A

GEOLOGICAL SURVEY OF CANADA · 1842 ·

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 70-1
Part A

REPORT OF ACTIVITIES,

Part A: April to October, 1969

Price, $2.00

1970

CANADA

GEOLOGICAL SURVEY OF CANADA

PAPER 70-1
Part A

REPORT OF ACTIVITIES,
Part A: April to October, 1969

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Available by mail from the Queen's Printer, Ottawa.

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

and at

Canadian Government bookshops in
HALIFAX - 1735 Barrington Street
MONTREAL - 1182 St. Catherine Street West
OTTAWA - Corner Mackenzie and Rideau
TORONTO - 221 Yonge Street
WINNIPEG - 499 Portage Avenue
VANCOUVER - 657 Granville Street
or through your bookseller

Price: $2.00 Catalogue No. M44-70-1

Price subject to change without notice

Queen's Printer for Canada
Ottawa
1970

CONTENTS

Page

GEOCHEMISTRY

GEOMATHEMATICS

GEOPHYSICS

Page

PALEONTOLOGY AND BIOSTRATIGRAPHY

PETROLOGY

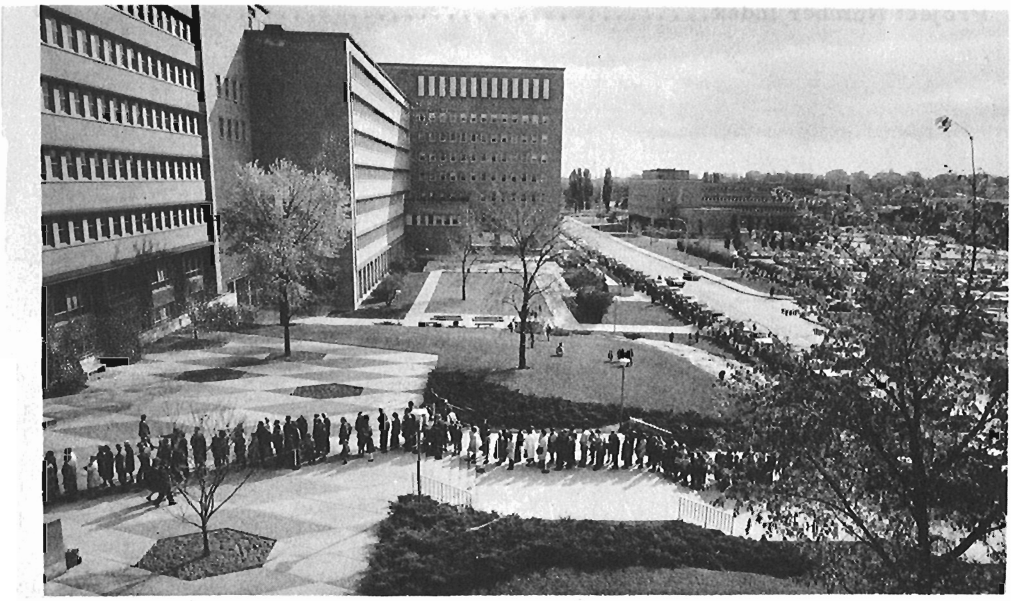
PRECAMBRIAN GEOLOGY

Page

QUATERNARY GEOLOGY; INVENTORY MAPPING AND STRATIGRAPHIC STUDIES

Page

GENERAL



The Geological Survey's change of pace from terrestrial to lunar studies drew much interest from the public. Nearly 25,000 people visited the Geological Survey Building in Ottawa to see three of the lunar samples collected by Apollo XI astronauts.

A distinguished visitor to the exhibition was H.R.H. Prince Philip, shown here with the Hon. J.J. Greene, Minister of Energy, Mines and Resources and Dr. J.A. Maxwell, Branch Co-ordinator of the lunar investigations projects of the Geological Survey of Canada.

ABSTRACT

This report, containing 143 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 1968.

1971

INTRODUCTION

The Geological Survey, one of Canada's oldest scientific agencies, is responsible for providing geological information that can be used in the evaluation of the Nation's mineral potential, in the search for mineral deposits, in planning in the fields of renewable and nonrenewable resources, in northern and regional development, and in land use and engineering studies. The investigation by the Survey of the geology of Canada provides a national and regional framework including correlation of geological knowledge between regions or provinces. Through research and study, competence in various specialized disciplines is provided, standards appropriate to the systematic investigation of the geology of Canada are maintained, and a national cadre of specialists available as a source of expertise is made available to industry, to various federal and provincial authorities and to the general public. The Survey also examines theories, develops and tests new techniques and carries out pilot projects on methods of potential application in geological research and in the search for mineral deposits.

In support of these objectives the Geological Survey had 489 active projects in 1969-70; of these about 220 had a field component and in the short papers that comprise this publication results from many of these studies are presented. To expedite the release of information that may be useful to industry and the general public, this publication is based on reports submitted by Survey officers soon after completion of their field work and prior to October 31, 1969. Scientific results reported in this publication are subject to confirmation by office and laboratory studies. Illustrative material used is as submitted by authors and the text has been given a minimum of editorial attention. The report is made up of 143 papers arranged in broad categories that roughly correspond to the principal scientific sections of the Survey. An index to geographic locations (arranged by province, territory, or district) and an authors' index follow the text, and for internal use project numbers are included with each paper; these are indexed serially following the text. Most reports are keyed to the National Topographic System (as revised in 1960). Requests for geological information, announcement cards concerning publication release dates, maps, reports, or information on specific areas or topics, should be addressed to: Geological Survey of Canada, Department of Energy, Mines and Resources, 601 Booth Street, Ottawa, Canada.

This publication (Paper 70-1, Part A) describes the activities of the Geological Survey between April and October, 1969. Paper 70-1, Part B, to be published in mid- 1970 will include brief reports on work done between November 1969 and March 1970. 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, provides a comprehensive accounting of the scientific work of the organization.

APPALACHIAN GEOLOGY

1. CATAMARAN FAULT, NORTH-CENTRAL NEW BRUNSWICK (PARTS OF 21 I, J, O, P)

Project 690013

F.D. Anderson

Field investigations of the Catamaran fault were concluded. The project involved the detailed study of the fault to determine its extent, offset, deformational style and history.

The fault was traced westerly beyond its previously mapped limits[1,2] for about 2 miles into Plaster Rock map-area (21 J/14) and thence southwestward for about 10 miles into Juniper map-area (21 J/11). Eastward, the fault has been traced for about 4 miles beyond McKendrick Lake map-area (21 J/16)[3] into Newcastle map-area (21 I/13), where it presumably passes beneath Carboniferous cover rocks.

Fabric elements such as fractures and slickensides, were examined in outcrops of relatively homogeneous rocks (i.e. granites and diabase) at regular intervals outward from the fault to determine the extent and nature of deformation attributable to the fault. Preliminary examination of data indicates that the deformation is limited in most cases to within a few miles. Latest movement on the fault was post-Middle Devonian and pre-Pennsylvanian. Several oriented specimens were collected from mylonite and granitic rock along the fault for microscopic examination.

---

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

2 Skinner, R.: Tuadook Lake map-area, New Brunswick; in Report of Activities, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A (this paper).

3 Anderson, F.D.: McKendrick Lake, New Brunswick; Geol. Surv. Can., Paper (in preparation).

2. SEABOTTOM BEDROCK GEOLOGY OF ST. GEORGES BAY, NOVA SCOTIA (11 F/12, and 11 F/13)

Project 660019

D.G. Benson

Field work was limited to scuba diving in St. Georges Bay. An unbroken sequence of strata located between the mouth of McInnes Brook and a point three-quarters of a mile offshore was examined and sampled for spore analysis. Hopefully these samples will provide spores in the interval near the Devonian-Carboniferous boundary not previously found in the Maritime Provinces.

Four seabottom outcrops were found and examined in St. Georges Bay with the assistance of Miss K. Kranck of the Atlantic Oceanographic Laboratory. Diving was undertaken from M.V. Fairmorse, under charter to the Atlantic Oceanographic Laboratory, and at sites selected from examination of sparker records and consideration of onshore geology. Three probable Canso Group outcrops were examined, and on outer Judique Bank samples were obtained of Horton wacke from near the Horton-Windsor contact. Spore analysis will be attempted on some of the samples.

3. OPERATION STRAIT OF BELLE ISLE, QUEBEC AND NEWFOUNDLAND-LABRADOR (PARTS OF 2M, 3D, 12I, 12P, 13A)

Project 680130

L.M. Cumming

Four component parts of a multidisciplinary study of the Strait of Belle Isle Region were undertaken during the 1969 field season:

1. Air gun reflection seismic profiles and conventional marine refraction profiles by G.D. Hobson.
2. Study and mapping of Pleistocene geology by D.R. Grant.
3. Study and mapping of Precambrian (Grenville) gneissic rocks by H.H. Bostock.
4. Study and mapping of Paleozoic strata by L.M. Cumming.

Basic data were obtained relating to resource development of the region, in particular in regard to (a) possible future engineering works in the narrowest part of the strait and (b) occurrence of base metal sulphides in carbonate rocks of western Newfoundland.

Components 1-3 (Projects 640049, 690065 and 680130 respectively) are reported upon separately elsewhere in this publication.

Paleozoic strata were studied and mapped on both sides of the Strait of Belle Isle, especially in parts of 12P and 12I.

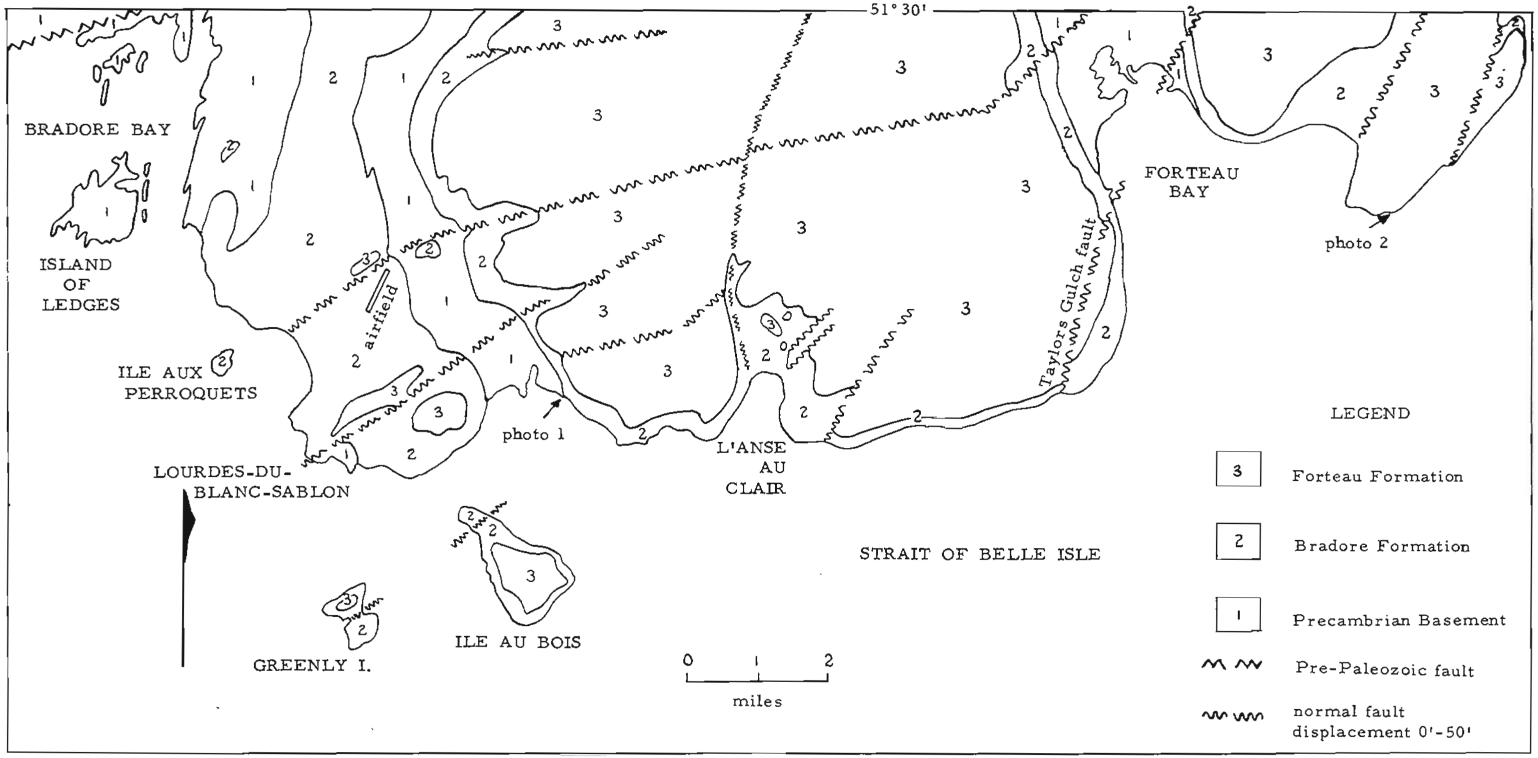


Figure 1. Geological sketch map, south coast of Labrador (12P/6, 12P/7).

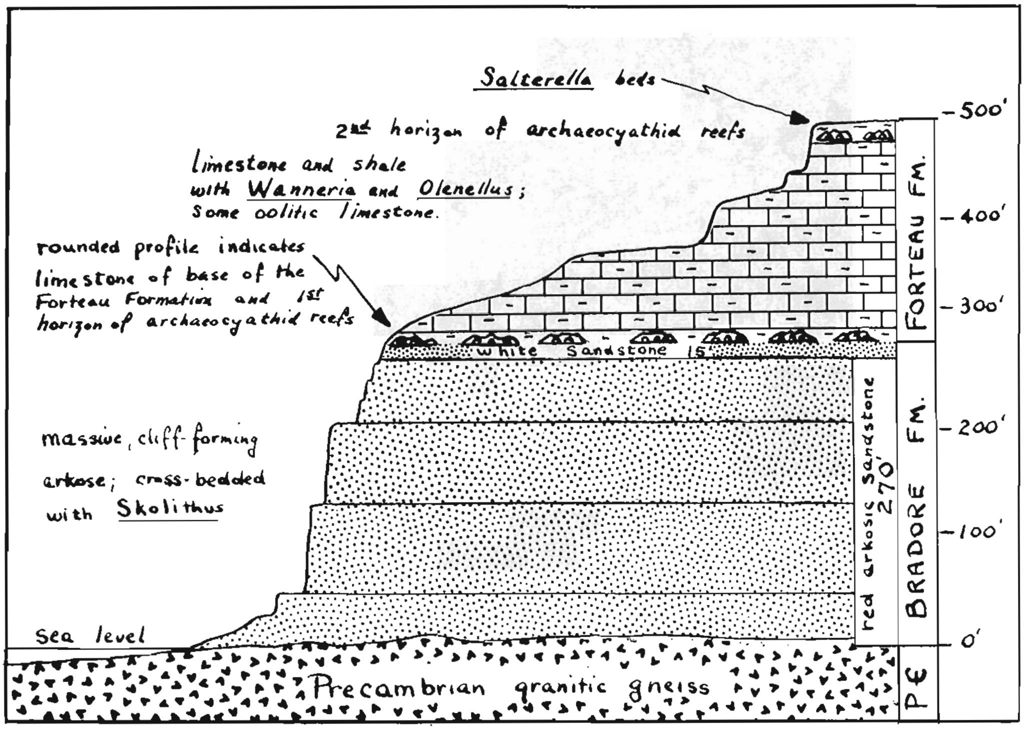


Figure 2. Profile and section of Labrador Group, Forteau Bay.

On the Labrador side, normal faults of small displacement cut the Bradore and Forteau formations of the Labrador Group (see Fig. 1 of parts of map-areas 12P/6 and 12P/7).

Three sets of these normal faults occur:- one trends N20°E, another at N55°E and a third at N80°E. In addition, two parallel and closely spaced faults trend approximately north from L'Anse au Clair. They are shown as a single fault on Figure 1. The two faults are expressed topographically as a narrow bedrock canyon. The canyon extends seaward beneath the strait and might be used to shield buried hydroelectric cables from the hazard of grounding icebergs.

A fault line scarp (shown in the upper left corner of Fig. 1) appears to be part of an older (Precambrian) system of faults which controlled the distribution of the Lower Cambrian cover rocks. This major fault was apparently inactive during Phanerozoic time. Indeed the entire Strait of Belle Isle area is now a stable tectonic region.

Lower Cambrian strata are in unconformable contact with Precambrian granitic gneiss and related rocks (see Fig. 3). The Precambrian surface is a peneplain which dips gently south beneath the Strait of Belle Isle (see Fig. 2). The most southerly exposures of the Lower Cambrian succession are on Ile au Bois and Greenly Island, where the dip averages 2 degrees south.

Assuming this homoclinal structure continues beneath the strait, then the Precambrian basement surface would lie at approximately 1,000 feet

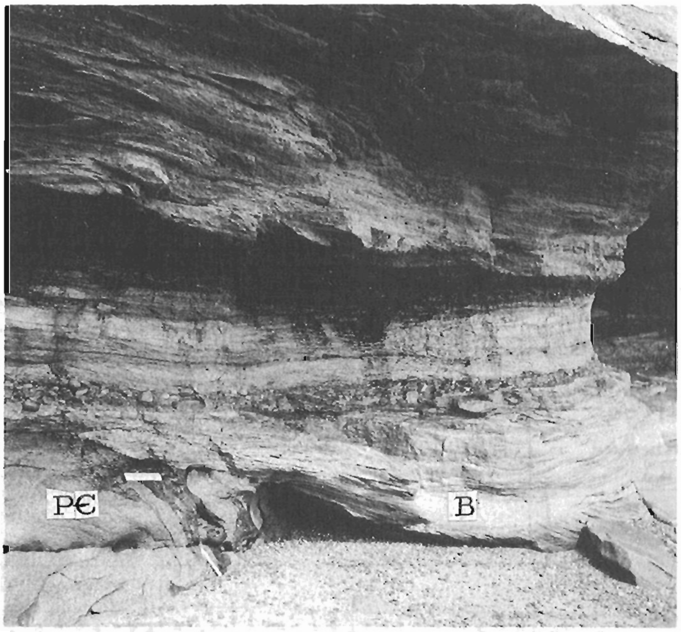


Figure 3. Basal beds (B) of Bradore Formation (Lower Cambrian, arkose and conglomerate) deposited upon the peneplained surface of Precambrian granitic gneiss (PЄ); south coast of Labrador, northeast shore of Baie-Blanc-Sablon, Quebec, at 57°07'30"W. See Figure 1. GSC photo 201248-E.

b.s.l. along the Newfoundland coast. The shoal area (submarine topographic ridge) near the middle of the strait (known as Centre Bank) would then consist of the resistant Lower Cambrian quartzite of the lower part of the Hawke Bay Formation. Stratigraphically this quartzite is underlain by less resistant shale and limestone of the Forteau Formation and overlain by less resistant carbonates of Cambrian and Lower Ordovician age (St. George Formation in part).

On the south side of the strait, Precambrian basement is exposed along the southeast side of a fault which crosses the southwest corner of Ten Mile Lake. There Precambrian granitic gneiss is overlain by arkosic sandstone and dark grey shale of the Bradore Formation, which in turn is succeeded by extensive archeocyathid-bearing limestone (Forteau Formation) which caps the ridge of Mount St. Margaret.

Extensive exposures of the St. George Formation were examined on Pointe Riche and Port au Choix peninsulas (12 I/11), where the following three members were recognized below the Table Head-St. George disconformity, in descending order:

Member 3: dolomite, mottled, 250 feet thick, in massive beds representing cyclic development of algal biostromes.

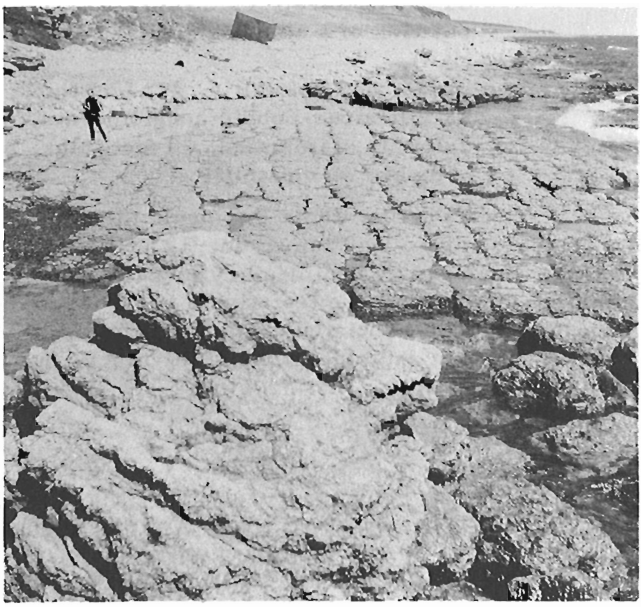


Figure 4.

Patch reefs of Lower Cambrian archeocyathid limestone, Forteau Formation, Pte. Amour, Newfoundland-Labrador. See Figure 1. GSC photo 201248-F.

Figure 5.

Sedimentary breccia north side of Hawke Bay, Newfoundland, at 57°16'30"W. Exposure is on a tidal flat; hammer provides scale and is underwater. GSC photo 201248-C.

Covered interval: a 40-foot stratigraphic interval beneath the waters of Port au Choix Cove. This represents the approximate stratigraphic position of a zinc mineralized zone at Zinc Lake (12 I/6 West Half).

Member 2: limestone, dolomitic, 425 feet thick, basal beds characterized by limestone-pebble conglomerate.

Member 1: dolomite, laminated, 30 feet thick, base not exposed, upper beds are stromatolitic.

At Port au Choix Peninsula the top of Member 1 is 715 feet below the disconformity. At Plum Point (12 P/2) and Hawke Bay (12 I/11), Member 1 is characterized by sedimentary megabreccias (see Fig. 5). These occur within Member 1 and are tentatively regarded as collapse breccias resulting from leaching of associated evaporite beds, indicating the possible development of a second and older zone of dilatancy, in addition to that between Members 2 and 3.

4. STRUCTURAL EVOLUTION OF ROCKS OF THE BATHURST-NEWCASTLE DISTRICT, NEW BRUNSWICK (21 O/7)

Project 690015

Herwart Helmstaedt

A two-year, detailed study of deformational structures of the Tetagouche Group and nearby Siluro-Devonian rocks of the Bathurst-Newcastle district was begun in order to establish the style, sequence of formation and age of the structures and their relationship to base metal sulphide deposits of the district. Four months were spent in the Portage Lakes-Upsalquitch Lake area, the northwest part of the district, which contains sulphide deposits near Portage Lakes, Murray Brook, and Devils Elbow. The area was chosen to compare structures in the Ordovician Tetagouche Group with those of the Siluro-Devonian rocks to the northwest[1] and to study the nature of the contact between these two regional units. At this early stage of the investigation, the following results are apparent:

1. Volcanic and sedimentary rocks of the Tetagouche Group in the Portage Lake-Upsalquitch Lake area become younger towards the northwest.
2. Mapping of mesoscopic structures in the Tetagouche Group confirms the existence of at least three distinct deformational structures (not including younger faults) which are comparable to structures found 20 miles to the east, within Tetagouche rocks[2].
3. One penetrative structure can be recognized in the Siluro-Devonian rocks; younger structures are developed only locally.
4. The contact between the Tetagouche Group and the Siluro-Devonian rocks is a fault in some places and an unconformity in others.
5. Upper Silurian conglomerates are composed mainly of pebbles of diabase, Tetagouche basic volcanics and serpentinized gabbroic rock which has

intruded the Tetagouche Group. Several clasts of red manganiferous cherty argillite of the Tetagouche Group containing a pre-deposition slaty cleavage, have been found in the conglomerate.

The presence of deformed Tetagouche clasts in the conglomerate clearly indicates that at least the first phase of deformation of the Tetagouche Group is a pre-Late Silurian event.

---

[1] Davies, J.L.: Geology of the Bathurst-Newcastle area, New Brunswick; Mines Division, New Brunswick Dept. Nat. Resources, Plate 68-18 (1968).

[2] Helmstaedt, H.: Structural geology of the head of Middle River and Wildcat Brook (06 Map-Sheet); Mines Division, New Brunswick Dept. Nat. Resources (in press).

