifton regional cleavage fan.

[1]Eisbacher, G.H.: Tectonic framework of Sustut and Sifton Basins, British Columbia; in Report of Activities, Part A: April to October 1969, Geol. Surv. Can., Paper 70-1, Pt. A, pp. 36-37 (1970).

[2]Eisbacher, G.H.: A subdivision of the Upper Cretaceous-Lower Tertiary Sustut Group in the Toodoggone Map-area, British Columbia; Geol. Surv. Can., Paper 70-68 (1971).

[3]Hedley, M.S., and Holland, S.S.: Reconnaissance in the area of Turnagain and Upper Ketchika Rivers; B.C. Dept. Mines, Bull. 12 (1941).

---

11. OPERATION FINLAY (94 C EAST HALF, 94 E, 94 F WEST HALF)

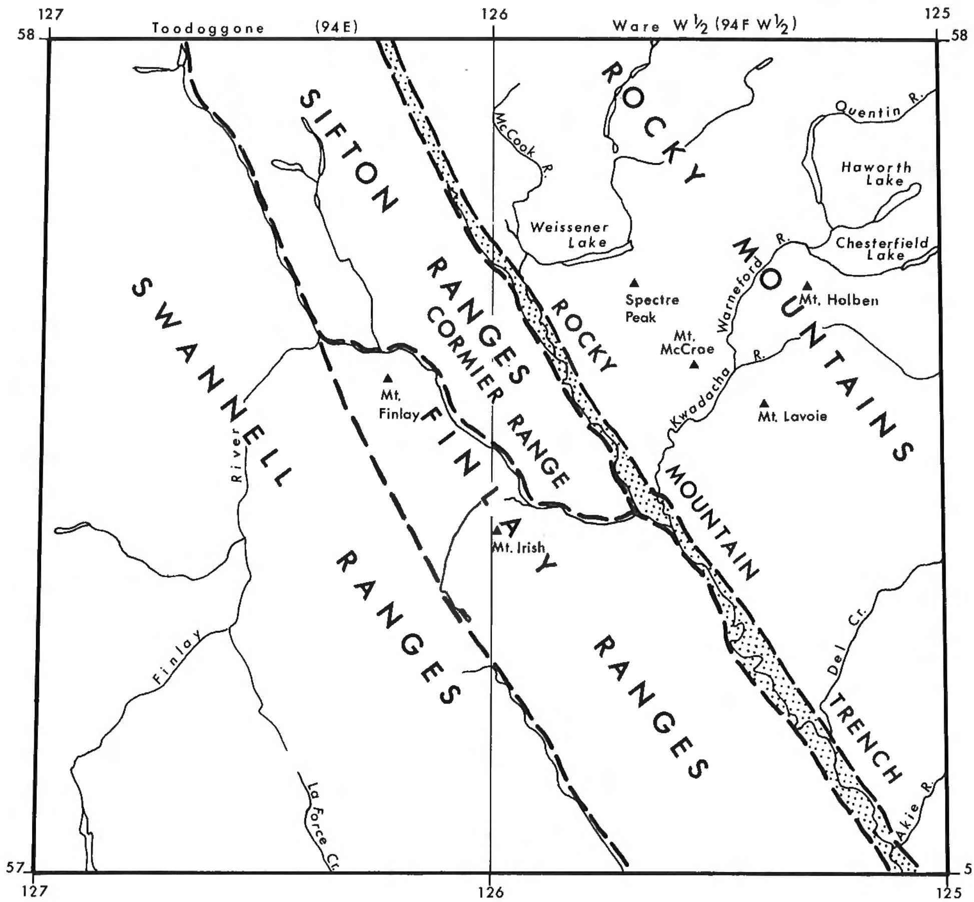
Project 700047

H. Gabrielse

During the 1971 field season geological reconnaissance mapping was carried out in Ware (94, west half) map-area and in the eastern part of Toodoggone (94 E) map-area. The north-northwestern trending Rocky Mountain Trench bisects the mapped area and separates terrains of markedly contrasting stratigraphy and structural style.

Rocky Mountains

Upper Proterozoic clastic strata are exposed in a narrow belt immediately east of the Rocky Mountain Trench from south of Akie River to north of Kwadacha River. They are continuous with rocks of the Missinchinka Group mapped farther south[1,2] and are regionally metamorphosed, mainly to low-grade chlorite- and sericite-bearing schists and phyllites. Probable correlative phyllites and slates have been reported by Bell[3] to the north in southwestern Tuchodi Lakes map-area. A remarkable Upper Proterozoic (?) diamictite, more than 1,000 feet thick containing angular to subangular clasts of quartzite, laminated dolomite, greenstone, green argillite and granitic rocks within a dolomitic or argillaceous matrix is unconformably overlain by Lower Cambrian rocks in the northeasternmost part of Ware (west half) map-area (see W.H. Fritz, this publ.).



Index Map, Operation Finlay.

Cambrian strata are best exposed in the region north of Quentin River, where they are nearly 3,000 feet thick (see W. H. Fritz, this publ.). There, Lower and Middle Cambrian sandstones, shales, siltstones and carbonates may be overlain disconformably by Lower Ordovician rocks whereas in the area between Akie River and Del Creek Upper Cambrian units are probably present (see discussion of section near Pesika Creek by W. H. Fritz, this publ.). A narrow belt of limestone crags, extending northerly from southeast of Mount Lavoie through Mount McCrae and Spectre Peak to beyond Weissener Lake, are considered to comprise Lower Cambrian klippen resting on Ordovician and Silurian strata. The limestones have yielded no fossils, however, and their dating and structural significance, are tentative.

Lower Ordovician argillaceous limestones as much as 4,000 feet thick are well exposed along Quentin River and are overlain by more than 2,000 feet of Ordovician and Silurian graptolitic shales, siltstones and sandstones[4]. Lower Ordovician rocks near Rocky Mountain Trench are more argillaceous and phyllitic than those farther northeast.

A synclinal region trending southeasterly from east of McCook River to the upper reaches of Kwadacha River includes Middle Devonian (?) limestone, as much as 400 feet thick (Dunedin Formation, see ref. 5) commonly occurring as tight, near isoclinal infolds in Silurian siltstones. The limestones are overlain unconformably by a sombre weathering sequence of noncalcareous shale, sandstone, gritty greywacke, chert-pebble conglomerate, and polymictic conglomerates, probably more than 2,000 feet thick. North of Warneford River the Middle Devonian (?) limestone has been completely removed below this unconformity. The clastic sequence is believed to be mainly of late Devonian age, although no fossils were found[2].

Buff-grey weathering, dark grey siltstones and dark grey to black siltstones and shales near the crest of the ridge trending southeast from Mount Holben between Warneford and Kwadacha Rivers contain late Triassic (Norian) pelecypods. Contacts with older rocks were not observed but a considerable thickness of Triassic strata may be present in this area.

Tight to open folds with southwesterly dipping axial planes and steep northeasterly directed thrust faults are the important structural elements in the Rocky Mountains. Particularly well developed chevron folds are abundant in Ordovician, Silurian and Upper Devonian (?) strata.

Cassiar and Omineca Mountains

Southwest of Rocky Mountain Trench, Sifton, Swannell, and Finlay Ranges are underlain mainly by rocks of late Proterozoic and early Cambrian age (see J. L. Mansy, this publ.). The rocks in Finlay Ranges are little metamorphosed whereas those in Sifton and Swannell Ranges are regionally metamorphosed, locally to high grades.

Upper Proterozoic clastic and carbonates of the Ingenika Group are in fault contact with Upper Trassic volcanic rocks along a line trending north-northwesterly from the valley of La Force and Fredrikson Creeks. To the east of this lineament a core of a broad anticlinorium of Proterozoic rocks exposes sillimanite-bearing schists and gneisses and in places, associated pegmatitic rocks. The grade of metamorphism decreases to the northeast and southwest so that the stratigraphically youngest rocks are low grade sericitic phyllites and grits.

Sifton Ranges appears to be an anticlinorium with a core of amphibolitic, migmatitic, and leucogranitic rocks but the detailed structure is complex with southwest directed folds and thrust faults dominating the structural style. Thus, all rocks between Rocky Mountain Trench and the valleys west of Sifton, and Swannell Ranges show a southwesterly directed structural asymmetry (see Mansy, this publication for a cross-section of Russell Range).

Late Cretaceous and/or early Tertiary deposition of the Sifton Formation was accompanied by block faulting and kink folding in Rocky Mountain Trench and along the southwestern flank of Sifton Ranges near Finlay River (see Eisbacher, this publ.). Lamprophyre and feldspar porphyry dykes occur in the faulted zones and, at least locally, cut rocks of the Sifton Formation. The northwesterly trending normal faults have defined the ranges and bounding trenches which are so conspicuous in the present topography.

Mineralization

Chalcopyrite and related malachite occur in volcanic greenstone associated with limestones that are cut by rusty, orange-weathering, brecciated and hydrothermally altered leucogranitic rocks along the crest of Cormier Range at 57°31'W and 125°54'W. Minor galena is present with the copper minerals. Chalcopyrite, azurite and malachite occur locally in Lower Cambrian carbonate on Mount Finlay and about 3 1/2 miles southwest of Mount Irish in northwestern Finlay Ranges.

The area underlain by Upper Devonian (?) clastic rocks trending northwesterly from Warneford River into Tuchodi Lakes map-area is characterized by numerous large limonitic gossans that appear concentrated along the lower slopes of valleys where groundwater issues from overburden.

[1] Gabrielse, H.: Operation Finlay; in Report of Activities, April to October, 1970, Geol. Surv. Can., Paper 71-1, Part A, pp. 23-26 (1971).

[2] Irish, E.J.W.: Halfway River map-area, British Columbia, Geol. Surv. Can., Paper 69-11 (1970).

[3] Bell, R.T.: Proterozoic stratigraphy of northeastern British Columbia; Geol. Surv. Can., Paper 67-68 (1968).

[4] Jackson, D.E., Steen, G., and Sykes, D.: Stratigraphy and graptolite zonation of the Kechika and Sandpile Groups in northeastern British Columbia; Bull. Can. Petrol, Geol., vol. 13, No. 1 pp. 139-154 (1965).

[5] Taylor, G.C. and MacKenzie, W.S.: Devonian stratigraphy of northeastern British Columbia; Geol. Surv. Can., Bull. 186 (1970).

---

12. STRATIGRAPHY AND STRUCTURE OF THE INGENIKA GROUP IN FINLAY AND SWANNELL RANGES (94 E, F)

Project 700047

J.L. Mansy

A study of the Ingenika Group undertaken in 1970[1] was continued with investigations in southwestern Ware (94 F) and southeastern Toodoggone (94 E) map-areas (Fig. 1). Seven formations of Late Proterozoic and Early Cambrian age exposed in Finlay and Swannell Ranges have an aggregate thickness of more than 8,000 feet. From oldest to youngest they are as follows:

1. A predominantly gritty clastic unit comprising thick-bedded members of shale, siltstone, quartzofeldspathic, gritty sandstone and conglomerate, and very minor limestone. Most of the rocks have been regionally metamorphosed to greenschist and higher facies. Characteristic grains and clasts are bluish, opalescent quartz and chalky white feldspar. Sedimentary structures other than bedding are extremely scarce. The unit is more than 5,000 feet thick.

2. Thin-bedded, sericitic, glossy, grey, mainly calcareous phyllite. Some of the calcareous rocks weather to shades of silver and green. The strata are highly crumpled and folded but the thickness is estimated to be about 600 feet.

3. Resistant, well-bedded, locally oolitic and pisolitic limestone. The lowest beds are sericitic. Dolostone is present in some white and red weathering cryptalgal beds. The average thickness is 400 feet.

4. The lower part of this unit is characterized by cyclical sedimentation of blue-grey limestone, green phyllite, impure quartzite and sandy limestone. Rocks of each cycle range in thickness from 15 to 20 feet. Facies equivalents of this sub-unit near Rocky Mountain Trench contain more detrital material with two thick sequences of massive quartzite and sandstone. The middle part of the unit consists of distinctive, commonly calcareous purple

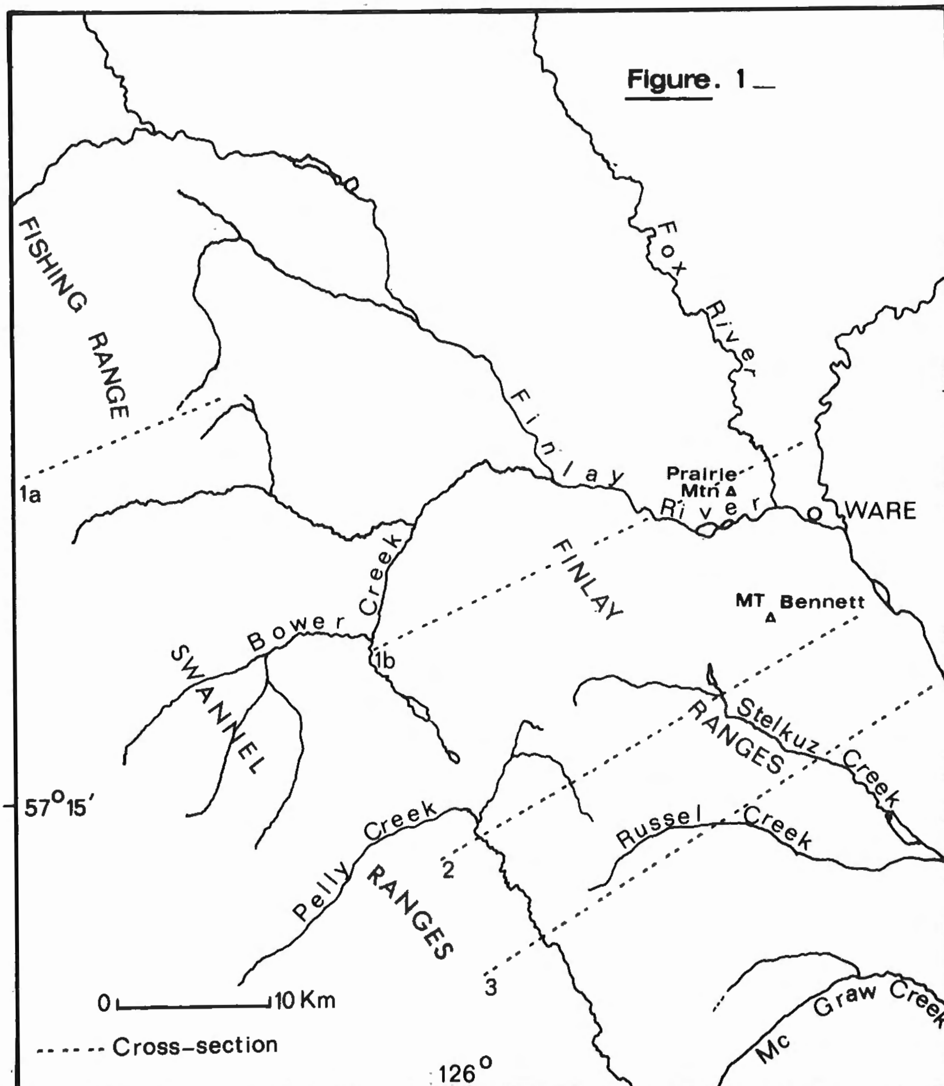
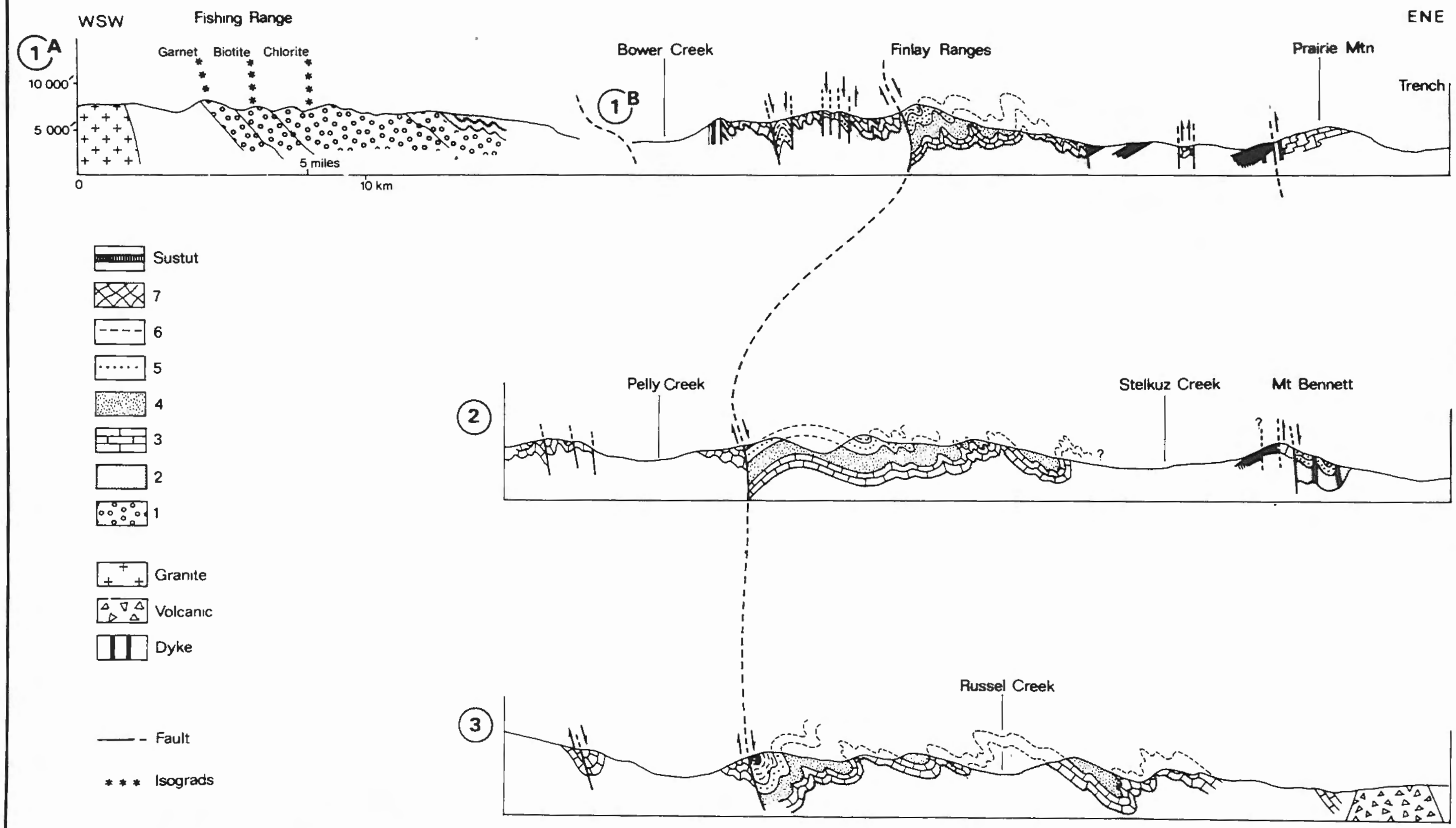


Figure. 2 — CROSS - SECTIONS OF FINLAY AND SWANNEL RANGES



and dark green shales. The upper part is characterized by buff-weathering; interbedded green phyllite and fine-grained, brown and grey impure sandstone. Total thickness is about 800 feet.

5. Resistant, pure white quartzite. Locally, beds are pale green, buff, or purple. This unit is an excellent marker averaging perhaps 400 feet in thickness.

6. Dark weathering, impure, brown and dark grey quartzite interbedded with shale, in part worm-burrowed. Locally, the upper part consists of 40 to 60 feet of thick-bedded quartzite and sandstone showing well developed crossbedding. In places, conglomeratic members include clasts of quartz as much as 5 cm in diameter. Total thickness is about 600 feet.

7. The youngest unit of the Upper Proterozoic to Lower Cambrian sequence comprises blue-grey limestone with a member of grey and green siltstone in the middle part. The limestone is of shallow water aspect with oolites, cryptalgae, and archeocyathids. Salterella sp. was found in the siltstone. Thickness is about 300 to 400 feet.

The units described above, all included in the Ingenika Group by Roots[2], can be readily correlated with formations and groups recognized in Cariboo and Cassiar Mountains. Units 3 to 4 are correlative with the Good Hope Group and units 5 to 7 with the Atan Group in Cassiar Mountains[3]. Correlation with rocks in the Cariboo Mountains appears to be as follows: unit 1 - Kaza Group; unit 2 - Isaac Formation; unit 3 - Cunningham Limestone; unit 4 - Yankee Belle Formation; unit 5 - Yanks Peak Quartzite; unit 6 - Midas Formation; unit 7 - Mural Formation[4].

Strata in Finlay Range are little metamorphosed whereas in Swannell Ranges sillimanite is present locally and garnet is widespread.

The structural style is depicted in Figure 2. Relative competencies of rocks within and between the various units play an important role in style of deformation. Minor décollements are common between phyllite and quartzite. Throughout the area folds are overturned to the southwest or are asymmetrical and have axial planes that dip northeast. A consistent northwest-trending cleavage related to this deformation is locally strongly kinked by late deformation associated with normal faulting. Late normal faults are numerous, and in places are marked by feldspar porphyry and lamprophyre dykes or by volcanic breccias.

[1]Mansy, J.L.: The Ingenika Group; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 26-28 (1971).

[2]Roots, E.F.: Geology and mineral deposits of Aitken Lake map-area, British Columbia; Geol. Surv. Can., Mem. 274 (1954).

[3]Gabrielse, H.: McDame map-area, Cassiar district, British Columbia; Geol. Surv. Can., Mem. 319 (1963).

[4]Mansy, J.L. and Campbell, R.B.: Stratigraphy and structure of the Black Stuart synclinorium, Quesnel Lake map-area, British Columbia, (93 A); in Report of Activities, Part A: April to October 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 38-41 (1970).

13. NOOTKA SOUND AREA, BRITISH COLUMBIA (92E)

Project 680038

J.E. Muller

Most of the field season was spent in completion of the mapping of Nootka Sound map-area (92E), begun in 1968 with a geological survey of the shorelines. D. Carlisle who in previous years had done a considerable amount of detailed geological mapping in Bute Inlet map-area (92K) completed this work under the auspices of the Geological Survey as a part of project 680038 (see this publ.).

Areal Geology

The reconnaissance geology of Nootka Sound map-area is shown on the revised reconnaissance map of Vancouver Island[1]. The eastern part of the area is underlain by a northerly trending structural culmination. Paleozoic sedimentary and volcanic rocks of the Sicker Group and their inferred metamorphic to migmatitic equivalents are exposed in the south part of this culmination, in the north it consists of the Vernon Batholith, mainly flanked by Triassic Karmutsen volcanics. Sicker and Karmutsen rocks also form inliers and roof pendants. The western part of the area contains the south part of a belt of southwest-dipping Karmutsen volcanics, succeeded by Upper Triassic Quatsino and Parson Bay sediments and Lower Jurassic Bonanza volcanics. This belt was mapped in Zeballos region by Hoadley[2] and only minor modifications of this work are needed.

Sicker Group volcanics are not widely exposed in the area but may well be represented in the bulk of the Westcoast Crystalline Complex[3]. Exposures on the southwest side of Nootka Island, north and west of Hesquiat Peninsula, and on the west and south coasts of Flores Island were mapped by Jeletzky[4] as Karmutsen and Quatsino Formations but are now tentatively assigned to the Sicker Group. The volcanics are chloritic, siliceous, commonly banded tuff and breccia, interbedded with minor greywacke and limestone. They contain dioritic veins and dykes, and grade into amphibolite, hornblende gneiss, and dioritic agmatite.

The similarity of less altered Sicker volcanics to Jurassic Bonanza volcanics creates a mapping problem in some places. However, exposures on Flores Island, nearly one mile north of Rafael Point, show heavily fractured Sicker metavolcanics with spotty dioritization overlain by tuff and coarse volcanic breccia believed to be the base of the Bonanza volcanics. Local beds of conglomerate and grit with clasts of metavolcanics and diorite occur above the unconformity.

Sicker Group sediments are known in several inliers in Nootka Sound area, not yet shown on the reconnaissance map[1]. They are no doubt related to those in the Tofino region[3] and others recently discovered east of Schoen Lake by D. Carlisle. They are invariably invaded by many basic sills which generally greatly exceed the intruded sediments in thickness and in some instances leave only thin lenses of sediments within a section. Most exposures of these sill-sediment complexes are in steep, barely accessible cliffs and gullies. Occurrences of these rocks, from less than one square mile to about 6 square miles in area and aligned in two north-trending strings, are listed here:

1. Flores Island, on Cow Creek and on coast 3 miles north of Dagger Point.

2. Sydney Inlet; east side of bay and small island 2 3/4 miles south-southeast of Driver Point.

3. A northwesterly striking belt west of Stewartson Inlet including the old Indian Chief Mine and continuing to the east and west side of Hesquiat Lake.

4. East of Mooyah River, from Mount Rufus to Mooyah Bay, and the point of land between that bay and Zuciarte Channel.

5. Part of the ridge north of the lower part of Conuma River.

6. The area surrounding Leighton Peak, northeast of the middle of Conuma River.

7. The northeast part of the range between Oktwanch River and Sebalhall Creek.

8. The north part of Magee Creek and enclosing valley-walls.

9. A small area near the head of Holiday Creek.

10. A larger area in Alert Bay map-area, east of Schoen Lake, extending south to the head of White River.

On the east side of Magee Creek a basal limestone is well exposed on a logging spur, one mile south of Upana road. It probably overlies tuff and volcanic breccia exposed farther north and west of the creek. The limestone consists of wavy beds of calcarenite, one-to-four inches thick, interlayered with siltstone. Some layers are coquinas containing coral and mollusc fragments.

B.E.B. Cameron of the Geological Survey succeeded in extracting silicified foraminifera from this limestone and his preliminary findings are here reported.

Lugtonia	-	Carboniferous (Visean to Namurian)
Earlandinita	-	Late Mississippian to Pennsylvanian
Calcitornella	-	Pennsylvanian to Jurassic
Ammodiscus ?	-	(possibly Monotaxinoides)

This preliminary examination suggests a probable Early Pennsylvanian age for the assemblage.

In a steep gully these beds are overlain by well-bedded silicified siltstone, perhaps tuffaceous, overlain by more clastic limestone. The rest of the succession, dipping 20 to 30 degrees in more than a thousand feet of relief, consists of diabase sills with intercalations of silicified sediments that are generally well-banded greywacke-argillite (turbidite) sequences.

The west tributaries of Oktwanch River also contain outcrops of diabase, limestone, commonly recrystallized to marble, and thin-bedded sediments. There fossils found some years ago by J. Lund were identified by E.W. Bamber as bryozoans indicating only a general Ordovician to Permian age.

This sedimentary sequence with diabase sills forming the upper part of the Sicker Group is now known to contain (underlying pillow lavas of the Karmutsen Formation) from which exploration geologists and later D. Carlisle collected fossils.

E.T. Tozer of the Geological Survey made a preliminary identification and reports they are Daonella sp. indicating a Middle Triassic (Ladinian) age.

Thus the sedimentary sequence that separates Sicker volcanics and Karmutsen volcanics may span the time from Lower Pennsylvanian to Middle Triassic and in this region does not appear to contain a disconformity, although the extensive development of sills and metamorphism preclude a definite conclusion.

The Jurassic batholith, about 15 miles wide, extends south from Vernon batholith and is believed to grade into Westcoast Complex rocks. However on Flores Island and on the adjacent shores of Sydney and Shelter Inlets sharp contacts of dark diorite and lighter coloured granodiorite might suggest two ages of intrusion. The writer considers the diorite to be Sicker volcanics, intruded by middle Jurassic granodiorite and dioritized with preservation of the intrusive contact.

Upper Jurassic sediments, underlying a small area southeast of Kyuquot Channel and described by Jeletzky[5] are of special interest as no rocks of that age have been found elsewhere on Vancouver Island.

It is probable that the group of Tertiary dykes and plugs of the Tofino-Catface Mountain area extends across Flores Island to north of Hotsprings Cove. These rocks are not easily distinguished from Jurassic granodiorite but one intrusive contact between probable Jurassic granodiorite and lighter coloured, finer grained, and closely jointed biotite quartz monzonite is visible on both sides of Sidney Inlet and is slightly mineralized with chalcopyrite and molybdenite. Detailed mapping, petrographic and age-determination work are needed to further outline these Tertiary plutons.

Economic Geology

The areal extent of Sicker Volcanics is small and so far there are no known deposits of massive sulphides similar to those of Western Mines.

Skarns at the contacts of Sicker Sediments with granitic intrusions are commonly mineralized, in some instances with magnetite and chalcopyrite and in others with sphalerite and galena. Gold and silver are also present locally. Properties in this category, past or present, are the Indian Chief Group west of Stewarton Inlet; the Hesquiat Group and others east and west of Hesquiat Lake; Silverado and Baltic on Silverado Creek and Shannon near Kleeptee Creek, the latter respectively south and north of Gore Island, Muchalat Inlet; and Oktwanch west of Oktwanch River.

The only example of economic skarn deposits at the contact of Quatsino Limestone and granitic rocks is the now defunct Zeballos Iron mine at the north edge of Nootka Sound map-area. In the same vicinity the Privateer gold mine contained gold-quartz veins in a Tertiary granitic stock.

The possibility of other Cu-Mo deposits on offshoots of the Jurassic batholith, similar to that of the new Island Copper mine seems remote within Nootka Sound map-area as the batholith has been unroofed too deeply. On the other hand Cu-Mo deposits related to Tertiary granitic intrusions similar to that on Catface mountain might be present elsewhere. So far Bonanza Volcanics have not yielded any massive sulphide deposits although they appear to be similar in chemistry and volcanic-depositional environment to those of the Sicker Group that contains the Western Mines and similar deposits.

[1] Muller, J.E.: Geological reconnaissance map of Vancouver Island and Gulf Islands, revised to July 1971; Geol. Surv. Can., Open File 9.

[2]Hoadley, J.W.: Geology and mineral deposits of the Zeballos–Nimpkish area, Vancouver Island, British Columbia; Geol. Surv. Can., Mem. 272 (1953).

[3]Muller, J.E., and Carson, D.J.T.: Geology and Mineral deposits of Alberni map-area, British Columbia; Geol. Surv. Can., Paper 68-50 (1969)

[4]Jeletzky, J.A.: Tertiary rocks of the Hesquiat–Nootka area, west coast of Vancouver Island, British Columbia; Geol. Surv. Can., Paper 53-17 (1954).

[5]Jeletzky, J.A.: Stratigraphy of the west coast of Vancouver Island between Kyuquot Sound and Esperanza Inlet, British Columbia; Geol. Surv. Can., Paper 50-37 (1950).

---

14. OPERATION SNAG-YUKON (115 H, J (EAST HALF) K (EAST HALF) N (EAST HALF))

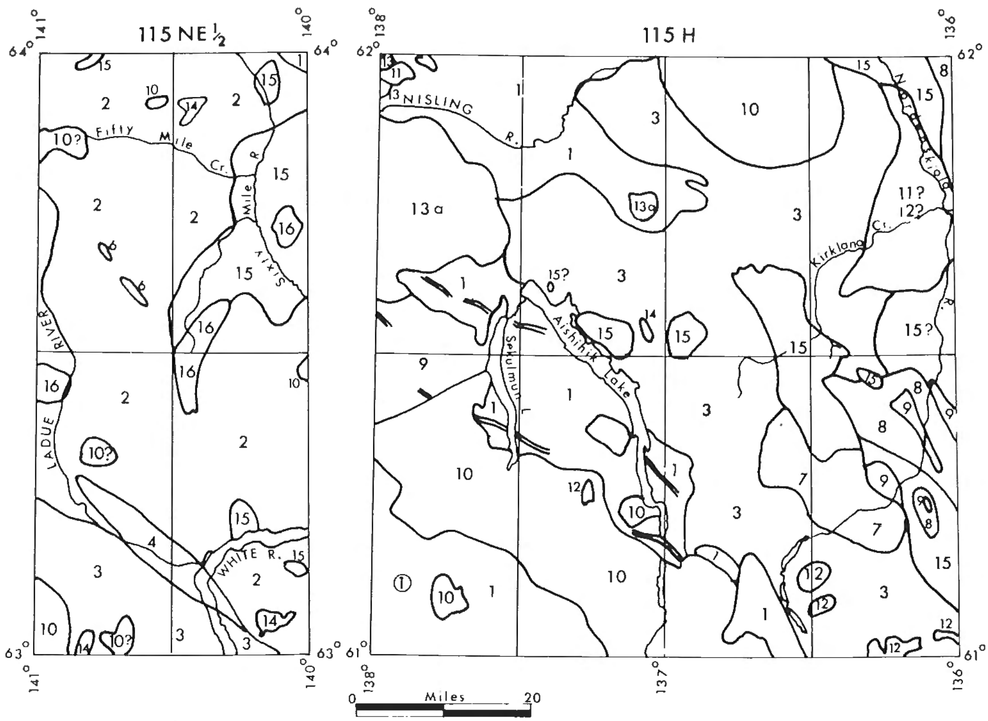
Project 700025

D.J. Tempelman-Kluit

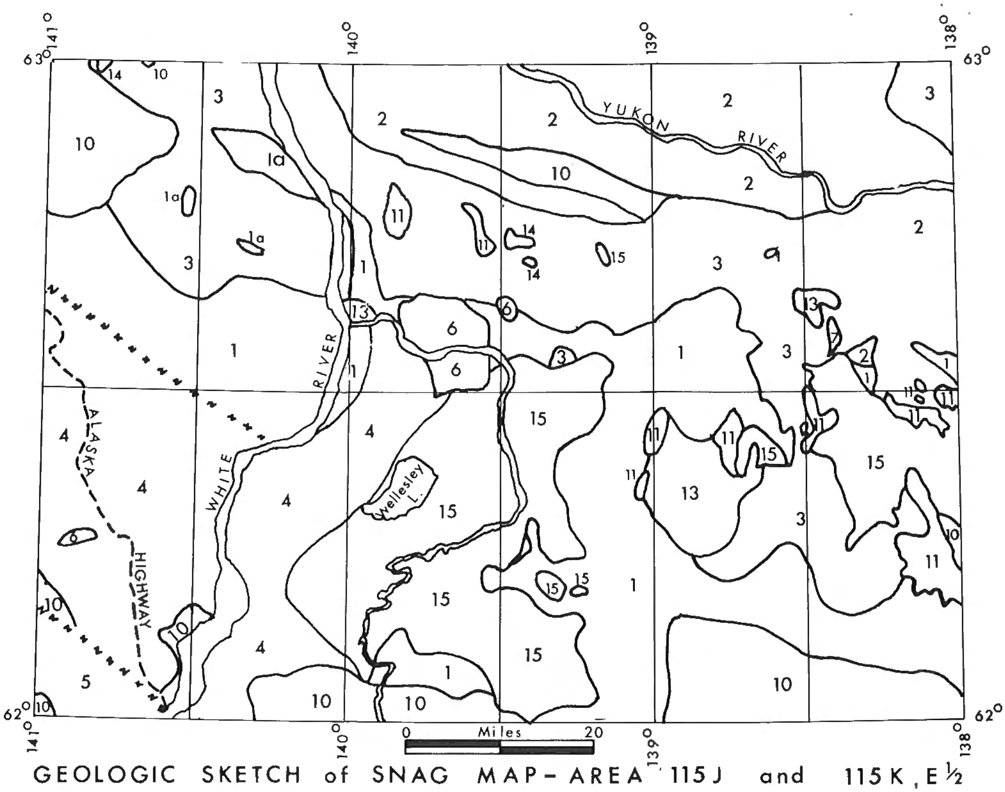
Operation Snag-Yukon is designed to provide reconnaissance geologic information for Aishihik Lake (115 H), Snag (115 J (east half) 115 K, E (east half)) and part of Stewart River (115 N (east half)) map-areas in west-central Yukon. Field work in 1971 consisted of ground traversing in all three map-areas with limited helicopter spot examination. This work largely completes the project and preliminary geological maps of these areas are in preparation. Limited follow-up work is planned. The writer acknowledges the very able assistance in the field provided by T. Booth, M. Delich, A. Edgeworth, I. Gibson, S. Gordey, J. Nitsch and B. Read without whose outstanding efforts the coverage obtained would have been impossible. The writer further acknowledges the superb air support provided by Bill Johnston, pilot, of Alpine helicopters and L. Vande Velde, engineer.

The distribution of major rock units in the project area is approximate in the accompanying sketch maps, which are based on rough field compilations. Age and correlation of rock units are therefore uncertain and must be regarded as tentative.

The age and correlation of the metamorphic rocks of units 1 and 2 are unknown. These rocks hitherto considered Precambrian and included in the "Yukon Group" are lithologically unlike Precambrian strata elsewhere in Yukon Territory. Parts of units 1 and 2 resemble mid-Paleozoic rocks. It is anticipated that units 1 and 2 can be roughly subdivided lithologically in final compilation. Metamorphism of units 1 and 2 varies throughout the project area reaching kyanite grade locally, but being no higher than garnet grade in most of the region. Isotopic dating of rocks from units 1 and 2 is planned to provide data on the age of metamorphism. The meagre data presently available suggests that these rocks were metamorphosed in early Triassic time.



GEOLOGIC SKETCH of AISHIHIK LAKE MAP-AREA 115 H and PART of STEWART RIVER MAP - AREA 115 NE ½



GEOLOGIC SKETCH of SNAG MAP-AREA 115 J and 115 K, E ½

LEGEND

TERTIARY	16	Quartz (feldspar) porphyry of rhyolitic composition
	15	CARMACKS VOLCANICS Vesicular and amygdaloidal, brown, purple, red, grey and green basaltic and andesitic flow rocks; includes minor acid volcanic rocks; locally includes undifferentiated massive poorly indurated pebble conglomerate, sandstone and shale.
	14	Dark green dense, massive basalt; minor cobble and boulder conglomerate. Possibly equivalent to 15 or 12.
	13	NISLING RANGE ALASKITE Coarse grained equigranular leucocratic miarolitic granite. 13a acid welded tuff and subvolcanic acid porphyrics with minor undifferentiated leucocratic microlitic granite.
	12	HUTSHI GROUP Massive basaltic and andesitic bomb and lapilli tuff; minor associated often rocks.
	11	MOUNT NANSEN GROUP Dense dark green massive basalt
MESOZOIC	10	Undifferentiated plutonic rocks of various ages including granodiorite, quartz monzonite, granite and syenite. Generally medium to coarse grained and equigranular to porphyritic, biotite is predominent mafic mineral.
		LOWER CRETACEOUS
	9	TANTALUS FORMATION Moderately well sorted and well indurated thick-bedded chert pebble and cobble conglomerate; minor sandstone and shale.
		JURASSIC
	8	LABERGE SERIES Poorly sorted, massive well indurated pebble and cobble conglomerate with clasts of various granitic and volcanic rocks; includes interbedded sandstone, shale and coal.
	7	Porphyritic (K-feldspar) red, coarse grained biotite leucogranite.
	6	Serpentinite and related ultramafic rocks
PALEOZOIC		PERMIAN AND EARLIER (?)
	5	Undifferentiated sandstone, argillite, slate, limestone and pebbly conglomerate; includes undifferentiated volcanic and plutonic rocks like those of unit 4.
		PERMIAN ?
	4	Dense massive greenstone and associated undifferentiated bodies of medium grained hornblende diorite.
	3	Medium to coarse grained equigranular (biotite) hornblende granodiorite to quartz monzonite; locally well foliated.
	2	Strongly foliated muscovite biotite granodiorite and undifferentiated gneiss with lesser quartz mica schist and minor micaceous quartzite.
	1	Quartz mica schist and micaceous quartzite; minor strongly foliated grano diorite; minor marble - 1a.

Hornblende granodiorite of unit 3 is strongly foliated near boundaries with the metamorphic rocks. No strong recrystallization accompanies the development of foliation.

Volcanic and associated plutonic rocks of unit 4 are lithologically like those seen in unit 5 and the age assignment of unit 4 is based on this similarity. Unit 5 is equivalent to units 10 and 11 of Muller (ref. 1).

Unit 6 may represent ultramafic rocks of different ages as the associations of these rocks are varied.

A wide variety of plutonic rocks is included in unit 10 and this unit undoubtedly represents granites of different ages. Isotopic work is planned to help distinguish these.

Relations between the Mount Nansen and Hutshi Groups are unknown. These rocks have similar relations to other stratigraphic units and may represent closely related strata. Detailed study in selected areas is planned.

The acid volcanic, hypabyssal and plutonic rocks included in unit 13 present interesting possibilities for study of interrelations between volcanic and subvolcanic rocks over extensive areas. These rocks are fairly well exposed, present a wide variety of igneous and volcanic textures and apparently are of some economic interest.

No new occurrences of mineralization were discovered. Copper mineralization in central Aishihik Lake map-area is in skarns associated with marble bands in metamorphic rocks of unit 1 where these are cut by aphanitic dykes of andesitic composition possibly related to the Mount Nansen Group. The Casino copper deposit is entirely surrounded by rocks of Klotassin batholith (unit 3), but is spatially associated with acid hypabyssal rocks probably equivalent to unit 13. Copper at Mount Cockfield is found in similar acid volcanic and subvolcanic rocks. Minor copper occurrences on Wolf Dome, the mountain 20 miles southwest of the mouth of White River, are in volcanic rocks of unit 14; this unit may be equivalent to the Carmacks or Mount Nansen Groups. Rocks of unit 13 appear to offer the best possibilities for copper occurrences in the region. The acid volcanic rocks of unit 16 are apparently barren.

[1]Muller, J.E.: Kluane Lake map-area; Geol. Surv. Can., Mem. 340 (1965).

---

15. SMITHERS MAP-AREA, BRITISH COLUMBIA (93 L)

Project 690009

H. W. Tipper

The re-examination of Smithers map-area continued in 1971. For reference the reader should note published geological reconnaissance maps by the Geological Survey of Canada[1, 2, 3] and the British Columbia Department of Mines and Petroleum Resources[4]. The 1971 work was concentrated in the west half of the map-area (Smithers map-area of Armstrong, 1944) and unless otherwise indicated, the following remarks refer to the west half.

The oldest layered rocks of the map-area are a group of metamorphic rocks, micaceous quartzite, phyllites, limestone, argillites, and green schists of possibly Paleozoic or (?) early Mesozoic age. The grade of metamorphism is higher than that of the Jurassic and younger rocks in the region. The group underlies a small area along the southwest margin of the area and extends southerly into the Whitesail Lake and Douglas Channel map-areas.

The Lower Jurassic rocks are mainly volcanic ranging in composition from basalts to rhyolites and underlie the west half of the area south of McDonnell Lake. Bedded breccias and tuffs, ignimbrites, minor vesicular flows, minor limestone reefs and lenses with rare siltstone and sandstone are widespread and are characterized by bright purple, red, maroon, and green colours. The rocks have been divided into two units, a lower one characterized by various shades of green and a pervasive epidotization and an upper unit that is mainly reddish volcanic rocks commonly showing epidotization, zeolitization, and prehnitization. The age of the volcanics is Early Jurassic (Hettangian ? to Upper Sinemurian).

A thin unit centered on Eagle Peak and characterized by waterlain red tuffs and breccias with minor sediments overlies the Lower Jurassic rocks disconformably. The age is probably early Middle Jurassic (Lower Bajocian).

A mainly sedimentary unit overlies the red tuff unit disconformably and consists of waterlain volcanic breccias and tuffs, conglomerate, greywacke, shale, and volcanic arenite that range in age from Middle Jurassic (middle Bajocian) to early Late Jurassic (Lower Oxfordian). Several disconformities are recorded within the unit. It is exposed mainly north of Telkwa River. South of Telkwa River, Middle Jurassic rocks are mainly nonmarine sediments and greenish volcanic breccias and tuffs. North of McDonnell Lake the sedimentary unit is overlain by a green, feldspathic, andesitic to basaltic unit of probable Late Jurassic (Oxfordian) age.

In the northern part of the area, the Upper Jurassic rocks are overlain, either unconformably or disconformably by a sequence of sedimentary rocks that grade from coarse conglomerate and sandstone at the base through greywacke to shale and micaceous sandstone at the top. These are interbedded marine and nonmarine rocks of unknown age - early Late Jurassic (Oxfordian) to mid-Early Cretaceous. At the top they are interbedded with red tuffs or overlain by coarse augite porphyry breccias. They are best displayed on Rocky Ridge and in the area around Kitsuns Creek.

Overlying the Jurassic rocks with angular discordance is a widespread group of probable late Early Cretaceous age (Albian ?). Characteristically it is black marine shale and greenish micaceous shale overlain by and in part interbedded with volcanic breccias and tuffs that are easily confused with Lower Jurassic volcanics. The Telkwa coal basin and other coal basins of the area are related to the sedimentary part of the group and may comprise the oldest part of the unit. This group is exposed intermittently from the north edge of the map-area to the south edge.

Tertiary volcanic rocks are present as small fault blocks in the southern part of the area. They are similar to the rocks of the Endako and Ootsa Lake Group of the east half of the map-area.

Intrusive rocks of more than one age are widespread as dykes, sills, and stocks. Several bodies of quartz monzonite present in the south part of the area are intrusive into Lower Jurassic volcanics and may be Jurassic in age. Coarse-grained quartz-diorites and granodiorites in Howson Range and along the west margin of the area may be early Tertiary in age; other felsites and porphyries may be genetically related.

Thrust faulting to the north and northeast and closely spaced block faulting are characteristic of the area. Folding is only recognized locally and appears to be related to thrust faulting.

[1]Armstrong, J.E.: Smithers, Coast District, B.C.; Geol. Surv. Can., Prelim. Map 44-23 (1944).

[2]Lang, A.H.: Houston map-area; Geol. Surv. Can., Map 671A (1942).

[3]Hanson, G.: Driftwood Creek map-area, Babine Mountains, B.C.; Geol. Surv. Can., Summ. Rept. 1924, Pt. A, pp. 19-37 (1925).

[4]Carter, N.C., and Kirkham, R.V.: Geological compilation map of the Smithers, Hazelton, and Terrace areas; B.C. Dept. Mines Petrol. Resources, Map 69-1 (1969).

---

16. PETROLOGY, METAMORPHISM, AND STRUCTURE OF THE MOUNT RALEIGH AREA, COAST MOUNTAINS, BRITISH COLUMBIA

Project 630016

G.J. Woodsworth

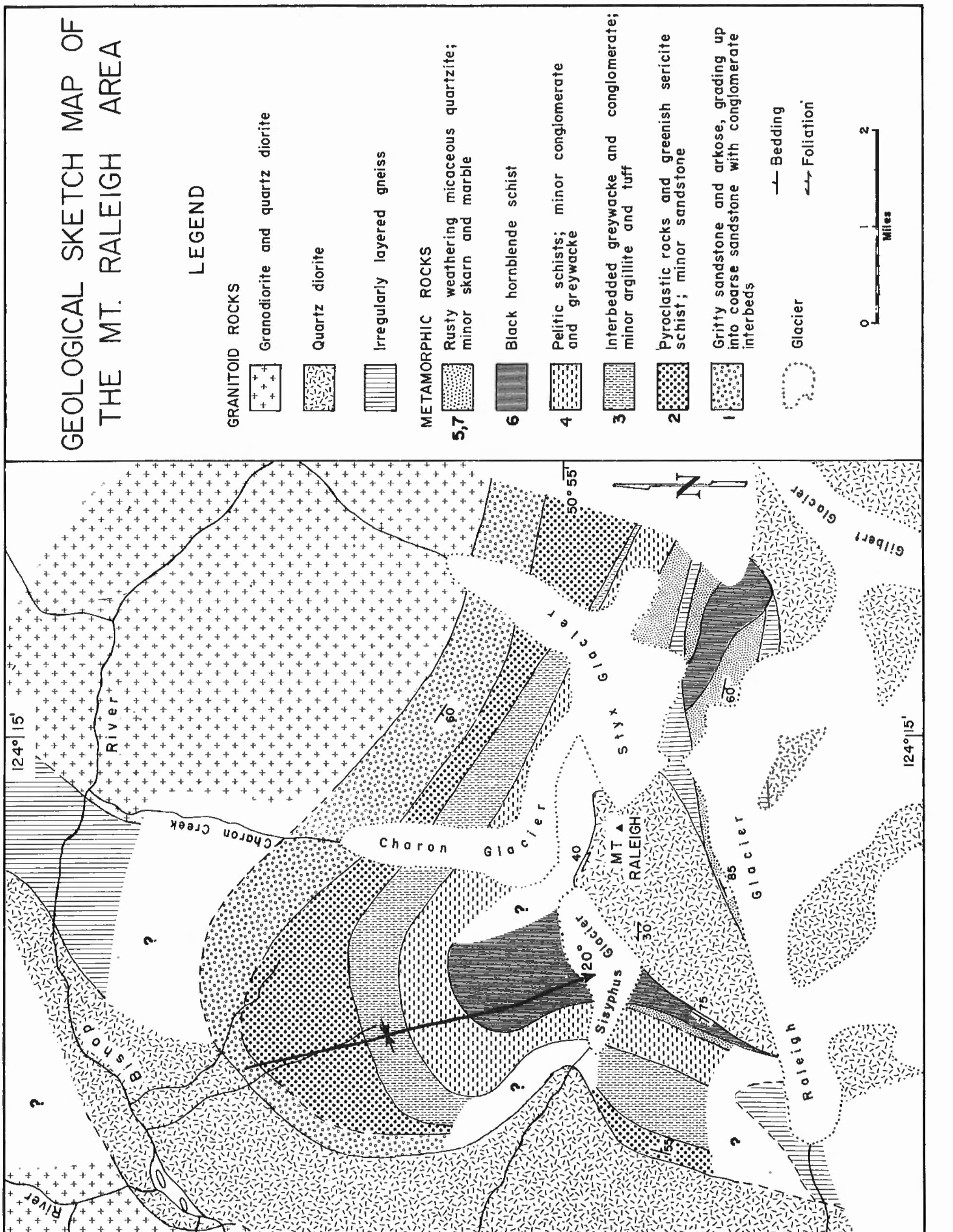
A detailed study of the Mt. Raleigh area was begun in July and August of 1971 as part.of a thesis project at Princeton University. Objectives of the project include the study of the relations between metamorphism, plutonism, and deformation in this part of the Coast Mountains; and the estimation of maximum pressures and temperatures reached during metamorphism. The area consists of about 110 square miles in the northeastern part of the Bute Inlet (92 K) map-area. Field work was restricted to the western part of the area. The general features of the Bute Inlet map-area have been outlined.[1] The Mt. Raleigh area consists of an east-northeasterly trending belt of metamorphosed sedimentary and volcanic rocks that is bounded by plutonic rocks and migmatites.

The best exposed section of stratified rocks is to the east and southeast of the Styx Glacier (Fig. 1). Seven units with a total thickness of about 12,500 feet are recognized. From oldest to youngest (north to south) these are:

1. Grey, coarse-grained, thick-bedded sandstone and arkose that grades up into coarse sandstone with cobble conglomerate interbeds. About 40 per cent of the cobbles are acidic plutonic rocks; the remainder are schists and volcanics. Crossbedding and graded bedding are locally common in the sandstone. This unit grades upward into unit 2.

2. Greenish, coarse- to fine-grained massive volcanic breccia, interbedded with minor pelitic schists and coarse thick-bedded sandstone. This unit grades upward into unit 3.

3. Interbedded gritty greywacke and pebble-conglomerate, with lesser amounts of greenish laminated tuff and black pelitic schists. Plutonic clasts are rare in the conglomerate. This unit grades upward into unit 4.


GEOLOGICAL SKETCH MAP OF THE MT. RALEIGH AREA
LEGEND
GRANITOID ROCKS
Granodiorite and quartz diorite
Quartz diorite
Irregularly layered gneiss
METAMORPHIC ROCKS
5,7 Rusty weathering micaceous quartzite; minor skarn and marble
6 Black hornblende schist
4 Pelitic schists; minor conglomerate and greywacke
3 Interbedded greywacke and conglomerate; minor argillite and tuff
2 Pyroclastic rocks and greenish sericite schist; minor sandstone
1 Gritty sandstone and arkose, grading up into coarse sandstone with conglomerate interbeds
Glacier
Bedding
Foliation
0 1 2
Miles
124°15'
50°55'
N
River
Charon Creek
Charon Glacier
Styx Glacier
Gilbert Glacier
Sisyphus Glacier
Raleigh Glacier
MT RALEIGH
Bishop River
Southgate River
20°
40
30
75
85
60
60
55

4. Pelitic schists, commonly black-weathering; minor fine-grained conglomerate, gritty greywacke, and quartz-sericite schist.

5. Thin-bedded, impure quartzite containing thin interbeds of marble, skarn and hornblende-biotite schist.

6. Black homogeneous hornblende schist, with rare 2-inch layers of skarn and marble.

7. Very rusty weathering laminated impure quartzite which is similar to that in unit 5; two 40-foot-thick layers of thin-bedded marble and skarn near the base.

These strata are lithologically very similar to those on Mt. Alfred in southeasternmost Bute Inlet map-area, and to those of the Gambier Group in the Vancouver map-area[2] in which ammonites of Albian age have been found (H. W. Tipper, pers. comm.).

North of Styx Glacier the base of the section is in sharp contact with poorly foliated biotite-hornblende granodiorite. The strata within several hundred feet of the contact are cut by numerous veins and dykes of pegmatite and garnetiferous aplite. To the west and south of the metamorphic rocks, and on Mt. Raleigh, the plutonic rock is a moderately foliated hornblende-biotite quartz diorite. Near Raleigh Glacier a zone of fine-grained irregularly laminated gneiss of quartz diorite composition forms a contact zone between the plutonic rocks and the quartzites, and is in sharp contact with both.

At least two episodes of deformation are recorded in the stratified rocks. Prior to metamorphism the strata were folded into a syncline plunging to the south-southeast (Fig. 1). The second deformation was, at least in part, contemporaneous with metamorphism, and is recorded by the foliation in the schists and by a southwest-plunging lineation. Foliation is generally parallel to the bedding, except near the northern part of the synclinal axis; there the foliation strikes northwest. The lineation is given by the direction of alignment of hornblende and andalusite, and by the direction of maximum deformation of pebbles in the conglomerate. The lineation lies within the foliation plane, and is widely developed only in the south and southwestern part of the area. Near Raleigh Glacier the lineation is locally present in the gneissic zone between the metasediments and the quartz diorite, but is everywhere absent from the plutonic rocks.

Except on Mt. Raleigh, contacts between the plutonic and metamorphic rocks are steep, with dips generally towards the metasediments. The upper 1,500 feet of Mt. Raleigh is composed of quartz diorite which is in sharp contact with the metasediments and appears to have been thrust up and northeastward over the metasediments.

Only one period of metamorphism of the stratified rocks was recognized in the area. The metamorphic grade of the stratified rocks increases from garnet grade near the biotite-hornblende granodiorite (north of the Styx Glacier) to sillimanite grade southwest of Sisyphus Glacier and near the head of Raleigh Glacier. Andalusite is abundant north of Sisyphus Glacier and east and west of Styx and Charon Glaciers. Sillimanite, pseudomorphous after andalusite, is common southwest of Sisyphus Glacier. Sillimanite has also been found in two localities near the head of Raleigh Glacier near the southern margin of the metasediments. Sporadic occurrences of staurolite and chloritoid have been found west of Charon Glacier and east of Styx Glacier.

In view of the decrease in metamorphic grade northwards towards the granodiorite it is unlikely that the granodiorite supplied the heat necessary for metamorphism. However, the granodiorite itself does not appear to have been metamorphosed. The intrusion of the quartz diorite is a more plausible heat source.

[1]Roddick, J.A., and Hutchison, W.W.: Coast Mountains Project; in Report of Activities, Part A: April to October 1970, Geol. Surv. Can., Paper 71-1, Pt. A, pp. 31-33 (1971).

[2]Roddick, J.A.: Vancouver North, Coquitlam, and Pitt Lake map-areas, British Columbia; Geol. Surv. Can., Mem. 335 (1965).

EXPLORATION GEOPHYSICS

17. GAMMA RAY SUPPORT

Project 670052

B.W. Charbonneau

During the summer of 1971 a total of approximately two months of field work was undertaken in three areas of the Precambrian Shield; Clyde Forks, Bancroft and Elliot Lake. In addition a prominent radioactivity anomaly north of Sudbury (north of Lake Wanipitei) was also examined.

In the Clyde Forks area (30 miles northwest of Perth, Ontario) a survey was made with a portable gamma-ray spectrometer as part of an integrated geophysical investigation (radiometric, magnetic, VLF electromagnetic, geological) to determine the form of the mercury-copper deposit and evaluate the area as a potential geophysical test site. The field trip also served as part of a training program for CIDA students.

The Clyde Forks property, owned by Carndesson Mines Ltd. whose cooperation is greatfully acknowledged, has also been used for mercury geochemical testing[1]. A VLF anomaly was found to strike northeasterly through the adit and appears to coincide with an area of mercury-copper enrichment in the soils. No radioactivity anomaly was found over the mineralized zone however two radioactive pegmatites were found approximately 500 feet to the south.

The work at Bancroft and Elliot Lake comprised the investigation of radioactivity anomalies found by the airborne gamma-ray spectrometer surveys of Bancroft[2] and Elliot Lake (to be released). The ground work concentrated on anomalies which were not readily explainable by existing geological information or by previous radioactivity studies in the area. The following comments are designed to illustrate only a few of the major findings.

In the Bancroft area within the major anomaly, which is some 15 miles long by 2 miles wide, it was found that all of the rock types (granite, syenite, gabbro and paragneiss) were enriched in both uranium and thorium relative to similar lithologies away from the anomalous zone. All the known past producing mines and major deposits within the survey area occur within this anomaly. Such a large zone of enrichment surrounding the economic deposits is encouraging from the point of view of distinguishing uranium deposits of the general pegmatitic type. A zone of thorium anomalies striking east-west and lying to the north of Lake Baptiste was found to relate to an increased thorium content in the granite gneisses. Another prominent feature observable on the survey maps is that the base level of uranium in the two major geological blocks within the survey area, namely the granite gneisses to the north and the metasediments to the south, is similar in value whereas the thorium values are much higher in the granite gneisses than in the metasediments. This large scale feature was validated on the ground.

Anomalies in the radioelement ratios such as the high U/Th value to the west of Silent Lake was correlated to granitic injections of high U/Th ratio which intrude the paragneissic host rocks. A prominent high Th/K anomaly to the north of Chandos Lake was due to injection of high thorium-low uranium granitic rock. Less sharp anomalies were found to generally relate to greater or lesser amounts of exposure of bedrock.

At Elliot Lake one of the major features examined was a large thorium anomaly in the northeast part of the survey area. This feature was found to correlate with an area where dark horizons were very prominent in the Lorraine Formation. These dark horizons are believed to contain heavy mineral concentrations (possibly monazite). A prominent thorium and uranium anomaly measured over the Cutler granite by the airborne gamma-ray spectrometer, appears to relate to a slight enrichment of radioelements in this granite relative to other rocks but the values are enhanced by the high degree of exposure.

The mapped limits of the Lower Mississagi Formation were well delineated by the uranium, thorium and thorium/potassium maps and areas of greater than average concentration of uranium and thorium within this formation were validated on the ground.

North of Sudbury (just north of Lake Wanipitei) a prominent anomaly from the cross-country profiles[3] was found to correlate to a granite body of quite high radioelement content which is flanked by Huronian strata. The granite body is mapped as Archean[4] however there exists the possibility that part of the body may be post-Huronian in age. Granites to the south of the belt of Huronian rocks are not very radioactive and appear to be of quite different petrological nature. A paper illustrating a selection of anomaly patterns with their geological explanation is in preparation.

[1] Jonasson, I.R.: Geochemical distribution of mercury and associated metals in soil samples from Clyde map-area, Ontario; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, p. 74 (1971).

[2] Darnley, A.G., and Grasty, R.L.: Bancroft Radiometric Survey; Geol. Surv. Can.; Open File 45 (1971).

[3] Darnley, A.G., Grasty, R.L., and Charbonneau, B.W.: Cross-country airborne gamma spectrometric profile; Geol. Surv. Can., Open File 22 (1970).

[4] Meyn, H.D.: Capreol sheet; Ont. Dept. Mines, Map P-367 (1966).

---

18. EXPERIMENTAL AIRBORNE GAMMA-RAY SPECTROMETRY SURVEYS

Project 670050

A.G. Darnley, K.A. Richardson, and R.L. Grasty.

The airborne gamma-ray spectrometer system was operated in the GSC Skyvan for several periods between May and October, 1971. Experimental gamma-ray surveys were undertaken in various parts of Canada.

1. Mont Laurier, Quebec Survey

This survey was a co-operative project with the Quebec Department of Natural Resources. The survey covered 3,730 line miles at 0.25 mile spacing in an area approximately 24 by 40 miles located about 40 miles north of Mont Laurier. The objective was to determine radioelement distribution within the survey area which contains many radioactive mineral occurrences.

A preliminary map of thorium distribution shows areas of high concentration relating to some of the areas mapped[1] as granite, granitic migmatite, and granitic gneiss. It appears that the results of the survey will be helpful in distinguishing between granitic rocks with different levels of radioactivity that have previously been mapped as single units. A number of locations with high uranium content have been found in the survey area, generally within but near the periphery of areas with high thorium content.

2. Ottawa-Yellowknife, N.W.T. Reconnaissance

The outward and return tracks of this survey were offset from the cross-country flights of 1969 and 1970[2] in order to verify and expand the results of the earlier traverses concerning the distribution of radioelements within and among the structural provinces of the Canadian Shield, and to examine the extent of some of the anomalous radioactive regions encountered previously.

Only a few generalized comments can be made because of the preliminary state of the data analysis. However, the general variation in radioelement content among the structural provinces of the Canadian Shield appears to be similar to that reported by Darnley et al.[2]. Clearly, the Churchill (northwest) subdivision of the Shield has the highest base levels of radioactivity. The K, U and Th "highs" between Reindeer and Wollaston Lakes reported by Darnley appear, as a result of the 1971 survey, to be part of a series of radioactive anomalies that stretch for at least 300 miles from the edge of the exposed Shield in Saskatchewan, northeast along the trend of the Wollaston Fold belt[3] to beyond the Manitoba border. This radioactivity is coincident with a magnetic "high" on the 1:5,000,000 Magnetic Anomaly Map of Canada (Map 1255A). Some pronounced uranium anomalies are seen on the cross-country profiles, notably between Black Lake and Charlebois Lake, Saskatchewan, where uranium-bearing pegmatites are extensively prospected about 1950; in an area about 40 miles northwest from Black Lake, and on the northeast side of Thubun Lakes, Northwest Territories.

3. Yellowknife-Coppermine Reconnaissance

A return profile Yellowknife to Coppermine also extended eastwards from Coppermine to about 111°W at 67°30'N. Approximately 900 line miles traversed the Bear Structural Province, and confirmed earlier evidence that particularly along its western side this is one of the most radioactive regions of the Canadian Shield. It is comparable to the zone north of Fort Smith[2]. Although the base level of radioactivity within the Slave Province is lower than in the Bear Province, the Slave does contain zones of very high radioactivity, for example over some tens of miles in the vicinity of 63°30'N, 113°W.

4. Yellowknife Survey

A total of 6,280 line miles of gamma-ray spectrometric data were collected in the southern part of the Slave Province of the Canadian Shield. An area bounded by the MacDonald Fault and the North Arm of Great Slave Lake was surveyed with east-west lines, spaced 2.5 kilometres (about 1.56 miles) apart, extending to a line approximately 40 miles north of Yellowknife. The same area was covered photographically during this field season[4]. The coverage extends northwards from the area surveyed in 1970.

Preliminary results of the gamma-ray survey show clear distinction between the Archean granitic rocks and the sedimentary, metasedimentary and volcanic rocks of the area. Ground measurements were made at several spots in the survey area with a portable field spectrometer, and all of these measurements showed that high thorium and uranium values were due to granitic rocks. Indications are that the survey results will provide a geochemical criterion for subdividing areas mapped[5] as "granite, granodiorite and allied rocks" into areas with normal thorium and uranium values, and areas with differing levels of high radioelement content and anomalous Th/U ratios.

5. Yellowknife-Whitehorse-Dawson-Watson Lake Reconnaissance

The main purpose of this reconnaissance was to establish how much useful data could be obtained with a fixed-wing aircraft spectrometer installation in mountainous terrain. The conclusion is that it is feasible and useful to fly a reconnaissance along the sides of major valleys under suitable weather conditions, but detailed surveys, or traverses across specific features, require a helicopter mounted system.

One of the interesting features observed in the course of the survey was a prominent radiometric anomaly confined to the uranium channel in the vicinity of Rabbitkettle Hotsprings in the South Nahanni Valley, Northwest Territories. It extended over about 4 miles centred about 1 mile east-northeast of the springs, at 60°58'N, 127°08'W. The most likely explanation (which requires confirmation) for the activity is the presence of radium and/or emission of radon associated with the springs. Test lines across copper occurrences in the vicinity of Granite Mountain, Freegold Mountain and Victoria Mountain in the Dawson Ranges midway between Whitehorse and Dawson City, did not show any distinctive radioelement anomaly pattern, although the general area does show some variations in potassium content. Unfortunately, some of the potentially most interesting test sites were inaccessible because of low cloud.

6. Ottawa-Goose Bay, Labrador Reconnaissance

With the exception of the area north of Mont Laurier, Quebec, the general levels of thorium, uranium and potassium were relatively low throughout this traverse which crossed the Grenville Front at several points. There is evidence of some increase in radioactivity in the vicinity of the Grenville-Superior boundary 60 miles west of Wabush, Quebec, and also in the vicinity of the Grenville-Churchill boundary 150 miles northeast of Wabush. This latter feature may be related to a granitic area on the southeast side of Michikamau Lake. Test lines over reported uranium occurrences[6] in the vicinity of Makkovik Bay showed some abrupt variations in radioelement abundances which appear to relate to geological boundaries, and some lines show above-average uranium abundances over distances of several miles. This is in keeping with observations in other areas of Canada containing known uranium occurrences[2].

In conclusion it may be noted that on present evidence the eastern half of the Canadian Shield (east of Lake Superior) contains fewer regions of high radioactivity as compared with the western half of the Shield, and the radioelement concentration within the zones that are present are not so high or so extensive as in the west. However, this generalization may change as more reconnaissance profiles are undertaken.

[1] Wynne-Edwards, H.R., Gregory, A.F., Hay, P.W., Giovanella, C.A., and Reinhardt, E.W.: Mont Laurier and Kempt Lake map-areas, Quebec; Geol. Surv. Can., Paper 66-32 (1966).

[2] Darnley, A.G., Grasty, R.L., and Charbonneau, B.W.: A radiometric profile across part of the Canadian Shield; Geol. Surv. Can., Paper 70-46 (1971).

[3] Money, P.L.: The Wollaston Lake fold-belt system, Saskatchewan-Manitoba; Can. J. Earth Sci., vol. 5, pp. 1489-1504 (1968).

[4] Slaney, V.R.: Multispectral photography; this publ.

[5] Henderson, J.F., and Joliffe, A.W.: Beaulieu River, District of Mackenzie, Northwest Territories; Geol. Surv. Can., Map 581A (1941).

[6] Gandhi, S.S., Grasty, R.L., and Grieve, R.A.F.: The geology and geochronology of the Makkovik Bay area, Labrador; Can. J. Earth Sci., vol. 6, pp. 1019-1035 (1969).

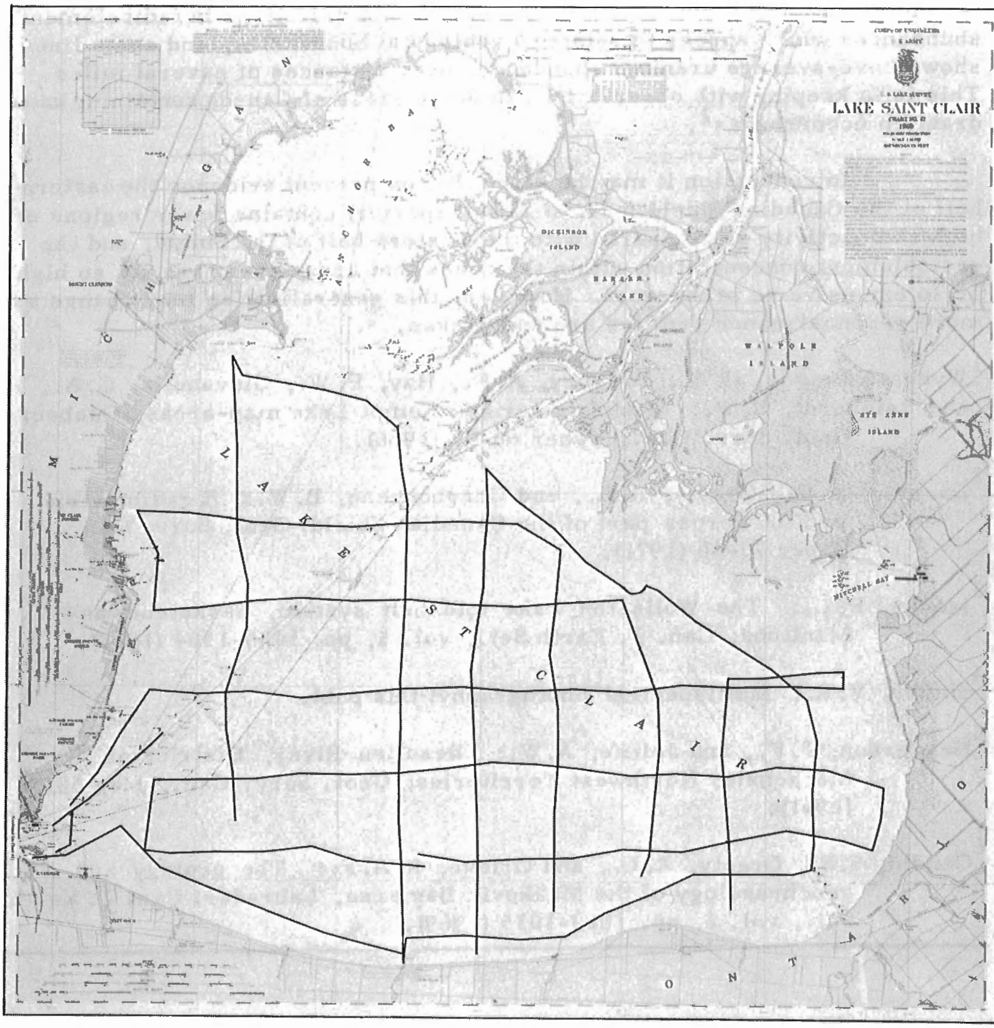
---

19. MARINE SEISMIC SURVEYS, GREAT LAKES AREA

Project 660054

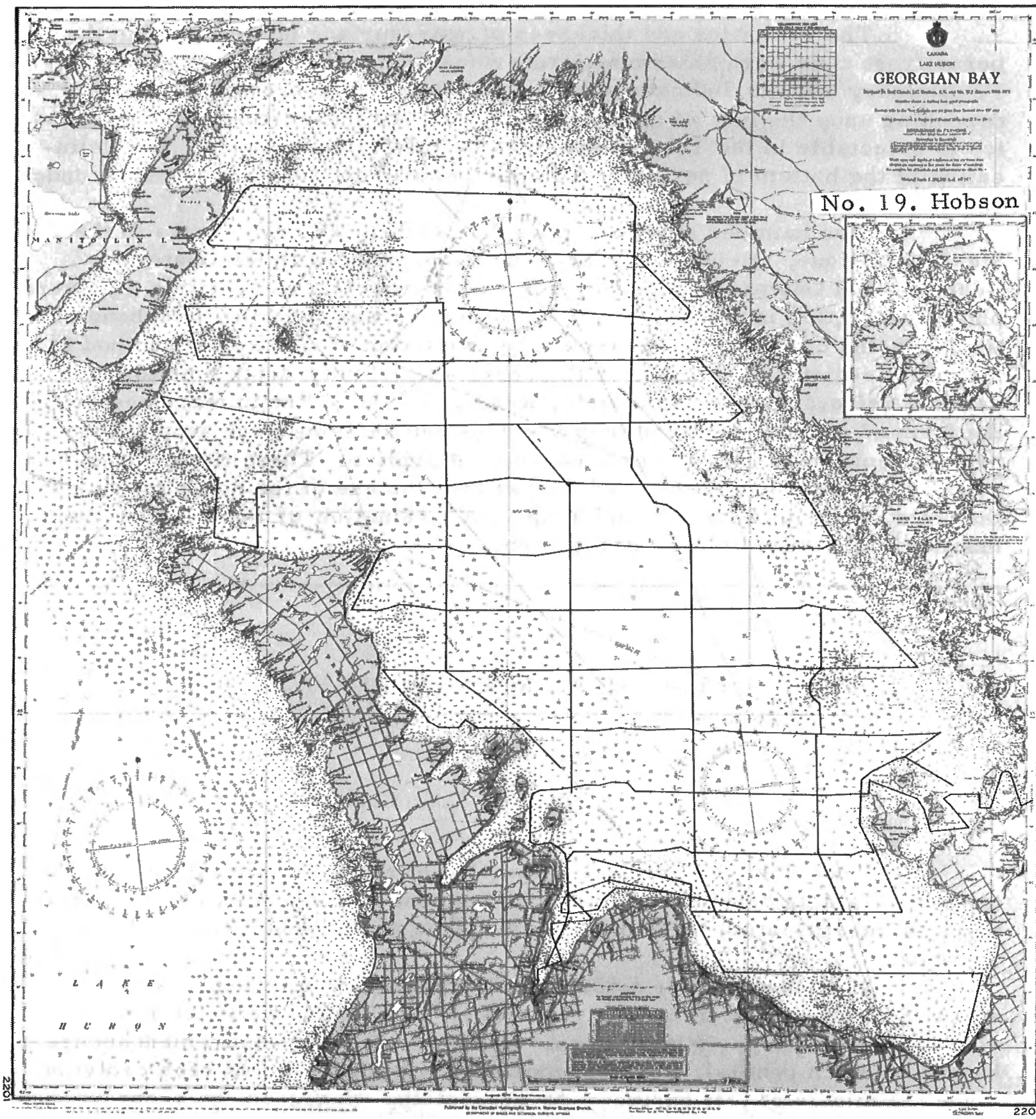
G.D. Hobson

A marine seismic survey of Lake St. Clair (Fig. 1) was undertaken July 29 - August 6, 1971 to determine depth of water, thickness of unconsolidated bottom sediments and stratification within those deposits overlying bedrock and bedrock topography where possible. The survey, covering 200 miles of track on a grid of 2 1/2 by 2 1/2 miles (4 km), was conducted from the vessel C.S.S. Lemoyne out of Burlington, Ontario. A Bolt air gun, 5 cubic inch chamber, was used as a repetitive energy source. The quality of the data recorded is only fair probably due to the fact the water depths in Lake St. Clair do not exceed 7 metres. Stratification within the bottom sediments



is discernible in general but the bedrock surface is not readily observed; a careful scrutiny of the records will be required and it is doubtful that a complete bedrock topography map can be derived. The interpretation of these data has begun.

A similar survey was undertaken in Georgian Bay (Fig. 2) August 16 - September 3, 1971. This survey covering 2,117 miles of line was conducted from C.C.G.S. Porte Dauphine in co-operation with Royal Ontario Museum and Great Lakes Institute. A side scan sonar device was used at the same time as the seismic profiler and 78 Shipek and gravity cores were also obtained. These data have not been interpreted; two more weeks of survey remained to be completed in November 1971. A cursory view of the seismic records (as they were obtained) indicates that Precambrian topography can be seen beneath the Paleozoic cover and stratification within the overlying unconsolidated sediments is very evident. The interpretation of these data will be undertaken in the near future.



20. SHALLOW SEISMIC SURVEYS, MACKENZIE VALLEY, NORTHWEST TERRITORIES AND STE-SCHOLASTIQUE, QUEBEC

Project 680037

J.A. Hunter and R.M. Gagne

A shallow seismic program was initiated in the Mackenzie Valley region to study seismic properties of permafrost in surficial deposits. Both the FS-3 hammer seismograph and the RS-4 12-channel seismograph were tested under winter and summer operating conditions. The sites occupied were as follows:

1. Fort Simpson (region of discontinuous permafrost)
2. Fort Good Hope (region of thin continuous permafrost)
3. Inuvik-Tuktoyaktuk (region of variable thickness of permafrost)

The velocities and thickness of near-surface layering within the permafrost zone were determined from refraction and reflection observations. Preliminary results indicate a wide variation of compressional velocity depending upon the type of material. As well, the presence of massive ground ice is detectable in the Tuktoyaktuk area by refraction methods. The delineation of the bottom of permafrost in thin permafrost zones is presently under study.

Two hammer seismic crews operated for 28 crew-weeks in the Ste-Scholastique, Quebec, map-area in co-operation with the Quaternary Research and Geomorphology Division. Shallow refraction seismic data were obtained at 2,338 locations. Field headquarters was linked by telephone to a time-sharing computer in Montreal; the evaluation of a computer method to obtain time-distance data, layer thickness and velocity-depth function from seismic refraction data in the field, was successful. Preliminary results in the form of computer-plotted map overlays and sections were supplied to the project geologist to assist in his concurrent studies. These timely progress reports could not have been produced without the use of the computer link in the field. Compilation of final maps and evaluation of the velocity-depth function are currently being undertaken.

---

21. ELECTRICAL ROCK PROPERTIES

Project 630049

T.J. Katsube and L.S. Collett

The study of electrical properties of rocks is carried out with the purpose of aiding development and improvement of new and existing exploration and interpretation techniques for airborne and ground electromagnetic systems.

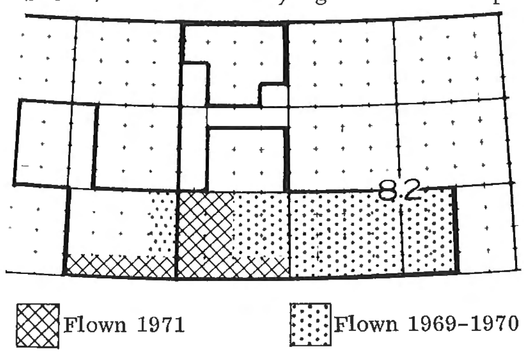
It is about a year since measuring systems for electrical parameters of rocks for the frequency range of 10^{-2} to 10^{7} Hz were set up in the electrical rock property laboratory. However, as the measurement accuracy has been low in general, work on improving the accuracy has been evolving since the middle of last spring. At present the measurement accuracy has reached $\pm$ 1.0% of international standards for the frequency range 10^{2} to 3 by 10^{7} Hz. From the middle of October 1971, this laboratory has been able to make standard measurements on electrical parameters of rock specimens on a production-line basis, with an accuracy of $\pm$ 2.0%, for the same frequency. At present, work is being done to improve the measurement accuracy of the lower frequency systems, and to make measurements under various atmospheric conditions. As soon as this phase of the project is completed, work will start on adding these systems to the production line. High accuracy measurement should produce data that can be highly relied upon, and therefore permit efficient use of the results.

Study on a suit of serpentinites is being carried out at present. The purpose of this study is to find out whether, false IP anomalies, that appear in regions where serpentinite bodies exist, can be differentiated from those caused by sulphide orebodies. High accuracy of the measuring systems are very important in this study.

---

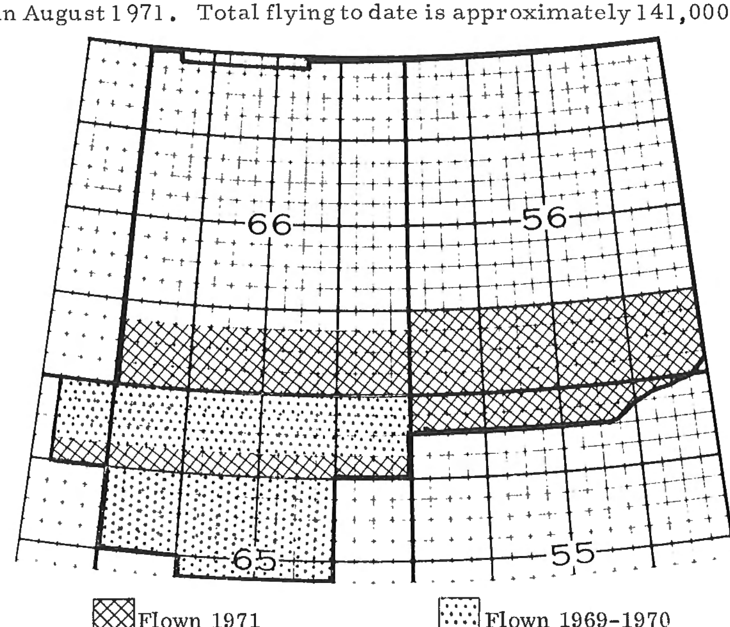
22. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS
British Columbia - Project 690066 - A. Larochelle

Approximately 6,000 square miles (11,000 line miles) of aeromagnetic surveys were flown using a helicopter from January to May 1971. No flying was carried out between May 15, 1971 and September 15, 1971. As per previous agreement with the contractor, survey flying was to be conducted only during winter months. As a result it was necessary to grant a six month extension to September 1972 when the flying is to be completed.

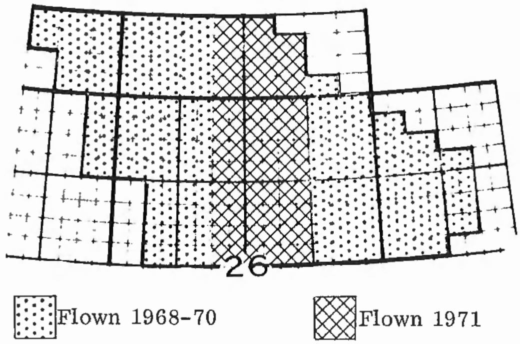


23. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS
Districts of Keewatin and Mackenzie - Project 690068 - A. Larochelle

During the 1971 field season, 38,000 square miles (76,000 line miles) of survey were flown. This contract was inspected in the field at Baker Lake, N.W.T. in August 1971. Total flying to date is approximately 141,000 line miles.



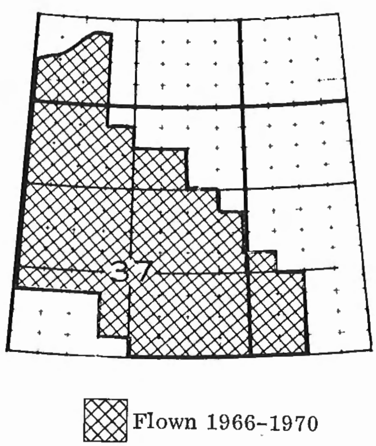
24. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS
Central Baffin Island - Project 690070 - A. Larochelle



During the field season 15,500 line miles (8,000 square miles) of aeromagnetic surveying were carried out to complete the flying on this contract. Fifty-six one-mile maps between 66° W and 70° W remain to be compiled and printed by March 1972.

---

25. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS
Northern Baffin Island - Project 690071 - A. Larochelle

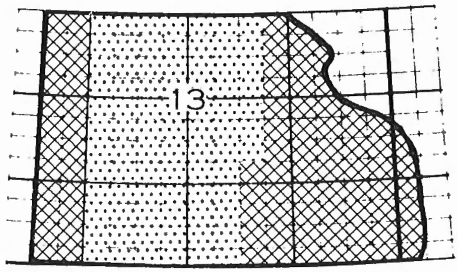


This contract, originally let in 1965, covered two years' work in the Yukon Territory and 85,100 line miles (42,000 square miles) in Baffin Island. Both the areas in the Yukon Territory have been published.

During 1970, 11,000 line miles were flown by Aero Photo Inc. on this contract to complete all the flying in Baffin Island. It is expected that all the maps on this contract west of 77° W (34 maps) will be printed and published by March 31, 1972 to complete the whole contract. All maps east of 77° W have been published.

---

26. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS
Labrador and Baffin Island - Project 690072 - A. Larochelle

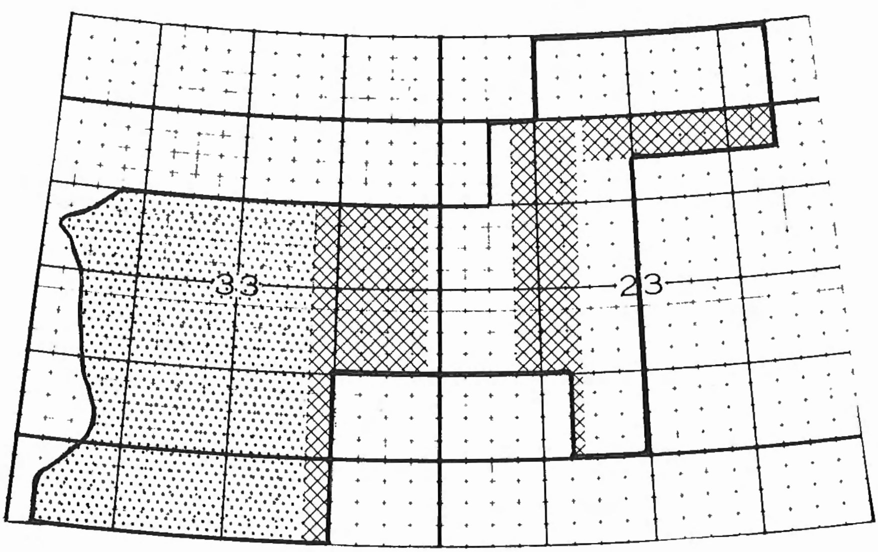


Flown 1971   Flown 1969-1971

Thirty-one thousand square miles (62,000 line miles) of aeromagnetic survey flying was achieved in Labrador during the field season using Goose Bay as a base. Fieldwork was not undertaken in southern Baffin Island during the 1971 field season.

---

27. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS
Quebec - Project 690073 - A. Larochelle

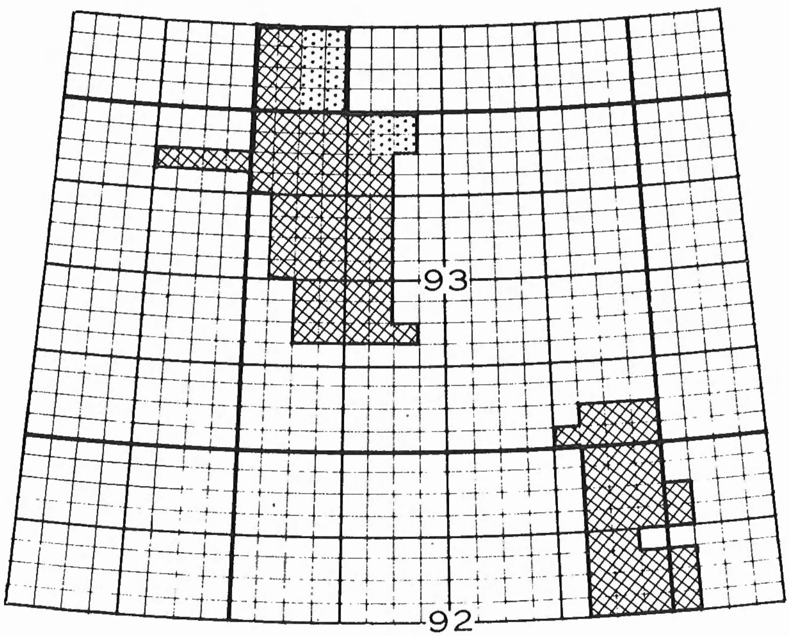


Flown 1971   Flown 1969-1970

As of September 11, 1971, 35,000 square miles (69,359 line miles) of surveying on this contract had been flown in the calendar year 1971. It is anticipated that flying on this contract will continue through the winter months and will be completed by March 31, 1972. Total contract mileage is 257,911 line miles. Total flown to date is 177,201 line miles.

---

28. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS
British Columbia - Project 700023 - A. Larochelle



To be flown   Flown and published to Dec., 1970

No survey flying was carried out during the normal field season of 1971 but the contractor returned to Smithers, B.C. on October 8 in an attempt to complete the area before the end of the calendar year. Total contract mileage is 78,500 line miles; approximately 6,000 line miles remain to be flown covering 12 one-mile sheets out of 114 sheets in the total contract.

29. SEISMIC REFRACTION STUDIES, INTERIOR PLATEAU, BRITISH COLUMBIA

Project 660051

H.A. MacAulay

Shot to detector times were recorded across several lakes in the Okanagan Valley and adjacent valleys. Both the shot and detectors were positioned on bedrock; bedrock velocities were measured on one or both sides of the valleys.

These data were gathered to test a theory that estimates of fill thickness in these glaciated valleys might be made without the conventional refraction or reflection requirement that either shots or detectors be placed at intervals along a profile across a valley. If such theory is correct, a simple method of determining the gross shape of a valley will be further developed and refined.

---

30. A SEISMIC EXPERIMENT OVER A METALLIC SULPHIDE DEPOSIT (32 C/14)

Project 700061

A. Overton

Tests were recently conducted preliminary to a comprehensive appraisal of the seismic method as a means of defining the location, shape and size of sulphide orebodies. The test site was chosen on a sulphide zone in Bartouille Tp., on highway 58, 27.5 miles from Senneterre toward Chibougamau. The mineral body consists of pyrite, pyrrhotite and some graphite, and its areal extent has been outlined by an SP survey, diamond drilling and trenching.

Preliminary tests consisted of a reversed refraction profile along a north-south line situated slightly to the east of the orebody, and of recordings into a seismometer profile along the same line from a series of shots along lines 200 feet east and west parallel to the seismometer profile. Thus, seismic paths from the western line of shots traverse the mineral body, while those from the eastern line of shots traverse host rocks consisting of metasedimentary breccias and tuffs interbedded with lava flows. These tests resulted in 307 time-distance determinations from 26 shots and 21 recording stations. Cursory analysis of the data indicate a significant difference in seismic velocities for the mineralized zone (about 18,000 ft./sec.) compared with that for the host rocks (about 15,000 ft./sec.). Detailed analyses, now in progress, will allow an excellent appraisal of seismic velocities through the mineralized zone and the host rocks, as well as indicating whether delay times through overburden, anistropic velocity effects, and random errors of measurement may be adequately resolved. Further tests will be considered based on these results.

---

31. HIGH RESOLUTION AEROMAGNETIC SURVEYS: 1971

Project 680081

P. Sawatzky and Peter J. Hood

During the 1971 field season three survey areas were flown with the Geological Survey's high resolution magnetometer survey system which is installed in a Queenair B80 aircraft. The areas were chosen in consultation with the appropriate provincial mines departments, and the experimental surveys were carried out in order to evaluate the contribution that high resolution aeromagnetic surveys may make to detailed geological mapping programs, such as the provincial mines departments carry out in Precambrian Shield areas.

Two of the survey areas were located north of Val-d'Or, Quebec (see Fig. 1) which was the base of operations. Approximately 10,000 line miles were flown in Quebec, including tie lines and reflights.

The third area was located east of Lake Nipigon (see Fig. 2) in the Geraldton-Jellicoe area of northwestern Ontario. The number of line miles flown in Ontario was slightly more than 10,000, including tie lines and reflights. The base of operations for this survey was Jellicoe.

In order to make the survey film available for the purpose of flight path recovery as soon as possible after the aircraft had returned from a survey flight, a continuous strip film processor was operated at each base of operation. This film processing capability enabled the flight path recovery to be performed in the field making it possible to keep a running check on the accuracy with which the survey lines were flown, and refly lines where the flight specifications were not acceptable.

Another survey innovation during the past season was the setting up of a mobile computer facility in the field which enabled the digitally-recorded magnetic tapes to be checked immediately after each flight. Any flaws in the digital data acquisition system were thus displated, making it possible to correct any malfunctions at the earliest opportunity rather than wait until the tapes had been checked in Ottawa, during which time the malfunctions could remain undetected throughout several survey flights.

The resultant high resolution maps will be issued in the form of total intensity maps at the smallest contour interval warranted for the accuracy of the data, and at the same scale as the published provincial geological map. It is well-known, however, that there is geologically-significant information contained in aeromagnetic survey data, often referred to as the 'fine structure', which does not appear on the standard total intensity maps because the contour interval used (10 gammas) in compiling the map is too coarse. For instance, many diabase dykes usually those having a tholeiitic composition, have no expression on the 10-gamma maps because they are too narrow and/or their effective magnetic susceptibility is not sufficiently high for them to produce a 10-gamma anomaly at the survey altitude of 1,000 feet. Further studies will be made to investigate the best method for the presentation of the 'fine structure' which will no doubt be some form of filtered map(s). The character and amplitude of the 'fine structure' is diagnostic of the inhomogeneity of the magnetization vectors of a given geological formation. Thus magnetization inhomogeneity may be considered to be a characteristic physical parameter i.e. one which geophysicists can utilize to distinguish one geological unit from

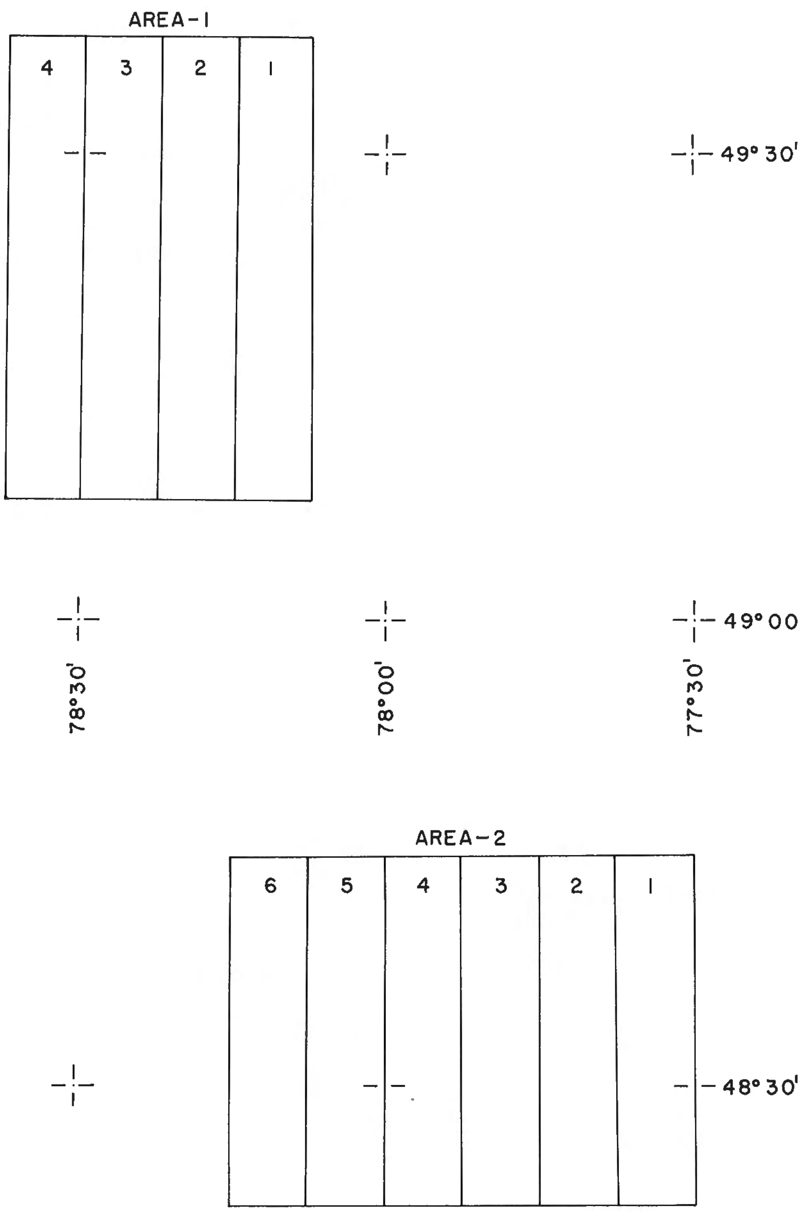


FIG.1 1971 SURVEY AREAS FLOWN WITH THE GSC HIGH RESOLUTION MAGNETOMETER IN P.Q.

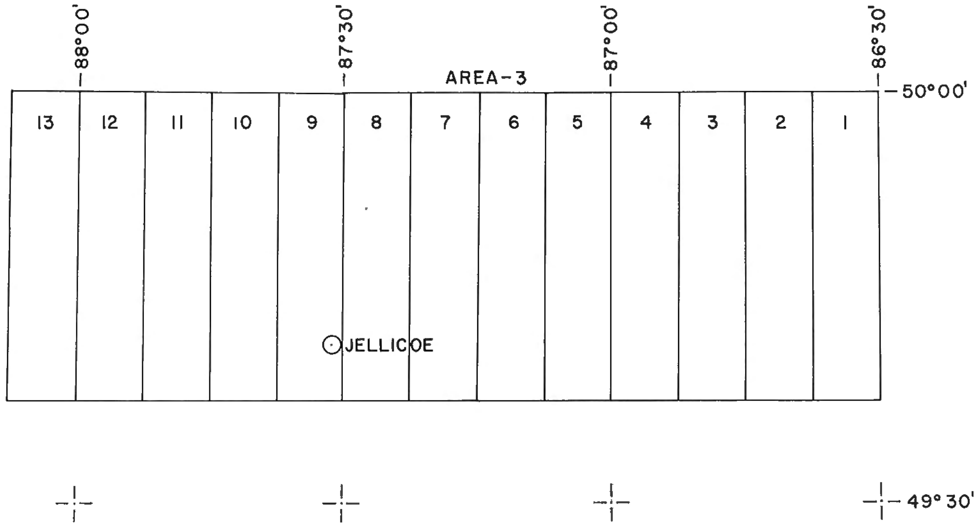


FIG.2 1971 SURVEY AREA FLOWN WITH THE GSC HIGH RESOLUTION MAGNETOMETER IN ONT.

another. It will be influenced by such factors as the inhomogeneity of the titanomagnetite distribution in the formation, the stability of the natural remanent magnetization and the metamorphic history of the geological formation.

A further objective of the field season was to ensure that the high resolution magnetometer and digital acquisition system was reliable in operation for long periods of time under actual survey conditions. The 1971 survey has demonstrated that this is the case. Personnel taking part in the foregoing surveys were full time - P. Sawatzky (Party Chief), K. H. Owens, A. Dicaire and H. W. C. Knapp; part time - R. Langlois and D. Abbinett together with three summer students.

---

32. VLF MAPPING

Project 670041

W.J. Scott

Ground VLF measurements employing the Radiohm technique were made in the Caledonian Mountain area of New Brunswick during the progress of an airborne VLF survey in the same area in 1971. Apparent resistivities determined from the ground measurements agreed qualitatively with those from the airborne survey although the ground values were on the average somewhat larger in magnitude.

Further measurements were made near Toronto and compared with pre-existing VLF data. Again the agreement was qualitatively good although airborne and ground values differed in magnitude. Work is continuing on this project.

---

33. COLOUR AERIAL PHOTOGRAPHY OF THE YELLOWKNIFE DISTRICT, NORTHWEST TERRITORIES (85 I, J)

Project 630031

V.R. Slaney

About 2,300 line miles of aerial colour photography has been flown within the area covered by sheets 85 I, Hearne Lake, and 85 J, Yellowknife. For this project, the Geological Survey's Skyvan aircraft was flown at a height of 7,500 feet above average ground level with a Wild RC8 camera using Kodak 2445 (colour negative) film. With flight lines at 3-mile intervals, the 1:15,000 scale (4.2 inches = 1 mile) provides approximately 70 per cent coverage of the 7,300-square-mile area.

The film has been developed and appears to be of reasonable to very good quality.

The photography will provide material for a photogeological interpretation of Precambrian areas within the two map-sheets. The interpretation will be used to support four related projects in the area:

1. An analysis of airborne gamma ray spectrometry data of the Yellowknife district (Project 670050).

2. An interpretation of existing airborne magnetic data (Project 660042).

3. Two Geological Survey mapping Projects 700015 and 710023.

Flight indices and log sheets for this imagery will be placed on Open File at the Geological Survey later in the year, and the negatives made available to the National Air Photo Library.

GEOCHEMISTRY

34. GEOCHEMICAL METHODS OF EXPLORATION IN PERMAFROST AREAS

Project 700046

R. J. Allan, E. M. Cameron, C. C. Durham and J. J. Lynch

Introduction

R. J. Allan

Canada's land area can be crudely divided into three parts: (1) nonpermafrost; (2) discontinuous permafrost; and (3) continuous permafrost. Most study sites for this program, which began in 1969, have been in the continuous permafrost zone. This has been for three reasons: (1) geochemical exploration techniques for nonpermafrost areas are fairly well established; (2) geochemistry as an exploration method in permafrost areas was virtually untested prior to 1969; and (3) should geochemistry be successful in the continuous permafrost zone, it follows that it will likely be successful in the discontinuous zone. Three widely spaced locations were visited during the summer of 1971. The results of the studies are described. As evidenced by the variety of sample media and the variable sample densities employed, the program is designed to devise and test detailed and regional techniques simultaneously.

(a) Low Sample Density Limnic Geochemistry - A New Technique For Reconnaissance Geochemical Exploration Within The Canadian Shield

R. J. Allan, E. M. Cameron, C. C. Durham and J. J. Lynch

Much of the Canadian Shield may be characterized as country of low relief dotted with many lakes. Although some areas are covered by thick glacial deposits, which partly mask the geochemical expression of the underlying rocks, most of the Shield is bare rock or is covered by thin Pleistocene or Recent drift. This terrane is quite suitable for certain geochemical methods of exploration. The low relief has produced an often complex drainage system within which inorganic sediments are irregularly developed. Thus, conventional methods of reconnaissance geochemical exploration, using stream sediment sampling, is impractical for most parts of the Shield. An obvious alternative is to sample lake waters and sediments - limnic methods of geochemical exploration.

Because of the difficulty of travelling across typical Shield terrain, geochemical sampling must be carried out using aircraft, generally helicopters. Sampling costs are high and to cover large areas economically the sample medium must be effective at a wide sampling interval.

Sampling and analysis of lake waters has been carried out previously in the Coppermine area (approx. 68° N, 116° W), N. W. T. for copper[1], in the

Kaminak Lake area for mercury[2] and for uranium within the Beaverlodge district of Saskatchewan[3]. In all of these cases sampling at site densities as low as 1 sample per 10 square miles gave positive results. At Coppermine this density outlined a 200-square-mile zone of copper mineralization in the Coppermine basalts. At Beaverlodge, the regional pattern of uranium distribution at 1 sample per 10 square miles is essentially similar to that at 1 square mile. Within the Kaminak Lake area the mercury in water distribution at 1 sample per 10 square miles correlates well with the known distribution of bedrock types underlying glacial drift.

In addition to the study of lake waters at Coppermine, lake sediments were collected and analyzed from the same 1,500-square-mile area.[4] These samples successfully outlined the areas of anomalous mineralization at a 1 per 10-square-mile sample density. The sediments of this area give far superior results compared to water. In part this is due to the difficulty of analyzing indicator elements at the low concentrations present in lake waters.

Concurrently with the lake water and sediment sampling program in the Coppermine area, a geochemical study of the rocks of the area was made.[5] This showed that parts of the Coppermine basalts contained widely distributed minor copper mineralization or "microdeposits". It was suggested that the deposits and microdeposits of the Coppermine basalts are genetically related, the deposits being the extreme right tail of a more general frequency distribution curve of copper mineralization within the basalts.

By combining the two sets of Coppermine data, that for the rocks and that for the lake sediments and waters, it was apparent that the enrichment of copper in the limnic materials throughout the 200-square-mile anomalous area was not due to copper derived from copper ore occurrences. Instead it was caused by copper derived from copper sulphides widely distributed through the rocks of the anomalous area. Thus the successful application of reconnaissance geochemical sampling programs at a density of 1 sample per 10 square miles depends on there being a suitable dispersion through the rock unit of the economic trace element sought. This dispersion should be in the same mineralogical form as the element is expected to take in economic ore occurrences. Prior to an extensive limnic geochemical survey planned for parts of the Bear and Slave provinces of the Canadian Shield in 1972, a combined lake sediment and water and rock geochemical study was carried out during the summer of 1971 in a number of areas within these geological provinces. Transport was by a Beaver aircraft. The purpose of the study was to establish the most generally useful indicator elements for a variety of mineral deposits; and to establish the types of deposits whose associated zones of mineralization could be picked up at a coarse sampling density. Eight areas were chosen and averaged 200 square miles in size. Seven contained known or suspected mineral occurrences of varied type; one contained no known mineralization. The areas were chosen to represent other varied conditions: north and south of the treeline; discontinuous and continuous permafrost; and high and low relief.

The results of this work indicate that water methods are best used only to confirm sediment methods because the background levels of most interesting indicator elements in natural waters are often below present analytical detection limits. Analytical methods are already of sufficient sensitivity for mercury. Future efforts in our laboratories to lower detection limits will increase the effectiveness of water sampling for exploration in the Shield. This is important because waters may be collected more readily and therefore more cheaply than sediment samples. Of significance is the fact that copper levels in lakes in the Coppermine area were virtually the same in 1969, 1970 and 1971.

The sediment data successfully outlined areas of higher trace element concentration around known economic deposits; again this appears to be caused by the microdeposit population associated with them. The size of the "anomalous" areas appears to be quite suitable for their discovery on a coarse sampling grid. "Anomalous" is used here to indicate areas of interest. These areas of interest have either very high concentrations of one trace element or higher concentrations of several trace elements relative to surrounding areas. Areas of interest because of their increased regional trace element content provide positive focus for detailed exploration to locate ore deposits. For instance, around two known greenstone belt sulphide deposits of copper-zinc and lead-zinc-silver, there were "anomalous" zones of 40 and 25 square miles respectively given by a number of different indicator elements. Although exploration can be focused in such areas of interest, this does not positively mean that areas of low trace element content do not contain mineral deposits. Because the range of trace element levels defining an anomalous zone is small, the interpretation of large scale surveys of this type can be critical.

For the Bear-Slave provinces, limnic methods of reconnaissance geochemical exploration are effective for outlining zones of higher than background metal content. These areas which are likely to be associated with mineralization serve as foci for more detailed mineral exploration. At a cost of approximately seven dollars per square mile, the methods are attractively economic. There is every possibility that the limnic method can be equally well applied to most areas of the Canadian Shield.

(b) Surficial Dispersion of Trace Elements in the Vicinity of a Ni Deposit, Raglan Area, Cape Smith–Wakeham Bay Belt, Ungava, Quebec

R. J. Allan

Samples of surface silty frost boils, sandy frost boils on eskers, stream and lake sediments and waters, snow and moss were collected above and around the ore zones of a Ni deposit (New Quebec Raglan Ltd. – approx. 61° 51'N, 73° 50'W) in Ungava. The NiS ore at this location is associated with a serpentinite sill, part of a Proterozoic geosynclinal volcanic-sedimentary sequence. Nickel is one of the elements which if present in large enough quantities can now be economically mined in the Arctic.

(i) Frost Boils

The ore areas have been disturbed by drilling activity; however, by careful selection, frost boil sample grids at approximate 100-foot spacings were collected above the main ore zones. The boils are developed in fine textured glacial drift. At locations where the serpentinite sill suboutcrops the surface is one of large angular frost-rived ultrabasic boulders and intervening silty frost boils. There is no difficulty anywhere in the area in finding frost boils, even in areas which at first glance appear to be completely felsenmeer. Silty frost boils were previously found to be the best sample medium for detailed prospecting for copper in the Coppermine River area[6].

Frost boil surface soil samples were collected from grids above three ore zones. The first ore zone suboutcrops beneath the shallow glacial cover. Ni contents in the frost boils were 300 to over 1,200 ppm in the < 80 mesh fraction. Analysis was by hot nitric acid leach and atomic absorption spectrophotometry. At the second zone, which is at shallow depth under the overlying rocks, the frost boil Ni concentrations were mainly from 150 ppm to 300 ppm. At the third zone, which is at the 700-foot-level, frost boil Ni concentrations were around 75 ppm to 150 ppm. This variation of 300 to 150 to 75 ppm Ni may be related to the formation of trace element haloes around the serpentinite and accentuated around ore pods within the sill.

These haloes may have been formed during emplacement of the sill eventually with accumulation of ore in pods, or during the serpentinization process when hot solutions may have redissolved sulphides and carried the Ni in solution along fractures and zones of weakness in the overlying and underlying rocks; in the case of Raglan, these were shales and basalt flows. The surface frost boil Ni concentrations may reflect the intersection of three haloes, in the immediately underlying bedrock, by the sample grids.

Frost boils at the edge of grid three, that above the 700-foot-level ore pod, had Ni concentrations less than 75 ppm. Also frost boils taken on a serpentinite sill thought to be unmineralized had Ni values less than 75 ppm. Should this halo hypothesis be correct, then surface frost boil sampling and analysis over large areas of mineralized serpentinite sill outcrop and suboutcrop would be a relatively inexpensive method of attempting to locate ore pods. The present method of location depends heavily on geophysics and diamond drilling. Should geophysical anomalies also be found to be geochemical anomalies or vice versa, this would be a considerable asset in deciding which to drill to locate other pods in the Ungava Ni belt.

(ii) Lake and stream sediments

Dispersions of Ni from the Raglan ore zones into stream and lake sediment reflects the presence of the mineralized serpentinite sill but did not define the location of the Raglan deposit in relation to other showings on the same sill.

The highest sediment concentrations were found in the bed of the Povungnituk River (now diverted by exploration operations). These were 100 to 200 ppm Ni. Lesser values of 75 to 125 ppm Ni were found in stream and river sediments close to the other showings immediately west of the Raglan area. Sample spacing to locate drill targets via stream sediments would have to be less than 1/4 mile to be meaningful.

(iii) Waters

The water results could not be directly used to assess the effect of the ore due to diversion of Povungnituk River by exploration activities. Samples of water taken from lakes and rivers near the Raglan sill had concentrations of 4 to 8 ppb Ni as opposed to samples taken in the vicinity of other sills which had 4 or less ppb Ni. The waters were analyzed by an organic extraction procedure and atomic absorption spectrophotometry. It would seem that collection of stream and river water samples at a sample spacing of less than 1,000-foot intervals, a very simple and rapid procedure, could help to separate stretches of sills with greater mineralization and therefore possibly greater ore potential.

(iv) Snow

The central part of the Raglan surface showing was covered with snow to a depth of 4 feet in late June. Samples of the snow from about one foot above the ground surface were collected which, on melting, produced crystal clear water apparently uncontaminated by aerosols. The snow samples contained 20 to 50 ppb Ni. Snow in general contains less than 1 ppb Ni (I. R. Jonasson, pers. comm.). Although only 15 samples were collected they did indicate the possible use of snow in the detection of underlying mineralization. The mechanisms of transport of the Ni into the snow are unknown.

(v) Colour photography

One of the significant observations was that in certain areas the frost boils with the highest Ni contents had a green coloration visible to the naked eye. There is a possibility that low-level airborne colour photography may prove useful in regional geochemical exploration in the Cape Smith–Wakeham Bay Belt.

(vi) Eskers

Samples were collected from sandy frost boils along the crests of two eskers, one about 2 miles southwest of Raglan and one about 2 miles northeast of Raglan. The sandy boil sediments were sieved to less than 40 but greater than 80 mesh and the solution obtained by hot nitric acid leach used for the determination of Ni. Ice movement was from south to north. The Ni concentrations in the surface frost boil samples from the esker to the south of Raglan were all less than 40 ppm. Those in the esker to the north ranged up to over 120 ppm and averaged 65 ppm Ni. There is some indication that sampling of surface sandy frost boils on eskers will act as regional indicators of mineralized sills. The present river drainage is in the opposite direction to the south to north glacial esker drainage and perhaps a combination of the two may be a useful regional technique.

(vii) Summary

(1) Silty frost boils are the best detailed soil sampling media.
(2) Stream sediments are not in themselves particularly successful. However only a small area was sampled due to lack of air support.
(3) Stream sediments provide greater focus when collected in conjunction with esker sandy frost boils and stream and river waters.
(4) Snow may be a possible detailed sample medium in early spring.

(c) Surficial Dispersion of Trace Elements in the Vicinity of a Pb-Zn Deposit, Little Cornwallis Island, District of Franklin

R. J. Allan

Samples of surface silty frost boils, and stream and lake sediments and waters were collected above and around the Eclipse ore zone (about 1 million tons 12.43% Zn, 2.18% Pb) on little Cornwallis Island (approx. 76° N, 97° W). This is a Pb-Zn deposit, owned by Bankeno Mines and

Cominco Ltd., that is associated with Paleozoic carbonates. Only recently another Cominco owned Pb-Zn deposit at Polaris on Little Cornwallis Island, has been reassessed to be of potentially large tonnage based on widely spaced drill holes. Pb-Zn is a commodity that along with Cu and Ni could possibly be economically mined in the Arctic.

(i) Frost boils

The surface frost boil samples taken from immediately above the ore zone contain between 3 and 7 per cent Zn. Contents in a false pedogeochemical anomaly located by soil sampling (Cominco Ltd., pers. comm.) were 0.1 to 0.6 per cent Zn in surface frost boils.

(ii) Stream and lake sediments

Sediments from two streams possibly draining the ore zone to the north and south contained 500 to 600 ppm Zn. Higher values relative to streams not affected by known mineralization were maintained up to 1.5 miles from the ore zone. Concentrations of Zn in stream sediments were considered anomalous when greater than 100 ppm in the < 80 mesh fraction. There are not sufficient lakes in the area to make lake sampling a feasible regional exploration method. The small lakes closest to the ore zone, about 0.5 mile away, had 190 and 84 ppm Zn, whereas those distant from the ore zone contained 30 to 50 ppm Zn in their sediments. However, streams in the area are easily visible, often appearing from the air as dark black lines on a brown and yellow background. Although the streams dry out, sediment can always be readily obtained. Weathering is intense and the rock types in the area, shales and carbonates, are reduced to deep weathered overburden. At least on Little Cornwallis Island, glacial transport appears to be minimal, as sub-outcropping rock boundaries can be traced by changes in the colour of the silty surface frost boils. Based on these conditions, and similar pilot study results, the area is ideal for regional stream sediment geochemistry. Such a regional geochemical survey was carried out in the late 1960's by Cominco Ltd. Anomalies were located on favourable rock types on Cornwallis Island and certain of these are now being explored in more detail. Regional stream sediment geochemical surveys in this part of the Arctic Islands is a feasible and useful exploration technique.

(iii) Stream and lake waters

Water samples from the stream draining the ore zone to the north had up to 40 ppb Zn. The presence of the ore zone could be detected by higher than normal zinc concentrations for up to 1 mile. None of the other streams, including that possibly draining the ore zone to the south, had anomalous zinc contents. Pb concentrations were anomalous only at sites immediately above the ore zone. Collection of waters at sample spacings of 1,000 feet maximum, at the end of the spring run-off, could be used as a confirmation technique for stream sediment sampling later in the season.

Future Analytical Determinations and General Conclusion

R. J. Allan

The samples of surficial materials, soils (frost boils), and stream and lake sediments collected at three main locations mentioned so far, i. e. Coppermine, Ungava and Little Cornwallis Island areas, will be analyzed in detail to investigate the dispersion phases and mechanisms for these elements in the permafrost zone. Selected samples of specific materials will be analyzed in several ways to determine the physical, chemical and mineralogical controls on the dispersion process. The three sample locations are in the western, eastern and high Arctic respectively.

The results presented above already show that at all locations the surficial dispersion of trace elements is sufficient to indicate the successful use of geochemical exploration at both detailed and regional levels. It will not be successful in all cases but, as geochemistry is a relatively inexpensive exploration tool, this should be no deterrent to its use in mineral exploration in permafrost areas.

[1] Boyle, R. W., Hornbrook, E. H. W., Allan, R. J., Dyck, W. and Smith, A. Y.: Hydrogeochemical methods application in the Canadian Shield; Can. Mining Met. Bull., vol. 64, No. 715 (1971).

[2] Hornbrook, E. H. W. and Jonasson, I. R.: Mercury in permafrost regions: occurrence and distribution in the Kaminak Lake area, N. W. T.; Geol. Surv. Can. Paper 71-43 (1971).

[3] Dyck, W., Dass, A. S., Durham, C. C., Hobbs, J. D., Pelchat, J. C. and Galbraith, J. H.: Comparison of regional uranium exploration methods in the Beaverlodge area, Saskatchewan; Can. Inst. Mining Met. Spec. Vol. 11, pp. 132-150 (1971).

[4] Allan, R. J.: Lake sediment: a medium for regional geochemical exploration of the Canadian Shield; Can. Mining Met. Bull., vol. 64, No. 715 (1971).

[5] Cameron, E. M. and Barager, W. R. A.: Distribution of ore elements in rocks for evaluating ore potential frequency distribution of Cu in the Coppermine River Group and Yellowknife Group volcanic rocks, N. W. T., Canada; Can. Inst. Mining Met. Spec. Vol. 11, pp. 570-576 (1971).

[6] Allan, R. J. and Hornbrook, E. H. W.: Exploration geochemistry evaluation study in a region of continuous permafrost, N. W. T.; Canada, Can. Inst. Mining Met. Spec. Vol. 11, pp. 53-66 (1971).

35. GEOCHEMISTRY OF GOLD DEPOSITS

Project 650438

R.W. Boyle

During the field season June-November 1971, sampling of materials for the study of the distribution of gold and silver in rocks was carried out in southwestern Ontario, eastern Ontario, and northern Ontario.

Point Pelee National Park was visited and samples of the soil, glacial and lake sand, and surface waters were collected for ecological studies.

The E.G.M.A. area of northern Ontario and Quebec was visited for two weeks by J.P. Lalonde preparatory to beginning a study on the ground waters in the area in 1972 (Project 710078).

36. PORTABLE INSTRUMENTATION FOR DETECTION AND MEASUREMENT OF Hg, As and Se

Project 700087

Q. Bristow

Work has continued on the development of the quartz crystal mercury vapour detector for soil gas measurements and several modifications were made to the injection system to improve the collection efficiency of the gold electrode surfaces. Approximately half of the mercury in the air stream is now purged out by the gold surfaces, even though their total area is only 0.4 cm^2. A series of laboratory calibrations were carried out to check the reproducibility of the crystals after heating to drive off accumulated mercury; the results were not as good as had been hoped for in this regard and an explanation is still sought for the discrepancies which have arisen.

A very brief field test was made over the cinnabar showing at Clyde Forks, Ontario to see if significant amounts of mercury could be detected in the soil gases there. The method consisted of drilling a 1-inch diameter hole with a hand auger, and inserting a tube around which a sealing cone was fitted, to a depth of approximately 1 foot, the cone sealing the top of the hole. A hand pump was then used to inflate a small air cushion, volume approximately 4 litres, which acted as a reservoir buffer to maintain a flow of one litre/minute over the crystal electrodes via a pressure regulator. Significant readings were obtained with the instrument but contamination of the pump by soil particulates threw doubt on the later results. However, the results are considered sufficiently encouraging to warrant a further field test using a more efficient type of probe.

A commercial high sensitivity mercury vapour detector, working on the atomic absorption principle and designed primarily for atmospheric monitoring, was tested both at the Clyde Forks location and in the Noranda area. No clear evidence of atmospheric mercury aureoles was found at ground level over any of the test areas selected. High soil gas readings (120-1300 nanograms/m^3) were obtained at Clyde Forks but much lower levels (less than 200 nanograms/m^3) were found at the selected test sites in the

Noranda area. A more efficient method of gas extraction and a smaller absorption cell might well effect a considerable increase in the overall sensitivity technique.

A prototype version of an atomic absorption instrument specific to mercury, and having a relatively small absorption cell volume, has been designed and is now under construction.

---

37. FEASIBILITY STUDY OF GEOCHEMICAL SAMPLING OF ARCTIC COASTAL STREAMS BY HELICOPTER FROM DEPARTMENT OF TRANSPORT ICEBREAKER

Project 710009

Willy Dyck and G.M. Thomas

To determine the feasibility of sampling streams along coastal waters of Arctic Islands using the helicopter on board a Department of Transport icebreaker, without interfering in the routine operation of the ship, a two-man party boarded the John A. Macdonald at Dartmouth early in July, 1971.

During the period July 9 to August 19, 1971, 69 water and sediment samples from 54 stream sites were collected from 8 regions. At 15 of these sites another sample from the brackish water zone, where the stream entered the sea, was also collected. Of the factors influencing sampling, the ship's route and weather were most decisive. The approximate location of the areas and the number of samples from each area are: Hudson Bay–Churchill River (19); Hudson Strait–Barrier Inlet (3); Deception Bay (9); Frobisher Bay–Buerger Point (7); Chase Island (5); York River (7); Ungava Bay–George River (4); Devon Island–Hope Monument (6); Croker Bay (9). The most striking features near glaciers, like those encountered at Frobisher Bay and Devon Island, are the short V-shaped stream beds, the unglaciated mountains with evidence of extensive weathering, large talus slopes, and abundant sediment at the mouth of streams. The well-rounded hills and gentler topography in the Ungava Bay and Hudson Strait and the flat relief around Churchill provided marked contrast.

The water samples were analyzed on board ship for radon, alkalinity and, using specific ion electrodes, pH, eH, oxygen, calcium, divalent, and chloride ions. A one-litre water sample was acidified with nitric acid for further analysis at headquarters. The 5- to 8-pound samples of sediments were dried in the helicopter hangar before packing for shipment to headquarters.

The analyses on board ship showed that the waters were essentially saturated with oxygen at the temperature and pressure at the sample site and fluctuated around 11 ppm; eH values were found to be about 160 to 210 mv with respect to the platinum electrode. Radon concentrations were generally near zero; however, waters from granitic regions contained easily detectable amounts of radon. The alkalinity test and the determinations of pH, calcium-, divalent-, and chloride ions gave clear evidence of rock types comprising the hinterland (e.g. limestone) and the intermixture of traces of sea water.

It is considered that the additional effort and cost required to obtain immediate analytical results on board ship is not warranted in view of the small number of samples that can be collected in any one season. Such analytical work could be done in the Ottawa laboratories by sending samples back during stops made by the ship at points served by scheduled aircraft. A detailed report will be prepared when all analytical results are available.

On the basis of this year's feasibility study, it is evident that, by omitting the laboratory and putting only one experienced student on a ship for the summer months, the method is an attractive and economical way of collecting geochemical information from the Arctic coastline, a region where normal field operations are very expensive.

---

38. REGIONAL GEOCHEMICAL CENSUS OF PLUTONIC ROCKS IN EASTERN YUKON TERRITORY (95 E, L, parts of 105 H, I)

Project 690036

R.G. Garrett

The regional rock sampling program commenced in 1970[1,2] was continued and completed. The Cretaceous acidic intrusions lying in NTS sheets 95 E and L, and the northeast half of 105 H and the southeast half of 105 I, were sampled. Approximately 8,000 square miles of mountainous terrain in the Yukon and Northwest Territories were covered, of this area only 1,750 square miles are intrusive acidic rocks. In 15 working days 934 samples were collected from 467 sites with the aid of a Bell 47G-3B helicopter; the majority of sites were between 5,500 and 7,000 feet above sea level, with extremes at 3,500 and 8,100 feet. Samples of the enclosing sedimentary rocks were also collected as had been done during the 1970 field season.

The sampled rocks of the southern part of the Selwyn plutonic belt can be divided into three groups. Firstly, coarsely porphyritic granodiorite and quartz monzonite, typical of the larger intrusions. Secondly, a finer grained variety of similar rocks mostly found around the margins of the larger intrusions and in small stocks; however, it should be mentioned that some small stocks are formed of porphyritic varieties. Lastly, in the northeast part of the Francis Lake sheet (105 H) an extensively altered variety occurs in which there is evidence of post-intrusive movement, as indicated by foliation and a generally sheared appearance together with a development of chlorite and epidote.

Three features of interest were noted which may have some relation to areas of mineral potential.

Firstly, in the intrusion southeast of Skinboat Lakes (NTS 95 E) two sites, approximately six miles south and on the western edge, were of interest. The first (UTM 09 626300 6774900) is a local area of hematitized quartz monzonite containing some arsenopyrite; and the second (UTM 09 627900 6775100), one mile to the east, is a local area of quartz diorite with minor tourmaline veins.

Secondly, at the southern end of the large intrusion lying between Coal River and West Coal River (NTS 95 E) two sites were visited where fine-grained quartz monzonite (UTM 09 567900 6773700) and a coarser grained variety (UTM 09 568600 6775900) were found to contain 2 per cent disseminated pyrite.

Lastly, a number of sites were visited in a pluton 11 miles south of Canada Tungsten (NTS 105 H) and within 2 to 3 miles of the Cantung Road, where evidence of mineralization and alteration were found. In a cirque at the south end of the intrusion (UTM 09 541200 6850700) porphyritic quartz monzonite float was found to contain rosettes of molybdenite. One mile to the north (UTM 09 541400 6852300) on the edge of a small glacier, float of both fresh quartz monzonite and greisen was obtained. One and one half miles northwest (UTM 09 540000 6854600) a schorl dyke 2 feet wide was found in an area of alaskite intrusive into the quartz monzonite of the intrusion. It is considered that the proximity of these occurrences indicates that this pluton was a focus of late stage magmatic activity and the area warrants further investigation.

The samples are currently being analyzed for a wide range of elements and any data of possible economic significance will be made available as a Geological Survey open-file report during 1972.

[1] Garrett, R.G.: Regional geochemical census of plutonic rocks in eastern Yukon Territory; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 72-73 (1971).

[2] Garrett, R.G.: Molybdenum, tungsten and uranium in acidic plutonic rocks as a guide to regional exploration, southeast Yukon; Can. Mining J., vol. 92, No. 4, pp. 37-40 (1971).

---

39. FEASIBILITY PILOT STUDY OF GEOCHEMICAL RECONNAISSANCE METHODS IN THE ENNADAI-RANKIN BELT, DISTRICT OF KEEWATIN

Project 700062

E.H.W. Hornbrook

Field studies were conducted near Kaminak Lake in the Ennadai-Rankin Belt of volcanic and sedimentary rock, Keewatin District, Northwest Territories, in order to determine the effectiveness of regional geochemical methods, particularly those of hydrogeochemistry.

Similar studies in 1970, in which 500 ml samples of water were collected, produced useful hydrogeochemical anomalies varying in size from a few square miles to 150 square miles, in the study area of 2,500 square miles[1]. Interpretation of the data and the preparation of geochemical anomaly maps was restricted by the very low, less than 1 ppb, background element concentrations which were below analytical detection limit. In order to improve the effectiveness of the technique by developing more sensitive analytical methods, large water samples were collected this year to enable the determination of the very low background concentrations; the analytical work is in progress.

Major emphasis was placed this summer on the collection of lake and stream waters, and stream sediments, to measure the occurrence of Hg in inlet bays and streams. Stream sediments have the highest Hg content and, in general, inlet bay water samples are equal to, or greater than the inlet stream waters in their Hg contents. It would appear that the Hg concentrations in inlet bay water samples correspond better to the Hg concentrations in stream sediments than do stream waters. The sampling carried out this year, at a density of approximately one sample per one-half mile of shoreline, is seen to be an improvement on that of last year (1 sample/10 square miles) because of the greater detail obtained. Mercury anomaly maps based on last year's data delineated major structures and discriminated between granitic plutons and sedimentary and volcanic rock in geological complexes extensively overlain by glacial deposits. The more detailed work has, in addition, indicated areas of till underlain by acid volcanics or sediments as well as the location of some of the known sources of mineralization.

Hydrogeochemical Hg surveys can thus be useful both for geological mapping and mineral exploration in these and, probably, similar till-covered sedimentary and volcanic belts, and in providing data of interest to environmental scientists.

[1] Boyle, R.W., Hornbrook, E.H.W., Allan, R.J., Dyck, W. and Smith, A.Y.: Hydrogeochemical methods - application in the Canadian Shield; in Proc. Annual Meeting Can. Inst. Mining Met., Quebec, P.Q., April 27, 1971; Can. Mining Met. Bull., vol. 64, pp. 60-71 (1971).

[2] Hornbrook, E.H.W. and Jonasson, I.R.: Mercury in permafrost regions: occurrence and distribution in the Kaminak Lake area, Northwest Territories; Geol. Surv. Can., Paper 71-43 (1971).

---

40. GEOCHEMICAL AND BIOGEOCHEMICAL SURVEYS IN THE TIMMINS-VAL D'OR AREA

Project 710079

E.H.W. Hornbrook

Mining Camps in the Timmins, Kirkland Lake, Rouyn-Noranda and Val d'Or areas were visited during August, 1971.

Samples of rock, basal till, clay, developed soil horizons, peat, vegetation, both lake and stream waters and sediments, and natural spring waters were collected with emphasis upon sediments and waters.

Intensive sampling was carried out adjacent to known mineralization in order to detect the presence of element haloes and to determine their intensity in various surficial materials and their size. Samples were also collected on a regional basis to obtain element background values and to determine, if possible, the relationship of the geochemistry of surficial materials to geology, structure, and the distribution of glacial sediments. At present, only the determination of Hg has been completed; no significant Hg occurrence or distribution was found, although a few sample sites had Hg concentrations above background.

There is a good potential for geochemical exploration, although its present use is not as common as that of exploration geophysics. In the selection of a drill target, use can be made of the geochemistry of basal till in clay terrain to discriminate among several geophysical anomalies. The application of rock geochemistry can be effective where outcrops are abundant and, where lacustrine clays are absent, surficial geochemistry may also be effectively used for local studies.

---

41. MERCURY IN SOIL GAS APPLIED TO EXPLORATION FOR SULPHIDE ORES

Project 690091

I. R. Jonasson

Work continued through 1970-71 on various aspects of the above project. Field work was restricted to short excursions into the Clyde Forks area, Lanark County, Ontario in both summer and winter. During the summer, routine sampling of soils, rocks, waters and sediments over a small mineralized area continued, with a view to further detailing geochemical distribution of mercury about known mineralization.

A beginning was made on a sampling program designed to assess the value of using mercury vapour in soil gases to map, in this case, the extensions of mineralized veins consisting mainly of tetrahedrite. So far, the results are quite favourable - soil gas mercury does in fact show anomalous levels along the strike of the mineralized veins. Anomalies produced from soil gas data coincide with those outlined by conventional pedogeochemical methods (see Geol. Surv. Can., Paper 71-1, Pt. A, p. 74). The instrumentation used for soil gas measurements was designed by Scintrex Canada whose scientists co-operated in the testing program (see Bristow, Q., this publ.).

Because of the anticipated mobility of soil gas mercury, it was considered reasonable to assume that mercury vapour may find its way into winter snows overlying mineralization. To check this possibility a series of samples of snow were taken at different depths over soils known to contain >500 ppm Hg and over soils known to contain <1 ppm Hg. Over unmineralized ground the mercury content of three feet of snow sampled at one-foot intervals was less than the detection limit of 0.01 ppb. Over mineralization, a concentration gradient was found for mercury in five feet of snow which ranged from <0.01 ppb at the surface of the snow to 0.52 ppb at one foot above ground level. Moreover, similar fifty-fold concentration gradients were found for Cu, Zn and Pb in the same samples.

These findings add considerable impetus to the search for other vapours emanating from sulphide deposits and which may find application in geochemical prospecting. It is considered likely that the source of all of the metals in snow, including mercury, is from volatile compounds produced in some way within the soils.

The recent acquisition of an integrated gas chromatography-mass spectrometer unit has provided for the project a capability which will enable direct measurement of concentrations of such vapours in soil gases as well as to assist in defining their chemical character. The instrumentation has been installed and is undergoing testing and adaption to the needs of the soil gas program.

MINERAL DEPOSITS

42. ULTRAMAFIC FLOWS AND NICKEL SULPHIDE DEPOSITS IN THE ABITIBI OROGENIC BELT

Project 630037

O.R. Eckstrand

Previous suggestions[1] that some of the Archean ultramafic rocks in the Abitibi orogenic belt are volcanic flows are now strongly supported by field evidence in exceptional exposures in Munro Township, northern Ontario. The purpose of this note is twofold: (1) to indicate presently known geographical distribution in Canada of the ultramafic rocks believed to be flows, and (2) to discuss their spatial relationship to nickel sulphide deposits.

Recognition and distribution of ultramafic flows

Certain Archean ultramafic rocks have a distinctive combination of textural and layered features. They are characterized by thin layers (1 to 5 feet) having a coarse, random to subradiating lathy texture, alternating with thicker layers having fine-grained, massive texture. The coarse, lathy texture has been called "spinifex", "chicken-track", "bird-track", "herringbone", "feather", or "quench" texture. The term "spinifex" which is the name of a species of grass in Australia that grows in radiating clumps, seems to have the broadest usage, and will be used in this paper. Occurrences of spinifex texture in the Abitibi orogenic belt have been described by Bruce[2], Prest[3], Satterly[4], Naldrett[1], Naldrett and Mason[5], and Pyke[6]. It has also been reported in Archean ultramafic rocks in the Pilbara block of Western Australia[7], and in the Barberton Mountainland of South Africa[8]. Some writers have attributed the development of this texture to metamorphic recrystallization, or to serpentinization of mafic flows, but more recently, others[5,9] have argued persuasively that it results from rapid crystallization of olivine in a super-cooled ultramafic magma.

Naldrett[1] has suggested that these layered and spinifex-textured ultramafic rocks in the Abitibi orogenic belt are volcanic flows, and cites an interpretation by Viljoen and Viljoen[8] to the same effect, concerning similar rocks in South Africa. During this past field season, the recognition of new evidence in excellent exposures in Munro Township north of Kirkland Lake, has made this interpretation highly probable[10,11]. The evidence will not be reviewed in detail in this note, but it seems worthwhile to consider some of the general features of occurrence and distribution.

The ultramafic flows generally seem to occur as a sequence of tabular, superposed flow units. Many of the flow units in the Munro Township locality contain zones of conspicuous spinifex texture, but many others do not. The latter can appear quite massive and featureless, except for inconspicuous fractured flow tops. Top determinations based on grain size gradation of spinifex texture and recognition of flow tops[11] are consistent with those obtained in adjacent supracrustal rocks. The latter may comprise any of the common lithologic units found in the Abitibi orogenic belt.

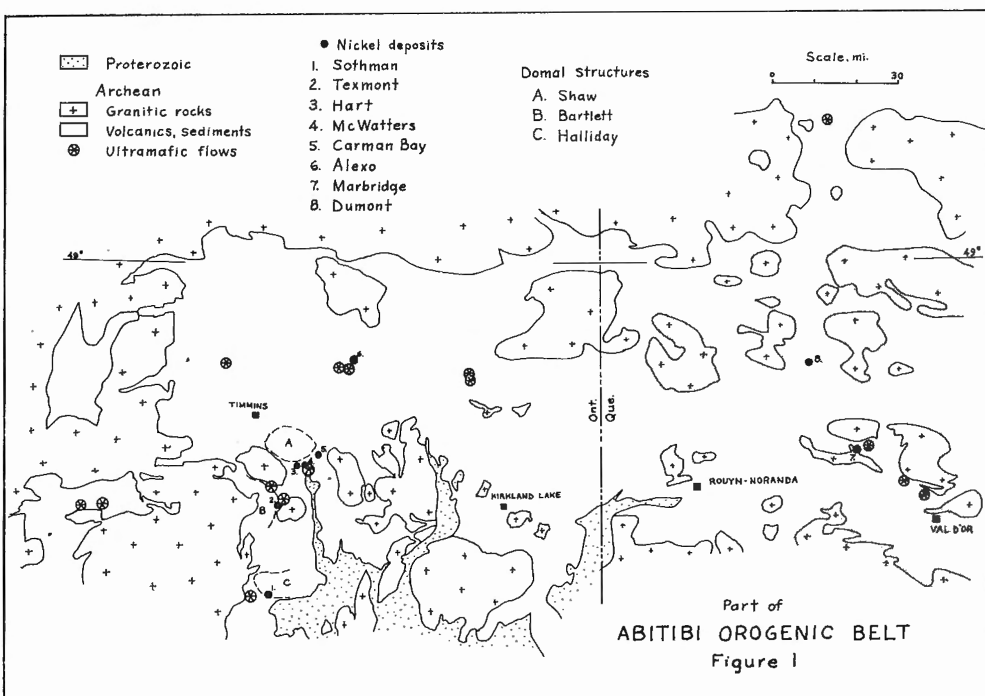
It should be noted that some ultramafic rocks in the belt have textures that appear to be of the spinifex type, but differ in other respects. These may not be flows.

A preliminary compilation of occurrences of ultramafic flows has been prepared, using the previously mentioned textural and layered features as criteria for extrusive origin. The resulting distribution is shown in Figure 1. Most of the occurrences lie within 50 miles of Timmins, or near Val d'Or. Almost all are in the southern part of the Abitibi orogenic belt. The only other occurrence in Canada of which the writer is aware is in the Puddy Lake area, west of Lake Nipigon, Ontario[12].

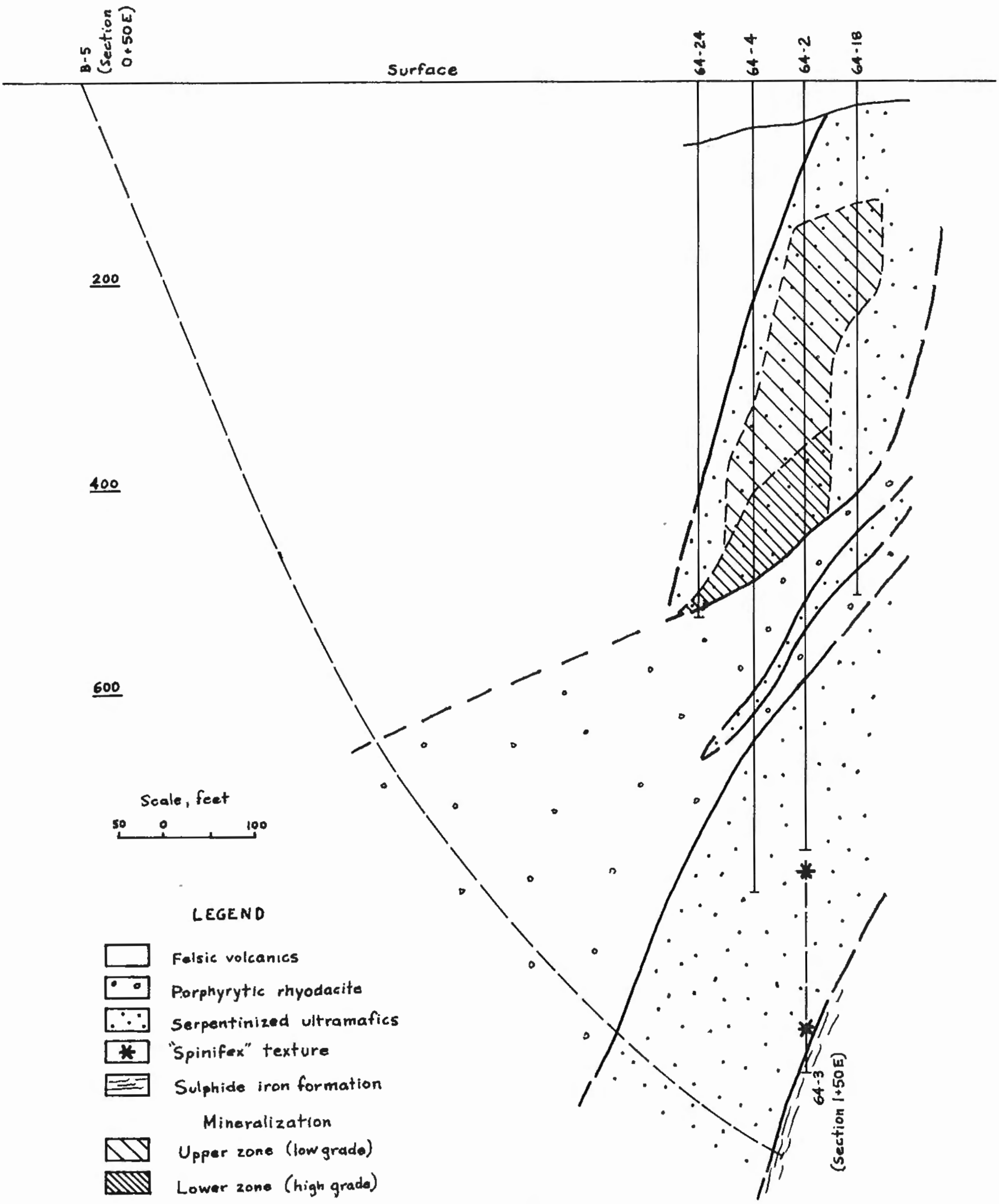
In the Barberton Mountainland of South Africa, ultramafic flows occur at or near the base of the Archean volcanic succession and have a rather wide distribution in one or more of the three oldest formations[8]. It appears possible that a similar age relationship exists in the Abitibi belt, namely, that ultramafic flows may be confined to the oldest part of the Archean volcanic sequence.

Relationship of ultramafic flows and nickel sulphide deposits

Nickel deposits in the Timmins and Val-d'Or areas occur in conformable, serpentinized ultramafic lenses. Nickel sulphides at most localities are concentrated at or near the base of the lenses, and show intercumulus-type textures, indicating that the sulphide existed as a separate liquid during emplacement and crystallization of the ultramafic host. There is a spatial association between nickel deposits and ultramafic flows (see Fig. 1). However, the exact genetic relationship is not known, and thus possible applications in exploration remain to be established.



Part of
ABITIBI OROGENIC BELT
Figure 1



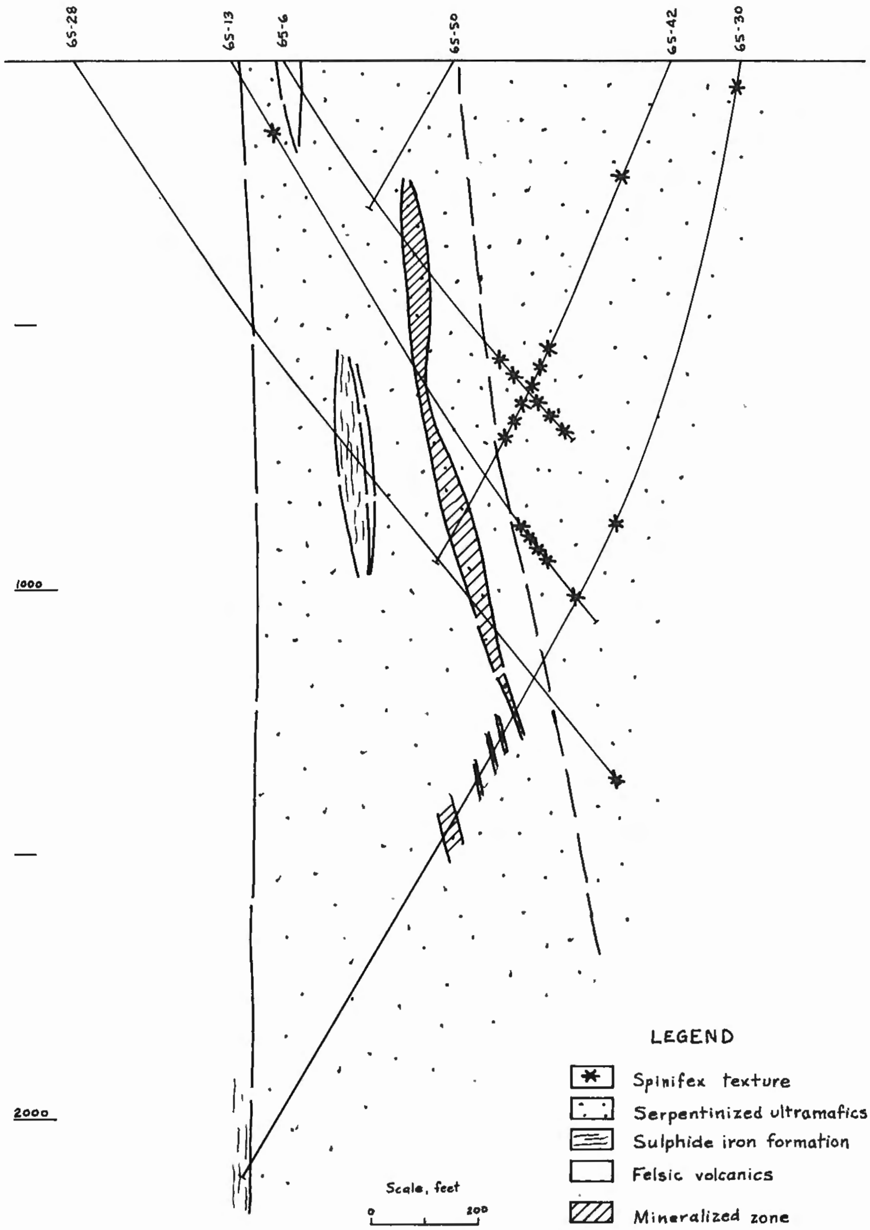
McWATTERS DEPOSIT

Langmuir township

Vertical section 1+00E, looking southwest

(Modified after Pyke, 1970, with additional information from Canadian Jamieson M.L.)