---

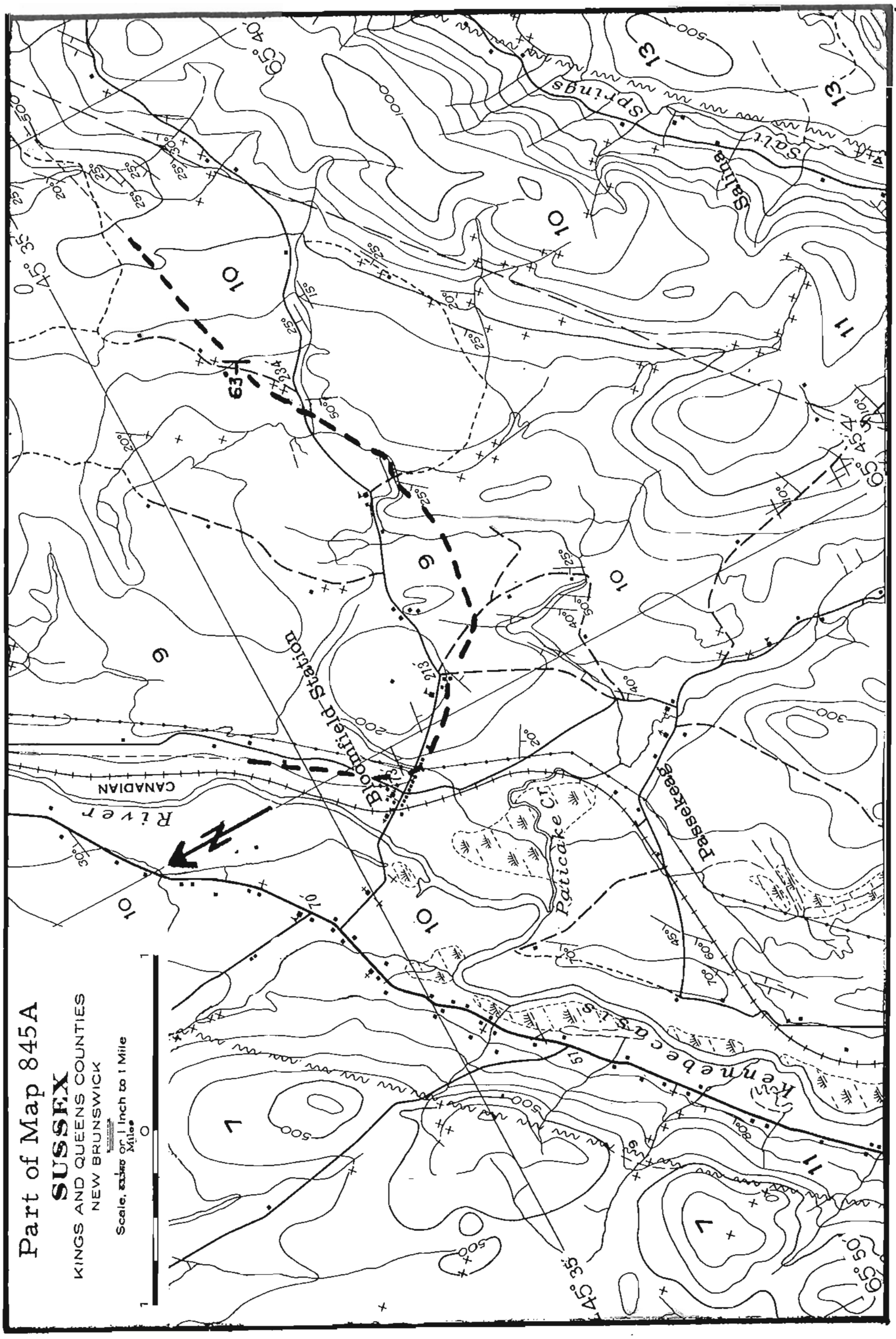
5. SUBSURFACE OIL AND GAS STUDIES, EASTERN CANADA

Project 600456

R.D. Howie

Ordovician strata were examined in the St. Lawrence Lowlands, and core and chip samples were collected from eighteen wells stored by Quebec Department of Natural Resources in preparation for a subsurface stratigraphic study.

In southern New Brunswick, the Albert Formation of the Upper Devonian and Mississippian Horton Group was examined in preparation for a subsurface stratigraphic study of the formation. The formation comprises an assemblage of grey, greenish grey and black shale, sandstone and conglomerate, which in part is highly bituminous and contains commercial quantities of gas and oil in the Stony Creek field. The Albert Formation overlies red beds of the Memramcook Formation and is overlain by red shale and red and green conglomerate of the Moncton Group. The Albert Formation can be best described as a thick sequence of grey to greenish grey shale with periodic intercalations of sandstone and conglomerate. In the Stony Creek gas and oil field, nine miles south of Moncton, the Albert Formation has been divided into six lithologic units[1], many of which are exposed in the Moncton Basin. The most persistent 'sandstone' sequence in the formation is unit 3. It consists of arkosic to subarkosic sandstone and conglomerate composed predominantly of quartz and feldspar. It is exposed at Indian Mountain, in road-cuts near Norton, on Moosehorn Creek and in road-cuts east and southeast of Bloomfield Station. At Mapleton, unit 3 contains conglomerates with clasts of chert, quartz and greenstone. At Elgin, it contains clasts of chert, quartz, felsite, greenstone, sandstone, shale, jasper and minor pyrite. Conglomerates at and near the base of unit 6 at Stuart Mountain and Rosevale are similar to those of unit 3 at Mapleton. Conglomerates at and near the


Part of Map 845A
SUSSEX
KINGS AND QUEENS COUNTIES
NEW BRUNSWICK
Bloomfield Station
Kennebecasis
Passekeag
Salina
Salt Springs
Paticake Cr.
River
CANADIAN
45° 35'
65° 40'
65° 45'
65° 50'

LEGEND

PALÆOZOIC

CARBONIFEROUS

MISSISSIPPIAN AND (?) PENNSYLVANIAN

HOPEWELL GROUP

13	*Red conglomerate, sandstone, and shale*

MISSISSIPPIAN

KENNEBECASIS GROUP, MONCTON GROUP

10, 11	*Grey to red conglomerate, sandstone, and shale*
9	*ALBERT FORMATION: grey shale, sandstone, conglomerate, and limestone*

PRE-CARBONIFEROUS

KINGSTON GROUP

7	*Volcanic rocks*

PROTEROZOIC

COLDBROOK GROUP

4	*Acid to basic volcanic rocks*

Parish boundary (approximate) .... —— ——

Continuation of geological contact ━ ━ ━

base of unit 6 at Mapleton and in the Imperial Pollett River No. 1 well[2] at the 6109-foot-depth are similar to those of unit 3 at Elgin.

In the Bloomfield Station area of the Sussex map-area (21 H/12)[3] the writer's conclusions on the distribution of the Albert, Kennebecasis and Moncton formations are illustrated on Figure 1. It indicates that the Moncton and Kennebecasis groups are equivalent and that both are underlain by the Albert Formation. The contact, previously unmarked in most of the area of Figure 1, is drawn between the Albert Formation and the Kennebecasis-Moncton Group.

---

[1] Henderson, J.A.L.: The development of oil and gas in New Brunswick; Trans. Can. Inst. Mining Met., vol. 43, pp. 159-178 (1940).

[2] Howie, R.D.: Catalogue of well samples from Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland at the Geological Survey of Canada, Ottawa, Geol. Surv. Can., Paper 65-40, p. 27 (1966).

[3] Alcock, F.J., and MacKenzie, G.S.: Sussex, Kings and Queens counties, New Brunswick, Geol. Surv. Can., Map 845A (1946).

---

6. TUADOOK LAKE MAP-AREA, NEW BRUNSWICK (21 J/15)

Project 680078

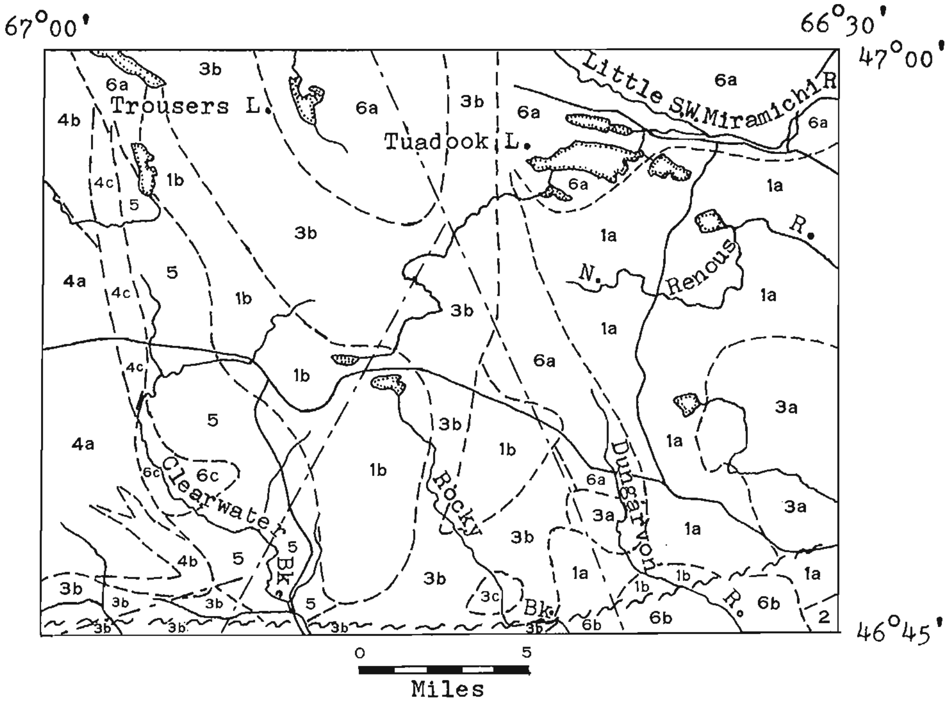
R. Skinner

Geological mapping of the bedrock of Tuadook Lake map-area for publication scale of 1 inch to 1 mile, started in 1968, was completed in 1969.

The map-area lies in the central part of the Miramichi Highlands of New Brunswick, 15 miles southwest of the Bathurst-Newcastle base metal mining camp, and is underlain mainly by Ordovician(?), and Devonian granites and moderately metamorphosed Cambro-Ordovician sedimentary rocks (Fig. 1). The western part of the area is underlain by a large body of Devonian gabbro flanked on the west by Siluro-Devonian volcanic rocks.

Unit 1 consists of shelf-type sedimentary rocks that have been moderately metamorphosed to metasiltstone, phyllite, and quartzite in the east (1a) and more intensely metamorphosed to paragneiss, schist, amphibolite and quartzite in the west (1b). These rocks are commonly magnetic and consequently produce characteristic anomalies on the aeromagnetic map of the area[1]. The strata are tightly folded on mainly northwesterly trending axes and are continuous with similar rocks of Cambrian and/or Ordovician age in adjoining areas[2, 3, 4].

Unit 2 contains basalt, rhyolite, red manganiferous slate, graptolitic black graphitic slate and chert, exposed best on the South Renous River about 2 miles east of the map-area[2].



DEVONIAN
6 6a Grey biotite granite
6b Red leucocratic granite
6c Pink biotite granite

5 Gabbro, minor diorite

SILURIAN AND/OR DEVONIAN
4 4a Rhyolite, red leucocratic granite, minor sedimentary rocks
4b Basalt, minor rhyolite, siltstone, chert
4c Red leucocratic granite

UPPER ORDOVICIAN OR LOWER SILURIAN
3 3a Pink foliated porphyritic granite and granodiorite
3b Pink foliated biotitic and leucocratic granite
3c Grey foliated diorite

MIDDLE ORDOVICIAN (?)
2 Basalt, minor rhyolite, slate, chert

CAMBRO-ORDOVICIAN
1 1a Metasiltstone, phyllite, quartzite, minor paragneiss
1b Paragneiss, schist, amphibolite, quartzite

Figure 1. Sketch map of Tuadook Lake map-area.

Unit 3 contains deformed and altered granitic rocks. In most, biotite has altered to chlorite, and the rocks have undergone cataclasis. In the west half of the area, some of these rocks are gneissic. All are believed to be the same age as those in the Hayesville map-area to the south which are presumed to be Upper Ordovician or Lower Silurian. Unit 3a consists of pink to grey, medium-grained, porphyritic granite and granodiorite, commonly with a well-developed foliation resulting from cataclasis. In places these rocks contain zoned pink feldspar phenocrysts as much as 1 1/2 inches long. Unit 3b contains greenish pink, medium-grained, in places porphyritic, distinctly foliated, biotite granite, and pink, fine- to medium-grained, leucocratic, sugary textured granite; unit 3c is greenish grey, medium-grained, foliated diorite.

Unit 4 comprises rhyolite, granite, basalt and minor sedimentary rocks. Unit 4a consists of pink, red and grey, commonly porphyritic rhyolite; related quartz-feldspar porphyry; red, medium-grained, leucocratic granite; and minor shale, siltstone and greywacke. Unit 4b consists of greenish grey basalt and minor rhyolite, chert and siltstone. Unit 4c consists of red, medium-grained, leucocratic granite similar to that found in unit 4a. This granite appears to be genetically related to rhyolite of unit 4a.

Unit 5 consists of greenish grey, medium- to fine-grained, massive gabbro and minor grey, massive diorite. It commonly contains inclusions of unit 1b and cuts unit 4 in a few places.

Presumed Devonian granitic bodies of unit 6 comprise noncataclastic, massive rocks in which biotite is relatively little altered. Unit 6a consists of grey, medium-grained, massive biotite granodiorite; unit 6b is red, medium- to coarse-grained, leucocratic granite with prominent grey quartz phenocrysts up to 3/4 inch long; unit 6c is pink, medium-grained, in places porphyritic, massive biotite granite.

The most prominent structural feature in the map-area is an easterly trending major fault, the Catamaran Fault, which extends across the southern part of the map-area and east-northeasterly for 20 miles or more across the adjoining McKendrick Lake map-area[2] (see report by F.D. Anderson, this publication).

No significant mineral occurrences are known within the map-area. Phyllite and quartzite (1a) contain rusty zones as much as 1/2 mile south of the Catamaran Fault in the southeast part of the area. Another rusty zone was noted in an outcrop of gabbro on the north side of the Plaster Rock-Renous Highway about 1 1/2 miles northwest of the J.D. Irving,Limited private road leading south across Clearwater Brook. The gabbro contains considerable magnetite and at least some pyrite and pyrrhotite.

---

[1] Geological Survey of Canada: Aeromagnetic Map 144G (1953).

[2] Anderson, F.D.: McKendrick Lake, New Brunswick; Geol. Surv. Can., Paper (in preparation).

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

[4] Anderson, F.D.: Geology, Big Bald Mountain, New Brunswick; Geol. Surv. Can., Map 41-1960 (1961).

7. BELLEORAM MAP-AREA, NEWFOUNDLAND (1 M/11)

Project 690030

H. Williams

Bedrock of the Belleoram map-area was mapped during the 1969 field season under a contract granted Memorial University of Newfoundland by the Department of Energy, Mines and Resources. The area is of economic interest for its molybdenite occurrences, and as well, presents several critical problems in stratigraphy and regional correlation. A molybdenite occurrence was recently discovered immediately west of the map-area during construction of the Belleoram-Pools Cove road. The occurrence, at the margin of a large granite batholith, is similar in most respects to the well-known occurrences north of Rencontre East[1] within the map-area.

Rocks of the map-area are Late Precambrian and Paleozoic volcanic and sedimentary rocks that have been folded about northeast-trending axes, faulted, and intruded by granite batholiths. Most of the map-area is underlain by a thick sequence of mainly silicic volcanic rocks, which are overlain in turn by grey sedimentary rocks, mixed volcanic and sedimentary rocks, and a thick red sedimentary sequence. These have been referred respectively to the Belle Bay, Andersons Cove, Mooring Cove, and Rencontre formations of the Long Harbour Group[2, 3]. All of these rocks are unfossiliferous and were assigned to the Paleozoic by White[2], Widmer[3], and Smith and White[4] all of whom interpreted the Belle Bay volcanic rocks unconformably to overlie dated Cambrian strata at Corbin Bay. This interpretation conflicts with the relationships at Long and Chapel islands where the Rencontre Formation appears to be conformably overlain by sedimentary rocks of either Late Precambrian or Cambrian age. The present investigation indicates that the Belle Bay Formation is faulted against the dated Cambrian strata at Corbin Bay, thus eliminating a major obstacle to the correlation of the Long Harbour Group with lithologically similar Late Precambrian rocks of eastern Newfoundland, e.g. the Musgravetown Group. Whole-rock Rb/Sr age determinations are presently in progress at the Geological Survey of Canada on volcanic rocks of the Belle Bay Formation.

A significant unconformity between the Bay du Nord Batholith and the Cinq Isle Formation[3] was uncovered by detailed mapping in the northwest part of the map-area. None of the rocks in this part of the area are dated by fossils but the stratigraphic succession and relative ages are now clear. The unconformity beneath red sandstones, pebble conglomerates, and micritic limestones of the Cinq Isle Formation is well-exposed northeast of Parsons Cove, East Bay, where arkosic sandstones at the base of the Cinq Isle assemblage overlie pink medium-grained massive granite. To the south, the Cinq Isle Formation is overlain conformably by red conglomerates that form the basal member of the Pools Cove Formation. Elsewhere the red conglomerates are overlain conformably by arkosic sandstone and coarse granite-boulder conglomerates that constitute most of the Pools Cove Formation. In the western extremity of the map-area, arkosic conglomerates of the Pools Cove Formation directly overlie the Bay du Nord Batholith.

The presence of numerous granite boulders in the Pools Cove conglomerates, many of which resemble Devonian granites of Newfoundland, suggests that the formation is Devonian. Also present are boulders of Garrisons Hills gneiss[3,5] that is exposed in the extreme northwest corner of the map-area.

Molybdenite deposits occur at the margin of the Ackley Batholith that has intruded the Long Harbour Group and constitutes much of the northern part of the map-area. The deposits are presently being investigated by Norlex Mines Ltd. and 8,000 feet of diamond drilling was conducted during the 1969 summer.

---

[1] White, D.E.: The molybdenite deposits of the Rencontre East area, Newfoundland; Econ. Geol., vol. 35, pp. 967-995 (1940).

[2] White, D.E.: Geology and molybdenite deposits of the Rencontre East area, Fortune Bay, Newfoundland; Princeton University, Princeton, N.J., unpubl. Ph.D. thesis (1939).

[3] Widmer, Kemble: The geology of the Hermitage Bay area, Newfoundland; Princeton University, Princeton, N.J., unpubl. Ph.D. thesis (1950).

[4] Smith, B.L., and White, D.E.: Geology of the Rencontre East area, Newfoundland; unpubl. ms., Geol. Surv. Can., 46 pp. (1954).

[5] Jewell, W.B.: Geology and mineral deposits of the Baie d'Espoir area; Geol. Surv. Newfoundland, Bull. 17, 29pp. (1939).

COAL RESEARCH

8. CARBONIFEROUS PALYNOLOGY IN THE ATLANTIC PROVINCES

Project 680109

M.S. Barss

Sample collecting was carried out in the Moncton, New Brunswick, and in the Windsor, Riversdale, Antigonish and Port Hastings areas of Nova Scotia, for the palynological study of the Horton, Canso, and Riversdale groups. These groups are considered to be of Tournaisian, Namurian A, and Westphalian A age respectively. However, the many sequences of rocks that have been assigned to these groups have, in many instances, yielded few or insufficient fossils for accurate age determinations. From previous work a miospore zonation has been established in the Horton Group, as well as the assignment of some Horton rocks to the Devonian.

The samples collected in the Moncton and Antigonish areas are from the sequences containing the Devonian age rocks. It is hoped that the Devonian-Carboniferous boundary may be established within these sequences. The samples collected from the Windsor area are from the type section of the Horton Group and complete the stratigraphic coverage of this group in the type area.

The type section of the Riversdale Group was sampled in the Riversdale area and the type section of the Canso Group in the Port Hastings area. These groups, although previously assigned different ages, contain sequences of rocks that are similar in age as revealed by the miospores. It has become evident from palynological studies that miospore zonation can be accomplished in these groups and with the promising material collected from the type section it appears that correlation of the many sequences of rocks assigned to these groups can be made.

9. COLLECTING COAL SAMPLES FOR PETROGRAPHIC ANALYSES, ELK RIVER COALFIELD, BRITISH COLUMBIA (82 G/15, 82 J/2)

Project 610269

A.R. Cameron

Coal properties on Fording River and Fine Creek in southeastern British Columbia were visited. These properties are about 36 and 15 miles north of Michel respectively and on both exploration leading to development of coking coal deposits is actively underway. On the Fording River property the 25-foot-thick No. 5 seam was sampled in 1-foot increments for petrographic analysis. On Fine Creek the No. 8 seam, comprising 34 feet of coal exclusive of partings, was sampled in 17 increments, the individual sample boundaries being determined by partings and visual changes in the character of the coal.

10. RADIOACTIVITY OF TERTIARY LIGNITES IN WESTERN CANADA

Project 680106

A.R. Cameron, P.A. Hacquebard and T.F. Birmingham

Radioactivity in lignites and lignite-bearing rocks was measured in a number of areas in Western Canada. In British Columbia thirty-two stations were checked. These were located on Graham Island in the Queen Charlotte Islands, on Long Bay north of Vancouver, and in the Driftwood Creek, François Lake, Cheslatta Lake, Fraser Lake, Nechako River and Cottonwood River areas of central British Columbia. Readings generally were low. The best obtained was in a road-cut between Tchesinkut Lake and François Lake. At this locality thin lignite beds gave values of 35 μ R per hour over a background of 10.

In the Yukon Territory, lignite exposures were checked near Granite Creek, Amphitheatre Mountain, Cement Creek, and Ptarmigan Creek west and southwest of Burwash Landing. In addition, coaly layers of higher rank were checked on Kimberley Creek, Sugden Creek, Goat Creek west and south of Haines Junction. The highest value yielded by twenty-two stations was only 16 μ R per hour over a background of 10.

In Alberta radioactivity was measured at fifteen localities in the Thelma Creek area of the Cypress Hills and the Rocky Mountain House, Saunders and Coalspur areas in west-central Alberta. All readings obtained were low with the highest being 18 μ R per hour over a background of 8.

In southwestern Saskatchewan several exposures were checked during the two previous field seasons. In 1969 data were obtained at 112 additional stations in the Cypress Hills, Wood Mountain, Fife Lake and Willow Bunch Lake areas. The highest value obtained was 65 μ R per hour over a background of 10 obtained from exposures on Mule Creek east of Chambrey. Readings of 50-60 μ R per hour were obtained on thin lignite beds 6 1/2 miles south of Wood Mountain and 1 mile south of Willow Bunch.

A total of 48 samples was collected for more accurate laboratory measurement of radioactivity by either the end window beta counter or chemical analysis.

11. RANK STUDIES OF COAL AND CARBONACEOUS MATTER, BRITISH COLUMBIA AND ALBERTA

Project 680102

P. A. Hacquebard

In order to provide additional material for the rank studies program a total of 24 samples of various ranks of coal were collected in British Columbia and Alberta. These included five samples of bituminous coal from the Comox, Party Hardy and Holberg Inlet areas on Vancouver Island. Three samples, of which one is lignite, were collected on Graham Island in the Queen Charlotte Islands. In the Crowsnest coalfield seven samples were collected in the Balmer South Mine and represent a layer in the No. 10 seam under different thicknesses of overburden. A similar suite of samples was collected in the Canmore field in Alberta, four of the samples coming from the No. 2 mine on the Stewart seam and five from the Wilson Mine. The No. 10 seam is low volatile bituminous in rank while the Canmore samples are low volatile to semianthracite.

12. PETROGRAPHIC CORRELATION OF COAL SEAMS AT CARMACKS, YUKON TERRITORY (115 I/1)

Project 690026

P. A. Hacquebard

In connection with an inquiry by the Department of Indian Affairs and Northern Development on economic aspects of coal in the Yukon the deposits in the Carmacks area were visited. One of the problems in this area is that of seam correlation and to aid in this regard the following five samples were collected for petrographic analysis:

A. Three column samples in the Tantalus Butte Mine, totalling 30 feet of coal.
B. A channel sample from a 20-foot-thick seam south of the Yukon River at Carmacks.
C. A channel sample taken from the south side of the Yukon River near the old Tantalus Mine. The seam sampled is at least 15 feet thick.

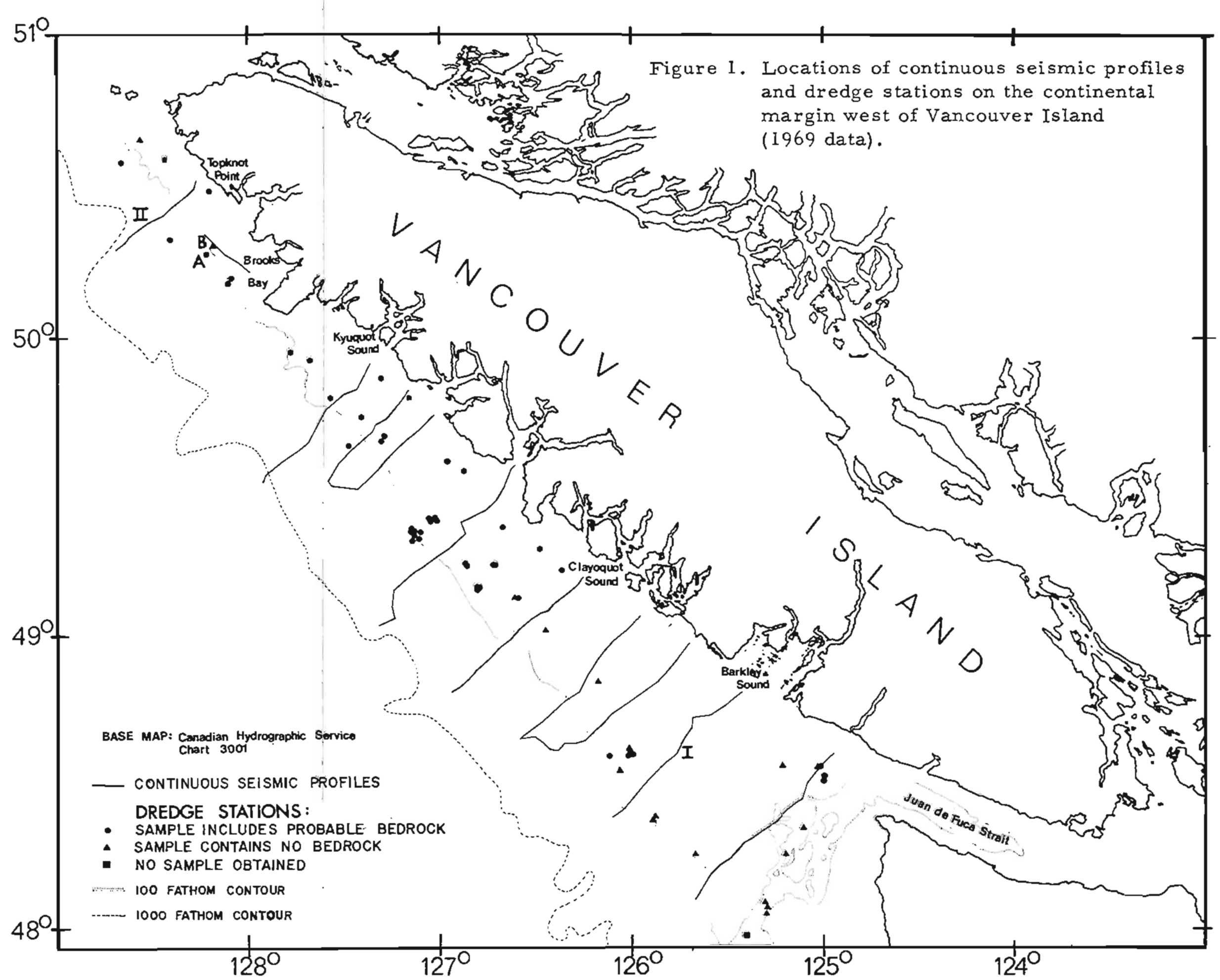


Figure 1. Locations of continuous seismic profiles and dredge stations on the continental margin west of Vancouver Island (1969 data).