Figure 2



TEXMONT DEPOSIT

(South zone)

Bartlett - Geikie townships

Vertical section 43+50N, looking north

(Most of the data supplied by Texmont Mines, Ltd. Spinifex texture logged by the writer)

Figure 3

South of Timmins, a number of nickel deposits occur in three domal structures in the volcanic strata (see Pyke and Middleton[13] and Ginn et al.[14]). The "domes" are centred successively on Shaw, Bartlett, and Halliday Townships. Each has a discontinuous peripheral belt of ultramafic rocks, some of which contain nickel sulphide deposits, and some of which are ultramafic flows. Pyke and Middleton[13] have pointed out that in the Shaw and Bartlett domes, the Carman Bay, McWatters, Hart and Texmont deposits all occur in ultramafic bodies lying in a horizon of felsic volcanics that contain numerous sulphide-bearing iron-formations. The same is true also of the Sothman deposit in the Halliday dome. In all cases, a second discontinuous belt of ultramafic rocks lies stratigraphically above the first, and is enclosed in mafic to intermediate volcanic rocks. This belt contains numerous spinifex-textured flows, but to date has not yielded significant concentrations of nickel sulphides.

In some areas, the nickel sulphide deposits and spinifex-textured flows are very closely associated, but their precise relationship is still ambiguous. Figure 2 shows a vertical section through the McWatters deposit (the same section that has appeared in accounts by Kilburn et al.[15] and Pyke[6]). This deposit lies on the southeast flank of the Shaw dome. The ultramafic rock was originally interpreted as a single dyke, separated by porphyritic rhyodacite into an upper ore-bearing part and a lower, low grade part. The writer found, on relogging the core, some good examples of spinifex-textured layers in the lower part, but only massive, cumulus-type textures in the upper. In spite of intense alteration and recrystallization, one spinifex occurrence shows grain size gradation that is sufficiently distinct to permit a top determination. The result is consistent with the regional structural interpretation. Consequently it is suggested that the upper ultramafic body is a semi-conformable lens with higher grade sulphides near the base and lower grade disseminated sulphides above, and possibly also a separate, nearly barren basal unit. The lower ultramafic body is probably composed of a succession of relatively barren, spinifex-textured flow units. The entire sequence is approximately conformable with the known attitude of sulphide iron-formation.

The Texmont deposit lies in an ultramafic mass on the east flank of the Bartlett dome. Spinifex texture is abundant in part of the mass (see Fig. 3). Spinifex-textured serpentinized flows appear to form a sequence more than 600 feet thick, stratigraphically overlying an essentially massive serpentinite body about 350 feet thick. The latter contains one spinifex-textured zone, and several intercalations of felsic volcanics, shaly sediments, and sulphide iron-formation. The nickel sulphide mineralization (south zone) occurs in a narrow, continuous, apparently conformable zone about 100 feet stratigraphically below the spinifex-textured flows. Six hundred feet north of this section, the main ore zone is composed of several subparallel approximately conformable lenses and layers of disseminated sulphides. All of the foregoing facts relating to the lower serpentinite are consistent with the interpretation that it, too, consists of a sequence of ultramafic flow units, some of which contain (basal?) zones of sulphide mineralization. The lack of conspicuous spinifex texture would be explained if these lower flow units were of the massive type observed in Munro Township, as described in a preceding paragraph.

Relations similar to those in the Texmont deposit are also observed in some of the Western Australian deposits.

Discussion

1. Some nickel deposits in the Abitibi orogenic belt are closely associated with spinifex-textured ultramafic flows, but most of the known flows of this type apparently do not contain significant quantities of nickel sulphides. Consequently it is not yet clear whether the chance of exploration success is enhanced or diminished by concentrating on spinifex-textured flows as opposed to massive serpentinite lenses.

2. In both the McWatters and Texmont deposits sulphide zones and spinifex-textured rocks occur in close mutual proximity. Although it has not yet been shown that a particular spinifex-textured flow unit contains sulphide ore, it seems quite possible that sulphide zones at Texmont occur in flow units of the massive type. Much additional documentation is required to clarify these relationships. However, this now seems within reach because the Munro Township exposures have provided a much clearer model of the morphology, layering and texture of Archean ultramafic flows.

3. The knowledge that flows are involved has certain geometric implications concerning the shape and distribution of mineralized zones that may be encountered. This could help in defining drilling targets.

Acknowledgments

The writer is indebted to many geologists in government, industry, and universities for extensive exchange of information and ideas. Information for Figures 2 and 3 were supplied, respectively by Mr. E. Neczkar, Canadian Jamieson Mines Ltd., and Mr. H.A. Pearson, Texmont Mines Ltd.

[1] Naldrett, A.J.: Ultramafic and related mafic rocks of the Abitibi orogen; in Symposium on Basins and Geosynclines of the Canadian Shield, A.J. Baer, editor; Geol. Surv. Can., Paper 70-40, pp. 24-29 (1970).

[2] Bruce, E.L.: Geology of McArthur, Bartlett, Douglas and Geikie Townships (Redstone River area), District of Timiskaming; Ont. Dept. Mines, vol. 35, Pt. 6, pp. 37-56 (1926).

[3] Prest, V.K.: Geology of the Keith-Muskego Townships area; Ont. Dept. Mines, vol. 59, Pt. 7, pp. 1-44 (1950).

[4] Satterly, J.: Geology of Munro Township; Ont. Dept. Mines, vol. 60, Pt. 8, pp. 1-60 (1951).

[5] Naldrett, A.J. and Mason, G.D.: Contrasting Archean ultramafic igneous bodies in Dundonald and Clergue Townships, Ontario; Can. J. Earth Sci., vol. 5, No. 1, pp. 111-143 (1968).

[6] Pyke, D.R.: Geology of Langmuir and Blackstock Townships; Ont. Dept. Mines, Geol. Rept. 86 (1970).

[7] Nesbitt, R.W.: Skeletal crystal forms in the ultramafic rocks of the Yilgarn block, Western Australia; Evidence for an Archean ultramafic liquid; Geol. Soc. Australia, Spec. Publ. 3 (in press).

[8]Viljoen, M.J. and Viljoen, R.P.: Evidence for the existence of a mobile extrusive peridotitic magma from the Komati Formation of the Onverwacht Group; Geol. Soc. South Africa, S.A.U.M.P. symposium volume (in press).

[9]Drever, H.I. and Johnston, R.: Crystal growth of forsteritic olivine in magmas and melts; Trans. Roy. Soc. Edinburgh, vol. 63, Pt. 2, No. 13, pp. 289-317 (1957).

[10]Pyke, D.R., Naldrett, A.J., and Eckstrand, O.R.: Archean ultramafic flows in Munro Township, Ontario (in prep.).

[11]Pyke, D.R.: Bartlett and Geikie Townships, District of Timiskaming; in Summary of Field Work, 1971, Ont. Dept. Mines, Misc. Paper (1971).

[12]Kretschmar, D. and Kretschmar, U.: Personal communication (1971).

[13]Pyke, D.R. and Middleton, R.S.: Distribution and characteristics of the sulphide ores of the Timmins area; Can. Mining Metall. Bull., vol. 64, June, pp. 56-66 (1971).

[14]Ginn, R.M., Savage, W.S., Thomson, R., Thompson, J.E., and Fenwick, K.G.: Timmins-Kirkland Lake sheet, Cochrane, Sudbury and Timiskaming Districts; Ont. Dept. Mines, Geol. Compilation Ser., Map 2046 (1964).

[15]Kilburn, L.C., Wilson, H.D.B., Graham, A.R., Ogura, Y., Coats, C.J.A., and Scoates, R.F.: Nickel sulphide ores related to ultrabasic intrusions in Canada; in "Magmatic Ore Deposits", Econ. Geol. Monograph 4, H.D.B. Wilson, editor, pp. 276-293 (1969).

---

43. GEOLOGY OF CANADIAN NICKEL DEPOSITS

Project 630037

O.R. Eckstrand

Field examinations of nickel deposits were conducted in the following areas: Hope and Grand Forks, southern British Columbia; Boundary Ranges and Cassiar Mountains, northern British Columbia; Kluane Ranges in Yukon Territory; the Muskox intrusion and the East Arm area of Great Slave Lake, District of Mackenzie, Northwest Territories; Ferguson Lake and Rankin Inlet in the District of Keewatin, Northwest Territories; Timmins and Timagami, northern Ontario; Val d'Or, Chibougamau and Renzy Lake, northwestern Quebec; and Bathurst and St. Stephen, New Brunswick. The deposits may be loosely classified into several descriptive types, as listed. Some show characteristics of more than one type.

1. Irregular disseminated and massive sulphide zones in simple to complex mafic intrusive plugs: Giant Mascot, Nickel Mountain and Turnagain River, British Columbia; and St. Stephen deposits and Goodwin Lake, New Brunswick.
2. Sulphide zones in conformable ultramafic lenses:
   a. basal concentrations of massive and disseminated sulphides: Rankin, Northwest Territories; Carman Bay, Alexo, Sothman, and McWatters in the Timmins area, Ontario; and Renzy, Quebec. The Renzy deposit differs from the others in showing well defined (primary?) layering of the ultramafic host rock and in being strongly metamorphosed and deformed.
   b. internal zones of disseminated sulphides: Texmont, near Timmins, Ontario; and Dumont, near Val d'Or, Quebec.

   (For a further discussion of some nickel deposits in the Timmins area and their relationship to ultramafic rocks that are probably volcanic flows, refer to another short paper in this publication.)
3. Sulphide zones at contacts of large, mafic intrusive bodies: the Muskox and Ferguson Lake deposits, Northwest Territories; and the nickeliferous pyrite zone at the Temagami mine, Ontario. The Nickel Mountain deposit (type 1) also occurs at the contacts of a small mafic intrusion.
4. Injected sulphide deposits in wall-rocks adjacent to ultramafic intrusions: Wellgreen and Canalask, Yukon Territory. In the Wellgreen deposit, some of the sulphide is in the ultramafic body.
5. Low-grade occurrences in serpentinized ultramafic rocks (approximately background content of nickel): the Chromex properties near Grand Forks, B.C.; Cassiar, Atlin, and Letain occurrences in northern British Columbia; and the Roberge sill near Chibougamau, Que. A sub-type consists of minor sulphides (usually millerite and pyrite) in carbonate alteration of ultramafic rocks: Opal Lake, west of Dease Lake, B.C.; and occurrences in Shaw Township near Timmins, Ont.
6. Arsenide vein deposits: Blanchett Island, Sachowia Lake, and Easter Island in the East Arm area of Great Slave Lake, N.W.T.; and Silverfields mine, Cobalt, Ont.
7. Miscellaneous unusual occurrences: minor nickel in the Henderson "A" vein copper orebody near Chibougamau, Que.; and disseminated fine-grained pentlandite in dacite near a serpentinite body at Frederick House Lake near Timmins, Ontario.

---

44. GEOLOGY OF COPPER AND MOLYBDENUM DEPOSITS

Project 700059

R.V. Kirkham

A second field season has been completed of a review study of copper deposits in Canada. Mine and property examinations were made mainly in the southern part of the Canadian Shield from Labrador to Saskatchewan and in the eastern part of the Cordilleran System, but some visits were also made in Newfoundland and the Northwest Territories. Important deposits were examined in many areas but only a few will be discussed here.

1. Porphyry deposits in the Canadian Shield

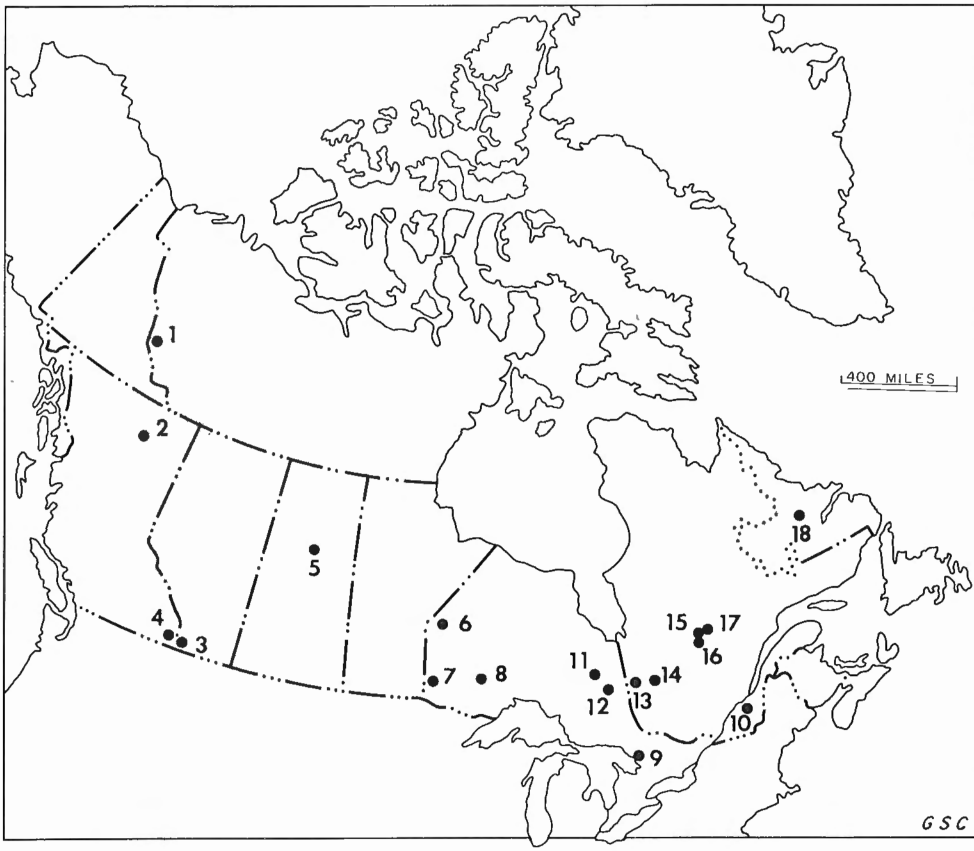
In recent years there has been considerable discussion about whether or not porphyry copper and molybdenum deposits, typical of the Cordilleran System, occur in Archean greenstone belts. During the course of field travels the writer has made an attempt to examine briefly as many deposits as possible in Archean terranes which have been called porphyry deposits or have been suggested might be somewhat similar to Cordilleran porphyry deposits. This report presents some preliminary views based on these brief examinations.

Without going into the many problems of what constitutes a porphyry deposit, it will suffice to say that porphyry deposits, which in many ways are similar to those in the Cordilleran System, are present in Archean greenstone belts. That is, large, low-grade deposits of copper and molybdenum in highly altered and fractured rocks spatially related to felsic and intermediate epizonal plutons are not uncommon in Archean greenstone belts. Figure 1 shows the location of some deposits and areas visited by the writer. Undoubtedly, judging from descriptions and specimens shown to the writer by Ontario and Quebec Resident Geologists and other individuals, deposits in areas that were not visited could also have been included.

It is premature to assess the overall nature and economic potential of these deposits but certain points can be made. Many of them on first inspection do not resemble too closely younger porphyry deposits. One of the reasons for this is that some of the deposits have undergone penetrative deformation and low-grade regional metamorphism. Many rocks in the vicinity of deposits are foliated and characteristic alteration assemblages have been destroyed or changed significantly. However, a few deposits, such as the one at Setting Net Lake[1], seem to have post-dated most of the deformation and show some rather striking similarities to some of the western porphyry deposits. This particular deposit, although it has somewhat simpler vein development, is similar to the Endako and Brenda deposits in British Columbia.

Perhaps the fact that many of these deposits have been infolded into their associated volcanic and sedimentary piles has permitted their preservation. Had they simply been late- or post-tectonic deposits emplaced at high levels in the crust they probably would have been eroded away. It is this deformation and metamorphism, however, that presents many unique problems for exploration. For instance, as Griffis[2] has indicated for the McIntyre copper deposit, the present pitch of the ore shoots could be due to elongation and stretching of pre-fold veins and sulphides. Certainly rodding of sulphides is common in this deposit and it is probable that the distribution of the higher grade ore shoots in the more widespread lower grade mineralization is largely controlled by "post-sulphide" folding in the area.

Disruption of initial hydrothermal alteration assemblages (such minerals as quartz and potash feldspar tend to survive in metamorphic environments), and possible tilting, folding and faulting of these deposits, lead to many additional problems in their exploration. Since some of the deposits probably represent only a part of what were enormous hydrothermal systems, without the typical alteration guides[3] it might be very difficult to reconstruct or model these systems. With this in mind it is recommended that special attention be given to sulphide distribution and any metal zonation that might be present, for it is features such as these that should be least affected by deformation and metamorphism.



Cordilleran Deposits

1. Redstone area
2. Churchill area
3. Clark Range
4. Bull River mine

Porphyry Deposits

6. Setting Net Lake
7. High Lake
11. McIntyre mine
15. Garth Lake
16. Talbot property

Possible Metamorphosed Stratiform Copper Deposits

5. Anglo-Rouyn mine
9. McGowan property
10. Harvey Hill property
18. Ellis and Adeline properties

Porphyry Deposit Affinities

8. Beidelman Bay property
12. Matachewan area (Webb and Ryan Lake deposits)
13. Don Rouyn mine
14. Savard property (Bourlamaque Batholith)
17. Grandroy mine

Figure 1. Location Map

The Garth Lake and Talbot properties at Chibougamau warrant special note. The writer examined the Garth Lake deposit for about a mile along the path of the power line about 4, 000 feet southeast of Garth Lake. Only trace amounts of copper and molybdenum were found in places in this area; however, it was noted that most rocks average from one to greater than ten per cent pyrite, both disseminated and in veins. Smith and Allard[4], moreover, have mapped metasomatic rocks of "uncertain origin" with pyrite over an area of about one square mile (Allard[5] has recently drawn attention to the area). Although this amount of pyrite with trace amounts of base metals is not particularly unusual for Archean rocks, this pyrite and associated quartz and magnetite veinlets are significant inasmuch as the mineralization can be demonstrated to be of "porphyry-type". That is, it can be shown to be temporally and therefore, genetically related to felsic porphyries that occur in the area. Some of the porphyry dykes and intrusive breccias are clearly "intermineral" in respect to pyrite and quartz veinlets (that is, some of the porphyries were emplaced during or between periods of mineralization). Although to date significant amounts of copper or molybdenum have not been found in this large pyritic deposit, there has been insufficient exploration to establish that they are not present. It is also very important to note that this pyritic porphyry deposit is only a short distance northwest of the Doré Lake mining camp with its economic copper deposits. Furthermore, Duquette[6], considering the close relationship between the copper deposits and dykes in the area, in his recent report on the Chibougamau region, has concluded that it is reasonable to suspect that the copper mineralization in the Doré Lake-Chibougamau Lake basin is genetically related to the Chibougamau pluton. This hypothesis is certainly consistent with the writer's observations, since the porphyry bodies in the Garth Lake area could be genetically related to the Chibougamau pluton.

The Talbot property southwest of Chibougamau Lake is also significant, since Cimon[7] has noted stockwork-type quartz-carbonate veinlets containing chalcopyrite with associated magnetite and pyrite over large areas in the Chibougamau pluton. In one outcrop area visited by the writer there is considerable veining and associated potash feldspar alteration with significant chalcopyrite over an area of a few hundred by a few hundred feet. In view of the nature of the mineralization this area warrants far more attention than it has received in the past.

On Figure 1 some properties have been indicated as having porphyry deposit "affinities" but their extent is either too limited to justify calling them porphyry deposits or there is insufficient information available on them to be certain of their overall nature. Nevertheless, the writer feels that it is reasonable to draw attention to their possible genetic affinities.

No general discussion of porphyry deposits in the Shield would be complete without considering some of the economic implications. Certainly no major economic porphyry deposit comparable to any in the Cordilleran System has as yet been outlined in the Shield; nor is there sufficient information to indicate that porphyry deposits are as abundant as in the young mobile belts. Nevertheless, exploration for and of this type of deposit in the Shield, in most areas, has been very limited; hence, it is difficult to be certain of their distribution and economic potential. Much of the primary documentation of these deposits remains to be done. However, perhaps simple recognition of deposits which in many ways are similar to younger, economically important deposits, will be sufficient incentive to do more work.

2. Copper deposits in the eastern part of the Cordilleran System

The eastern part of the Canadian Cordilleran System, namely the Rocky and Mackenzie Mountains, has not been a traditional exploration area for copper or other heavy metals. It was only during the last decade that its potential for copper and other metals became widely recognized. The main reason for this hesitancy to explore the area is perhaps the relative scarcity of post-Precambrian igneous rocks and especially the notable absence (even in the Precambrian sequences) of felsic intrusive and extrusive rocks, thought to be so important in the ore forming processes. Nevertheless, it is now known that productive and potentially productive deposits occur in the area. Although a number of copper occurrences are known in the region in rocks of various ages, at present there are two main types of deposits, vein and stratiform, in Proterozoic rocks which seem to offer the most immediate exploration potential.

The most significant type of vein deposit is represented by those in the Churchill area in northeastern British Columbia and the Bull River mine in southeastern British Columbia (see Fig. 1). Essentially these are quartz-carbonate-sulphide veins with the predominant sulphides being chalcopyrite, pyrite and in some areas pyrrhotite. (Preliminary microprobe analyses indicate that most of the vein carbonates in the Churchill area are ferroan dolomites with about 6 to 7 per cent $FeCO_3$). These veins are rather unusual, as they are one of a very few types of veins which seem to be reasonably attractive economic sources of copper. The veins in the eastern part of the Cordilleran System probably belong to a previously unrecognized but widespread peculiar class of copper deposits. They are very similar to cupriferous vein deposits in the Elliot Lake area of Ontario which have been mined in the past (e.g. Bruce Mines, Consolidated Bi-Ore Mines, etc.) and, except for the fact that it is essentially stratiform, the Icon-Sullivan vein in Quebec. It is quite possible that some deposits in the Northwest Territories (e.g., East Arm of Great Slave Lake) are also of this type. The veins are apparently characteristic of Proterozoic sedimentary basins especially in areas that have been intruded by numerous diabase dykes or sills. No diabase has been reported at the Icon-Sullivan deposit but since it is immediately adjacent to the Grenville Front, a complete reconstruction of this deposit is not possible. Based on the writer's preliminary examinations, although it appears as if there is probably an indirect genetic relationship between the mafic intrusions and veins, the diabase bodies in the immediate vicinity of the deposits do not appear to have been local sources for the metals or hydrothermal fluids responsible for the vein formation. In northeastern British Columbia some veins are exposed for several thousand feet vertically and appear to have been very "deep rooted" phenomena.

The second type of copper deposit which seems to offer significant exploration potential are the stratiform deposits in Proterozoic sediments. To date they are known in two areas, Redstone River area in the Northwest Territories and Clark Range in the southern part of the Rocky Mountains. In both areas there is an obvious association of these deposits with red bed sequences. At Redstone copper occurs at the top of a red siltstone and argillite succession in pale green and grey limy and dolomitic siltstones immediately below a fetid marine carbonate formation[8]. Chalcopyrite and bornite are the main copper minerals. In the Clark Range there are a number of copper occurrences in light coloured quartzite beds within the red bed sequence of the Grinnell Formation[9]. At most localities chalcocite and bornite are the most important copper minerals. Chalcopyrite is important in some areas. Copper mineralization occurs also in other formations of the Purcell System.

3. Stratiform copper deposits in metasedimentary sequences

Although a number of areas in Canada that contain stratiform copper deposits in sedimentary sequences have been recognized, to date little attention has been given to looking for such deposits in metamorphic terranes. The writer has examined briefly deposits in some areas where there is a high probability that some of the deposits are of a metamorphosed stratiform type (see Fig. 1). It is important to recognize this possibility because it could greatly enlarge areas in Canada favourable for exploration for this type of deposit. Moreover, it could greatly improve the general understanding of such deposits which, of course, could aid significantly in exploration and possible development. Nevertheless, because rocks and probably the contained deposits in some of these areas have been extremely highly deformed and metamorphosed the original nature of the deposits must, for the time being, remain somewhat speculative.

[1]Ayres, L.D., and Averill, S.A.: The Setting Net Lake stock - An Early Precambrian porphyry molybdenum deposit (abstract); Geol. Assoc. Can. - Min. Assoc. Can., Abstracts of Papers - Joint Meeting of May 1971, pp. 2-3 (1971).

[2]Griffis, A.T.: A geological study of the McIntyre Mine; Can. Inst. Mining Met. Trans., vol. 65, p. 54 (1962).

[3]Lowell, J.D., and Guilbert, J.M.: Lateral and vertical alteration-mineralization zoning in porphyry ore deposits; Econ. Geol., vol. 65, pp. 373-408 (1970).

[4]Smith, J.R., and Allard, G.: South half of McKenzie Township; Geol. Rept. 95, Que. Dept. Mines (1960).

[5]Allard, G.: Lac Doré Complex; in Field Work, Geol. Services, Que. Dept. Natl. Resources, p. 90 (1970).

[6]Duquette, G.: Archean stratigraphy and ore relationships in the Chibougamau district; S.P. 8, Que. Dept. Natl. Resources (1970).

[7]Cimon, J.: NW. Quarter of Queylus Township and NE. Quarter of Haüy Township; in Field Work, Geol. Services, Que. Dept. Natl. Resources, pp. 76-77 (1970).

[8]Coates, J.A.: The Redstone bedded copper deposit and a discussion on the origin of red bed copper deposits; unpubl. M.Sc. thesis, Univ. Brit. Col. (1964).

[9]Northcote, K.E.: Akamina; in Minister Mines Ann. Rept., B.C., p. 270 (1968).

45. URANIUM IN CANADA

Project 670029

H. W. Little

In May and June trips were made to Bancroft and Elliot Lake largely for the purpose of preparing part of a guidebook for International Geological Congress excursion C67, a tour of Canadian uranium deposits. No exploration for uranium is being done in those areas. At Bancroft the Faraday mine is being kept unwatered in preparation for production should a contract to supply uranium concentrate be concluded. At Elliot Lake, Denison mine is milling 4,000 tons per day, [1] and Rio Algom Mines Limited, having phased out the Nordic mine, are decreasing production from the Quirke I mine while increasing development in, and production from, the New Quirke mine.

In Beaverlodge area, Saskatchewan, Eldorado Nuclear Limited have mined out their Bolger deposit and have begun production from the Hab mine. The main production, however, is from the Fay mine, below the 13th level.

At Rabbit Lake, which was not visited by the writer, Gulf Minerals are said to be developing the property in preparation for production scheduled for 1974. Exploration by Mokta Canada Limited on their claims in the Carswell dome area is continuing and most interesting and encouraging results have been obtained. A number of radiometric anomalies occur in rocks of low resistivity, which was determined from a survey by Mokta crews, and some of these anomalies are being tested by diamond drills and by percussion drills.

The best mineralization found to date occurs in the southern part of the Carswell dome a short distance east of the north end of Cluff Lake. There the structure is most complex; basement gneiss rests on top of Athabasca Formation sandstone, conglomerate, and pelite which dip moderately north and are overturned, but are truncated at a low angle against the gneiss. Pitchblende replaces mainly the pelitic layers, but also sandstone and gneiss. The mineralogy is similar to that at Beaverlodge, except that that hematitization is sparse, being observed mainly in the pitchblende-bearing vein that cuts the basement gneiss and is exposed in trench D. Age determinations made on pitchblende from this trench are said by the company to range from 1,100 to 1,400 m.y.

Other uranium mineralization occurs in the basement rocks and is apparently related to north-trending faults. Two papers have been submitted by staff geologists for presentation at the International Geological Congress in 1972.

Imperial Oil Enterprises have done radiometric surveys and geological mapping in Nonacho Lake area[2, 8], some 5 miles east of Walker Lake. The writer examined, on the former Ben claims, veins that were discovered previous to this year's exploration. In a shear zone about 1 foot wide and 280 feet long, that trends 160°, are anastamosing quartz veins up to an inch or so in width. Within the shear zone and adjacent sheared Nonacho conglomerate, hematitization is strong locally and radioactivity is strongest in those places. Near the middle of the zone a pod of pitchblende with secondary uranium minerals occurs but elsewhere mineralization is sparse. One hundred and fifty feet to the northeast, trenching has revealed three small radioactive occurrences which also trend 160°. The mineralization cannot be related to the granite to the west which McGlynn[3] states is pre-Nonacho and therefore of Archean age.

Properties of Vestor Explorations Ltd. on Simpson Islands and at Toopon Lake near McLean Bay were examined. On Simpson Islands some 10 mineralized zones have been tested. Radioactivity is closely associated with hematitization in the sandstone, pebbly beds, and conglomerate of the Hornby Island Formation[4] of the Sosan Group but where dark grey sandstone is present, this is usually the most radioactive, more so than the adjacent hematitized sandstone. The zones are irregular in shape and are not far from northeasterly-trending faults that are probably related to the McDonald fault. The mineralization occurs as near as 30 feet to the base of the formation and up to at least 800 feet from the base. In hand specimens no primary uranium minerals were detected by the writer nor were introduced quartz or carbonate seen, but secondary uranium minerals are locally abundant. Mineralized parts of the drill cores from No. 5 zone[5] were not on the property and therefore could not be examined.

At Toopon Lake two of three mineralized zones were seen, and on these only one trench had been blasted. The mineralization is similar to that on Simpson Islands, but occurs in sandstone of the Kluziai Formation.

In Makkovik-Moran Lake area, Labrador, extensive exploration for uranium is being done by British Newfoundland Exploration Limited in partnership with Metallgesellschaft A.G. The northwest side of the area[6] is underlain by Archean Hopedale gneiss, succeeded to the southeast by a succession of feldspathic quartzite and basic lava, the latter being largely altered to amphibolite, that comprise the Aillik Group, of Aphebian (Early Proterozoic) age. Some of the quartzofeldspathic rocks may, however, be of igneous origin rather than metasomatized sediments.

The writer examined trenches and some diamond drill cores of the Michelin deposit, which is about 35 miles southwesterly from the Kitts deposit, and about 11 miles south of the east end of East Micmac Lake, and occurs in rocks of the Aillik Group.[7] Five trenches expose what is probably porphyroblastic quartzite, strongly sheared, and rather well hematitized. The drill core is less hematitized but is generally most radioactive where hematite is most abundant. Pyrite is sparse. No carbonatization was seen in the trenches but much finely divided calcite was seen in the drill cores. No other type of alteration occurs, and no other gangue minerals were introduced. No primary uranium minerals could be seen with a hand lens, but a yellow secondary uranium mineral occurs on some fracture surfaces. The mineralized zone trends about N60°E and dips 55° to 65° SE. It is nearly 4,000 feet long and is up to 30 feet or so wide, but divides and fingers out along its trend, so that some drill holes intersect several mineralized sections. Mineralization persists to a depth of at least 400 feet.

The writer is grateful to the mining and exploration companies for their co-operation and hospitality; and to A. Boyer and W.P. Barto for assistance in the field.

[1]Northern Miner, 17 June 1971.

[2]Henderson, J.F.: Nonacho Lake, District of Mackenzie; Geol. Surv. Can., Map 526A (1939).

[3]McGlynn, J.C.: Study of the Nonacho Group of sedimentary rocks, Nonacho Lake, Talston and Reliance areas, District of Mackenzie; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 154, 155 (1971).

[4]Hoffman, P.F.: Stratigraphy of the Lower Proterozoic (Aphebian), Great Slave Supergroup, East Arm of Great Slave Lake, District of Mackenzie; Geol. Surv. Can., Paper 68-42 (1968).

[5]Northern Miner, 29 July 1971.

[6]Ghandi, S.S., Grasty, R.L., and Grieve, R.A.F.: The geology and geochronology of the Makkovik Bay area, Labrador; Can. J. Earth Sci., vol. 6, No. 5, pp. 1019-1035 (1969).

[7]Stevenson, I.M.: Rigolet and Groswater Bay map-area, Newfoundland (Labrador); Geol. Surv. Can., Paper 69-48 (1970).

[8]Taylor, F.C.: Geology, Nonacho Lake, District of Mackenzie; Geol. Surv. Can., Map 1281A (1971).

---

46. GEOLOGY OF CANADIAN LITHOPHILE METALS (Li, Be, Sn, W)

Project 530014

R. Mulligan

About three weeks of field work was done in the Salmo and Revelstoke areas of southeastern British Columbia to investigate tungsten deposits and acquire further data on the distribution of lithophile metals in mineralized zones, pegmatites, and granitic rocks.

In the Iron Mountain area 6 miles south by east of Salmo, tungsten has been produced prior to 1958 from the Emerald, Feeney and Dodger orebodies[3] and more recently lead and zinc from the Jersey orebody. In 1971 Canadian Exploration Ltd. resumed productions of scheelite from the newly developed Invincible orebody and the Dodger east zone. The Invincible zone is about 3,000 feet northeast of the old Emerald mine and contains an estimated 278,000 tons of ore grading 0.78% (WO_3)[4]. Scheelite occurs chiefly in pyrrhotite-rich skarn bands in limestone in contact with Dodger granite in a trough between the Emerald and Dodger stocks. In the present Dodger workings the ore zone is a greenish garnetiferous skarn with disseminated scheelite and relatively little pyrrhotite. Quartz-filled gash veins cut the skarn along a gradational contact with argillite. They contain scheelite and are locally rich in molybdenite, which is more abundant in the Dodger than in the Invincible orebodies. Molybdenum may be more commonly associated with the Dodger stock which outcrops about a thousand feet east of the Emerald stock. Several mines farther east, molybdenum deposits are common along the west contact of the large granite-mass that extends across Lost Creek. Some of these contain minor tungsten minerals. Samples of these granite bodies were collected for examination and analysis.

At the Snowflake—Regal Silver property at Stannex Minerals Ltd. about 4 miles northwest of Albert Canyon, a considerable amount of new exploration and development work has been done since 1967. Scheelite was produced as well as silver-lead concentrate in 1953-1954. The scheelite occurs principally in a pyrite-chlorite-rich zone encompassing several levels in the lower central part of the vein system. Stannite is concentrated mainly in the uppermost part of the system, associated with pyrite, sphalerite, galena, chalcopyrite and argentiferous sulphosalts. No granite outcrops near the mine but a large area of granitic rocks, with which scheelite and cassiterite are associated, extends from the southeast to within 7 miles of the property. Pegmatite and greisen zones are abundant in some phases of the granite,[1] and such areas are especially favourable for tin and tungsten deposits.

[1]Wheeler, J.O.: Rogers Pass map-area, British Columbia and Alberta, Geol. Surv. Can., Paper 62-32 (1963).

[2]Fyles, J.T. and Hewlett, C.G.: Stratigraphy and structure of the Salmo lead-zinc areas; B.C. Dept. Mines, Bull. No. 41 (1959).

[3]Little, H.W.: Tungsten deposits of Canada; Geol. Surv. Can., Econ. Geol. Ser. No. 17 (1959).

[4]Pastoor, D.W.: Geology of the Invincible tungsten ore zone of Canadian Explorations Limited, Salmo, B.C.; in Lead zinc deposits of the Kootenay Arc, Northeast Washington and adjacent British Columbia; State of Washington, Nat. Resources Bull. No. 61, pp. 103-106 (1970).

---

47. GEOLOGY OF RARE-EARTH DEPOSITS OF CANADA

Project 670028

E.R. Rose

Four days were spent in the Perth area, Ontario, investigating possible sites for International Geological Congress field excursions A47 and C47a. Granite pegmatite dykes in the Perth area have been a source of feldspar, and in places they also carry interesting occurrences of perthite, peristerite, euxenite and other rare element minerals. The pegmatite occurs in a swarm of en echelon dykes that trend in a northeasterly direction, intruding gneisses and schists of the Grenville province. The dykes are associated spatially and genetically with late stage Grenvillian granite intrusions that also trend northeasterly.

---

48. GEOLOGY OF LEAD-ZINC DEPOSITS IN CANADA

Project 650056

D. F. Sangster

Massive sulphide deposits were examined in the Uchi Lake area of Ontario and at Fox Lake and Sherridon, Manitoba. With regard to the latter two deposits (particularly Fox Lake) which occur in Kisseynew-type metamorphic terrain but nevertheless, still retain many of the features of a normal volcanogenic massive sulphide deposit[1], the author takes this opportunity to re-emphasize that metamorphism is not necessarily detrimental to ore potential. In fact, under proper conditions, it may even improve it[2,3].

Re-examination of the host rocks at the Bathurst-Norsemines Group (Hackett River deposit) by Shegelski and Thorpe (see elsewhere in this publication) has led to a re-interpretation of the character of these rocks. Previously[4,5] it had been reported that the immediate host rocks to the ore were apparently quartzites with intercalated limestones. New information, resulting from company mapping since the time of the writer's visit over a year ago, has revealed that volcanic rocks are much more extensive in the area than previously suspected and that the "quartzites" are, in reality, probably highly silicified and metamorphosed acidic volcanic rocks, possibly rhyolitic pyroclastics. If so, then the geological environment of the Hackett River deposits is the normal volcanic association of this type of ore and not the anomalously sedimentologic one as previously interpreted by the writer.

[1]Sangster, D. F.: in Report of Activities, Part A, April to October 1969, Geol. Surv. Can., Paper 70-1, Pt. A, pp. 105-106 (1970).

[2]Sangster, D. F.: in Report of Activities, Part A, April to October 1968, Geol. Surv. Can., Paper 69-1, Pt. A, pp. 117-119 (1969).

[3]Sangster, D. F.: Metamorphism as an ore-forming process; Econ. Geol., vol. 66, pp. 499-500 (1971).

[4]Sangster, D. F.: in Report of Activities, Part A, April to October 1970, Geol. Surv. Can., Paper 71-1, Pt. A, p. 92 (1971).

[5]Sangster, D. F.: in Report of Activities, Part B, November 1970 to March 1971, Geol. Surv. Can., Paper 71-1, Pt. B, p. 12 (1971).

49. STUDY OF SELECTED MINERAL DEPOSITS IN THE BEAR AND SLAVE PROVINCES

Project 710043

R.J. Shegelski and R.I. Thorpe

Certain mineral deposits were examined in the Bear and Slave Provinces in order to investigate their geological setting, to obtain an understanding of their mode of genesis, and to test some prior concepts of metallogenesis.

In the Bear Province the Terra silver-copper mine on the Camsell River, a copper property in the Isabella Lake area, a cobalt-arsenide property at Lou Lake, and the former Rayrock uranium mine, were visited. In the Slave Province studies were made of Zn-Pb-Ag-Cu mineralization at Homer Lake, low-grade Cu-Zn mineralization in the Beaulieu River area, Zn-Pb-Cu mineralization at Turnback Lake, a Zn-Pb-Ag-Cu massive sulphide deposit at Indian Mountain Lake, similar massive sulphide mineralization in the Hackett River area, and low-grade gold mineralization on Back River.

The concept that a fairly massive copper-rich sulphide zone at the Terra Mine might be syngenetic was investigated. Insofar as could be ascertained, the sulphide zone is conformable with the predominantly tuffaceous host rocks of the Echo Bay Group. The zone was found to contain considerable ankerite, dolomite, and calcite, in addition to the abundant chalcopyrite and pyrite and minor sphalerite and galena. These mineralogical characteristics of the zone, together with argillaceous interbeds, suggest that the immediate sulphide horizon was originally a shaly carbonate sediment, a conclusion also reached by others[1]. The most copper-rich portions of the zone are very lenticular and textures of the ore and immediate host rock indicate in situ growth of minerals or considerable recrystallization, while the metamorphic grade of the tuffaceous country rocks appears to be low. These features suggest a metasomatic origin for the sulphides[1]. However, the possibility of a syngenetic volcanic exhalative origin cannot be eliminated. If the sulphides are syngenetic it should, of course, be possible to find such copper-rich zones elsewhere within tuffs of the Echo Bay Group in the Bear Province.

The host rock of the Isabella Lake copper occurrence, located at about 64°56'N and 117°47'W, is interpreted to consist predominantly of lavas of the Echo Bay Group. These lavas include siliceous and lenticular porphyritic units and are intruded by a small body of grey porphyry which has a darker border phase. The lavas are flanked by extensive, more massive porphyry bodies; it is not obvious whether these bodies are intrusive or extrusive and this problem is one which will require concerted attention during future mapping in the Bear Province. The chalcopyrite mineralization of the area is fracture-controlled and the more siliceous units are most fractured and therefore most mineralized. This mineralization supports other evidence (for example see Terra, above) that rocks of the Echo Bay Group are favourable for the discovery of copper deposits.

Work in the Lou Lake area (approx. 63°34'N, 116°45'W) resulted in the discovery of a wide magnetite iron-formation about 500 feet west and a short distance stratigraphically below the arsenide zones that have been trenched. The oxide iron-formation is flanked by highly amphibolitic and chloritic arsenide-bearing sediments. The economically interesting arsenides have been concentrated in shear zones trending 110°, and in a weaker shear set at 70°, possibly by remobilization from the sediments overlying the iron-formation. In the Rayrock area a sediment consisting of siliceous and amphibolitic beds and containing some arsenopyrite was located at about 63° 28'54"N and 116°36'09"W, 250 feet southeast of a small pond in a swampy valley area 2.6 miles northwest of the former mine. This arsenopyrite-bearing sediment, with minor associated underlying iron-formation, may represent a unit extending, probably discontinuously due to faulting and intrusion, northwest for 7 1/2 miles to the Lou Lake area. This stratigraphic horizon should be further examined to test this possibility. Exploration of the horizon for gold, cobalt and bismuth is recommended.

In the Homer Lake area, about 15 miles north of Yellowknife, small Pb-Zn-Ag lenses are located near and on either side of a quartz-porphyry dyke about 100 feet wide that cuts volcanics of the Yellowknife Group[2]. The genesis is not obvious for these massive sulphides nor for similar replacement (?) bodies along minor shears in the volcanics. Nearby in the vicinity of Likely Lake minor molybdenite is present in quartz veins and dykes of porphyritic granodiorite, a few inches to 6 feet wide, that cut the volcanics. This mineralization is considered to be related to the contact of the granitic batholith ("Western Granodiorite"), which intrudes the Yellowknife volcanic belt along its western margin. Northwest of the north end of Likely Lake a body of quartz-feldspar porphyry at least 105 feet wide (ref. 2, p. 76) contains pyrite, pyrrhotite, chalcopyrite, molybdenite and fluorite on fracture surfaces and in tiny quartz veinlets. The porphyry body is very leucocratic and shows some shearing at its eastern margin. The mineralization is similar in character to that of the porphyry copper-molybdenum class of deposits. A chip sample taken by Jolliffe[3] assayed 0.24% MoS_2 across 105 feet. The body may be of economic interest since it is drift covered at its northwest edge and could thus be more extensive than its exposed width.

In the Turnback Lake area (approx. 62°44'N and 112°38'W) the base metal mineralization, as indicated by pits and zones of gossan, is confined to one stratigraphic unit, and perhaps to a single stratigraphic horizon or two closely spaced horizons within the unit. Essentially barren pyrrhotite-bearing zones occur elsewhere in the general sedimentary unit. The sedimentary unit consists predominantly of quartz-biotite schist, and less abundant quartz-muscovite schist with skarn, amphibolite, and very siliceous (rhyolite tuff?) interbeds. The unit has been extensively intruded by pegmatites which, in the vicinity of the showings, generally strike subparallel to bedding. The most massive base metal sulphide mineralization is immediately adjacent to the contacts of pegmatite dykes, suggesting that the pegmatites have concentrated the metals from primary mineralization of a more disseminated stratiform type. The primary mineralization appears to have been closely associated with a limestone unit. Regional mapping by A. Davidson (see separate report, this publication) has indicated that the occurrence of base metal mineralization in association with limestone is widespread in the area.

In the Beaulieu River area showings were visited on the KK claim group of Shield Resources at about 63°12'15"N and 112°16'W. Pyrrhotite and pyrite, with minor sphalerite and chalcopyrite, form disseminated to massive conformable bands in slaty black argillite, graphitic in part, and in associated more cherty beds. Sphalerite and chalcopyrite show some evidence of remobilization, possibly as a result of structural deformation since the host rock shows little evidence of metamorphism. Angular to rounded fragments of slaty argillite and rhyolite (?) are found at some places in a matrix of sulphides, and are themselves mineralized in some cases. Similar mineralized zones are present on the EE and UU claims at about 63°18'30"N, 112°22'W, and 63°18'N, 112°24'30"W, respectively. The black shale here is quite graphitic and the mineralization does not extend into flanking intermediate volcanics. Some carbonate is present in the matrix of agglomerate in the volcanic sequence, and it appears that limestone fragments may have been an original component of the agglomerate.

In the Indian Mountain Lake area (about 63°02'45"N and 110°56'55"W) the BB deposit was visited and some core from drilling in the area was examined. The Kennedy Lake zone of copper mineralization (ref. 4, p. 38) shows general characteristics of an alteration "pipe" of the type recognized as feeders to many massive sulphide deposits in the Precambrian Shield[5, 6]. The normal hydrothermal minerals of the pipe, i.e. chlorite, sericite and carbonate, have been metamorphosed to garnet, biotite, actinolite (?), and cordierite, and the pipe is thus very similar to that on the Hackett River property (see below). The Kennedy Lake pipe may have been a feeder to the small massive sulphide zone underlying the lake, rather than to the main BB deposit, since there is no obvious direct relationship between the pipe and the latter deposit. However, the Kennedy Lake massive sulphide zone and the BB deposit may be at the same stratigraphic horizon.

Base metal deposits in the Hackett River area are located at about 65°50'N, 108°20'W and were the subject of active exploration during the past season. The deposits are in a sequence of highly metamorphosed sediments and pyroclastics that have been mapped as part of the Yellowknife Group. The generalized stratigraphic sequence near a number of the ore zones has been interpreted to be, from bottom to top, (1) metasediments, probably originally greywacke, (2) limestone, (3) tuffaceous felsic volcanics, mapped at least in part as crystal tuff, (4) agglomerate, mapped as very discontinuous bodies along strike, possibly due to masking of the original character of the rock by superimposed hydrothermal alteration and later metamorphism, (5) ore horizon, (6) recrystallized pyritic chert, mapped as ash tuff and perhaps localized to the immediate vicinity of ore, and (7) tuffaceous felsic volcanics. Hydrothermally altered rock in the general footwall area of several of the deposits has been interpreted as representing alteration pipes[5, 6, 7]. Due to metamorphism these altered rocks are now represented by the assemblages quartz-muscovite, quartz-sillimanite-biotite-pyrite, biotite-quartz-pyrite-cordierite, garnet-anthophyllite, quartz-muscovite-cordierite-garnet-biotite, quartz-pyrite-pyrrhotite, and quartz-magnetite-pyrite. Some diopside and diopside-garnet rocks are also found in very close association with the ore zones. Chalcopyrite is irregularly distributed in the altered rocks, which are identical in many of their characteristics to those of the Kennedy Lake copper zone in the Indian Mountain Lake area. In the Hackett River area silicification, which probably formed part of a single hydrothermal alteration process, appears to have been quite intense and extends beyond the defined alteration pipes.

Low-grade gold occurrences and lean iron-formation along the Back River south of Regan Lake at about 64°50'N, 107°40'W were examined. The general geology of the occurrences has been described by Schiller[8]. Areas on the property that have been mapped as "limy conglomerate" consist of siderite and dolomite with an abundance of siliceous fragments up to about 1 inch in diameter. These fragments are probably lapilli and the matrix carbonate may thus be largely a volcanic exhalative product. The same genesis is postulated for the lean iron-formation which is stratigraphically near the "limy conglomerate" and consists of chert, ferruginous hematitic chert, and siderite. Veins of black "Toby" quartz, in part gold-bearing, are found cutting most of the rock types of the area, including intrusive bodies of porphyry. The source of the gold contained in these veins is not obvious, but it might have been the lean iron-formation and "limy conglomerate" units.

[1]Badham, J.P.N., Robinson, B.W., and Morton, R.D.: The geology and genesis of the Great Bear Lake silver deposits (pers. comm., paper in prep.).

[2]Lord, C.S.: Mineral industry of District of Mackenzie, Northwest Territories; Geol. Surv. Can., Mem. 261, 336 pp. (1951).

[3]Jolliffe, A.W.: Yellowknife Bay - Prosperous Lake Area, Northwest Territories; Geol. Surv. Can., Paper 38-21 (1938).

[4]Thorpe, R.I.: Mineral exploration and mining activities 1966 to 1968, Mainland Northwest Territories (Excluding the Coppermine River area); Geol. Surv. Can., Paper 70-70 (in press).

[5]Gilmour, P.: The origin of the massive sulphide mineralization in the Noranda district, Northwestern Quebec; Geol. Assoc. Can. Proc., vol. 16, pp. 63-81 (see esp. p. 71) (1965).

[6]Roscoe, S.M.: Geochemical and isotopic studies, Noranda and Matagami areas; Symposium on Strata-Bound Sulphides, Trans. Can. Inst. Mining Met., vol. 68, pp. 279-285 (1965).

[7]Sangster, D.F.: Geology of lead and zinc deposits in Canada; in Report of Activities, Part A: April to October, 1970, Geol. Surv. Can. Paper 71-1, Pt. A., pp. 91-94 (1971).

[8]Schiller, E.A.: Mineral industry of the Northwest Territories, 1964; Geol. Surv. Can., Paper 65-11, p. 4 (1965).

---

50. GEOLOGICAL STUDY OF SILVER DEPOSITS IN CANADA

Project 680060

R.I. Thorpe

Field work consisted of visits to massive sulphide deposits of the Bathurst camp in New Brunswick, silver-arsenide vein deposits in the Cobalt-Gowganda area, Ontario, the Echo Bay silver mine at Great Bear Lake, District of Mackenzie, massive sulphide deposits in the Hackett River area, District of Mackenzie, sulphosalt-bearing veins in the Smithers-Hazelton area, British Columbia, the complex Sam Goosly copper-silver deposit near Houston, British Columbia, silver-bearing vein and replacement deposits in the Alice Arm area, British Columbia, the Premier gold-silver replacement deposit near Stewart, British Columbia, and vein deposits at various locations in southern British Columbia.

Work in the Cobalt area included some sampling of mineralization in the Keewatin interflow sediments, of mineralized pebbles and cobbles in the immediately overlying Coleman Formation, and of sulphides in the silver-arsenide veins for lead isotope investigation. At the Echo Bay Mine specimens were collected for further petrographic, mineralogical, and paragenetic study, as well as for age dating purposes. It is hoped that it will be possible to date the diabase sheet as well as an older set of diabase dykes.

A few of the deposits visited in British Columbia appear to be types not previously encountered by the writer. The Sam Goosly copper-silver deposit near Houston, is an unusual type. The host rock is largely light-coloured rhyodacite to dacitic andesite tuff of Mesozoic age which forms a window in gently-dipping trachyandesite and trachyte lavas of Tertiary (Eocene?) age.[1] The Mesozoic host tuff has been noted by Church[1] to be generally bleached and kaolinized. The tuff shows considerable evidence of brecciation in situ and chalcopyrite, argentiferous tetrahedrite and bournonite have been introduced into the matrix in disseminated form and also replace rock fragments to some extent. Massive sulphide bands consisting of chalcopyrite, pyrite and/or pyrrhotite, with rarely some sphalerite, are a less common ore type with undefined relationship to the sulphosalt type of mineralization. In some cases the massive sulphide bands contain what appear to be fragments of pyrite. Very rarely stringers or pods of massive sulphosalts are found. The mineralization is considered as possibly of Tertiary age.[1,2]

The Torbrit deposit in the Alice Arm area occurs in pyroclastics and volcanic breccia of the Hazelton Group of Mesozoic age. The deposit is a wide, irregular, somewhat hook-shaped deposit of questionable origin. Although Campbell[3] felt that the evidence favoured replacement and filling of a sheeted and brecciated zone, he considered replacement of a sequence of favourable beds, or replacement and filling of a tectonic breccia zone or a diatreme-like pipe as other possible modes of origin. The presence of a breccia including large blocks of barite gangue in part of the mine may only indicate late tectonic activity, but, in combination with an apparent funnelling of the deposit downward, could be evidence of a diatreme environment.

The Premier deposit in the Stewart area also occurs in pyroclastics and lavas of the Hazelton Group. The orebodies are considered to have formed as replacements along major cataclastic zones. They are sulphide-rich lenses in silicified and pyritized country rock along two major intersecting fracture zones, known as the Northwest and Northeast systems.[5] Grove states that, "In general, ore-grade mineralization appears to be concentrated at or near sheared contacts between fragmental volcanics and feldspar porphyries...." Tetrahedrite, electrum, native silver, polybasite, argentite, and other silver-bearing minerals were found to be most abundant in the upper part of the mine and lead and zinc to increase with depth. Grove[5] has pointed out that in silver production the Premier camp was second to the Sullivan Mine, and in gold production second only to the Bralorne Mine. Discovery of another such deposit would thus be of great economic significance.

[1]Church, B.N.: Goosly Lake, p. 142-148 in Geology, Exploration, and Mining in British Columbia 1969; B.C. Dept. Mines Petrol. Resources (1970).

[2]Sutherland Brown, A., Cathro, R.J., Panteleyev, A., and Ney, C.S.: Metallogeny of the Canadian Cordillera; Can. Mining Met. Bull., vol. 64, No. 709, pp. 37-61 (1970).

[3]Campbell, F.A.: The geology of Torbrit Silver Mine; Econ. Geol., vol. 54, pp. 1461-1495 (1959).

[4]Langille, E.G.: Premier Mine, pp. 121-124 in Structural geology of Canadian ore deposits; Vol. 1, Can. Inst. Mining Met. (1948).

[5]Grove, E.: Portland Canal, Silbak Premier Mines Limited, in Ann. Rept., B.C. Dept. Mines, pp. 21-22 (1964).

MINERALOGY

51. MICA GROUP MINERALS AND RELATED SILICATES IN CANADIAN MINERAL DEPOSITS (NTS 41, 52)

Project 700067

J.H.Y. Rimsaite

In connection with the study of mica-spinel association in Canadian nickel deposits[1], chromite and nickel mines were visited in the Bird River area in eastern Manitoba and western Ontario (NTS 52). Following the preliminary electron probe study of the micas and associated spinels in thin-polished sections (Figs. 1, 2, 3), larger specimens were obtained from the Bird River diabase, Dumbarton and Gordon Lake – Werner Lake nickel deposits for detailed mineralogical studies. Illustrated reports are being compiled on textural relationships between the oxides, silicates and sulphide minerals for the mining companies which donated the specimens. The other mines visited in the Bird River area include abandoned cobalt mines and the Bernic Lake Rare Minerals deposit. Lithian micas and associated minerals were collected for comparison with the Li-Rb-Cs-micas from Ontario and Quebec. Micas and associated feldspar from the Bernic Lake deposit were concentrated for analysis. The lepidolite is similar to that from the Val-d'Or Li-pegmatite[2], and consists of fine-grained aggregates with minute specks of quartz and muscovite. X-ray spectrographic analysis of the lepidolite indicated the presence of 2.25% Rb, 0.4% MnO, and Sn. A paper on Canadian Li-micas,

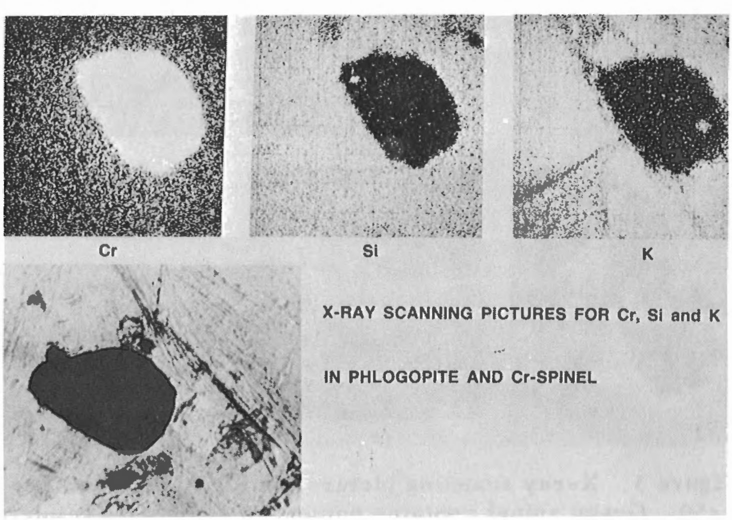


Figure 1. Red chromite in phlogopite, x50. The chromite contains silicate inclusions, and the phlogopite is partly altered along the fractures (depleted K in the X-ray scanning picture for potassium, right).

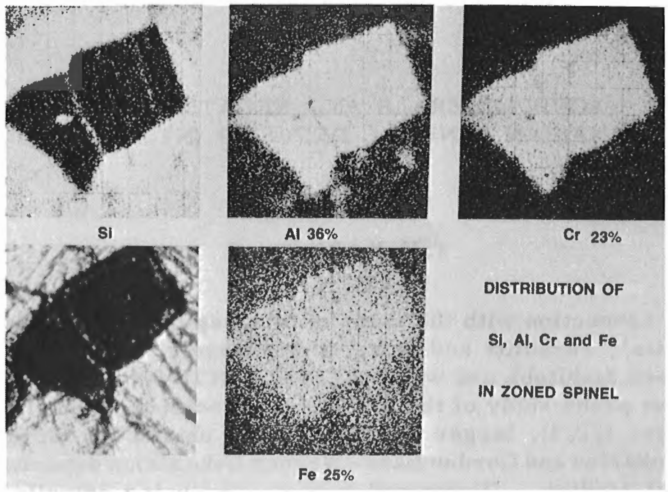


Figure 2. X-ray scanning picture for Si, Al, Cr and Fe, x100. The green spinel contains silicate inclusions and serpentine veinlets, and shows incipient separation of iron from the bleached, speckled edges. The percentages of Al, Cr and Fe oxides were determined by point counting in selected areas of the spinel.

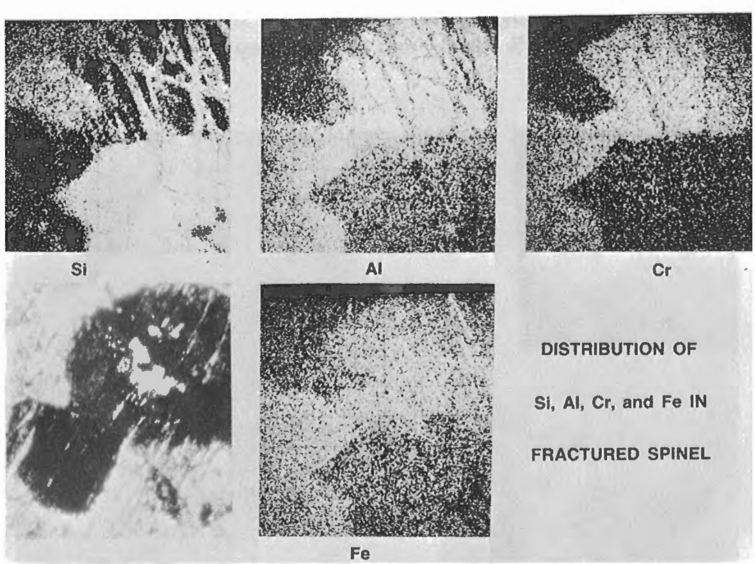


Figure 3. X-ray scanning picture for Si, Al, Cr and Fe, x50. Green spinel contains numerous serpentine veinlets (X-ray scanning picture for Si, left). The serpentine veinlets contain less aluminum and chromium than the host spinel. This figure also shows that it is difficult to obtain clean concentrates of spinels.

in preparation, will include information on the chemical, optical and structural properties of the complex di- and trioctahedral micas.

The following mines were also visited in the Sudbury area (NTS 41) and specimens collected for the project: Falconbridge, Strathcona, Longvack nickel mines; Elliot Lake uranium deposit; Moose Mountain iron formation. Problems concerning ore genesis and the most suitable sampling techniques were discussed with the staff members of both the Falconbridge Nickel Mines Limited and Consolidated Canadian Faraday Limited, who kindly donated drill-core specimens and large rock specimens representing dominant petrographic units and ore types. The results of this study of micas are of interest to mining companies because micas are commonly associated with the sulphide orebodies.

[1] Rimsaite, J.H.Y., and Lachance, G.R.: Spinel-mica paragenesis in the Thompson Nickel Belt, Manitoba; Geol. Assoc. Can. - Mineral. Assoc. Can. Sudbury Meeting, May 1971, Abstr., p. 58 (1971).

[2] Rimsaite, J.H.Y.: Geochemistry, mineralogy and petrology of polymica rocks; XXIII Int. Geol. Cong., vol. 6, Fig. II-3, p. 56 (1968).

PALEOMAGNETISM

52. PALEOMAGNETIC CORRELATION OF BASIC INTRUSIVE AND EXTRUSIVE ROCKS IN THE REGION OF THE GRENVILLE FRONT

Project 710058

W.F. Fahrig and K.W. Christie

Approximately 400 oriented cores were collected from the Mealy Mountain anorthosite, Michael gabbro, Seal Group, Shabogamo gabbro and Ottish Mountain intrusion of Quebec and Labrador. This extends collections made previously from some of these rocks. The collections are made in order to measure the paleomagnetic remanence of these predominantly basic intrusive and extrusive rocks that lie in the vicinity of the Grenville Front. It is expected that remanence directions will be useful in correlating these rocks, in checking the position of the Grenville Front, and in investigating the movement of blocks such as the Makkovik subprovince relative to other parts of the Canadian Shield.

Two hundred and fifty oriented cores were obtained from the early Aphebian Kaminak Lake diabase dykes and younger lamprophyre dykes of the Kaminak Lake area, District of Keewatin. Paleomagnetic measurements on the diabase dykes are expected to throw some light on the position of the Archean rocks (which they cut) relative to other Archean shield areas, prior to the Hudsonian Orogeny.

---

53. THERMOMAGNETICS OF SINGLE MINERALS AND ROCKS

Project 700054

E.J. Schwarz

Sampling for a variety of rock magnetic studies was carried out in the Sudbury area (Ontario).

1. Additional oriented samples were collected from the Sudbury norite in the southern part of the basin. The purpose is to investigate both the direction and intensity of the geomagnetic field at the time of cooling of the rocks and thereby to test some geological applications of this type of work.

2. Oriented samples were obtained from a diabase dyke intruding the norite and of the norite along a line at right angles to the contact between diabase and norite. These samples will be used to study in detail the effect of magnetic overprinting in contact metamorphism, and, in conjunction with the collection mentioned under point 1, may allow an assessment of the use of paleointensity as a geological tool.

3. Oriented samples were collected of pyrrhotite-containing rocks in the Strathcona and Falconbridge Mines in collaboration with the Falconbridge Mining Company. The purpose is to determine the spatial distribution of different pyrrhotite phases, the natural remanent magnetization as well as anisotropy of susceptibility. These results should provide information of practical geological and geophysical value as a test case for a new method of investigation.

PETROLOGY

54. PETROLOGICAL STUDIES IN THE VICINITY OF THE KISSEYNEW FRONT (Parts of 63 J, K)

Project 700065

E. Froese and J.M. Moore

During the summer of 1971 mapping on a scale of one inch equals one-half mile was continued in the Snow Lake area (63 K/16 E1/2 and 63 J/13 W 1/2). Two periods of deformation may be distinguished. The earlier folds, with axes of varying attitude, are open in the western part of the area becoming isoclinal towards the east. The later folds having axes with a persistent northeasterly plunge produced the presently most obvious structural features. Two isograds in pelitic rocks may be mapped on the basis of reactions:

1. staurolite + chlorite + muscovite + quartz ⇄ kyanite + biotite + water
2. staurolite + muscovite + quartz ⇄ sillimanite + almandine + biotite + water.

Isograd (1) follows approximately the northwest shore of Wekusko Lake and isograd (2) passes through Squall Lake and Herblet Lake.

---

55. DALY BAY METAMORPHIC COMPLEX, DISTRICT OF KEEWATIN

Project 700048

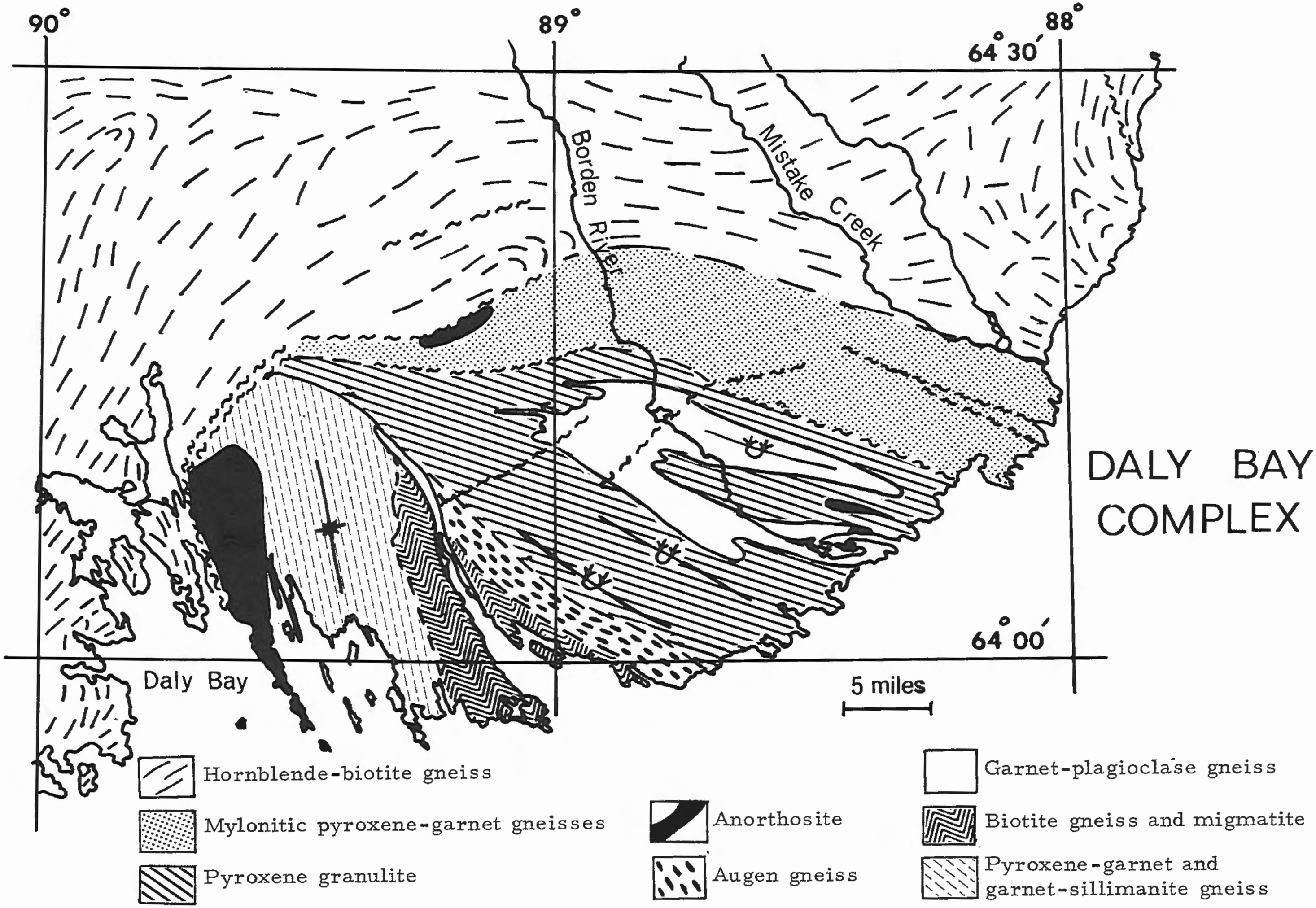
T.M. Gordon

A helicopter and float-equipped fixed-wing aircraft were used to support continued mapping in the Daly Bay Complex and surrounding rocks[1, 2]. Field notes were taken in a form compatible with the SAFRAS[3] system of data storage and retrieval. The utility of this system in expediting mapping and petrologic studies will be tested during the winter.

Principal map-units, defined by a combination of mineralogical, textural, and structural criteria, are shown in Figure 1. Contacts between gneiss units are gradational due to interlayering of the main lithologies.

Hornblende-biotite gneiss, surrounding the complex, contains plagioclase, potash feldspar, quartz, and varying amounts of hornblende and/or biotite. Locally this unit includes amphibolite, migmatite, and granitic rocks. Layers range from 5 to 50 cm in thickness and are often contorted by complex folding.

Mylonitic pyroxene-garnet gneiss, containing feldspar, quartz, pyroxene, garnet, and minor hornblende and biotite, occurs along the north and northeast margins of the complex. These rocks have a well-developed foliation parallel to compositional layering and show a strong mineral lineation. Conformable shear zones and faults are common.


90°
89°
88°
64°30′
64°00′
Borden River
Mistake Creek
Daly Bay
5 miles
DALY BAY
COMPLEX
Hornblende-biotite gneiss
Mylonitic pyroxene-garnet gneisses
Pyroxene granulite
Anorthosite
Augen gneiss
Garnet-plagioclase gneiss
Biotite gneiss and migmatite
Pyroxene-garnet and
garnet-sillimanite gneiss

Scattered rusty zones, usually less than 50 square feet in area, are due to oxidation of local pyrite concentrations.

Pyroxene granulite. Weakly foliated but well-layered rocks composed of microcline, plagioclase, quartz, and clinopyroxene, with varying amounts of hypersthene, biotite, and hornblende, outcrop in the central part of the map-area. Layers range from 1 to 50 metres and have been deformed into overturned isoclinal folds with southwest dipping axial planes.

Augen gneiss contains potash feldspar phenocrysts in a quartz-feldspar-biotite-hornblende matrix. This rock type occurs in all map-units, but is concentrated in a northwest-trending belt in the south-central part of the map-area.

Garnet-plagioclase gneiss is the dominant rock-type in a unit composed of metamorphosed sediments. Well-layered to massive, the rocks include biotite-sillimanite and garnet-cordierite sillimanite schists as well as minor impure quartzite and marble. Graphite is a common accessory mineral.

Biotite gneiss and migmatite form a highly contorted, complex series of rocks bordering Bernheimer Bay. These rocks differ from the hornblende-biotite gneisses surrounding the complex in the common occurrence of garnet and blue quartz.

Pyroxene-garnet and garnet-sillimanite gneiss, with interlayered hornblende-biotite gneiss, garnet-plagioclase gneiss, and augen gneiss, outcrop as a heterogeneous, well-layered unit east of the main anorthosite body. These rocks have been isoclinally folded and in addition have migmatitic and boudinaged layers.

Anorthosite and gabbroic anorthosite occur in three main bodies and several minor layers. The contacts are commonly crushed and foliated parallel to the enclosing rocks. Contorted, discontinuous layers of garnet amphibolite occur at the margins of the larger bodies and probably represent metamorphosed primary igneous layers.

Structural style in the complex ranges from flow-folding in the rocks at Berheimer Bay outward through a zone of isoclinal folding to mylonization at the margins of the complex. The Daly Bay Complex appears to be faulted against the surrounding biotite-hornblende gneisses, although subsequent metamorphism has obscured this relationship in places.

Rocks in the central part of the complex have been metamorphosed under conditions where the assemblage potash-feldspar + sillimanite is stable with respect to muscovite + quartz. Preliminary evidence suggests that the margins of the complex have undergone retrograde metamorphism with amphibole and biotite replacing pyroxene and garnet. The relationship of metamorphism to deformation will be the subject of a continuing petrographic study.

No mineral occurrences of economic interest were encountered. The occurrence of pyritic gossans, shear zones and minor quartz veining in the mylonitic rocks bordering the complex suggests this map-unit as the most favourable locality for prospecting activity.

[1]Heywood, W.W.: Geological notes, northeastern District of Keewatin and southern Melville Peninsula, District of Franklin, Northwest Territories; Geol. Surv. Can., Paper 66-40, pp. 7-9 (1966).

[2]Gordon, T.M.: Petrology and Structure of Daly Bay Complex, District of Keewatin; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 111-112 (1971).

[3]Sutterlin, P.G., and DePlancke, J.: Development of a flexible computer-processible file for storage and retrieval of mineral deposits data; in Proceedings of a symposium on decision-making in mineral exploration II, A.M. Kelly and A.J. Sinclair, Editors. Vancouver, (1969).

---

56. PENRHYN GROUP METAMORPHIC COMPLEX, MELVILLE PENINSULA, DISTRICT OF FRANKLIN

Project 710053

J.E. Reesor

About a month was spent in the area of the Penrhyn Group metasediments and associated gneisses, immediately north and northeast of Lyon Inlet on Melville Peninsula[1].

Ubiquitous thin layers of pelitic schist containing the assemblage sillimanite-almandine-biotite, with or without potash feldspar show the rocks to be in the uppermost amphibolite facies of regional metamorphism. Although a consistent 'stratigraphy' is difficult to distinguish in these highly metamorphosed and intensely deformed metasediments a tentative succession can be mapped, progressing from orthoquartzite through pelitic schist to biotite-quartz-plagioclase paragneiss, massive marble, calcium silicate gneiss, followed by biotite-quartz-plagioclase paragneiss, schist and quartzitic schist.

Rusty zones characterized by iron oxide stains are associated with pelitic schist and graphitic quartz paragneiss layers containing a great deal of pegmatite. These zones are most common in the 'stratigraphic' layer just above the orthoquartzite. However, some rusty zones are associated with pelitic horizons within the marble-calcium silicate succession. Large amounts of graphite are commonly present, in places with a little sulphide, usually pyrite.

Associated with the metasediments are lenses and sheets of quartz-feldspathic gneiss and migmatite. These rocks, even in small outcrops, display a great variety of rock types; medium-grained biotite-quartz-feldspar gneiss, coarse, grey, biotite granitoid gneiss, hornblende-quartz-feldspar gneiss, networks of coarse pink granite and pegmatite, and minor amphibolite boudins and lenses.

Major structures are dominated by the tongues and lenses of gneiss in the cores of large northward-verging folds outlined by the metasedimentary succession. Lenses of gneiss appear to have moved to different 'stratigraphic' levels in the covering metasediments and migmatite can be seen to underlie, penetrate and overlie various horizons in the metasedimentary succession. Small-scale structures in gneiss and metasediments are concordant and no structures were found in the former that were discordant to those in the metasediments or that seemed to belong to a different phase of folding than that which affected the sediments.

Foliation in the gneiss tongues is commonly even and regular near the contacts with metasediments. In the cores of gneiss lenses foliation is commonly much folded and in some places lineation becomes the dominant feature of the gneiss. Small scale, commonly isoclinal, folds in the associated gneiss metasediments change plunge and orientation with the orientation and plunge of the associated gneiss lens.

Any sequence of events based on the work so far done is quite tentative, and further work may result in a quite different picture as more information is accumulated. Structural deformation and metamorphism were synchronous, and both appear to have been initiated by the movement of tongues and slices of migmatite into an overlying, lithologically varied, metasedimentary succession. Although orientation and plunge of folds varies from place to place they are related to the size and orientation of the gneiss and therefore do not constitute a recognizable separate phase of deformation.

[1] Heywood, W. W.: Geological notes Northeastern District of Keewatin and Southern Melville Peninsula, District of Franklin, N.W.T.; Geol. Surv. Can., Paper 66-40 (1967).

PRECAMBRIAN GEOLOGY

57. PRECAMBRIAN GEOLOGY, STRAIT OF BELLE ISLE, NEWFOUNDLAND AND LABRADOR

Project 680130

H.H. Bostock

Reconnaissance study of the Precambrian rocks of the northern part of the Long Range Mountains, Newfoundland, and of southeastern Labrador south of 52° N was completed[1,2].

The oldest rocks are lithologically similar on both sides of Strait of Belle Isle. They consist of leucocratic to melanocratic, potassic gneisses with some siliceous and pelitic gneisses and minor calcsilicate gneisses. Sillimanite is present throughout the pelitic gneisses. North of the strait, gneisses (as opposed to granitic plutonic rocks) are more extensive than shown on Geological Survey of Canada Map 1250A.

Granitic plutonic rocks intrude the gneisses on both sides of the strait. They are coarse to medium grained, and contain megacrysts of feldspar. Some granite is partly foliated. The granitic rocks in the Long Range Mountains are generally megacrystic and those in Labrador more commonly are nearly equigranular. Biotite is the typical mafic mineral in the Long Range Mountains whereas both biotite and hornblende are common in the granitic rocks of Labrador.

Four small, medium-grained gabbro bodies were found in Labrador, one at Red Bay and three near Henley Harbour. Two somewhat larger bodies of medium- to coarse-grained feldspathic rock, some of which is anorthosite, were examined, one on Pinnware River about 9 miles north of its mouth, and a second about 15 miles north-northeast of Bradore Bay.

Foliation in the gneisses surrounding granitic plutons in the Long Range Mountains commonly dips moderately toward the plutons but in Labrador it dips steeply. Mineral lineation is commonly prominent in gneisses of the northern Long Range Mountains. North of the Strait of Belle Isle, near Henley Harbour, such lineations are also prominent, but farther west their orientation becomes less consistent and they are more difficult to detect.

No deposits of economic interest were examined during the summer. Specimens of massive chalcopyrite and of massive ilmenite, said to have been collected from the drift near the gabbro body at Red Bay, were shown to the writer by local people.

[1] Bostock, H.H.: Precambrian rocks, Long Range Mountains, northwest Newfoundland (12 I); in Report of Activities, Part A, April to October 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 125-129 (1970).

[2] Bostock, H.H.: Precambrian geology, Strait of Belle Isle, Newfoundland; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 122-123 (1971).

58. GRANITE STUDIES IN THE SLAVE PROVINCE (Parts of 85 I)

Project 710023

A. Davidson

These studies are aimed at determining the types of plutonic rock that occur in the Slave Province, their lithologic, structural, and age relationships, and their role in the development of the Archean crustal block that constitutes the province. This past summer field work was initiated in two areas within the Hearne Lake (Beaulieu River) map-area: the plutonic complex in the vicinity of Blachford Lake (85 I/1 and /2), and the region of plutonic rocks between Cameron and Beaulieu Rivers (85 I/10, /11, /14, and /15).

Blachford Lake area

The plutonic rocks in the vicinity of Blachford Lake were previously mapped at a scale of 4 miles to 1 inch as a complex of gabbro, diorite, and anorthosite, later invaded by granitic rocks[1,2]. This relationship was confirmed during detailed mapping, and it was found in addition that the later granitic rocks are made up of at least 6 distinct plutonic units, some of unusual type (Fig. 1). The basic complex (1a, 1b) intrudes metasediments of the Yellowknife Supergroup (As). Presumably larger before intrusion by the later plutonic rocks, the complex now consists of a western rim and a southwest dyke-like extension of gabbro (1a), commonly rich in magnetite, which grades eastwards with increasing grain size to coarse leucogabbro and anorthosite (1b) whose mafic minerals are magnetite and hornblende, locally with coarse, fresh biotite. Although crude layering was observed in a few places in the gabbro, the rocks are usually massive. Plutons of grey, even-grained biotite tonalite and granodiorite (2) and of cream to pink biotite leuco-adamellite with K-feldspar megacrysts (3), of uncertain mutual age relationship, intrude the gabbro. The adamellite (3) was apparently emplaced close to the original margin of the gabbro, for in places the two are separated by metasedimentary hornfels against which the gabbro is chilled. Elsewhere the adamellite has cut through this contact into coarse gabbro. Although the southwest extension of the gabbro appears like a large dyke in Figure 1, it was observed to be intruded by granitic rocks at several places.

East of Caribou Lake, green, brown-weathering hornblende syenite (4a), in most places containing a little visible quartz, forms an incomplete ring around a central melange (4b) of huge blocks of metasediment (As), gabbro and anorthosite (1a, 1b), and tonalite (2), separated and cut by syenite dykes. A pluton of pink, red-weathering hornblende quartz syenite (5), commonly containing scattered xenocrysts of dark grey plagioclase with K-feldspar overgrowths, intrudes the basic complex north of Great Slave Lake, and at its west contact cuts across dykes of adamellite (3) in metasediments (As). Parts of its north contact are subhorizontal, exposed on the flanks of anorthosite-capped hills. An immense raft of anorthosite lies in the central part of this pluton. The anorthosite (1b) and both syenites (4a, 5) are cut by small plutons of fine-grained, pink, hornblende-biotite granite (6) characterized by subhedral K-feldspar phenocrysts in a peppery textured groundmass. Dykes of both syenites and granite (4a, 5, 6) are common in the main mass of leucogabbro and anorthosite.

Coarse-grained hornblende alkali granite (8a), locally almost devoid of hornblende, forms a cylindrical pluton 12 miles (19 km) in diameter. Its outer contact dips steeply and cuts cleanly across the older plutonic rocks to the west. At its western margin near Great Slave Lake it contains rafts of syenitized anorthosite and red quartz syenite. It surrounds a core of massive hornblende syenite (8b) composed of euhedral K-feldspar with scattered, large, intersertal hornblende crystals. At its north and east sides the syenite appears to overlie the granite with a shallow south and west dipping abrupt gradational contact. Both granite and syenite contain rare, large xenoliths of recrystallized metasediment. A mass of relatively fine-grained hornblende diorite or monzonite (7) seems to be a giant inclusion of an earlier plutonic unit.

It is noted that contacts between the plutonic units outlined above continue undisturbed where they cross topographic lineaments close to and parallel with the north shore of Great Slave Lake. The granitic rocks of units 2 and 3 have similar or identical counterparts among the common granitic rocks elsewhere in the Slave Province. The syenites and granites of units 4 to 8, however, are unlike any other granitoid rocks so far reported in the province. None is deformed or foliated, and weathering, although commonly deep, appears to be the only alteration in most places. The age of these rocks is not yet known.

Narrow east-trending veins containing niccolite in a carbonate gangue, identical to those already reported[1], have been found and trenched

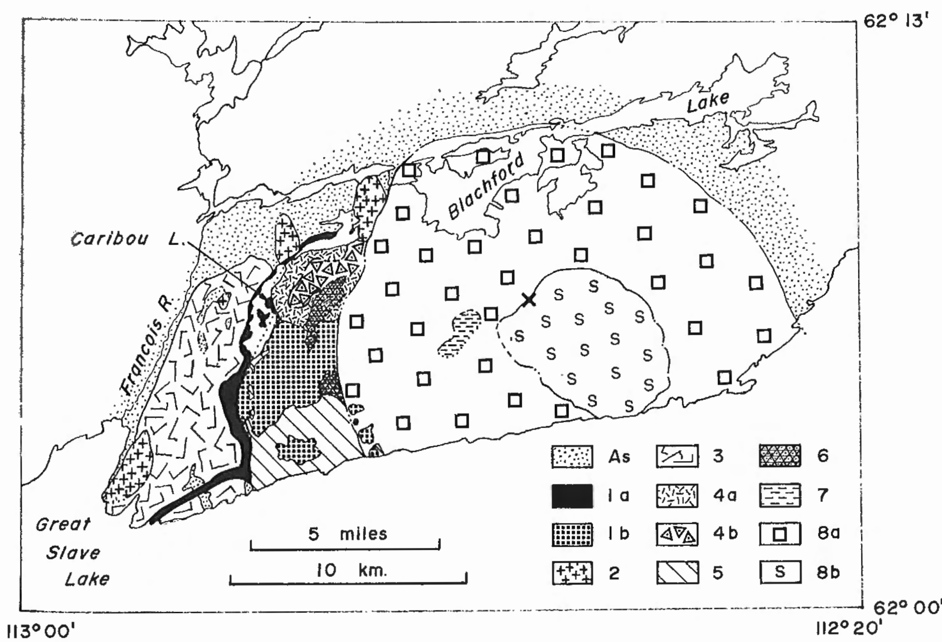


Figure 1. Geology of the plutonic rocks in the Blachford Lake area. (see text for legend)

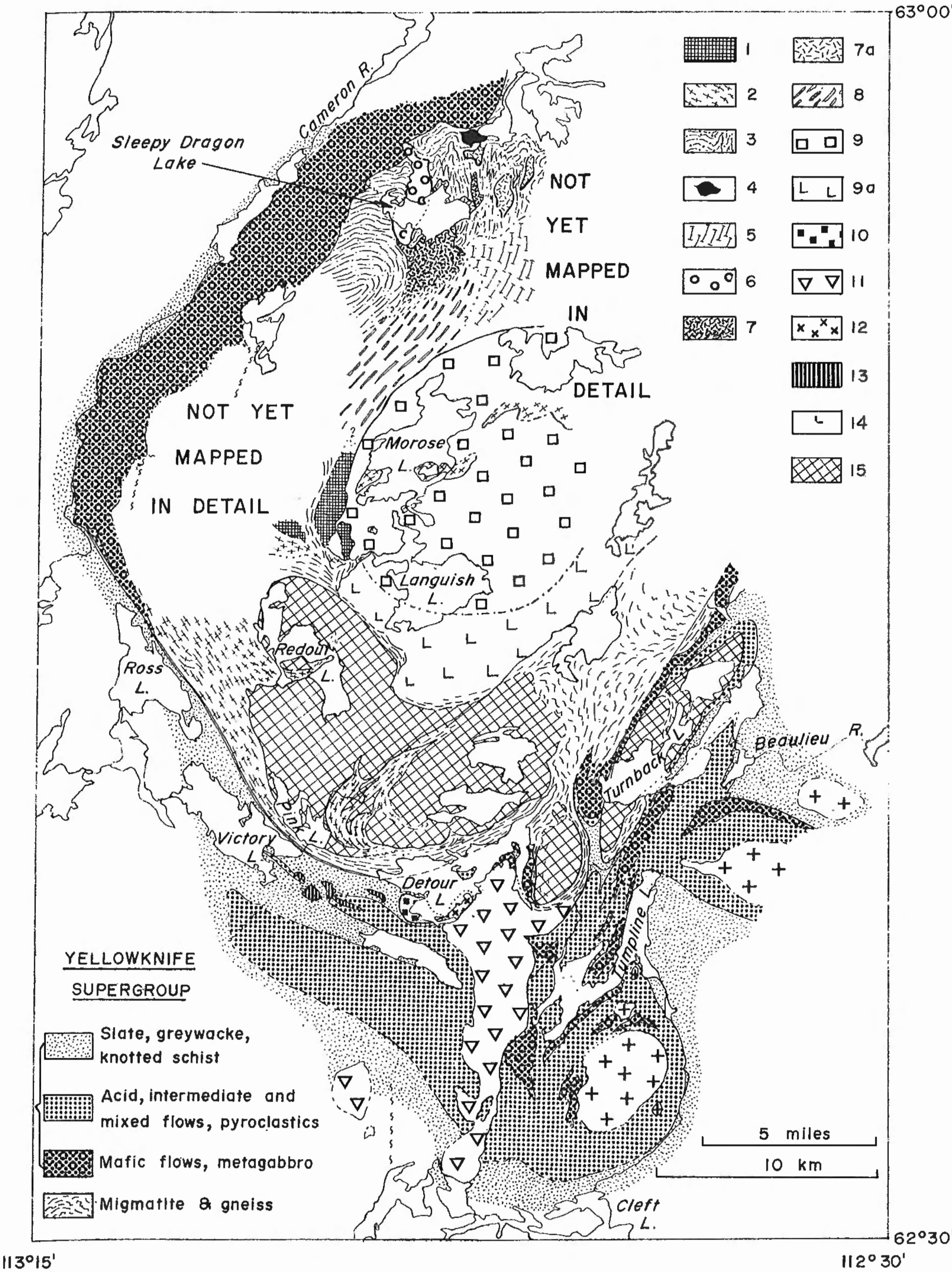


Figure 2. Geology of the plutonic rocks in the area between Cameron and Beaulieu Rivers. (see text for legend)

at the south end of Caribou Lake, and were observed to cut pink quartz syenite (5). At the location marked X at the northwest contact of the syenite (8b), recent staking has covered an area of brecciated and altered rocks, pervaded by quartz veins, in which dark micaceous rocks with local purple fluorite are mildly radioactive.

Cameron River–Beaulieu River area

In the area between Cameron and Beaulieu Rivers (Fig. 2), two types of granitic rocks were recognized[3, 4] and have been referred to since as the Ross Lake Granodiorite and the Redout Lake Granite[5]. The older Ross Lake Granodiorite (2) is cut by a swarm of closely spaced, northwest-trending mafic dykes, now amphibolite. Both have undergone deformation, expressed in the granodiorite by foliation and progressive reduction to quartz-muscovite schist and even mylonite. The more competent dykes progressively develop biotite schist margins, become longitudinally sliced, and are last recognized as narrow zones of biotite and amphibole (possibly gedrite) that in places swell and contain hornblende schist cores. Foliation is subvertical and strikes northwest. Deformation effects become more intense as the southwest contact is approached, where subsequent recrystallization has produced a dense, white, feldspathic rock with little or nothing to suggest its origin. The adjacent mafic pillowed flows and conglomerate give the impression of having been considerably less deformed. No intrusive relations were seen. The Redout Lake Granite (15) cuts across the foliation of the Ross Lake Granodiorite and locally contains abundant inclusions of both granodiorite and amphibolite. It is usually pink, fine- to medium-grained, and has a sugary texture, but is commonly quite variable, even within a single outcrop. It normally contains both muscovite and biotite, more rarely tourmaline. Small pegmatitic patches are common. Pegmatite dykes that cut the Ross Lake Granodiorite and amphibolite dykes to the west are considered to be related to the Redout Lake Granite[6].

Mapping to the south and east of Redout Lake has revealed the full extent of the Redout Lake Granite. East of Pink Lake, the older granitic rock within it is highly recrystallized granodiorite orthogneiss containing folded amphibolite lenses, presumably derived from the Ross Lake Granodiorite and amphibolite dykes. On its south and east sides the Redout Lake Granite has a complicated pegmatite-riddled contact with migmatitic gneisses, apparently derived mainly from supracrustal rocks, that invariably separate the granite from unequivocal strata of the Yellowknife Supergroup. West of Detour Lake these gneisses are in sharp conformable contact with conglomerate containing amphibolite pebbles that is overlain by marble, skarn, and calcite-cemented acid volcanic breccia, followed by pelitic cordierite knotted schist of the Yellowknife Supergroup. This sequence is penetrated by pegmatite and late granite dykes unlike either the Ross Lake Granodiorite or the Redout Lake Granite, although possibly related to the small stocks of biotite granodiorite (13) one mile to the south. A dome of Redout Lake–type granite east of Detour Lake has a narrow carapace of migmatitic gneiss around its west, south, and east sides. An elongate dome of similar granite at Turnback Lake is in part in direct contact with Yellowknife strata and has a halo of pegmatite bodies that extends as a tail for 4 miles southwards along the trace of the dome axis. The area of migmatite and gneiss northwest of Turnback Lake contains patches of both layered gneiss and orthogneiss and is full of small masses of Redout Lake-type granite and pegmatite. West of Turnback Lake, between the three main masses of Redout Lake-type granite, highly metamorphosed Yellowknife strata (pelitic rocks contain sillimanite) show early folds refolded about shallow undulating axes that trend between north and northeast. At the northwest side of the Turnback Lake dome, a major syncline overturned to the southeast appears to be overthrust by mafic metavolcanic rocks on the west side.

At and south of Detour Lake, 5 different types of granitic rock are present. The earliest appears to be fine-grained, grey quartz porphyry (10) that intrudes the metasediments in the south bay of Detour Lake. It is foliated and contains innumerable dykes of massive, grey, fine- to medium-grained biotite granodiorite that penetrate its contact and cut the surrounding metasediments. This grey granodiorite (12) also forms small separate plutons in and around the lake, and is probably younger than the large mass of medium-grained, foliated biotite muscovite granite (11) that extends southwards towards Cleft Lake. This two-mica granite is deformed and recrystallized in the carapace of the Redout Lake-type granite dome east of Detour Lake. Small, irregular bodies of lilac-grey to pink microgranite with muscovite phenocrysts and scattered tourmaline poikiloblasts (not shown in Fig. 2) occur at Detour Lake and towards Turnback Lake, and are probably a late phase of the Redout Lake Granite. Southeast of Victory Lake, small irregular bodies of biotite granodiorite (13) cut Yellowknife strata and are older than pegmatites presumed related to the Redout Lake Granite.

East of a line between Tumpline and Turnback Lakes are three large and three small plutons, sharply defined and in detail crosscutting, of generally homogeneous, massive biotite granodiorite (14), quite different in appearance to the granitic rocks to the west.

The core of the plutonic area between Cameron and Beaulieu Rivers is occupied by a large pluton of two-mica adamellite (9) that is coarse, massive, homogeneous, commonly white, and contains K-feldspar megacrysts. Its north and west contacts are sharp, and it clearly intrudes older metamorphosed diorite (1), granodiorite (2), and a variety of migmatitic gneisses to the west. Several large masses of older granodiorite and tonalite are included within it at Morose Lake. To the south it grades, through loss of megacrysts, into uniform grey to pinkish grey two-mica adamellite or granodiorite (9a). This becomes foliated close to the Redout Lake Granite (15), but in most places it is separated from it by a zone of older migmatitic gneisses. North of Morose Lake the coarse adamellite (9) is in contact with migmatitic granitoid gneisses (5) and dark dioritic gneisses (8) that trend northeast with steep dips. Towards Sleepy Dragon Lake the dioritic gneisses give way along strike to a unit of more massive diorite and mafic tonalite (7) that is intimately associated with a later grey granodioritic phase. To the east, the granitoid gneiss (5) swings northwards and changes, by virtue of being less recrystallized, to cataclastic gneiss (3) that includes augen granite gneiss, mylonitic granite and pegmatite, and thin amphibole schist lenses. The north-trending foliation east of Sleepy Dragon Lake becomes recognizable as an axial planar foliation north of the lake, about which the earlier cataclastic foliation becomes progressively less severely folded westwards; west of the lake the cataclastic foliation trends westerly with moderate north dip and shows only broad open folds. Small masses and thin layers of schistose amphibolite are contained by and have been deformed with the cataclastic gneiss (3). In places these show tight intrafoliar folds lying in the plane of cataclastic foliation.

Southwest of Sleepy Dragon Lake and west of the younger diorite unit (7), the cataclastic foliation forms a large fold around which the intrafoliar folds are folded. This northeast-trending fold may be older than the northerly folds north of Sleepy Dragon Lake, but structural relationships are not yet clear.

North of Sleepy Dragon Lake the cataclastic gneiss (3) contains a mass of metagabbro (4). At Sleepy Dragon Lake it is cut by a pluton of metamorphosed and foliated granodiorite (6). Both gneiss and granodiorite (3, 6) are cut by north-northwest-trending amphibolite dykes that are massive except for foliated biotitic margins. The gneiss, metagabbro, granodiorite, and amphibolite dykes are cut by several small plutons and dykes of fine-grained diorite (7) and microgranitoid (7a).

West and north of Sleepy Dragon Lake, the contact with mafic flows of the Yellowknife Supergroup, Cameron River belt, in places truncates the foliation of the cataclastic gneiss (3). Pillows in the volcanics are well preserved within a few hundred feet of the contact and indicate a uniformly facing succession across the belt to Cameron River, where the volcanics are overlain by slate and greywacke. Although metamorphic grade and intensity of deformation (flattening of pillows) increase towards the cataclastic gneiss, no evidence of intrusion by granitic rocks was seen. What is more, the cataclastic foliation in the gneiss (3), indicative of severe penetrative deformation, does not continue into the metavolcanic rocks. The north-northwest-trending amphibolite dykes that cut the gneiss also cut deformed mafic flows near the contact. Like the mafic dykes in the Ross Lake Granodiorite (2) to the south, these dykes contain scattered plagioclase phenocrysts, but whether or not they are part of the same swarm has yet to be determined. It seems plausible, on structural grounds, to make the interpretation that the cataclastic gneiss in the vicinity of Sleepy Dragon Lake is older than and is basement to the adjacent Yellowknife mafic flows, and that the contact is an unconformity, albeit considerably modified. However, it is also possible to interpret the observed structural discordance as the result of faulting, with subsequent healing during metamorphism. Further detailed work should resolve this problem.

During the course of mapping the granitic rocks and their surrounding structures, it was noted that calcareous rocks commonly occur near and at the top of parts of the acid and intermediate volcanic strata. The contact between these rocks and the overlying pelitic metasediments is a useful marker horizon, and is also the locus of sulphide minerals. What appears to be a single unit of calcareous rocks can be traced from Ross Lake to Detour Lake, through the islands in Detour Lake, and around the north end of the biotite-muscovite granite body (11). The same unit occurs at the top of the volcanic succession that is exposed in the anticline just south of Detour Lake, is present as inclusions in the granite (11) to the east, and reappears on the west side of Beaulieu River where it enters Tumpline Lake, whence it can be traced sporadically northwards towards Turnback Lake. It is absent on the long peninsula in Turnback Lake, but appears again to the north in the same stratigraphic position around the north end of the elongate dome of granite (15). Base metal sulphides, predominantly sphalerite with some chalcopyrite, are present at Turnback Lake for a strike length of at least 6,000 feet to the south beyond which the calcareous rocks peter out (XL Group). Zinc mineralization occurs at Victory Lake (Victory Lake Mines) and is reported by Henderson (see elsewhere in this publ.) in the same stratigraphic position at Ross Lake. Lenses of massive iron sulphides, conformable with bedding occur with skarn at several places along this horizon, notably at and south of Detour Lake. Stratigraphic restriction and the apparent lack of association with any one of the several types of granitic rock lead to the suggestion that this mineralization is stratabound, and possibly volcanogenic in origin.

The initial phase of these studies has shown that regions of plutonic rocks in the Slave Province, as expected, may be highly complex, but can be broken down into meaningful map-units. More than twenty distinct plutonic units have been established in the two areas studied, where only three had been separated previously. The next phase will involve an attempt to recognize the main plutonic units in adjacent regions during less detailed mapping at a smaller scale, with detailed follow-up in critical areas.

[1] Henderson, J. F.: Geol. Surv. Can., Paper 39-1 (1939).

[2] Henderson, J. F.: Geol. Surv. Can., Map 581A (1941).

[3] Henderson, J. F.: Geol. Surv. Can., Map 645A (1941).

[4] Fortier, Y. O.: Geol. Surv. Can., Paper 47-16 (1947).

[5] Green, D. C. and Baadsgaard, H.: J. Petrol., vol. 12, p. 177 (1971).

[6] Hutchinson, R. W.: Geol. Surv. Can., Bull. 34 (1955).

---

59. THE HARP LAKE INTRUSION, LABRADOR

Project 670003

R. F. Emslie

Reconnaissance structural and petrological studies were continued in 1971 on the Harp Lake intrusion. Layered structures in troctolite, leucogabbro and anorthosite are widely distributed and all have low to moderate dips. The contact of the intrusion was observed at two localities. Where examined, the north contact against foliated migmatite and granulite dips nearly vertically and the south contact with similar rocks dips about 70 degrees north.

A swarm of vertical olivine gabbro dykes 50 to 200 feet thick cuts across the intrusion in an east-northeast direction. These intrusions are subparallel to Harp Lake and other lineaments and thus define a major fracture system. It is uncertain whether these dykes are related to the anorthositic complex or are distinctly younger. The dykes appear not to extend beyond the limits of the Harp Lake intrusion and this favours the former interpretation.

Along the southern boundary of the intrusion, at two localities, clastic dykes of red sandstone were discovered in the anorthosite. Outcrops of flat-lying Shipiskan Formation (red sandstone, grit and conglomerate; interbedded basalt) lie near the intrusion and this conclusively demonstrates an unconformable relationship.

Large pieces of black, magnetic oxide float were found in the southwestern part of the Harp Lake intrusion. This year one deposit was discovered and brief examination indicates an interesting pocket of coarsely crystalline massive magnetic oxides. About 25 square feet was uncovered on one side of the deposit which occurs in coarse leucotroctolite. The occurrence is at 63° 06'W, 54° 47'N on a rocky rise about 300 yards north of a small lake.

---

60. PRECAMBRIAN GEOLOGY OF NORWAY HOUSE (63 H), GRAND RAPIDS (63 G), AND BERENS RIVER (63 A(WEST HALF)) MAP-AREAS, MANITOBA

Project 710025

I. F. Ermanovics, L.S. Jen* and J.A.R. Stirling*

Field work has been completed in Norway House and Grand Rapids map-areas and the data are being processed for publication of a preliminary map (1:250,000). As predicted from aeromagnetic map 7739G, rocks of the northern and southern portions of the total area mapped exhibit different tectonic styles; the change occurs along an east-west, curvilinear mylonite zone, 2 miles wide, and centred about 53° 30'N. North of this break 40 per cent of the area is underlain by ultramafic and volcanic rocks (The Stevenson-Ponask Lakes volcanic belt), altered gabbros and quartz diorite, mafic granodiorite, tonalitic-trondjemitic- and granitic-gneiss, and altered diabase and gabbroic dykes. Fourteen unaltered quartz and olivine diabase dykes were discovered. South of 53° 30'N, large, acid to intermediate granodioritic plutons (85 per cent) enclose layered mafic and granitized gneisses (15 per cent) confined mainly to the eastern part of the area. This southern granitic complex in Manitoba represents the northern extent and termination of 12,000 square miles (between 51° 30'N to 53° 30'N) of dominantly granitic terrain mapped in 1968 and 1969[1], whereas the area north of 53° 30'N is similar to portions of the Cross Lake area[2].

The volcanic belt (an extension of the Island Lake volcanic belt) comprises 70 per cent basalt (fine-grained amphibolite) and ultramafic rocks; the remaining 30 per cent comprises a sequence of dacite, andesite, rhyodacite and intercalated ultramafic rocks and tuffs. Pyroxenite altered to actinolite-tremolite and serpentinitic peridotite are two ultramafic rock varieties that were recognized. The belt has a maximum width of 4 miles, but a true thickness of not more than 2,000 feet. Metamorphism has advanced to lower amphibolite facies and compression on the belt has produced isoclinal folds which are superimposed upon broader, open folds.

Mineralization has produced zones of disseminated pyrite and pyrrhotite in all sheared rocks and in layered rocks, specifically in andesite and dacite. Airborne electromagnetic and magnetic surveys and ground electromagnetic and magnetometer surveys completed in 1959 delineated a number of conductive zones in the volcanic belt. The present work demonstrates that these anomalies are underlain by ultramafic rock.

---

* Student assistant.

[1] Ermanovics, I. F.: Geology of Berens River–Dear Lake map-area, Manitoba and Ontario; Geol. Surv. Can., Paper 70-29 (1970).

[2] Bell, C.K.: Cross Lake map-area, Manitoba; Geol. Surv. Can., Paper 61-22 (1962).

---

61. YELLOWKNIFE AND HEARNE LAKE MAP-AREAS, DISTRICT OF MACKENZIE WITH EMPHASIS ON THE YELLOWKNIFE SUPERGROUP (ARCHEAN)

Project 700015

John B. Henderson, M.P. Cecile*, and D.C. Kamineni*

This is a continuing project begun last year involving the mapping of Archean parts of the Yellowknife and Hearne Lake map-areas on a 1:250,000 scale. The Hearne Lake area has previously been mapped on a 4 mile:1 inch scale[1]. Except for a short period in the northeastern part of the Yellowknife area, field work was restricted mainly to the sediments and volcanics of the Yellowknife Supergroup in the Hearne Lake area. The granitic rocks in the central-northeast and south-central parts of the Hearne Lake area were mapped in detail this past season by A. Davidson (see separate report, this publ.).

Approximately half the area is underlain by supracrustal rocks of the Yellowknife Supergroup of which about 90 per cent are of sedimentary origin. The sediments consist almost exclusively of greywacke mudstone turbidites. The turbidites vary considerably in character ranging from massive, thick-bedded 'proximal' beds commonly with amalgamation of individual units, to thin-bedded siltstones with the pelitic part of the bedding unit greatly exceeding the coarser grained part of the beds. Despite the structural complexity and metamorphism in much of the area internal sedimentary structures are well preserved. Compositionally the sediments range from volcanogenic greywackes to quartz wackes. Throughout the area the maximum grain size of the sediment is typically restricted to medium sand although in a few isolated cases gravel sized material does occur. Units of carbonaceous mudstone up to several tens of feet thick are associated with the greywacke mudstones throughout the area. These commonly contain finely disseminated sulphides. No regional variation of the greywacke mudstone facies is apparent and correlation of the whole unit with the Burwash Formation described at Yellowknife[2] is indicated.

East of Ross Lake and parallel with the contact with the Ross Lake Granodiorite is a complex metasedimentary unit generally less than 300 feet thick consisting of conglomerate, tuffaceous sediments, carbonate-cemented sandstones and intercalated felsic volcanics. This unit is the southward transition of the thinning mafic volcanic sequence east of the Cameron River. There is no evidence of an unconformity between the volcanics and the sediments. The presence of granitic pebbles similar in many respects to the Ross Lake Granodiorite that are found in the upper part of the conglomerate

---

* Graduate Field Assistant.

suggests that the granitic body may be older. There is no evidence of an intrusive relationship at the contact and the contrast between the highly sheared Ross Lake Granodiorite and the generally well preserved supracrustal rocks is striking. Although there may have been considerable movement at the contact obscuring the details of an unconformable relationship it appears likely that in the Ross Lake area the granitic body to the east is older than the Yellowknife supracrustal rocks to the west.

Approximately half the area underlain by Yellowknife supracrustal rocks is in the greenschist facies of metamorphism. The cordierite isograd defining the uppermost limit of this facies is outlined on the existing map of the area[1]. With the possible exception of the Gordon Lake region which was not mapped this season, most of the lower grade metasediments contain biotite. At the north end of Hearne Lake, among other areas, is a thick section of very volcanogenic greywackes lacking biotite. This is believed to be more a reflection of the composition of the sediments than of the metamorphic conditions. Amphibolite-grade metamorphism occurs in two wide zones. One on the west side of the map-area contains several large plutons of biotite-muscovite granite. Within this zone assemblages of biotite, andalusite, garnet, gedrite and cummingtonite are found. Biotite and cordierite are common throughout this area while andalusite and garnet are more common closer to the granites. Gedrite occurrences, governed by compositional restrictions, represent the highest grade assemblages. Sillimanite-bearing assemblages were not identified in the field. Staurolite also occurs in a few localities north of Prosperous Lake where the sediments are unusually argillaceous. The other large amphibolite facies zone north of the granitic complex in the south-central part of the area is typified by biotite-cordierite assemblages with only rare occurrences of andalusite, garnet and amphiboles. Thin amphibolite facies aureoles generally less than three miles wide with similar mineral assemblages occur adjacent to the other major granitic bodies in the area.

Structurally the area is very complex. The sediments are typically isoclinally folded with steeply dipping axial planes that are variably spaced from several miles to less than a few hundred yards and with axes that are horizontal to very gently plunging. The strata in many cases are refolded into structures varying from broad open warps to tight, steeply plunging folds. In the Duncan Lake region and south of Cleft Lake broad open folds occur in which the beds commonly dip at less than 20 degrees. Faulting has been extensive throughout the area but displacements are difficult to determine due to the lack of distinctive marker horizons in the sediments. In some cases considerable vertical displacement is indicated by contrasting metamorphic grade across the fault line. A regional, generally north-northwesterly cleavage is developed throughout the area; this appears to be independent of the earlier structures.

Of possible economic interest is the extensive gossan developed along much of the prominent ridge marking the contact between the Yellowknife supracrustal rocks and the granodiorite in the Ross Lake region. Sphalerite-galena mineralization was noted at one point on this ridge east of the southernmost bay of Upper Ross Lake. It is of interest that the conglomerates and carbonate-rich sediments of their equivalents on this ridge can be traced south and eastwards through Detour Lake and ultimately to Turnback Lake where sediments at this stratigraphic level are extensively mineralized with base metal sulphides (see Davidson, separate report, this publ.). In the Yellowknife map-area west of Greyling Lake near the Yellowknife River an oxide iron-formation lies in the contact area of the Kam mafic volcanics and the granodiorite. In the northern part of the large biotite-muscovite granitic body east of Duncan Lake, scattered small patches of yellow uranophane occur on smooth surfaces of the granite. No primary uranium mineralization was observed. This staining is very similar to that seen in the granitic rocks east of the Stagg River in the Yellowknife map-area[3].

[1] Henderson, J. F.: Beaulieu River map-area; Geol. Surv. Can., Map 581A (1941).

[2] Henderson, J. B.: Stratigraphy of the Archean Yellowknife Supergroup, Yellowknife Bay–Prosperous Lake area, District of Mackenzie, Geol. Surv. Can., Paper 70-26 (1970).

[3] Henderson, J. B. and Elliot, A. J. M.: Yellowknife and Hearne Lake map-areas, District of Mackenzie; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 133-134 (1971).

---

62. CROSS-SECTION OF THE CORONATION GEOSYNCLINE (APHEBIAN), TREE RIVER TO GREAT BEAR LAKE, DISTRICT OF MACKENZIE (86 J, K, O, P)

Project 690024

P. F. Hoffman

The exposed part of the Coronation Geosyncline[1] is divisible into an eastern sedimentary belt (Epworth Group), a central metamorphic belt and a western volcanic belt. During most of the final field season of the project, a ground-reconnaissance was made of the stratigraphy, structure, metamorphism and plutonism in the central and western belts. Detailed mapping was done along the Coppermine River between 66° 20'N and 66° 40'N, between Muskox and Akaitcho Lakes, north and east of Wentzel Lake, east and south of Dumas Lake, and east of McLaren Lake. In addition, critical locations around the basement uplifts[2] in the eastern belt were briefly visited.

The field petrographic descriptions reported here are subject to revision following laboratory studies.

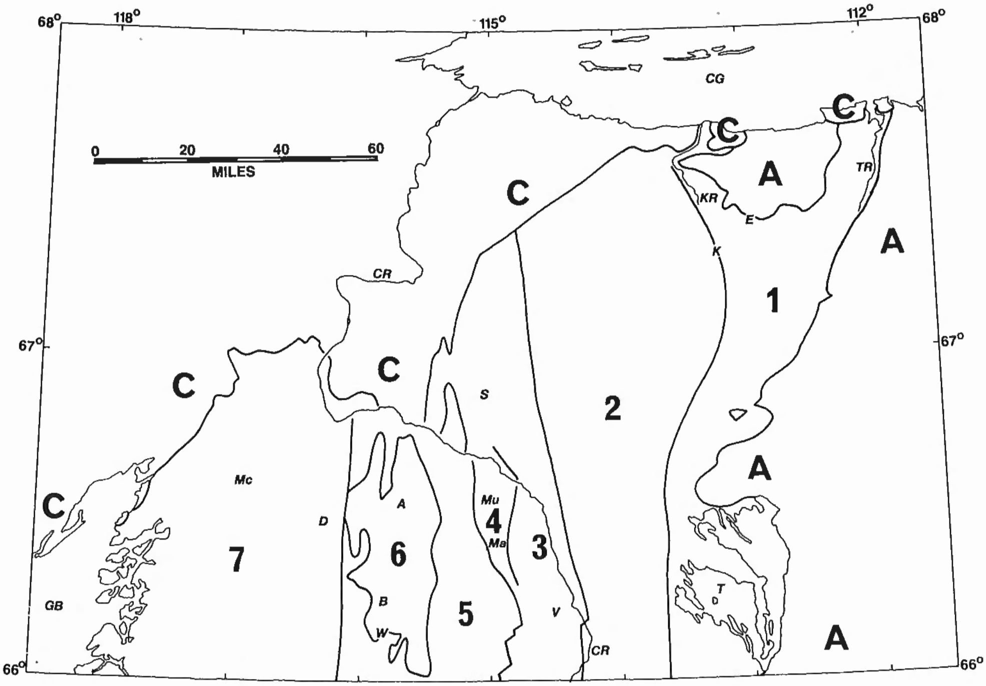
Eastern Sedimentary Belt – Area 1

The belt is divided into three areas (Fig. 1) on the basis of differences in sedimentary facies and structural style. In Area 1, the stratigraphic succession is as follows:

(5) Takiyuak Formation – 1,000 feet plus of red crossbedded lithic and feldspathic sandstone of westerly derivation,

(4) Cowles Lake Formation – 1,500 feet of grey laminated shaly limestone with greywacke turbidites of westerly derivation,

(3) Recluse Formation – 2,500 feet of green pyritic and concretionary mudstone with siltstone of easterly derivation at the base and westerly derivation above,



A - Archean basement uplifts

K - Kikerk Lake

GB - Great Bear Lake

CR - Coppermine River

KR - Kugaryuak River

CG - Coronation Gulf

TR - Tree River

T - Takiyuak Lake

E - Eokuk Lake

C - post-Aphebian cover

V - Vaillant Lake

Ma - Marceau Lake

M - Muskox Lakes

S - Stanbridge Lake

A - Akaitcho Lake

B - Belleau Lake

W - Wentzel Lake

D - Dumas Lake

Mc - McLaren Lake

Figure 1. Areas of the Coronation Geosyncline referred to in the text. Geological boundaries are modified from Fraser et al., Geol. Surv. Can., Map 18-1960.

(2) Rocknest Formation – 1,500 feet of rhythmically interstratified varicoloured stromatolitic dolomite and mudstone of easterly derivation,

(1) Odjick Formation – 500 feet of white and pink crossbedded orthoquartzite of easterly derivation with 150 feet of black mudstone and dolomite at the base.

The Odjick and Rocknest Formations in this area represent the thin inner part of the early shelf or miogeocline of the geosyncline. The Recluse, Cowles Lake and Takiyuak Formations here represent the thin distal part of the later foredeep or exogeocline. The two youngest formations are preserved only in Area 1 in the region south and west of Takiyuak Lake.

The sediments in Area 1 are autochthonous; they have not been tectonically detached from the subjacent Archean granitic basement. They are nearly flat lying except in the fold belts along the borders of the large areas of uplifted basement rocks east of Area 1 and on the coast of Coronation Gulf between the Tree and Kugaryuak Rivers. The margins of the basement uplifts are unfaulted and have more than 5,000 feet of structural relief. Locally, the basement-sediment unconformity is compressed into recumbent buckles, about 2,000 feet in wavelength and 500 feet in amplitude, with arched crests and acute troughs. On the overturned limbs of the buckles, the basement gneiss together with the unmetamorphosed basal mudstone and dolomite have been rotated as much as 160 degrees with no differential slip between them. In the tight troughs of the buckles, the basal sediments have a gently dipping cleavage-fan and are penetratively deformed. Maximum extension of strain indicators is in the cleavage plane and perpendicular to the buckle hinges. Spectacular flexural-flow folds that occur in the Rocknest dolomite 1 to 6 miles from the uplifts are asymmetric but not fully recumbent. The northeast-trending synclinorium forming the broad valley of the Tree River is the result of compression between the two major basement uplifts, the margins of which are well exposed at the northwest end of Eokuk Lake and southeast of the mouth of the Tree River. The presence of the uplifts is apparent only where the deformed cover is preserved as the basement rocks themselves have no megascopic fabric related to uplifting. Perhaps unsuspected basement uplifts account for the anomalous Aphebian radiometric ages in the northern Slave Province east of Tree River.

Eastern Sedimentary Belt – Area 2

Area 2 contains the thick outer part of the miogeocline and the thick proximal part of the exogeocline. The miogeoclinal Odjick and Rocknest Formations are lithologically similar to Area 1 but are 3,000 feet plus and 3,500 feet thick respectively. The exogeoclinal Recluse Formation is as much as 6,500 feet thick and consists largely of westerly thickening tongues of coarse greywacke turbidites, the feather edges of which coincide with the boundary between Areas 1 and 2. The flysch-like turbidite succession is separated from the underlying Rocknest dolomite by 300 feet of recessive black laminated pyritic shale.

The sediments in Area 2 are allochthonous; they have been transported eastward tectonically above a detachment surface near the base of the Odjick Formation. West-dipping imbricate thrust sheets, commonly thousands of feet thick and separated by bedding-plane faults, with basal Odjick on the hanging-wall and upper Rocknest or even Recluse on the footwall, occur on the limbs of complex anticlinoria. The easternmost of such thrusts is the boundary between Areas 1 and 2. Lesser thrusts that repeat parts of the Rocknest Formation are very common, particularly in the western half of the area, and their discovery is predicted on intimate stratigraphic familiarity. The anticlinoria and thrusts have northerly trends but, in addition, east-trending folds, related to basement uplifts in Area 1, are prevalent north of Kikerk Lake. The absence of basement outcrops in the anticlinoria of Area 2, suggests that, unlike Area 1, deformation involves only the supracrustal rocks. Between the anticlinoria are broad structural basins of relatively gently folded Recluse greywacke.

Eastern Sedimentary Belt – Area 3

The boundary between Areas 2 and 3 coincides with important facies changes marking the outer edge of the miogeoclinal shelf. The Odjick Formation passes westward into a thick monotonous sequence of laminated silty mudstone with only scattered thin beds, probably turbidites, of orthoquartzite. The thick Rocknest stromatolitic dolomite of Area 2 thins abruptly to less than 400 feet of off-shelf mudstone and dolomite submarine slide breccia containing blocks up to 150 feet long. As in Area 2, the Archean basement is nowhere exposed but two previously unrecognized formations occur beneath the Odjick Formation in a major anticlinorium that trends from Vaillant Lake to Stanbridge Lake. The older consists of pillowed and ropy basalt flows, flow breccia and agglomerate, and the younger of stromatolitic dolomite with abundant coarse quartz sand grains. The west limb of this anticlinorium is faulted against slate and greywacke of the Recluse Formation, lithologically unchanged from Area 2. Gabbro sills up to 600 feet thick occur in the upper Odjick and lower Recluse Formations, particularly near the boundary between Areas 2 and 3.

The boundary between Areas 2 and 3 also marks the eastern limit of regional penetrative deformation and similar folds with pervasive cleavage-fans. The fold hinges are mostly near-horizontal and north-trending. Rare strain indicators, mostly chlorite blebs in the basalt flows, have a steeply plunging westerly elongation in the cleavage planes. A major west-dipping thrust fault near the western boundary of the area places Odjick Formation on the hanging-wall against Recluse Formation on the footwall and possibly pre-dates the regional cleavage. Northeast-trending dextral strike-slip faults along the eastern boundary of the area and northwest-trending sinistral ones along the western boundary transect all other structures.

Central Metamorphic Belt – Area 4

Area 4 contains the metamorphosed equivalents of the Odjick Formation and, along part of its eastern boundary, the Recluse Formation. This boundary is defined as the biotite isograd, westward from which the metamorphic grade increases in the high temperature-low pressure facies series[3]. The progression is from phyllite with small clots of biotite and muscovite, to mica schist with large knots of cordierite and/or andalusite, to augen paragneiss with bands of sillimanite. Garnet occurs rarely in the schist and paragneiss, but staurolite and kyanite are absent. North of Marceau Lake, a 3-mile-long stock of massive muscovite-biotite quartz monzonite is discordant with the metamorphic isograds.

The area is one of pervasive west-dipping cleavage-fans and isoclinal similar folds that, westward, become progressively more overturned. Locally, in the west half of the area, a subhorizontal second cleavage obliquely transects both the isoclinal folds and their cleavage-fans. In the paragneiss, bedding is transposed to such an extent that cleavage and bedding cannot be distinguished. Here, the resulting foliation dips gently to the east or west. Elsewhere, late kink folds in the cleavage are very common, as they are in Area 3.

Central Metamorphic Belt – Area 5

This area is underlain mainly by massive to weakly foliated, commonly porphyroblastic, biotite granodiorite. The feldspar porphyroblasts postdate the intrusion of aplite dykes and contain poikilitic inclusions of quartz and biotite. Migmatite with blocks of sillimanite and/or garnet paragneiss and amphibolite occurs in a broad zone along the eastern margin, and in narrow zones in the central part, of the granodiorite. Foliation in the granodiorite and migmatite generally parallels that in the adjacent paragneisses of Areas 4 and 6, but there is commonly an intervening discordant intrusion of massive quartz monzonite or anorthositic gabbro.

Central Metamorphic Belt – Area 6

Area 6 contains a lithologically complex and intensely deformed succession of highly variable metamorphic grade and uncertain age relative to the formations of the eastern sedimentary belt. Relations within the area are further complicated by late northwest-trending faults of uncertain displacement that commonly juxtapose greenschists and extensive sillimanite-garnet paragneiss. Metamorphism is of a low pressure intermediate facies series[3], with garnet, andalusite and/or cordierite common, staurolite rare and kyanite absent. In an area of greenschist facies north of Belleau Lake and pillowed and massive basalt flows interstratified with thin units of bedded chert, feldspathic quartzite and slate, and thick intensely sheared sills or laccoliths of hornblende quartz-diorite(?). Elsewhere, thick units of granite-pebble conglomerate occur with the feldspathic quartzite.

Rocks in all parts of the area have a very strong lineation that plunges gently north or south, parallel to the fold hinges. Stretched pebbles and other strain indicators have suffered extreme elongation parallel to the lineation (in contrast to Areas 1 and 3, where elongation is perpendicular to fold hinges). Poikilitic garnet and andalusite with snowball inclusion trains rotated about the regional lineation are common. Most of the rocks have a strong foliation that is parallel to the axial planes of isoclinal folds in the few places where bedding can be seen. The foliation is itself folded into upright chevron-like folds, many miles across, coaxial with the earlier isoclinal folds. It is unfortunate that only the most highly metamorphosed rocks of this area are well exposed, for detailed mapping over a large region will be required to decipher the stratigraphy and structure of this area.

Western Volcanic Belt – Area 7

The belt consists of intermediate to acidic volcanic rocks and derived clastic sediments, both intruded by comagmatic plutons, with only local contact metamorphism, ranging in composition from diorite to granite. The thousands of feet of varicoloured felsite, mostly with whole or broken phenocrysts of feldspar and quartz, and in places with eutaxitic banding, are interpreted as welded crystal and vitric tuffs. They are complexly interstratified with andesite flows, commonly porphyritic, and sediments. The sediments are mostly laminated silty mudstone with discontinuous units of pink sandstone and boulderstone composed entirely of volcanogenic clasts. Intrusive into the volcanics and sediments are laccoliths of coarsely porphyritic felsite.

The stratiform rocks are thrown into broad folds of variable trend. Near the contacts with the large plutons, most of which are granodiorite or quartz-monzonite in composition, the limbs are steep or overturned, and intruded by swarms of criss-crossing dykes. There is an unbroken textural continuum between the extrusive fragmental felsites, the porphyritic laccoliths, dykes and chilled border phases of the plutons, and the uniformly coarse-grained interior parts of the plutons.

Many of the plutons contain disseminated chalcopyrite and, judging from the similarities in character and tectonic setting of these rocks with the Cretaceous plutons of western North and South America, large but low grade copper deposits may be expected. Exploration here must not follow the traditional Shield practice of ignoring the granites in favour of the volcanics.

All the rocks in Area 7 are off-set by northeast-trending dextral strike-slip faults but by far the most important fault in the entire geosyncline is that forming the sharp eastern boundary of the area. This earlier fault is correlative with the Wopmay River fault to the south, which also places highly metamorphosed rocks (Snare Group) to the east against little metamorphosed volcanics and derived sediments (Cameron Bay Group) to the west. The overall length of the north-trending fault exceeds 200 miles.

Unlike the granodiorite of Area 5, Area 7 is an excellent example of the shallow emplacement of a granitic batholith roofed only by its own volcanic ejecta[4]. Such batholiths, particularly where associated with andesite volcanoes, occur above subduction zones where the over-riding crustal plate is continental, as in the central Andes at the present time. Such volcano-plutonic arcs are invariably flanked by an oceanic trench. As there is little evidence of a fossil trench in the form of ophiolites or blueschist melanges east of Area 7, it is probable, however unfortunate, that the trench rocks lie buried beneath the Phanerozoic cover west of Area 7. Hopefully, the polarity of the arc-trench system can be determined indirectly by mapping the potash/silica ratios of the plutons[5].

[1]Hoffman, P.F., Fraser, J.A. and McGlynn, J.C.: The Coronation Geosyncline of Aphebian age; in Geol. Surv. Can., Paper 70-40, pp. 200-212 (1970).

[2]Hoffman, P.F., Geiser, P.A., and Gerahian, L.K.: Stratigraphy and structure of the Epworth fold belt; in Report of Activities, Part A, April to October 1970, Geol. Surv. Can., Paper 71-1, Pt. A, pp. 135-138 (1971).

[3]Miyashiro, A.: Evolution of metamorphic belts; J. Petrol., vol. 2, pp. 277-311 (1961).

[4]Hamilton, W.: The volcanic central Andes as a model for Cretaceous batholiths and tectonics of western North America; in State of Oregon, Dept. Geol. Min. Ind., Bull. 65, pp. 175-184 (1969).

[5]Dickinson, W.R.: Relations of andesitic volcanic chains and granitic batholith belts to the deep structure of orogenic arcs; Geol. Soc. London Proc., No. 1662, pp. 27-30 (1969).

---

63. PALEOMAGNETIC STUDY OF PROTEROZOIC RED BEDS OF WESTERN CANADIAN SHIELD

Project 680012

J.C. McGlynn

Approximately two weeks were spent in the field collecting samples of red beds and volcanic rocks of the Cameron Bay Group and from gabbro sills which intrude these rocks. Samples of Nonacho Group sediments and basic dykes which cut the sediments were also collected. This material, along with samples obtained in previous years of Nonacho, Et-Then and Dubawnt strata, will yield data useful in correlating these widely separated late Aphebian or Paleohelikian rocks. This work is being done as a joint project with E. Irving of the Earth Physics Branch of the Department of Energy, Mines and Resources.

---

64. RAMAH GROUP AND PROTEROZOIC-ARCHEAN RELATIONSHIPS IN NORTHERN LABRADOR

Project 710012

W.C. Morgan

This project is designed to investigate stratigraphy, sedimentology, structure and metamorphism in the Ramah Group, and relationships between Archean rocks in the Nain structural province, as recently defined by Taylor[1], and Proterozoic rocks in the Churchill structural province. The area is in the Torngat Mountains, situated between Saglek and Nachvak Fiords, on the coast of north Labrador, and has been previously mapped at a scale of 8 miles to 1 inch by Taylor [2,3]. A part of the area, lying between Bears Gut and Dèlabarre Bay, was mapped at a scale of 1:50,000, and Archean and Proterozoic rocks in the vicinity of Saglek Fiord were examined. After breakup on 13 July field work was accomplished by shoreline and foot traversing in parts of the area accessible by rubber boat. A helicopter, available for about two weeks, was used to traverse inland areas.

Archean rocks underlie the eastern part of the area and consist dominantly of foliated or banded leucocratic gneisses, of granitic or granodioritic composition, and migmatites. Mafic gneiss and amphibolite are less common but bands between 200 and 600 feet thick form important marker horizons. Numerous veins of granite and pegmatite are present in some parts of the area. Ultrabasic rocks are relatively common and usually form small inclusions or bodies less than 1/2 mile long. The largest body mapped is approximately 1 1/2 miles long and 1,000 feet thick. Field evidence indicates that the Archean rocks have undergone retrogressive metamorphism and have been downgraded from granulite facies to amphibolite facies. The leucocratic gneisses are mainly in the amphibolite facies, but locally contain mineral assemblages indicative of granulite facies. Mafic bands commonly contain granulite facies mineralogy. The Archean rocks have a general northerly trend and are complexly deformed. Large-scale tight overfolds about north-trending axes are present. Diabase dykes of Archean age are abundant and have an east to northeast trend. The majority of the dykes are fresh with chilled margins and transect the regional foliation; others are deformed and metamorphosed. Some of the fresh post-tectonic dykes may be post-Hudsonian intrusions.

Proterozoic rocks that form part of the Churchill structural province underlie the western part of the area. These rocks have a migmatitic aspect and were metamorphosed under granulite facies conditions. They are mainly quartzo-feldspathic granulites, characterized by the presence of hypersthene, with subordinate mafic granulite horizons that vary in thickness from a few feet or less to a maximum of 500 feet. Diabase dykes with an east to north-east trend are common, and may represent dyke swarms of more than one age. Whereas some dykes are fresh and cut sharply across the foliation, others have a schistosity or weak foliation parallel to the regional trend and are metamorphosed.

TABLE I

Revised Stratigraphy of the Ramah Group

Greywacke
Multicoloured rusty slate, diabase sills
Dolomite, dolomitic shale, dolomitic sandstone, turbidite, minor gypsiferous horizons, stromatolites
Banded slate, pyrite rich slate, chert, dolomitic shale
Laminated fine grey quartzite, massive dolomite
Quartzite, intercalated slate and shale
Amygdaloidal andesite flow
Quartzite, minor conglomerate
Conglomerate, breccia

The contact between the Archean and Proterozoic is gradational over a short distance and separates Proterozoic rocks, metamorphosed under granulite facies conditions during the Hudsonian Orogeny, from Archean rocks that have been downgraded from granulite facies to amphibolite facies during the Kenoran Orogeny. The precise nature of this contact has not been determined at this stage in the investigation.

Sedimentary rocks of the Ramah Group are preserved in a north-trending rock unit that is up to 10 miles wide, and has a general open synclinal nature. The eastern contact, with underlying Archean rocks, is a well-defined angular unconformity. The western contact, in the area examined, is a west dipping fault plane along which older gneisses have been thrust to the east over Ramah Group sedimentary rocks.

Several partial sections of the Ramah Group have been measured by Christie[4] and Douglas[5]. Field work has revealed that substantial stratigraphic subdivision of the group is possible, and the majority of the units shown in Table I have been traced for more than 20 miles along northward and southward extensions of the belt.

The Ramah Group is characterized by a deformation that has resulted in folds, about north-trending axes, that vary in style from open to tight. The intensity of deformation increases from east to west across the belt. The eastern margin of the Ramah Group is in general not folded, but is cut by several west-dipping, north-trending thrust faults of low inclination. Tight inclined folds are developed in the central and western portions of the belt. Diabase sills form prominent marker horizons and are less intensely folded than the slates into which they have been intruded. Sills of diabase occur at lower stratigraphic horizons in the south and west of the area investigated. Minor amounts of ultrabasic rock are associated with diabase sills that cut the Ramah Group south of Little Ramah Bay. Much of the Ramah Group has undergone greenschist facies metamorphism and although penetrative cleavage is extensively developed primary structures are abundant.

Lean silicate-oxide facies iron-formation was observed in two mafic gneiss bands within Archean rocks on the east side of the Little Ramah Bay. A 20-foot-thick band and a 30-foot-thick band were examined.

Veinlets of cross-fibre asbestos, up to 1/2 inch thick, occur in small ultrabasic bodies in Archean rocks, near Saglek (58° 29'30"N, 62° 38'50"W) and east of Little Ramah Bay (58° 46'00"N, 63° 07'25"W), and in the Ramah Group south of Little Ramah Bay (58° 45'08"N, 63° 13'00"W).

A 6-inch-thick vein composed mainly of galena with some chalcopyrite and minor amounts of pyrrhotite and sphalerite cuts Archean gneisses immediately east of the Ramah Group contact on the north side of Ramah Bay (58° 54'48"N, 63° 11'00"W).

Minor amounts of chalcopyrite and pyrite were observed in a small fault zone that cuts Archean rocks on the east side of Little Ramah Bay (58° 47'45"N, 63° 08'35"W). Slight malachite stain and traces of molybdenite occur in a mafic gneiss band in the Archean east of Little Ramah Bay (58° 50'45"N, 63° 08'10"W).

Archean rocks that immediately underlie Ramah Group sedimentary rocks form a regolith that is locally silicified and enriched in magnetite and carbonate to a depth of approximately 20 feet. The regolith is well exposed on the east side of Little Ramah Bay (58° 45'50"N, 63° 09'10"W) where malachite stain is present. Traces of chalcopyrite and malachite stain also occur in the overlying Ramah Group quartzite.

Bodies of pyrite with an outcrop length of 400 to 600 feet and 2 to 3 feet thick immediately underlie the chert horizon within the lower slate unit of the Ramah Group on the south shore of Rowsell Harbour and on the southern slopes of Quartzite Mountain. These occurrences and results of assays have been described by Douglas[5]. A 6-foot-thick extensive body of pyrrhotite with minor amounts of finely disseminated chalcopyrite and traces of arsenopyrite has been located immediately above the chert horizon, within slates, south of Little Ramah Bay (58° 44'40"N, 63° 11'05"W).

Thin quartz veins, usually less than 1 inch thick, within a fault zone that cuts Ramah Group quartzite at the south end of Little Ramah Bay contain minor amounts of chalcocite and malachite. Some veins are rich in specular hematite.

The only prominent mineralization that was observed in the Proterozoic granulites and associated rocks occurs approximately 4 miles east of the head of Ugjuktok Fiord (58° 17'N, 63° 28'W). Specimens of mineralized garnet-quartz-feldspar-graphite gneiss containing chalcopyrite were collected for assay from blocks in a talus slope.

[1] Taylor, F.C.: A revision of Precambrian Structural Provinces in northeastern Quebec and northern Labrador; Can. J. Earth Sci., vol. 8, pp. 579-584 (1971).

[2] Taylor, F.C.: Reconnaissance geology of a part of the Precambrian Shield, northeastern Quebec and northern Labrador; Geol. Surv. Can., Paper 68-43 (1969).

[3] Taylor, F.C.: Reconnaissance geology of a part of the Precambrian Shield, northeastern Quebec and northern Labrador; Part II, Geol. Surv. Can., Paper 70-24 (1970).

[4] Christie, A.M.: Geology of the northern Coast of Labrador, from Grenfell Sound to Port Manvers, Newfoundland; Geol. Surv. Can., Paper 52-22 (1952).

[5] Douglas, G.V.: Notes on localities visited on the Labrador Coast in 1946 and 1947; Geol. Surv. Can., Paper 53-1 (1953).

---

65. VOLCANIC STRATIGRAPHY AND METALLOGENY OF THE KAMINAK GROUP

Project 700052

R.H. Ridler

Introduction

Stratigraphic and metallogenetic study of the Archean Kaminak Group was continued in the Rankin Inlet - Ennadai Belt of the southern District of Keewatin. Operations were based at Last Lake (62° 17'30"N, 93° 44'W), about sixty miles southwest of Rankin Inlet.

Three stratigraphic cross-sections were sampled and a section begun last summer[1] was completed. Several areas of stratigraphic, structural, and/or metallogenetic interest were examined in detail. An attempt was made to trace out along strike the regional exhalite zone(s) (ref. 2, p. 50) and a concerted effort was directed towards discovery of an Archean ultramafic suite.

The author owes much of the success of the operation to the competent professional work of his senior assistants J. Thurlow and L. Covello and to the enthusiastic support of junior assistants L. Tihor, R. Vaivada and G. Wright. Several geologists visited the camp. Each contributed materially to the success of the mission especially as regards their own speciality. Without referring specifically to individual contributions here the visitors were D.F. Sangster, O.R. Eckstrand, W.F. Fahrig, K.W. Christie, of the Geological Survey, R.T. Bell of Brock University and S.M. Roscoe.

General Geology

The Kaminak Group in the area examined is divided into three complete and one incomplete mafic to felsic volcanic cycles (Fig. 1). Clastic sedimentation occurs either above or as a facies of the felsic phases of the first and third cycles. Exhalite caps the first cycle and is widely distributed within the felsic volcanics and sediments of the third. Interflow exhalite was conspicuous at several localities.

The first and third cycles envelope large plutonic complexes, the west part of the Kaminak Lake Complex and the Tavani Complex respectively[3]. The second and fourth cycles are less obviously associated with central plutonic complexes. Thick accumulations of felsic volcanics occur at irregular distances within the main upper felsic phase of each complete cycle. These accumulations probably represent individual strato-volcanoes within the much larger volcanic complex represented by each cycle. However, nowhere do thicknesses exceed 16,000 feet and thicknesses of a few thousand feet are more common. The maximum homoclinal thickness observed is approximately 50,000 feet on the north side of the Kaminak Lake Complex. The thickest portion of any one cycle nowhere exceeds 40,000 feet.

In addition to petrological information published previously[1,4] the occurrence of significant amounts of exhalite fragments and matrix within the felsic breccias and tuffs of cycles two and three bears emphasizing. Massive sulphide (pyrite) and siderite fragments up to twelve inches in diameter were observed. Locally, the exhalite fragments constituted better than thirty per cent of the fragment population. Minor chalcopyrite was noted at several localities. Phase-layered mafic sills are rare. The two examined are well differentiated into ultramafic bottoms and mafic to intermediate tops. Neither sill exceeds 500 feet in thickness in the area examined, but they are apparently quite extensive laterally. Each occurs within the mafic plate of the third cycle. Immediately east of the Ferguson River the oldest of the two sills (62° 07'30"N, and 93° 23'W) is approximately 300 feet thick comprising, in ascending order, 50 feet of talc-carbonate soapstone, 100 feet of serpentinized peridotite, and 150 feet of medium-grained gabbro. About 100 feet above the base of the sill lies a zone up to ten feet thick composed of massive (up to 18 inches thick) and heavily disseminated pyrite with minor chalcopyrite. The soapstone and sulphide zones have apparently localized strain-slip, and the pyrite displays an excellent "milled" or "augen" texture. The pyrite did not give a positive "di-methyl" test for Ni. The second, apparently younger sill, is not as well exposed, but appears to have similar phase layering and an analogous sulphide zone in which the disseminated sulphides exhibit "droplet" texture.

Intermediate to mafic stocks are common within and stratigraphically below the base of the first and third cycles. Locally these are cut by late quartz veins with minor chalcopyrite. Ultramafic phases of one such stock (62° 09'N, 94° 00'W) returned positive dimethyl tests for Ni, but no significant sulphide mineralization is visible.

The stratigraphically oldest portion of the Archean succession, wherever examined, was found to be discordantly intruded by a variety of plutonic rocks. On a regional scale, basal portions of individual cycles do conform crudely to the outlines of the major plutonic complexes and face outwards.

Structure

On the limbs of the large domical complexes, structure is relatively simple and isoclinal in style. Wavelengths exceed several tens of thousands of feet and amplitudes several miles. Within the synformal nodes between

Fig. 1

Geological Sketch Map
Kaminak Lake Area
Rankin Inlet - Ennadai Belt

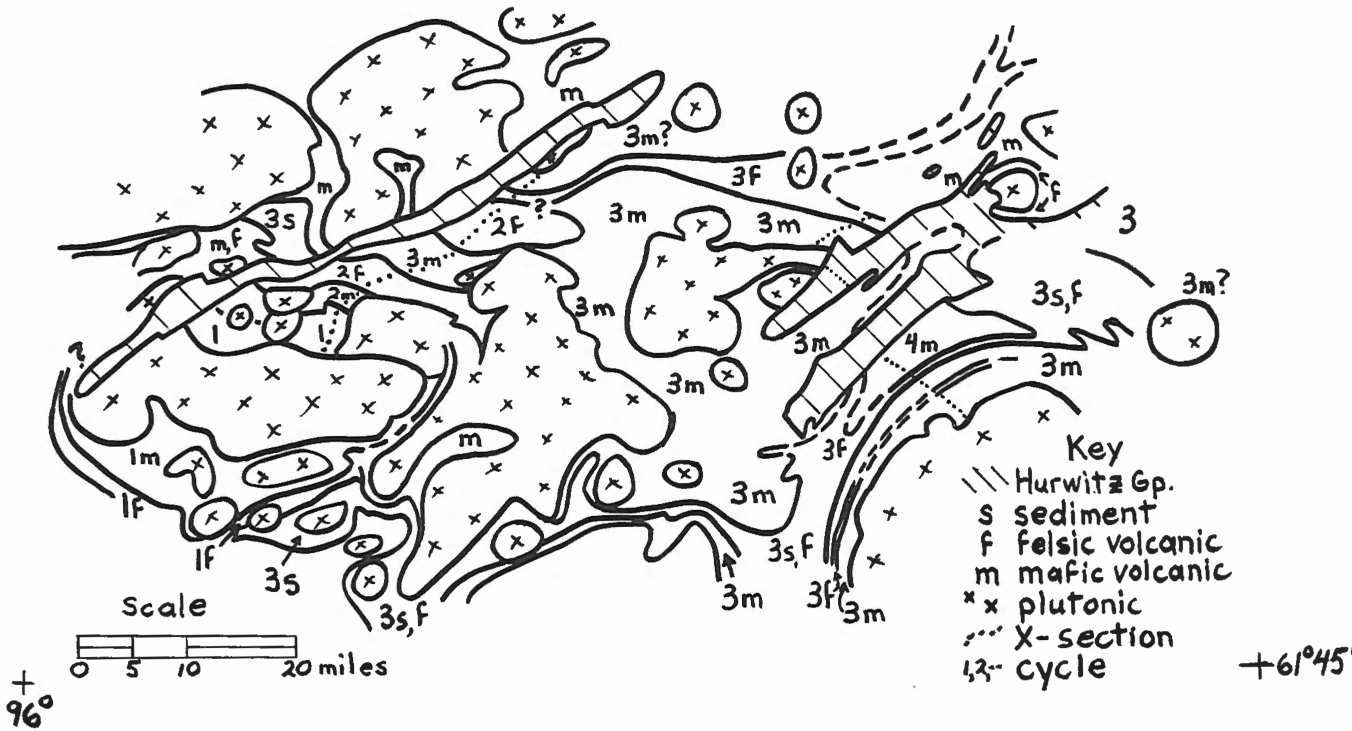


TABLE 1

Representative Analyses, Kaminak Group Volcanics

Type	MnO	TiO_2	CaO	K_2O	SiO_2	Al_2O_3	MgO	FeO	Fe_2O_3	Na_2O	P_2O_5	CO_2	H_2OT	Lat.	Long.
Massive basalt	0.25	1.41	8.2	0.5	48.8	12.0	8.2	12.1	2.5	1.9	0.14	0.6	4.0	62°24'15"	94°36'40"
Basalt pillow lava	0.18	1.04	10.4	0.2	47.0	14.5	5.5	8.9	3.0	1.4	0.07	2.7	4.2	62°19'10"	94°52'25"
Andesite pillow lava	0.17	0.84	7.9	0.3	54.1	13.7	4.6	6.5	1.9	3.3	0.14	4.5	3.4	62°18'30"	94°56'40"
Dacite breccia	0.05	0.27	6.7	1.5	61.8	14.7	0.8	1.9	0.7	4.7	0.06	4.6	1.7	62°22'25"	94°38'10"
Rhyodacite tuff	0.08	0.47	2.3	2.6	68.1	13.6	0.9	3.1	0.9	2.7	0.10	2.1	1.7	62°15'55"	94°59'40"
Rhyolite breccia	0.02	0.11	1.0	2.8	72.9	13.6	0.4	1.0	0.7	3.8	0.0	0.8	1.0	62°21'40"	94°41'00"
High potash massive rhyolite	0.02	0.10	0.9	6.7	72.1	12.8	0.5	1.2	0.6	1.2	0.0	1.1	0.8	62°21'05"	94°42'15"

the domes, structural complexity increases and the early isoclinal fold axes are folded into somewhat more open folds with wavelengths of several thousand feet and amplitudes of a few miles or less. Alternatively, an interference pattern due to intersecting axes occurs. Some of the sediments of cycle three may rest unconformably on the folded mafic plate of the same cycle.

Significant post-Archean ductile deformation is apparently absent from critical areas subjacent to structural extensions of Aphebian fold belts. Even the pervasive "Hudsonian" cleavage of N40-50° E was not observed to show any direct relation to proximity to a preserved Aphebian fold belt.

Chemical data

Examination of final chemical analyses from samples collected in the summer of 1970, reveals that calc-alkaline intermediate to felsic volcanics are well represented. No ultramafic lavas were encountered but a few alkaline flows are present. The initial cycle differentiates through to rhyolite. Table I shows six typical analyses ranging from basalt to rhyolite plus one of the less typical but interesting alkaline rocks.