CONTINENTAL MARGINS

13. STRUCTURE OF THE CONTINENTAL MARGIN WEST OF VANCOUVER ISLAND, BRITISH COLUMBIA

Project 680138

Sandra M. Barr, and J.W. Murray

Department of Geology,

University of British Columbia

The program of geological and geophysical investigation of the continental margin west of Vancouver Island was continued in the summer of 1969. This project, initiated by the University of British Columbia in 1967, has in subsequent years been supported by the Geological Survey of Canada.

In 1968 continuous seismic profiling equipment, consisting of a 5,000 joule sparker, a sensitive 20-element hydrophone array, and an amplifier-filter unit was purchased. Recording was accomplished by feeding the amplifier output to an Alden wet-paper recorder. Twenty-six seismic profiles (733 miles) were obtained. In addition sixteen successful dredge hauls were made for bedrock samples on the continental shelf and slope[1].

The purpose of the 1969 study was two-fold:

1. To run additional continuous seismic profiles to increase coverage of certain critical areas between profiles obtained in 1967 and 1968.
2. To dredge geologically important sites selected from the 1967 and 1968 continuous seismic profiles in order to identify the age and lithology of subbottom reflectors.

The tracks of the 1969 continuous seismic profiles and the locations of the dredge stations are shown in Figure 1. Precision echo-sounding was run simultaneously with the seismic profiling.

Continuous Seismic Profiles

In the summer of 1969 the continuous seismic profiling equipment was augmented by the addition of a Model 600 B PAR Air Gun. Three hundred and eighty miles of continuous seismic profiles were obtained of which one hundred and fifty miles are air gun lines and the remainder sparker lines.

In the shallow waters of the continental shelf the air gun profiles show less detail than the sparker profiles, and water multiples mask the bottom penetration. However in deeper water the air gun profiles give greater bottom penetration than the sparker.

These continuous seismic profiles reveal that the continental margin west of Vancouver Island includes four distinct provinces:

1. In the area from Barkley Sound south to Juan de Fuca Canyon, the continental shelf is underlain with Pleistocene strata characterized by 'cut and fill' structures. Locally this material is truncated at the slope

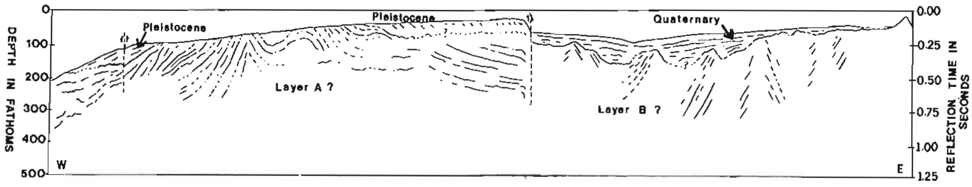


Figure 2. Line-drawing interpretation of continuous seismic profile I on Figure 1.

which is considerably steeper than in adjacent areas immediately to the north. However in most places the Pleistocene sediments form a prograding upper continental slope.

The inner shelf in this area is a series of steep-sided banks and basins partially filled with sediment. The steep sides of some of the banks suggest that they may be fault controlled (Fig. 2). These banks are composed of Pleistocene sand and gravel. Flat-lying Recent sediments in the intervening basins lie unconformably on the irregular Pleistocene surface.

2. In the area north of Barkley Sound and south of Kyuquot Sound the shelf surface is more regular and lacks the basin and bank topography characteristic of the area to the south. However, bedrock topographic highs with as much as 80 feet of relief occur frequently on the shelf surface. Nearshore, the shelf surface becomes convex upward where the younger Tertiary strata wedge out against older, more resistant sedimentary rocks.

Subbottom structures in this area show great variation. In the southern part, off Clayoquot Sound, the shelf is underlain by strata folded into a series of broad anticlines and synclines with some faulting. On the continental slope these strata dip seaward paralleling the sediment-water interface. This youngest sedimentary bedrock unit has been designated Layer A[1]. It is a soft greyish green mudstone of late Tertiary age. Samples of Layer A were obtained by dredging in 1968 and 1969 and microfaunal studies are now being made by the Geological Survey of Canada (see B.E.B. Cameron, this publication).

In the central and northern parts of this area two distinct seismic units are recognized - a gently west-dipping younger unit (Layer A) and a more steeply dipping and more reflective older unit (Layer B)[1]. In the central part of this area, Layer A strata are supratenuously folded over uplifts of Layer B strata. Thinning in some parts of Layer A suggests that Layer B strata were actively deforming during the time of deposition of at least some of the overlying sediments.

Proceeding to the north in the same general area Layer B strata actually pierce through overlying Layer A, in which the strata are tectonically pinched and thinned against the cores of the Layer B uplifts. These Layer B uplifts often break through the surface of the continental shelf and give rise to bedrock topographic highs with as much as 80 feet of relief. In areas of these piercement structures petroleum prospects would be associated with the flanks of the piercements where the younger strata pinch out against the core of the piercement.

In all profiles in this area a prograding cap of Pleistocene (?) sediments rests on older rocks near the shelf break.

3. Between Kyuquot Sound and Brooks Bay Layer A lies on the shelf edge, outcrops on the upper continental slope and appears to be present in slump blocks on the slope. The shelf is underlain primarily by Layer B, many samples of which have been obtained by dredging. Seismic energy does not generally penetrate this hard material but some profiles show strata locally dipping steeply westward.

The shelf in this area is relatively narrow, varying in width from 4 to 18 miles. The surface topography is rugged with up to 100 feet of relief. The upper continental slope has an average dip of approximately 20 degrees, with a continental borderland to the west.

4. In the area north of Brooks Bay the west-dipping strata of Layer A lie unconformably on a more steeply dipping basement and dredging has not obtained any Layer B rocks. The shelf here is about 10 miles wide. The inner shelf, where the basement reaches the surface, has a rugged topography, whereas the surface of the outer shelf, underlain by Layer A, is relatively featureless. A cap of prograding Pleistocene (?) sediments rests on Layer A in the vicinity of the shelf break. A wide continental borderland lies west of the steep (approximately 12-degree) upper continental slope. Seismic profiling has shown that this borderland is underlain by stratified rock. It is uncertain whether this intermediate depth area formed by foundering of parts of the continental shelf along major north-south faults related to the Queen Charlotte-Denali Fault System[2], or by slumping of soft sediments down a relatively steep slope.

Line-drawing Interpretations

Line-drawing interpretations of two seismic profiles (I and II in Fig. 1) are shown in Figures 2 and 3.

Figure 2 is an air gun profile (five-cubic-inch firing-chamber at 2,000 psi) extending from the entrance of Barkley Sound across the continental shelf, a distance of forty miles, and ending on the upper continental slope. In this profile the eastern part of the shelf is generally deeper than the western part. The contact between the two is a steep escarpment near the centre of the profile. The average dip on the outer shelf in the profile is 0°18'. The dip of the upper slope is 1°54'.

Figure 2 shows the deeper nearshore basin partially filled with essentially flat-lying Quaternary sediments lying unconformably on an irregular bedrock surface (possibly correlative with Layer B to the north). The top-of-the-bank in-the-central-part of Figure 2 is underlain by Pleistocene sediments. Gently folded strata (possibly correlative with Layer A) underlie most of the outer shelf except near the shelf break (depth 100 fathoms) where Pleistocene (?) sediments are present.

The sparker profile in Figure 3 begins two and one half miles off Topknot Point near the northern end of Vancouver Island and extends eighteen miles offshore (Fig. 1). It is typical of the northern area of the shelf, under which the rugged pre-Tertiary basement surface dips westward more steeply than the overlying strata. Seismic energy does not readily penetrate this basement material, from which dredge hauls have recovered metasedimentary and gneissic rocks.

Unconformably overlying this basement are layered strata dipping west at a slightly steeper angle than the shelf surface and truncated on

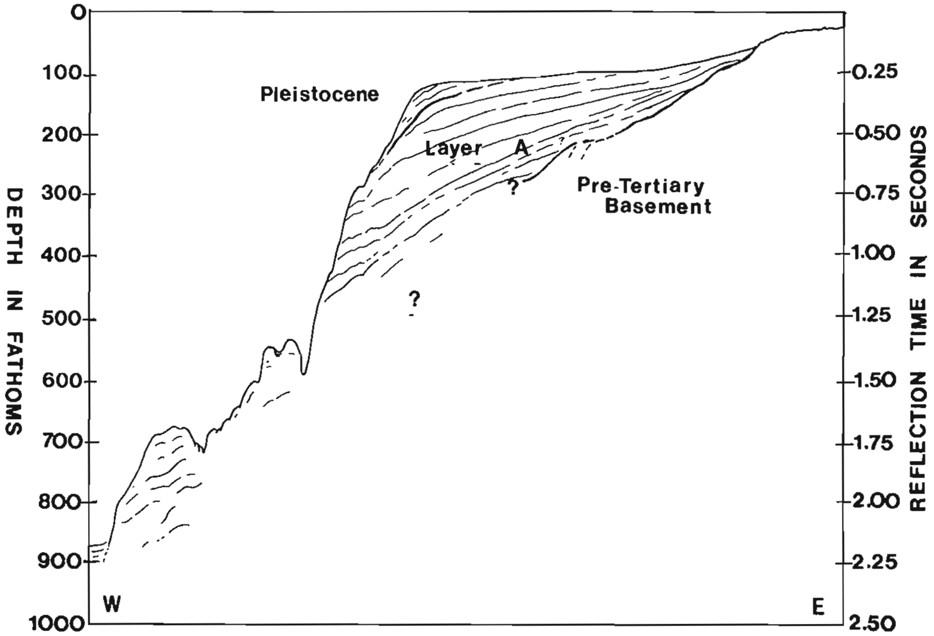


Figure 3. Line-drawing interpretation of continuous seismic profile II on Figure 2.

the slope. This unit is unfolded Layer A. In the area of the shelf break a cap of Pleistocene (?) sediments overlies Layer A.

The dip of the upper continental slope in Figure 3 is 12° 36'. Farther seaward a borderland is present.

Dredging

Sixty-four dredge sites were selected where rugged topography or steep slope suggested outcrops of bedrock. In eighteen cases these sites were completely covered by unconsolidated mud, sand, or gravel and no bedrock samples were obtained. In forty-three hauls probable bedrock was obtained. At the other three stations no sample was obtained because of hard bottom.

Using the seismic profiles in conjunction with the echo-sounder, it is possible to determine the stratigraphic position from which the samples came. All the samples from the dredge hauls – consolidated and unconsolidated – are currently being examined for microfossils.

Sea Level Lowering

The seismic profiles from the continental margin west of Vancouver Island indicate that sea level at some time during the Quaternary was at least 100 fathoms lower than its present level. Caps of prograding sediments, resting on late Tertiary bedrock, as displayed on the profiles in Figures 2 and 3, lie near the 100-fathom depth on most other profiles.

Further evidence for sea level lowering is the extensive erosion found on the continental shelf almost to the shelf edge. If this is submarine erosion, then it is on a scale previously unreported. It is more likely that much of the present shelf was exposed and undergoing subaerial erosion at some time during the Pleistocene, and sediments were deposited seaward from a Pleistocene shoreline.

Two dredge sites (A and B in Fig. 1) were selected from a seismic profile adjacent to and similar to that shown in Figure 3. A haul on the steeper part of the slope from 220 fathoms to 140 fathoms contained sand, a characteristic blue clay, and soft grey-green mudstone of Layer A. Similar blue clays contain Pleistocene Foraminifera (B.E.B. Cameron, pers. comm., 1969). A second dredge haul at the shelf break in depths from 100 fathoms to 80 fathoms contained green muddy sands and rounded pebbles. These data indicate that the caps of strata overlying Layer A on the shelf edge are of Pleistocene age, and thus substantiate at least a 100-fathom lowering of sea level during some stage of the Pleistocene.

---

[1] Murray, J.W., and Tiffin, D.L.: Structure of the Continental Margin west of Vancouver Island, British Columbia; in Report of Activities, April to October, 1968, Geol. Surv. Can., Paper 69-1, Pt. A, pp. 14-17 (1969).

[2] Sutherland Brown, A.: Geology of the Queen Charlotte Islands, British Columbia; British Columbia Dept. Mines and Petrol. Resources, Bull. No. 54, 1968.

---

14. TERTIARY FORAMINIFERAL SUCCESSION OF THE WESTERN CORDILLERA AND PACIFIC MARGIN (PARTS OF 92 and 102)

Project 690075

B.E.B. Cameron

This project was initiated by a detailed study and sampling program in three areas.

1. Sooke Area (92B and 92C)

Approximately one week was spent examining exposures of Tertiary rocks under the guidance of J.E. Muller. The oldest rocks studied were the Eocene Metchosin volcanics. Limestone lenses within the volcanic and associated greywacke sequences yielded many molluscs and orbitoid foraminifers. The latter are currently being sectioned so that specific identifications may be undertaken. Close correlation of the Metchosin with the Crescent volcanics of Olympic Peninsula is anticipated.

Isolated exposures of younger Tertiary sedimentary rocks were systematically sampled from Sooke to Port Renfrew on the west coast of Vancouver Island. Foraminiferal content is moderately good and should be sufficient to enable correlation with offshore samples and the more extensive exposures farther north.

2. Nootka Island (92E)

About 3,700 feet of exposure was systematically sampled of the Oligo-Miocene rocks outcropping in this area. These are the sediments described by Jeletzky[1] as Divisions A, B, C and D of the Tertiary. Foraminifera, ostracodes and various other fossil groups are abundant in most of the measured intervals and indicate depositional environments ranging from shallow marine (miliolidostracode assemblages) to outer shelf (planktonic-Cyclammina assemblages). Planktonic foraminifers, at this early stage of the study, appear to be satisfactory in terms of abundance and variety for close correlation with established foraminiferal zones along the Pacific coast and elsewhere. It is evident from the total assemblages that ultimately more of these rocks will be assigned to the Miocene than previously supposed.

3. Pacific Continental Margin

A program of continuous seismic profiling and bedrock dredging of the western coast of Vancouver Island was carried out under the direction of J.W. Murray of the Department of Geology, University of British Columbia. More emphasis was placed on the recovery of bedrock material for age and lithologic determinations than previously. Sixty-one successful dredge hauls were made from selected exposures. A wide variety of rock types were recovered including limestone, marl, indurated sandstone and many varieties of mudstone. One of the significant findings resulting from these dredgings is a preliminary age determination of Layer B[2], the older sedimentary unit which appears seismically as the cores of anticlines and other structures. A good assemblage of outer shelf foraminifers suggest a middle Miocene age for this unit. Analyses of the remaining dredge samples is continuing. Other aspects of the 1969 offshore program are reviewed by S.M. Barr, and J.W. Murray (see this publication).

---

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

[2] Murray, J.W., and Tiffin, D.L.: Structure of the Continental Margin west of Vancouver Island, British Columbia; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1 Pt. A, pp. 14-17 (1969).

15. SEDIMENTS IN BARKLEY SOUND AND THE ADJACENT CONTINENTAL SHELF, SOUTHWESTERN BRITISH COLUMBIA

Project 680138

L. Carter and J.W. Murray

Department of Geology, University of British Columbia

The field study of the sediments in Barkley Sound and the adjacent continental shelf was begun in 1968, and continued during the summer of 1969. Several weeks were spent sampling the rocks and the sediments around the Barkley Sound shores, while offshore work was carried out from the Canadian Survey Ship Vector during the period 12-18 May. The purpose of this cruise was to make depth sounding runs, sample the bottom sediments, photograph the sea floor, core, collect foraminiferal samples, and obtain water samples.

A gravity corer was used to penetrate the sediments, and produced satisfactory results with cores up to 5 feet in length which had little disruption of bedding. Coring was most successful in fine-grained sediment, but proved to be difficult in sands due to poor penetration, deflection and/or blocking of the core barrel by cobbles and boulders, and loss of sediment as the core was brought to the surface. The cores were examined ashore and revealed two distinct bedding forms: (i) the muds on the shelf and in the well-oxygenated waters of the sound are massive – a feature produced by extensive reworking of the sediment by the large infauna; (ii) sediments in the barred basins of some of the inlets that lead into the sound are finely laminated, presumably because the anaerobic environment does not favour an abundant infauna.

Water samples were taken at a series of stations which ran from the coast to the edge of the continental shelf. It was found that the amount of suspended matter in these samples decreased away from the coast, and increased with depth at any one station.

Sampling of the rock exposures along Barkley Sound shoreline was undertaken in order to shed light on the provenance of the sediments in this area. It was found that there is a distinct correlation between beach sands and the rock type in the vicinity of the beach, e.g. where Pleistocene drift was exposed, the sands were light brown and rich in quartz and feldspar; sands adjacent to intermediate plutonic rocks tended to be slightly darker due to higher concentrations of lithic grains and mafic minerals, whereas sand near Mesozoic sandstone, and basic volcanic rock, is medium to dark grey, the result of even more lithic fragments. These field observations will be checked with detailed mineralogical examinations of both rock and sediment samples.

Laboratory work during the winter of 1968-69 involved:

(i) pipette and sieve grain size analysis of 208 samples, with computerization of the results,
(ii) determination of organic and $CaCO_3$ contents of 103 samples,
(iii) identification of the fauna contained in the sediments,
(iv) detailed examination of cores.

This laboratory program will be continued with clay mineral analyses, petrography of the sediments, and heavy mineral studies.

16. SEDIMENTS OF QUEEN CHARLOTTE SOUND, BRITISH COLUMBIA

Project 680138

John L. Luternauer and J.W. Murray

Department of Geology, University of British Columbia

This report is a sequel to one previously presented[1] and the reader should refer to that report for a reference map of the study area.

The final sediment collection cruise for this investigation was undertaken on the CNAV Laymore during the period June 16-22, 1969. Eighty Pettersson and Dietz La Fond grab samples were obtained. Most of these samples were obtained in the previously unsampled central seaward portion of Queen Charlotte Sound, although several are from grid points where sampling had proven unsuccessful on previous cruises. Thus, grab samples, collected along an approximate four-mile grid, are available for most of the sound. Seven gravity cores (three 9-foot cores and four 4-foot cores) were obtained on the last cruise. The greater success of the coring operations on this cruise than on previous ones can probably be attributed to the fact that analysis of grab samples from previous cruises permitted localization of sites with the finest, best sorted sediments where core barrel penetration is usually best. Fifty small samples were also obtained on the last cruise for a study by the Geological Survey of Canada of foraminiferal distribution.

The grab samples obtained on this cruise revealed sediment characteristics observed on previous cruises: (a) patchy sediment distribution and (b) widespread occurrence of rounded gravels alone or intermixed with other sediment sizes. Both factors point to considerable glacial effects which recent sedimentation has been unable to mask. The cores which were taken in the troughs between the submarine banks reveal a uniform blue-grey clay below the upper foot or two of coarser sediments in the cores.

Three quarters of the samples obtained on the research cruises undertaken for this project have been size analyzed and computer processed for various statistical parameters. Various means of comparing and presenting these results have been programmed for the UBC IBM 360-67 computer. One quarter of the samples have been analyzed for their shell-carbonate content. Thirty widely spaced samples have been selected for trace element analysis which is presently in progress. Faunal assemblages have been sorted from the samples.

---

1 Luternauer, J.L., and Murray, J.W.: Sediments of Queen Charlotte Sound, British Columbia; in Report of Activities, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 9-11 (1969).

CORDILLERAN GEOLOGY

17. OPERATION STEWART, YUKON TERRITORY, DISTRICT OF MACKENZIE (105N, O; 106B, C)

Project 680119

S.L. Blusson and D.J. Tempelman-Kluit

For 1969 field work emphasized the major sedimentary and tectonic features of the project area. Stratigraphic work was limited to Bonnet Plume map-area (106B), including sections in both shale and carbonate facies of Ordovician to Devonian strata and a detailed section in the Lower Cambrian Sekwi Formation by W.H. Fritz (see this publication).

The oldest units, those restricted to the northwest part of Nadaleen map-area (106C), have been previously described[1, 2] from the adjoining Nash Creek map-area. New evidence supports a Late Proterozoic age for the informally named 'Grit' unit (7). In central Nadaleen map-area the upper part may contain carbonates of Lower Cambrian age. The Sekwi Formation (8a) thins out into the Selwyn shale basin just south of Keele Peak.

Northeast of the Territorial boundary the Sekwi Formation is overlain by many thousands of feet of dark recessive shales, platy argillaceous limestone and siltstone (unit 10), containing, near the top, crinoidal carbonate banks of Lower Middle Devonian age. Near the east margin of Bonnet Plume map-area the upper and middle parts of unit 10 change facies southeastward to grey dolomite of unit 9. Here unit 9 includes Sombre, Arnica, Landry and Headless formations and is overlain by noncalcareous, in part rusty weathering, black shale and argillite probably correlative with Fort Simpson Formation. Elsewhere unit 9 is indivisible, uniform, light grey weathering, mostly thick-bedded carbonate. Where it overlies orange and buff weathering Lower Cambrian strata (8) in east-central Nadaleen map-area, unit 9 contains a bright red-weathering basal sand and cobble conglomerate member, locally as much as 75 feet thick.

Continuous sections of intercalated dark shales and chert as much as 10,000 feet thick were noted in unit 12 but its extensive development suggests a far greater total thickness. In southern Niddery Lake area (105O) unit 12 includes, near midsection, a resistant member of chert-pebble conglomerate almost 1,000 feet thick and a highly altered volcanic flow or sill as much as 300 feet thick.

Granitic intrusions are widespread in Lansing (105N) and Niddery Lake map-areas, though confined to argillaceous host rocks.

No new mineral occurrences were found. The host rocks of the Amax tungsten property 9 miles southeast of Keele Peak appear correlative with the Lower Cambrian section at the Canada Tungsten Mine.

Main structural elements are upright, mostly open folds and faulted blocks of gently dipping strata. No pronounced sense of overturning is evident though thrusting is mainly northeastward. Structures southwest of the Territorial boundary are characteristically more compressed and more

Legend

Tertiary

15 — andesite and basalt

Cretaceous

14 — Biotite and hornblende biotite quartz monzonite and granodiorite

Carboniferous or Permian

13 — Light grey and buff weathering thin-bedded dolomite and sandstone

Devonian and (?) Mississippian

11 — Dark grey and black shale and argillite; may include unit 10

Ordovician to Devonian

9 — Light grey weathering thick-bedded dolomite and limestone

Cambrian and Precambrian

8 — Orange and grey weathering thin-bedded limestone dolomite and quartzite; includes Sekwi Formation - 8a, Sekwi Formation

Cambrian and/or Precambrian

6 — light grey weathering limestone

5 — Varicoloured dark slate, quartzite and minor conglomerate; grey and orange weathering limestone and dolomite

Precambrian

4 — 4a Orange weathering dolomite and quartzite. 4b dark shale and argillite

3 — Orange weathering platy dolomite, minor slate and phyllite

2 — Dark thin-bedded argillite, slate and phyllite

1 — Grey weathering thin-bedded limestone and argillite

Devono-Mississippian and Earlier

12 — Dark grey and black shale, argillite, chert, chert-arenite and chert-pebble conglomerate; includes minor Ord-Silurian graptolitic shale.

Upper Cambrian to Devonian

10 — Platy and thin-bedded black limestone shale and siltstone; includes Road River Formation; may include unit 11.

7 — Gritty quartzite, brown, red and green shale and conglomerate, rare limestone and dolomite 7a brown shale, minor limestone dolomite and quartzite 7b dark green volcanic breccia and agglomerate age uncertain, 7c mainly phyllite, schist and quartzite.

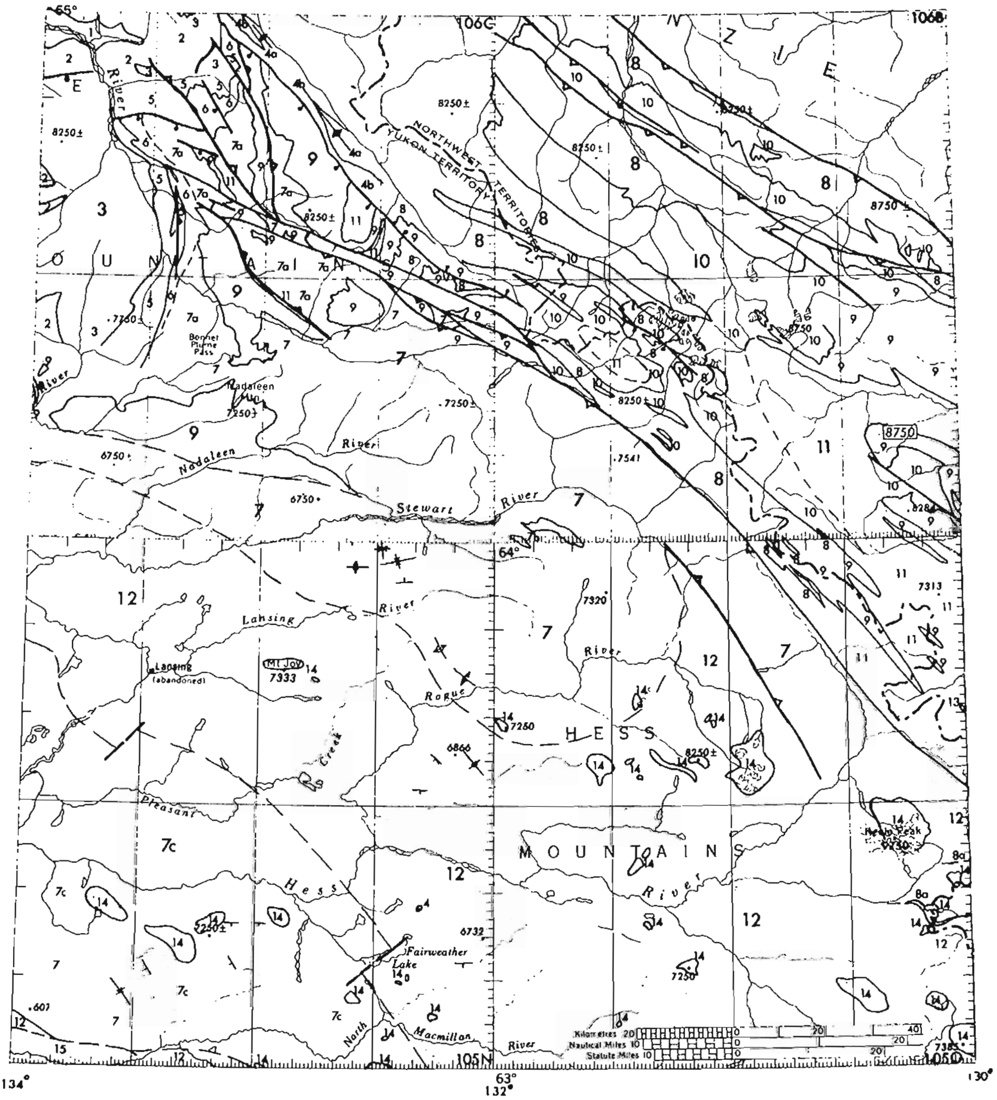


Figure 1. Geological sketch map of Lansing (105 N), Niddery Lake (105 O), Bonnet Plume (106 B) and Nadaleen River (106 C) map-areas, Yukon and District of Mackenzie.

variable in orientation though this seems to reflect a change to less competent argillaceous units rather than differing regional dynamics. There is no evidence to suggest differing structural episodes in the Mackenzie Mountains and Selwyn Basin.

---

1 Wheeler, J.O.: A geological reconnaissance of the northern Selwyn Mountains Region, Yukon and Northwest Territories; Geol. Surv. Can., Paper 53-7 (1954).

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

---

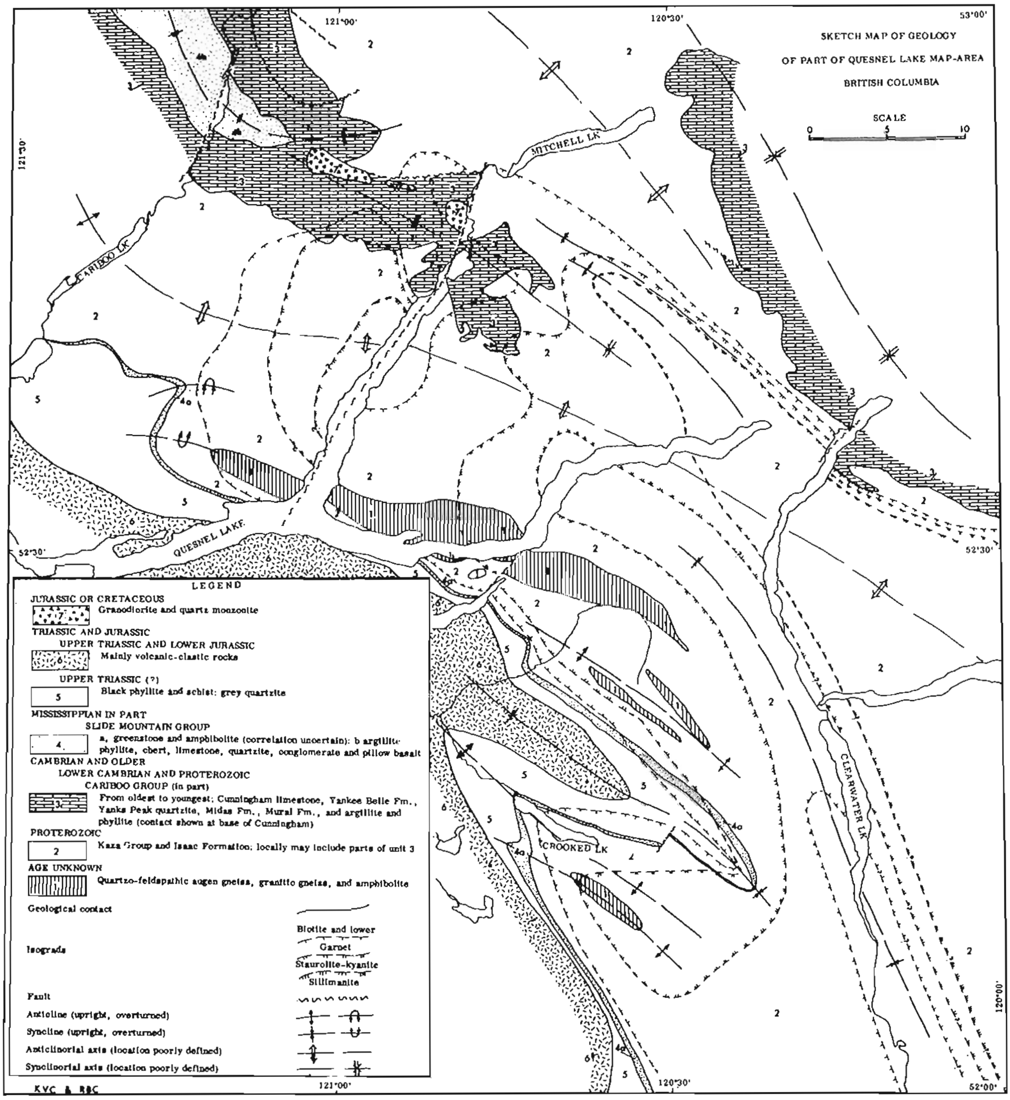
18. QUESNEL LAKE MAP-AREA, BRITISH COLUMBIA (93A)

Project 680066

K.V. Campbell and R.B. Campbell

The 1969 field season was devoted to studies of special problems in the Quesnel Lake (93A) map-area. Earlier work was reported by one of the authors[1, 2]. J.L. Mansy conducted a detailed study in the Black Stuart Synclinorium (see this publication) in the northwestern part of the area. K.V. Campbell continued work begun in 1968[3] in the Crooked Lake region and R.B. Campbell assisted by C.J.N. Fletcher re-examined much of the metamorphic terrane between the areas of detailed study. Fletcher collected material upon which he will conduct an exhaustive study of the metamorphic assemblages with special emphasis on the mineralogical changes across isograds.

The work by Mansy was a study of Cariboo Group rocks unconformably overlain by a sedimentary sequence presently correlated with the Slide Mountain Group. His work has provided detailed information on the structure and stratigraphy of the area and necessitates a reappraisal of the interpretation of Holland[4] and Sutherland Brown[5] in the Yanks Peak-Roundtop Mountain and Antler Creek areas. Mansy's report deals with most aspects of the stratigraphy. An indirect result of his study casts doubt on the validity of the Snowshoe Formation as the highest member of the Cariboo Group, a doubt previously expressed by one of the authors[6]. Mansy's work shows that the Midas Formation is succeeded by carbonate of the Mural Formation followed by several hundred feet of argillite overlain unconformably by a thick sequence consisting dominantly of dark argillite. It had previously been thought that the Snowshoe Formation lay directly above the Midas just a few miles away near Roundtop Mountain and Yanks Peak. It now seems that the Snowshoe Formation is equivalent to the Kaza Group though some possibility remains that it lies unconformably above the Cariboo Group and that it cannot, at present, be correlated with any known stratigraphic unit. Such a possibility seems most remote.



Stratiform bodies of granitic gneiss (unit 1, Fig. 1) near the southeastern margin of the area of metamorphic rocks are more extensive and widespread than previously recognized[1,2]. These bodies, apparently structurally concordant with the enclosing metamorphic rocks, lie on the limbs of major folds that are inclined or overturned toward the southwest. The gneiss appears to vary in concert with the metamorphic grade of the enveloping rocks; that is, it varies from quartzofeldspathic biotite-chlorite augen-gneiss near the junction of the arms of Quesnel Lake to roughly equigranular granodiorite gneiss farther east. Amphibolite and garnet-epidote gneiss is associated with the granitic gneiss near the eastern end of the largest body. Swarms of pegmatite dykes cut the rocks surrounding the bodies of gneiss, particularly the largest. The age and significance of the gneiss are not known; possibly it represents sheets of crystalline basement upon which the sedimentary sequence was deposited though it may possibly be the product of transformation in situ of some otherwise unrecognized unit.

The amphibolite of unit 4a is believed to be equivalent to the Antler Formation of the Slide Mountain Group[5] to the north and to the Fennell Formation[7] and Tsalkom Formation[8] to the south. If this correlation is valid then the lower contact of the amphibolite with the Kaza Group represents the surface of the same unconformity that lies above the Cariboo Group just a few miles to the northeast (see Mansy, this publication). This implies that the unconformity bevels the entire Cariboo Group in a distance of about 15 miles across the regional trend whereas along the trend the underlying beds are bevelled at very low angles. The correlation also implies that the nature of the rocks overlying the unconformity changes radically across the trend, being sedimentary in the northeast and volcanic in the southwest. One of the authors[3] has found field evidence believed to support the concept of an unconformity beneath the amphibolite near Crooked Lake though intense deformation and the development of penetrative foliation make interpretation difficult.

The black phyllite and argillite (unit 5) previously thought to be part of the Midas Formation[1,2] are now believed to be late Triassic[3,7] though evidence is not completely conclusive. The unit can be traced, with few gaps from the Bowron River east of Prince George to just west of Little Fort on North Thompson River. It is thought to continue farther to the southeast into Vernon map-area[8] where it is included with both the Mount Ida and Cache Creek groups. This unit is believed to rest unconformably above the amphibolite though again the evidence for a discordance is not completely conclusive. Upward the pelitic rocks of unit 5 seem to be interlayered and conformable with the late Triassic and early Jurassic volcanic and sedimentary rocks of unit 7 near Crooked Lake.

The major folds and associated minor structures now apparent in the field affect all the rocks including the early Mesozoic dominantly volcanic-clastic assemblage (unit 7) thus the major deformation was early Jurassic or younger. This suggests that folding associated with the unconformities mentioned above was not intense and may have been little more than regional tilting.

Apparently all observed minor folds developed synchronously with the major folds as previously reported[3] except for local northeasterly trending flexures that deform the other structures. Minor folds on the limbs of major folds are generally intrafolial and commonly are isoclinal though the related larger structures may be relatively open. Although this relationship suggests two phases of folding, the fact that the form of the minor folds is not reflected in the surface pattern of large stratiform units (e.g. unit 4a near Crooked Lake) implies that the minor folds are parasitic on the major ones and do not reflect an earlier episode of deformation.

The conclusion that apparent multiphase folding is produced by a single episode of deformation is supported by the observed regional transitions from complexly deformed rocks through zones of decreasing metamorphism and structural complexity (e.g. southeast of Mitchell Lake). In the low grade rocks simple folds display well-developed cleavage commonly parallel to axial planes but locally fanned. Over large areas the rocks are essentially unfolded and unmetamorphosed. As the complexly deformed rocks are stratigraphically equivalent to the nearby gently folded or flat-lying beds, the conclusion seems clear that, in this case at least, apparent multiphase folding is the result of a single episode of intense deformation of metamorphic rocks and that regional interpretations based on the analysis of mesoscopic structures may be misleading in the extreme.

Petrographic study, particularly of rocks from near Crooked Lake, discloses that the minor folds, and hence the major structures, developed synchronously with the period of metamorphism. Evidence of earlier metamorphic events, if any existed, has been obliterated.

Isograds form a complicated pattern that broadly reflects the form of major structures but in detail transects structures (e.g. as near Crooked Lake).

The remarkably rapid transition in metamorphic grade on either side of the area of metamorphism and particularly on the northeast side southeast of Mitchell Lake (originally mapped as a fault by one of the writers[2]) testify to extremely steep thermal gradients during the metamorphic event. By contrast the relatively widely spaced isograds within the metamorphic area imply less steep thermal gradients and indicate that the isograd surfaces are gently dipping probably in rough concordance with the regional plunge of the folds. This possibility is well illustrated by the emergence of staurolite, kyanite, and sillimanite schist on the northwest side of the north arm of Quesnel Lake. These rocks are believed to have moved upward along a fault under the lake. Prior to the faulting the isograds associated with these rocks are believed to have been on the extension of gently northwest dipping isograd surfaces now exposed several miles to the southeast.

Little of economic interest has been found in the area studied. Claims have been staked on showings of galena in the carbonates west of the head of the north arm of Quesnel Lake. Low grade lead-zinc mineralization has been reported from the carbonate east of Hobson Lake near the head of Goat Creek. A large low grade deposit of fluorite has been under development for many years just east of the north arm about 2 miles north of the junction with the east arm of Quesnel Lake.

---

[1] Campbell, R.B.: Quesnel Lake, west half, B.C.; Geol. Surv. Can., Map 3-1961 (1961).

[2] Campbell, R.B.: Quesnel Lake, east half, B.C.; Geol. Surv. Can., Map 1-1963 (1963).

[3] Campbell, K.V.: Structural studies near Crooked Lake, Quesnel Lake map-area, B.C.; in Report of Activities Pt. A, April to October, 1968; Geol. Surv. Can., Paper 69-1, pp. 18-20 (1969).

[4] Holland, S.S.: Yanks Peak-Roundtop Mountain area, B.C.; B.C. Dept. Mines, Bull. 34 (1954).

[5] Sutherland Brown, A.: Geology of the Antler Creek area, Cariboo District, B.C.; B.C. Dept. Mines, Bull. 38 (1957).

[6] Campbell, R.B.: McBride map-area, B.C.; in Report of Activities Pt. A, May to October, 1967; Geol. Surv. Can., Paper 68-1, pp. 14-19 (1968).

[7] Campbell, R.B. and Tipper, H.W.: Bonaparte River map-area, B.C.; Geol. Surv. Can., Map 3-1966 (1966).

[8] Jones, A.G.: Vernon map-area, B.C.; Geol. Surv. Can., Mem. 296 (1959).

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

Project 690032

G.H. Eisbacher

Field work was carried out within the western portion of the Sustut Basin in heretofore unmapped parts of Toodoggone and McConnell Creek map-areas. Particular attention was paid to the relationship between rocks of the Sustut Group[1] and rocks of the underlying Bowser Group[2].

The marine Bowser Group of Late Jurassic-Early Cretaceous age consists of clastic rocks which represent regressive cycles grading from mudstones to lithic greywackes and chert-pebble conglomerates. The general lack of quartz clasts in Bowser chert-pebble conglomerate helps to distinguish these rocks from similar conglomerates of the Sustut Group.

The continental Sustut Group of Late Cretaceous-Early Tertiary age consists of numerous upward-fining cycles of lithic arenites to dark grey mudstones. It can be divided into a lower unit with basal polymictic grit and conglomerate, characteristic quartz conglomerates, and red mudstones, and an upper unit, the base of which is marked by the abrupt appearance of thick polymictic conglomerate interlayered with volcanic tuffs (Fig. 1a).

The lower unit of the Sustut Group overlies the Bowser Group with distinct angular unconformity and is in turn overthrust by Bowser rocks along strike. This relation is illustrated in Figure 1b.

The trend of the Sustut Basin follows closely the trend of the Omineca Geanticline to the east. Most of the clasts in Sustut conglomerates can be readily related to pre-Cretaceous units exposed in the Omineca Geanticline.

Folding and thrusting within the Sustut Basin is most intense along its present western boundary and is controlled by folds and thrusts in underlying Bowser rocks. The structure of both Bowser Group and Sustut Group in the area is dominated by smoothly concave synclines and tight, piercing anticlines which change rapidly into northeasterly directed thrusts along strike. A well-defined monocline marks the northeastern border of the intensely deformed part of the Sustut Basin; northeast of this monocline only widely spaced gentle fold pairs exist. The monocline probably indicates the edge of the Bowser Basin underneath the Sustut Group.

Deposition of Sustut sediments was therefore controlled by the rising Omineca Geanticline, whereas deformation resulted from tectonic events within the domain of the Coast Geanticline.

---

1 Lord, C.S.: McConnell Creek map-area, Cassiar District, British Columbia; Geol. Surv. Can., Mem. 251 (1948).

2 Souther, J.G. and Armstrong, J.E.: North-central belt of the Cordillera of British Columbia; in Tectonic History and Mineral Deposits of the Western Cordillera, Can. Inst. Mining Met., Special Volume No. 8, pp. 171-185 (1966).

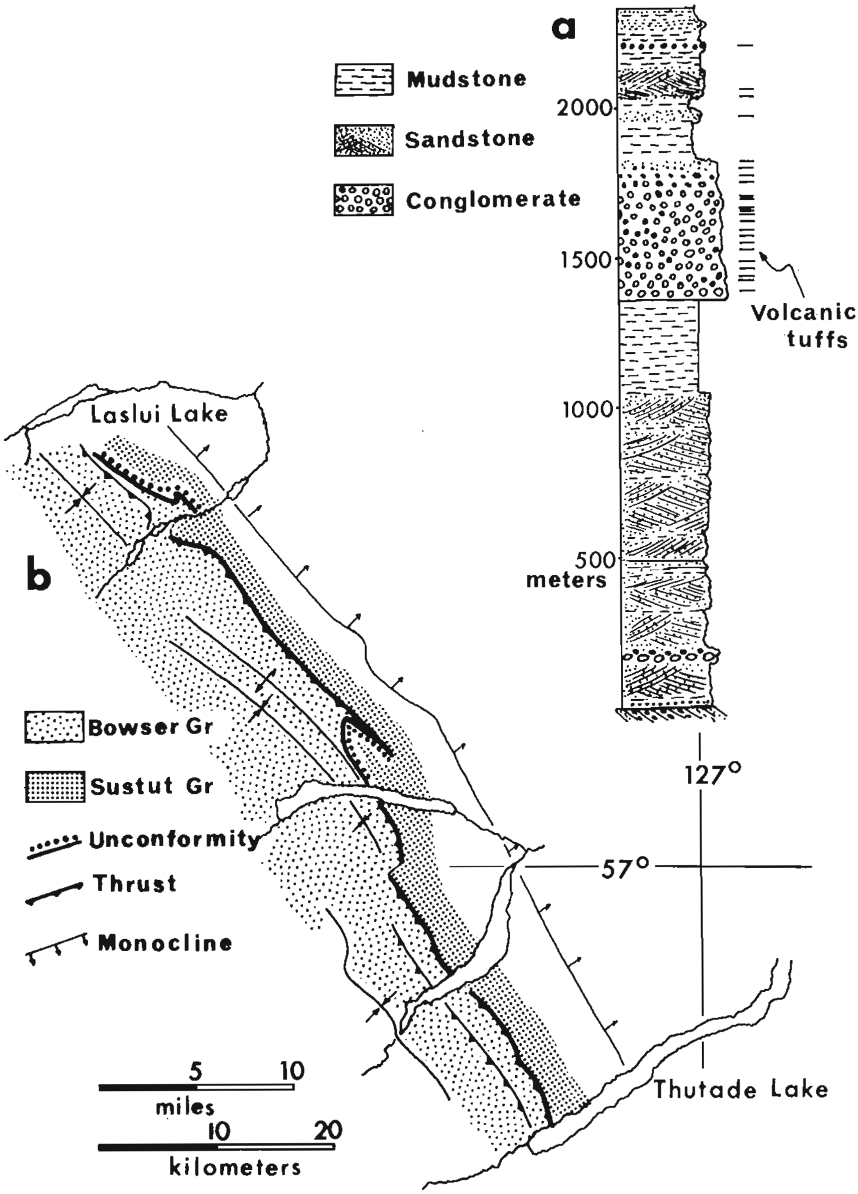


Figure 1. (a) Generalized section of Sustut Group between Laslui Lake and Thutade Lake.
(b) Sketch map of the relationship between Bowser Group and Sustut Group in the western part of Toodoggone and McConnell Creek map-areas.

20. # STRATIGRAPHY AND STRUCTURE OF THE BLACK STUART SYNCLINORIUM, QUESNEL LAKE MAP-AREA, BRITISH COLUMBIA (93A)

Project 680066

J.L. Mansy and R.B. Campbell

A detailed examination of the stratigraphy and structure of the Black Stuart Synclinorium was part of a program of restudy of certain aspects of the geology of Quesnel Lake map-area. The results of other work are reported elsewhere in this publication (see Campbell, K.V. and Campbell, R.B.). The area studied straddles the synclinorium in the region between Cariboo River and the north arm of Quesnel Lake north of Little River (Fig. 1).

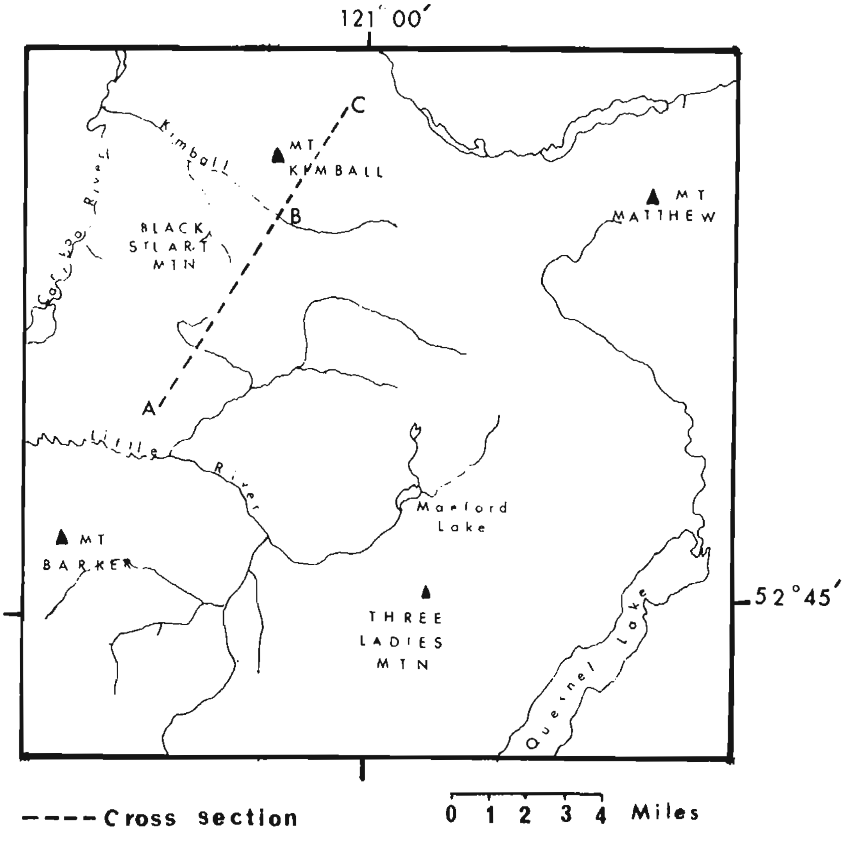


Figure 1

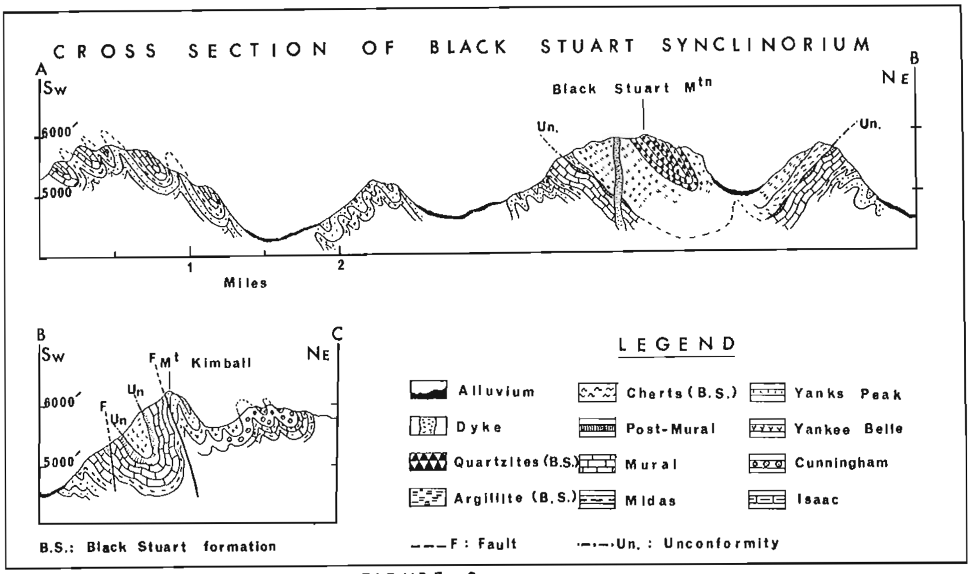


FIGURE 2

The Black Stuart Synclinorium was originally recognized and named by Sutherland Brown[1]. His work was an extension of his earlier study in the Antler Creek area[2] and that of Holland in the Yanks Peak-Roundtop Mountain area[3]. Later Campbell[4, 5] did not suggest a need for major revisions until the stratigraphy and structure in McBride map-area[6, 7, 8] showed inconsistencies with the early interpretations. The McBride work demonstrated that two distinct carbonate units had been inadvertently mapped as one in the earlier studies and it became clear that a detailed restudy was necessary if all available data were to be reconciled.