Metallogeny of Exhalite

The areal distribution of exhalite facies postulated earlier (ref. 1, Fig. 2, p. 144) was extended successfully on a regional scale. A central zone, predominantly of carbonate facies, is flanked to the north and south by extensive oxide facies. Within the main carbonate zone significant amounts of oxide and sulphide facies are developed locally. Three chemical analyses of the carbonate facies returned siliceous siderite. The massive carbonate horizon which caps the third volcanic cycle appears to be endogenetic over significant strike lengths, and locally (62° 10'N, 93° 24'W) bears significant disseminated pyrite and arsenopyrite strongly reminiscent of "flow ore" of the Larder Lake type[5].

On the west side of the Kaminak Lake Complex the main exhalite zone capping the first cycle is in sulphide facies. At Spi Lake (62° 04'N, 95° 53'W) this part of the exhalite zone reaches approximately twenty feet in thickness with massive stratiform mineralization exhibiting a copper-rich base and a zinc-rich top. It appears to lie within a rhyolite tuff and breccia zone not far from the mafic lavas at the base of the succeeding cycle. Faults of short displacement and the presence of a few diabase dykes complicate correlation of the exhalite horizon in detail.

The occurrence of two main periods of exhalite deposition separated by two entire volcanic cycles suggests the possibility of determining sequential changes in basin configuration and/or chemical physical parameters. Observations to date suggest remarkable stability in these relations.

Samples of glacial float bearing significant copper/zinc mineralization were noted at two localities. A first-sized piece of massive sulphide rich in sphalerite was discovered down (glacial) "stream" from the central exhalite zone at 62° 09'N and 93° 11'W. On the west shore of Helika Lake at 62° 22'30"N and 94° 06'W, boulders normally beneath water level carried disseminated to massive sulphide mineralization rich in chalcopyrite. The latter occurrence is immediately down (glacial) "stream" from the felsic phase of the third cycle.

Hurwitz Group Extension

A significant stratigraphic extension of the Hurwitz Group is proposed. Two to three thousand feet of coarse agglomeratic mafic breccia, pillow lava and tuff, intruded at the base by gabbro (Hurwitz F_a & F_b of Bell, ref. 6) conformably overlie the characteristic white orthoquartzite in a belt centred on Last Lake (62° 15'N, 93° 45'W). A. Davidson of the Survey had previously suggested this relationship to the author. During the field season the writer benefited from consultation in the field with R. T. Bell in confirming these findings. Mudstones and siltstones of Hurwitz E are present as felsenmeer at appropriate localities. Older Hurwitz sediments, in particular conglomerate, may be present in the area studied although differentiation from similar rocks of the Montgomery Lake Group is difficult. The structure of the belt appears to be that of an anticline with flanking synclines. Dips increase and wavelengths decrease from northwest to southeast. Plunges are generally less than thirty degrees and undulate gently along strike.

Aeromagnetic Features

An interesting sidelight of the investigation of ultramafic and exhalite occurrences was the discovery by ground checks of significant local errors in the placement of magnetic anomalies on the standard aeromagnetic map available for the area. Anomaly crest lines were as much as three hundred feet off. Since the errors lacked any consistent pattern they are ascribed to original field problems and lack of adequate topographic control.

Alkaline Complexes

Two high annular magnetic anomalies with central lows centred on 62° 24'30"N, 93° 46'30"W and 62° 29'N, 93° 45'W were investigated. The southerly of the two appears to be an alkaline complex with a magnetic border phase. Outcrop and hand samples collected on the rim at 62° 24"N, 93° 46'W are anomalously radioactive. No outcrop of the more northerly complex was found. Glacial drift is predominantly granitic and sands exposed on an esker which traverses the anomaly were found to be anomalously radioactive at 62° 29'30"N and 93° 46'W.

Conclusions

Compositionally and texturally the Kaminak Group is similar to the younger volcanic groups of the Wawa-Abitibi Belt[7]. Identical regional exhalite zones are present. However, in structural style, areal distribution, and thickness of units the Rankin Inlet-Ennadai Belt resembles the Superior Province in northwestern Ontario. When weighed with the virtual absence of the nickeliferous ultramafic suite of intrusives and flows the author concludes that the Kaminak Group is a relatively mature phase of the de-sialification of the proto-mantle, in an evolutionary sense[2]. Thus, metallogenetically that part of the belt examined to date is favourable for iron, copper, zinc, silver and gold but unfavourable for nickel and asbestos.

Within the confines of the Rankin Inlet-Ennadai Belt proper, structural complexity varies greatly due to the interplay of Archean fold episodes but is not significantly influenced by the structural events which caused the folding of the overlying Aphebian cover. The intrusion of post-Archean plutons, or the remobilization of Archean plutons during post-Archean time appears responsible for some of the structural complexity observed. The latter almost certainly explains the lack of any apparent pre-Kaminak basement.

[1] Ridler, R.H.: Volcanic stratigraphy and metallogeny of the Kaminak Group; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 142-148 (1971).

[2] Hutchison, R.W., Ridler, R.H., and Suffel, G.G.: Metallogenic relations in the Abitibi Belt, Canada; Can. Mining Met. Bull., vol. 64, No. 708, pp. 48-57 (1971).

[3] Davidson, A.: Eskimo Point and Dawson Inlet map-areas; Geol. Surv. Can., Paper 70-27, p. 21 (1970).

[4] Ridler, R.H.: Relationship of mineralization to stratigraphy in the Archean Rankin Inlet-Ennadai Belt; Can. Mining J., vol. 92, No. 4, pp. 50-53 and vol. 92, No. 5, p. 74 (1971).

[5] Ridler, R.H.: Relation of mineralization to volcanic stratigraphy, Kirkland Lake, Ontario; Geol. Assoc. Can., Proc., vol. 21, pp. 33-42 (1970).

[6] Bell, R.T.: Preliminary notes on the Proterozoic Hurwitz Group; Geol. Surv. Can., Paper 68-36 (1968).

[7] Goodwin, A.M., and Ridler, R.H.: The Abitibi Orogenic Belt; in Symposium on Basins and Geosynclines of the Canadian Shield; Geol. Surv. Can., Paper 70-40, pp. 1-24 (1970).

QUATERNARY GEOCHRONOLOGY AND PALEONTOLOGY

66. QUATERNARY PALYNOLOGY, ONTARIO AND QUEBEC

Project 690064

R.J. Mott

In a continuing program to collect surface samples from different landform vegetation zones to compare modern pollen spectra with extant vegetation and to aid in interpreting fossil pollen spectra, twenty-three lakes in the three geographic regions were sampled. Twelve lakes were sampled in the region to the south of Algonquin Park, Ontario between Renfrew in the east, Huntsville in the west and Bancroft in the south. Six lakes along a transect between North Bay, Ontario and Rouyn, Quebec and five lakes between Ottawa and Val d'Or, Quebec were also sampled. Sediment at the mud/water interface from shallow and deep parts of these lakes were collected and depth, temperature, pH and conductivity were observed. These samples will also provide reference diatom assemblages.

Complete cores of the organic sediment from three lakes were taken for pollen analysis and radiocarbon dating. Round Lake, a kettle lake in the McConnell Lake moraine west of Temiscaming, Quebec (46°45.6'N, 79°19'W) yielded a core of 565 cm of organic sediment. A sample of the basal organic sediment has been submitted for dating and should provide a minimum age for deglaciation and formation of the moraine. A small unnamed lake about 6 miles east-northeast of Belleterre, Quebec (47°25'N, 78°35'W) contained 755 cm of organic sediment. The lake is above the maximum limit of glacial lake Barlow-Ojibway and minimum age for deglaciation of the area should result from a radiocarbon date on the basal organic sediment. The third lake, also unnamed, is located about 10 miles west of Low, Quebec. At an elevation of about 810 feet it is above the limit of the Champlain Sea and a date on the basal organic sediment should provide a minimum date for deglaciation. However, carbonate sediments at the base of 1,150 cm of organic sediment may cause an erroneous date and samples have not yet been submitted.

In co-operation with employees of the Otonabee Conservation Authority, a pothole in the Warsaw Caves Conservation Area about 12 miles northwest of Peterborough (44°27.2'N, 78°07.5'W) was excavated to recover material for radiocarbon dating. The pothole was carved into Ordovician limestone by the abrasive action of boulders swirled by water pouring down the Indian River Channel. The channel was a spillway during the Kirkfield phase of glacial Lake Algonquin. Charcoal fragments recovered from the silty clay partially filling the pothole have been submitted for radiocarbon dating and should date the final stages of flow through the spillway.

67. QUATERNARY STUDIES IN THE SOUTHWESTERN PRAIRIES

Project 650027

A. Mac S. Stalker

Field work this past summer consisted of preparation for the International Geological Congress field trip C-22, the continued collection of fossil bones, and the collection of samples from the beds near Medicine Hat for the study of pollen, seed, and plant remains. No archeological work was done.

Dr. C.S. Churcher, vertebrate paleontologist at the University of Toronto, was again in the field to direct the collection of vertebrate remains. Samples of clay and silt were taken from the Wellsch Valley Site near Swift Current, Saskatchewan, for examination of the remains of small animals. Animals identified from this site up to the end of 1970 included:

Megalonychidae indet., ? Megalonyx sp. (large ground sloth)
? Hypolagus limnetus (Gazin's marsh rabbit)
Citellus ? meadensis (Meade ground squirrel)
Geomyidae indet., ? Geomys or Thomomys spp. (pocket gopher)
Cricetidae indet., ? Pliophenacomys Meadensis (Meade vole)
Borophagus diversidens (Cope's bone-eating dog)
Lynx sp., cf. Lynx rufus (lynx or bobcat)
Mammuthus sp., cf. M. haroldcooki (Cook's mammoth)
Equus pacificus (extinct pacific horse)
Equus complicatus (extinct eastern horse)
Platygonus ? bicalcaratus (Cope's peccary)
Camelops sp. (extinct camel)
Antilocapridae indet. (extinct prongbuck)
Bovidae indet., ? Platycerabos dodsoni (Dodson's flathomed cattle).

The overlap in time range of those animals suggests an Aftonian age for the Wellsch Valley beds, an age somewhat older than had been suggested previously[1].

A small amount of vertebrate material was collected from the various pits near Empress, Alberta, but no age can be suggested as yet for these deposits. Reconnaissance visits were made to potential vertebrate sites near Camrose and Red Deer with meagre results. Otherwise, bone collecting was restricted to Galt Island Bluff near Medicine Hat and concentrated on the lowest beds (Kansan-Yarmouthian) and mid-Wisconsin.

In the latter part of the summer Dr. J.H. McAndrews, paleobotanist at the Royal Ontario Museum, Toronto, joined the writer in examining some deposits near Medicine Hat and in the collection of potential samples from promising sites. Samples were taken chiefly from the woody and peaty bed of probable Kansan-Yarmouthian age, near the base of the Medicine Hat section, and from the mid-Wisconsin beds at Galt Island and Evilsmelling Bluffs.

[1]Stalker, A. Mac S.: Quaternary studies in the southwestern Prairies; in Report of Activities, Part A, April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 180-181 (1971).

QUATERNARY GEOLOGY: ENVIRONMENTAL AND ENGINEERING GEOLOGY STUDIES

68. TERRAIN PERFORMANCE, MELVILLE ISLAND, DISTRICT OF FRANKLIN (Parts of 78, 79, 88, 89)

Project 710042

D.M. Barnett and M. Kuc

This project was designed to complement surficial geology and geomorphology studies of Melville Island. It is aimed at evaluating the effects of man's activities on a variety of terrain units.

All sites of major terrain disturbance associated with oil exploration were visited and three categories recognized; (1) intensive activity at well sites, landing strips and semi-permanent camp locations; (2) extensive systematic activity along seismic lines; (3) miscellaneous nonsystematic overland movement. Each type has left a distinctive mark on the landscape and the object was to document and evaluate the results including an attempt to identify significant geologic-geomorphic parameters.

To date, seven well areas have been drilled (three holes at Drake Point). They are: Winter Harbour, Drake Point, Homestead Hecla, Kitson River, Marie Bay, Sandy Point and Towson Point. Of these, Winter Harbour is the oldest (1960-61) and was drilled prior to widespread concern about Arctic terrain and ecology. Drilling at some more recent sites has caused greater disturbance both areally and morphologically than at Winter Harbour.

Figure 1. Gullying initiated on gentle slope after single pass of tracked vehicle with moulded cleats. Sherard Bay, Melville Island (GSC photo 201832).

In contrast to these spot locations are the wide-ranging overland seismic vehicle traverses the dates of which are known. Seismic shooting has been conducted each month from March to October and the terrain disturbance is visible to differing degrees. Runs made during the snow season have left only occasional discontinuous imprints, whereas those during the height of the spring run-off have in some instances, churned the surface materials as deep as the frozen layer.

Numerous nonsystematic vehicle movements appear to have been made during the summer period although precise documentation of timing is not available. A variety of vehicle types were identifiable from track prints including vehicles heavier than those used on seismic work.

There are two basic shapes of track cleat – the linear rectangular cleat and the moulded double flange cleat with a central downward protrusion to accommodate pneumatic tires. The latter type has the disadvantage of concentrating surface water in the continuous central depression which, on a slope, can initiate gullying (Fig. 1). Much of the disturbance was identified with this type of cleat.

Two types of track disturbance are common. First, the imprint of the form of the track, which is essentially only 'damage' in the aesthetic sense or on a microscopic scale. Many miles of seismic line are characterized by imprint only with the shot holes marked by a small mound of drilling waste, a numbered marker and perhaps a small depression. In low level terrain where snow is not blown clear, some seismic lines show no sign of tracked vehicles as, for example, those run in March and April 1971.

A second and more serious track disturbance results when vehicles churn the surface materials displacing both vegetation and the thawed layer in places to depths of 20-30 cm. In some cases this has led to extrusion of material to form lateral ridges on the outer side of the tracks and a ridge approximating the shape of the vehicle frame between the tracks. The result is a pair of channels up to 50 cm deep which may initiate gullying on slopes as gentle as two degrees. The vegetation mat is apparently destroyed and the track bottom is exposed to above freezing temperatures in summer, allowing further penetration of thawing. However, preliminary results suggest lesser amounts of ground ice are present on Melville Island than in the Mackenzie Delta[1]. If such is the case, then less dramatic thermokarst subsidence is to be expected than reported by Mackay[2] for other parts of the western Arctic.

Terrain performance units are still to be defined but lithological units were examined as a first order division of the landscape. Tonal differences on air photographs attributable to vegetation were studied in the field by M. Kuc to assess the role of vegetation in terrain performance. Numerous measurements of thaw depth were made, none of which exceeded one metre. Climatic data from Sherard Bay were gathered to relate to the progress of seasonal thaw however, local variation of depth was often as great as that attributable to other factors such as slope, aspect or lithology.

Five-centimetre core samples from the surface and depths of 25-30 cm, 45-50 cm, and 95-100 cm were collected for grain size analysis and natural water content determinations, the latter being done in the field. This sampling program of one-metre cores remains incomplete.

Ten sites at Sherard Bay were established to document detailed change through time resulting from the passage of one or more tracked vehicles. At five of these sites, M. Kuc made very detailed observations of the vegetation, including photographic record of individual plants with recognition of one-centimetre specimens possible. All sites included a disturbed and undisturbed area. Three of the sites were actively gullying and, at one, headward erosion of one metre occurred (40 cm deep and 175 cm wide) following rainfalls of 0.84 and 0.78 inch. A detailed map of one of the more extensive gullies was made by D.L. Forbes.

Four sites were set up at Drake Point, two to monitor changes in vegetation and other surface characteristics and two where gullying was active.

Preliminary conclusions indicate that even quite coarse-grained surface materials (several cm in diameter) are unsuitable for vehicular traffic at spring run-off. Conversely even the most susceptible fine-grained materials may dry out in summer to give a firm surface suitable for vehicles.

Where vehicular disturbance has led to particularly unstable conditions, such as at cut river banks, active gullying and slumping has resulted. These areas approach equilibrium conditions quite rapidly, consuming the tracks which triggered the process, and leaving a natural looking landscape. However where surface materials have been churned on a moderately stable environment, for example across a slope, then the process of natural reworking is somewhat longer term. The Winter Harbour examples indicate that the track-forms mute with time but that ten years later the tracks may still be visible and, in places, carry standing water.

[1] Rampton, V.N., and Mackay, J.R.: Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island and nearby areas, District of Mackenzie; Geol. Surv. Can., Paper 71-21, 16 pp. (1971).

[2] Mackay, J.R.: Disturbances of the tundra and forest tundra environment of the western Arctic; Can. Geotech. J., vol. 7, No. 4, pp. 420-432 (1970).

---

69. NATURAL SLOPE STABILITY IN THE FRASER CANYON AREA, BRITISH COLUMBIA (92 G, H, I)

Project 710086

W.F. Bawden

Field work was concentrated in the Fraser Canyon area and the Fraser and Thompson river valleys between Lytton, Lillooet and Cache Creek, British Columbia (N.T.S. 92 G, H, I). The Porteau Bluffs area south of Britannia Beach on the Squamish highway was also visited. The study-area was selected on the basis of abundance of known slides and their relevance to transportation routes, hydro-electric transmission lines and inhabited areas. All the slide areas studied are easily accessible by road.

The study was restricted to landslides involving slippage in the bedrock. A total of 18 slides were mapped, encompassing a wide variety of geological environments. The slides can be grouped into four general categories:

Slide Type Number	Description
1	Simple block sliding on an inclined plane.
2	Wedge failure slides. (a) Small two-plane wedge failures; (b) Large multiple-plane wedge failures.
3	"Thin skin" slides.
4	"Apparent" mudflow slides.

The first three slide types can be correlated with the rock type or types present and their inherent fracture patterns. The subsurface geology of the "apparent" mudflow slides (type 4), is not sufficiently known to permit a positive identification of the sliding mechanism. However, two possibilities exist:

(1) the slide area is an old preglacial valley with a very thick till deposit, and the slide is strictly a till slide with no bedrock slippage involved (J.S. Scott, pers. comm.) or

(2) the slide was initiated as a bedrock slump, carrying the till cover with it. As the slide progressed, the bedrock could be broken up and incorporated with the till (H. Naysmith, pers. comm.). Due to the paucity of outcrop in the "apparent" mudflow slide areas and the lack of subsurface data, it is impossible at this time to determine which hypothesis is correct.

Accurate dates could not be obtained for most of the slides studied. However, field evidence suggests that many of the rock slides occurred during late glacial or early postglacial time. At several locations, possible slide debris deposits were found intercalated with glacial till and/or stratified glaciofluvial deposits. These slides may have come down on or near stagnant ice and, as the ice melted, may have "mixed" with the glacial materials.

It is reasonable that a large number of slides may have occurred during late glacial and early postglacial time. Valley walls, oversteepened by ice action, would be left unsupported as the glaciers melted back. Groundwater regimes also would have been considerably different during late glacial time and high pure water pressures combined with the removal of toe support from the oversteepened valley walls could have initiated landslides in the more unstable areas. The occurrence of the Hope slide of 1965, however, adequately demonstrates that major rock slides are by no means restricted to late glacial time.

The Hell's Gate area in the Fraser Canyon was also visited. Although not an actual landslide, this is an important area of rock slope instability. Slope problems at Hell's Gate are directly attributable to the geological structure and appear to be independent of the rock type. A regional fault zone which parallels the Fraser River intersects both highway and railroad rock-cuts in the Hell's Gate area. Here, two main types of slope problems result; (1) toppling of large rock slabs and (2) areas of continuously spalling rock.

Remedial measures in the areas of toppling rock generally include rock bolts, rock anchors and drainage, whereas in zones of spalling rock, retaining (catchment) walls and occasionally gunite and drainage are used.

70. ENVIRONMENTAL GEOLOGY, TUKTOYAKTUK, DISTRICT OF MACKENZIE (107 C)

Project 710002

M. Bouchard and V.N. Rampton

Detailed geological mapping of Tuktoyaktuk and environs (Fig. 1) was carried out during the field season, the location of aggregate being given top priority. Two areas of gravel have been located and are outlined on Figure 1. In the eastern area, 2 to 8 feet of interbedded sand and gravel are present at the surface. To the west gravel is present in an area that includes much of Tuktoyaktuk itself. Here the gravel averages 4 to 5 feet and ranges from 2 to 8 feet in thickness with local areas of peat and lacustrine deposits overlying the gravel in most depressions. Gravel is also known to be present at depths of 5 feet or more under organic and fine-grained lacustrine deposits at other localities, for example, between the two main bodies of gravel on the west side of Tuktoyaktuk Harbour[1]. The only other known major areas of gravel are the large spits and beaches along the coastline which contain gravel 2 to 8 feet in thickness. Minor gravels occur as beach deposits around some lakes and Tuktoyaktuk Harbour, but for the most part only form a thin veneer.

West of Ibyuk Hill and in the northeast part of the map-area, low areas are underlain by peat and clayey organic-rich colluvium and lacustrine deposits, whereas the hills are underlain by thick clayey till. Many depressions at sea level near the coast are swampy and are periodically flooded by salt water.

Adjacent to Tuktoyaktuk Harbour, those areas not underlain by fluvial deposits or peat are either underlain by fine-grained lacustrine deposits or a thin clayey colluvium (<5 ft). The colluvium is generally only a couple of feet thick on most hills, but thickens in the depression. All deposits in this area are underlain by fluvial sands.

Known occurrences of massive ground ice and icy sediments within the upper 100 feet are shown on Figure 1. Within the hamlet of Tuktoyaktuk, the ice generally occurs within sands from a depth of about 8 to 15 feet[1].

East of Tuktoyaktuk Harbour, massive ice and icy sands underlie 10 to 20 feet of clayey lacustrine and colluvial sediments. Most of the till-capped hills in the peripheral parts of the mapped area have cores of massive ice at depths of 30 to 50 feet[1]. All pingos are ice-cored, and ice-wedges are common throughout the area.

Most sediments were either near saturation or are supersaturated with respect to ice content. If melted, clayey till and colluvium in the area will generally not contain any excess water, even though they commonly contain ice lenses. Frozen fine-grained lacustrine and marine deposits generally contain excess ice amounting from 10 to 60 per cent of their total volume[1], whereas fluvial sands generally contain excess ice amounting from 0 to 15 per cent of their total volume (the sand has been sampled to depths of over 150 feet at two localities in the immediate vicinity of Tuktoyaktuk). Frozen peat generally does not contain water in excess to what can be held by the fibres, but the moisture content of samples may be as high as 1,200 per cent water by dry weight, and averaged 200-300 per cent.

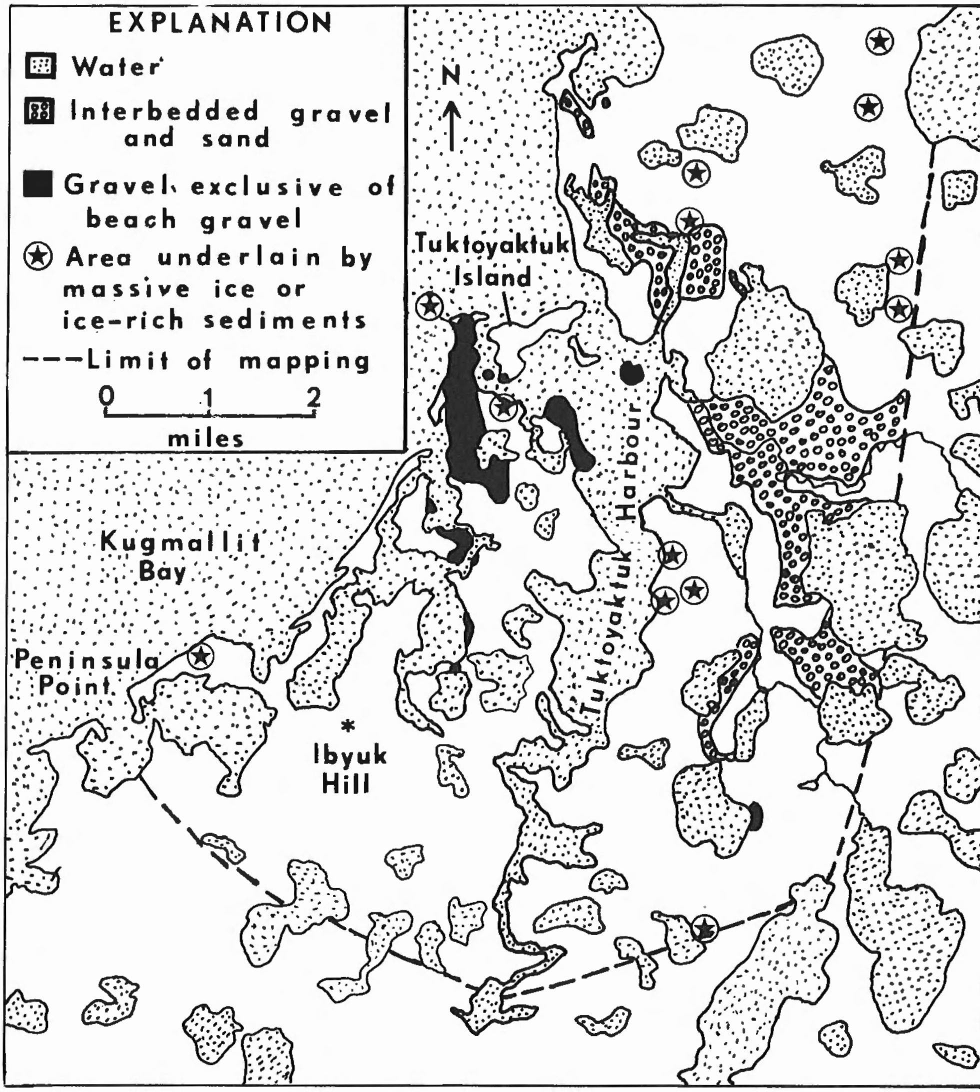


Figure 1. Area of detailed geological mapping in the vicinity of Tuktoyaktuk, District of Mackenzie.

Coastal retreat is most rapid at three locations where the coast is not protected by gravel beaches and spits, namely; at the north side of Tuktoyaktuk Island, the tip of the peninsula on which Tuktoyaktuk is located (the ground ice location on Fig. 1), and east of Peninsula Point (here the coast has retreated at one point at a rate of 20 to 30 feet per year over the last 35 years[1,2]). At the latter two locations the presence of massive ground ice or ice-rich sediment have probably accelerated coastal recession. Rapid erosion of the shoreline on the east side of Tuktoyaktuk Harbour is also occurring where massive ice is present near sea level.

[1]Rampton, V.N., and Mackay, J.R.: Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island, and nearby areas, District of Mackenzie; Geol. Surv. Can., Paper 71-72, 16 pp. (1971).

[2]Mackay, J.R.: The origin of massive icy beds in permafrost, Western Arctic Coast, Canada; Can. J. Earth Sci., vol. 8, pp. 397-427 (1971).

---

71. ENGINEERING GEOLOGY, MACKENZIE VALLEY TRANSPORTATION CORRIDOR

Project 700094

R.M. Isaacs and J.A. Code

The field component of this project consisted in part of geological reconnaissance, the development and evaluation of drilling techniques in permafrost for the recovery of frozen soil samples, and an assessment of the performance of small drilling machines and light-weight split-spoon sampling equipment. Other parts of the field program involved (1) a study of the slopes and river bank erosional processes along sections of the Mackenzie River and its tributaries, (2) an evaluation of a specific area for granular material for construction purposes, (3) the establishment of a field laboratory for standard soil classification tests as well as thermal tests on frozen soil samples, and (4) the permanent installation of instrumentation in boreholes.

General reconnaissance was done in the initial stages of the program in order to obtain a preliminary assessment of the engineering significance of the various terrain units mapped by O.L. Hughes[1]. This reconnaissance was done in the Fort Good Hope and Sans Sault Rapids map-areas to serve as a basis for planning of 1971 drilling operations.

In drilling for the recovery of frozen soil samples, a modified Boyles Brothers Model 17A diamond drill with HQ wire-line capability was used. The drilling liquid temperature was lowered and maintained within specified limits by means of a chiller unit.

Two drilling liquids were used: (a) Therminol 55, an impure alkylbenzene from Monsanto Canada Ltd., and (b) Arctic grade diesel fuel. It was found that further development of the chiller unit will be required for successful utilization of Therminol 55 as the drilling fluid but that there were no significant problems in chilling the diesel fuel. However, cores obtained from boreholes drilled with the diesel fuel were more difficult to work with because of drilling fluid contamination than were cores from holes drilled using Therminol.

A five-foot Longyear Q-3 series HQ-size triple-tube swivel-type wireline core barrel equipped with a face-discharge diamond bit was used. It proved very successful in obtaining frozen cores and permitted the removal, wrapping, labelling, and storing of the core in the Revco freezer to be performed in three to five minutes. Despite its success in frozen sediment this technique did not provide satisfactory cores from unfrozen clay containing ice lenses.

Augering in permafrost with the GW10 and GW15 (Winkie) drills manufactured by J.K. Smit and Sons Diamond Products Ltd., Toronto, proved unsuccessful primarily because of the small size of the equipment. The drills were therefore adapted to use NX diamond-drilling equipment, the drilling fluid being water from nearby lakes and ponds. Double-tube swivel-type core barrels, five feet long, were used but core recovery proved poor and removal of the cores from the core barrel was difficult at times. A Longyear NV-3 swivel-type triple-tube core barrel with a face-discharge diamond bit was very successful, yielding 90 to 95 per cent core recovery except for the upper six feet or so.

The light-weight split-spoon sampling equipment used, consisted, in part, of a sixteen-foot sectional aluminium derrick to a leg of which a light-weight motorized hoist was clamped. This leg had to be replaced by one made of steel as the aluminium leg did not possess adequate strength or rigidity. This sampling technique proved very successful, yielding a productivity up to four times that of a Winkie drill while at the same time requiring a smaller crew. As water is not used in the sampling, the samples obtained were superior to those produced by the Winkie drills.

All boreholes were logged and representative samples and cores were taken to the field laboratory for testing.

A preliminary study of slopes was made along the banks of the Mackenzie River and its tributaries between Sans Sault Rapids and Payne Creek. In this operation, information was compiled relating to such features as the forms of slopes, the types of failure occurring, the surficial geology. In addition, consideration was given to the active erosional processes which were contributing to failure of the slopes. The study is intended to serve as a rational basis for assessing the behaviour of the river banks with respect to engineering activities.

Some of the more notable features observed were:-

- failure of the upper portion of slopes
- block slumping of frozen glaciolacustrine sediments
- flow slides of silt-clay soils
- an accelerated rate of failure of slopes in areas recently burnt by forest fires
- downslope creep.

A preliminary assessment was made of a potential source of granular materials adjacent to Fort Good Hope. The work was carried out by hand sampling of fresh sections of surficial materials which have been recently exposed along the Hare Indian River. Grain size analyses were carried out on these samples in the field laboratory. Substantial deposits of gravel and sand were indicated, associated with and usually overlain by varying thicknesses of sand, till and fine-grained sediments.

A thermal laboratory, supervised and staffed by personnel from the Seismology Division of the Earth Physics Branch, made measurements of thermal conductivity and thermal diffusivity on selected samples of frozen core. Equipment used was the "divided bar" and "needle probe", the latter being specially adapted to limit the temperature rise of the probe.

Logging of the frozen core, including the occurrence and nature of any ice, as well as standard soil classification tests for grading curves, moisture content, Atterberg Limits, pH, etc. were performed in another section of the field laboratory under the supervision of D.E. Lawrence (see separate report, this publ.).

Thermistor cables were installed in five boreholes. Automatic recording equipment was attached to monitor the thermistor temperatures until the start of the 1972 field season. This instrumentation is intended to yield information on temperature gradients, mean annual air and ground temperatures, climatic changes, as well as in situ thermal parameters. Similar recording equipment will be installed at the other boreholes this winter.

The following information will be made available early in 1972:

1. Logs of boreholes showing stratigraphic detail as well as variations in the occurrence of ground ice with depth – accompanied by data on Atterberg Limits, moisture content, thermal conductivity and diffusivity which will be related to locale, topography and vegetative cover.

2. Data on variations of thermal conductivity with soil type and temperature.

3. Information regarding temperature gradients (several years of data are required to make any meaningful assessment of mean annual air and ground temperatures).

[1]Hughes, O.L.: Surficial deposits and landform maps along the Mackenzie Valley; Geol. Surv. Can., Open File 26 (1970).

---

72. TERRAIN SENSITIVITY EVALUATION AND MAPPING, MACKENZIE VALLEY TRANSPORTATION CORRIDOR (96 C, E, F)

Project 710077

P.J. Kurfurst and J.A. Heginbottom

The project was initiated in June 1971. During the summer of 1971 approximately eight weeks were spent in the field by P.J. Kurfurst and two weeks by J.A. Heginbottom.

The main objectives for the field season were the preliminary reconnaissance survey and study of the response of various soil and rock materials to different types of natural and man-caused disturbances; secondary objectives comprised extensive soil sampling and investigation of potential drill sites for the 1972 field season.

The area studied included the northern part of the Fort Norman map-area (96C), the southern part of the Norman Wells map-area (96E) and Mahony Lake map-area (96F).

Ten days were spent in the Fort Norman area with approximately half of this time devoted to investigation of the river banks and landslides along the Mackenzie, Great Bear and Brackett Rivers. The remaining time was spent studying power and seismic lines, winter roads and borrow pits; measurements of active-layer thickness and permafrost depth were also taken.

Five weeks were spent in the Norman Wells area. Apart from general mapping and sampling, close attention was paid to older engineering features such as the Canol Road and Canol Pipeline, a winter road and drill sites at Oscar Creek and winter roads, seismic lines, and borrow pits of various ages. Sampling and investigation of the landslides and river banks were the object of study in the Imperial River and Vermillion Creek areas.

The effects of forest fires and of man-caused terrain disturbance on permafrost and the active layer were studied. Some time was devoted to measuring active-layer thickness and permafrost mapping the occurrence in all disturbed areas.

---

73. GEOTECHNICAL FIELD LABORATORIES

Project 680017

D.E. Lawrence

Two geotechnical field laboratories were operational in 1971. One in the Fort Good Hope area, District of Mackenzie (Project 700094 Engineering Geology, Mackenzie Valley Transportation Corridor) and the other at Ste-Scholastique, Que. (Project 710044 Environmental Geology and the New Montreal International Airport Region). The Northwest Territories laboratory was in operation for 3 months while the Ste-Scholastique laboratory is expected to operate until September, 1972 (16 months continuous operation).

The objective of laboratory supported field operations is to provide geotechnical classification data on site to facilitate planning of surface and subsurface sampling programs and to provide sample analysis data at the earliest possible date.

The Ste-Scholastique laboratory was set up on expropriated property in the town. Sample preparation was done in a small outbuilding while a 22-foot by 8-foot mobile soils trailer and first floor of a house provided ample space for the laboratory. Test facilities and personnel were such that approximately 20 samples could be processed per day. The following data were provided,. by the laboratory: grain size analyses, Atterberg Limits, total carbonate, natural moisture content, specific gravity of soil particles, bulk density of soil, PL, and munsell colour designation. These were presented in a form suitable for computer processing. (For flow sheets for surface and subsurface samples see report by D. St-Onge, Project 710044, this publ. .)

The Fort Good Hope laboratory carried out essentially the same standard soils tests as described above with the addition of determination for excess water by volume and description of frozen material in accordance with NRC Technical Memorandum No. 79 "A Guide to a Field Description of Permafrost for Engineering Purposes". Special preparatory techniques were devised to prepare borehole samples contaminated with drilling fluids (Therminol 55 or diesel fuel). These fluids were used instead of water because they permitted core to be recovered in a natural frozen state. Borehole samples were stored in freezer chests at -5°C prior to laboratory description and testing. A laboratory for determination of thermal conductivity and diffusivity was instrumented, staffed and supervised by A.S. Judge of the Earth Physics Branch of Energy, Mines and Resources.

The disposition of the Fort Good Hope facilities were such that approximately 4 or 5 samples could be processed per day. Soil description preparation and other dirty operations were carried out in a 12-foot by 14-foot frame tent whereas the more critical measurements were done in an air conditioned 28-foot by 8-foot trailer.

---

74. ENGINEERING GEOLOGY: LAND USE REGULATIONS

Project 710083

E.B. Owen

The principal objective of the project is to provide engineering geological consultation and advice to the Northern Economic Development Branch of the Department of Indian Affairs and Northern Development in relation to the composition and applicability of the Territorial Land Use Regulations.

Activities related to the project consisted of field examinations of various operations in Yukon Territory and the Northwest Territories and discussions with operators and Departmental Resource Management officers concerning problems encountered during the operations, especially in regard to the stipulations laid down in the permit under which the operation was being conducted. The information obtained from these visits was compiled into reports which were submitted to the Northern Economic Development Branch. It was found that most operators, especially those associated with larger companies, were extremely co-operative and desirous of minimizing damage to the ecology by their operation.

---

75. ENVIRONMENTAL GEOLOGY PROTOTYPE STUDY; OTTAWA-HULL AREA (PARTS OF 31 F, G)

Project 700049

J.S. Scott

During 1971, activities were directed toward two major aspects of the project. Surficial geological mapping at a scale of 1:50,000 was continued by S.H. Richard and a continuation of the development of data processing techniques for use in a SYMAP program was done by J.R. Belanger.

Surficial geology mapping was concentrated in the east half of the Carleton Place (31 F/1) map-area. In this area, flat-lying to gently dipping Paleozoic limestones and dolomites, and crystalline Precambrian rocks are either exposed or only thinly covered by discontinuous patches of surficial deposits. Numerous marine beaches of the Champlain Sea occur between elevations of 425 feet and 520 feet a.s.l. on the top and flanks of the topographically high parts of the limestone and dolomite platform. The marine beaches are commonly fossiliferous and have not been found at elevations higher than 520 feet a.s.l. along the western margin of the map-area, west of Almonte and north of Innisville, nor have they been found above 475 feet a.s.l. near Prestonvale in the southern part of the map-area.

It is probable that these high level beaches represent early phases of the Champlain Sea and therefore marine shells for radiocarbon age determinations are being collected. Marine shells from an elevation of 445 feet a.s.l., near Ashton, represent the highest beach sampled thus far.

A late phase of the Champlain Sea in the Ottawa–Hull region[1] has been dated for the first time by the Radiocarbon Laboratory of the Geological Survey of Canada as 10,000 ± 320 years B.P. (GSC-1553). The date was obtained for marine shells (mainly Macoma balthica) collected in 1970 by S.H. Richard from a marine sand deposit at elevation 230 feet a.s.l. located 3 miles (4.8 km) south of Russell, Ontario.[2] The youngest previously published date[3] for the late phase of the Champlain Sea in the Ottawa–Hull area (10,420 ± 150 years B.P. (GSC-454)) was obtained from whale bones collected by N.R. Gadd at an elevation of 300 feet a.s.l. from a marine sand deposit at Uplands Airport, Ottawa.

Surficial geological mapping of the west half of the Russell (31 G/6) map-area is also planned.

Data processing activities were directed toward verification of borehole, seismic and other data collected during 1970, to the recording of these data on magnetic tapes and to the programming of a retrieval system and cartographic output.

Data sheets have been devised to contain all the information pertaining to each borehole or seismic sounding. The present version of the data sheet allows the recording of 21 different parameters divided into two categories or fields. It is possible to add any number of parameters to the existing ones enabling the system to deal with more complex scientific information.

All information was checked against topographic maps to detect possible errors of location or elevation. Coded information was then transferred to punched cards and finally to magnetic tapes. The main program of the retrieval system, written in PL 1, is stored on a magnetic tape. To obtain a listing of the information contained in the memory bank, the user must specify the required code and the extreme co-ordinates of the desired area.

When a cartographic output is specified, the retrieval system produces a series of statements which will serve as input to the SYMAP program.

Six types of maps were developed. The first three types are standard isoline maps: bedrock topography, drift thickness, and water table elevation. The fourth type of map is the distribution of a simple or complex surface material (e.g.: clay, till, sand and gravel, etc.). This type of map gives three zones: the areas where the specified material is present, an intermediate zone and a zone where the material is not present. The last two types of maps developed are proximal ones. The proximal map consists of spatial units defined by the nearest neighbour method from the data points. The first of these maps is a "surface deposit map". Each deposit or material appears under a different symbol, up to a maximum of ten materials. The second is similar in appearance to the first although it can be used to show distribution of several materials grouped into classes. This type of distribution may be useful to portray the relation between different materials or deposits; for example, all materials containing clay may appear under one symbol while those containing sand or gravel, etc. may appear under another symbol.

Different techniques were investigated in order to give some indication of the accuracy of the maps produced from a finite number of control points irregularly distributed over an area. The indicator takes into account the number of data points available and the distribution of these control points over the map-area. Preliminary testing of the indicator showed satisfactory results, but more trials are required before output map accuracy can be established.

[1] Prest, V.K.: Quaternary Geology of Canada; in Geology and Economic Minerals of Canada; Geol. Surv. Can., Economic Geology Report No. 1, 5th Edition, Fig. XII-16 0., p. 721 (1970).

[2] Scott, J.S.: Environmental Geology prototype study - Ottawa-Hull region; in Report of Activities, Part A: April to October 1970; Geol. Surv. Can., Paper 71-1, Pt. A, p. 156 (1971).

[3] Dyck, W., Lowdon, J.A., Fyles, J.G., and Blake, W., Jr.: Geological Survey of Canada Radiocarbon dates V; Geol. Surv. Can., Paper 66-48, p. 8 (1966).

---

76. ETUDE GEOSCIENTIFIQUE, REGION NORD DE MONTREAL

Projet 710044

D.A. St-Onge

Le projet a pour but de déterminer les caractéristiques physiques du matériel non consolidé reposant sur la roche en place dans la région nord de Montréal. En d'autres termes, cette étude doit aboutir à la création d'un modèle tridimensionnel de la géologie comprise entre Terrebonne, St-Jérome, Lachute et Oka, soit l'annexe B du Bill 60 qui comprend le site du Nouvel aéroport international de Montréal, la zone expropriée et une frange périphérique à cette région.

TABLEAU 1

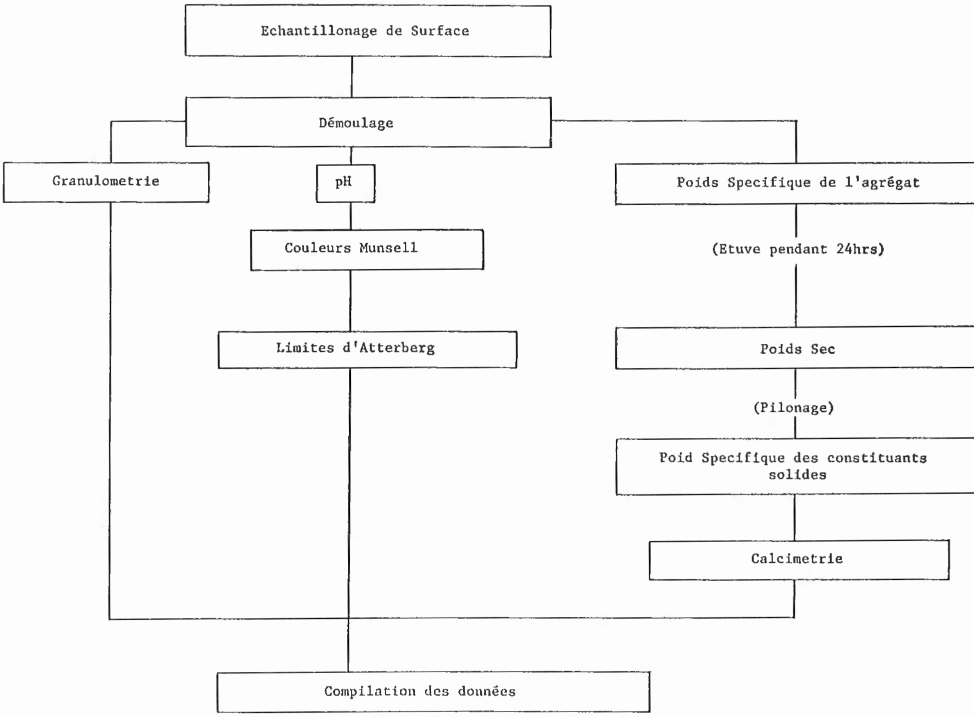
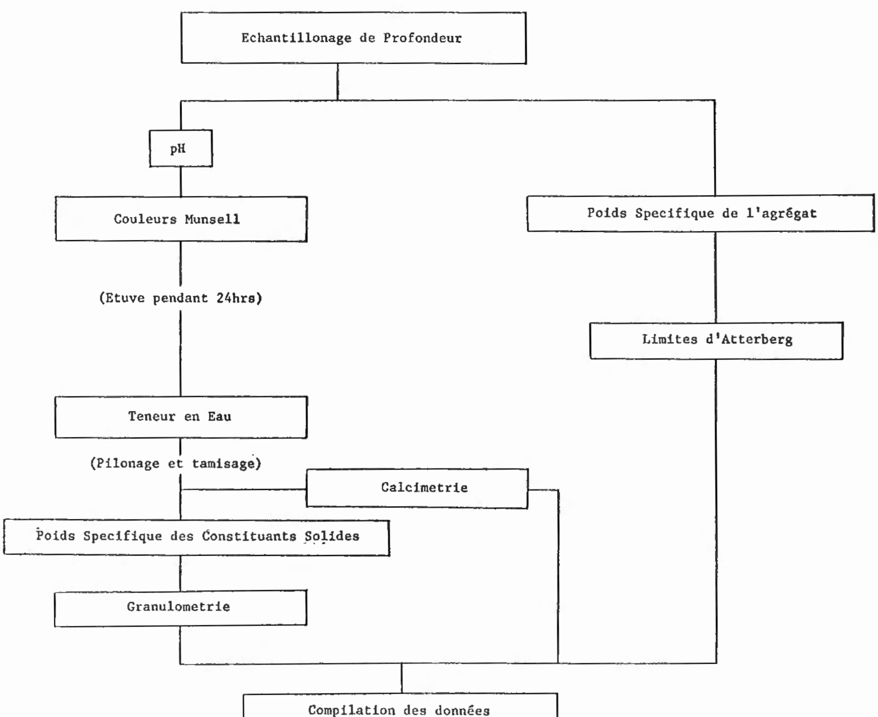


TABLEAU 2



Le travail est divisé en deux aspects complémentaires: 1) la collecte des échantillons et, 2) les analyses en laboratoire.

Le programme de collecte des échantillons est conçu de façon à déterminer les caractéristiques physiques des différents types de sédiments. Les grandes unités lithologiques (till, argile, limon, sable, etc.) sont délimitées à partir de documents pré-existants et d'observations de terrain. Les échantillons de surface (entre 1 m et 1,5 m) sont prélevés dans un tube Shelby enfoncé dans le matériel à l'aide d'un cric hydraulique monté sur un camion (Fig. 1). Ces échantillons sont soumis à une série d'analyses, tel qu'indiqué sur le tableau 1.

Les forages profonds, localisés en se basant sur les levés séismiques au marteau, sont creusés à l'aide d'une rotative Mayhew 2000 du ministère des Richesses Naturelles du Québec. Les forages sont localisés de façon à couvrir la région d'un réseau aussi régulier que possible. Les levés séismiques par réfraction donnent une première estimation de l'épaisseur des dépôts meubles et permettent d'éviter des sondages aux endroits où le roc est à faible profondeur.

Des mesures géophysiques sont effectuées dans chaque trou: résistivité, potentiel, gamma-gamma, normales ainsi que des mesures de diamètre. Des échantillons récupérés par carottage dans les parois du trou sont analysés au laboratoire en suivant la séquence indiquée sur le tableau 2.

Les résultats des analyses sont codés puis inscrits sur une fiche de compilation. Eventuellement ces données seront transcrites sur cartes perforées pour faire partie d'une banque de données qui servira à la cartographie automatique des types de dépôts et de leurs propriétés physiques.

A la fin de la présente compagne sur le terrain (déc. 1971) les basses terres à l'est de Lachute et au sud de St-Jérôme auront été étudiées.

La requête pour effectuer cette étude provient du Ministère de l'ExpansionEconomique et Régionale. Les organismes-clients sont le Bureau d'aménagement du nouvel aéroport international de Montréal (BANAIM) et le Service d'aménagement du territoire de la région aéroportuaire (SATRA). La Commission géologique du Canada et le ministère des Richesses naturelles du Québec sont responsables pour diverses aspects du projet.

QUATERNARY GEOLOGY: INVENTORY MAPPING AND STRATIGRAPHIC STUDIES

77. SURFICIAL GEOLOGY AND GEOMORPHOLOGY OF MELVILLE ISLAND, DISTRICT OF FRANKLIN

Project 710041

D.M. Barnett

This project was undertaken to provide reconnaissance scale surficial geology information for one of the last major arctic islands for which surficial geology information is not available. The work is being done at this time to provide terrain information pertinent to implementation of the Territorial Land Use Regulation and to petroleum exploration and associated activities. In this, the first season of the project, much of the area east of 112°W was examined.

Remarkably few glacial landforms are present north of the Winter Harbour moraine although erratics are ubiquitous and recently emerged shore features indicate uplift which is assumed to be glacio-isostatic in origin. The bedrock is generally poorly consolidated or even unlithified with the Paleozoic age rocks more lithified than the younger formations. No striations were found and only a few possible glacial grooves were located. The uplands from Cape Mudge to Towson Point (dissected by the two arms of Weatherall Bay) carry several cirques which are north-, northwest- or northeast-facing. There is little or no evidence of end or lateral glacial features along the arms of Weatherall Bay to support their apparent fiord origin.

The most extensive surficial deposits are alluvial deltaic sequences. Good examples of these occur on the Cretaceous bedrock around Sabine Peninsula where the prograding deltaic sequences are characteristically narrow fingers of sand. They usually lack distinctive morphological breaks which might suggest a steady relative rise of the land. The distinctive digitate morphology of the deltas is surmised to be due to opening of the rivers while the sea is still solid. This protection of the sea ice allows prograding without wave modification at the mouth. Another probability is that the initial flow is on ice frozen to the stream bed.

Extensive sandy expanses of alluvial fill are also associated with pre-Cretaceous lithologies. These areas generally have little vegetation cover and are prone to deflation even in moderate winds of 20-30 m.p.h.

Sediments associated with one of the larger streams which flows eastwards into Sherard Bay were examined in some detail and yielded an interesting variety of fossils and sedimentary structures. At least six species of marine shells (echinoid fragments were found by M. Kuc), algae pieces up to 10 cm long, bryozoans, some unidentified calcareous tube fragments and a considerable amount of fossil vegetation were found. Large pieces of driftwood from 24 metres and 16 metres above sea level will, when dated, add to the chronology and paleogeographical interpretation of the sequence.

A total of 18 major driftwood localities were sampled. The largest log was 6 m 24 cm long and 26 cm diameter. The wood ranged from sea level to 79 m but no wood was found between 62 m and 24 m. Previously the highest driftwood collected was from 1.8 m[1]. The highest wood, Larix is older than postglacial yielding a radiocarbon date of >41,000 (GSC-1609).

Confident identification of the upper marine limit is difficult both because of widespread mass movement and the high level occurrence of marine shells older than postglacial. One potentially useful indicator of a former marine environment is the presence of halophytic vegetation observed in some of the valleys on Sabine Peninsula. Sabine Peninsula was an island cut off across the isthmus between Sherard and Eldridge Bays at the time of the maximum postglacial submergence. The highest evidence of marine inundation on Vesey Hamilton Island is a beach at 9 m. However, no datable material was associated with this former marine level.

Several of the patches of till reported by Tozer and Thorsteinsson[2] were visisted and lithologies examined. Shield rocks were identified and clasts appeared to become smaller towards the north. No datable organic material was found associated with these glacial deposits.

Fossil wood from the Eureka Sound Formation was collected from the northern tip of the Sabine Peninsula.

[1] Henoch, W.E.S.: Postglacial marine submergence and emergence of Melville Island, N.W.T.; Geog. Bull, No. 22, pp. 105-126 (1964).

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

---

78. SURFICIAL GEOLOGY: SEPT-ÎLES - CAP CHAT (PARTS OF 22 G, J)

Project 710083

L. Dredge

Field work in 1971 was directed towards (1) the production of a map of surficial deposits along the Quebec North Shore between Rivière des Rapides and Rivière Pentecôte, and (2) the acquisition of stratigraphic information concerning these deposits, particularly in areas where landslides have occurred. Map-sheets 22 J/1, 2, 3E 1/2 and 22 G/14E 1/2, 15 were completed.

The area consists of a coastal plain of postglacial sediments backed by rocky uplands of the Canadian Shield. Most of the granite and anorthosite in the uplands has been scoured and polished by ice advancing from the north-northwest. Other areas, however, bear no evidence of erosive activity. Numerous pockets of weathered anorthosites have been found with jointings and pegmatite dykelets in situ.

The surficial sediments consist principally of till, clay and beach sand. All surficial deposits of till are found on or near the bedrock uplands, more than 7 km north of the present coast. The till rarely exceeds 1 m in depth except where morainic ridges occupy the heads of two river valleys. Many areas are completely free of till, and in others the "till" consists of weathered anorthosites in which textures have been altered by short transport.

The lithology and granulometric characteristics of the till vary widely because of differences in bedrock characteristics and history of transport. Despite these differences, stratigraphic evidence suggests that only one till sheet is present.

South of the uplands the till is overlain by clays and sands, which comprise the coastal plain. Massive fissured grey silty-clay deposits more than 30 m thick are found along river cuts. Exposed surfaces are dry, strong, hard and brittle. When the clays are moistened, however, they become soft and plastic, and lose strength. Failures are caused by undercutting which result in parallel bluff retreat. Farther inland, in embayments of former river valleys, the clays are stratified but the silty-clay component has characteristics similar to those of the massive deposits nearer the coast. The intervening partings of fine sand, however, are usually planes of weakness. Most of the landslide scars are found in these banded sediments, in places where they are capped by several metres of permeable beach sand.

The clays have been truncated by well-sorted, approximately horizontally bedded beach sands, which make up the major surficial deposit on the flat coastal terraces. Near Ste. Marguerite (in the central part of the area) the sand plain abuts the granitic escarpment at an elevation of 80 m. Towards Pentecôte the sands extend inland to the morainic deposits. The contact, and hence the provisional marine limit, is at an elevation of 117 m.

The stratigraphy has been interpreted from composite sections since deep cuts are absent from the area. The present field evidence suggests that there is only one till sheet, deposited by ice moving south-southeast. The till is consistently succeeded by a marine offlap sequence. Reconnaissance in map-sheet 22 G/14 (west half) suggests the possibility of a final localized valley glaciation but the stratigraphy of the deposits has not yet been established. Quantitative till analyses are in progress, but the data have not yet been evaluated.

79. THE GLACIAL CHRONOLOGY OF THE ARCHER FIORD - LADY FRANKLIN BAY AREA, NORTHEASTERN ELLESMERE ISLAND, DISTRICT OF FRANKLIN

Project 710055

J.H. England

The study was concerned with determining the late-glacial chronology and differential postglacial uplift in the fiord systems bordering the southern edge of the Lake Hazen Plateau. The field area extended from Fort Conger in the northeast to the head of Beatrix Bay, Archer Fiord, in the southwest. The data collected therefore follows the north shore of Archer Fiord and Lady Franklin Bay for 70 miles and extends inland to within 10 miles of Lake Hazen. Logistical support for the program was supplied by the Polar Continental Shelf Project.

The major emphasis of the work was determining the ages and elevations of the marine limits and lower, raised marine features in Archer Fiord - Lady Franklin Bay. In addition to the marine deposits all other accompanying surficial deposits and related landforms were mapped. All the major valleys leading from the Lake Hazen Plateau into Archer Fiord and Lady Franklin Bay are characterized by glacially over-deepened troughs inlain with vast glaciomarine deltas, postglacial river terraces and silts often 200 feet in thickness. At the head of Ida Bay, silt terraces over 150 feet in depth extend intermittently up-valley for over 6 miles. In all but a few cases the successive elevations of the delta surfaces and their stratigraphically controlled C^{14} samples were surveyed by levelling.

Ten mountain summits adjacent to the investigated valley streams were ascended in order to evaluate the vertical coverage of the ice during the last or previous glaciations along the outer edge of the Lake Hazen Plateau. No continuous moraines were observed, however, youthful, sharp-crested lateral moraines and pro-talus features were often associated with the marine limit deltas. Diffuse ground moraine was present everywhere and is particularly extensive at the head of Chandler Fiord where conical, dead ice topography is abundant above the glaciofluvial river terraces in the upper Ruggles River valley.

Between Fort Conger and Beatrix Bay 10 marine limits were observed ranging from a minimum of 225 feet a.s.l. at the head of Chandler Fiord to a maximum of 349 feet a.s.l. at the head of Ida Bay. In relation to these marine deposits, 36 C^{14} samples were collected providing the basis for 10 predicted uplift curves. In each of these there are also additional stratigraphically-controlled shell samples. In a delta sequence at the head of Discovery Harbour, four C^{14} samples were collected in order to construct an observed uplift curve. Three driftwood samples were also found: one on a raised marine beach (181 ft. a.s.l.) and two others, in situ, at the base of the marine limit deltas in Discovery Harbour and Beatrix Bay - the sample elevations were 135 and 108 feet a.s.l. respectively. On all the mountain summits climbed, samples were collected for mechanical analysis of the surface materials.

On the basis of the distribution and density of the aforementioned data, it should be possible to construct an accurate picture of the deglaciation and postglacial uplift of Archer Fiord - Lady Franklin Bay.

---

80. QUATERNARY GEOLOGY, WINNIPEG MAP-AREA (63 H, EAST HALF)

Project 700053

M.M. Fenton

The purpose of the summer's work was to complete mapping the surficial geology, began in 1970[1] and to gather further information on the Quaternary stratigraphy. The three months' field work consisted of: (i) examination of surface deposits including the drilling of about 400 hand augered holes (1 metre deep) (ii) the drilling of 30 power augered holes (3-30 metres deep) and (iii) the preliminary examination of some river sections.

Three general north-south trending geological units can be distinguished: (i) lacustrine clay in the west, (ii) till partially mantled by lacustrine sand in the centre and (iii) a sandy moraine in the east. The lacustrine clay forms a level plain - part of the Red River basin of Glacial Lake Agassiz. The till unit, a combination of units (ii) and (iii) of the earlier publication[1] forms two low ridges in the north and a level to slightly rolling plain in the south. The more westerly of the ridges forms the eastern boundary of the lacustrine plain in the northern and central portions of the area and may overlie a series of fine- to coarse-grained ice marginal deltas. The lacustrine sand, where present, is generally less than five feet thick. In a few areas, however, it thickens and, in association with lacustrine clay, forms a mantle over the till more than 25 feet deep. The sandy moraine forms a highland in the east composed of more than 30 metres of predominantly well sorted sand. In some places, the sand has been blown into dunes and, in a few areas, it is mantled by till.

Strandlines of Glacial Lake Agassiz are best marked by two well-developed, although discontinuous, scarps cut in the sandy moraine and by two nearly continuous beach ridges developed on the till. However, many other parts of the area show evidence of wave wash.

The stratigraphy includes at least three tills. A sandy silty till which forms the main surface unit over a major part of the area has been recognized both east and west of the sandy moraine. This till is underlain by stratified drift ranging from sand to clay and by at least two other tills.

[1] Fenton, M.M.: Quaternary Geology Winnipeg (east-half); <u>in</u> Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A., p. 160 (1971).

---

81. MARINE DEPOSITS, GATINEAU VALLEY, QUEBEC

Project 710081

N.R. Gadd

A preliminary study commenced in mid-August is designed to identify some of the parameters significant to delimiting deposits of the Champlain

Sea. This is an initial phase of a study of the eastern Canada landslide problem. This work is being undertaken in co-operation with Quebec Department of Natural Resources.

Among the problems included in a study of distribution of landslides in eastern Canada is that of defining the boundary of Champlain Sea, whose bottom sediments appear to be those most commonly associated with a mudflow type of slide. Clearly defined marine beaches bearing characteristic shore-facies shells of the Champlain Sea are the most useful boundary markers.

One such beach was discovered in Masham-Nord municipality approximately 2 miles west-southwest of Farrelton. Fossiliferous (Macoma sp.) silty sand occurs forty feet below an abandoned beach which lies at an elevation of about 605 feet a.s.l. This shore feature is some fifteen miles north of high (ca. 550 ft) fossiliferous gravel at Meach Lake[1,2].

Massive to faintly stratified blue-grey silt containing widely scattered marine fossils (Portlandia sp.) indicate that marine conditions extended as far north as Low. These sediments occur only below 450 feet a.s.l. and are overlain by a 100-foot-thick unit of unfossiliferous silty sand. The upper unfossiliferous unit could be marine but rhythmites occurring in upper parts of sections suggest a glaciolacustrine origin. The upper unit becomes thicker and sandier to the north and appears to grade into outwash between Venosta and Kazabazua.

The above observations appear to suggest that, in the Gatineau Valley, the Champlain Sea terminated as a glacial lake related to an ice front in the vicinity of Kazabazua. The lateral transition from marine to freshwater conditions appears to have occurred over about 10 miles. The varved (?) sediment overlying marine deposits suggest a vertical transition from marine sedimentation below 450 feet a.s.l. to glaciolacustrine sedimentation above.

Areas known to be underlain by fine-grained marine sediments are marked by flow-type landslide scars. However steep slopes in areas of probably glaciolacustrine sediments north of Venosta are characterized by minor gravitational slumps. Because marine and nonmarine sediments, which appear virtually identical, fail in such drastically different ways, it is important that further study be given to methods of differentiating between fine-grained nonfossiliferous marine deposits and glaciolacustrine material.

[1] Buckley, J.T.: Geomorphological map of the Gatineau Park; in Report of Activities, Part B, November 1967 to March 1968; Geol. Surv. Can., Paper 68-1, Pt. B, p. 79 (1968).

[2] Lowdon, J.A. and Blake, W. Jr.: Geological Survey of Canada Radiocarbon Dates IX; Geol. Surv. Can., Paper 70-2, Pt. B, pp. 59-60 (1970).

---

82. SURFICIAL GEOLOGY, WESTERN NEWFOUNDLAND

Project 690065

D.R. Grant

One week was spent mapping evidence of glacial dispersion and field checking geomorphic interpretation of bedrock structures in order to aid current exploration for base metals based on mineralized float that is known to originate in fracture-controlled stratiform deposits. This work complements more detailed studies farther north[1, 3] as well as airphoto interpretation of an area adjoining to the south[2]. The former described a three-phase glacial sequence and interpreted the geomorphology as a myriad of linear glacial elements superimposed on a reticulate pattern of strike ridges and depressional fracture lineaments. The latter dealt with evidence of late Wisconsin piedmont glaciers that spread westward over the lowlands from troughs in the Long Range plateau. This report covers both topics with emphasis on features pertinent to drift prospecting and bedrock mapping.

Except for a narrow coastal zone, the entire sea is mantled with drift, mainly composed of glacial till averaging 10 to 20 feet in thickness with a mantle of marine sand or mud below 300 feet elevation. Distinct glacial landforms are sparse in the southern half of the area but abound near Brians Pond, and in the north where multitudes of short, arcuate, narrow, sharp-crested, bouldery, De Geer moraines clearly show the pattern of ice retreat, as well as the direction of ice flow and the extent of marine inundation. Together with several segments of end and interlobate moraines, they delineate former configurations of five coalesced piedmont ice lobes. The largest crossed the lowland and extended beyond the present coast along the Hawke Bay valley. A sublobe apparently occupied River of Ponds Lake with its southern margin near Bateau Cove. A second major lobe is inferred to have emanated from Portland Creek Pond, with its northern margin near Daniels Harbour. In between these were three less extended lobes that spread westward across Eastern and Western Blue Ponds and southwestward across Brians Pond. Seven miles north and south of Bellburns there is a marked paucity of plateau erratics, and De Geer moraines are lacking over a broad area. This may indicate weaker or less extended ice in this sector; the limit of piedmont ice may be just beyond the moraine near Zinc and Bellburns Lakes.

All known boulder trains of mineralized erratics are parallel to the few measured striations, and both are perpendicular to the trend of De Geer moraines. All this confirms that the last direction of ice flow was to the west. Bedrock sources should therefore be sought "up-glacier" to the east, the exact direction being that suggested by movement indicators in the immediate vicinity of the float. The distance of transport might be a mile or less if the float occurs in abundance in the till, but could be several miles if the float occurs only on the till surface.

The limit of postglacial marine submergence varies from 200 to 425 feet, presumably reflecting varying times of disappearance of the several ice tongues. A chronology of deglaciation is emerging that differs from that to the north. A radiocarbon date of 12,400 ± 360 yr. (GSC-1485) on shallow-water marine shells near marine limit at 350 feet just beyond the moraine at Zinc Lake, and another ca. 12,000 yr. (GSC-1601) on equivalent material indicate that piedmont ice abandoned at least two major morainal positions prior to 12,000 years ago. This retreat is significantly earlier than that occurring farther north near Ten Mile Lake where a major readvance occurred shortly after 11,000 years ago. Further dating is underway to test interpretations as to the relative persistence of the ice lobes, and to test whether De Geer moraines are annual.

Bedrock structural elements are greatly obscured by thick drift and vegetation. Some major depressional lineaments are shown; these mark fracture lines and generally group into northeast and north-northeast trending sets. Ridges controlled by stratification are even more indistinct. They meander generally northwest where they are gently dipping and strike more northerly where they dip steeply. These geomorphic elements agree well with existing bedrock formation.

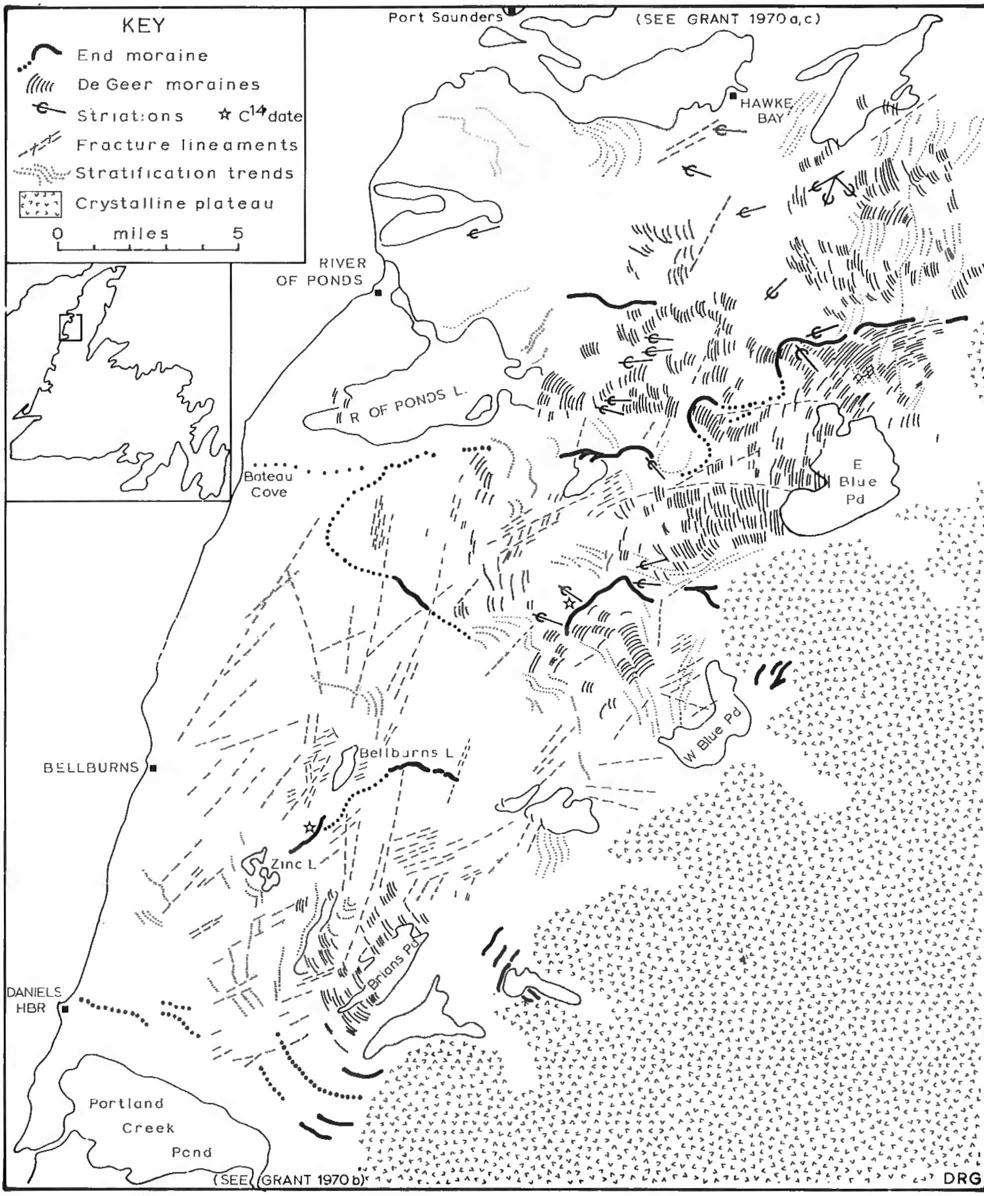


Figure 1. Geomorphic features, western Newfoundland.

[1] Grant, D.R.: Quaternary geology, Great Northern Peninsula, island of Newfoundland; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A., pp. 172-174 (1970).

[2] Grant, D.R.: Late Pleistocene re-advance of piedmont glaciers in western Newfoundland; Maritime Sediments, vol. 5, No. 3, pp. 126-128 (1970).

[3] Grant, D.R.: Surficial deposits, geomorphic features, and late Quaternary history of the terminus of the Northern Peninsula of Newfoundland, and adjacent Quebec-Labrador; Maritime Sediments, vol. 5, No. 3, pp. 123-125 (1970).

---

83. SURFICIAL GEOLOGY OF SOUTHEAST CAPE BRETON ISLAND, NOVA SCOTIA

Project 700056

D.R. Grant

Field study of the geomorphology and surficial deposits of Cape Breton lowlands is 75 per cent complete except for the area between East Bay and the highlands. This report complements an earlier report on southwest Cape Breton[1] and an overview of the entire island[2]. Emphasis is being placed on determining the various directions of glacial transport that have been earlier inferred from photo-mapped drift lineations. Observation of rock-inscribed features confirms that the area was glaciated from three widely divergent directions, and supports a revised hypothesis of Maritime glaciation embodying the concept of several independent ice caps[3]. In this connection, lowland Cape Breton provides valuable insight into the complexities produced by a fragmenting ice cap, consisting of shifting local centres of accumulation, such as was apparently also present in Newfoundland. Information is also being gathered on the composition, stratigraphy and thickness of the drift mantle. This mantle of transported material provides a more stable source of granular aggregate than ocean beaches and is suspected of concealing "buried" valleys which may contain potential aquifers.

In general, two or three till sheets are recognized and even though these can be satisfactorily explained as products of various phases of the last glaciation there is a strong possibility that some of the thicker accumulations predate the last glaciation. For example, of the many 50 to 100-foot-thick sections exposed along the north shore of East Bay, one near Eskasoni shows (from the top down) 15 feet till, 20 feet organic silt, 5 feet till, 40 feet sand, 5 feet organic silt dating more than 42,000 years (GSC-1577) over 15 feet gravel. Also an anomalous reddish till composing certain large east-west ridges in the south may correlate with a red till to the west that contains shell fragments ca. 32,000 years old.

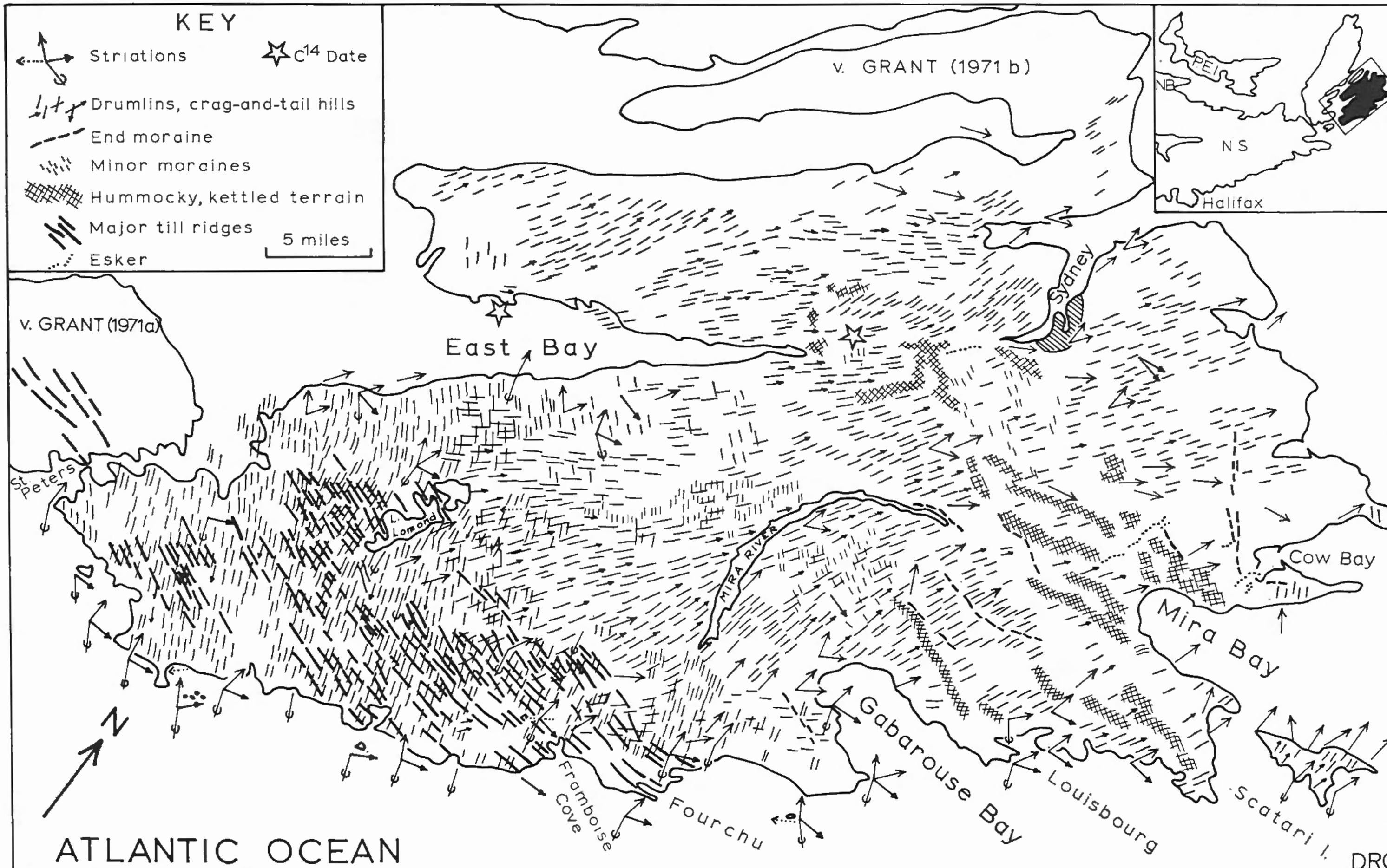
In general, the bedrock structural fabric is greatly obscured by overburden, mainly till, averaging 50 feet in thickness. Most of the fabric so obvious in the terrain consists of drumlins and fluted ground moraine. A large drumlin field blankets much of the area northeast of Loch Lomond with the exception of a coastal belt between Gabarouse and Sydney. Flutings trending perpendicular to the drumlins (towards the southeast), are found superimposed on older till ridges. The two drift lineations diverge from an elongate zone between Cape Gabarouse and St. Peters, within which both patterns are interpenetrating and criss-crossing.

South of this divergence are major ridges 1-5 miles long, 1/2 mile wide, and 100-200 feet high oriented east-west. They are composed of a reddish till that is dissimilar lithologically to the underlying grey igneous rock and are generally straight or arcuate, concave northwards. The ridges have been fluted by later ice movements that smeared and detached thinner red till masses and mantled them with a locally derived till. They may be giant drumlins produced by a strong early easterly ice flow or, less likely morainal ridges built by southwest-moving ice, of which there is very meagre evidence.

Earlier interpretations of the sequence and direction of ice movements based on photo-mapped terrain lineaments and previous work in the west are confirmed by abundant directional measurement of stoss-and-lee forms and miniature crag-and-tail features. An early easterly movement scoured southern Cape Breton, evidently from a source to the west of the island. This movement may represent the advance phase of the Wisconsin or, as implied above, may be relict from a former glaciation. No clues to its age were found, unless it is significant that the easterly striations are often overlain by the red "foreign" till, and also occur in the area characterized by the east-west ridges. Cross-cutting these striations, at least in the southern parts, are others directed to the north and northwest. This movement has been referred to the Wisconsin maximum when an ice-dome of the Appalachian glacier complex was centred offshore on the continental shelf[1,2]. The younger northeast and southeast ice-flow trends relate to final recession of the lowland ice mass. It is inferred that the centre of the offshore ice dome was shifted landward and eventually became an ice divide extending (within the map-area) between Cape Gabarouse and Loch Lomond. During this shift, southeast flow markings became superimposed on older features oriented east and northeast. At a late stage during recession to this divide, there was a minor readvance which emplaced till over a peat deposit near the head of East Bay dating 10,300 ± 150 years B.P. (GSC-1578), and which probably also produced the belts of hummocky moraine and kettled gravel stretching east to Mira Bay. Thereafter, the shrinking ice mass narrowed toward the divide and, at the same time, wasted away on the exposed seaward end, until eventually the latest ice became trapped in the Bras D'Or Lake Basin, with a lobe projecting down East Bay spilling ice southeastward over the confining hills.

This information concerning the three or more very divergent ice movements, can be utilized in prospecting provided that the identity of the till sheet containing ore grade float is known so that correct transport direction information can be applied. This method has recently been successful in locating a dolomite occurrence beneath thick till near Mira Bay. It has yet to be tried in the case of celestite boulders found north and west of the Kaiser property near Loch Lomond; these may have been derived by northward transport from the known orebody or by northeast transport from another still concealed beneath the thick clayey till.

Examples of partly buried valleys may be cited for their potential as aquifers. Mira River probably had an outlet via Broughton to Cow Bay before being dammed by drift and forced to cut a bedrock channel to Mira Bay. Curiously, the expanded southern reach of the "river" seems to have a connection



Surficial features, southeast Cape Breton Island, Nova Scotia through thick drift to Framboise Cove. Other similar major re-entrants along the south coast may represent the mouths of ancient watercourses. For example, Loch Lomond almost certainly once had a much larger exit to the sea via Grand River than it does now along the meandering valley cut in drumlins and till ridges.

Sand and gravel in the Sydney area seems sufficient to meet demand, but is in short supply elsewhere. This has led to exploitation of coastal beaches despite their protection by law. While these commodities are not widespread they are locally voluminous. Major parts of the potential supply underlies areas developed for recreation and suburban residential use, as along lower Mira River valley and the valley between East Bay and Sydney where eskers, kame moraines and kettle lakes abound. However, enough occurs in areas still undeveloped to constitute an adequate reserve, if properly managed. However, inventories should be made and priorities established to ensure a continuing supply without land-use disruption. A hitherto unreported glaciofluvial gravel complex covering several square miles northwest of Mira Bay seems thin and of lesser quality than that now being exploited along Meadows Road southwest of Sydney.

[1] Grant, D.R.: Surficial geology, southwest Cape Breton Island, Nova Scotia; in Report of Activities, Part A, May to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 161-164 (1971).

[2] Grant, D.R.: Glaciation of Cape Breton Island, Nova Scotia; in Report of Activities, Part B, November 1970 to March 1971; Geol. Surv. Can., Paper 71-1, Pt. B, pp. 118-120 (1971).

[3] Prest, V.K., and Grant, D.R.: Retreat of the last ice sheet from the Maritime Provinces - Gulf of St. Lawrence region; Geol. Surv. Can., Paper 69-33, 15 pp. (1969).

---

84. QUATERNARY GEOLOGY, GOODERHAM-APSLEY AREA, ONTARIO

Project 700093

E.P. Henderson

Striae and associated ice-flow features indicate ice movement of about south 24 degrees west over the northern half of the Gooderham-Apsley region and average south 13 degrees west over its southern portion towards Apsley. The more southerly flow is almost perpendicular to the extensive Dummer moraine[1] which extends east-west a few miles south of the map-area and is in close agreement with previously recorded ice movement to the east, in the Marmora-Coe Hill[2] and Madoc-Bancroft[3] regions.

Glacial deposits, everywhere underlain by Precambrian rocks, are the most widespread unconsolidated materials in the area and characteristically are thin and discontinuous. Locally, however, the till attains a thickness of more than 10 feet, particularly on the flanks of hills and in one drumlin in which till has accumulated to over 40 feet. In two areas, one extending for two miles west from Gooderham south of the Ironwood River and the other east of Highway 24, 4 miles north of Apsley, the till consists almost entirely of sand. The sand till evidently records small local readvances that incorporated glaciofluvial sediments, previously deposited in meltwater channels lying north of these positions, into the till.

Glaciofluvial sediments are generally present as small isolated kames but, in two places, form series of ice-contact and associated valley-train deposits, linked by intervening stretches of narrow bedrock valley of considerable extent. The larger meltwater channel wherein these deposits formed was traced for 18 miles along Cope Creek and Irondale River drainage west and south across the northwesterly third of the map-area from 4 miles northeast of Tory Hill to 6 miles west of Gooderham and beyond. Trenching by the modern river has left terraces along the Irondale valley that generally lie 10 feet to 20 feet above the river but are considerably higher at one point a few miles west of Gooderham. The second and somewhat smaller meltwater channel originated as a spillway at the south end of Joe Bay on Paudash Lake, and was traced south into the Eels Creek drainage, which it follows south past Apsley. Sand and gravel are derived from kame deposits in several places, but principally from outwash gravels along the Ironwood River and Paudash Lake-Eels Creek meltwater drainage routes. Most of the meltwater sediments are sand deposits up to 40 feet thick rather than more commercially desirable gravel which is present principally where ice-contact deposits mark temporary stands of the ice at two places along both meltwater channels. Kettle ponds and closed depressions indicate where buried ice blocks melted after deposition of the coarse glaciofluvial sediments ceased. The largest gravel deposits are on either side of the Irondale River 4 miles northeast of Tory Hill where only about 15 per cent of easily exploited material appears to have been removed.

Seven miles south of Gooderham between Pencil and Galloway Lakes rotted, coarse-grained, granitic bedrock was exposed to a depth of over 4 feet in a borrow pit used for road maintenance, and is similar to material previously observed 15 miles to the east, north of the village of Oak Lake. Because of the short time available for the formation of deep weathering in these rocks, such weathering profiles suggest that rotted bedrock may represent parts of a deep regolith developed during a previous interglacial, or even earlier, time, which has escaped erosion during subsequent glaciation of the area.

[1] Chapman, L. J., and Putnam, D. F.: The physiography of southern Ontario; Univ. Toronto Press (1951).

[2] Henderson, E. P.: Quaternary geology, Kingston, Ontario; in Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 167-168 (1971).

[3] Henderson, E. P.: Quaternary geology, Kingston (north half), Ontario, in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 176-178 (1970).

85. QUATERNARY RECONNAISSANCE NORTHWEST DISTRICT OF MACKENZIE (106 I, J, K, M, N, O)

Project 710020

O. L. Hughes and D. A. Hodgson

This project is an expansion of earlier reconnaissance work (project 690046)[1]. The objective of the new project is to provide inventory surficial geology and permafrost distribution data pertinent to pipeline construction, road building and other land use activities that might take place in the Mackenzie Valley Corridor.

Field work was devoted mainly to field checking of 1:125,000 scale photo-interpretive maps, prepared in advance of the field season, of map-areas 106 I, J, K, M, N, O. In addition, a number of exposures were studied in detail for stratigraphic information, and a large number of slides were studied in order to determine qualitatively the roles of geological materials and ground ice content in slope failures.

The following are some important features of the Quaternary geology. (1) A large area of glaciolacustrine sediments with thermokarst lakes in the southwestern part of 106 I and the southeastern part of 106 J, plus several smaller areas adjacent to Mackenzie River in 106 N, and O. The sediments in general have high ground ice content and are potentially highly unstable, especially along stream banks. (2) A broad belt of mostly low relief hummocky moraine extending from west of Fort McPherson to Arctic Red River and northeast to Renleng River. Although scattered hummocks consist of coarse gravelly till with little ground ice apparent, much of the belt is underlain by till rich in silt and clay with locally high ice content. (3) Discontinuous but locally well-developed linear moraines lying east and north of Mackenzie River in map-area 106 O, and on the south and west flanks of Grandview Hill (map-areas 106 J, O). The moraines appear to mark significant late Wisconsin readvance(s) of the Laurentide ice sheet. (4) A broad irregular belt of low relief hummocky moraine on the east flank of Richardson Mountains, overlain along many of the valleys by glaciolacustrine sediments. The sediments and, locally, the till of the hummocky moraine have high ice content and are potentially highly unstable. (5) Extensive very flat areas between Mackenzie and Peel Rivers, plus a narrow belt between Peel River and the east flank of Richardson Mountains and an area east of Mackenzie River and north of the moraine mentioned in (2) above. They are underlain by shale, siltstone and sandstone with a thin till cover, commonly less than 10 feet thick, and discontinuous organic cover. Although ground ice content is locally high near the contact of the organic cover and the till, it is lacking in the underlying bedrock, so that total ground ice content is low.

Field evidence indicates that, in areas of glaciolacustrine sediments and also in patterned peatlands, thermokarst activity is enlarging many ponds and boggy depressions whereas encroaching vegetation and development of pals and peat plateaus is reducing others. Rates of these processes and their net effect have not been determined.

S. C. Zoltai and R. Strang of Canadian Forestry Service, and W. Pettapiece, Department of Agriculture, were attached to the field operation. Zoltai and Strang determined the relationship of vegetation to surficial geology, landform and permafrost conditions, and Pettapiece studied the relationship of soil development to the same factors. Summer students, working under the direction of D. Delorme, Inland Waters Branch, Department of the Environment, collected modern ostracods and mollusca, plus environmental data relevant to the collections, as background data for future paleocological studies.

[1] Hughes, O.L.: Quaternary reconnaissance, northwest District of Mackenzie, in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 178-179 (1970).

---

86. QUATERNARY GEOLOGY INVENTORY, LOWER NELSON RIVER BASIN (53 M, 54 C, D, 63 O, P, 64 A, B)

Project 710092

R. W. Klassen

The main purpose of this project is to prepare surficial geology maps (1:250,000 scale) of about 40,000 square miles in the boreal forest region of northeastern Manitoba. Maps will be compiled primarily on the basis of airphoto interpretation verified by scattered field observations.

This summer's field work was the first phase of a tentative schedule of operations which includes the preparation of preliminary maps (winter of 1971-72), field verification of preliminary maps (summer of 1972) and final preparation of maps for publication (winter of 1972-73). First phase field studies were aimed at establishing the general nature of the map-area and at collecting lithologic and gemorphic details of selected localities within the various types of terrain. This entailed 28 hours of flying by helicopter, 5 hours of flying by fixed wing aircraft and limited road traversing by motor vehicle.

Five general types of terrain within the map-area are: (1) Canadian Shield bedrock terrain (63 O, 64 B and part of 63 P) that consists of bedrock ridges and intervening low areas underlain by clay over till; (2) morainic terrain (parts of 54 D and 64 A) consisting of irregular hills and distinctive ridges underlain by sand and/or bouldery gravel; (3) drumlinized terrain (53 M and parts of 54 D and 63 P) underlain mainly by till; (4) lacustrine terrain (parts of 63 P, 64 A and 54 D) consisting of flat to gently undulating surfaces underlain by clay; (5) marine terrain (54 C) characterized by flat, featureless surfaces underlain by silt and clay. In addition to these general regional units local patches of lacustrine clay and isolated kames, eskers and small deltas occur throughout the map-area west of the marine terrain.

The drift along the lower part of the Nelson River is some 100 to 150 feet thick and generally includes a lower till unit, an intermediate glaciofluvial(?) unit and an upper glaciomarine unit. Solifluction debris is widespread along most banks and commonly masks stratigraphic details.

87. QUATERNARY GEOLOGY OF THE GREAT LAKES

Project 680055

C.F.M. Lewis and T.W. Anderson

Theoretical studies of uplift and its associated effect on postglacial drainage in the Great Lakes area clearly indicate an episode of extremely low lake levels in the Huron - Georgian Bay Basin[1,2]. It is probable that several separate lakes were formed in the Huron Basin as a result of the low base level and rugged basin relief. These inferred lakes, impounded behind three cuestas developed in the southwesterly dipping Paleozoic rock formations underlying Lake Huron, drained northward over a succession of thresholds around Manitoulin Island into Georgian Bay and ultimately into the Champlain Sea via the Mattawa-Ottawa valley system.

Field work in September 1971 consisted of detailed echo sounding and the collection of critical sediment sequences in piston cores from the research vessel Machi Karlsen. This work, directed towards obtaining field evidence for the low water levels and paleolimnology of Lake Huron, is being compiled jointly with staff of the Limnogeology Section at Canada Centre for Inland Waters.

A total of 23 piston cores ranging up to 21 m in length were collected and examined for evidence of subaerial erosion or deposition. Unconformities, commonly indicated by thin units of sand, gravel, shells or plant detritus, were revealed in the late glacial-postglacial sediment sequence at 9 localities distributed throughout the Huron Basin. Of particular significance is an extensive bed of buried plant detritus indicating a previous marsh environment. The detritus underlies an area of at least 20 sq./cm, 17 km east of the Michigan shoreline at latitude 44° 30'N., where the present water depth is 59 m.

Interpretation of echo sounding patterns and judicious bottom sampling provided new bathymetric and sedimentologic information in critical areas such as the inter-basin connecting channels and the complex 'hill and vale' topography of northern Lake Huron.

Regional seismic reflection surveys were organized for Lakes St. Clair, Georgian Bay and North Channel to provide reconnaissance data on bedrock topography and the distribution and thickness of Quaternary deposits. The surveys were carried out jointly between June 20 and November 12 with G.D. Hobson (GSC) and W.M. Tovell, Royal Ontario Museum, using vessels provided by the Great Lakes Institute, University of Toronto and the Canada Centre for Inland Waters (see G.D. Hobson, Project 660054, this publ.).

[1] Hough, J.L.: Lake Stanley, a low stage of Lake Huron indicated by bottom sediments; Geol. Soc. Am. Bull., vol. 73, pp. 613-620 (1962).

[2] Lewis, C.F.M., Tovell, W.M., and McAndrews, J.H.: Differential uplift and low lake levels in the Huron and Georgian Bay Basins. Unpubl. ms. (1971).

88. MARINE ACTIVITIES IN HUDSON BAY, 1971

Projects 710066, 710090

C. F. M. Lewis and B. V. Sanford

Geological Survey of Canada investigations in Hudson Bay during the 1971 field season consisted of two interrelated projects directed towards:

1. Delineating the regional offshore distribution of Paleozoic formations as part of the current Basin Analysis Program of the Survey for the evaluation of petroleum and natural gas resources.

2. Studying the Quaternary sediments in order to: (1) provide information related to potential foundation problems of offshore structures; (2) to improve the interpretation of ocean bathymetry in aid of item 1 above; (3) to reach a better understanding of glaciation and ice movements in central Canada; and (4) to extend our knowledge of modern sedimentary processes within Hudson Bay.

During August and September 1971 the Survey participated with Aquitaine Company of Canada Ltd. in a marine geological investigation of Hudson Bay. The two groups shared the equipment and facilities of M. V. Hudson Handler a 90-foot-long vessel, designed to launch and recover a submersible Pisces III. Both submersible and surface vessel were equipped with rock drills. Sediment samplers, echo sounder, side-scan sonar and a shallow seismic reflection profiler were also available. Position control was provided by a single channel satellite navigation system. The ship traverse, totalling 2,500 miles, started at Coral Harbour, N. W. T. and ended at Povungnituk, P. Q. Intermediate ports of call included Rankin Inlet, N. W. T., Eskimo Points N. W. T., Churchill, Man., and the Belcher Islands, N. W. T.

A new electro-hydraulic diamond rock drill, controlled from the surface, was extremely successful in recovering short (up to 1 m) bedrock cores of 4 cm diameter where overburden was less than 2 m thick. This drill was the chief tool by which bedrock stratigraphic control points were established.

The submersible Pisces III was utilized in a minor way only. Some use was made of it in studying specific bedrock targets and it's success in providing a detailed view of complex bottom environments enhanced the interpretation of bottom grab samples. Selective sampling, including the recovery of short oriented cores from till, was successfully undertaken.

A total of 15 widely distributed bedrock stratigraphic control samples were recovered. The cruise confirmed that most first-order features of the bathymetry are bedrock controlled and that major ridges, cuestas, etc. may be used to delineate certain formational boundaries. A 1:1,000,000 scale map of the Paleozoic geology of the Hudson Bay Basin is being prepared by using information collected on this cruise in conjunction with extrapolations from existing knowledge of onshore stratigraphy and bedrock physiography.

The surficial deposits are difficult to penetrate seismically because of the prevalent occurrence of highly reflective sand and gravel near surface. High-energy, low frequency sound sources, such as the 5-cu.-in. air gun used in this survey, proved marginally satisfactory for profiling the bedrock surface. The results are not of high-resolution quality and are suitable for mapping stratification within the surficial deposits in local areas only. Some second-order physiographic features noted are probably accumulations of Quaternary materials which originated as ice marginal glacial deposits. The bottom sediments were sampled by grab sampler and/or gravity corer at 75 stations. The chief surficial sediment facies are silt muds and gravel-veneered till or glacio-marine deposits.

---

89. QUATERNARY GEOLOGY, CHARLIE LAKE, BRITISH COLUMBIA (94 A)

Project 710085

W.H. Mathews

A field investigation of the Quaternary geology of the Charlie Lake area (NTS map-sheet 94 A) was undertaken in July as an extension of previous work undertaken by the writer in the early 1950's for the British Columbia Department of Mines in the Fort St. John area[1]. Conclusions reached in this earlier study served over the larger area with minor changes and additions:

1. A newly recognized unit, a sub-till gravel deposit of strictly westerly provenance, at an altitude of 2,350 feet north of Clayhurst, is identified as a channel fill of a preglacial Peace River, 1,000 feet above its modern counterpart.

2. A lower channel deposit, 400 to 600 feet above Peace River, hitherto recognized near Fort St. John where it yielded groundwater[2], unfortunately of poor quality, is also present south and west of Clayhurst. Rare pebbles from the Canadian Shield in gravel of this channel fill show that it postdates the first glaciation of the area rather than being preglacial as inferred previously.

3. Only a single till sheet has been identified with late Wisconson glaciation of the area. In it, Precambrian detritus becomes progressively less abundant from east to west across the area, but is still present southwest of Hudson Hope. Cordilleran material deposition is present throughout the till because of hypothesized coalescence of Laurentide and Cordilleran ice. Patterns of surface grooves in the western part of the area, seemingly of glacial origin , may be a product of late ice advances from the mountains to the west and northwest but no tills have yet been found associated with these.

4. A narrow belt of shoreline gravels of a late glacial ice-dammed lake, occur at an elevation of about 2,250 feet, from the Alberta border west 50 miles to Upper Cache Creek, indicating little or no postglacial tilting. Similar gravels farther west, near longitude 122° occur at higher levels, 2,350 to 2,400 feet, and this, together with a rise in the upper limit of glaciolacustrine sediments from an altitude of 2,750 feet near Fort St. John to more than 3,000 feet at longitude 122° , suggests a differential uplift in the west.

5. Meltwater channels and an apparent lack of glaciolacustrine sediments on the surface above the 2,250-foot contour in the eastern third of the map-area indicate that ice lingered in this vicinity until free drainage was possible down to the 2,250-foot level and after the accumulation of the Portage Mountain kame moraine, dated at 11,600 years B.P.[3].

[1] Mathews, W.H.: Quaternary stratigraphy and geomorphology of the Fort St. John area, northeastern British Columbia; B.C. Dept. Mines Petroleum Resources, 22 pp. (1963).

[2] Mathews, W.H.: Ground water possibilities of the Peace River Block, British Columbia; B.C. Dept. Mines, Ground Water Paper, No. 3 (1955).

[3] Rutter, N.W.: Quaternary geology, Pine Pass-Jasper area, British Columbia and Alberta; in Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A., pp. 178-179 (1971).

---

90. QUATERNARY GEOLOGY, BOW RIVER VALLEY (PARTS OF 82 J, O)

Project 670061

P. McLaren and N.W. Rutter

The object of the summer's work was to produce a surficial map of the Calgary area. This will complement subsurface data from a drilling and well-logging program carried out by N.W. Rutter in 1967 and 1968[1]. The map and subsurface data are intended to be a basis for engineering geology in the City of Calgary.

Map-sheets covered were 82 O/8E, 82 O/1E and that portion of the city on 82 J/16E. Airphoto interpretation provided much of the geomorphic data and field work consisted primarily of examining road-cuts and construction sites. In the city, difficulty was experienced in identifying deposits because of modifications by man. In many areas the original topography could be studied only by the use of old airphotographs.

Deposits in the area could be identified only to their genetic and textural characteristics. In general, ground moraine consisting of various localized till lithologies covers much of the northeast plains and highland areas. However to the west, north of the Bow River, there is a highland area of thick hummocky disintegration moraine. Much of the west side of the city is underlain by thick lake silt deposited in glacial lake Calgary which occupied the Bow Valley. The eastern areas of the city contain large numbers of drainage channels which isolate "islands" of mixed till and lake deposit. To the southeast, these tend to open out into large areas of outwash.

[1] Rutter, N.W., and Wyder, J.E.: Application of borehole stratigraphic techniques in areas of mountain glacial drift in Alberta, Canada; Geol. Surv. Can., Paper 69-35, 15 pp. (1969).

---

91. QUATERNARY GEOLOGY, ARCTIC COASTAL PLAIN, DISTRICT OF MACKENZIE AND HERSCHEL ISLAND, YUKON TERRITORY

Project 690047

V.N. Rampton

A. Eskimo Lakes stratigraphy

The Pleistocene stratigraphy along the northern edge of Liverpool Bay and throughout the length of the Eskimo Lakes was investigated in detail during the field season. In the vicinity of locality 1 (Fig. 1), crossbedded grey sand with gravelly lenses typically overlies fine-grained brown sand, the contact being 30 feet above sea level. Both the land surface and the contact rise to the west. In the vicinity of locality 2 (Fig. 1) a thin ice-rich clayey till (maximum thickness, 10 ft) appears at the base of the grey sand, and gravel beds become more common in the grey sand. At locality 3 (Fig. 1), a crossbedded medium-grained grey sand appears under the brown sand. This

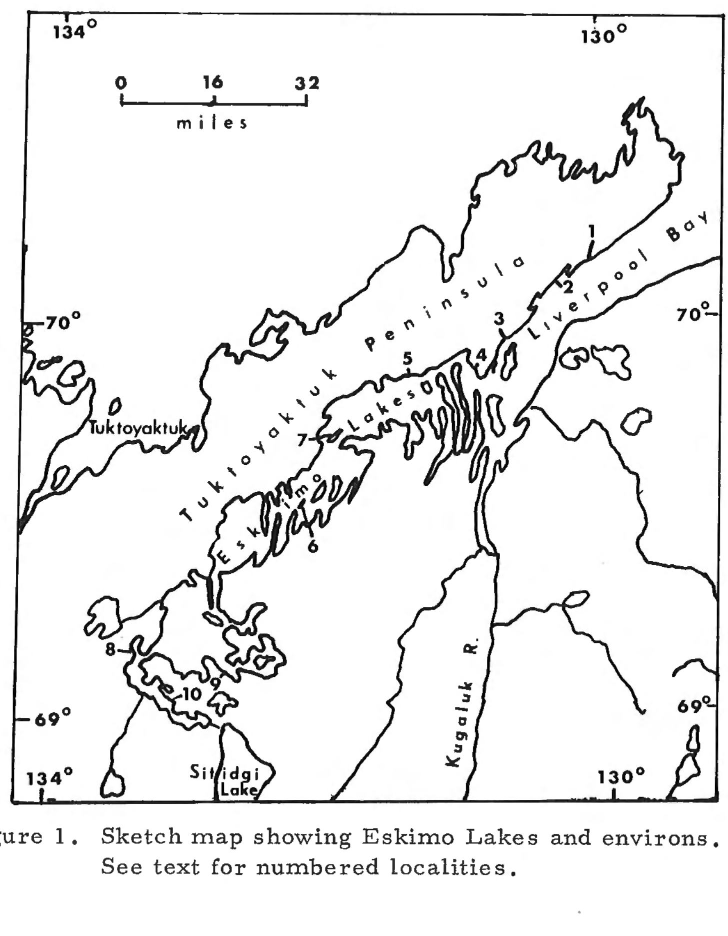


Figure 1. Sketch map showing Eskimo Lakes and environs. See text for numbered localities.

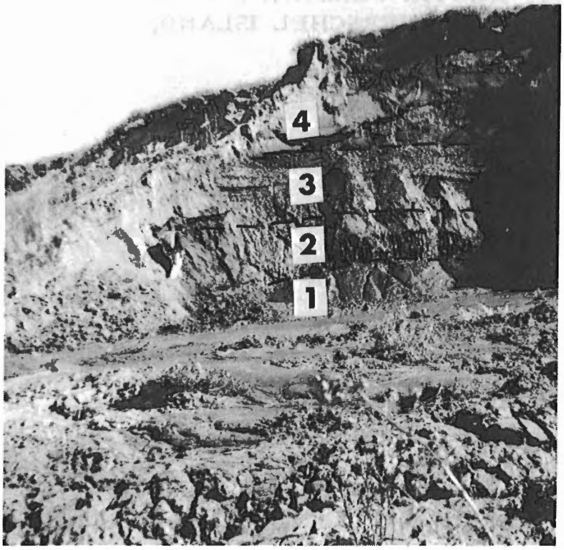


Figure 2.

Exposure at locality 6 on Figure 1.

Unit 1: pure massive ground ice.

Unit 2: clayey till.

Unit 3: lacustrine clay with many thin ice lenses (1/2 inch thick).

Unit 4: outwash sands.

A typical mud-flow formed from thawing of these units is in the foreground. GSC photo 201831.

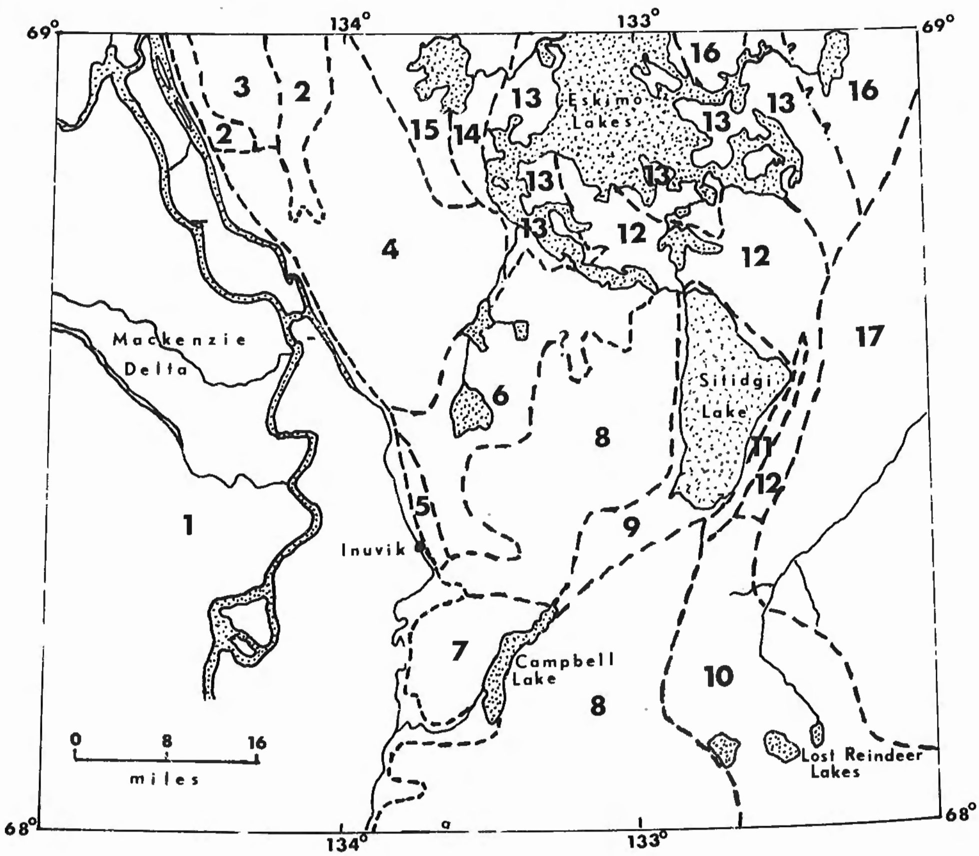


Figure 3. Sketch map showing surficial deposits, east half of Aklavik sheet (NTS 107B). See text for description of numbered areas.

lower grey sand is present as far west as locality 4 on the northern edge of the strait connecting Liverpool Bay and the Eskimo Lakes, and is also present throughout the southeastern two-thirds of the fingers to the south (Mackay[1] noted a similar distribution for this unit). The brown sands are generally capped by thin ice-rich clayey till, except where channels cut in the brown sands have been filled with grey gravel and sand (one of the larger channel fills appears to be contiguous with an outwash body leading from the nothern end of the Eskimo Lakes towards an outwash plain on the northern part of the Tuktoyaktuk Peninsula)[1,2]. The brown sands are only present as far west as locality 5 (Fig. 1), as they disappear below sea level at this point.

Figure 2 shows a stratigraphic sequence common to the area surrounding the eastern and central parts of the Eskimo Lakes. The sands at Locality 6 (Fig. 1) are part of an outwash body whose source is at the southern end of the Eskimo Lakes and which extends as far east as locality 7 (Fig. 1). A postglacial origin is suggested for the Eskimo Lakes, as these outwash sands, in some places, occur on islands. The lakes possibly were formed by differential thawing of ground ice from a prism of sediment that originally had a plane surface[3,4]. The lacustrine clay (Unit 3, Fig. 2) seems to be confined to the eastern part of the Eskimo Lakes (east of locality).

In the southern end of the Eskimo Lakes the outwash thickens to 50 feet and gravel beds are a common component. Till and ground ice are exposed under the outwash as far south as localities 8 and 9. Generally the outwash sands and gravels lie directly on fluvial sands. However, at two exposures (vicinity of 10 on Fig. 1), the outwash overlies interglacial sequences of peat, silt, and sand[1] more than 80 feet thick.

Low terraces[1,5] formed by a lake postdating the outwash sequence have been inset within the sequence described at localities 7 and 10. Towards locality 7, the low terrace materials are commonly clay, silt and fine sand whereas, towards localities 8-10, the terrace materials are generally sand and, occasionally, gravel.

B. Surficial geology of the east half of the Aklavik sheet (107B)

Mapping of the above map-sheet at a scale of 1:125,000 was completed and a preliminary evaluation of the collected data suggests that the area can be divided into 17 terrain units (Fig. 3), each having a unique arrangement of near-surface unconsolidated sediments. The surficial geology outlined here is in general agreement with previous studies done by Mackay[1] and Hughes[6].

Area 1 (see Fig. 3) is the postglacial Mackenzie Delta whose surface is mainly clay, silt, and fine-grained sand, all high in organic content.

The surface of area 2 is mainly glaciofluvial gravels and sands that have been deeply pitted by thermokarst depressions. The lithologies of clasts in the gravels indicate that much of this material has been eroded from the Reindeer Formation to the south.

Most exposures in area 3 consist of a veneer of clayey till (± 10 ft) which overlies sand. Locally the till may thicken to 30 feet or more. Drained lakes which occupied thermokarst depressions are common in this area.

Area 4 is that part of the Caribou Hills having a negligible or thin glacial drift cover. In the northern part of the area most cuts on the uplands expose Tertiary gravel, whereas in the southern part weathered shale is the common surface material. Local areas in the southern corner may be underlain by clayey till up to 20 feet in thickness.

Near Inuvik, a broad band of clayey alluvium lies between the Caribou Hills and the Mackenzie Delta (area 5). Gravel generally underlies the clay and is common at the surface at Inuvik[1]. Ground ice is occasionally present under the gravel[1] and in the fine-grained alluvium.

Area 6 is a zone of hummocky moraine. Exposures in this area as well as the relief, indicate that the clayey till is generally at least 20 feet, and possibly more than 60 feet thick. Ice slumps exposing massive ground ice and icy till at shallow depths can be seen occasionally around lakes in this area. In places, as, for instance, just west of Inuvik, stream action has cut into the underlying bedrock and weathered shale is common on the slopes. Gravel and sand may be present throughout the moraine in the east half of the area.

In area 7, bedrock is either very close to the surface or is capped by a thin veneer of colluvium and drift.

The till veneer overlying the shales in area 8 is very thin, probably negligible in many cases. Most fluting in this area is probably in the bedrock[1]. The till may thicken near the northern edge of this area as the boundary between the hummocky moraine to the north (area 6) and (area 8) is not sharp. Scattered kames and eskers are present along the east side of Campbell Lake and southeast of Sitidgi Lake[6]. In the southeastern corner of this area, small areas of thick organic deposits are common.

Area 9 is underlain by silty clay, mostly lacustrine in origin, but some undoubtedly of fluvial origin. Although much of the area is very marshy, the organic cover seems to be thin, generally no greater than 2 feet.

Area 10 is an area of hummocky to rolling moraine. Till is probably more than 30 feet thick throughout most of the area. Gravel kames are present at Lost Reindeer Lake.

Area 11 is a narrow flat till plain and bedrock escarpment bordering the east side of Sitidgi Lake. At the crest of the escarpment and to the north of the lake is a belt of hummocky moraine interspersed with numerous gravel kames (area 12). The drift east of Sitidgi does not appear as clayey as most tills in the region and is possibly ablation till.

Area 13 is a relatively flat outwash plain. Thick gravel beds are common in the outwash along the southern fringe of the area. The deep thermokarst basins developed in the outwash and occasional exposures of massive ground ice indicate that relatively thick (10 ft +) ground ice is common at depth under the outwash.

Area 14 is also outwash but, in contrast to area 13, it has a hummocky surface and gravel is a more common constituent. Gravel knobs, twenty feet and more in height stand out as positive features throughout the area.

In area 15, 10-25 feet of icy till overlies sand. Thermokarst activity has been intense in this area, and lake formation and drainage of the thermokarst depressions has left much of the area underlain by fine-grained postglacial lacustrine deposits.

Area 16 is difficult to evaluate as there are few exposures. Although the terrain is hummocky and clayey till is exposed in the shallow cuts that are present (suggesting a hummocky moraine origin), it is believed that most relief is due to thermokarst activity and that the area consists of relatively thin clayey till overlying sands (a common situation in the area immediately north[2]).

Area 17 appears to be a dissected shale upland. Moderate thicknesses of glacial drift may be present in the southern half of the area.

C. Herschel Island

One week was spent reviewing the coastal exposures of Herschel Island with Michel Bouchard. Clayey silt, sand and gravel of estuarine origin are common along parts of the coast, even though massive marine clay is the most common material exposed. The complexity of the estuarine sequence plus the deformation resulting from glacial ice-thrust[7, 8] make it very difficult to reconstruct a stratigraphic sequence, and to make stratigraphic correlations from one part of the island to another part.

Large bodies of massive ground ice, in excess of 30 feet across, are visible at various heights in coastal and near-coastal exposures.

D. Ground ice investigations

Experiments begun in 1970[2], in co-operation with Gravity Division of Earth Physics Branch, to determine if gravity can be used to detect and estimate the thickness of ground ice were completed. Ice samples were also collected from a number of ice bodies of different age and genesis for O-isotopes studies in co-operation with Prof. J. Ross Mackay, University of British Columbia.

[1] Mackay, J.R.: The Mackenzie Delta area, N.W.T.; Geogr. Br. Can., Dept. Mines, Tech. Surv., Mem. 8 (1963).

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

[3] Mackay, J.R.: The origin of massive icy beds in permafrost, western Arctic Coast, Canada; Can. J. Earth Sci., vol. 8, pp. 397-422 (1971).

[4] Rampton, V.N., and Mackay, J.R.: Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island, and nearby areas, District of Mackenzie; Geol. Surv. Can., Paper 71-21 (1971).

[5] Fyles, J.G.: Mackenzie Delta and Arctic coastal plain; in Report of Activities, Part A, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 34-35 (1967).

[6] Hughes, O.L.: Surficial geology of northern Yukon Territory and northwestern District of Mackenzie, N.W.T.; Geol. Surv. Can., Paper 69-36 (in press).

[7] Mackay, J.R.: Glacier ice-thrust features of the Yukon coast; Can. Dept. Mines Tech. Surv., Geogr. Br., Bull. 13, pp. 5-21 (1959).

[8] Bouchard, M.: Surficial deposits, Herschel Island, Yukon Territory; in Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A., p. 168 (1971).

92. QUATERNARY GEOLOGY, DAWSON CREEK, BRITISH COLUMBIA (93 P)

Project 690049

T.H.F. Reimchen and N.W. Rutter

Most of the 1971 field season was spent in mapping Cenozoic deposits and landforms of the Dawson Creek (93 P) map-sheet. A preliminary evaluation of the data collected during this and previous seasons, suggests that the western part of the area was covered by three advances of the Cordilleran ice sheet and the eastern part by one and possibly two advances of the Laurentide ice sheet.

The included time-distance diagram (Fig. 1) summarizes the senior author's present views on the stratigraphy of this area.

The lowermost deposits, quartzite gravels, occupy plateaus west of Fellers Heights between the 2,500-foot and the 3,000-foot contours. These gravels, consisting predominantly of buff to brown rounded quartzite cobbles contain vertically oriented cobbles and fossil ice wedges, covered by horizontal bedded gravels, suggesting partial formation in a periglacial climate. A horse molar resembling ?*Pliohippus* sp. suggests a late Tertiary age for the lower part of this unit.

An old Cordilleran till, stratigraphically above the quartzite gravels, lies above the 3,000-foot contour north and east of Mt. Puggins in the central part of the area. In the mountainous regions to the west striations above 5,000 feet as well as erratics as high as 8,250 feet are possibly connected with this same glaciation. This old till is weathered to a variable depth of 10 to 14 feet. The weathered till is composed mainly of quartzites, conglomerates and sandstones; the unweathered till contains about 10 per cent limestone pebbles. Eastward, toward the nose of the plateaus, the till is absent but weathered erratics of both Cordilleran and Laurentide provenance are present.

Phase I lacustrine deposits are thought to have formed when Laurentide ice blocked the northeasterly drainage of the area. Drift and outwash resulting from Cordilleran and Laurentide ice advances interfinger with the lacustrine material. Gravels of Cordilleran origin, from which a partial molar of *Mamuthus* sp. (3 ridge plates in 50 mm) was recovered, overlies Laurentide outwash indicating at least partial drainage of the proglacial lake prior to deposition of the upper part of phase I lacustrine deposits. An *Equus* sp. molar was found in upper phase I lacustrine deposits.

Major advances of Laurentide and Cordilleran ice ended phase I lacustrine deposition. A zone of mixed Cordilleran and Laurentide till suggest at least a 15-mile overlap of areas covered by mountain and continental ice. Drumlins built by the Cordilleran advance truncate drumlins of Laurentide ice origin in the southwest part of the area indicating that the maximum mountain ice advance postdates that of continental ice in at least this one area. Outwash, from the Cordilleran ice, blocked northerly drainage of the Pine River north of Chetwynd and diverted flow into Murray River to the east.

Large proglacial lakes formed during final glacial recession. Beaches, wave-cut niches and wave-washed surfaces record shorelines at about 2,750, 2,420, 2,370, 2,330, 2,260, 2,180 and 2,150 feet. Silt mounds in this

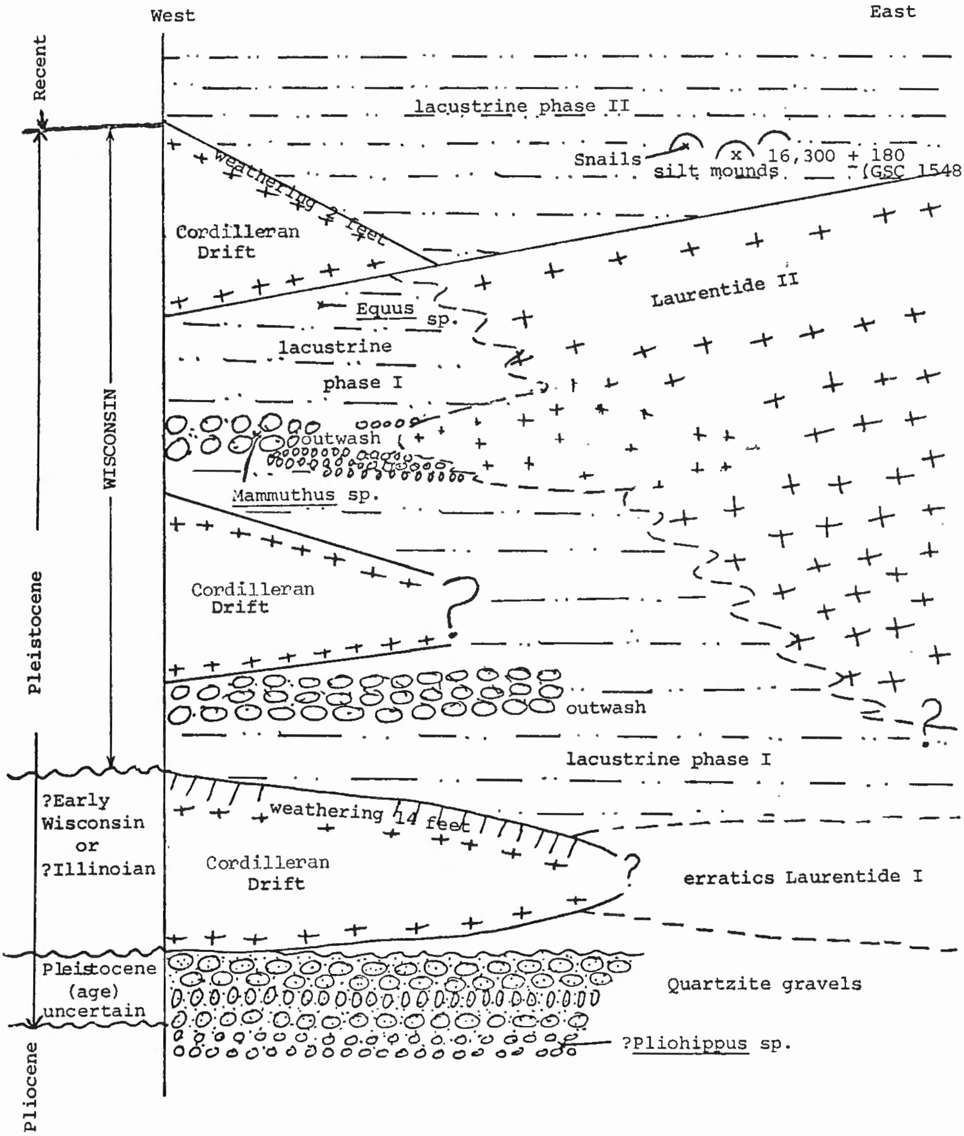


Figure 1. Schematic time-distance diagram of the stratigraphy of the Dawson Creek area.

lacustrine basin may have been formed by deposition in and around ice blocks. A radiocarbon age of 16,300 yrs. B.P. (GSC 1548) was obtained for snails collected from the centre of a silt mound which lay below the ±2,260-foot shoreline.

Artifacts have been recovered from scattered postglacial aeolian deposits in the area.

93. SURFICIAL GEOLOGY AND LAND CLASSIFICATION MACKENZIE VALLEY TRANSPORTATION CORRIDOR (85 E, 95 A, B (SOUTH HALF), H, J)

Project 710047

N. W. Rutter and Gretchen V. Minning

Quaternary deposits and geomorphology were mapped at a scale of 1/125,000 for map-sheets 85 E, 95 A, H, J and the southern half of 95 B. The selection of map-units and geological data was determined partly by what would be most beneficial to those engaged in pipeline construction and associated activity. Other aspects of the environment were investigated by personnel of co-operating agencies. These consisted of soils, vegetation and land parameters within surficial geological units, studied by L. M. Lavkulich and others, University of British Columbia; forest cover-landform relationships by C. Crampton, Department of the Environment; and seismic studies and resistivity for detecting the presence of permafrost and ground ice, by J. Hunter and J. E. Wyder, Geological Survey of Canada. Results of these investigations will be incorporated into a final environmental report.

The area mapped includes parts of the eastern portion of the Mackenzie Mountains, Great Slave Plain and Alberta Plateau. The Plain, interrupted by several uplands or plateaus and portions of the Mackenzie and Liard Rivers covers most of the area investigated.

Preliminary airphoto interpretation was completed prior to the field season. During the three month field season, the interpretation was checked and geological data gathered by numerous helicopter and boat traverses.

Continental till is the dominant surficial deposit. It is characterized by a silty matrix and from 1 per cent to 20 per cent pebble-sized or larger material. The till consists of landforms varying from drumlins to ground moraine and is from 1 foot to over 50 feet thick. Beach gravels, lacustrine silts and clays, and deltaic sands and gravels, are widespread in the Fort Simpson (95 H) and Mills Lake (85 E) map-areas. Stratified deposits are only common in the valleys of the Mackenzie Mountains.

Evidence is present for two advances of Continental ice, the latest of which covered the entire area mapped. Striations, flutings and drumlins indicate that the latest ice flowed generally to the southwest. Near the Mackenzie Mountain Front some movement indicators suggest flow toward the west and others, flow toward the northwest. Erratics are found up to at least 5,100 feet in the Mackenzie Mountains indicating ice flow across mountains.

During deglaciation, several recessional moraines were constructed in the mountains and plains. Glacial Lake McConnell formed, depositing extensive silts and clays and constructing a prominent beach at about 850 feet and others at lower elevations. When glacial Lake McConnell drained to the north, many of the lake deposits were eroded.

Deposits and features which should be considered as potential construction and engineering hazards are: slumps and flows in bedrock shale, discontinuous area with permafrost within 12 inches of the surface even in the southernmost areas, thick lacustrine silts and clays; silty, clayey till and widespread lacustrine deposits with segregated ice masses; and flowage of slope mantling surficial deposits.

94. GEOLOGICAL STRUCTURE OF THE MACKENZIE CANYON AREA OF THE BEAUFORT SEA

Project 700092

J.M. Shearer

Seismic reflection work during the summers of 1970 and 1971 in the Mackenzie Bay area of the western Canadian Arctic have enabled the origin and structure of the Mackenzie Canyon to be worked out.

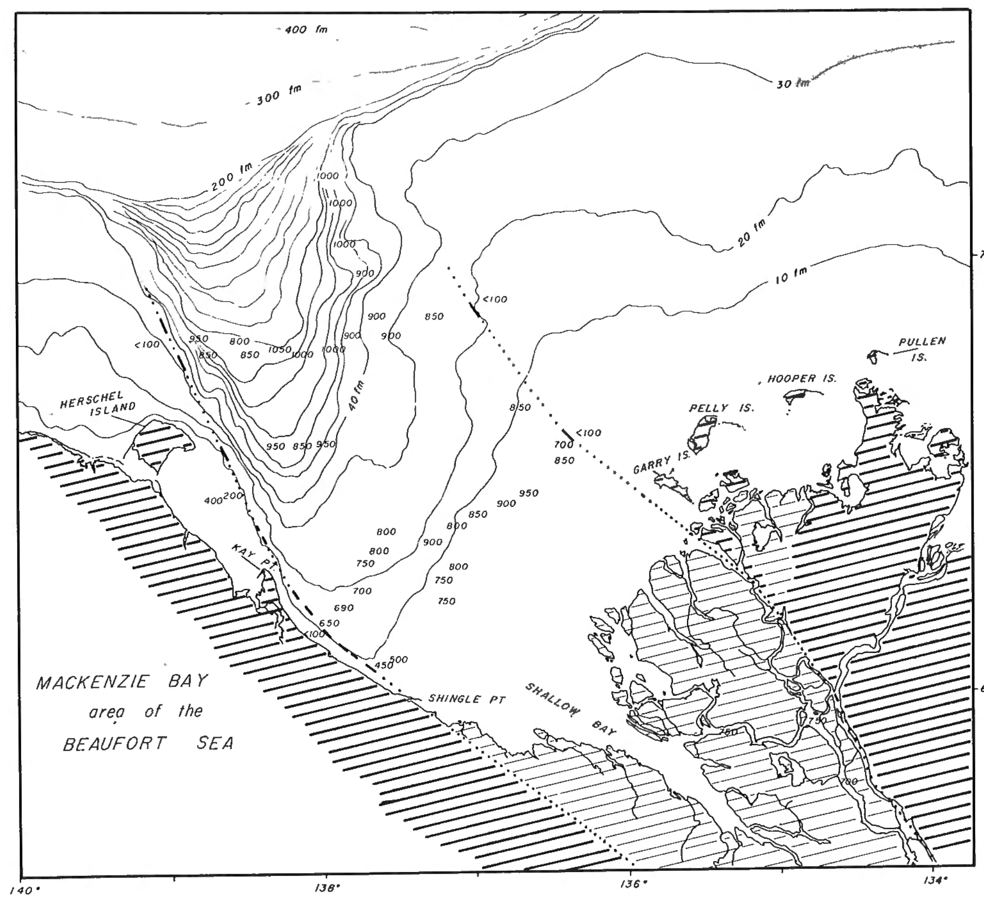


Figure 1. Offshore bathymetric contours demonstrate extent and magnitude of the Mackenzie Canyon. Solid black lines and dots are the known and assumed edges respectively of the buried ice scour channel. Small figures are depths to base of scour channel and those outside of the channel represent thickness of sediment deposited in post scour times. Light hachured lines delineate distribution of modern Mackenzie Delta sedimentation; dark hachure, areas of older Quaternary sediment.

Previous work[1] on the west side of the study area demonstrated a break in the lateral continuity of the sedimentary section, which has been interpreted as the west bank of a buried ice scour channel or canyon. Further work this past summer (1971) confirmed the existence of a buried canyon wall on the east side of Mackenzie Bay (see Fig. 1). The scour channel consists mainly of a fill of well bedded-outwash deltaic deposits overlying a seismically heterogeneous and irregular-shaped basal till-like unit. In many areas, the bottom of this scour canyon is masked by a number of distinct overlapping till-like units. The age of these units is not known but the observed stratigraphy can be adequately explained by the irregular advance and retreat of one ice tongue during classical Wisconsin. The ice probably followed a pre-Wisconsin fluvial valley, incorporating the existing fluvial deposits into the till-like units. Where possible, depths to the base of this scour channel were measured and plotted (Fig. 1). The bottom of the channel is apparently quite flat, with a gentle slope seaward, presumably intersecting the continental slope at a depth where the ice tongue began to float (1,000 - 1,200 ft below datum). This box-like glacial trough has been filled with sediment preferentially on its eastern side.

This ice tongue was thought to have receded south of the area shown in Figure 1 between 14,000 and 16,000 years B.P. when sea level was 200 to 300 feet lower[1]. At this time sediments, supplied by glacial meltwater was deposited in the channel. Pilot of Arctic Canada reports dominantly easterly flowing currents at present and Coriolis' force would also favour easterly deflection of north moving water. Hence, there was a preferential build-up of sediment on the eastern side of the channel. As much of the volume of sediment filling the scour channel was deposited in early postglacial times, the basic morphology of the Mackenzie Canyon is presumed to have developed at this time, and hence to have little expression at depths less than 200 to 300 feet.

As sea level rose, a blanket (maximum thickness 200 ft) of recent silts and clays was deposited on the original outwash deposit and older terrain, with greater deposition occurring on the east side of the channel (see Fig. 1). This has apparently modified the original Mackenzie Canyon by shoaling the original lip of the canyon by an amount equal to the thickness of recent sediment in that area (100 ft).

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

[2]Hughes, O.L.: Surficial Geology, northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 69-36 (in press).

95. QUATERNARY GEOLOGY INVENTORY, SOUTHERN LABRADOR (PARTS OF 13 E, 23 H)

Project 690043

R. D. Thomas and R. J. Fulton

Reconnaissance mapping of the surficial deposits in the area of Churchill Falls power project, including NW 1/4 13 E, and the NW, NE and SE quarters of 23 H was completed. This was the final field phase of the project which was initiated primarily to provide the Newfoundland Department of Mines, Agriculture and Resources with basic Quaternary geology information required for a forest land capability study of southern Labrador.

The general mapping procedure and the legend used were those developed by Fulton and Hodgson in earlier phases of this project. The power project development has provided good access to much of this area so that ground observations were made along roads and in various pits and trenches. The surficial geology map has been plotted on uncontrolled mosaics at a scale of 1:50,000 which will be placed on file.

The area may be divided into three major northwest-southeast-trending physiographic regions. The northernmost region is comprised of rock-cored drumlins with large eskers in shallow valleys. The central region is characterized by rock thinly veneered by till and contains interspersed till plains and scattered drumlins. The southern region consists of low drumlins separated by large swamps and scattered eskers. Minor moraines and meltwater channels occur throughout the area.

The common till in the area is very sandy and ranges from massive with no apparent structure, through massive with some segregations of sorted sand, to poorly sorted and stratified sand containing patches of massive till. Towards the west and northwest, where the material was derived from the Labrador Trough, the till appears to contain a significantly higher content of silt, shows little structure and has a distinctive red colour.

The general direction of ice movement, as determined from the orientation of drumlins, crag-and-tails, roches moutonnées, striations and boulder, cobble and pebble counts, was towards the east in the northern part of the area, swinging towards the southeast farther south. Michikamau Lake basin appears to have influenced the direction of ice flow at least during deglaciation as flow direction indicators tend to converge on the lake basin.

Data was collected concerning the transport of material in eskers. At each location 50 cobbles, 100 pebbles (1.0-2.5 cm) and a sand sample were collected. The cobbles and pebbles have already been identified, counted and the results plotted. A good correlation is found between the underlying bedrock and the material found downstream in the esker. In general, cobbles were found to be a more sensitive indicator of bedrock change than pebbles. In some cases, however, where the bedrock was very friable, a change was only noted in the pebble content.

QUATERNARY GEOLOGY: TRACING MINERAL DEPOSITS

96. DRIFT PROSPECTING IN THE KAMINAK LAKE AREA, DISTRICT OF KEEWATIN

Project 700014

W.W. Shilts

Over 1,500 samples of glacial sediments were collected in reconnaissance grids located near Carr, Kaminak, Southern and Townsend Lakes. Most of the samples were till or modified till collected from pits dug in frost boils.

Three physically and chemically distinct materials can be present in any frost boil in the study region:

1. Cobbles and humic debris: occur around the perimeters of frost boils. This material is easy to avoid and was not sampled.

2. Compact sandy diamicton: essentially till or marine sediment that has had clay and silt removed by surface runoff after extrusion at the surface during the active phase of frost boil formation. It is low in clay content compared to its parent sediment. Samples of parent sediment have trace-element concentrations up to 10 times those of modified material from the same frost boil (in material finer than 230 mesh (63μ)).

3. Parent material: till, silty marine sediment, or colluvial deposits. The parent material of frost boils has high silt-clay content with resulting high degree of plasticity when saturated. High plasticity of sediment in the active zone is thought to be required to form most frost boils in this area. Sulphide minerals have been found in parent material only in the few samples collected below the permafrost table.

An effort was made to sample only parent material, but at many sites frost boils have stabilized so that only sandy, hard diamicton could be found. Thus, in any of the grids sampled, trace-element concentration determined on the <230- mesh fraction of any sample may represent either parent material, of which till, marine silty clay, and colluvium are the most common members, or it may represent sandy, compact, modified parent sediment one of at least four different possible origins. Sand-size heavy minerals will be analyzed for all samples. It is expected that use of the coarse-grained fraction will avoid the problem of the influence of varying clay content on apparent cation concentration – a factor that has previously hindered interpretations of anomalies in this region[1].

Figures 1-4 are hand-contoured representations of copper and zinc concentrations for four 1971 grids. Most of the samples are assumed to be till or modified till. Concentrations of Cu and Zn were obtained in a field laboratory by colorimetric methods after controlled hot HCℓ leach of material finer than 230 mesh. The contrast between anomalous and background values is thought to be higher than the expected variation due to modification of parent material.

Although concentrations of Cu and Zn may appear to be low in areas defined as anomalous on Figures 1-4, they are generally 4 to 10 times values

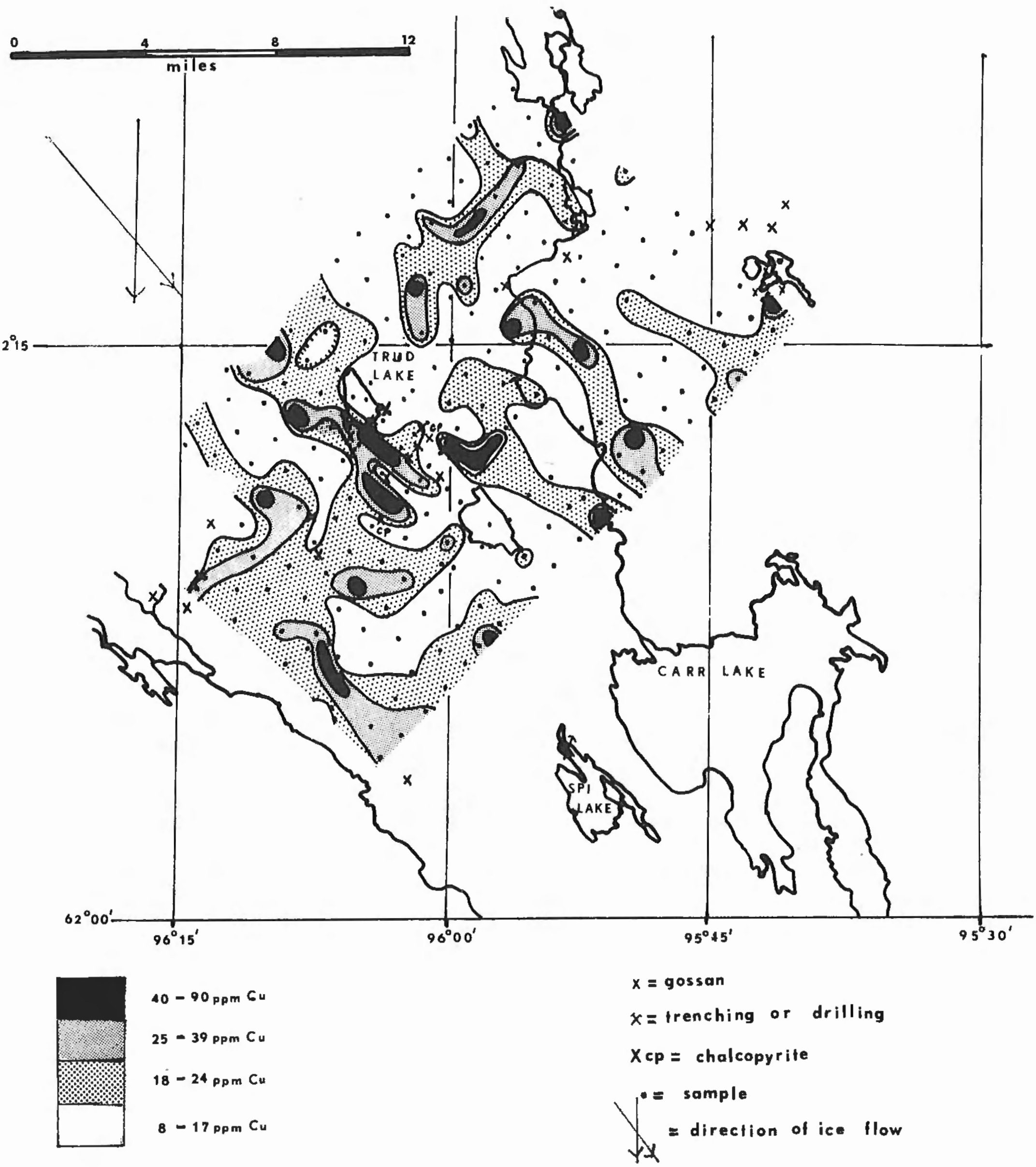


Figure 1: Grid CL-1; dispersal of Cu in till; concentrations determined in field colorimetrically after hot leach in HCℓ; compare with maps (2) (4) ; note correspondence of anomalies to known mineralization.

taken as background. Relatively low Cu and Zn values seem to be typical in dispersal fans in till from this region. Till samples collected within a 500 metre radius of the well-known Cu-Zn-Pb showing at Spi Lake consistently produce values of 48-55 ppm Cu and 95-120 ppm Zn. Although significantly above background (8-15 ppm Cu, 15-35 ppm Zn), these values are not as high as some of the anomalies depicted on the dispersal maps presented here.

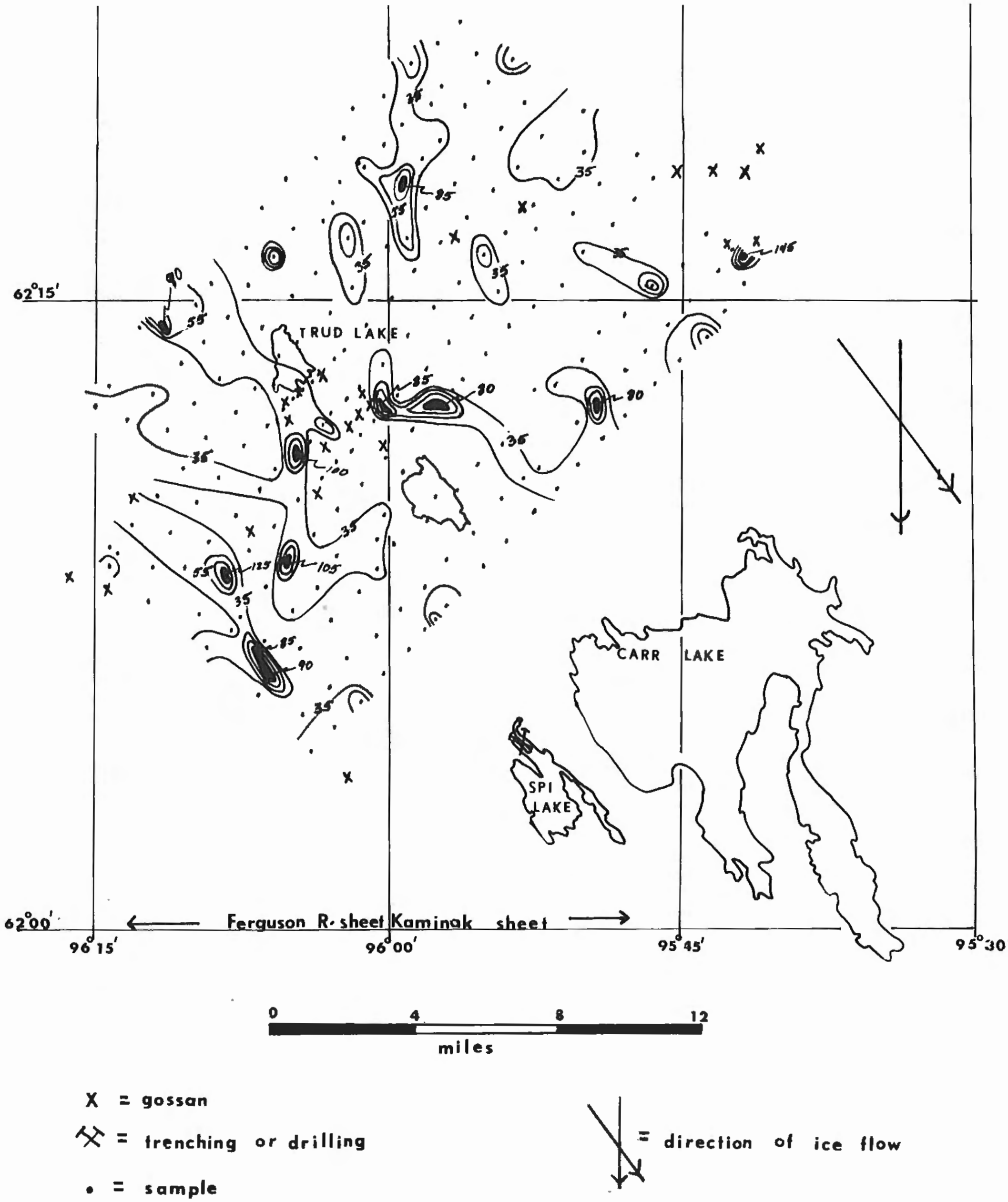


Figure 1a: Grid CL-2, dispersal of Zu in till; concentrations determined in field colorimetrically after hot HCℓ leach; compare with maps (2) (4); note correspondence of anomalies to known mineralization.

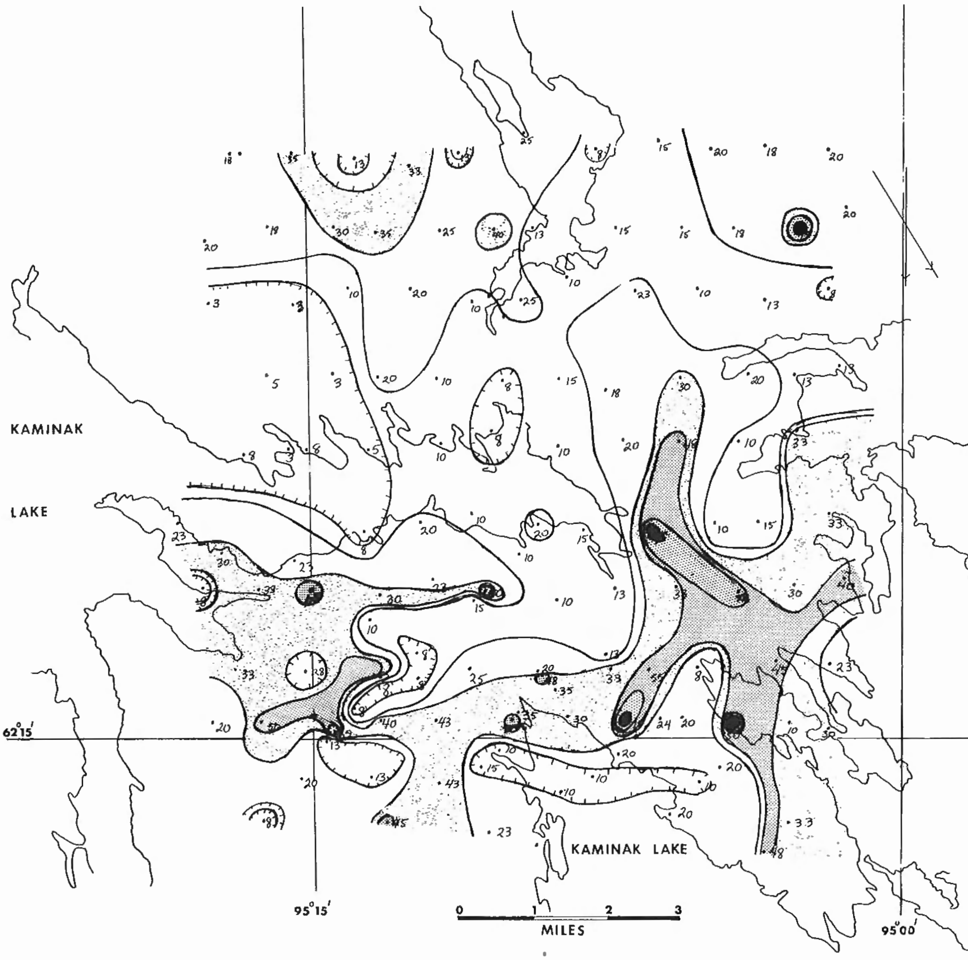


Figure 2: Grid NK-1; dispersal of Cu in till; concentrations determined colorimetrically in field after hot HCℓ leach; very low values on west side correspond to samples of marine silty-clay; shaded areas on south closely approximate outcrops of felsic volcanic rocks.

The trace-element concentration maps reflect three basic trends:

1. East and northeast strike of bedrock units: higher copper and zinc values generally correspond to areas underlain by felsic and mafic Archean volcanics or "iron formation" as shown on the bedrock maps [2, 3, 4]. High copper values but low zinc values are found in some groups of samples on gabbro or diorite.
2. Earlier, southward glacial movement first described by Lee[5]: zinc patterns in the "CL" grid particularly reflect this trend (Fig. 1a).
3. Latest, southeast glacial movement: strongly indicated independently by striations and drumlin orientations.