Structural complexities are such that it was impractical to measure directly stratigraphic sections in the field. The thicknesses of units mentioned below are deduced from field estimates and structural cross-sections (Fig. 2) and generally give the maximum possible thicknesses. The metamorphic grade increases from northwest to southeast so that limestone and argillite or phyllite near Mount Kimball becomes marble and schist near Maeford Lake. The following remarks refer to the least metamorphosed rocks near Mount Kimball.

The section of Cariboo Group rocks is conformable from the Isaac Formation to the post-Mural strata. The Cunningham limestone overlies the mainly pelitic Isaac Formation and consists of about 1,200 feet of dominantly medium grey fine-grained limestone with thin interbeds of argillite and phyllite most common near the top. The Yankee Belle Formation, dominantly greenish with minor buff and pink phyllite and some limestone, is between 500 and 900 feet thick. The pelitic rocks are commonly pyritiferous. From 600 to 1,000 feet of white, buff, and green quartzite comprises the Yanks Peak quartzite. Because of structural complexities the estimates of thickness for the Yankee Belle Formation and Yanks Peak quartzite cannot be given more precisely. Relatively uncomplicated sections of the Midas Formation are exposed on the north side of Kimball Creek valley; the top and bottom of the section are clearly marked by exposures of the Mural Formation and Yanks Peak quartzite. The section, from 150 to 200 feet thick, consists dominantly of lustrous greenish phyllite commonly becoming dark grey or black near the top of the section. At the base thin quartzite interbeds give way upwards to limestone interbeds. Much of the phyllite is remarkably similar to parts of the Yankee Belle Formation. The Mural Formation forms prominent grey outcrops of medium grey fine-grained limestone. Interbeds of phyllite are absent. The limestone, about 400 feet thick, locally contains fragments of archeocyathids and algal remains. Above the Mural is as much as 300 feet of dark argillite and phyllite containing well-preserved trilobites immediately north of Kimball Creek. These beds are only locally preserved beneath an unconformity that cuts down into the Mural Formation.

Overlying the unconformity is a sedimentary sequence informally named the Black Stuart Formation. The angular discordance at the unconformity cannot be perceived in any single outcrop but the map pattern demonstrates that the older rocks are bevelled at a slight angle. The base of the Black Stuart Formation is marked by prominent but discontinuous grey chert, chert breccia, and minor limestone breccia having a maximum thickness of 500 feet. The chert may have formed by the silicification of limestone breccia. In earlier mapping[1, 4, 5] the chert and limestone breccia together with the Mural Formation were shown as the Yanks Peak quartzite on the ridge south of Kimball Creek.

Dark grey and brown argillite and phyllite with minor limestone, possibly 1,500 feet thick, is the dominant unit of the Black Stuart Formation. These rocks were originally correlated with the Midas Formation[1, 4, 5]. Overlying the argillite is rusty-stained grey quartzite, with interbedded argillite and phyllite, perhaps 800 feet thick. The top of the section is not known. Some argillite beds contain possible fossil corals.

The character of the folding is depicted in the cross-section (Fig. 2) which shows that many folds are nearly isoclinal and are overturned toward the southwest. The folds plunge gently to moderately northwestward. Both Cariboo Group and Black Stuart Formation strata appear to have been folded together. Pre-Black Stuart Formation folding was evidently gentle and may have amounted to little more than regional tilting.

The detailed information on the thickness and character of the Midas Formation is a highly significant aspect of the study. This, coupled with the earlier recognition of the presence of the Mural Formation[6] in the region casts doubt on the stratigraphic column erected by Holland[3] in the Yanks Peak-Roundtop Mountain area and extended by Sutherland Brown[2] in the Antler Creek[2] and Black Stuart[1] areas. Much of what was mapped as Midas is part of the Black Stuart Formation and other parts are probably Isaac Formation. Much of what was mapped as Cunningham limestone is now known to be Mural Formation. The sequence from the true Cunningham limestone through the Yankee Belle Formation to the Yanks Peak quartzite is verified. These formations together with the true Midas, the Mural, possibly the post-Mural, and the Black Stuart Formation extend through or past the Roundtop Mountain area and into the Antler Creek area.

---

1 Sutherland Brown, A.: Geology of the Cariboo River area, B.C.; B.C. Dept. Mines, Bull. 47 (1963).

2 Sutherland Brown, A.: Geology of the Antler Creek area, Cariboo District, B.C.; B.C. Dept. Mines, Bull. 38 (1957).

3 Holland, S.S.: Yanks Peak-Roundtop Mountain area, Cariboo District, B.C.; B.C. Dept. Mines, Bull. 34 (1954).

4 Campbell, R.B.: Quesnel Lake, west half, B.C.; Geol. Surv. Can., Map 3-1961 (1961).

5 Campbell, R.B.: Quesnel Lake, east half, B.C.; Geol. Surv. Can., Map 1-1963 (1963).

6 Campbell, R.B.: McBride map-area; in Report of Activities Pt. A, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 53-55 (1967).

7 Campbell, R.B.: McBride map-area, B.C.; in Report of Activities, Pt. A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 14-19 (1968).

8 Young, F.G.: McBride Area, B.C.; Lower Cambrian stratigraphic studies; in Report of Activities Pt. A, May to October; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 21-23 (1968).

---

21. UPPER PALEOZOIC ROCKS OF STIKINE ARCH, BRITISH COLUMBIA (PARTS OF 104B, G, K)

Project 690023

J.W.H. Monger

The stratigraphic relationships between previously dated[1,2] Mississippian and Permian limestones and associated sedimentary and volcanic rocks were studied in detail in the vicinity of Sphaler Creek, Mess Creek and Chutine River in Telegraph Creek map-area (104G), Tatsamenie Lake in Tulsequah map-area (104K) and Hole Lake in Iskut River map-area (104B) (Fig. 1).

The most complete upper Paleozoic section, complicated by probable thrust-faulting, is exposed near Sphaler Creek. Here, the lowest recognizable unit is several thousands of feet of phyllite, whose base is not exposed. The lowest part of this unit, pale grey quartzose phyllite, is overlain by a much thicker sequence of green or maroon phyllite derived largely from tuff and agglomerate that contains local metaquartzite and rare limestone lenses with probable Mississippian corals, bryozoa and crinoid fragments. Conformably above this is Mississippian limestone of which the lower 350 feet, consisting of pale grey, coarse-grained crinoidal calcarenite[3], is commonly separated from the upper 2,000 feet of dark grey, massive to thin-bedded calcarenitic limestone[3] by a tongue of tuff, agglomerate, volcanic conglomerate and chert up to about 500 feet thick. The limestone locally contains an abundant fauna of foraminifera, corals, brachiopods and bryozoa. It is succeeded by at least 700 feet of pale green crystal tuff and

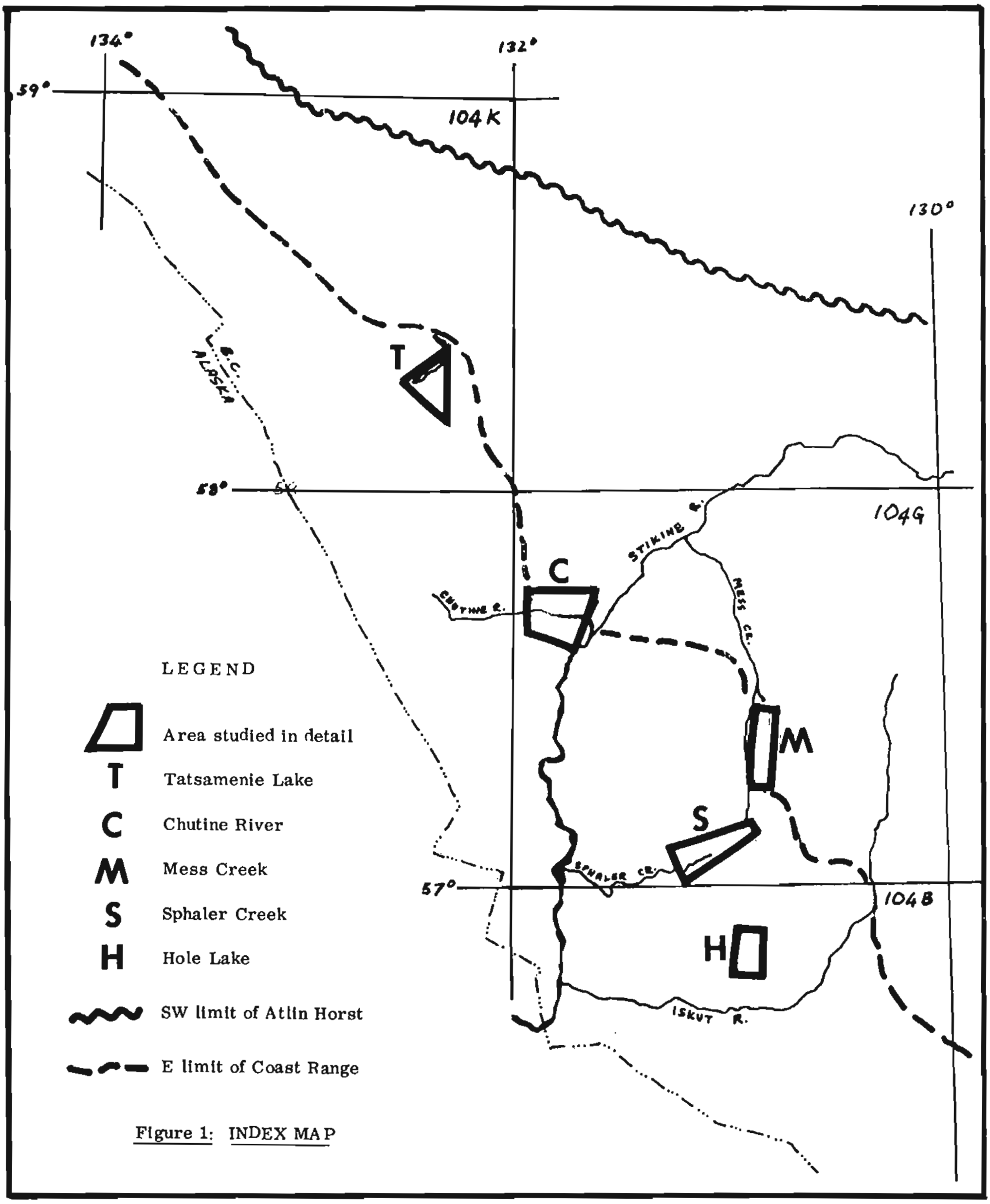


Figure 1: INDEX MAP

maroon volcanic breccia, with volcanic sandstone and limestone lenses at the top containing probable Permian corals, brachiopods and clams. The upper contact of this unit was not observed. No angular discordance between these rocks and the underlying limestone was seen in outcrop, but 3 miles along strike only a few pods of Mississippian limestone remain beneath these Permian volcanics, providing evidence of a profound post-Mississippian, pre-Permian unconformity.

Apparently thrust over this entire sequence is more than 1,000 feet of banded, silicified grey-green crystal tuff, maroon, foliated tuff, agglomerate and flow rocks with minor limestone lenses that are correlated on lithology with the Permian volcanic rocks described above. This unit passes gradationally upwards into more than 800 feet of limestone, of which the lower part is brownish grey weathering, dark grey, thin-bedded, argillaceous calcarenitic limestone[3] and the upper part is buff or pale grey, massive, dolomitic calcarenite[3]. Permian fusulinids, corals, brachiopods and bryozoa are abundant in many horizons. These rocks are apparently unconformably overlain here by dark green to maroon upper Triassic flow rocks.

Mississippian rocks similar to those described above, form fault blocks near Hole Lake and Mess Creek. At the latter locality Mississippian limestone grades upwards into about 200 feet of maroon tuff that in turn is unconformably overlain by Triassic rocks.

Permian limestone exhibits the twofold division seen near Sphaler Creek of a lower thin-bedded limestone and an upper massive dolomitic limestone near Mess Creek, Chutine River and Tatsamenie Lake.

These rocks differ in several ways from time-equivalent rocks in the Atlin Horst[4], whose southwestern margin is only 30 miles northeast of Tatsamenie Lake. Volcanic rocks of the Atlin Horst are mainly basic flows, in many places closely associated with ultramafic rocks, whereas those of the Stikine Arch are mainly andesitic pyroclastics. This suggests a fundamental difference in tectonic setting that may also be reflected in the absence of a major post-Mississippian, pre-Permian unconformity in the Atlin Horst. Perhaps related to the differing nature of the vulcanism is the abundance of bedded chert in the Atlin Horst and its paucity in the Stikine Arch; conversely, fine-grained clastic material is far more common in the Stikine Arch. The Permian fusulinid faunas differ considerably as well, for those in the Stikine Arch have affinities to faunas in the southwestern United States, whereas those in the Atlin Horst have Asiatic affinities.

---

[1] Souther, J.G.: personal communication

[2] Rigby, J.K.: Upper Paleozoic rocks of central and northern British Columbia; Geol. Soc. Am. Sp. Paper 68, Abstracts for 1961, p. 253 (1962), and personal communication.

[3] Powers, R.W.: Arabian Upper Jurassic carbonate reservoir rocks; in Classification of Carbonate rocks; Am. Assoc. Petrol. Geol., Mem. 1 (1962).

[4] Monger, J.W.H.: Late Paleozoic rocks of the Atlin Horst; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A (1969).

22. NORTHERN VANCOUVER ISLAND, BRITISH COLUMBIA (92E, K, L, 102I)

Project 680038

J.E. Muller

Reconnaissance geological mapping of the Alert Bay (92L) and Cape Scott (102I), Nootka Sound (92E) and Bute Inlet (92K) map-areas was started in 1968 by a survey of the coastline. In 1969 the reconnaissance was completed in Alert Bay and Cape Scott areas and some progress was made in Nootka Sound area. The work was done by means of helicopter and motor vehicle as well as arduous but more penetrating classical geological foot-traverses. J.A. Jeletzky consulted with the writer in the field in 1968 and also made available his unpublished manuscript and maps dealing with Quatsino Sound and the west coast between Esperanza and Brooks Peninsula. Previous mapping in the area was carried out by G.M. Dawson[1], H.C. Gunning[2], J.W. Hoadley[3], and W.G. Jeffery[4].

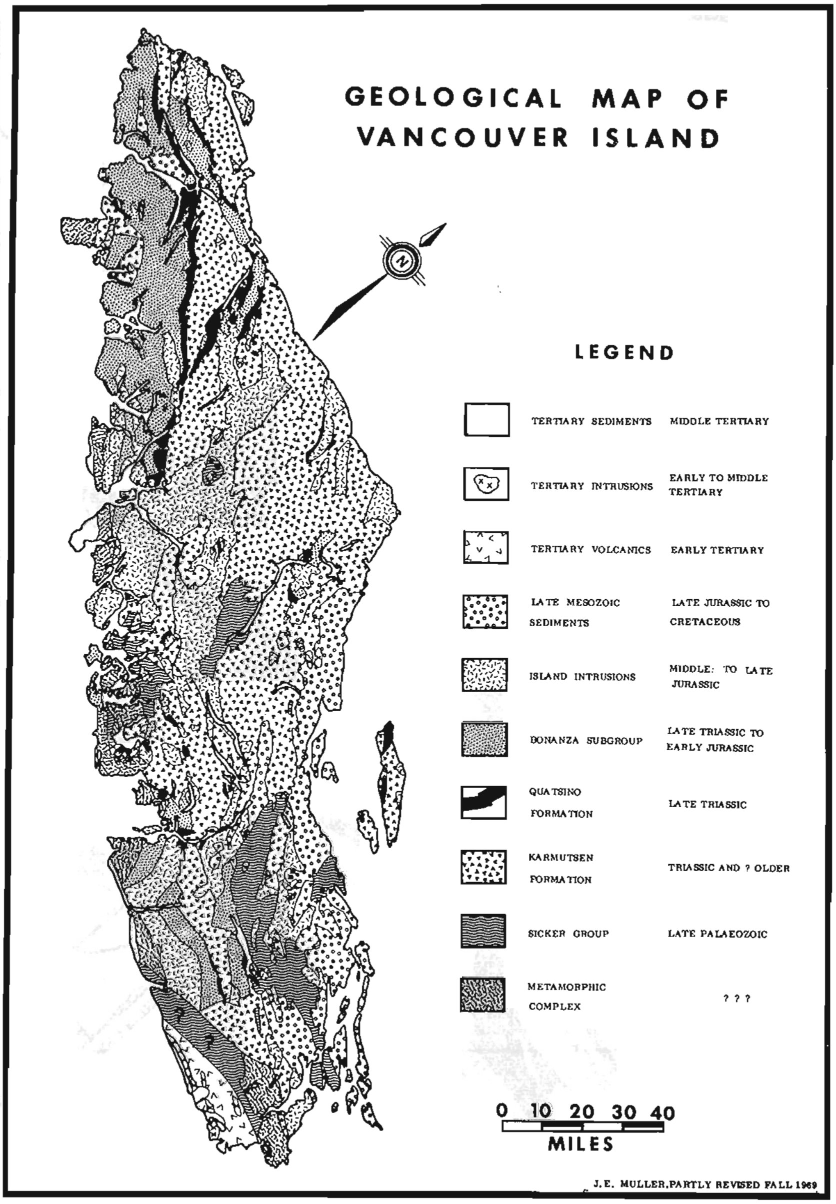
The Karmutsen Formation is a great plateau of basaltic lavas, 10,000 to 20,000 feet thick, the lower part mainly pillow-lavas and pillow-breccias, the upper part massive lava flows, a few feet to about 50 feet thick and of Triassic age. This great lava plateau, up to 60 miles wide and elongated along an axis trending slightly more northerly than the geographic axis of Vancouver Island, affords an excellent geological panorama from the air and occupies the northeastern part of the map-area.

The Quatsino Limestone and Bonanza Sediments now exposed in three fault-bounded belts were deposited mainly on the western flank of the lava-plateau in Late Triassic time. The eastern belt runs along the east side of Nimpkish Lake, the wide central belt from Zeballos to the head of Quatsino Sound and south of Holberg Inlet, and the western belt, which is much thinner and fragmented by numerous faults, extends along the west coast from Kyuquot to Klaskino Inlet.

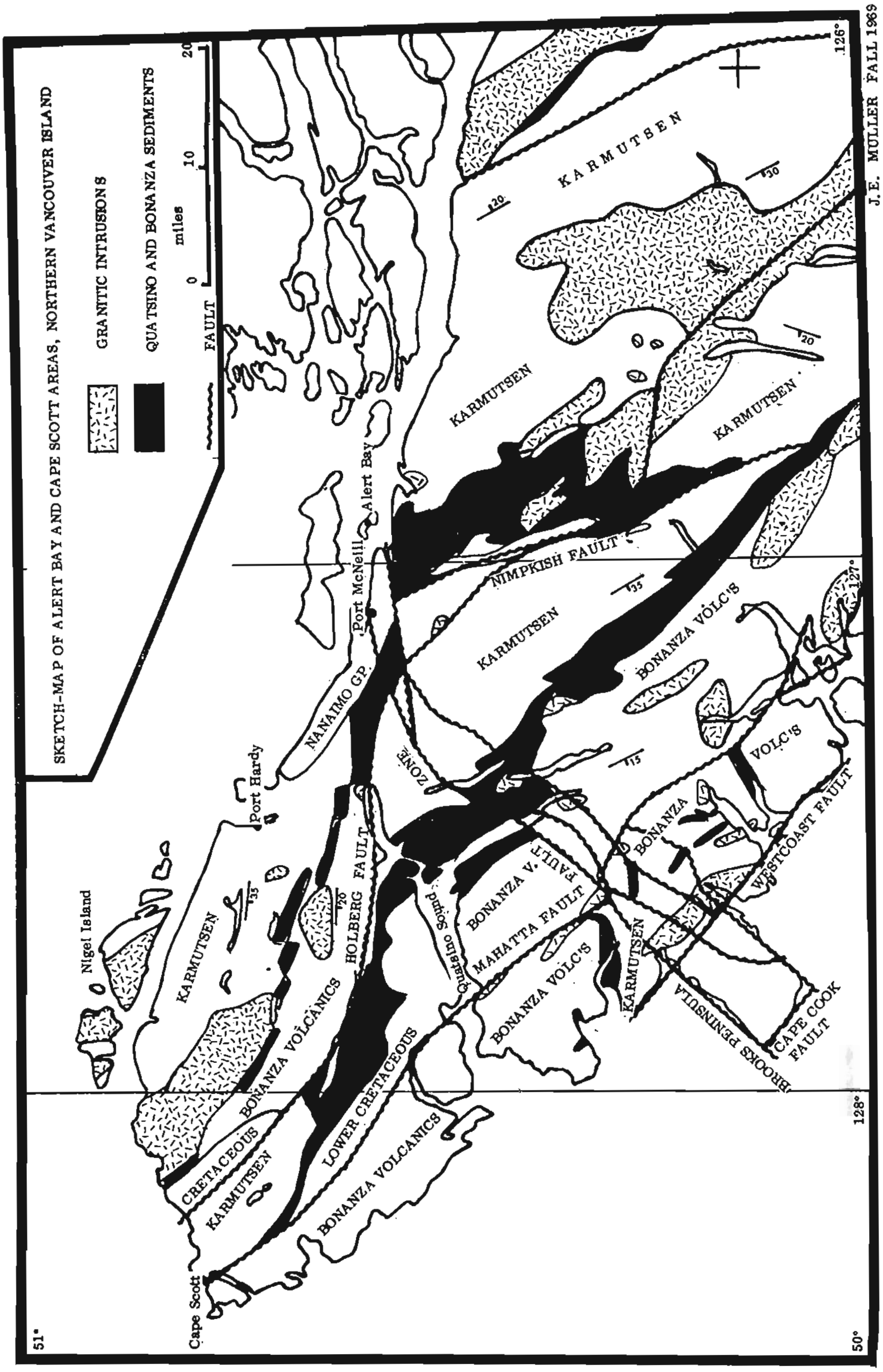
Representative stratigraphic sections of the sediments were studied by R.A. Rahmani and the writer, in the eastern belt south of Beaver Cove, in the central belt south of Alice Lake, and in the western belt west of Klaskino Inlet. Some difficulty was encountered in piecing together complete, but nonrepetitive sections from scarce exposed fault-bounded partial sections.

The Quatsino Formation, of thick-bedded to massive grey limestone commonly has a well-defined basal contact with Karmutsen basalt. Thickness of the Quatsino is 930 feet in the northeastern section, 2,590 feet in the central section, and 760 feet in the western sections. However, towards the north, in the Port Hardy and Cape Scott areas, it is represented by two or more limestone layers, 10 to 50 feet thick, separated by basalt. In the western section only the lowest 80 feet are grey massive limestone. The overlying beds, transitional into Bonanza Sediments, contain grey limestone, in beds up to 2 feet thick, interbedded with black calcareous siltstone, greywacke and minor limestone breccia.

The basal part of the overlying Bonanza Sediments consisting of thick-bedded grey limestone is overlain by thin-bedded black calcareous siltstone, greywacke, and argillite in places with abundant *Monotis subcircularis*.



The Bonanza Sediments exhibit a great variety of lithologies formed by the mixing of coarse and fine volcanic debris and carbonate material. These are black calcareous siltstone and greywacke, breccias with fragments of limestone and volcanic rocks, and more or less silty limestone, commonly concretionary and in places reefoid beds with colonial corals. The assemblage includes the 'thin-bedded member', 'arenaceous member', 'Sutton limestone' and 'Waterlain breccia' of Jeletzky[5, 6, 7]. These members represent various facies of a volcanic-clastic-carbonate mélange, deposited in a


SKETCH-MAP OF ALERT BAY AND CAPE SCOTT AREAS, NORTHERN VANCOUVER ISLAND
GRANITIC INTRUSIONS
QUATSINO AND BONANZA SEDIMENTS
FAULT
0
10
20
miles
KARMUTSEN
NIMPKISH FAULT
BONANZA VOLC'S
Alert Bay
Port McNeill
NANAIMO GP.
ZONE
Port Hardy
Nigel Island
HOLBERG FAULT
Quatsino Sound
BONANZA V.
FAULT
MAHATTA FAULT
BONANZA
VOLC'S
WESTCOAST FAULT
BROOKS PENINSULA
CAPE COOK FAULT
BONANZA VOLCANICS
LOWER CRETACEOUS
CRETACEOUS
Cape Scott
51°
50°
126°
127°
128°
J.E. MULLER FALL 1969

time of local volcanic quiescence. The sedimentary sequence is commonly intruded by sills and dykes of andesitic to rhyodacitic composition, probably mainly comagmatic with the overlying Bonanza volcanic rocks.

The thickness of the sediments in the northeastern belt is difficult to establish due to abundant enclosed sills but is probably less than 500 feet; in the central belt a thickness of 1, 565 feet was measured and in the western belt 580 feet.