Drawn from data obtained in the field, the maps are useful in delineating areas where more detailed sampling may produce targets for drilling.

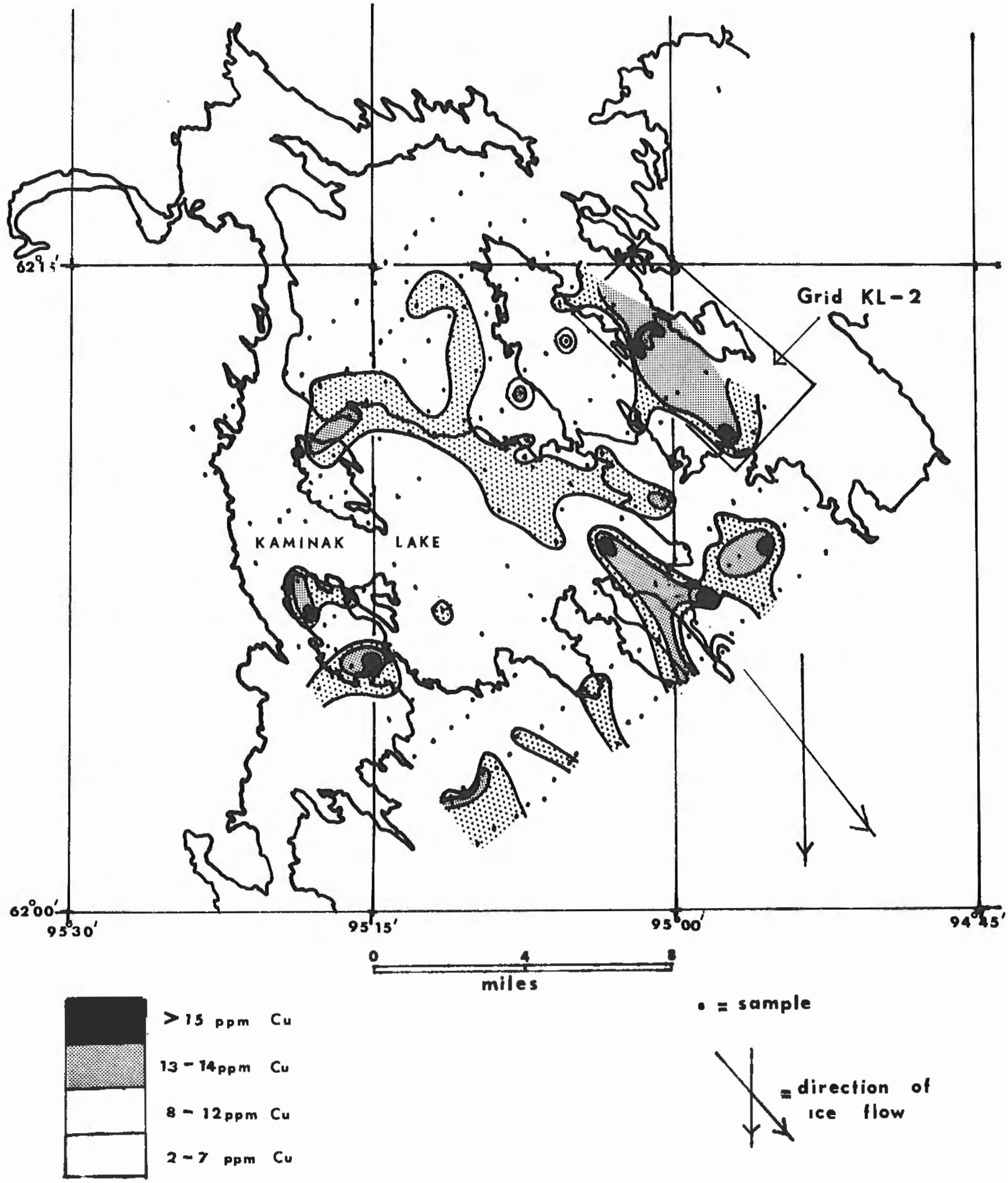


Figure 3: Grid KL-1; dispersal of Cu in till; concentrations determined colorimetrically in field after cold HCℓ leach; area of rectangle on northeast side selected for closely spaced sampling (Fig. 4).

They also indicate large areas where the chances of finding mineralized zones are small. The maps have reflected anomalies near most zones of mineralization shown on Bell's and Davidson's maps and have added several new

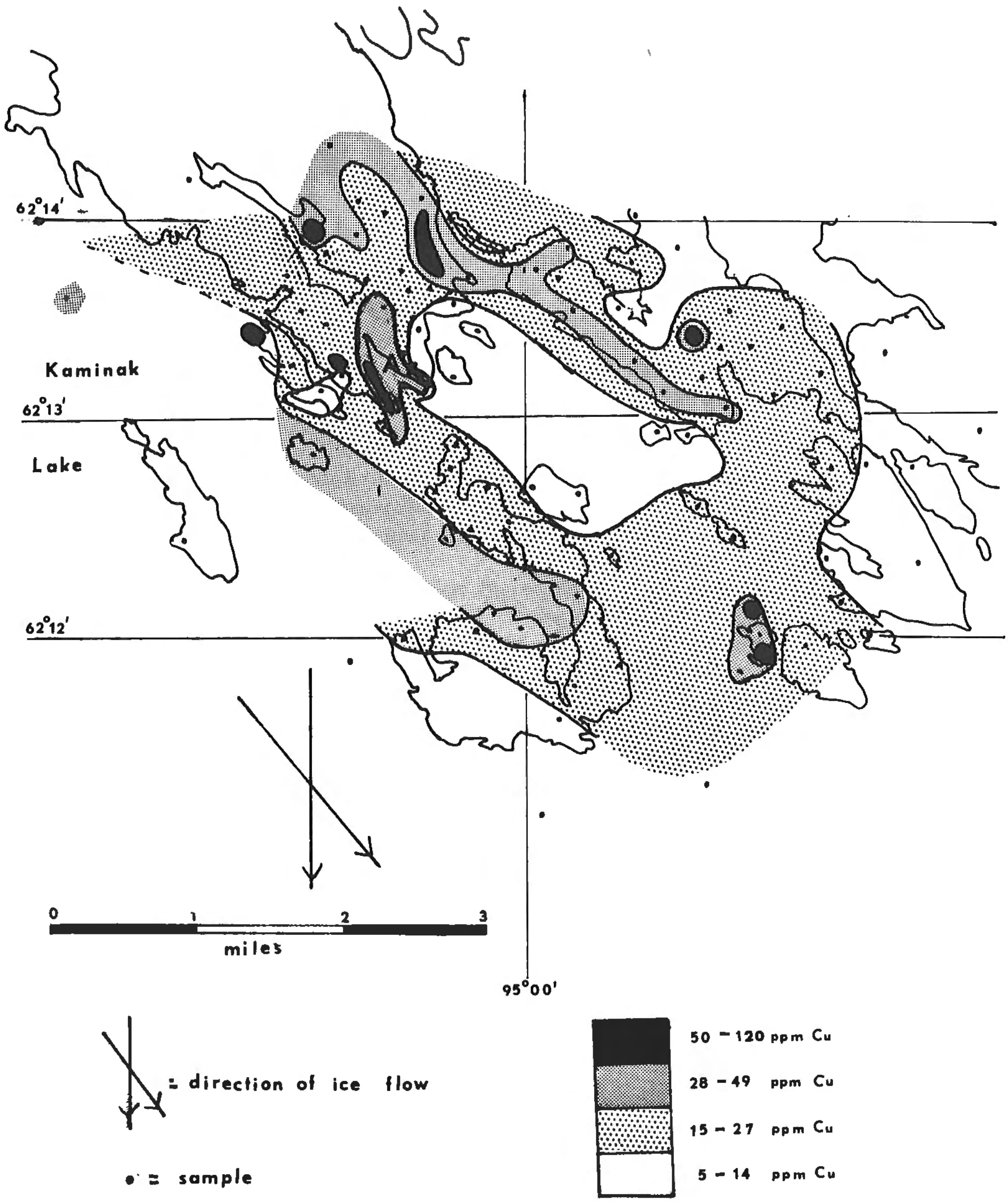


Figure 4: Grid KL-2; dispersal of Cu in till; concentrations determined colorimetrically in field; many small copper-rich gossans discovered on gabbro near anomaly at A.

areas of potential interest. It is hoped that analyses to be performed over the winter on these and other samples from this region will confirm the anomalies apparent from field data and allow other anomalous areas to be identified.

Appendix

In addition to the systematic sampling program described above, various samples collected from gossans, eskers and frost-boil inclusions have yielded base-metal values that may be related to economically significant deposits. The localities are described briefly below.

1. Esker and till samples. Anomalously high Cu (50-350 ppm; background ~ 10 ppm), Co (40-98 ppm; background ~ 10-20 ppm, high values in esker only), Zn moderately high, Ni moderately high in esker (55-78 ppm), Pb, Mo, Ag low. Analyses on -230 mesh samples; hot HCℓ - HNO_3 leach and Atomic Absorption. (UTM coordinates, 15432200 6894900).

2. Greenish yellow, 5 cm x 5 cm inclusion in frost-boil; may be decomposed pebble. Very high Mo (57 ppm, background 1 ppm), high Pb (170 ppm, background ~ 10 ppm), high Ag (3.7 ppm; background ~ 0.3 ppm), high Zn (170 ppm, background ~ 15-20 ppm), moderate Cu (55 ppm), low Ni, Co. Analyses on -230 mesh. (UTM coordinates, 15432600 6895400).

3. Granite or granodiorite pebble with 1 cm x 1 cm inclusions of molybdenite; found on esker surface. High Cu (150-360 ppm; background 20-50 ppm), moderate Zn (80-120 ppm), moderate Co (25-55 ppm), moderate Ni (40-75 ppm), low Pb, Mo, Ag for nearby samples. Analyses on -230 mesh. (UTM coordinates, 15434400 6892550).

4. Esker samples across inferred volcanic - granite contact. High Cu (70-130 ppm; background 8-20 ppm), high Pb (30-65 ppm; background 8-15 ppm), moderate to low Zn, Ag, Co, Ni. Analyses on -230 mesh. (UTM coordinates, 15374700 6910500).

5. Till sample 1.5 miles southeast of Spi Lake showing; high Pb (100 ppm; local background ~ 8-10 ppm). Moderate to low Cu, Zn, Ag, Co. Could be derived from Spi Lake showing (?) analyses on -230 mesh. (UTM coordinates, 15351000 6883700).

6. Townsend Lake Gossan; very high Pb (500-3800 ppm); very high Ag (18-30 ppm); very low Cu (8-16 ppm), Zn (16-35 ppm), Ni (8-11 ppm), Co 13-16 ppm. Gossan largest in region — covers several acres. Analyses on -230 mesh. For comparison, gossan on showing at Spi Lake has Cu (1300-1500 ppm), Pb (175-3800 ppm), Zn (210-2200 ppm), Ni (8-9 ppm), Co (20 ppm), Ag (10-30 ppm). (UTM coordinates, 15386900 6948500).

7. Gossan on Gabbro (field colorimetric analysis for Cu, Zn after hot HCℓ leach); high Cu (400 ppm) low Zn (< 20 ppm). Several small gossans within radius of 1-2 miles of site were not sampled. Local till characterized by high Cu, low Zn. Analyses on -230 mesh. (UTM coordinates, 15394400 6899800).

[1] Shilts, W. W.: Till studies and their application to regional drift prospecting; Can. Mining J., April, 1971, pp. 7-12 (1971).

[2] Davidson, A: Kaminak Lake map-area, District of Keewatin; Geol. Surv. Can., Paper 69-51 (1970).

[3] Davidson, A.: Eskimo Point (north half) and Dawson Inlet (north half) map-areas, District of Keewatin; Geol. Surv. Can., Paper 70-27 (1970).

[4] Bell, R. T.: Geology of Henik Lakes (east half) and Ferguson Lake (east half) map-areas, District of Keewatin; Geol. Surv. Can., Paper 70-61 (1971).

[5]Lee, H.A.: Surficial geology of southern District of Keewatin and the Keewatin ice divide, Northwest Territories; Geol. Surv. Can., Bull. 51 (1959).

---

97. APPLICATION OF QUATERNARY GEOLOGY TO MINERAL EXPLORATION TIMMINS-VAL D'OR MINING DISTRICT (Parts of 31 M, N; 32 C, D; 41 O, P; 42 A, B, G, H)

Project 710080

R. G. Skinner

A feasibility study was carried out in the Timmins-Val d'Or mining region to assess the type of Quaternary geology studies needed to aid mineral exploration. Field work consisted of sampling soils and sediments, and examining road-cuts to gain some appreciation of the stratigraphy. About 125 samples of Cochrane till from between Fraserdale and Cochrane will be analyzed for base metals to determine the usefulness of Cochrane till as a sampling medium for drift prospecting. Some 250 samples from the Rouyn-Noranda area, including till, reworked till, and glaciolacustrine and esker sediments will be analyzed for their base metal content. Vertical profiles from the B-horizon down through glaciolacustrine and glaciofluvial facies, loose, ablation(?) till, and compact, lodgement(?) till, overlying bedrock, were sampled at close intervals to determine variation in base metal content within and between different sediments.

Quaternary deposit stratigraphy is neither simple nor consistent throughout the area, and any drilling program aimed at sampling 'basal till' should be predicated on an awareness of the possible stratigraphic complexities. Study of several sections indicates that true lodgement till or so-called 'basal till' rarely immediately underlies lake sediments; commonly, a layer of loose ablation till or coarse glaciolacustrine sediment separates compact till and lake clay. At some sections, clayey varves 1 or 2 cm thick rest directly on striated and polished bedrock. Analyses planned for the various sediment types will help determine the quality of each as a sampling medium.

A massive sulphide boulder (mainly pyrite, minor sphalerite, trace of chalcopyrite) approximately 40 cm in diameter was discovered in a new road-cut along Highway 101 in Keefer Township (48°17'48"N; 81°46'33"W). The gossan-covered boulder was found in colluvium, perhaps reworked till, about 1.0 m below the surface, 0.75 m above bedrock (altered greenstone).

Table I:

Changes in thickness of active layer

Dates of observations:		30 May 8 June 69	16-17 Sept. 69	4-5 July 70	26-31 Aug. 70	30 June 2 July 71	17-18 Sept. 71
Terrain Type		Thickness of active layer (cm)					
Unburned	Minimum	0	0	6	9	0	21
	Median	10	43	28	41	36	42
	Maximum	23	75	64	75	73	77
Burned	Minimum	0	18	10	21	16	25
	Median	7	42	38	50	69	55
	Maximum	20	75	75	75	84	100
Scarified (Firebreak)	Minimum	0	38	30	72	36	38
	Median	10	65	60	75	75	100
	Maximum	22	75	75	75	100	138

No. 98 Heginbottom

QUATERNARY SEDIMENTOLOGY AND GEOMORPHOLOGY

98. EROSION IN A PERMAFROST ENVIRONMENT, INUVIK AREA, DISTRICT OF MACKENZIE (107 B)

Project 690054

J.A. Heginbottom

This project was initiated in 1969, following the forest fire at Inuvik, N.W.T., in August 1968. This year three visits were paid to the field area. A short visit was made in March to carry out the planned disturbance of the "terrain manipulation plots" installed in 1970[1]. A visit in July and August permitted inspection of the experiments begun in 1969 in the burned area[2]. Other work included detailed surveying of the disturbed plots and the installation of twelve 2-metre ground temperature cables. Eight of these are to investigate ground temperature gradients across the boundary of a disturbed area, while the other four are to record the penetration of the fall cold wave into the ground. The readings from two of these cables are being recorded continuously. The third visit to the field area, made in September, was for a resurvey of the ground height and active layer thickness at the sites reported on previously[1, 2] (Table I).

[1] Heginbottom, J.A.: Erosion in a permafrost environment, District of Mackenzie; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 196-197 (1970).

[2] Heginbottom, J.A.: Erosion in a permafrost environment, District of Mackenzie; in Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 185-186 (1971).

---

99. ETUDE SUR LE RAVINEMENT DANS LES COLLINES SWAN

Projet 700035

Jean Lengellé

L'été 1971 a permis la continuation du projet commencé en 1970[1], en particulier en testant la carte géotechnique dressée à partir des données morphologiques et géologiques.

Les parcelles d'érosion mises en place ont suffisamment résisté pour donner des résultats encourageants quant aux méthodes curatives à utiliser, malgré des précipitations intenses (34.3 cm en 3 semaines).

De ce fait, une expérience à plus grande échelle est en cours sur la nouvelle route de Swan Hills à Kinuso, de façon à envisager des mesures préventives à grande échelle par réutilisation du sol superficiel et du till.

Deux éléments nouveaux de l'histoire géologique ont été mis en évidence dans les graviers oligocènes et demandent confirmation par des analyses précises: d'une part des cailloux redressée (cryoturbation?) d'autre part la présence d'argile rouge (paléosol?).

Deux(?) couches superposées de cendres volcaniques identifiées en LSD 14, sec. 21, tp. 67, rge. 10, W 5th. et non encore décrites ont été analysées par M. J.A. Westgate (University of Alberta):

	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO
Couche supérieure	77.35	0.01	12.78	1.21	0.06	0.72
Couche inférieure	75.23	0.12	13.84	2.01	0.12	0.78

	Na_2O	K_2O	Cl
Couche supérieure	3.01	4.75	0.10
Couche inférieure	3.05	4.79	0.06

La source de ces cendres est inconnue.

[1] Lengellé, J.G.: Etude sur le ravinement dans les Collines Swan; dans Report of Activities, Part A: April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 186-188 (1970).

---

100. GEOMORPHIC PROCESSES, MACKENZIE VALLEY, ARCTIC COAST, DISTRICT OF MACKENZIE (107 B, C, D)

Project 680047

J. Ross Mackay

Permafrost (N.T.S. 107C, 107D)

Resistivity and seismic studies were carried out in an attempt to map the thickness of permafrost and also to detect areas with massive ice. Near Point Atkinson, resistivity surveys appeared successful in detecting the bottom of permafrost where the depth, from other data, had been estimated at nearly 1,500 feet. Resistivity sounding and profiling, across areas with known bodies of massive ice[1,2], gave good indications of its presence, but much less information on its depth and thickness.

Pingos (N.T.S. 107C, 107D)

Five growing pingos are under observation. Precise levelling over a two-year-period suggests that: the tops of the pingos are growing at a faster rate than the sides; the growth rates are irregular; and that faulting may cause the irregularities observed in the growth rates. As a rough estimate, probably one per cent or more of the pingos in the Mackenzie Delta area are now growing, and probably one or more pingos have commenced growing each decade for the past 100 years. Studies show that if the unfrozen ground beneath aggrading permafrost in a drained lake basin is in a closed system, or if it is effectively "closed" because of the impermeability of the sediments at depth, high pore water pressures may build up beneath the aggrading permafrost. Tension cracks, hundreds of yards in length may result from permafrost aggradation. Bench marks have been installed in four recently drained lakes in order to study the effects of permafrost aggradation because, if a closed system does exist beneath the lakes, some lake bottom heave would be expected.

Garry Island, N.W.T. (N.T.S. 107C)

Year round measurements at a depth of 3 feet, for 10 sites with different winter snow covers and exposures, show a mean annual ground temperature range of about 1.0°C. Six thermotubes (one-way heat pumps) have been installed in order to determine what effect, if any, they may have in cooling the top of permafrost. Nine "permanent" frost meters, measuring summer thaw depths, were placed to provide a record of yearly changes in thaw depth.

Observations (summer and winter, 1968 to 1971) have been carried out across 100 ice-wedge sections to determine the time of cracking; frequency of cracking; crack position; width and depth of cracking. About 60 per cent of the ice-wedges cracked between 1968 and 1971, and among those which did crack, there was a strong tendency for yearly cracking to take place. The smaller fissures cracked more frequently than the larger fissures. The cracks tended to be near the middle of the fissures and often penetrated down to depths exceeding 10 feet. Most cracks opened up in late January, February, and early March. The width of the cracks was usually greater than the horizontal displacement of steel tubes, used as reference markers, on the raised rims of the polygons. The summer-winter horizontal displacements of the reference markers across ice-wedges may exceed a quarter of an inch, but are typically a tenth to a twentieth of an inch.

The mean annual rate (1965-1971) of downslope movement of several earth hummocks, on a moderate hill slope, ranged from 0.1 to 0.4 inch. The downslope rate of movement is believed to reflect, to a large degree, the downslope component of the ice veins which grow in the active layer in winter. As some of the ice veins are more than a tenth of an inch in thickness, the cumulative downslope component of a number of veins may be quite large.

Lake Temperatures (N.T.S. 107C)

Six thermographs have been installed in lakes in the Tuktoyaktuk area to obtain temperatures in lakes of different sizes, shapes, and depths.

Results of the fire, Inuvik, August, 1968 (N.T.S. 107B)

To record the changes in depths of thaw resulting from the 1968 forest fire, three burnt and unburnt sites, near Inuvik, were staked at the time of the fire using a total of 58 wooden dowels driven down to the frost table. Since 1968, there has been little change in the summer thaw depth at the unburnt sites, but a marked increase has occurred at all burnt sites. In the burnt over areas, the increased depth of thaw is well correlated with the vegetation cover and the ground ice content at the top of permafrost. In areas with bare mud (mud hummocks), increased thaw has occurred primarily in the interhummock depressions where it has averaged 10 to 15 per cent. At sites which formerly had a continuous vegetation cover, the increased depth of thaw has averaged 60 to 100 per cent. Although the increase in thaw depth from 1970 to 1971 was generally less than in previous years, there was sufficient change to suggest that there will be a further increase for the summer of 1972.

Mackenzie River

Thirty temperature profiles were run between Fort Norman and Point Separation, N.W.T. The cross-profiles showed that mixing of the Mackenzie River, as a result of the entrance of cold Great Bear River water, was so gradual that the river was not isothermal 400 miles downstream (study initiated under the former Geographical Branch and continued partly with equipment purchased from a Water Resources Research Grant, Department of Energy, Mines and Resources).

[1] Mackay, J.R.: The origin of massive icy beds in permafrost, western Arctic Coast, Canada; Can. J. Earth Sci., vol. 8, No. 4, pp. 397-422 (1971).

[2] Rampton, V.N., and Mackay, J.R.: Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island, and nearby areas, District of Mackenzie; Geol. Surv. Can., Paper 71-21, 16 pp. (1971).

---

101. FACTORS AFFECTING THE DISTRIBUTION OF PERMAFROST, MACKENZIE DELTA, DISTRICT OF MACKENZIE (107 B, C)

Project 680047

Michael W. Smith

During 1971, field work was completed for a study of permafrost distribution over a small area in the eastern part of the Mackenzie Delta. A particular terrain complex is under study, comprising a laterally shifting major river channel which is eroding frozen sediments beneath a geomorphically mature surface along its cut bank, with consequent degradation of permafrost, and depositing new alluvium on slip-off slope, where permafrost is forming *ab initio*. This landform assemblage is common throughout the region.

The knowledge of permafrost distribution gained from ground temperature cables, which were installed over the previous two years' fieldwork, was confirmed and expanded this year using electrical resistivity surveying techniques. Bathymetric surveys of all water bodies in the area were also carried out. This will allow the delimitation of areas which probably remain unfrozen through the winter—as winter frost cannot penetrate sediments underlying the deeper water bodies. The probable distribution of frozen and unfrozen material must be known before calculations of local heat flow can be made.

Ground temperatures vary widely over small areas; permafrost thickness varies from about 65-70 metres beneath geomorphologically mature surfaces, to 1-2 metres or so on the most recently exposed slip-off slopes. The major pattern of variation is associated with the geomorphological sequence described above. Other patterns of variation, due to seasonal snow cover distribution and differences in vegetation types have been identified and studied.

STRATIGRAPHY AND PALEONTOLOGY

102. STRUCTURE AND STRATIGRAPHY, RINGNES ISLANDS AND NEARBY SMALLER ISLANDS, DISTRICT OF FRANKLIN (PARTS OF 59, 69, 79)

Project 710003

H.R. Balkwill

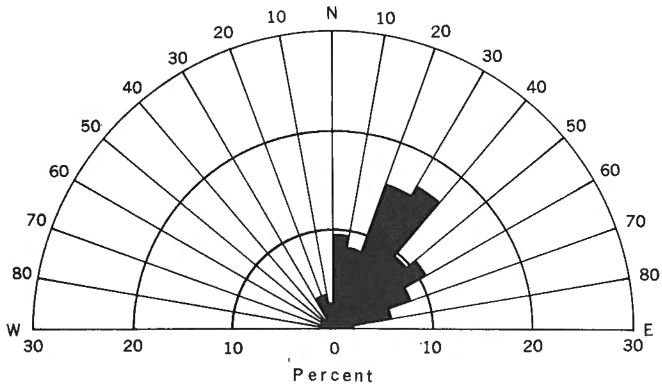
Stratigraphic sections of Cretaceous and Tertiary rocks were examined and fossils collected on Amund Ringnes Island (Stratigrapher River and Structural River) and Ellef Ringnes Island (Hoodoo Dome and Helicopter Bay), preparatory to detailed structural and stratigraphic studies in the central part of the Sverdrup Basin.

The exposed stratigraphic column is dominated by a conformable alternating sequence of alluvial plain, intertidal, and shallow marine, sparsely macrofossiliferous, very poorly indurated, mature quartz sandstones, and dark grey shales and mudstones, comprising the Deer Bay, Isachsen, Christopher, Hassel, Kanguk, and Eureka Sound Formations[1,2,3]. Older Mesozoic rocks occur in structural culminations along Cornwall Anticline on Amund Ringnes Island. Paleozoic anhydrite, gypsum, and limestone, in the exposed cores of elongate, northwest-trending diapirs, along with diabase sills and dykes that intrude Lower Cretaceous and older rocks, form topographic prominences in otherwise gently rolling terrain; sills are especially prevalent in the upper part of the Deer Bay Formation and lower part of the Isachsen Formation. Tertiary/Quaternary sands and gravels (Beaufort Formation) blanket the northernmost part of Ellef Ringnes Island.

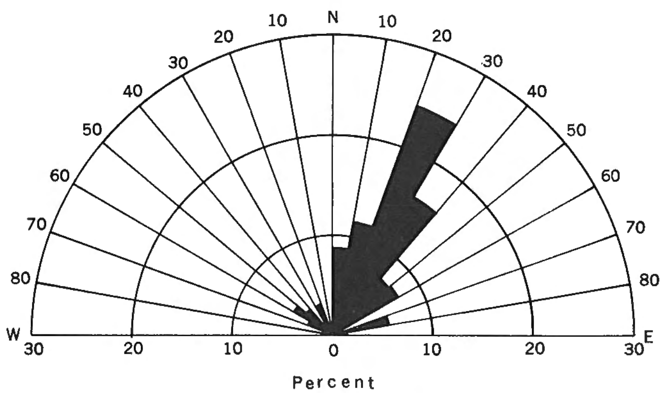
Folds and elongate, spectacular diapirs[4] are the dominant structural elements in exposed rocks on the Ringnes Islands. Along the eastern part of Amund Ringnes Island upright box folds have relatively straight axial traces, which consistently trend about N40° W (subparallel to the structural grain of the Eureka Sound Fold Belt on western Axel Heiberg Island); in contrast, Cornwall Anticline and folds west of this regionally high structure have vaguely defined, sinuous axial traces, which although trending generally northwest, clearly lack the degree of structural organization that exists in more easterly parts of the Sverdrup Basin.

Except for the special case of diapir sheaths, faults do not appear to have been significant deformational mechanisms in the exposed sequence. The faults are mainly or entirely steeply dipping extensional faults with throws on the order of several tens of feet, and in a few places, a few hundred feet; diabase dykes are locally coplanar with the faults. The statistically dominant fault trend (Fig. 1) parallels the strike of prominent subsea magnetic lineaments west of Ellef Ringnes Island that Bhattacharyya[5] interpreted as diabase dykes.

[1] Heywood, W.W.: Isachsen area, Ellef Ringnes Island, District of Franklin, Northwest Territories; Geol. Surv. Can., Paper 56-8 (1957).



A. Amund Ringnes Island (84 faults).



B. Ellef Ringnes Island (158 faults).

Figure 1. Strike-frequency diagrams of faults and major fracture lineaments, Ringnes Islands. Data from ground observation, airphoto interpretation, and Stott (1969).

[2]Fortier, Y.O., et al.: Geology of the north-central part of the Arctic Archipelago, Northwest Territories; Geol. Surv. Can., Mem. 320 (1963).

[3]Stott, D.F.: Ellef Ringnes Island, Canadian Arctic Archipelago; Geol. Surv. Can., Paper 68-16 (1969).

[4]Gould, D.B., and de Mille, G.: Piercement structures in the Arctic Islands; Bull. Can. Petrol. Geol., vol. 12, pp. 719-753 (1964).

[5]Bhattacharyya, B.K.: Analysis of aeromagnetic data over the Arctic Islands and continental shelf of Canada; Geol. Surv. Can., Paper 68-44 (1968).

103. TERTIARY FORAMINIFERAL SUCCESSION OF THE WESTERN CORDILLERA AND PACIFIC MARGIN

Project 690075

B.E.B. Cameron

Field activities were carried out in two areas of the Pacific Margin during the spring of 1971. A summary of preliminary results from this work is presented herein.

1. Offshore areas

During April and May, 1971, a dredging and coring program was carried out on the continental shelf and slope off the west coast of Vancouver Island (Fig. 1). Preliminary age determinations based on Foraminifera and the lithological or sedimentalogical composition of the recovered material is presented in Table I.

Two areas were emphasized this year. The very thick Pleistocene sediments on the shelf near the mouth of Juan de Fuca Strait mask the geology of the underlying Tertiary. An attempt was made this year to dredge those areas which seemed to have a reasonable chance of yielding Tertiary rocks as evidenced by seismic profiles. In one area (D71-24), grey, blocky mudstones yielded foraminifers of probable Pliocene age. D71-17 yielded sandy conglomerates which, while having unweathered, freshly broken surfaces, are probably not in situ. In general, a good deal of difficulty was experienced in locating Tertiary outcrop areas.

A second area of interest was to the northwest where, south of Brooks Peninsula, Pliocene and possibly Miocene bathyl water mudstones were recovered on the shelf and upper continental slope. These rocks are shown seismically to unconformably overlie Oligocene sandstones and shales which are also in submarine outcrop in this area. In addition, several good exposures of conglomerate and argillite of probable Mesozoic age are present, presumably representing fault blocks similar to those on Vancouver Island.

2. Nootka Sound area, northwest Hesquiat Peninsula, west coast of Vancouver Island (92 E)

Four weeks were spent studying the Tertiary geology in the area of Escalante River, northwestern Hesquiat Peninsula. A preliminary geological map of the area is under preparation.

a) Structure

The succession in this area is difficult to follow systematically due to pronounced fracture systems in these rocks. Two sets of fractures predominate, bearing approximately 235° to 240° to 300°. Horizontal displacements along these fractures are in the order of five to ten feet, while the maximum observed was thirty feet. In addition, several major faults create repetitions in the Tertiary succession along the coast to the south.

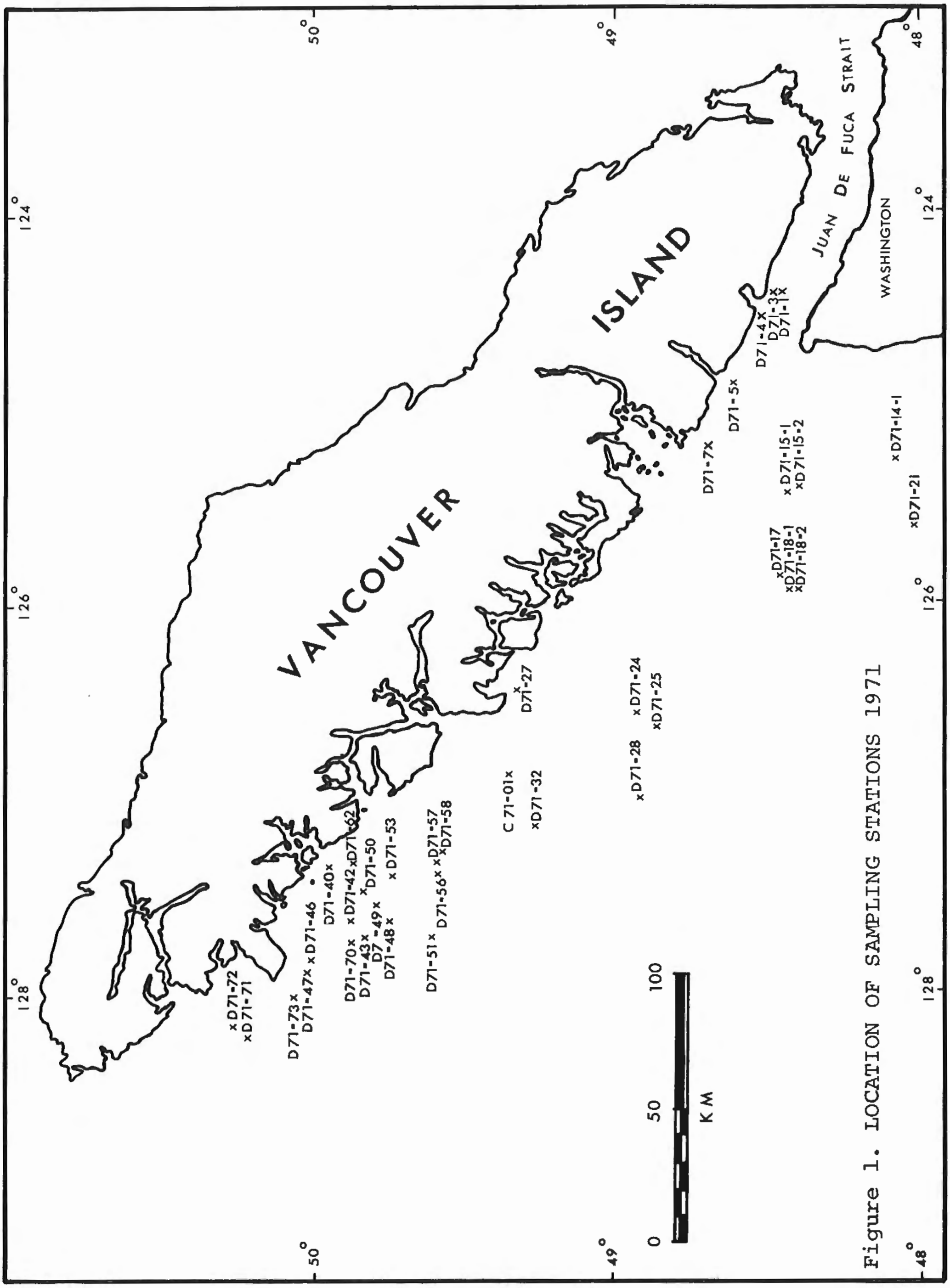


Figure 1. LOCATION OF SAMPLING STATIONS 1971

TABLE 1

PRELIMINARY RESULTS OF SAMPLING PROGRAM

STATION	DEPTH (fathoms)	Preliminary Age	LITHOLOGY/Sediment
D71-1	64-58	Recent	mud, dark grey
D71-3	36-28	Pleistocene	mud, olive green, silty
D71-4	approx 30	Pleistocene	sand, olive green
D71-5	approx 30	Pleistocene	glacial boulders
D71-7	23	Pleistocene	glacial boulders
D71-14-1	106	Pleistocene	sand, silty olive green, pebbly
D71-15-1	76-80	Pleistocene	mud, olive green, shelly
D71-15-2	80-68	Pleistocene	glacial boulders
D71-17	57-63	Mesozoic?	Conglomerate
D71-18-1	128-95	Pleistocene	mud, blue-grey, pebbly
D71-18-2	150-120	Pleistocene	mud, grey-brown, pebbly
D71-21	138-86	Pleistocene	mud, grey-brown, pebbly
D71-24	270-200	Pliocene ?	mudstone, grey, blocky
D71-25	490-360	Pleistocene	mud, olive green
D71-27	28-26	Pleistocene	sand, brown, pebbly
D71-28	860-830	Pleistocene	mud, blue-grey
D71-32	430-380	Pliocene ?	mudstone, grey, sandy
D71-40	25-22	Pleistocene	glacial boulders
D71-42	70-66	Mioc.- Pliocene	mudstone, grey-brown, radiolarian
D71-43	330-260	no fauna	mudstone, brown
D71-46	260-160	Mesozoic ?	Conglomerate
D71-47	580-355	Pleistocene	mud, olive green
D71-48	230-188	Pleistocene	mud,blue-grey
D71-49	57-52	Pliocene	mudstone, grey
D71-50	38-40	Mioc-Pliocene	mudstone, grey, sandy
D71-51	600-550	Pleistocene	mud, olive green
D71-53	42	Pliocene?	mudstone, dark brown
D71-56	260-220	Pleistocene	mud, blue-grey
D71-57	145-110	Pliocene?	mudstone, grey, sandy, diatomaceous
D71-58	240-160	Pleistocene	mud, grey, sandy, consolidated
D71-62	approx.40	Pleistocene	mud, blue-grey, pebbly
D71-70	approx. 300	Pleistocene	mud, olive green
D71-71	590-380	Mioc-Pliocene	mudstone, grey, sandy, radiolarian
D71-72	250-200	Pleistocene	mud, blue-grey
D71-73	246-160	Mesozoic ?	argillite, dark grey
C71-01	approx 80	Pleistocene	mud, olive green, sandy

(prefix D = dredge site, C = coring station)

b) Succession and Age

The part of the Tertiary succession comprises sandstones and conglomerates which overlie tuffaceous and basaltic rocks of the Mesozoic Bonanza Group (J. E. Muller, pers. comm., 1971). The contact between these units, an erosional angular unconformity, is well exposed during low tide levels. The basal Tertiary unit (Escalante Formation of Bancroft[1]) is approximately 700 feet thick and consists of lithic sandstones with conglomerate lenses and tongues. The Escalante Formation is sparsely foraminiferal. A precise age and paleoenvironmental interpretation at this time is premature. An Upper Eocene marine environment is indicated however.

The Escalante Formation is in gradational contact with shales and siltstones which represent the base of an unnamed Tertiary unit mapped as Division C by Jeletzky[2]. This unit has a cumulative thickness of approximately 980 feet and through fracturing and faulting is repeated for several miles south along the coast of Hesquiat Peninsula. From the base, the succession grades from argillaceous siltstones and sandstones to interbedded shales and sandstones and finally to massive and lenticular conglomerates. The latter are replaced by sandstone along strike and in dip direction. Good foraminiferal assemblages have been recovered from this unit and indicate an Upper Eocene, Narizian to lower Refugian age. All assemblages, including those from shale interbeds above, below and from within the conglomerates indicate deposition was in bathyl water depths.

c) Summary

In the northwestern Hequiat Peninsula area;

i) The Cenozoic overlies the Mesozoic Bonanza Group with an erosional angular unconformity.

ii) Most of the Tertiary rocks are of deep water origin and are Upper Eocene in age.

iii) Most of the succession appears to be older than the finer clastic sequence exposed on the adjacent Nootka Island (ref. 2, 3).

iv) Conglomerates in this area pinch out along strike and in dip direction indicating that the supply of coarse clastic material to the deep water environment was largely restricted to channels which were cut into the older sediments.

[1] Bancroft, M.F.: Gold-bearing deposits on the west coast of Vancouver Island between Esperanza Inlet and Alberni Canal; Geol. Surv. Can., Mem. 204 (1937).

[2] Jeletzky, J.A.: Tertiary rocks of the Hesquiat-Nootka area, west coast of Vancouver Island, British Columbia; Geol. Surv. Can., Paper 53-17 (1954).

[3] Cameron, B.E.B.: Tertiary Foraminiferal succession of the Western Cordillera and Pacific margin, in Report of Activities, Part A, April to October 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 25-26 (1970).

104. BIOSTRATIGRAPHIC CONTRIBUTIONS FROM THE ARCTIC COASTAL PLAIN WEST OF THE MACKENZIE RIVER DELTA

Project 700064

T.P. Chamney

The sequence of Cretaceous strata exposed along Fish River, Cache Creek and adjacent creeks was described and sampled for micropaleontology from the Yukon border to Coalmine Lake on the west flank of the Delta. Only cursory examination of the microfossil recovery has been possible to date but biostratigraphic correlations can be made with the sequence of Cretaceous strata exposed on the east flank of the Delta[1]. Some correlation with subsurface equivalents in the Delta area has been previously published[2] but can now be reported more accurately in terms of more recent stratigraphic nomenclature[3].

The Bituminous Shale Zone equivalent was considered to be best exposed on a tributary creek of Fish River (68°30'20"N, 136°27'30"W). It was designated in the field as section CR2-71, 0 to 456 feet. The stratigraphic position of Bituminous Shale Zone equivalent is within the yellow-weathering shale unit. More precisely, it underlies a "chert conglomerate and sandstone" unit and overlies (?transitional) a "bedded ironstone" unit. The significant surface expression of the Bituminous Shale Zone equivalent is the wavy pattern of contorted yellow bands (?jarosite and ferruginous bentonite) contrasting with the dark grey shale of the rock unit; selenite crystals and clay-iron concretions (sideritic) are common also.

The rock unit is tenatively divided into three biostratigraphic subdivisions in descending order as follows:

Upper: (250 to 400+ feet) Fish scales, vertebrate bone, Hyperammina spp. Haplophragmoides spp. and rare Trochammina sp. 400+ refers to approximately 50 feet of additional section covered by scree.

Middle: (100 to 250 feet) radiolaria spp. and rare Trochammina sp.

Lower: (0 to 100 feet) discoid ?radiolarians, rare foraminifers.

Similar assemblages have been reported from the Bituminous Shale Zone of the Anderson Plain and Keith Arm of Great Bear Lake (Chamney, Paleo. Rept. Mes. 1 and 2 - 1969). The top of the equivalent biostratigraphic unit in the subsurface of the Mackenzie Delta is tentatively placed at 10,720 feet in the Reindeer D-27 borehole. This is based on the uppermost occurrence of the fragmentary vertebrate remains associated with the radiolarians.

The Upper Cretaceous unnamed shale unit overlying the Bituminous Shale Zone equivalent and underlying the basal Moose Channel Formation sandstones is approximately 1,125 feet thick on Cache Creek (pers. comm., F.G. Young). As previously reported (ref. 2 - addenda), this depositional sequence contains the very significant index species "Cyclammina" sp. 1A of the biostratigraphic Division 11 in Reindeer D-27 well (9,000 to 9,880 feet). From a cursory examination of the field samples, the top or uppermost range of this species occurs about the middle of the "no name" shale. This is followed upward in the sequence by elements of the Trochammina sp. G10 and the Verneuilinoides "borealis" (requires new species name). This Upper Cretaceous shale sequence is represented by 1,125 feet of strata on the mainland, west flank of the Delta, and by 3,760 feet in the Reindeer D-27 borehole (6,960 to 10,720 feet) approximately 52 miles north and east of Cache Creek.

Laboratory preparation of the "bedded ironstone" and "concretionary silty mudstone" units successively underlying the Bituminous Shale Zone equivalent has not been completed to date. Cursory examination of a few samples from the "concretionary silty mudstone" unit overlying the Upper Sandstone Division[4] indicates some elements of the Neocomian (?Barremian) and some younger Aptian or earliest Albian equivalents. The Moose Channel Formation on Fish River, the red-weathering beds and red "clinker" shales on the creeks flowing into the Mackenzie Delta north of Fish River represent the youngest strata of the mainland on the west flank of the Delta. A new assemblage of foraminifers has been recovered from these samples which will require considerable study; this microfauna may include younger assemblages of early Tertiary age.

[1]Chamney, T.P.: Abnormally thick Tertiary-Cretaceous sequence, Mackenzie Delta, District of Mackenzie; In Report of Activities, Part B, November 1968 to March 1969, Geol. Surv. Can., Paper 69-1, Pt. B, 1 table, 2 figs., pp. 69-72 (1969).

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

[3]Young, F.G.: Mesozoic stratigraphic studies, northern Yukon Territory and northwestern District of Mackenzie: in Report of Activities, Part A, April to October 1970, Geol. Surv. Can., Paper 71-1, Pt. A, pp. 245-247 (1971).

[4]Jeletzky, J.A.: Uppermost Jurassic and Cretaceous rocks of Aklavik Range, northeastern Richardson Mountains, Northwest Territories; Geol. Surv. Can., Paper 58-2 (1958).

---

105. CAMBRIAN AND ORDOVICIAN STRATIGRAPHY AND TRILOBITES OF NEWFOUNDLAND

Project 690006

W.T. Dean

Investigations continued on the age and trilobite faunas of the Long Point Formation (Ordovician) in the Port au Port Peninsula. The boundary within the overlying Clam Bank Formation received particular attention and is expected to provide evidence of a considerable disconformity.

Collections from the Summerford Group (Ordovician) at New World Island, northeastern Newfoundland, in the summer of 1970 showed evidence of faunal affinities with, on the one hand, the Porterfield Stage of the

Virginia Appalachians and, on the other, the Llandeilo Series of the British Isles. The scope of this activity was extended during the summer of 1971.

The succession of Upper Cambrian and Tremadoc rocks, Elliotts Cove Formation and Clarenville Formation respectively, at Random Island, eastern Newfoundland, was investigated further. Additional collections of trilobites were obtained and are expected to prove of stratigraphical value.

---

106. STRUCTURAL INVESTIGATIONS IN WHITE UPLIFT, NORTHERN YUKON TERRITORY

Project 690005

L.D. Dyke*

During the course of Operation Porcupine in 1962, a number of fault-bounded uplifts were identified and mapped in northern Yukon Territory and western District of Mackenzie[1]. Because some of these may be serving as structural traps for migrating hydrocarbons beneath Mackenzie Bay and southern Beaufort Sea, one was selected for detailed structural analysis in order to obtain basic information about the nature and genesis of these uplifts. The work was carried out during a period of six weeks in the 1971 field season and was under the direct supervision of D.K. Norris.

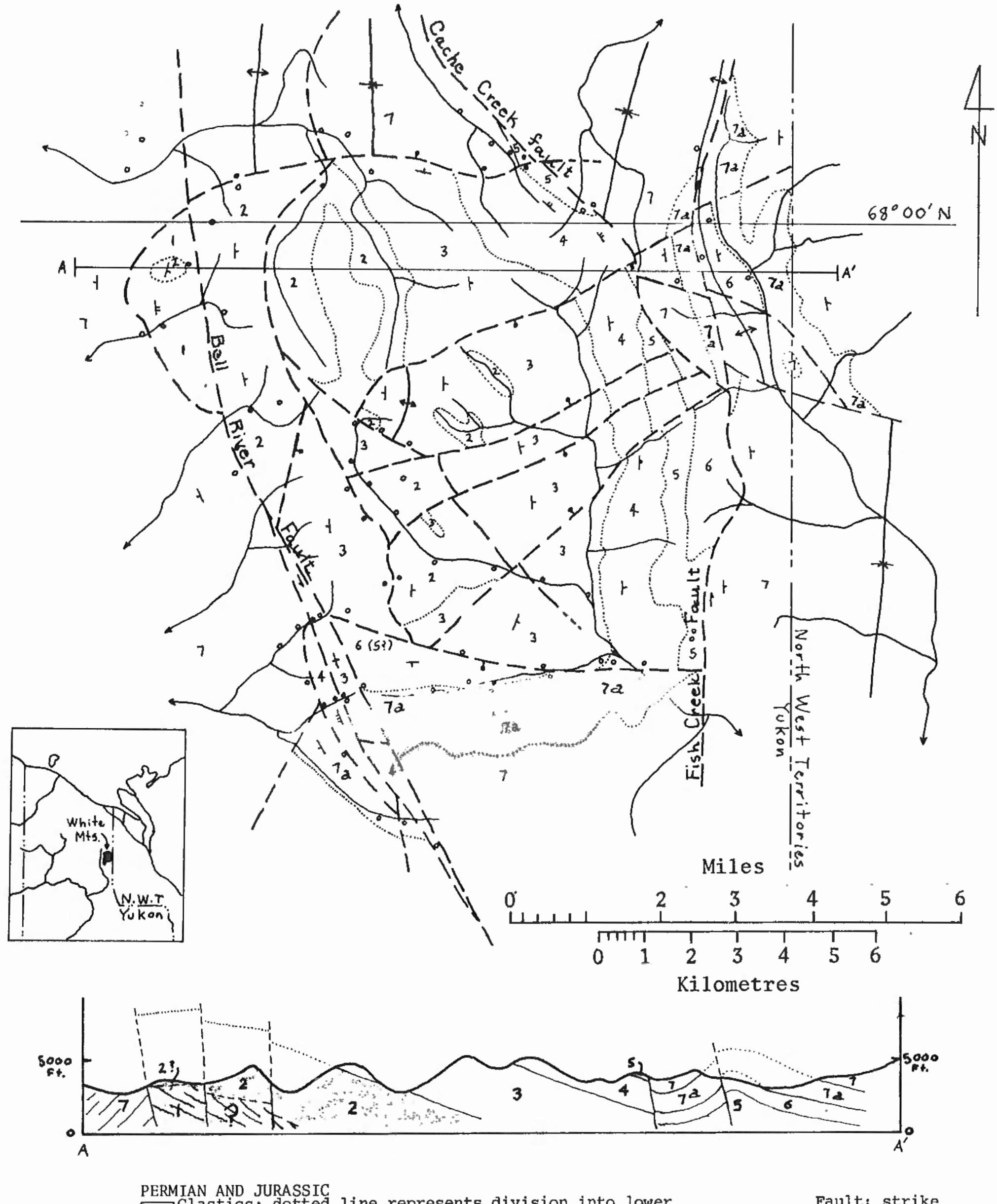
White Mountains uplift was chosen for the study not only because of the clarity of some of the structures defining it, but also because it has a carbonate core. Stress induced calcite twinning in the carbonate rocks may add considerably to the understanding of the stress history of the uplift. The area was mapped at a scale of 1:50,000, sixty-five samples of the fracture fabric were taken for mesoscopic analysis, and oriented specimens of the carbonate rocks were collected for thin section study. The constituent rocks are composed mainly of pelletoid and fine-grained limestones and dolomites that suggest a steady depression at the site during parts of Ordovician, Silurian, Devonian and Permian times. This is in stark contrast to the present configuration of these rocks.

White Mountains, a structural as well as physiographic entity of the northern Yukon Territory, are located about 80 miles (130 km) southwest of Inuvik, N.W.T., in northern Richardson Mountains. Aptly named, they comprise a roughly rectangular massif measuring approximately five by seven miles (8 by 11 km) with an average relief of 2,500 feet (760 m). Structurally, this feature is an uplifted and tilted block of Paleozoic carbonate rocks bounded on all sides by clastic rocks mainly of Permian and Jurassic ages. It has been defined as White Uplift[2].

Stratigraphically, White Uplift is composed of sedimentary and igneous rocks ranging in age from Proterozoic to Early Jurassic (Norris, D.K., op. cit., Table 1). The oldest exposed rocks are carbonates with a few interbeds of agglomeratic and tuffaceous material. Regionally these are overlain with strong angular unconformity by shales of Early Cambrian age; in the uplift this unconformity may be represented where shallowly dipping carbonates

---

*University of British Columbia.



PERMIAN AND JURASSIC

| 7a | Clastics; dotted line represents division into lower silty to shaly interval and upper primarily sandy interval.

Disconformity {MIDDLE PENNSYLVANIAN TO EARLY PERMIAN

| 6 | Limestone and minor sandstone

Disconformity {MIDDLE DEVONIAN

| 5 | Ogilvie Formation; limestone

UPPER SILURIAN TO MIDDLE DEVONIAN

| 4 | Gossage Formation; banded dolomite

LOWER ORDOVICIAN AND POSSIBLY UPPER CAMBRIAN TO MIDDLE SILURIAN

| 3 | Vunta Formation; massive fine grained and pelletoid limestone

PROBABLY CAMBRIAN

| 2 | Mostly dolomite, some sandstone and shale near base

Probable Unconformity {PROBABLY PRECAMBRIAN

| 1 | Mostly carbonates, minor interbedded volcanics

Fault; strike slip, dip slip, indicating down thrown side.

Continuation of fault uncertain

Geological boundary

Anticlinal axis

Synclinal axis

Bedding; shallow, moderate, steep, vertical dip.

o Fracture fabric station, also oriented specimen location in carbonates.

Figure 1. Geological map of White Uplift, northern Yukon Territory.

and quartzose carbonates overlie, throughout a very small area, the oldest rocks mentioned above. Poor exposure obscures the exact relationship. Interrupted by a fault, the succession then continues with carbonates interbedded with clastics and minor amounts of shale of Cambrian (?) age, in turn succeeded by limestones and dolomites of probably late Lower Ordovician, Middle and Upper Silurian[3], Middle Devonian (Norris, A.W., 1968, p. 232), and Middle Pennsylvanian and Early Permian[4] ages. Shales and sandstones of Early and Middle Permian age overlie this carbonate sequence disconformably and are themselves overlain diconformably by Lower Jurassic sandstones of the Bug Creek Formation (Norris, D.K., pers. comm., 1971). The total thickness of the sedimentary and igneous succession in the uplift is approximately 12,000 feet (3,800 m). The lithologies of the carbonate rocks suggest deposition on a fairly shallow bank of restricted lateral extent (Norford, idem.), and the uppermost part of the Middle Devonian interval includes coralline and stromatoporoidal limestones[5].

The basic structure of the uplift and much evidence as to the nature of the deformation are revealed on the perimeter of White Mountains. The north side shows the greatest amount of discontinuity between the structure of the uplift and that of the enclosing clastics. There the structural elements in the clastics are broad, south-trending folds offset by a few major, vertical faults. The folds are oriented perpendicular or subperpendicular to the uplift and end abruptly against a major, vertical, west-trending fault with significant dip-slip separation that forms the north boundary of the uplift. Westward, successively lower units in the uplift are introduced along the fault so that the oldest exposed beds in the northwest corner of the uplift are of probably Precambrian age. They form a fault-bounded pod which protrudes westward into the Permian clastic succession.

South-trending Bell River fault cuts the pod of Precambrian (?) sedimentary rocks and defines the west boundary of the uplift. Along it occurs a vertically dipping slice of carbonate rocks, assigned to the Vunta and Gossage Formations, which trends southeast and forms the prominent spur extending about two miles (4 km) beyond the southwest corner of the uplift. East of the slice, the lower Paleozoic carbonates dip at a moderate angle toward it and west of the slice the Permian clastics dip at a moderate angle away from it.

Apart from this spur, the south flank of the uplift appears structurally the least complicated. There the Permian clastic succession is seen to rest disconformably on the carbonates, both dipping south at moderate angles. The only complication near the southern margin is an uplifting of the carbonate succession slightly to the north of the disconformity by another vertical fault. Inclination of strata in the uplifted block is moderated toward the east or southeast. This fault is truncated along the western flank of the uplift by Bell River fault. It approaches the disconformity at a low angle, truncating it and ending abruptly eastward against Fish Creek fault.

Fish Creek fault defines the southern half of the eastern limit of White Uplift. It trends north and its dip is nearly vertical. To the west of it the upper and middle Paleozoic carbonates dip moderately eastward and may be in part equivalent to the carbonates below the disconformity on the south side of the uplift. Beyond the southeast corner, Fish Creek fault forms the contact between the south-dipping Permian and Jurassic clastic sequence above the disconformity on the south flank and the strike continuation of the east-dipping clastics forming the east flank of the uplift.

About midway along the east flank, Fish Creek fault offsets a northwest-trending, vertical fault which defines the remainder of the east flank of the uplift. This is Cache Creek fault. Its northeast side is relatively depressed and strata adjacent to this fault are extremely deformed. Basically, the Permian and Jurassic successions there comprise an anticline-syncline pair which trends southward and is probably an eastward continuation of the fold train truncated by the boundary fault along the north flank of the uplift. Permian limestones occur in the core of the anticline and the resistant clastic rocks immediately above, in the east limb of the anticline, are the structural basis for a prominent cuesta. The clastic rocks appear to be structurally conformable with the carbonates on the east side of this inlier, hence this contact probably is equivalent to the disconformity on the south flank of the uplift. The inlier is bounded on the remaining three sides by steeply dipping faults including the northward continuation of Fish Creek fault. Dragfolding along this fault in the inlier suggests high-angle, reverse fault relationships.

The fundamental structure of the carbonate core is that of a faulted dome with a marked westward asymmetry. Strata dip toward the margin of the uplifted block on all sides and they are shallowly dipping to horizontal in the centre. The thick, gently dipping sequence of Upper Silurian and younger strata on the east flank of the uplift is absent on the west and the succession there is comprised of steeply dipping to vertical formations of Middle Silurian and older ages. The expression of the uplift could have been enhanced if an upward protruding configuration of reef-forming carbonates and their associated debris existed until the time of uplift.

Within the carbonates the faulting appears to be of two principal types, strike-slip and dip-slip. The strike-slip faults are roughly north-trending, parallel and subparallel to Bell River fault; they are nearly vertical and are confined to the western half of the uplift. The dip-slip faults are east and northeast-trending, are bounded on the east by Fish Creek and Cache Creek faults, and accommodation of differential vertical movement in the uplift may have been accomplished by them. In general, deformation is most intense along the western border of the uplift, consistent with the maximum stratigraphic separation observed there along Bell River fault.

[1]Norris, D.K., Price, R.A., and Mountjoy, E.W.: Geology of northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Map 10-1963 (1963).

[2]Norris, D.K.: Tectonic styles of northern Yukon Territory and northwestern District of Mackenzie; Proc. Second International Symposium on Arctic Geology, Am. Assoc. Petrol. Geol., in press (1971).

[3]Norford, B.S.: Reconnaissance of the Ordovician and Silurian rocks of northern Yukon Territory; Geol. Surv. Can., Paper 63-39 (1964).

[4]Norris, D.K.: Structural and stratigraphic studies, Blow River area, Yukon Territory and western District of Mackenzie; _in_ Report of Activities, Part A: April to October 1969, Geol. Surv. Can., Paper 70-1, Pt. A, pp. 230-235 (1970).

[5]Norris, A.W.: Reconnaissance Devonian stratigraphy of northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 67-53 (1968).

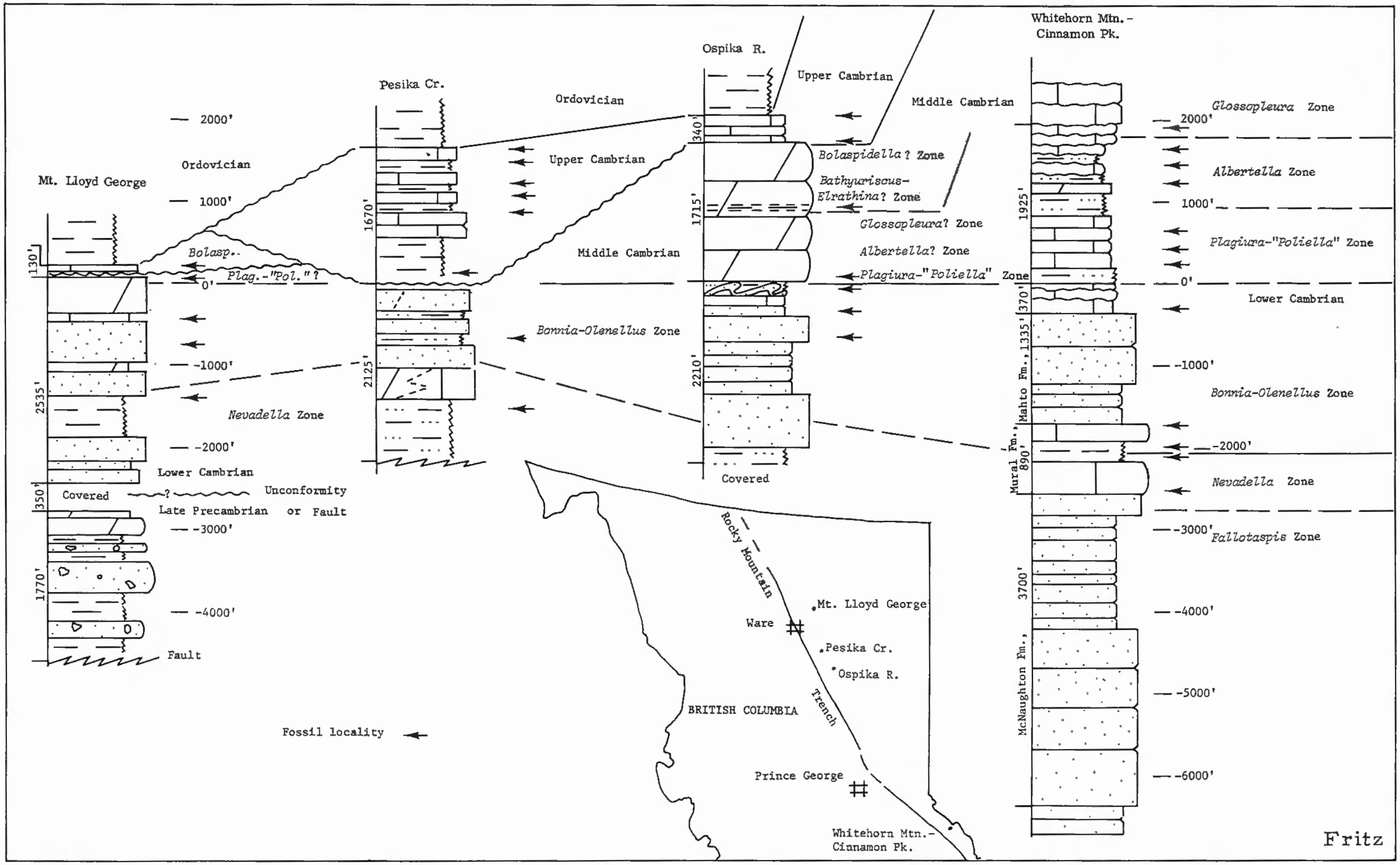


Figure 1. Cambrian stratigraphic sections near the eastern margin of the Rocky Mountain Trench and locality map.

107. CAMBRIAN BIOSTRATIGRAPHY WESTERN ROCKY MOUNTAINS, BRITISH COLUMBIA (83 E, 94 C, 94 F)

Project 650024

W.H. Fritz

Three Cambrian sections were measured while the author was taking part in Operation Finlay (see Gabrielse, this publ.). Named for nearby physiographic features, they are Ospika River (lat. 56°34 3/4', long. 124° 01 1/2-03'), Pesika Creek (lat. 57°00 1/4', long. 124°39 1/2'), and Mount Lloyd George (lat. 57°59 1/2', long. 125°02 1/2-04 1/2'). A fourth section was measured between Whitehorn Mountain and Cinnamon Peak (lat. 53°05-07 1/2', long. 119°16-17') in the classical Mount Robson area. Data from the four sections are summarized in Figure 1. In the figure the positions of two zones being described[1] in the Mackenzie Mountains, the Fallotaspis and Nevadella Zones, are shown. Arrows indicate the general distribution of fossil localities. Where localities are closely spaced, especially in the Upper Cambrian, a single arrow represents numerous collecting horizons. The following discussion briefly supplements the data in Figure 1.

In the Whitehorn Mountain-Cinnamon Peak section, the lower beds of the Mural Formation contain Nevadia sp. indicating the Nevadella Zone. No diagnostic fossils were found below the Nevadia sp. horizon. Since Nevadia sp. occupies a low position in the Nevadella Zone elsewhere, the boundary of the Nevadella Zone with the underlying Fallotaspis Zone is tentatively placed high in the McNaughton Formation and a short distance below the Nevadia sp. locality. The middle shale unit of the Mural contains the boundary between the Nevadella and Bonnia-Olenellus Zones. The zone boundary here is in nearly the same position as in a similar, threefold Mural succession west of the Rocky Mountain Trench near Dome Creek in the northern Cariboo Mountains. Above the Mahto is 370 feet of Lower Cambrian limestone that correlates with the Peyto Member of the Gog Group in the southern Canadian Rocky Mountains. This limestone, plus 1,925 feet of orange and medium grey weathering limestone and light brown shale represents the lower part of Mountjoy's[2] map-unit 3.

In the Ospika River section, Lower Cambrian slump structures (Fig. 2a) in interbedded light quartzite and dark siltstone suggest paleo-relief during latest Bonnia-Olenellus time. Overlying these strata is 1,715 feet of Middle Cambrian dolomite with a 24-foot-thick shale unit near the middle. The shale contains trilobites questionably assigned to the Bathyuriscus-Elrathina Zone, and therefore may be equivalent to the Stephen Shale to the south. The resemblance between this dolomite-shale-dolomite succession and the Cathedral-Stephen-Eldon succession in the southern Canadian Rocky Mountains is striking, but it is not recommended that this formational nomenclature be extended to the Ospika River section. Above the dolomite is 340 feet of Upper Cambrian strata that may represent a depositionally condensed succession as compared to the more typical, thicker, Upper Cambrian sections elsewhere in the Cordillera.

Strata in the Pesika Creek section have been tectonically disturbed, so that all stratigraphic thicknesses must be questioned. Middle Cambrian strata is absent, and it seems probable that all of the Middle and some Lower

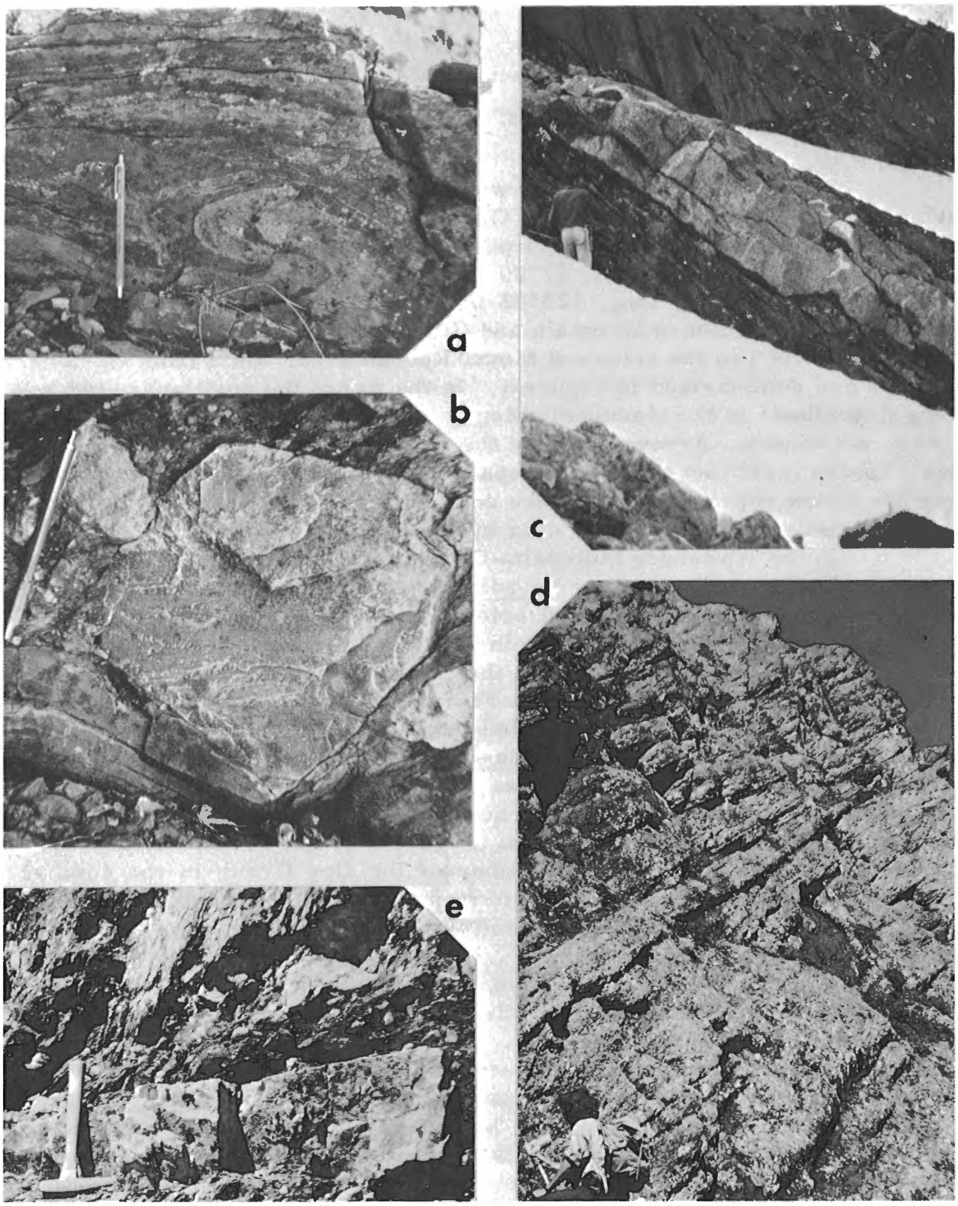


Figure 2. Late Lower Cambrian slump-fold in the Pesika Creek section (a), and Late Precambrian pebbly mudstone in the Mount Lloyd George section (b-e). GSC photo 201853.

Cambrian have been removed by pre-Upper Cambrian erosion. The Upper Cambrian is represented by a far greater thickness of strata than in the Ospika River section and contains far more shale.

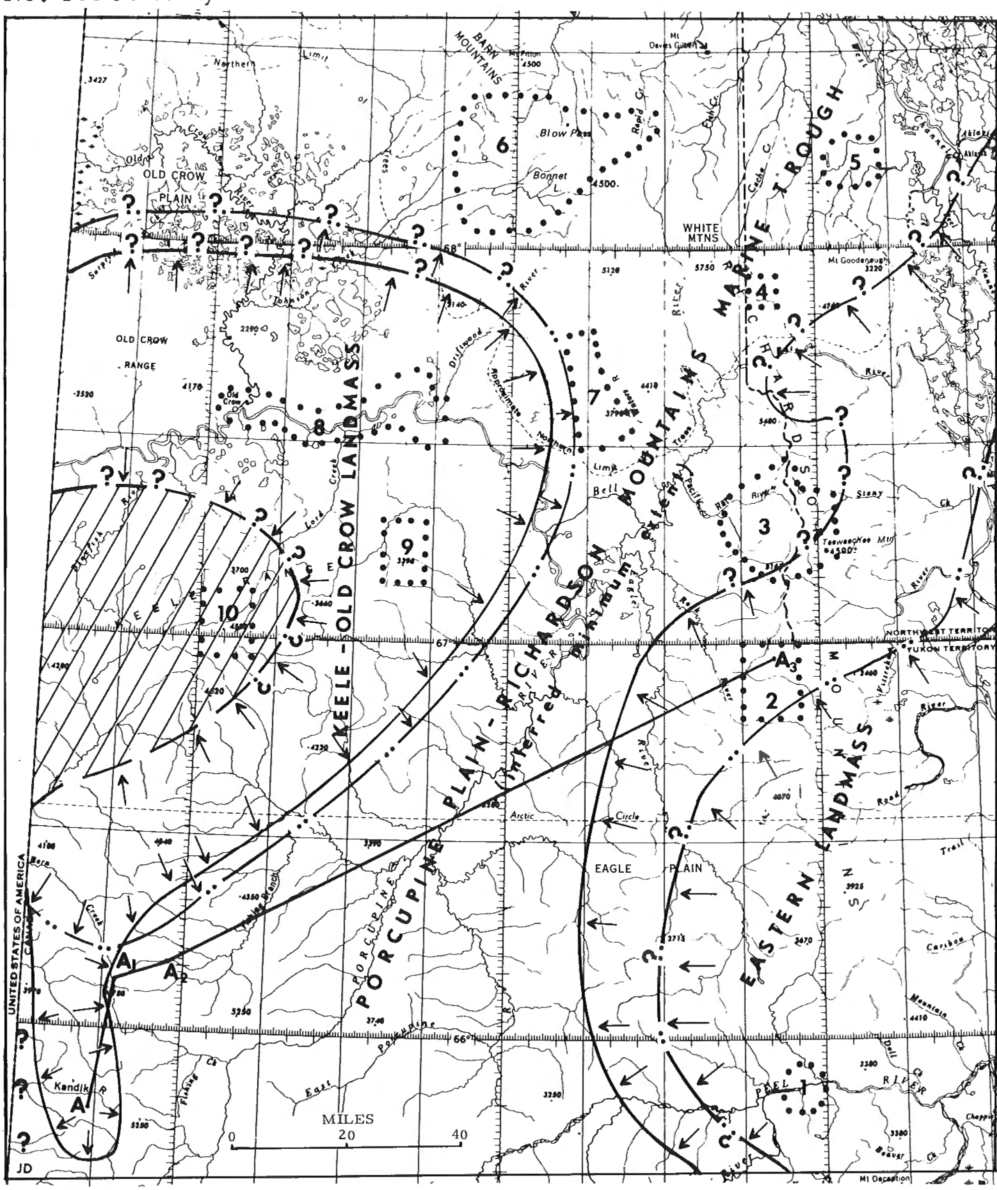
The Mount Lloyd George section is of particular interest, as here Lower Cambrian strata are in close proximity with Precambrian strata that could be interpreted as being either tillites or turbidites. Most of the interbedded black shale and pebbly mudstones in the Precambrian of this section is quite different from the Lower Cambrian slump deposits of the Ospika River section (compare Fig. 2a with Fig. 2b-e). The pebbly mudstones are in beds of fairly uniform thickness (Fig. 2d) that exhibit little or no vertical grading. No evidence of scouring or channelling was seen. Only in rare instances (Fig. 2b) was evidence found of large clasts having sunk into underlying beds. The large clasts average two and one half inches in diameter. One clast (Fig. 2e) is a portion of a quartzite bed that averages eight inches in thickness and is four feet long. Like most clasts, it is "floating" in a mudstone matrix. Near the top of the mudstone-black shale succession are tongues of light coloured, nearly pure dolomite breccia (Fig. 2c). Above this is continuous dolomite breccia with only sparse "foreign" clasts of quartzite. Finally, the uppermost dolomite exposed is in thin, laminated beds free of "foreign" clasts.