Thus the combined Quatsino-Bonanza sequence appears to be an elongated lens of sediments deposited on the southwest flank of the Karmutsen basaltic plateau.

The Bonanza volcanic sequence overlying the Bonanza Sediments, consists of a great variety of flows, some pillow-breccias, agglomerates, breccias, tuffs and ignimbrites. The lower part is andesitic and some rocks are similar to Karmutsen lavas. The upper part comprises andesite, rhyodacite and rhyolite, is maroon, light green and light brown in colour and contains distinctive red or white sodic plagioclase phenocrysts.

A section 8, 500 feet thick along the Pacific Coast north of Quatsino Sound contains in the lower part a 200-foot interval of calcareous greywacke, argillite, and breccia and in the upper part a 25-foot sedimentary interval; the sediments contain probable Early Jurassic fossils.

The Jurassic volcanic rocks indicate the appearance of presumably smaller, and in part, explosive volcanoes of intermediate magmatic composition on the southwest flank of the Karmutsen basaltic plateau. Directly northeast of Vancouver Island, on Nigei, Balaclava and Harbledown islands, Lower Jurassic argillites and greywacke are devoid of volcanic flows and thus apparently no volcanism occurred in Early Jurassic time on the 'inland' side of the basaltic ridge.

The Island Intrusions, composed of quartz monzonite, granodiorite and quartz diorite, were intruded into the two volcanic complexes and intermediate sedimentary sequence in Middle to Late Jurassic time. Within the map-area a great batholith intruded the axial part of the basalt plateau and smaller plugs invaded the southwestern flank.

The Westcoast Metamorphic Complex and related diorite, presumably derived from metamorphosed older rocks during the same major plutonic period, underlies most of Brooks Peninsula.

Lower Cretaceous clastic sediments are confined to the southwestern flank of the Karmutsen lava plateau barely reaching south of Quatsino Sound. They unconformably overlie the Jurassic and older rocks and the Island Intrusions and have been preserved in narrow half-grabens. According to Jeletzky[8] the lower part, composed of greywacke, siltstone and minor conglomerate, is Valanginian to Barremian in age and more than 3,000 feet thick. The upper part consists mainly of coarse conglomerate, containing clasts of Karmutsen and Bonanza volcanic and intrusive rocks. This nearly flat-lying conglomerate is about 3, 000 feet thick.

The writer's data demonstrates a northeastward onlap of Cretaceous rocks onto the old volcanic highland: basal Cretaceous rocks are Valanginian on the western and middle part of Quatsino Sound and on the Pacific coast, but they are Barremian or Aptian at Holberg Inlet. The conglomerate indicates a general emergence of the land in mid-Cretaceous time.

The Upper Cretaceous Nanaimo Group of greywacke, siltstone, sandstone, conglomerate and minor coal is the only formation deposited chiefly on the northeast side of the geographic axis of Vancouver Island. It overlies Lower Cretaceous beds only north of Jeune Landing in the 'axial' zone. The Late Cretaceous sedimentary basin between Vancouver Island and the mainland has recently been described in detail[9].

Finally, small remnants of volcanic flows, tuffs, ashbeds, breccia and volcanic conglomerate occur on Twin Peaks and on some conspicuous small buttes south of Port McNeill. They apparently overlie Nanaimo beds and Karmutsen volcanic rocks and are probably Cenozoic in age although so far no proof of age has been obtained.

The map-areas, like other parts of the island, exhibit a southwestward increasingly complex block-fault structure. The greater fragmentation of the southwestern belt is possibly related to the thinning of the rigid 'shield' of Karmutsen volcanic rocks. Two principal northwest-trending faults separate three major southwestward tilted fault blocks. The youngest formations lie along the southwest side of the half-grabens thus forming the belts of Quatsino-Bonanza sediments mentioned earlier. The Nimpkish Lake fault is traced from north of Zeballos through Nimpkish Lake and possibly turns sharply westward to connect with the Holberg fault discovered by G.M. Dawson through Rupert Arm and Holberg Inlet. The Mahatta fault leads from Kyuquot Sound northwestward across Quatsino Sound east of Cape Scott. The Westcoast fault is characterized by a zone of crushed rock and mylonite as much as several hundred feet wide. It leads along the coast from Kyuquot village across the head of Brooks Peninsula. The southwest coast of that peninsula is also a fault bringing a fringe of highly crushed (Cretaceous?) greywacke, argillite and conglomerate in contact with the metamorphic complex. Most of these faults affect Lower Cretaceous rocks and are therefore Late Cretaceous or Tertiary in age.

The Brooks Peninsula fault zone leads northeastward across the island to the Port McNeill area. This cross-fault or fault zone is prominently displayed on the magnetic map of the region. It apparently has wrenched the Mahatta fault and may be connected with the sharp westward bend from the Nimpkish fault to the Rupert-Holberg fault. The locus of Tertiary (?) volcanism south of Port McNeill is on this fault zone. Brooks Peninsula is a horst of the Westcoast Metamorphic Complex bounded by this fault on the northwest and a parallel one on the southeast. The Brooks Peninsula fault also continues southwest across the continental shelf and separates the 'Tofino Basin' in two parts[10]. All these fault zones have subsidiary branch-faults and many more small faults not shown on the sketch-map give the map the appearance of a shattered glass plate. The narrow elongate smaller intrusions of the southwestern belt seem to be spatially related to faults but it is not clear whether the intrusions invaded fault zones or the faults offset the intrusions. In the former case the small intrusive bodies would be Tertiary in age.

The economic possibilities of the area appear to be favourable and are referred to in a general way in a previous paper[11]. Occasional visits to exploration camps during the field season have emphasized to the writer that many prospects are in areas underlain by the Quatsino-Bonanza sedimentary sequence and in the vicinity of small intrusions. Commonly these sediments are invaded by sills and dykes of rhyodacite and related porphyries causing considerable silicification of the carbonates and alteration of the intrusive rocks.

---

[1] Dawson, G.M.: Report on a geological examination of the northern part of Vancouver Island and adjacent coasts; Geol. Surv. Can., Ann. Rept., 1886, vol. 2, Pt. B, pp. 1-107 (1887).

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

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

[4] Jeffery, W.G.: Preliminary geological map, Alice Lake-Benson Lake area; B.C. Dept. Mines Petroleum Resources (1962).

[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).

[6] Jeletzky, J.A.: Geological history of the west coast of Vancouver Island and Quatsino Sound; Bull. Geol. Soc. Am., vol. 65, No. 12 (2) (1954).

[7] Jeletzky, J.A.: Mesozoic and Tertiary Stratigraphy of northern Vancouver Island; in Report of Activities, Part A, April to October 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 126-134 (1969).

[8] Jeletzky, J.A.: Mesozoic and (?) Tertiary Rocks of Quatsino Sound, Vancouver Island; unpubl. ms. (1968).

[9] Muller, J.E. and Jeletzky, J.A.: Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia; Geol. Surv. Can. (in press).

[10] Murray, J.W. and Tiffin, D.L.: Structure of the continental margin west of Vancouver Island, British Columbia; in Report of Activities, Part A, April to October 1968, Geol. Surv. Can., Paper 69-1, Pt. A, pp. 14-17 (1969).

[11] Muller, J.E. and Carson, D.J.T.: Geology and Mineral Possibilities of Vancouver Island; Can. Min. J., May issue, pp. 66-70 (1969).

---

23. CORDILLERAN VOLCANIC STUDY, 1969; TELEGRAPH CREEK, BRITISH COLUMBIA (104G)

Project 690063

J.G. Souther

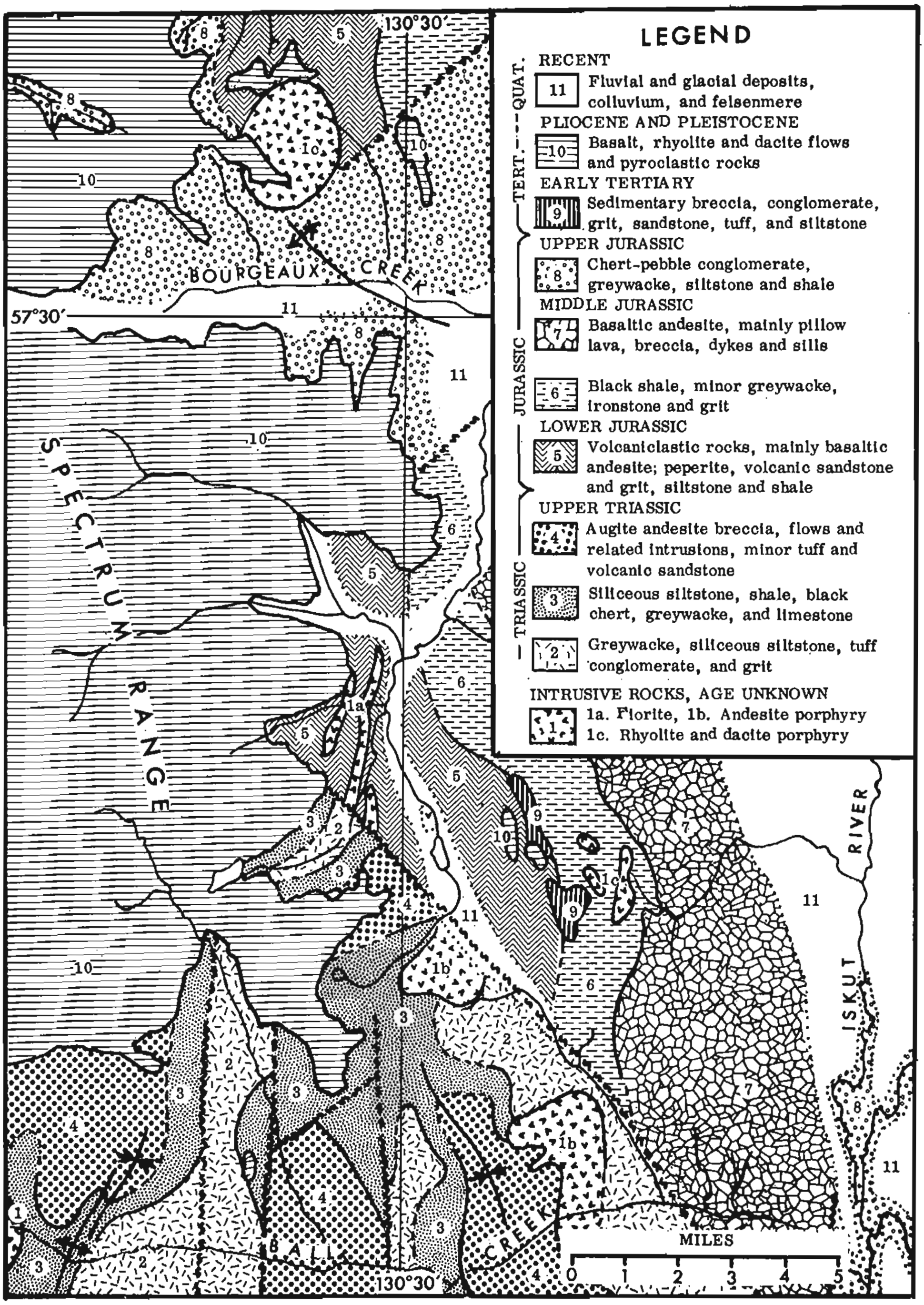
Selected areas within Telegraph Creek map-area were studied in an attempt to clarify problems of Mesozoic stratigraphy, particularly the sequence of volcanic rocks. Tentative compilation of this new data suggests that the present map[1] and stratigraphic interpretation[2] are in need of important revisions. Most of these arise from recognition, during the 1969 field season, of sparsely fossiliferous but widespread Lower and Middle Jurassic shale and associated volcanic rocks that were formerly considered part of the Triassic succession.

The largest of four areas studied (Fig. 1) includes the deeply dissected mountain ranges drained by Bourgeaux Creek, Little Iskut River and Ball Creek. It is bounded on the east by the fault-controlled valley of Iskut River, which forms the western limit of the Bowser Basin[2], and on the west by flat-lying lavas of the Spectrum Range.

The oldest exposed rocks are Triassic sediments (unit 2) comprising more than 3,000 feet of thick-bedded volcanic greywacke, grit, and chert-bearing sedimentary breccia, interbedded with massive, featureless members of fine-grained khaki-coloured, tuffaceous siltstone. These rocks are overlain conformably by relatively thin-bedded sediments (unit 3) beginning with a persistent basal limestone member that varies in thickness from a few feet to a maximum of 200 feet in locally developed reef facies. This basal limestone is overlain by at least 2,300 feet of interbedded carbonaceous shale, black ribbon chert, siliceous siltstone, greywacke, grit and discontinuous lenses of limestone. Thin beds of tuff and volcanic breccia interbedded with siltstone in the uppermost part of unit 3, suggest that no break occurred between deposition of the sediments and eruption of a thick overlying pile of volcanics (unit 4). The latter comprise at least 4,000 feet of green, purple and grey augite andesite breccia in thick, massive beds interlayered with a few flows and lenses of volcanic sandstone and tuff. The entire pile is riddled with augite andesite dykes, sills, and irregular intrusive bodies that are considered to be part of the subvolcanic feeder system.

Age of the Triassic rocks is based on fossils, including Halobia, from black shale near the base of unit 3 and Monotis from siltstone near the top of unit 3, indicating respectively a Karnian (mid-Upper Triassic) and Norian (late Upper Triassic) age.

Within the mapped area Triassic rocks are in fault-contact with Lower Jurassic strata, however, a few miles farther west near Mess Creek, Lower Jurassic conglomerate rests directly on Permian strata. A major unconformity must therefore separate the Triassic rocks of units 2, 3 and 4 from Lower Jurassic rocks of unit 5. The latter consists of at least 4,000 feet of dull greenish brown tuffaceous siltstone, sandstone and grit interbedded with fragmental volcanic rocks, of which brownish grey peperite of basaltic andesite composition is the most abundant and most distinctive.



LEGEND
QUAT.
RECENT
11 Fluvial and glacial deposits, colluvium, and felsenmere
TERT.
PLIOCENE AND PLEISTOCENE
10 Basalt, rhyolite and dacite flows and pyroclastic rocks
EARLY TERTIARY
9 Sedimentary breccia, conglomerate, grit, sandstone, tuff, and siltstone
JURASSIC
UPPER JURASSIC
8 Chert-pebble conglomerate, greywacke, siltstone and shale
MIDDLE JURASSIC
7 Basaltic andesite, mainly pillow lava, breccia, dykes and sills
6 Black shale, minor greywacke, ironstone and grit
LOWER JURASSIC
5 Volcaniclastic rocks, mainly basaltic andesite; peperite, volcanic sandstone and grit, siltstone and shale
TRIASSIC
UPPER TRIASSIC
4 Augite andesite breccia, flows and related intrusions, minor tuff and volcanic sandstone
3 Siliceous siltstone, shale, black chert, greywacke, and limestone
2 Greywacke, siliceous siltstone, tuff conglomerate, and grit
INTRUSIVE ROCKS, AGE UNKNOWN
1 1a. Fiorite, 1b. Andesite porphyry 1c. Rhyolite and dacite porphyry
130°30′
57°30′
BOURGEAUX CREEK
SPECTRUM RANGE
ISKUT RIVER
BALL CREEK
MILES
0 1 2 3 4 5

Unit 5 is overlain conformably by 3,500 feet of friable black shale (unit 6) containing a few thin beds and concretionary layers of rusty-weathering ironstone and a few beds of greywacke and grit. The shale dips consistently toward the east and is overlain structurally by a massive pile (unit 7) of dark grey, basaltic andesite pillow lava and related flows, dykes and sills having a composite thickness of at least 8,000 feet. The change from shale to pillow lava is abrupt, with no evidence of interbedding, yet the contact reveals no evidence of faulting. It is concluded, therefore, that the pillow lavas were erupted very rapidly into the mid-Jurassic marine basin within which the shale of unit 6 accumulated.

Age of the Lower and Middle Jurassic rocks is based on ammonites collected from the upper part of unit 5 and from the middle of unit 6. The former include Harpoceras ? of Toarcian (late Lower Jurassic) age and the latter are tentatively assigned a Bajocian (early Middle Jurassic) age.

Upper Jurassic rocks (unit 8) in Bourgeaux Creek valley are equivalent to Bowser[2] strata east of Iskut River but differ markedly in the relative proportions of coarse- and fine-grained sediments. Whereas conglomerate is a minor component of typical Bowser sections east of Iskut River, the Bourgeaux Creek section (unit 8) consists of a lower, predominantly chert-pebble conglomerate member more than 3,000 feet thick, overlain by an upper shale member at least 2,000 feet thick that contains about 10 per cent conglomerate beds. Evidence of channelling, shingling, and crossbedding in the lower conglomerate member indicate a fluvial origin and suggest that the Bourgeaux Creek strata represent a continental facies of the marine Bowser east of Iskut River.

About 300 feet of light yellowish brown, moderately indurated beds are exposed in the two small remnants of Early Tertiary strata (unit 9). The predominant rock is sedimentary breccia containing subangular clasts of chert, and volcanic rocks ranging in composition from rhyolite to andesite. The latter are similar to volcanic rocks of the Sloko Group[2] and suggest that the sedimentary breccia was derived from a nearby pile of acid volcanic rocks that has subsequently been removed by erosion. The three small intrusions of dacite porphyry (unit 1c), about a mile east of unit 9, may be the subvolcanic equivalents of such a pile.

Flat-lying lavas of the Spectrum Range (unit 10) are approximately equivalent to those of Mount Edziza[3]. Unlike Mount Edziza which is mainly basaltic, the Spectrum Range consists of a relatively thin basaltic platform overlain by an immense pile of rhyolite and dacite. The circular stock of rhyolite porphyry (unit 1c) north of Bourgeaux Creek is a concentrically zoned, cauldron subsidence, ring-dyke complex that may be the source of an early, acid phase of the Spectrum Range volcanics.

Medium-grained, glomeroporphyritic, hornblende-biotite diorite (unit 1a) occurs as flat-lying intrusive sheets cutting Lower Jurassic rocks. The two small stocks of andesite porphyry (unit 1b) exhibit sharp intrusive contacts with the Upper Triassic sediments and volcanics. The more southerly of the two is extremely variable in texture and composition and includes highly fractured and altered zones in which traces of copper mineralization were noted.

The style of deformation is closely related to the age of the rocks involved. Triassic rocks (units 2, 3, 4) in the southwest part of the mapped area have undergone intense east-west compression resulting in northeasterly to northwesterly trending, near-isoclinal folds in the sedimentary rocks (units 2, 3) and a myriad of north-trending fractures and faults in the massive volcanics (unit 4). These structures are truncated by a major northwest-southeast fault that follows the valley of the north fork of Ball Creek and separates Triassic rocks on the southwest from Lower and Middle Jurassic rocks on the northeast. The latter (units 5, 6, 7) have a persistent north-northwest strike and a regional dip of 30 to 45 degrees toward the east. Although thin-bedded shale of unit 6 is locally crumpled, the Lower and Middle Jurassic sediments are nowhere as intensely deformed as those of the Triassic, nor have the Middle Jurassic volcanic rocks (unit 7) undergone the intense fracturing so characteristic of the Triassic volcanic rocks (unit 4). In Bourgeaux Creek area shale near the top of the Upper Jurassic succession (unit 8) is deformed into northwesterly trending concentric folds with wave lengths of one-quarter to one-half mile, however, these structures are not reflected in the thick underlying conglomerate member. The latter is warped into a single broad, west-northwest-trending arch in which dips seldom exceed 15 degrees. The youngest structures appear to be north-south normal faults that cut Early Tertiary sediments (unit 9) but do not affect flat-lying lavas (unit 10) of the Spectrum Range.

From the standpoint of mineral exploration the recognition of Middle Jurassic pillow lava (unit 7) is significant. In the Stikine region thick piles of intermediate volcanic rocks have commonly been mapped as Triassic and, because of their association with copper occurrences they have been considered favourable prospecting terrain[4]. The question now arises as to whether pillow lavas associated with copper deposits in the Stikine region are of Triassic or Middle Jurassic age, or whether lithologically similar rocks of both ages are potential hosts for copper mineralization.

---

[1] Geological Survey of Canada: Stikine River area, Cassiar District, B.C.; Map 9-1957 (1957).

[2] Souther, J.G. and Armstrong, J.E.: North-central belt of the Cordillera of British Columbia; in Tectonic history and mineral deposits of the western Cordillera, Can. Inst. Mining Met., Special Volume No. 8 (1966).

[3] Souther, J.G.: Cordilleran Volcanic Study, 1966, in Report of Activities Part A, May to October, 1966, Geol. Surv. Can., Paper 67-1, Pt. A, pp. 89-92 (1967).

[4] Souther, J.G.: Volcanism in relation to mineral tectonics; Western Miner, vol. 38, No. 4, pp. 56-58 (1965).

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

Project 690009

H.W. Tipper

Re-examination by Hans Frebold and J.A. Jeletzky of fossils collected in Smithers map-area since 1910 by officers of the Geological Survey of Canada, by geologists of British Columbia Department of Mines and Petroleum Resources, and by mining geologists, has indicated that the rocks included in the widespread Hazelton Group range in age from late Triassic (?) to early Upper Jurassic. Recent mapping by geologists of British Columbia Department of Mines and Petroleum Resources[1] reveals a greater structural complexity than previously interpreted. The continuing intense mineral exploration in this and adjoining areas emphasizes the need for more structural and stratigraphic information regarding the Mesozoic and Tertiary rocks of the region. For these and other reasons the Smithers map-area will be restudied with emphasis on stratigraphy and structure and their relation to the mineral deposits. In 1969 one and one-half months were devoted to a rapid reconnaissance of the area in preparation for a future helicopter-supported program of mapping and study.

The Tertiary rocks of the southeast quarter[2], previously undivided, appear to include rocks referable to the Endako Group and to the Ootsa Lake Group. The Endako Group overlies and apparently has a wider distribution than the Ootsa Lake Group.

The lowest volcanic division of the Hazelton Group[3] yielded several collections of Lower Jurassic (Sinemurian?) fossils. Lower Jurassic fossils (Hettangian, Sinemurian?, and Pliensbachian) were also collected from the rocks near Fulton Lake and on the islands of Babine Lake. The overlying sedimentary division yielded fossils of early and late Middle Jurassic age (Bajocian and Callovian) and outcrops discontinuously from Babine Lake to Babine Mountains and in the northwest quarter of the map-area. No new evidence of an Upper Jurassic age for part of the Hazelton Group was found but this age (Oxfordian) is indicated from older collections for part of the group as previously mapped.

---

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

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

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

ENGINEERING GEOLOGY

25. ENGINEERING GEOLOGY OF DAM SITES AND OTHER CONSTRUCTION PROJECTS, NORTHWESTERN ONTARIO (PARTS OF 42, 43, 52, 53)

Project 670038

E.B. Owen

In 1969 this project will consist essentially of an examination of bedrock cores obtained by Inland Waters Branch during the summer of 1969 from potential dam sites on Albany and Severn Rivers in northwestern Ontario. Field work was not required during the 1969 season. The cores will be examined from the engineering geology viewpoint regarding the suitability of bedrock as foundation material and as a source of construction materials.

26. ENGINEERING GEOLOGY AND MAPPING, WELLAND CANAL, ONTARIO (30 L/14g, M/3b, M/3g)

Project 620052

E.B. Owen

Field work was concentrated on NTS sheets 30 M/3b (Allanburg) and 30 L/14g (Welland Junction) where excavations for the 8-mile-long Welland Canal By-Pass between Port Robinson and Port Colborne, Ontario are continuing. With the exception of the two ends where the new canal will join the existing Welland Canal, almost all the By-Pass is presently being excavated. As well, excavations for diverting Welland River are continuing. Preliminary excavations for two tunnels which will pass beneath the By-Pass have been completed.

The materials exposed in the excavations were examined and a geological section along the entire length of the By-Pass is being prepared. The geological information obtained was periodically compared with that described in the specifications supplied the various contractors at the time of bidding the excavation contracts. Soils exposed in the excavations consist of glaciolacustrine clayey silt overlying soft, brown, clayey, silty till. A more dense reddish brown, granular till underlies the upper till. A discontinuous water-laid deposit consisting of various materials ranging from fine-grained, sandy silt to varved clay separates the two tills. Slumping has occurred along the sides of the excavation in the more sandy phases of this deposit. A third till not exposed in the excavations, but whose presence has been indicated by test borings, overlies bedrock.

During preparation of the contract specifications a 'zoning' technique was used with considerable success to identify the various materials encountered in test borings. A geotechnical profile was prepared for each test boring from which soil samples had been taken. The physical properties of the materials as computed in the soil laboratory of The St. Lawrence Seaway Authority were plotted in adjacent vertical columns. The properties used included the water content, natural wet density, shear strength, particle size and the results of the standard penetration test (blows per foot). By comparing these properties, especially the water contents, in many instances the contacts between similar materials encountered in test borings could be readily determined. It was also helpful in correlating the soils encountered in adjacent test borings.

Surface mapping of surficial deposits was confined to areas adjacent to the excavations. About one-half of map-sheet 30 L/14g and one-third of map-sheet 30 M/3b have been completed.

GEOCHEMISTRY

27. GEOCHEMICAL FEASIBILITY STUDY IN THE COPPERMINE AREA, DISTRICT OF MACKENZIE (86 O)

Project 680051

R. J. Allan and E. W. H. Hornbrook

A preliminary field study was made to determine the feasibility of geochemical surveys as an exploration method for locating copper deposits in an area of continuous permafrost. The study was conducted near Hope Lake, which is approximately 42 miles southwest of the village of Coppermine on the Arctic coast or 350 miles north of Yellowknife.

Pedogeochemical (silty frost boils; organic surface and B horizons of Arctic Brown soils), water (lakes) and stream sediment geochemical, and biogeochemical surveys were made in the vicinity of known copper deposits.

Analysis of 25 lake water samples produced background values for copper of about 2 ppb, threshold about 8 ppb and anomalous about 18 ppb. No significant variations in Zn, Ni, Co, Pb, or Mn were noted in the same samples. Cu in lake waters can apparently be related to and used to detect known Cu occurrences, including the major 47-zone deposit of Coppermine River Limited. Preliminary examination of data for selected samples of the other types of materials collected, shows that (1) Cu alone appears to have a sufficient contrast for use as an element in geochemical prospecting in the Coppermine Basalts and (2) each type of material appears to be equally useful in this respect.

This preliminary analytical data indicates that (1) there is active dispersal of Cu from known deposits and (2) there is much potential for the development of geochemical prospecting techniques in permafrost regions.

28. GEOLOGY AND GENESIS OF URANIUM DEPOSITS IN THE HURONIAN AND ASSOCIATED GEOLOGY, BLIND RIVER, SUDBURY, AND GOWGANDA AREAS, ONTARIO (41 I, J, O, P)

Project 690014

T. J. Bottrill

A detailed study was undertaken of the well-exposed and lowest reef of the ore-zone in the Manfred Member of the Matinenda Formation. Thirty-four samples were collected from twenty-one surveyed stations to provide a grid for determining directional variations in the primary structures and geochemical features of the ore. Such variations when correlated will provide a means for testing the placer hypothesis of ore genesis of the conglomerates. The conglomerates were seen in detail to be a series of relatively tightly packed lenses of quartz, and minor chert and jasper pebbles in a matrix and interbedded units of variably feldspathic sandstones. Orientation of the lenses should provide a further test of predicted directional trends in the ore. Preliminary investigation indicated that the uranium distribution was not controlled by features of detrital origin. An alternative is suggested that the reefs represent a suitable geological environment for the syngenetic precipitation of uranium, later enriched by epigenetic groundwaters, probably before deposition of overlying formations.

Contemporaneous volcanics in the Matinenda may have provided suitable local topographical relief as well as geochemical conditions favourable to the concentration of uranium to form ore. The volcanic units were found both in outcrop and in diamond-drill core to be far more extensively distributed than was previously known, but always occur below the Ramsay Lake Conglomerate. These volcanic units were examined and sampled, especially where their relationship to silica-pebble conglomerates is known. It is hoped that chemical analysis will provide a tool for correlating the various volcanic units. It was found that in some cases Huronian volcanics had previously been misinterpreted as diabase dykes or pre-Huronian basement rocks.

Samples of calc-alkali pre-Huronian basement rocks were collected at regular intervals from the Kapuskasing magnetic high, south to the edge of the Huronian unconformity. These samples will provide the preliminary data for an evaluation of the provenance of the various elements in the uraniferous ores, arkosic sandstones and non-ore conglomerates. All radioactive occurrences in the Archean basement are post-Huronian, and so could not constitute a source for syngenetic ores in the Matinenda Formation. This suggests that the uranium in the sedimentary ores was derived from a widely dispersed source, such as granites similar to those currently exposed, which would also provide a source for the uranium in the structurally later shear zone deposits in the Archean. Stratigraphic and sedimentological data were collected throughout a large area of the Huronian from recent diamond drilling. An attempt will be made to correlate across the region, the members and various lithofacies of the dominantly clastic formations of the Huronian, with special attention to the Matinenda.

A measured section of the Hough Lake and Quirke Lake groups was completed on Quirke Lake in co-operation with J.A. Robertson of the Ontario Department of Mines, chairman of the Federal-Provincial Committee on Huronian Stratigraphy.

29. GEOCHEMISTRY OF GOLD AND ITS DEPOSITS

Project 650438

R. W. Boyle

(I) Sampling of waters, gossans, oxidized zones, soils, and muskeg in the vicinity of gold deposits in the following areas were carried out:
1. Falcon Lake area, Manitoba - gold deposits in granite.
2. Bird River area, Manitoba - low gold-bearing deposits associated with Ni-Cu sulphides
3. Uranium City area, Saskatchewan - gold deposits in granite (Box Mine and Athona Mine).
4. Yellowknife - Tibbett Lake area, Northwest Territories - gold deposits in greenstones and sediments.

(II) The work was undertaken to determine the factors bearing on the surficial migration of gold and its associated elements (As, Sb, Te, Ag) in Precambrian glaciated terrains.

(III) Preliminary results indicate that As and Sb are good indicators of gold in most areas in natural waters, gossans, soils, and muskeg.

30. GAMMA-RAY LOGGING OF WATER WELLS, SOUTHEASTERN ALBERTA AND SOUTHWESTERN SASKATCHEWAN (62 E, 72 E AND 72 F)

Project 690021

Jim Bushell

This project was suggested by J.E. Wyder who supervised the installation of and instructed in the operation of the logging equipment, and supervised the field work. The writer is indebted also to E.J.W. Irish and H.W. Little for advice received. The co-operation of the farmers whose wells were probed is gratefully acknowledged.

It was intended to select the water wells that had penetrated continental sediments, particularly the deeper wells. It was found, however, that few logs existed except in the newer wells, and these logs for the most part lacked suitable lithological descriptions. It was necessary, therefore, to depend on geological maps of the areas investigated and on charts that indicated thickness of overburden.

It was realized before the project was undertaken that nearly all wells would have casings which would act as shielding, thus reducing the apparent magnitude of the anomalies, and would also prevent calipering so that great accuracy in measurement of gamma radiation of the sedimentary strata would not be possible. Nevertheless it was hoped that some trends would be recognized and possibly that a large anomaly might be recorded.

The instrument used, a portable borehole gamma-ray logging unit, built by Gearhart - Owen Industries Incorporated, to Dr. Wyder's specifications, was installed in a panel truck. Although it had been designed to probe deep wells it proved impossible to measure any of these because they were either flowing (artesian), or else had heavy pumping equipment installed that could not be removed by one man and for the most part would require two to six hours work by two men to remove. During the field season 156 water wells were probed.

The first area investigated was in southeastern Alberta mainly north of Cypress Hills where some 68 water wells were tested in a belt extending from Little Plume east to the Interprovincial Boundary. These wells were dug in the Upper Cretaceous Bearpaw and Eastend formations. To the south, in an area between Thelma and Ranchville, seven water wells were probed that penetrate the Bearpaw, Eastend, and the Paleocene Ravenscrag formations. No anomalies were encountered in any of the Alberta wells probed.

In Alberta, within the Eastend and Ravenscrag formations south of Cypress Hills, some lignite seams outcrop. Some of these were tested with the probe and two registered strong anomalies. One of these, in the Eastend Formation 4 1/2 miles west-southwest of Thelma, gave a reading about 4 times background. The other, in the Ravenscrag Formation 1 1/2 miles southwest of Thelma, recorded some 30 times background.

In southwestern Saskatchewan the largest group of water wells investigated lies within a triangular area 25 miles along the base, which lies roughly on a line from Frontier to Olga, and 50 miles to the apex which lies several miles north of Notukeu Lake. The wells tested penetrate the Upper Cretaceous Eastend and Whitemud, the Paleocene Ravenscrag, and the Oligocene Cypress Hills formations. Weak anomalies were detected in single wells 7 miles south-southwest of Eastend, 4 miles south-southeast of Chambery, and 6 miles south of Shaunavon. Stronger anomalies were found in two wells 2 to 3 miles southwest of the last named well. All these wells penetrate Ravenscrag beds. The strongest anomaly, about 4 times background, occurs in a well 3 1/2 miles east of the south end of Notukeu Lake, and nearby another weak anomaly was found. These wells occur in the Eastend Formation. Three miles north of Notukeu Lake and in a well 1 1/2 miles east-northeast of that point, anomalies of 3 times background occur in wells that penetrate the Cypress Hills Formation.

Six other wells in the Ravenscrag Formation west and southwest of Estevan were probed but without anomalous results.

31. COMPARISON OF REGIONAL GEOCHEMICAL URANIUM EXPLORATION IN THE BEAVERLODGE AREA, SASKATCHEWAN (74 N/9)

Project 680028

Willy Dyck, A.S. Dass, C.C. Durham, J.C. Pelchat and J.H. Galbraith

To evaluate the relative merits of regional geochemical exploration methods for uranium, particularly those employing radon and uranium in surface waters, a 500-square-mile area in the Beaverlodge area, Saskatchewan, was sampled during the 1969 field season. The region sampled extends for about 22 miles north from the shore of Lake Athabasca and 23 miles east from the town of Eldorado. Surface lake water samples were collected at an average density of 1.3 samples per square mile. Stream water samples and sediment samples from the same site were collected at a sampling density of about one sample per square mile. Approximately 95 rock samples from the major rock formations were collected also. All field notes and analytical results were recorded on cards for computer storage and processing. Radon, pH, and alkalinity of all samples were determined in the field laboratory, and the temperature measured on site. Acidified aliquots were shipped to Ottawa for uranium and other trace element analyses.

Estimates indicate that the background value for uranium lies under the detection limit of the method employed for this work, i.e. 0.4 parts per billion, for both lake and stream waters. Radon background values in streams and lakes are approximately 30 and 2 picocuries per litre, respectively. The raw data outline a number of known uraniferous zones. There are at least six regions not counting the region within about three miles of Eldorado, in which radon and uranium concentrations in lakes were greater than two times background. These regions are between Cornwall and Fishhook bays, near Gibbs Lake; between Cuttler and Mickey lakes; in the vicinity of Dyke Lake; between Donaldson and Gebee lakes; and south of Dusyk Lake. Another area in the vicinity of Beckwall Lake gave anomalous uranium values in the lakes and streams and anomalous radon values in streams only.

Seasonal tests of samples from four lake sites and four stream sites over an eight week period show little variation in the concentration of ionic species, i.e. uranium, pH, and bicarbonate. The radon content at the surface of lakes on the other hand varies considerably from day to day. In streams the variation in radon concentration with time is less than in lakes.

In general the uranium pattern compared to that of radon is somewhat more diffused, particularly in the lakes. This is most likely due to the fact that uranium is more soluble in natural waters than radium.

In rugged terrain like the Beaverlodge area, lake sampling is more economical than stream sampling. However, analytical costs are somewhat higher for lake samples because of lower concentration levels.

Radon and uranium in surface waters outline uraniferous areas about equally well and should both be used where practical. Being simpler, the radon method is preferable where analytical facilities are scarce.

32. REGIONAL GEOCHEMICAL CENSUS OF PLUTONIC ROCKS IN THE EASTERN YUKON (105 N, O, 106 D)

Project 690036

R.G. Garrett

A preliminary investigation of the areal variability of the granitoid plutonic intrusives of the eastern Yukon and their relationship to known tungsten deposits was carried out. Five plutons of varying size were sampled, of these, two were associated with tungsten mineralization and the remaining three are believed to be unrelated to major mineralization. The plutons were sampled in detail, by a method described elsewhere, in order to assess the local and overall variability[1]. To date the following elements have been determined: Co, Cu, Mo, Ni, Pb, W, and Zn; the major elements together with Mn and Ti are being determined at present.

A study of the results in hand reveals significant differences in geochemistry between the plutons; several of the elements show variations of particular interest. Tungsten is significantly higher in both the plutons associated with scheelite mineralization than in the three plutons unassociated with mineralization. The feldspar megacrysts in the one megacrystic pluton are reflected by significantly higher lead values than are found elsewhere. Cobalt, nickel and zinc appear to behave very similarly in all plutons and to vary inversely with the lead content. The molybdenum results reveal patterns of interest but more work is necessary before these can be interpreted.

In general it would appear that there are significant and mappable variations in the geochemistry of the plutons and that some of these variations are related to possible mineral potential.

---

[1] Garrett, R.G.: The determination of sampling and analytical errors in exploration geochemistry; Econ. Geol., vol. 64, No. 5, pp. 568-569 (1969).

---

33. TRANSPORT AND DEPOSITION OF ORE INDICATOR ELEMENTS IN STREAMS AND SEDIMENTS, NEW BRUNSWICK (21P/13E, 21P/13W, 21O/7E, 21O/9W, 21O/10E)

Project 690039

Andrew Nigrini

A stream-sediment reconnaissance survey was made in the area of Bathurst, New Brunswick to select a number of anomalous streams associated with known mineral occurrences for detailed geochemical studies. Three situations were selected: (1) where mineralization is exposed in the bed of the stream; (2) where the mineralized zone is buried under several feet of overburden at the headwaters of a stream; and (3) where a stream is contaminated by the tailings pond of a worked out Cu-Pb-Zn mine.

In each of these three systems, a series of closely spaced stream sediment and water samples was collected. The stream sediments were analyzed, in a mobile field laboratory, for Cu, Pb, Zn and Mn using atomic adsorption spectroscopy. At each sampling site, two 1-litre water samples (one was acidified with nitric acid) were collected for total analysis in Ottawa. Six 4-ounce glass jars of water, for dissolved CO_2 analysis, were also collected. In situ electrode measurements for temperature, dissolved O_2, Eh, pH, Ca^{2+}, M^{2+}, Cu^{2+}, and Cl^- were taken or attempted.

Little difficulty was encountered with the measurements of temperature, dissolved O_2, Eh, and pH. Calibration difficulties with the Ca^{2+} and M^{2+} electrodes forced cancellation of these measurements. Cu^{2+} and Cl^- electrodes functioned well, but their ionic levels were either below or just at the detection limits of the electrodes.

Preliminary observations suggest that (i) Cl^- and Cu^{2+} electrodes are not sufficiently sensitive for measurements in waters that are close to equilibrium with the atmosphere; (ii) the chemical character of stream waters across ore-grade outcrops is constant which suggests a mechanical or adsorption mode of transport; (iii) where chemical leaching of buried deposits occurs, the resultant charged waters equilibrate rapidly upon exposure to the atmosphere and deposit their chemical load within a few tens of feet of exposure and subsequent transport is by mechanical means or by adsorption.

34. THE GEOCHEMISTRY OF ULTRAMAFIC ROCKS AND ORE BEARING POSSIBILITIES FROM THEIR GEOCHEMICAL CONTENT

Project 680061

G. Siddeley

Several ultramafic bodies of the Canadian Shield were visited. Sampling units were located near Waboden (Manitoba), south of the Timmins area (Ontario), and Chibougamau, Renzy Lake, Eastern Townships, Shefferville and Ungava (Quebec).

A variety of ultramafic occurrences are involved, from small lensoid bodies of homogeneous peridotite (Timmins area) to extensive sheets of well-layered to poorly differentiated ultramafics (Ghost Range, Ontario; Ungava, Quebec). Where ores are known to occur, they vary considerably, being local or extensive, massive and/or disseminated, contact phenomena, differentiates, or interstitial. In some areas, mines for nickel and copper are operating or under construction. Ultramafic samples from such bodies provide 'ore associated' chemical values which are being compared to data from presumed barren units. Revisits were made to some of the 1968 localities where preliminary results showed interesting Ni and Cu content.

Approximately 300 selected specimens of peridotite, dunite and serpentinite have been submitted for chemical analysis and thin section study.

The primary dispersion of ore indicator elements appears to be a variable feature largely dependent on the geometry of the ore and the mobility of the elements. Thus fissure deposits have only a local geochemical expression (regarding indicators) in considering the ultramafic body as a whole. Mobile constituents such as Cu depend also on factors such as (solid) rock permeability. Thus erratic Cu values are related to fine chalcopyrite mineralization along irregular veinlets. Higher than average (though still erratic) values are noted from most ore-associated ultramafic bodies.

Generally, indicator elements are related to the presence of sulphide minerals scattered at varying concentrations between and throughout ultramafic units. Samples obtained during 1969 (with those of 1968) will be used to determine element values within units from a standpoint of ore proximity.

GEOMATHEMATICS

35. A STATISTICAL METHOD FOR SELECTING AREAS WHOSE GEOLOGY IS FAVOURABLE TO OCCURRENCES OF MINERAL DEPOSITS

Project 690038

F. P. Agterberg

During a visit to the British Columbia Research Council in August, a modification of A. M. Kelly's method of predicting probability of occurrence of mineral deposits in specific areas, was developed in collaboration with Mr. Kelly and Dr. DeVerle Harris. To test the method, the whole of British Columbia was subdivided into 818 'cells' in the form of squares each 20 miles by 20 miles in size. Two groups of variables are considered in the statistical model which is used to determine probability of occurrence of mineral deposits: (a) 75 geological variables as compiled by Kelly and (b) 27 parameters related to geographic location of the cells.

Procedure

1. Regression on (1) 75 geological variables, and (2) 27 polynomial terms (sextic trend surface). Total area (818 cells). Logarithmic transformation of values for producing cells; zero values for empty cells.
2. The final equation is divided into two parts: (a) Linear function of the geological variables; (b) Polynomial function. The average value for the 818 values assumed by the linear function is zero.
3. Cells with positive value for the linear function (= positive geology) indicate an environment that is favourable for finding mineral deposits.

First Interpretation of Model

It is assumed that the intensity of exploration in British Columbia is positively correlated to the trend (polynomial part of equation). If the trend is eliminated from the equation, areal variations in the intensity of exploration are also eliminated to a large extent. Example: For total dollar value, the trend may be as low as 0.2 in parts of northern British Columbia and as high as 5.0 in parts of southern British Columbia. Elimination of the trend is equivalent to multiplying the value of 0.2 by 25 if they are made comparable to the value 5. It is further assumed that mineral deposits tend to occur in cells with a favourable geological environment. The linear function of the geological variables is considered to be an index for the probability of a cell containing valuable mineral deposits.

Test: 255 out of 818 cells have positive geology and 88 out of 818 cells each have known value exceeding $1,000,000. Of the 818 cells 64 have positive geology and 24 have negative geology.

Conclusion

These tests indicate that of the 88 cells known to contain mineral deposits with reserves worth $1, 000, 000 or more, 64 were in the group of 255 for which the method indicated the geology is favourable and 24 were in areas for which the method indicated unfavourable geology. The method would appear, therefore, to have promise as a means of selecting areas favourable for prospecting. As a byproduct it is expected that those geological variables that show the greatest statistical correlation with the occurrence of mineral deposits can be determined. Specific consideration could then be given to recording these variables in the course of geological mapping.

It is expected that this method and its results will be published in a joint paper with Kelly and Harris.

GEOPHYSICS

36. RADIO WAVE MAPPING ACROSS THE GLOUCESTER FAULT, ONTARIO (31 G/5)

Project 670041

A. Becker

The current experiment is a continuation of the investigation of the effects of near surface ground conductivity variations in the field vectors of VLF (10-50 Khz) radio waves which was initiated in 1966[1].

Once again, the radio waves employed for the tests originated from station NAA in Cutler, Maine. This is a 1 Mw. transmitter which broadcasts at 17.8 Khz. As before, the geological structure under study was the Gloucester Fault, southwest of Leitrim, Ontario[2]. This geological feature, which forms a boundary between resistive dolomites to the southwest and highly conductive shales to the northeast, constitutes a very favourable test area for the evaluation of any electrical or electromagnetic method of ground conductivity mapping.

The experiment reported here was primarily aimed at a further evaluation of the effectiveness of the recently patented RADIOHM method[3]. In a manner quite analogous to the magnetotelluric method, RADIOHM yields a measurement of ground conductivity from a comparison of the orthogonal telluric (horizontal electric along the direction of wave propagation) and horizontal magnetic VLF field vectors. The equipment employed was designed and fabricated for the Geological Survey of Canada by the Geoscience Division of Westinghouse.

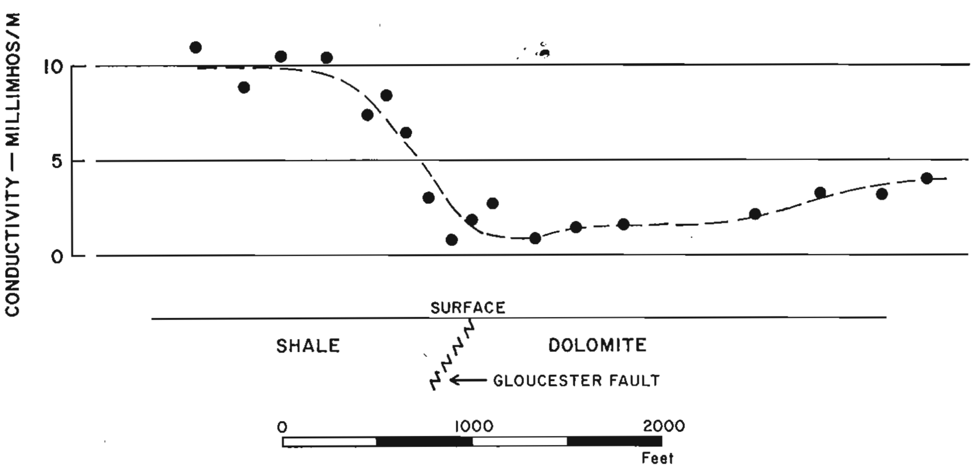


Fig. 1 – RADIOHM TRAVERSE OVER THE GLOUCESTER FAULT, LEITRIM, ONTARIO

The results of the test traverse are shown in Figure 1. It is evident that the RADIOHM method is quite effective for locating a near surface contact of two formations whose electrical properties differ considerably. It is also interesting to note that the electrical conductivity of the dolomite as derived from RADIOHM corresponds closely to the conductivity values obtained for this formation from conventional resistivity measurements. The RADIOHM values for the shale, however, are much lower than those obtained conventionally (500-25 millimhos/m).

---

[1] Becker, Alex: Radio wave mapping of ground conductivity; in Report of Activities, Part A, May to October, 1966; Geol. Surv. Can., Paper 67-1, pp. 130-131 (1967).

[2] Wilson, A.E.: Geology of the Ottawa - St. Lawrence Lowland, Ontario and Quebec; Geol. Surv. Can, Mem. 241 (1946).

[3] Collett, L.S. and Becker, Alex: Radiohm method for earth resistivity mapping; Canadian Patent No. 795,919 (1968).

---

37. HI-RESOLUTION AEROMAGNETIC DATA, ONTARIO AND DISTRICT OF MACKENZIE (42 A, 85 C, D (PARTS OF))

Project 680140

B.K. Bhattacharyya

A high-sensitivity aeromagnetic survey has been completed over an area in Ontario extending from 81°W to 81°45'W longitude and from 48°22.5'N to 48°45'N latitude. The survey was conducted with a cesium-vapour magnetometer. The total field was measured in units of 1/50th of a gamma and the vertical gradient, in units of 1/200th of a gamma. The total field, gradient, time, along- and cross-track Doppler readings, barometric and radar altitude readings were recorded digitally in IBM-compatible 7-track magnetic tapes.

A similar type of survey is now being carried out over an area in Northwest Territories extending from 60°N to 60°30'N latitude and 116°W to 118°W longitude.

38. GAMMA-RAY SUPPORT, BANCROFT, ONTARIO AND GATINEAU AREA, QUEBEC (PARTS OF 31 C, D, E, F; 31 F, G)

Project 670052

B.W. Charbonneau and A.G. Darnley

A new ground gamma-ray spectrometer model CPD 153C manufactured by Atomic Energy of Canada Ltd. was received at the beginning of the season. The design of this instrument was considerably influenced by Geological Survey experience with the older model CPD 153B during the two previous seasons. It retains a 3 X 3 in. NaI (Tl) detector with pre-programmed channel selection for survey and calibration purposes and digital presentation of cumulative count in four spectral windows. By reducing the number of channels from 1000 to 128, weight has been reduced from 45 to 25 pounds and the unit rendered more compact. A comparison of count rates from the old and new instruments on our calibration pads at Uplands Airport showed excellent agreement.