Between the Precambrian succession and the Lower Cambrian is a 350-foot interval containing a covered strike valley. The cover may conceal an unconformity or possibly a fault. An exposure of this interval four miles to the south contains evidence of an angular relationship between the Cambrian and Precambrian, but the reason for this relationship is still unresolved.

At the top of the Lower Cambrian succession in the Mount Lloyd George section is a thin limestone and siltstone unit containing early Middle Cambrian fossils belonging to either the Plagiura-"Poliella" Zone or the Albertella Zone. Unconformably above these strata is a thin unit containing latest Middle Cambrian fossils of the late Bolaspidella Zone. This unit is in turn unconformably overlain by silvery, light brown shale that is locally unfossiliferous, but contains Lower Ordovician fossils elsewhere.

[1] Fritz, W.H.: Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, northwestern Canada; Geol. Surv. Can., Bull. 212 (in press).

[2] Mountjoy, E.W.: Mount Robson (southeast) map-area, Rocky Mountains of Alberta and British Columbia, 83 E/SE; Geol. Surv. Can., Paper 61-31 (1962).



LEGEND

MID-VALANGINIAN TO ? APTIAN EMBAYMENT (EASTWARD ONLAP) OF CENTRAL ALASKAN BASIN UPON UPPER JURASSIC TO BERRIASIAN-EARLY VALANGINIAN KEELE RANGE-OLD CROW LANDMASS.

APPROXIMATE OR ASSUMED SHORELINES OF THE LATE BERRIASIAN TO MID-HAUTERIVIAN (TIMES OF LOWER SANDSTONE AND COAL BEARING DIVISIONS) LANDMASSES.

APPROXIMATE OR ASSUMED SHORELINES OF THE LATE OXFORDIAN TO LATE VOLGIAN (APPROX. TIME OF HUSKY FORMATION AND UNNAMED UPPER JURASSIC SANDSTONE UNIT) LANDMASSES (MAXIMUM EXTENT).

INFERRED DIRECTION OF TRANSPORT OF SEDIMENTS FROM LANDMASSES.

APPROXIMATE LIMITS OF SURVEYED AREAS.

LINE A-A_1-A_2-A_3 SHOWS APPROXIMATE COURSE OF GEOLOGICAL PROFILE OF FIG. 2.

Figure 1. Index map showing locations of surveyed areas, that of the cross-section of Figure 2 and that of the shorelines of Upper Jurassic and early to mid-Lower Cretaceous landmasses.

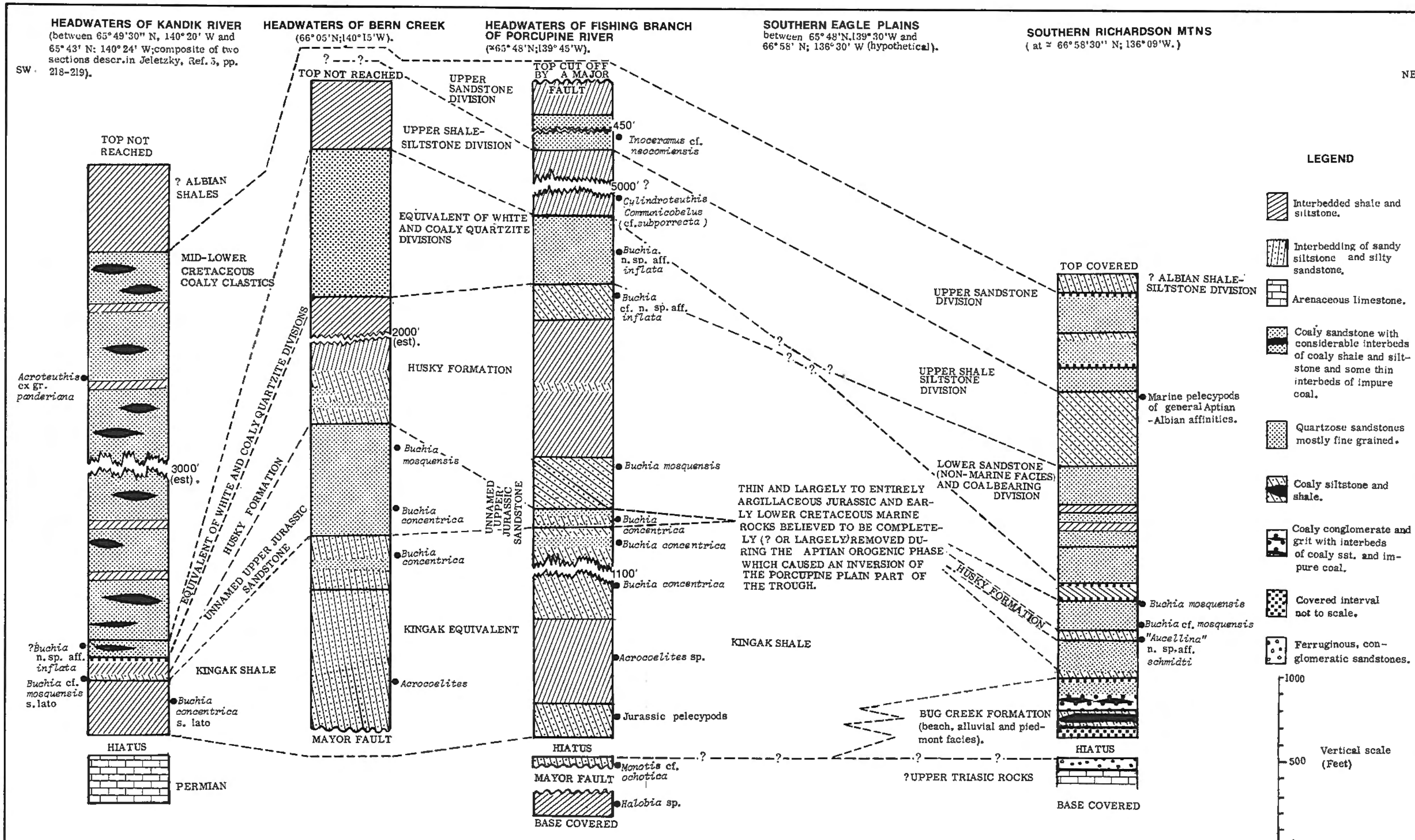


FIG. 2. RESTORATION OF JURASSIC AND LOWER CRETACEOUS (PRE-ALBIAN) FACIES ACROSS THE SOUTHERN PART OF NORTHERN YUKON. THE APPROXIMATE POSITION OF THE CROSS SECTION IS SHOWN BY LINE $A-A_1-A_2-A_3$ ON FIG. 1.

No. 108 Jeletzky

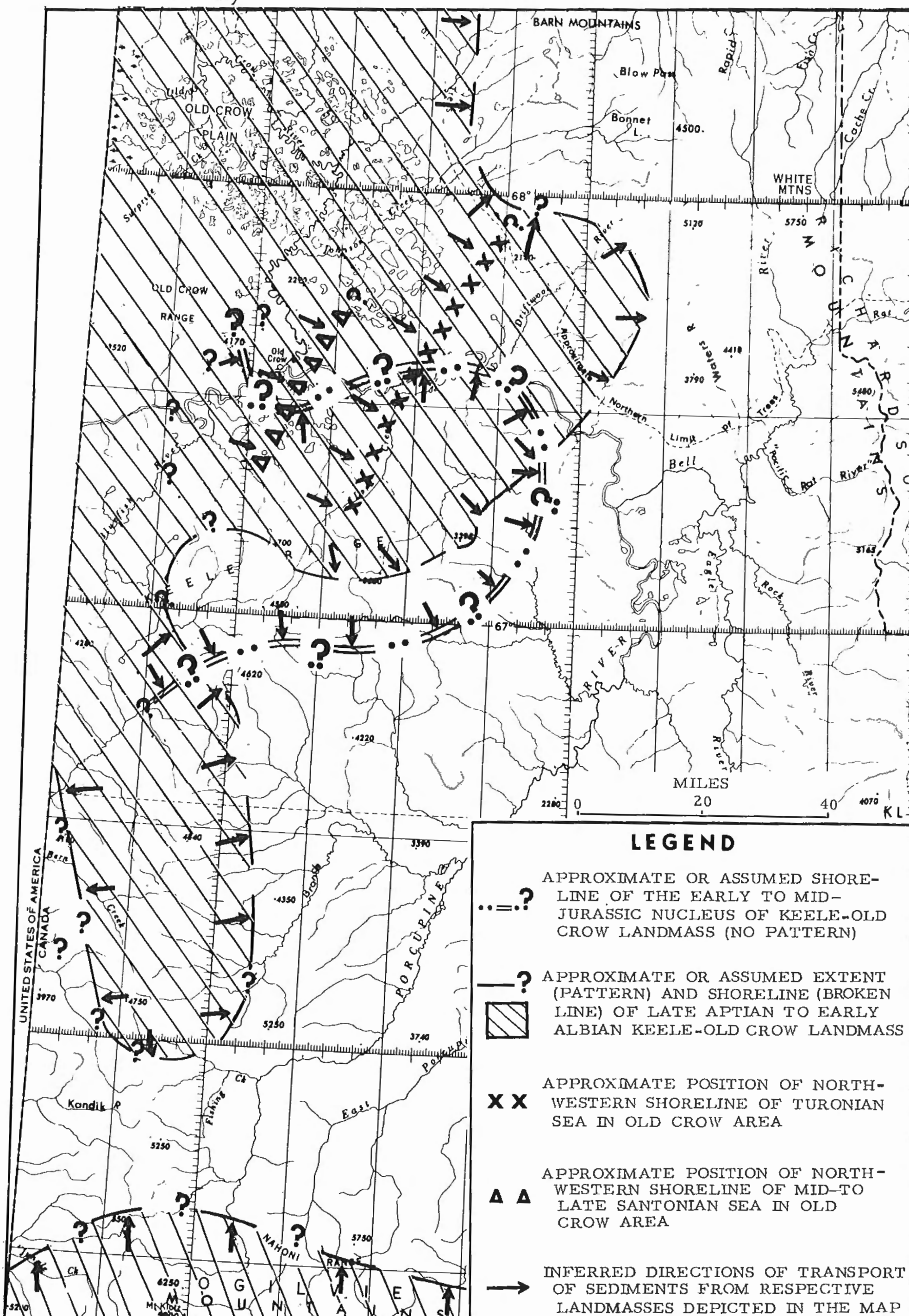


Figure 3. Tentative reconstruction of the early to mid-Jurassic, late Aptian to early Albian, and early to mid-Upper Cretaceous shorelines and land-masses of north and central Yukon.

108. STRATIGRAPHY, FACIES AND PALEOGEOGRAPHY OF MESOZOIC AND TERTIARY ROCKS OF NORTHERN YUKON AND NORTHWEST DISTRICT OF MACKENZIE (NTS- 107 B, 106 M, 117 A, 116 O(N 1/2))

Project 550004

J.A. Jeletzky

From June to August 1971 about nine weeks were spent in a stratigraphical- paleontological study of Mesozoic and Tertiary rocks of the northwestern part of District of Mackenzie and northern Yukon Territory and in support of the field work of F.G. Young in the adjacent areas of these territories.

Camp facilities, air support, and field assistants have been made available at the invitation of Shell Oil, Canada Ltd., Calgary. This assistance and co-operation are deeply appreciated.

The approximate boundaries of the principal areas surveyed in 1971 are indicated in Figure 1 where they are numbered from 1-10 inclusive, Figures 1-3 summarize the main stratigraphic and paleogeographic conclusions. Detailed supporting text with full documentation is being placed on the Geological Survey Open File for general consultation.

---

109. SOUTHWEST ELLESMERE ISLAND, WESTERN DEVON ISLAND, DISTRICT OF FRANKLIN (OPERATION GRINNELL)

Project 670016

J. Wm. Kerr and D.W. Morrow

An airborne geological study of eastern Grinnell Peninsula and the adjacent Douro Range was carried out during June, July, and August of 1971. Numerous ground traverses were completed and sections measured. A report and a geological map on a scale of 1:125,000 are now in preparation and will be placed on open file.

The stratigraphic column reported in the Douro Range[1] has largely been confirmed, but will be refined. The column on adjacent parts of Grinnell Peninsula is similar except for the presence of a major angular unconformity at the base of a dolomite unit, tentatively regarded as the Disappointment Bay Formation, and which is probably equivalent to the lower part of rocks in the Douro Range[1] regarded as the Blue Fiord Formation. The unconformity is not usually obvious as angularity is slight and a basal conglomerate is rarely present.

The Devonian section reported in the anticline at Tucker River[2] has been confirmed. Moreover, it is now known that a major angular unconformity underlies this section and separates it from Ordovician rocks in the core of that anticline.

A second angular unconformity, younger and more pronounced than the one mentioned above, apparently is confined to Grinnell Peninsula. It is overlain by a poorly consolidated quartz sandstone that has not yet yielded fossils. This sandstone may correlate with the Griper Bay Formation.

A major gypsum-anhydrite unit of about Middle Devonian age occurs in the area and is exposed best at Hornby Head. This unit forms an evaporite basin which has a narrow east-west extent, and appears to trend north-northeast along Arthur Fiord.

A prominent mountain range that occupies much of the study area curves from east-central Grinnell Peninsula southeast through the Douro Range. This range probably was once a broad anticline, which was later broken into three segments by a complicated arrangement of thrusts and oblique, normal and tear faults. The Douro Range, which comprises the southeasterly segment, is a north-dipping allochthonous block which overrode southward on the Grinnell Thrust. Traced to the northwest, the thrust dies out in the back limb of a sharply folded anticline. Bedding plane thrusts are common here in the Thumb Mountain Formation. In the central segment most of the southwest limb of the old anticline is exposed. The northwest segment, which curves to a nearly due north trend, contains several subparallel westerly directed thrust faults.

[1]Thorsteinsson, R.: Prince Alfred Bay; in Fortier, et al., Geol. Surv. Can., Mem 320, pp. 221-232 (1963).

[2]McLaren, D.J.: Eastern Grinnell Peninsula in the vicinity of Tucker Point; in Fortier, et al., Geol. Surv. Can., Mem. 320, pp. 244-250 (1963).

---

110. BAUMANN FIORD FORMATION EVAPORITES OF CENTRAL ELLESMERE ISLAND

Project 710007

Grant D. Mossop

A detailed study of the Lower Ordovician Baumann Fiord Formation[1] was initiated in 1971 in the form of a field survey carried out during the months of June, July and August. The writer is indebted to field assistant D.S. Turner for his valuable aid. J. Wm. Kerr (Operation Grinnell) provided field support and offered helpful advice on logistics.

Four successive camps were established on West Central Ellesmere Island (Fig. 1a). In each locality a number of complete sections of the Baumann Fiord Formation were measured, examined in detail and extensively sampled. Listed below are some field observations:

a) In the sections examined, the measured thickness of the Baumann Fiord Formation ranged between 1,850 feet at locality 1 (Type section, Kerr[1,2]) and 670 feet at locality 4. A threefold division of the formation (Fig. 1b) was recognized in all areas except locality 2. In that region, the C member is absent and the B member is rendered indistinguishable from the regional Eleanor River Formation limestone. All the sections have undergone apparent thickness modification due to flowage and folding.

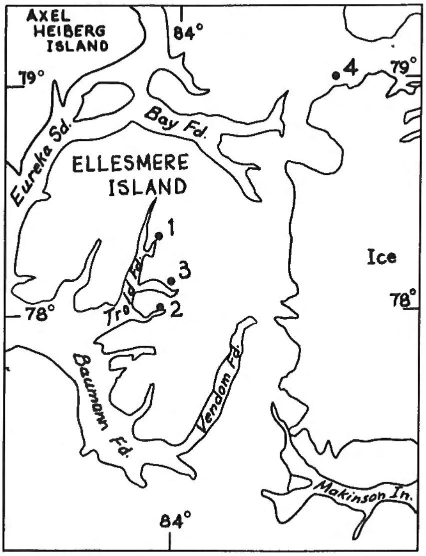


Fig. 1a. Index map of Baumann Fiord Fm. sections examined

0 20 40 60
Miles

M. ORD.	LLANDEILIAN	BAY FIORD FM.	
M. ORD.	LLANVIRNIAN	ELEANOR RIVER FM.	Limestone, med.-grey, buff-weathering, thick bedded, resistant
LOWER ORDOVICIAN	ARENIGIAN	ELEANOR RIVER FM.	Limestone, med.-grey, buff-weathering, thick bedded, resistant
LOWER ORDOVICIAN	ARENIGIAN	BAUMANN FIORD FM.	C- Gypsum-anhydrite B- Limestone A- Gypsum-anhydrite
LOWER ORDOVICIAN	TREMADOCIAN	COPES BAY FM.	Limestone, silty and shaly, often gypsiferous, flat-pebble, conglomerate common
			Disconformity

Fig. 1b Correlation chart of Lower Ordovician strata, Central Franklinian Miogeosyncline, Ellesmere Island (after Kerr [2])

b) Anhydrite is exposed at the surface only in places where erosion is active (stream cuts and rock slides). A weathered zone of white, powdery gypsum has formed as a result of hydration of the anhydrite where surface drainage is impeded. This zone ranges in thickness from a few centimetres to many tens of centimetres.

c) The A member of the Baumann Fiord Formation (Fig. 1b) consists chiefly of coarse crystalline "bedded" anhydrite, nodular mosaic anhydrite and anhydrite-carbonate laminite interbedded with periodic bands of micritic limestone (2 feet to 10 feet thick). The sequence is intrinsically cyclical in these components except for the laminite, which occurs almost exclusively at or near the base of the succession. Characteristic of the carbonate bands is the presence of limestone flat-pebble conglomerate, a variety of stromatolitic structures and occasional desiccation cracks. Chert concretions are common in the anhydrite. Well-sorted quartz sand occurs in minor amounts at locality 4 near the base of the A member.

d) The B member is generally on the order of 150 feet thick and consists of medium grey, thin- to thick-bedded, micritic limestone. The C member reaches a maximum thickness of 220 feet (locality 1). Bedded anhydrite in association with anhydritic limestone and laminite is characteristic of this horizon. Well-developed mudcracks consistently occur in the uppermost 200 feet of the unit.

An extensive petrographic and geochemical study of the sampled material is being undertaken currently.

[1] Kerr, J. Wm.: New nomenclature for Ordovician rock units of the eastern and southern Queen Elizabeth Islands, Arctic Canada; Bull. Can. Petrol. Geol., vol. 15, No. 1, pp. 91-113 (1967).

[2] Kerr, J. Wm.: Stratigraphy of central and eastern Ellesmere Island, Arctic Canada. Part II. Ordovician; Geol. Surv. Can., Paper 67-27 (1967).

111. DEVONIAN AND OLDER PALEOZOIC ROCKS, SOUTHERN AND CENTRAL DISTRICT OF MACKENZIE

Project 700060

W.S. MacKenzie

The author, T. Uyeno, and A.E.H. Pedder spent 20 days near Norman Wells and Sans Sault Rapids in the District of Mackenzie studying outcrops of the carbonate body known variously, either in part or in whole, as the Ramparts, Beavertail, or Kee Scarp Formation. Stratigraphic sections were measured and fossils collected at Kee Scarp, Carcajou Ridge, Jan Lake, Powell Creek, and Beavertail Mountain. The carbonate sequence was studied also in Ramparts Gorge near Fort Good Hope along the south bank of Mackenzie River at the upstream part of the Narrows. Unfortunately, the disconformity described by Crickmay[1] at this latter locality, between overlying limestone conglomerates of the Beavertail Formation and underlying bedded limestones of the Ramparts, could not be observed because of high water level.

Physical stratigraphy of the carbonates studied indicates that there are local erosional features within them, particularly where reef-like facies have developed. One of these at Carcajou Ridge shows relief of up to eight feet. Reef debris, consisting of globular stromatoporoids and angular limestone fragments in a matrix of crinoidal mudstone, now fills the depressions. These stromatoporoidal clastic beds are comparable in many respects to reef debris beds described previously at Powell Creek[2]. Sharp planar contacts between underlying bedded carbonates and overlying rubbly stromatoporoidal debris at measured sections in the Beavertail Mountains and at Jan Lake suggest that erosion may have removed part of the carbonates locally prior to accumulation of the clastic stromatoporoidal material which presumably was derived from nearby topographically higher areas. However, preliminary paleontological studies indicate that erosion was probably less severe than suggested[1]

[1] Crickmay, C.H.: Ramparts, Beavertail, and other Devonian Formations; Bull. Can. Petrol. Geol., vol. 18, No. 1, pp. 67-79 (1971).

[2] MacKenzie, W.S.: Allochthonous reef debris - limestone turbidites, Powell Creek, Northwest Territories; Bull. Can. Petrol. Geol., vol. 18, No. 4, pp. 474-492 (1970).

---

112. SILURIAN-DEVONIAN PALYNOLOGY OF THE ARCTIC ISLANDS

Project 680113

D.C. McGregor

Four stratigraphic sections of Upper Silurian and Devonian rocks were measured and sampled for palynomorph studies. This work is a continuation of the project, begun in 1968, on stratigraphic palynology of Upper Silurian and Devonian rocks of the Franklinian miogeosyncline.[1]

Samples were obtained from 2,755 feet of the Weatherall Formation on Kellett Strait southward from Humphreys Head, Melville Island; from members 2, 3 and 4 (7,242 feet) of the Okse Bay Formation, east and south of Okse Bay, Ellesmere Island; from the Vendom Fiord, Blue Fiord, and Okse Bay Formations (total 2,524 feet) and unnamed clastic rocks beneath the Vendom Fiord Formation (983 feet), south of the head of Cañon Fiord, Ellesmere Island[2]; and from the Douro, Devon Island, Sutherland River and Prince Alfred Formations (total 1,679 feet), south of the Grinnell fault on Sutherland River, Devon Island.

[1] McGregor, D.C. and Uyeno, T.T.: Stratigraphic ranges of spores and conodonts in Devonian rocks of Melville and Bathurst Islands, District of Franklin; Geol. Surv. Can., Paper 71-13 (in press).

[2] Section 14 in Kerr, J.W.: Proc. Internatl. Sympos. Devonian System, vol. 1, pp. 677-692 (1968).

---

113. PERMIAN "HYDROZOAN" MOUNDS DISCOVERED ON SOUTHWESTERN ELLESMERE ISLAND

Project 680064

W.W. Nassichuk

During the 1971 field season special problems in Carboniferous and Permian stratigraphy were investigated in eastern and northern regions of the Sverdrup Basin. One phase of this study resulted in the discovery of a number of Lower Permian carbonate mounds built by the organism Palaeoaplysina Krotow, previously unknown in the Sverdrup Basin; the taxonomic position of Palaeoaplysina is uncertain, but it has been compared with the Hydrozoa by Davies (ref. 1, p. 981). Emphasis is given to these mounds in this report because of their relevance to current exploration for hydrocarbons in the Basin. In co-operation with K.J. Roy, relationships between Permian and Triassic rocks near the eastern margin of the Basin were examined and results are briefly summarized by Roy elsewhere in this publication. The author spent several weeks in the Hare Fiord region of Ellesmere Island with G.R. Davies and carried out a detailed study of evaporite and carbonate rocks and faunas in the typical Lower Pennsylvanian Otto Fiord Formation. Middle Pennsylvanian and Lower Permian carbonate developments, some of which are mounds, were examined in the Hare Fiord Formation in the same general area; results of both the Otto Fiord and Hare Fiord Formation studies will be published jointly with Davies. The author was accompanied by E.W. Bamber in examining several Carboniferous and Permian sections near the axis and eastern edge of the Basin; numerous corals collected will form the basis of an independent study by Bamber.

Reef-like bodies of carbonate rocks are known to occur in both Upper Carboniferous and Lower Permian strata in the Sverdrup Basin[2]. The best known of these are of Middle Pennsylvanian (Moscovian) age and occur near the base of the Hare Fiord Formation in the general vicinity of Hare Fiord, northern Ellesmere Island; Lower Permian mounds are now known to occur higher in the same formation. The Hare Fiord Formation is confined to axial regions of the basin and occurs in the Central Shale Belt of Thorsteinsson and Tozer[2]. The thickest known development of Pennsylvanian reef-like carbonates in the Hare Fiord Formation extends for at least 15 miles along the trace of a major thrust fault on the northwest side of the Blue Mountains; these rocks were discovered by Thorsteinsson in 1956 and described by Bonham-Carter[3,4]. Faunas from a contemporaneous but considerably less extensive sequence of bedded carbonate rocks in the form of a mound on the north side of Hare Fiord, also discovered by Thorsteinsson in 1956, were described by Nassichuk[5,6] and by Nassichuk and Furnish[7]. Thorsteinsson and Tozer[2] reported reefoid development in the lower part of the Nansen Formation in areas of northern Ellesmere Island where the Nansen Formation grades into shales of the Hare Fiord Formation; the Nansen Formation is the principal rock unit in the Northwest Carbonate Belt[2]. All other carbonate mounds known in the Sverdrup Basin occur in the Belcher Channel Formation relatively near the eastern margin of the Basin, near Blind Fiord and on Bjorne Peninsula, southwestern Ellesmere Island. Many of these mounds are composed principally of the skeletal remains of Palaeoaplysina. In contrast, Palaeoaplysina is not known from carbonate rocks in the Hare Fiord and Nansen Formations. Spectacular limestone mounds occur on the west side of Blind Fiord in the upper part of a sequence of skeletal argillaceous limestones that were designated 'Grey Beds' by Tozer[8] and Nansen Formation by Thorsteinsson and Tozer[2]; the author refers at least the upper part of this sequence to the Belcher Channel Formation. The largest of these mounds is several hundred feet thick and extends along strike for nearly 2,000 feet; lesser mounds only a few tens of feet thick and extending a few hundred feet along strike occur directly beneath the largest mound. Several miles to the east of Blind Fiord several additional mounds were discovered near the top of the same formation; the smaller of these are about 15 feet thick, and 20 feet long and the larger are in the order of 50 feet thick and several hundred feet long. A major thrust fault separates Belcher Channel rocks on the west side of Blind Fiord from those on the east thus precluding the testing of a possible physical continuity of individual mounds between the two areas. All of the mounds in the Blind Fiord area contain plates of Palaeoaplysina encased in a matrix of skeletal limestone; the genus was identified by G.R. Davies (pers. comm.) who authored the first description of Palaeoaplysina mounds in Permian rocks in Canada[1]. Davies' (ibid.) important work dealt with a mound in a sequence of Lower Permian clastic and carbonate rocks deposited on the northern shelf of the ancestral Aklavik Arch in the northern Richardson Mountains of the Yukon Territory. Some of the mounds east of Blind Fiord are composed almost entirely of Palaeoaplysina plates, and although the genus is present in more basinward mounds to the west of the fiord it does not appear to constitute the dominant faunal element. In some places on the east side of Blind Fiord, oncolites which may be indicative of shallow shelf conditions occur above and below the mounds. With the exception of newly discovered mounds in the Belcher Channel Formation on Bjorne Peninsula the only other occurrence of Palaeoaplysina in the Sverdrup Basin is in the Tanquary Formation, a few miles south of Mount Bridgeman in the Sawtooth Range. Palaeoaplysina is abundant in a two-foot-thick bed of skeletal limestone 682 feet above the base of the formation; the bed overlies oolitic limestone, indicative of deposition on a shallow carbonate shelf.

On north-central Bjorne Peninsula, ten miles southwest of Schei Point, the Belcher Channel Formation is incomplete and poorly exposed but contains Palaeoaplysina mounds near the top; the formation in this area consists mainly of skeletal limestone, is nearly 1,000 feet thick and is capped by a diabasic sill that is 50 feet thick. The formation rests conformably on the Canyon Fiord Formation which contains about 2,000 feet of red-weathering sandstone, sandy skeletal limestone and minor calcareous siltstone; the base of the Canyon Fiord Formation is in fault contact with lower Paleozoic limestones in the Franklinian Miogeosyncline. The Belcher Channel Formation is overlain by several hundred feet of shales and dark grey to black chert of the upper Lower Permian van Hauen Formation. A multiple development of Palaeoaplysina mounds occurs between 600 feet and 950 feet above the base of the formation. Three mounds are arranged step-like, en echelon, with the steps rising progressively towards the northwest. This appears to suggest a basinward migration of the shoreline and a complementary migration of shallow-water shelf carbonates; additonal field work is required to elucidate local stratigraphic and regional relationships. Each of the three mounds has an average thickness of between 50 and 70 feet and each is estimated to be at least 600 feet long. All of the mounds are made up essentially of Palaeoaplysina remains in a bioclastic limestone matrix but an abundance of brachiopods, gastropods and other organisms all showing little indication of abrasion, are included. The mounds are separated by nearly 100 feet of strata, most of which are covered by blocky talus from the mounds; the lack of exposure of intermound strata precluded the observation of features that might be indicative of cyclic deposition.

[1] Davies, G.R.: A Permian hydrozoan mound, Yukon Territory; Can. J. Earth Sci., vol. 8, pp. 937-988 (1971).

[2] Thorsteinsson, R. and Tozer, E.T.: Geology of the Arctic Archipelago; Geol. Surv. Can., Econ. Geol. Rept. 1 (5th ed.) pp. 548-590 (1970)

[3] Bonham-Carter, G.F.: The geology of the Pennsylvanian sequence of the Blue Mountains, northern Ellesmere Island; unpubl. Ph.D. thesis, Univ. Toronto (1966).

[4] Bonham-Carter, G.F.: An example of the analysis of semi-quantitative petrographic data; Seventh World Petroleum Congress Proceedings, vol. 2, Origin of Oil, geology and geophysics, pp. 567-583 (1967).

[5] Nassichuk, W.W.: Pennsylvanian ammonoids from Ellesmere Island, Canadian Arctic Archipelago; Ph.D. thesis, Univ. Iowa (1965).

[6] Nassichuk, W.W.: A morphologic character new to ammonoids portrayed by Clistoceras gen. nov. from the Pennsylvanian of Arctic Canada; J. Paleontol., vol. 41, No. 1, pp. 237-242 (1967).

[7] Nassichuk, W.W., and Furnish, W.M.: Christioceras, a new Pennsylvanian ammonoid from the Canadian Arctic; J. Paleontol., vol. 39, No. 4, pp. 724-728 (1965).

[8] Tozer, E.T.: Blind Fiord; in Geol. Surv. Can., Mem. 320, pp. 380-386 (1963).

114. DEVONIAN BIOSTRATIGRAPHY OF LAKE MANITOBA - LAKE WINNIPEGOSIS REGION, MANITOBA

Project 640032

A.W. Norris

T.T. Uyeno and the writer spent about a week (May 2-7, 1971) in Winnipeg logging and sampling cores from small diameter, shallow boreholes drilled in 1969 and 1970 by the Manitoba Mines Branch. The boreholes were positioned at carefully selected scattered sites to provide maximum information across and along the largely drift-covered Devonian outcrop belt of southern Manitoba. Beds penetrated include the Ashern Formation (Middle Devonian and/or older), Elm Point, Winnipegosis, and Dawson Bay Formations (Middle Devonian), and the Souris River Formation (early Upper Devonian). Data from the boreholes will augment biostratigraphical information already obtained from a study of the scattered outcrops (ref. 1, 2, 3, 4). Important new information obtained includes thicknesses of formations, contacts between formations, facies, reef and offreef relations, and parts of the Devonian sequence not represented in outcrops. In addition, it is hoped that the sampled cores will provide more complete information on the distribution of conodonts to assist in dating and correlation with other areas, when these are studied by Uyeno.

[1] Norris, A.W.: Devonian biostratigraphy of Lake Manitoba-Lake Winnipegosis area; in Report of Activities, field, 1964; Geol. Surv. Can., Paper 65-1, p. 99 (1965).

[2] Norris, A.W.: Devonian biostratigraphy of Lake Manitoba-Lake Winnipegosis area; in Report of Activities, May to Oct., 1965; Geol. Surv. Can., Paper 66-1, p. 143 (1966).

[3] Norris, A.W., and Uyeno, T.T.: Stratigraphy and Conodont Faunas of Devonian Outcrop Belts, Manitoba (Abst.); Geol. Assoc. Can.-Mineral. Assoc. Can., Programme and Abstracts, Ann. Meeting, Aug. 30 - Sept. 2, 1970, Winnipeg, p. 39 (1970).

[4] Norris, A.W., and Uyeno, T.T.: Stratigraphy and Conodont Faunas of Devonian Outcrop Belts, Manitoba; Geol. Assoc. Can., Special Paper No. 9 (in press).

---

115. JURASSIC STUDIES, BRITISH COLUMBIA (93 E, K, L)

Project 710015

T.P. Poulton

Jurassic sedimentary and volcanic rocks (Hazelton Group) in the Smithers and adjacent map-areas were examined for biostratigraphy and sedimentology. Logistic support and valuable advice were supplied by

H.W. Tipper (Project 690009) who is responsible for the present understanding of the Jurassic stratigraphy[1,2]. Fossils were collected from rocks dated by ammonites as ?Hettangian, Sinemurian, Bajocian, ?Bathonian, Callovian, and Lower Oxfordian, and from higher Jurassic rocks which have not yielded diagnostic ammonites. Pelecypods, particularly the family Trigoniidae, appear to be useful for stratigraphic correlation, at least locally. Detailed study of the Trigoniidae is being undertaken. Other potentially useful fossils include belemnites, corals, brachiopods, and nautiloids.

Except in occasional alpine exposures, the stratigraphy of the Hazelton Group is difficult to study because of thrust faulting, closely spaced normal faulting, lithologic similarity of rocks of various ages, restricted distribution of fossils, rapid facies changes, and generally poor outcrop below treeline. The Jurassic rocks are approximately 10,000 feet thick, as judged from the single probably continuous stratigraphic section known.

The thick Lower Jurassic volcanic succession consists of a lower green and grey unit, mainly breccias, and an upper largely red unit, consisting of flows, ignimbrites, breccias, and minor sedimentary rocks. These units have yielded ?Hettangian or Sinemurian and Upper Sinemurian to Pleinsbachian fossils respectively. Fossiliferous limestones occur locally within the red volcanic unit, and possibly represent a single horizon, approximately. A small coral-rich bioherm at this level was studied in the Telkwa Mountains. Lower Bajocian rocks consist mainly of siltstones and sandstones with minor limestones, conglomerates, and locally thick waterlain red tuffs. Middle Bajocian rocks are mainly blue-grey to green-grey sandstones, a monotonous shallow-water, well-bedded, very fossiliferous facies. The clastic rocks of Middle Bajocian age and earlier consist largely of volcanic rock fragments; those of succeeding rocks are richer in quartz, chert, and feldspar grains. Scattered occurrences of bright green, very fossiliferous, shallow-water sedimentary rocks represent part of late Bajocian or Bathonian time. Lower Callovian sedimentary rocks range from ammonite-bearing, well-bedded, probably "deeper water" siltstones to shallow-water, very fossiliferous sandstones. Known Middle and Upper Callovian rocks occur only in the west-central portion of Smithers map-area and comprise poorly to moderately fossiliferous siltstones and sandstones. Early Oxfordian time is represented by crossbedded, coarse sandstones and black siltstones with fossiliferous limestone concretions. Post-Lower Oxfordian Jurassic rocks are mainly sandstones, conglomerates, and volcanic rocks, of probable continental to shallow marine environments.

[1] Tipper, H.W.: Smithers map-area, British Columbia; in Report of Activities, Part A: April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 34-37 (1971).

[2] Tipper, H.W.: See separate report, this publ.

116. BJORNE FORMATION (LOWER TRIASSIC), WESTERN ELLESMERE ISLAND

Project 710069

K. J. Roy

The Bjorne Formation is a Lower Triassic unit, composed mainly of sandstone, overlying Permian strata along the southern and eastern margins of the Sverdrup Basin. The Bjorne is considered to be mainly nonmarine[1] and, on Melville Island, forms a fan-shaped delta[2]. At the type section, on Bjorne Peninsula, Ellesmere Island, it is about 1,700 feet thick and thickens to more than 4,000 feet in the Sawtooth Range[3] on Fosheim Peninsula. Farther north, at the mouth of Tanquary Fiord, the thickness decreases again to about 1,500 feet.[4]

Six sections were measured between Bjorne Peninsula and Greely Fiord on Ellesmere Island (Table 1) in order to examine thickening trends and to delimit facies in the formation. The Bjorne thickens markedly toward the central Sawtooth Range along the northwesterly line of sections from locations 1 to 6. Westerly thickening is indicated also by the thin section at Trold Fiord any by a section about 24 miles southeast of location 3 toward Mount Low. This section was not measured but is about 1,000 feet thick and appears to be similar to the section at Trold Fiord.

Two major facies are represented by the six sections measured. Section 1 (near the type Bjorne) and sections 3, 4, 5 and 6 are similar in terms of lithology and sedimentary structures whereas section 2 differs from the others. Sections 1, 3, 4, 5 and 6 are fine to medium quartz arenites with minor interbeds of red and grey shale. Conglomerate is absent except for minor amounts in section 6. Trace amounts of black and white chert pebbles as large as 2 centimetres in diameter are scattered throughout the formation but little lateral or vertical variation is seen in the size of quartz grains. A common feature in these rocks is the presence of greenish grey to moderate reddish brown shale clasts up to 10 centimetres in diameter. These are often concentrated on bedding planes and in places form thin beds of conglomerate. The shale clasts are composed of the same material as the shale interbeds and appear to be locally derived.

The Bjorne sandstone, generally friable and porous, contains variable amounts of calcite cement. The porosity may, however, be a weathering feature since, at location 4, where glacial ice has "recently" melted off the outcrop, the rock contains more cement and is less porous than usual.

Most of the Bjorne sandstone is crossbedded in sets that do not exceed 3 feet in thickness and which are generally less than 1 foot thick. Both planar and trough crossbeds are present and in places multidirectional transport is indicated. A sparse sample of directional indicators (Table 2) suggests general sediment movement toward the west. Rill marks, ripplemarks, rib and furrow structures and burrows are present but are not abundant, and mudcracks associated with red shales are present in the lower part of section 4. Only one piece of fossil wood was found and no coal was seen.

At these five localities (1, 3, 4, 5 and 6) the formation weathers dark yellowish brown with minor bands of moderate reddish brown, except at locality 6 where the upper part of the section is red.

The Bjorne is thinnest at locality 2 and contains rock types and sedimentary structures different than those at the other localities. The lower 200 feet of the formation consists of grey and tan shales. Overlying these shales are about 300 feet of crossbedded, fine to medium quartz arenites with minor shale interbeds. (These rocks are similar to the bulk of the sandstones at the other localities). Overlying the crossbedded sandstones are about 350 feet of interbedded fine to medium quartz arenite and grey shale and siltstone occurring in cycles of sandstone-siltstone-shale-siltstone-sandstone. These rocks are distinctly burrowed and casts of pelecypod shells are common.

The remainder of the formation, about 450 feet, consists of interbedded sandstone, shale and siltstone with minor amounts of conglomerate. The sandstone makes up most of the interval and is similar to that below. The conglomerate is made up of black and white chert pebbles and pebbles of siltstone and shale (apparently locally derived). The lower three-quarters of this upper interval contains pronounced wide, deep channels. The shale and siltstone content increases toward the top of the interval and the upper 50 feet of the formation is composed of red shale and siltstone surrounding lenses of sandstone.

Table 1.

Location of sections of Bjorne Formation measured during this project (location 1 is about one and one half miles southeast of the Bjorne Formation).

	Location	Lat.	Long.	Thickness (ft.)
1.	Bjorne Peninsula	77°46'N	87°25'W	1,625
2.	Trold Fiord	78°37'N	84°35'W	1,306
3.	"Sawtooth Range"	79°31'N	83°25'W	3,845+
4.	"Sawtooth Range"	79°34'N	83°20'W	4,824
5.	"Sawtooth Range"	79°51'N	82°56'W	3,795
6.	North of Cañon Fiord	80°13'N	81°41'W	3,140

Table 2.

Current direction data, in 45 degree groupings, from all localities.

Azimuth	0-45	45-90	90-135	135-180	180-225	225-270	270-315	315-360
planar foresets	1					11	9	5
trough axis	1	1	4	1	1	8	10	7
ripple crests					1	4	2	1
rill marks					1	5	2	
rib and furrow						1	5	

The upper half of the formation at locality 2 weathers to a reddish brown colour; the rest is dark yellowish brown with minor bands of light grey.

At the base of the Bjorne Formation, at all localities, there is a very recessive interval; this is generally covered, but in some places, such as locality 2, it is exposed as a grey shale. In the Sawtooth Range five divisions of the Bjorne can be made on the basis of topographic expression (broad units of resistant and less resistant rocks). The less resistant units are largely poorly cemented, platy sandstones rather than shale. The shale beds in the formation, except for the basal shale, seem to be of limited lateral extent.

The basal shales of the Bjorne at Trold Fiord (location 2) appear to be marine. Although no fossils were found at this locality, the ammonite Otoceras has been reported from the lower part of the section at Trold Fiord[1]. The basal shales in the Sawtooth Range may be correlative with the basal shales at Trold Fiord and may also be marine.

The upper half of the section at Trold Fiord appears to be largely fluviatile with abundant channels and much red weathering. There is also a noticeable increase in red weathering colour as well as a small increase in abundance of conglomeratic sandstone toward the top of the Bjorne Formation in section 6.

In the central part of the Trold Fiord section there are crossbedded sandstones similar to the bulk of the rocks in the Bjorne at localities 1, 3, 4, 5 and 6, which presumably indicate deposition in a complex of environments along the shoreline.

The reason for the thicker Bjorne Formation in the Sawtooth Range is not apparent at present. The trend of regional shoreline appears to have been northwesterly in this region and with regional slope to the west. The Bjorne Formation, in this area, appears to have been deposited during a period of marine transgression followed by regression. This may be a reflection, in the Bjorne, of conditions that resulted in the paraconformity between the Bjorne and overlying Schei Point Formations at Tanquary Fiord.[4]

[1] Tozer, E.T.: Triassic stratigraphy and faunas, Queen Elizabeth Islands, Arctic Archipelago; Geol. Surv. Can., Mem. 316 (1961).

[2] Trettin, H.P., and Hills, L.V.: Lower Triassic tar sands of northwestern Melville Island, Arctic Archipelago; Geol. Surv. Can., Paper 66-34 (1966).

[3] This name is in local use for the range that extends across Fosheim Peninsula from Cape With in Cañon Fiord, to the entrance of Vesle Fiord.

[4] Tozer, E.T.: Mesozoic and Tertiary Stratigraphy, western Ellesmere Island, Axel Heiberg Island, District of Franklin; Geol. Surv. Can., Paper 63-30 (1963).

117. OFFSHORE DISTRIBUTION OF PALEOZOIC FORMATIONS, HUDSON BAY

Project 710066

B.V. Sanford

See Report 88 of this publication.

---

118. JURASSIC AND CRETACEOUS STRATIGRAPHY OF ROCKY MOUNTAIN FOOTHILLS, NORTHEASTERN BRITISH COLUMBIA AND ALBERTA (83 E, I, 93 I, O, P, 94 B, G)

Project 680084

D.F. Stott

Field investigations of Jurassic and Cretaceous rocks of northeastern British Columbia and Alberta were concluded in 1971. This work completes the writer's regional stratigraphic studies along the northern Foothills and the mapping of these rocks between latitudes 54° and 60°. The mapping program is part of Operation Smoky. Most of the work in 1971 was concentrated between Narraway River and Mountain Park.

The Jurassic Fernie Formation is in the order of 3,000 feet thick east of Cecelia and Coté Creeks near the junction of the McBride (93 G), Monkman (93I), Wapiti (83 L), and Mount Robson (83 E) map-sheets. A sandy unit occurs in the upper, but not uppermost part, but is not recognized elsewhere along the Foothills. Farther east, between Smoky River and Mountain Park, the thickness of the Fernie ranges between 800 and 1,000 feet. In that area, the standard lithologic units found within the formation in the central and southern Foothills can be recognized.

The Minnes Group between Narraway and Berland Rivers is divided into two major units; a basal fine-grained quartzose sandstone, and a thick overlying cyclic sequence of carbonaceous sediments. In this region, the basal sandstone ranges from 1,000 to 2,000 feet thick and the overlying succession, from 1,300 to 3,700 feet. These beds are truncated southward and eastward by the pre-Cadomin unconformity. Although thin layers of coal occur in the upper unit, no major seams were observed.

The succession overlying the Fernie Formation between Berland River and Mountain Park has generally been assigned to the Nikanassin Formation. It is 930 feet thick at Folding Mountain and in the order of 1,800 feet at Mountain Park. Although some carbonaceous sediments are present, the succession consists dominantly of alternating units of fine-grained sandstone and dark grey shale, presumably of marine origin.

Additional data were obtained on the distribution and facies of the Bullhead and Fort St. John Groups. The Moosebar marine shales are readily recognized throughout the Foothills in the region of Smoky River. A thick coal seam, occurring above the basal Commotion (Gates) sandstone appears to extend over a large area north of Grande Cache, and other major seams occur in both Gething and Commotion strata.

---

119. SILURIAN IGNEOUS ROCKS IN THE WESTERN ROCKY MOUNTAINS, NORTHEASTERN BRITISH COLUMBIA (93 H, I)

Project 680084

G.C. Taylor, R.B. Campbell, and B.S. Norford

East of the Rocky Mountain Trench, within the southwest corner of Monkman Pass (93 I) and northwest corner of McBride (93 H) map-area, lies a poorly exposed volcanic complex of Silurian age. Taylor and Campbell studied these exposures in an attempt to relate them to the regional geology and Norford examined the associated faunas.

Exposures are not good, being largely confined to a series of small exposures along the Bearpaw Ridge, the crest of which lies very close to timberline. Fossils are scarce, and to date have been recovered only from the younger sequence which contains the volcanics.

A local stratigraphic succession was established for Bearpaw Ridge which could be correlated only tentatively with a well-established succession farther to the east. The oldest strata identified appear to be representative of the McNaughton Formation of the Early Cambrian Gog Group. Quartzites of the McNaughton outcrop in the floor of the Torpy River valley. These are overlain by thick resistant limestones belonging to the Mural Formation which outcrop low on the east flank of Bearpaw Ridge. Farther up the flank there is a second thick resistant carbonate which is mainly dolomite. Some of these strata have been assigned to the Titkana Formation as they exhibit the peculiar "zebra mottling" that is characteristic of the Titkana Formation of the Dezakio Range. The Titkana is overlain by a thick sequence of light grey weathering, recessive, calcareous shales and argillaceous limestones. True thickness of this interval is difficult to determine because of local structures, incomplete exposure, and lack of internal distinctive marker beds, but is estimated at a few thousand feet. The sequence is probably coeval with the Lynx and Chushina Formations of the Dezakio Range and may also include equivalents of the Skoki and Beaverfoot Formations. No fossils have yet been found to demonstrate this conclusion, but the interpretation is reasonable on the basis of stratigraphic position and anticipated facies change. This sequence is overlain transitionally by more resistant, dark grey dolomitic shales, dolomite, and limestone which are the highest stratigraphic units on Bearpaw Ridge. A white orthoquartzite unit occurs low in this succession constituting the only distinctive local stratigraphic marker. Silurian fossils have been collected both above and below the quartzite marker. In addition, Norford examined a thick well-defined Silurian section that is exposed fifteen miles to the northeast in the Dezakio Range and concluded that both these successions should be assigned to the well-known Nonda Formation of Northeastern British Columbia. Two collections (GSC loc. C-10505, C-10506), considered to be part of the same assemblage, were made from dolomites intimately associated with volcanic rocks on Bearpaw Ridge; they include Catenipora sp., Cystihalysites 2 spp., Favosites 2 spp., Favosites cf. F. favosus (Goldfuss), Mesofavosites sp., ?Multisolenia sp., and Pentamerus sp. Norford has assigned a late Llandovery age (late Early Silurian) to this fauna.

Greenstone sills are common within the Nonda Formation near the summit peaks of Bearpaw Ridge. Farther north along the ridge a distinctive sequence of volcanic sediments occurs locally within the Nonda carbonates. Coarse agglomerates, including much scoriaceous material, were deposited contemporaneously with the carbonates. Much of the volcanic material exhibits rinds caused by subaerial weathering but is now enclosed in fossiliferous marine carbonates. All variations from dolomite breccias with volcanic matrix to volcanic bombs in a carbonate matrix occur. The carbonates, where associated with the volcanics, have a distinctive orange-brown weathering colour. Near the site of maximum deposition of the volcanic sediments a small pluton was observed. The rock is medium- to coarse-grained sodalite syenite. The only contact metamorphic effect noted was a very fine grained hornfels at the contact of the pluton with the sediments. Exposures of the pluton are very poor but boulder samples taken from streams adjacent to the pluton indicate the occurrence of diverse differentiates of hornblendite, to porphyritic trachyte, to near monomineralic orthoclase syenite.

In summary, near the north end of what is now Bearpaw Ridge, it would appear that a small alkalic volcano developed near the end of Early Silurian time. The volcano erupted on the site of carbonate deposition and formed a small atoll-like island. Most of its surface activity appears to have been of an explosive nature as flow material constitutes a very small percentage of the igneous material preserved.

No significant mineralization was observed within the volcanics, although a small showing of copper mineralization was noted within the Mural Formation near the northeast terminus of Bearpaw Ridge.

---

120. CRETACEOUS STRATIGRAPHY BETWEEN BLOW AND FISH RIVERS, YUKON TERRITORY

Project 700068

F.G. Young

The author spent seven weeks in the area shown on the inset map (Fig. 1) to obtain stratigraphic information on mainly Cretaceous rocks, particularly those of the Aptian–Albian sequence. Considerable help was given by J.A. Jeletzky, who reconnoitered the stratigraphy with the writer for several days; T.P. Chamney, who collected samples for micropaleontological research; and D.H. McNeil, senior assistant.

In northeastern Yukon Territory, three sequences of sedimentary rocks represent almost the entire Cretaceous System. Each sequence is depositionally and petrographically distinct: the lowest one is a marginal cratonic sequence Jurassic to Early Cretaceous (Barremian) in age; the middle one a flyschoid clastic wedge (late Early Cretaceous); and the highest one a molasse-like clastic wedge (Late Cretaceous to possibly Early Tertiary).

Jurassic - Lower Cretaceous Sequence

The lowest sequence has been well documented by Jeletzky[1, 2, 3] in areas immediately to the southeast and southwest of the study area. In this area, exposures are limited mainly to Fish River gorge and north-south trending Gilbert Anticline to the southwest of Mount Davies Gilbert. In Gilbert Anticline the lower sandstone, white quartzite, and coaly quartzite divisions of Jeletzky are all represented by lenticular sandstone bodies which are separated laterally and vertically by bioturbated silty mudstone. These rocks may represent a series of barrier-island and nearshore bars. At the southern end of the anticline (68°20'45"N, 136°50'00"W), this facies comprises a zone that is about 1,800 feet (540 m) thick, but northward and northeastward it thins markedly. The total thickness of Neocomian sandstone beds on Fish River (68°27'N, 136°32'W) is only 25 feet (7.5 m). Based on tentative identifications of pelecypods by Jeletzky and observations of weathered zones on Fish River, it seems probable that the thinning is due partly to erosional truncation of these divisions prior to deposition of the upper shale-siltstone division.

The upper shale-siltstone division of Jeletzky[1] is 860 feet (260 m) thick on Fish River at 68°28'N, and consists of a basal unit of grey shale and silty mudstone with clay ironstone concretions (250 feet or 76 m), a medial unit of grey mudstone with silt-streaks (440 feet or 135 m), and an upper unit of dark grey burrowed shale (170 feet or 52 m).

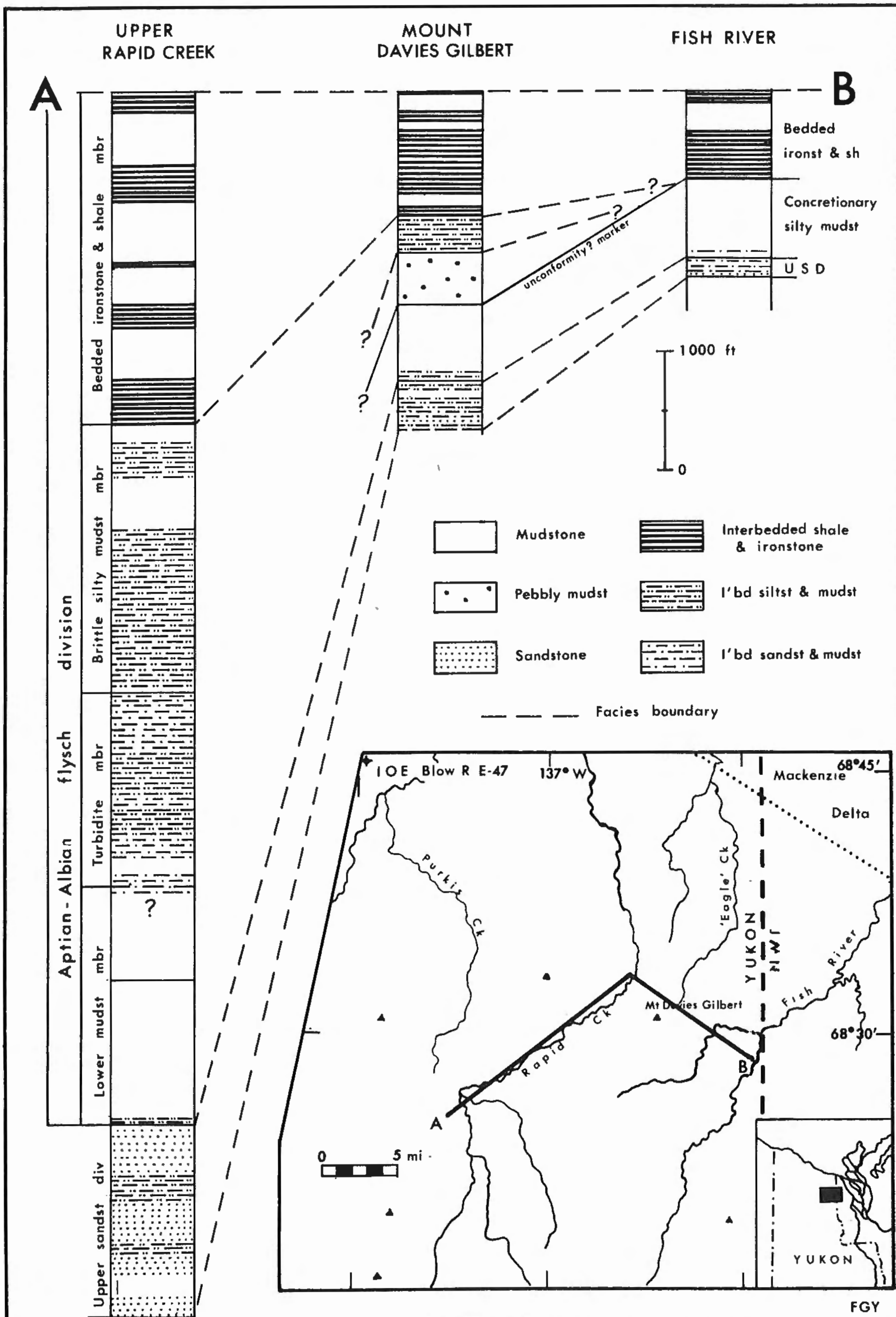
The upper sandstone division overlies the upper shale-siltstone division gradationally east of 136° 45'W, and seems naturally a part of the lowest sequence. Westward, however, a thick sandstone formation in the equivalent stratigraphic position abruptly overlies the upper shale-siltstone division, possibly disconformably, near Blow River where a 400-foot-thick conglomerate marks the base of the unit. Internal relationships of the upper sandstone division are still being worked out.

This division is relatively thin in Fish River gorge and near Mount Davies Gilbert (Fig. 1), and is overlain gradationally by the concretionary, silty mudstone division. Westward and southward the upper sandstone division thickens rapidly, possibly as a facies change with the concretionary, silty mudstone division. At the southern end of Gilbert Anticline, the upper sandstone division is at least 1,000 feet (305 m) thick. From there toward the north-northwest, the unit intertongues with marine shale at the headwaters of Rapid Creek (ref. 3; Fig. 1), then becomes nearly all sandstone and conglomerate in the highland between Blow River and Purkis Creek. This conglomerate contains phenoclasts of quartzose sandstone exhibiting probable Jurassic Neocomian pelecypods, indicating that a source area lay nearby which included uplift strata of the underlying units.

Sandstones from the upper sandstone division are noticeably richer in chert fragments than the nearly pure quartz arenites of Jurassic and Neocomian ages. In Gilbert Anticline and between Rapid Creek and Blow River the upper two-thirds of the upper sandstone division is rich also in limestone fragments.

Aptian - Albian Flysch Sequence

The Aptian - Albian flysch sequence overlies gradationally and with apparent conformity the upper sandstone division equivalent in the western


UPPER RAPID CREEK
MOUNT DAVIES GILBERT
FISH RIVER
A
B
Bedded ironstone & shale mbr
Brittle silty mudst mbr
Turbidite mbr
Lower mudst mbr
Upper sandst div
Aptian - Albian flysch division
Bedded ironst & sh
Concretionary silty mudst
U S D
unconformity? marker
1000 ft
0
Mudstone
Pebbly mudst
Sandstone
Interbedded shale & ironstone
I'bd siltst & mudst
I'bd sandst & mudst
Facies boundary
IOE Blow R E-47
137° W
68°45'
68°30'
Mackenzie
Delta
Purkis Ck
'Eagle' Ck
Rapid Ck
Mt Davies Gilbert
Fish River
YUKON
NWT
0
5 mi
YUKON
FGY

part of the study-area. This sequence of brittle, dark grey mudstone, ferruginous (sideritic) argillite, and fine-grained turbidite sandstone attains a thickness in excess of 10,000 feet (3,050 m) in the drainage basins of Purkis and upper Rapid Creeks. Due to intense structural deformation in these areas the stratigraphic succession is difficult to establish, but the part shown in Figure 1 is definite.

The lowest member consists of dark grey, brittle mudstone, between 2-4,000 feet (610 - 1,220 m) thick. The turbidite member is somewhat greater than 1,600 feet (500 m) thick, and consists of interbedded mudstone and siltstone or very fine-casts, and load-casts on the undersurfaces of the beds. Petrographic studies show that these sandstones belong to the "greywacke" clan, with granular components of approximately 50 per cent quartz, 25 per cent chert, and 25 per cent sedimentary rock fragments. This member may be the lateral equivalent of the chert conglomerate unit of the sequence near Bonnet Lake[3].

Above the turbidite member the brittle, silty mudstone member is transitional in character between the turbidites and the bedded ironstone and shale member. It forms a thick, recessive, poorly exposed section in the order of 2,200 feet (670 m) thick.

In gradational contact above the brittle mudstone member is the bedded ironstone and shale member which exceeds 2,800 feet (850 m) in thickness in the Purkis Creek area, but decreases eastward to about 700 feet in the Fish River–Cache Creek area (Fig. 1). The thick western sequence is dominated by dark grey splintery shale, silty in the basal 500 feet (150 m), with only minor amounts of bedded siderite ironstone. The latter rocks and transitional sideritic shale beds weather to a characteristic irridescent bluish grey. This member becomes richer in ironstone beds eastward and consequently becomes more resistant, forming steep-walled gorges on Rapid Creek and Fish River. The bedded ironstone and shale member oversteps older members eastward, and was observed to lie unconformably upon the upper sandstone division five miles (8 km) east of Mount Davies Gilbert.

Two random samples of bedded ironstone, spaced 240 feet (73 m) apart in the Fish River section, were analyzed by X-ray and chemical techniques (Table 1)(A.E. Foscolos, internal report).

Of possible economic interest are the relatively enriched portions of iron, manganese, and phosphate.

Toward the area of Mount Davies Gilbert the flysch sequence thins very rapidly (Fig. 1). Above the concretionary, silty mudstone division, the sequence here consists of a pebbly mudstone member, 440 feet (135 m) thick, a siltstone member 310 feet (95 m) thick; the bedded ironstone and shale member, 835 feet (255 m) thick; and a yellow-weathering shale member, more than 250 feet (76 m) thick.

The yellow-weathering shale unit is relatively recessive, and oxidizes to bright red and ochre colours in outcrops. It is commonly disharmonically folded in the eastern part of the study area. The top of this unit is not exposed near Mount Davies Gilbert, but near Fish River, where it is well exposed, it is about 400 feet (120 m) thick. There, grey-black montmorillonitic claystone forms most of the unit. It contains several prominent yellowish bentonite beds, septarian carbonate concretions, and a few selenitic mudstone beds. According to Chamney (this publication), microfauna from this unit indicate a correlation with the Bituminous Zone of Anderson Plain east of Mackenzie Delta.

TABLE 1

CHEMICAL AND MINERAL ANALYSES OF BEDDED IRONSTONE

Total Chemical Analyses	Sample 108-YA-1	Sample 108-YA-4
% SiO_2	15.00	9.60
% Al_2O_3	4.53	4.73
% TiO_2	0.17	0.17
% Fe_2O_3*	38.61	34.12
% MnO	5.72	4.52
% Na_2O	0.18	2.26
% K_2O	0.37	0.60
% CaO	3.31	5.99
% MgO	2.87	2.56
% BaO	0.00	0.04
% P_2O_5	7.85	20.00
% L.O.I.	21.08	14.75
% TOTAL	99.69	99.54
Mineral Analysis		
% Apatite	5.94	10.75
% Kaolin	8.14	6.88
% Pyrite	0.06	2.12
% Siderite	55.95	31.06
% Quartz	11.28	6.46
% Non-crystalline components	18.64	42.73

* Total % iron reported as % Fe_2O_3.

Upper Cretaceous Sequence

The Upper Cretaceous sequence includes, in ascending order, the basal chert conglomerate and sandstone division, the Upper Cretaceous shale division[4], and the Moose Channel Formation[5]. Detailed field studies indicate that the type section of the Moose Channel Formation on Fish River[6] does not include at least 900 feet (275 m) of younger, mostly nonmarine strata. These beds are exposed near Coal Mine Lake along the banks of "Eagle Creek" (inset map, Fig. 1).

The contact between the chert conglomerate and sandstone division and underlying yellow-weathering shale unit is either abrupt or deeply scoured. The contact may represent an unconformity locally or simply a normal channel-fill deposit where a deltaic distributary scoured its way into a previously deposited series of prodeltaic siltstone and shale beds. The unit is extremely variable in thickness and lithology, weathers to a characteristic dark orange-brown to red-orange, and is as much as 200 feet (60 m) thick. Preliminary modal analyses indicate that the sandstone of the unit consists of 67 per cent grey to black chert and 33 per cent quartz.

Owing to the recessive nature of the Upper Cretaceous shale division, no complete section is available. However, it appears to thicken from 1,200 feet (370 m) on Cache Creek to over 2,500 feet (760 m) on lower Rapid Creek. The major part of this unit is dark grey, soft shale which weathers light grey, and contains minor beds of sand, silt, fluted sandstone, and marlstone.

Overlying the section of the Moose Channel Formation exposed on Fish River is a coal-bearing member at least 900 feet thick. On "Aklak" Creek which drains into the southern end of Coal Mine Lake, this member consists of chert-pebble conglomerate, fine- to medium-grained arenite (in part carbonaceous), silty mudstone, red siltstone, red sintered rocks, and coal and coaly mudstone in two seams which are each 20 feet (6 m) thick.

The Upper Cretaceous strata are rarely flat lying, but are deformed into broad, large-scale folds, with dips commonly 20 to 40 degrees. Structural grain in these rocks is north-northwest near the northwest corner of Mackenzie Delta, in contrast with the northeast structural trends displayed by Albian and older rocks in the Fish River area. The upper Cretaceous rocks are broken by widely spaced northeast-trending faults which almost invariably display apparent left-lateral displacement.

[1] Jeletzky, J.A.: Uppermost Jurassic and Cretaceous rocks of Aklavik Range, northeastern Richardson Mountains, Northwest Territories; Geol. Surv. Can., Paper 58-2 (1958).

[2] Jeletzky, J.A.: Uppermost Jurassic and Cretaceous rocks, east flank of Richardson Mountains between Stony Creek and lower Donna River, Northwest Territories; Geol. Surv. Can., Paper 59-14 (1960).

[3] Jeletzky, J.A.: Stratigraphy, facies and paleogeography of Mesozoic rocks of northern and west-central Yukon; *in* Report of Activities, Part A: April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 203-221 (1971).

[4] Jeletzky, J.A.: Upper Jurassic and Lower Cretaceous rocks, west flank of Richardson Mountains between the headwaters of Blow River and Bell River, Yukon Territory; Geol. Surv. Can., Paper 61-9 (1961).

[5] Mountjoy, E.W.: Upper Cretaceous and Tertiary stratigraphy, northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 66-16 (1967).

[6] Young, F.G.: Mesozoic stratigraphic studies, northern Yukon Territory and northwestern District of Mackenzie; in Report of Activities, Part A: April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, pp. 245-247 (1971).

---

121. STRATIGRAPHY OF THE UPPER MIETTE GROUP, CENTRAL ROCKY MOUNTAINS (83 E, 93 H (EAST HALF))

Project 670059

F.G. Young

The stratigraphy of the upper Miette Group was examined at seven localities in the western half of Mount Robson map-area (NTS 83 E) and the eastern half of McBride map-area (NTS 93 H). This investigation has led to refined concepts of the transition from Windermere to Lower Cambrian sedimentation in this area, and revised correlations among units in the upper Miette, Gog, and Caribou Groups. Published and unpublished stratigraphic data kindly provided to the writer by O.L. Slind of Shell Canada Limited inspired the writer to make the present investigation.

In western Mount Robson map-area the following succession of stratigraphic units was established in ascending order from the middle to the top of the Miette Group:

1. a feldspathic grit and sandstone unit (top of middle Miette), which is variably interbedded with mudstone and rare limestone beds; grades laterally into the type Byng Formation which has coarse arkose and feldspathic dolostone at its top; thickness of zone ± 1,600 feet (490 m) thick.

2. a lower mudstone unit, generally with interbedded siltstone and very fine grained sandstone, recessive; measured thicknesses range from 700 to 1,800 feet (210-550 m).

3. a calcareous unit, consisting of interbedded calcareous siltstone, quartz sandstone and mudstone; probably grades laterally into the Cunningham Formation equivalent in McBride map-area to the west; thickness 0-300 feet (0-90 m).

4. a quartz sandstone unit, commonly displaying burrows, crawling trails and other ichnofossils, in part interbedded with silty mudstone; weathers to a characteristic banded orange-brown and grey pattern in relatively thick developments of the unit; thickens from 90 feet (27 m) near Twintree Lake to over 1,500 feet at the junction of Chalco Creek and Holmes River (53°22'N, 119°56'W).

5. an upper silty mudstone unit, dark brown and recessive, containing burrows and trails commonly, in sharp contact above unit (4) where observed in Snaring Thrust Sheet, and sharply overlain by feldspathic pebble-conglomerate and quartzite beds of the McNaughton Formation; observed thicknesses range from 100 to about 1,800 feet (30-550 m) thick.

At Holy Cross Mountain (53°47'N, 120°48'W) in McBride map-area the McNaughton quartzite is underlain by a succession having characteristics similar to the one described above and to the lower part of the Caribou Group of the west side of the Rocky Mountain Trench. Particularly striking is the similarity of the greenish grey phyllitic mudstone unit underlying the McNaughton to the Yankee Belle Formation of the Caribou Group. This 1,000-foot (305 m) thick unit is in turn underlain by 220 feet (67 m) of quartzitic sandstone, which is followed below by a dominantly carbonate formation, 440 feet (134 m) thick. The carbonate unit is similar in lithology and stratigraphic position to the Cunningham Formation of the Caribou Group. This section allows direct correlation of lithological units from one side of the Rocky Mountain Trench to the other[2,3], and also implies equivalence of the Yanks Peak Formation of the Caribou Group to the basal quartzite member of the McNaughton Formation at this locality. However, complex changes in facies and thicknesses of the McNaughton and underlying units occur in many directions from Holy Cross Mountain, and remain to be resolved.

[1] Slind, O.L., and Perkins, G.D.: Lower Paleozoic and Proterozoic sediments of the Rocky Mountains between Jasper, Alberta and Pine River, British Columbia; Bull. Can. Petrol. Geol., vol. 14, pp. 442-468 (1966).

[2] Campbell, R.B.: McBride (93 H) map-area; in Report of Activities, Part A: May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 53-55 (1967).

[3] Young, F.G.: McBride area, British Columbia (93 H), Lower Cambrian stratigraphic studies; in Report of Activities, Part A: May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 21-23 (1968).

GENERAL

122. PREPARATION OF COLLECTIONS OF CANADIAN ROCKS AND MINERALS FOR DISTRIBUTION TO THE PUBLIC

Project 400006

J.M. Larose

From May 26 to October 1 more than 26 tons of rocks, minerals, ores and fossils used in various collections produced by the Geological Survey of Canada have been collected from 72 localities in Nova Scotia, New Brunswick, Quebec and Ontario. Over 13,000 miles have been covered. During the field season I was ably assisted by Mr. B. Machin from the Mineral Separation Unit.

---

123. THE NATIONAL MINERAL COLLECTION

Project 550101

H.R. Steacy

H.R. Steacy examined classic mineral occurrences in the Grenville structural province of southwestern Quebec and southeastern Ontario in connection with related excursions of the International Congress in 1972, and collected specimens at the occurrences for the National Mineral Collection.

---

124. MINERAL COLLECTING AREAS ALONG THE ALASKA HIGHWAY

Project 640048

Ann P. Sabina

About 75 mineral and rock occurrences were investigated along the Alaska Highway and in adjacent areas of British Columbia and the Yukon. The purpose was to obtain up-to-date information on occurrences of interest to tourists, collectors and mineralogists. A guidebook describing the localities and giving detailed directions to reach them is being prepared.

The collecting sites include mines (copper, silver-lead-zinc, nickel, asbestos, tungsten), river beds and lake-shores (jasper, epidote, chalcedony), and road-cuts. The most sought after minerals (by visitors) are jade and placer gold. Jade (nephrite) occurs both in British Columbia (Cassiar) and the Yukon (Watson Lake area), placer gold in the Atlin, Mayo, Dawson areas. Visitors may collect from the dumps of most of the active mines and in former operations.

Access to most occurrences is by automobile; for some, a vehicle with 4-wheel drive would be necessary. Others are reached by hiking.

AUTHOR INDEX

LOCATION INDEX

PROJECT NUMBER INDEX