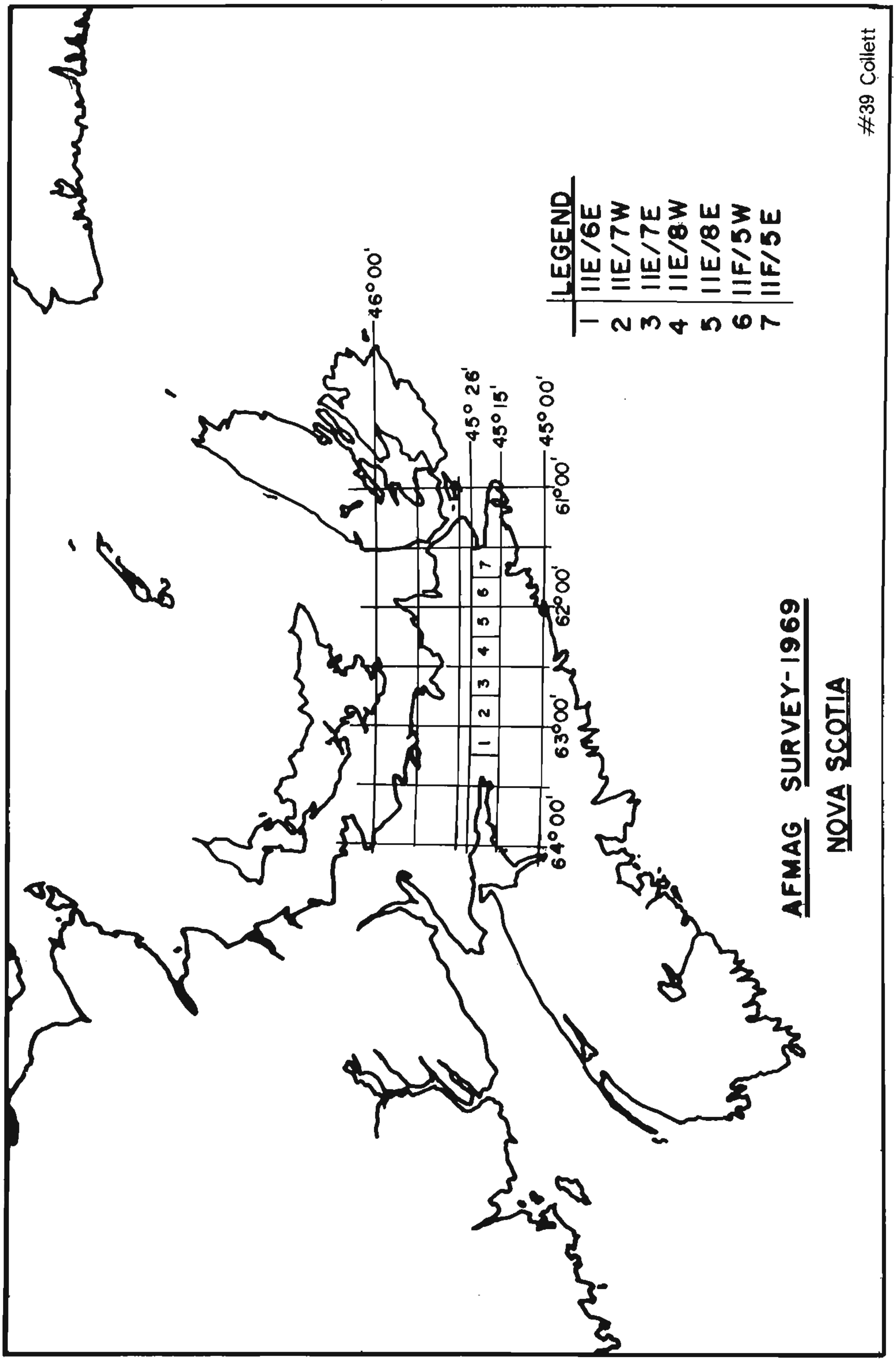
Ground work was undertaken at the beginning of the season in Gatineau Park and the adjoining area northeast of the Ottawa River to investigate some radiometric features shown up in airborne gamma-spectrometer test flights over the area. A belt of relatively high thorium, and above average thorium/uranium ratio was found to lie between Highway 8 and the Ottawa River northwest of Breckenridge. This coincides with a unit mapped as a nonmarine clay, probably developed from underlying marine clay during the last stages of the Champlain Sea and during subsequent estuarine and fluvial periods[1, 2]. It is probable that the radiometric signature of the clay is due to radioactive heavy minerals in the small amount of sandy matter enclosed within it. A preliminary study of an autoradiograph of separated sandy material showed the presence of radioactive grains.

The homogeneous radiometry of the clay belt and the presence of a convenient straight length of railway line to act as a marker renders it suitable as a calibration area for comparing airborne count rates with known ground concentrations.

A third summer of work in the Bancroft area[3, 4, 5] (parts 31 C, D, E, F) was planned to increase the number of areas in which there are comparative ground and air measurements. However the program was severely curtailed by recurring mechanical problems with the supporting helicopter. Nevertheless the repeatability of airborne measurements made in 1968[4, 5] was verified, and in several areas a comparison of count rates was made at 250 and 400 feet with the helicopter equipment [3 (5 X 5) in. Na(Tl) detectors] so as to provide correlation with the Skyvan [12 (9 X 4) in. Na(Tl) detectors] survey at 400 feet. Ground spectrometer measurements were made and samples were collected in a number of localities which were shown by the Skyvan survey of the area to possess distinctive radiometric features.

---

[1] Gadd, N.R.: Surficial geology of the Ottawa map-area, Ontario and Quebec; Geol. Surv. Can., Paper 62-16 (1963).


46°00'
45°26'
45°15'
45°00'
61°00'
62°00'
63°00'
64°00'
1
2
3
4
5
6
7
LEGEND
1 11E/6E
2 11E/7W
3 11E/7E
4 11E/8W
5 11E/8E
6 11F/5W
7 11F/5E
AFMAG SURVEY-1969
NOVA SCOTIA
#39 Collett

[2] Lajoie, P.G.: Soil survey of Gatineau and Pontiac counties, Quebec; Research Br., Canada Dept. Agriculture (1962).

[3] Fleet, M.: Ground gamma-ray spectrometer survey, Bancroft, Ontario; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, p. 71 (1968).

[4] Darnley, A.G. and Slaney, V.R.: Gamma-ray support, Bancroft, Ontario; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 80-81 (1969).

[5] Darnley, A.G., Grasty, R.L. and Charbonneau, B.W.: Airborne gamma-ray spectrometry and ground support operations; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. B, p. 10 (1969).

---

39. AFMAG SURVEY, ST. MARY'S RIVER AREA, NOVA SCOTIA (11 E/6, 7, 8 AND 11 F/5)

Project 680123

L.S. Collett

An AFMAG survey was flown in late August 1969 in the St. Mary's River area, Nova Scotia, between Truro and Chedabucto Bay as shown in Figure 1. The area is approximately 85 miles long and 13 miles wide and was flown both in an east-west and north-south direction with an aircraft elevation of 650 feet terrain clearance.

All the geological evidence points to a deep elongated basin consisting of sandstones, shales and conglomerates of the rarely fossiliferous Lower Carboniferous Horton Group. The rocks of the Horton are very quiet magnetically while the rocks to the north and south are very magnetically active. The thickness of the sediments in the Horton is believed to be greater than 3,500 feet.

There are very few outcrops in the Horton, faulting is known to exist. The purpose of the AFMAG survey is experimental to test whether it can assist further in working out the geology of the region.

40. AIRBORNE GAMMA SPECTROMETRY

Project 670050

A.G. Darnley and R.L. Grasty

Two operations have been undertaken during the summer with the Skyvan aircraft totalling 150 flying hours. These are a detailed survey of approximately 720 square miles in the Bancroft area of Ontario and a round-trip reconnaissance profile from Ottawa to Yellowknife, with some additional profiles in the vicinity of Uranium City.

The detailed survey (2,850 line miles) has been undertaken using the complete 12 detector system (3000 in.^{3} NaI (Tl)[1, 2] flying at 120 mph at 400 feet terrain clearance, with 0.25 mile line spacing. The area surveyed is approximately 24 miles east to west, 30 miles north to south, centred about 78°00'W, 45°00'N. All data has been recorded on magnetic tape and is now being processed. The spectrometer unit has proved very stable and reliable in operation. The equipment as a whole has performed satisfactorily during its first season with the exception of the spectrometer/tape-recorder interface. A variety of faults resulted in incomplete and/or garbled recording of data, necessitating numerous re-flights before data of an acceptable quality could be obtained.

A preliminary assessment of the data shows a very good correlation with known geology with a clear indication of the distribution pattern of uranium and thorium enrichment across the whole area. Computer plotted profiles are now being obtained from the raw data and it is intended that these will be used to prepare a geochemical contour map of the area. Results will be published as soon as possible.

The regional reconnaissance profiles were obtained along the following flight line on the outward journey: Ottawa (Kinburn beacon) - North Bay - Sudbury - Timmins - Kapuskasing - Nakina - Sioux Lookout - Red Lake - God's River - Thompson - Lynn Lake - Stony Rapids - Uranium City - Fort Smith - Yellowknife. On the return the same route was followed with an offset of 5 miles, as far as Sioux Lookout. Thence the track was via Lakehead, Sault Ste. Marie, Elliot Lake and Sudbury. The total length of profile along which data was recorded was 5,180 miles, including an additional 1,030 line miles flown out of Uranium City.

Six detectors (1500 in.^{3}) were used for the reconnaissance flights which were flown at 140 mph at 500 feet. All parts of the system performed perfectly during these trials. Substantial radiometric differences between regions were observed with the highest average concentration of radioactive elements occurring in the region between Lake Athabasca and Great Slave Lake. Results will be published as soon as compilation work has been completed.

---

[1] Darnley, A.G., Bristow, Q. and Donhoffer, D.K.: Airborne gamma-ray spectrometer experiments over the Canadian Shield; Symposium Nuclear Techniques and Mineral Resources, International Atomic Energy Agency, Vienna, pp. 163-186 (1968).

[2] Darnley, A. G.: Airborne gamma-ray spectrometry. Annual meeting Can. Inst. Mining Met.; Montreal, 1969 (in press).

---

41. SEISMIC REFRACTION PROGRAM, WELLAND-PORT COLBORNE, ONTARIO (30 M/3, 30 L/14)

Project 670074

George D. Hobson

About 500 locations were investigated between Niagara-on-the-Lake and Port Colborne and between the Welland Canal and the Niagara River by seismic refraction methods to investigate the thickness and nature of the overburden and to determine the bedrock topography. This is a continuing project in areas of interest in the development of the new Welland Canal channel and tunnel approaches and to complete the Pleistocene mapping and bedrock topography of adjacent areas. One 1:25, 000 map-sheet remains to be surveyed to complete the project. The data are of good quality and a preliminary compilation of all project data has been started.

42. MARINE SEISMIC PROGRAM - LAKE HURON (40 O, P; 41 A, B, G)

Project 660054

George D. Hobson

A reconnaissance marine seismic survey of Lake Huron was undertaken during June-July 1969 to determine depth of water, thickness of unconsolidated bottom sediments and stratification within those deposits overlying bedrock, bedrock topography and stratification and structure within bedrock formations if possible. The survey, covering 2, 800 miles of track, was conducted from the vessel C. S. S. Limnos out of Burlington, Ontario, and was conducted by Huntec Limited under contract to the Geological Survey of Canada. A Bolt air-gun was used as a repetitive source. A side-scan sonar device was also towed astern to assist in the identification of bottom materials.

The quality of the data recorded is generally good. The combination of data recorded by the echo sounder, continuous profiling device and the side-scan sonar will permit a more detailed interpretation of bottom and subbottom geology. Very interesting escarpment features extending across the lake have been observed. The data are now being processed prior to interpretation.

43. HAMMER SEISMIC SURVEYS, TORONTO - TRENTON AND PETERBOROUGH, ONTARIO (30 M, N AND 31 D/8)

Project 680037

George D. Hobson and H. A. MacAulay

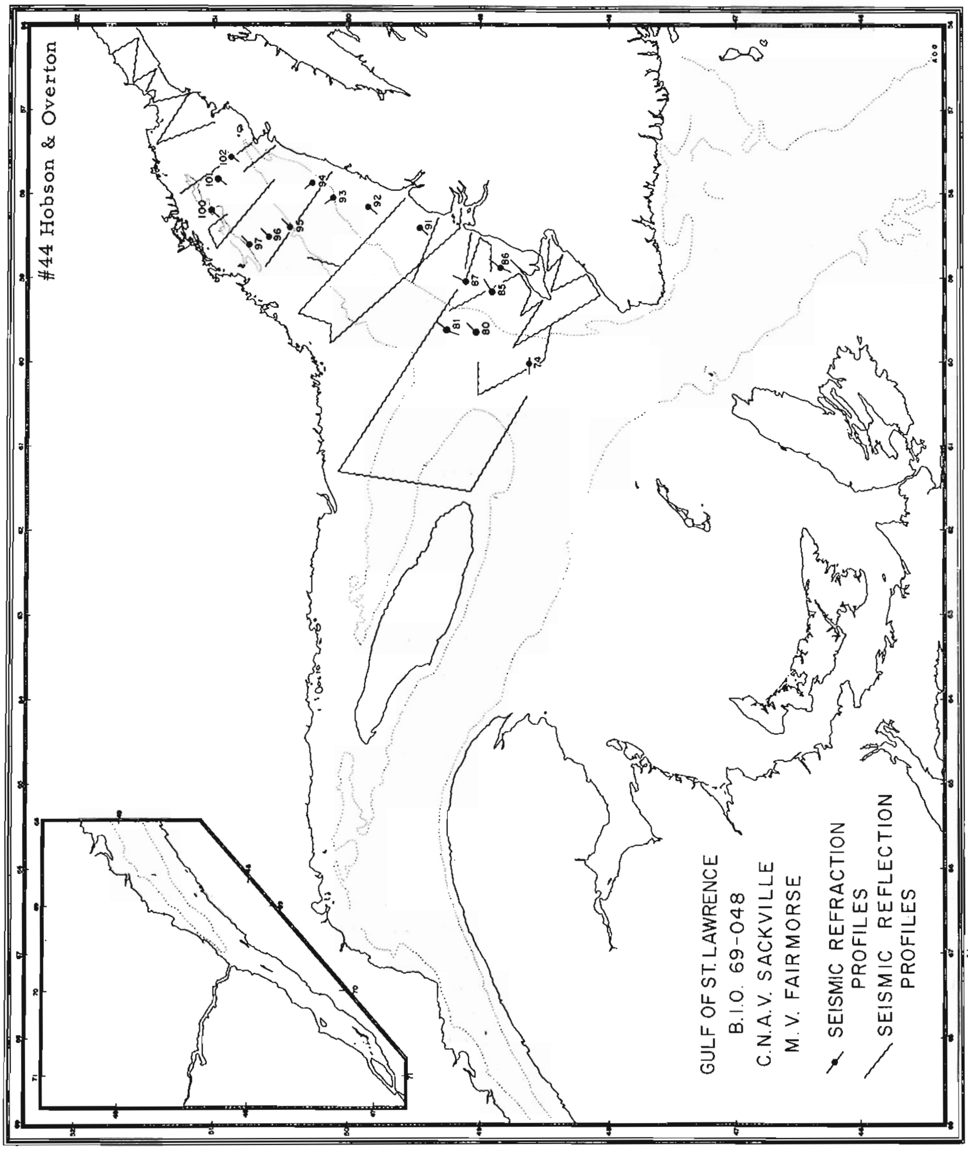
A bedrock topography profile has been drawn from data procured by using portable hammer seismographs from the east end of the Murray Canal near Trenton to Highland Creek in east Toronto along the north shore of Lake Ontario. The survey was generally conducted along the shore of the lake unless access was forbidden by erosion of the shore in which case tests were carried out on nearby roads or farmland. Of prime interest to the survey was the detection and delineation of bedrock depressions to complement the current drainage basin studies. Detection of a bedrock depression along the shore profile was followed by further tests inland; in some cases the depression was not found to extend inland and therefore probably would not be part of a preglacial or interstadial drainage system. A rapid increase in surface elevation, with a generally equivalent increase in drift thickness, was encountered inland from the shoreline; it was therefore not always possible to confirm or trace bedrock depressions inland if the depth to bedrock exceeded the capability of the instrument while using a hammer energy source.

Depths to bedrock referred to a lake level of 246 feet above sea level vary from exposed bedrock to 100 feet. Depths greater than 100 feet were indicated at two locations but are considered questionable. Bedrock has been found shallower than 30 feet below lake level for about 80 per cent of the shoreline surveyed.

The esker described by Bannerjee[1] north of Peterborough, Ontario, was investigated by seismic methods to define the underlying bedrock topography and describe the esker materials. These data are being compiled and interpreted; preliminary conclusions indicate a shallow (about 40 feet) depth to bedrock and the presence of a till overlying bedrock under the southwestern portion of the esker.

---

[1] Bannerjee, I.: Sedimentology of an esker north of Peterborough, Ontario; in Report of Activities, Part B, November 1968 to March 1969; Geol. Surv. Can., Paper 69-1, Pt. B, pp. 61-62 (1969).


#44 Hobson & Overton
GULF OF ST. LAWRENCE
B.I.O. 69-048
C.N.A.V. SACKVILLE
M.V. FAIRMORSE
SEISMIC REFRACTION PROFILES
SEISMIC REFLECTION PROFILES

44. MARINE SEISMIC PROGRAM, GULF OF ST. LAWRENCE (12 B, C, F, G, I, J, K, O, P)

Project 640049

George D. Hobson and A. Overton

The reconnaissance seismic program in the Gulf of St. Lawrence was continued and completed during September, 1969. Sixteen conventional marine refraction seismic profiles were obtained as shown in Figure 1,(p. 75).

Two ships, CNAV Sackville recording and MV Fairmorse shooting, were engaged for the operation. Geogel explosives were used for energy sources.

In addition to the conventional seismic program, the Atlantic Oceanographic Laboratory was offered part of CNAV Sackville's cruise time to run continuous air gun profiles throughout the area. As a result, about 1,000 miles of air gun profiles were also obtained as shown in Figure 1. These are useful in delineating the Precambrian contact and sedimentary stratification on the seafloor.

45. LABRADOR SEA: LOW-LEVEL AEROMAGNETIC INVESTIGATIONS IN 1969

Project 650007

Peter Hood and Margaret E. Bower

The co-operative aeromagnetic project with the National Aeronautical Establishment was continued during 1969 and Figure 1 shows the 13 aeromagnetic profiles obtained across the Labrador Sea during April and May 1969. The survey equipment used was an optical absorption magnetometer installed in the North Star aircraft of the National Aeronautical Establishment. Approximately 11,000 line miles of total field magnetic readings were digitally recorded on magnetic tape at an average flight elevation of 1,000 feet. A Tracor Inc. Model 599R Omega receiver was tried out during the project in order to evaluate the Omega navigation system in the area surveyed. The frequency used was 13.6 KHz rather than 10.2 KHz because only the Omega plotting charts for that frequency were available at the time of the survey. Some delay was experienced prior to take-off on each sortie due to the crystal oven in the Omega receiver requiring a considerable time to reach its operating temperature, and it was found that the reception from Omega Station C in Hawaii was in general poor. Otherwise for a first try, the Omega navigation system worked reasonably well. To detect any lane jumps both the Omega channels were chart recorded. Loran A and astro fixes and Doppler were also used to ascertain the aircraft track. An Inter Data Corp.

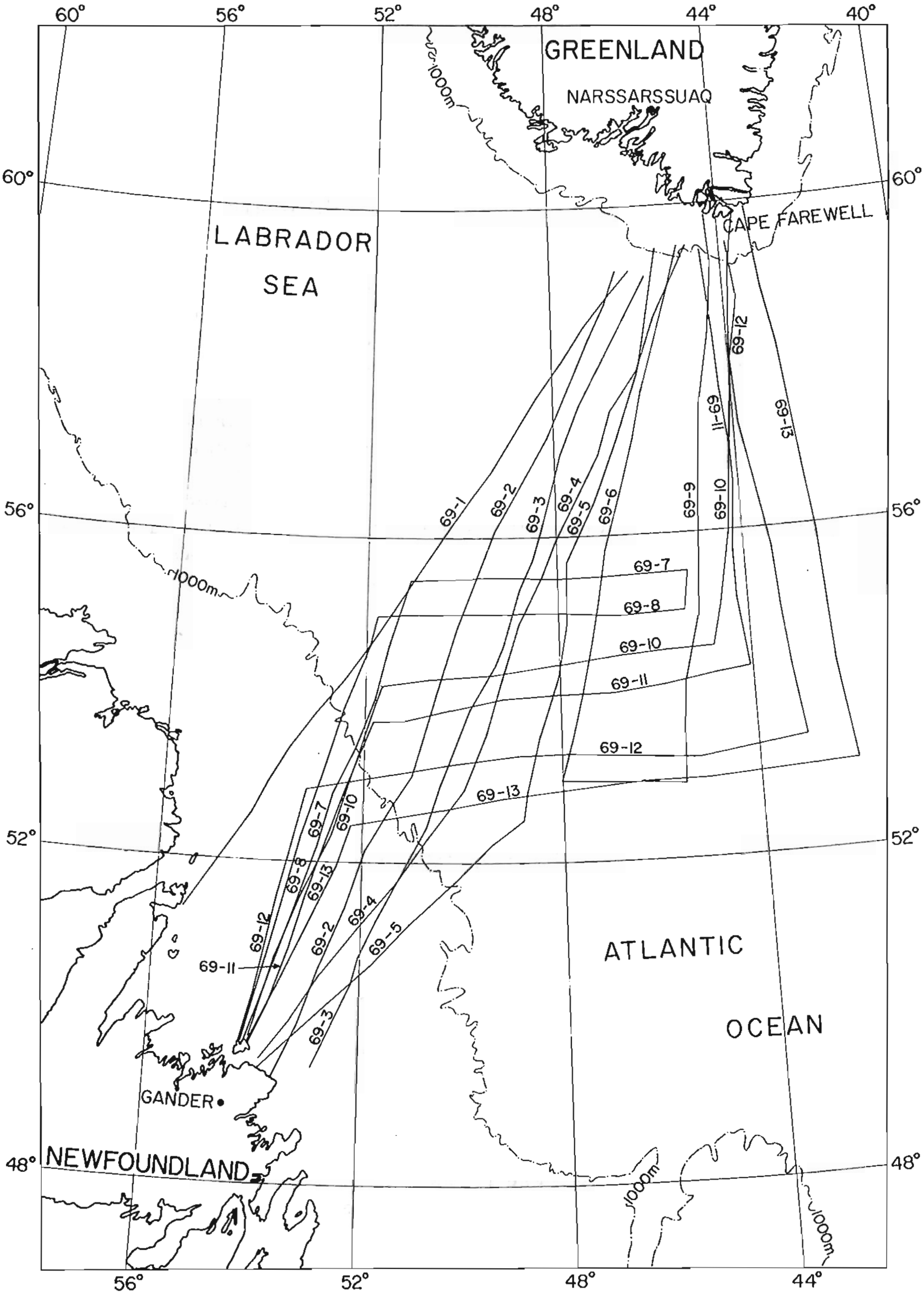


Figure 1. Tracks of the aeromagnetic survey aircraft in the Labrador Sea.

Model 4 computer was also flown in the aircraft for the first time on a survey operation. The computer was programmed to take the rubidium frequency from the magnetometer sensor and convert it into total field magnetic values with 0.01 gamma sensitivity every 0.5 second. These total field values were digitally recorded in an IBM-compatible format on a Kennedy 1400 RFC magnetic tape recorder together with the navigation information which was manually inputed. The system worked very well providing the computer operator did not make a mistake.

The survey lines were positioned to fill in areas in which the previous aeromagnetic survey coverage was sparse or nonexistent. A particular objective was to ascertain whether the magnetic stripes which are found in the Labrador Sea and off the east coast of Greenland bend around the southern tip of Greenland. A preliminary examination of the resultant reduced profiles indicates that the linear magnetic anomalies do appear to bend around Cape Farewell. It therefore follows that the Labrador Sea and Baffin Bay widened contemporaneously with the North Atlantic Ocean probably during Mesozoic time. The two prominent bands of anomalies described in earlier reports resulting from Project 650007[1] are also clearly evident on all the profiles. In the area surveyed northeast of Newfoundland, it was found that linear bands of prominent magnetic anomalies extend in a northwest direction along the outer part of the continental shelf. These are probably due to a large swarm of diabase dykes which have been intruded into the sedimentary section whose tops are buried at no great distance below the seafloor.

---

[1] Godby, E.A., Baker, R.C., Bower, M.E. and Hood, P.J.: Aeromagnetic reconnaissance of the Labrador Sea; J. Geophys. Res., vol. 71, pp. 511-517 (1966).

---

46. PALEOMAGNETISM-APPALACHIAN INTRUSIVES, QUEBEC AND NEW BRUNSWICK (12E, 21G, J, 31H)

Project 680058

A. Larochelle

Oriented samples were collected from diabase dykes on Anticosti Island and the Woodstock-Fredericton area in an attempt to use paleomagnetism as a means of dating these rocks.

Oriented samples were also collected from dykes and sills presumed related to the Monteregian Hills in an attempt to identify the relative age of these rocks on the basis of their magnetic polarity.

Laboratory measurements on these suites of samples will be carried out during 1969-70.

47. AEROMAGNETIC INTERPRETATION APPALACHIA, NEW BRUNSWICK AND NOVA SCOTIA (11 D, E, F, K; 20 O, P; 21 A, G, H, J)

Project 680121

P. H. McGrath

Continuing the survey initiated in 1968[1], in situ magnetic susceptibility measurements were obtained at three hundred and seven sites in southern New Brunswick and Nova Scotia during the 1969 field season (Fig. 1). Also seventy-two 1 1/4-inch diameter rock cores were obtained for laboratory analysis.

One of the purposes of the field survey was a study of the Halifax slates with which are associated prominent linear magnetic anomalies[2]. Also smaller, more circular anomalies are associated with the Goldenville quartzites. The slates and quartzites are intruded by nonmagnetic Devonian granite[3].

A summary of in situ magnetic susceptibility determinations for the Goldenville and Halifax formations of Nova Scotia is given in Figure 2. A thermal demagnetization study of selected samples of these two formations indicates, (1) that the Goldenville quartzite contains a single magnetic phase of almost pure magnetite (Curie Point $\simeq 570°C$), and (2) that the magnetic effect of the Halifax slates is primarily caused by pyrrhotite ($k < 300 \times 10^{-6}$ emu/cc); however, within the more highly metamorphosed contact aureoles surrounding the intrusive Devonian granites, magnetite seems to be the dominant magnetic mineral (1000×10^{-6} emu/cc $< k < 6500 \times 10^{-6}$ emu/cc) in the Halifax Formation.

The formation of pyrrhotite within slates is generally attributed to thermal decomposition of pyrite[4] with an accompanying loss of sulphur. The occurrence of pyrite in the Halifax slates has been noted by several workers[5, 6, 7]. Regionally the pyrite crystals in the Halifax Formation are altered to pyrrhotite within sheared slates, whereas in nonsheared slates the pyrite is generally unaltered. Some of the moderately-sheared slates contain both pyrite crystals and pseudomorphs of pyrrhotite after pyrite. After discussing the problem of the pyrrhotite formation in the Halifax slates with E.J. Schwarz, it is felt that the pyrite-pyrrhotite transition appears to have been promoted both by thermal metamorphism and by the sulphurous degassing of the Halifax slates within shear zones.

---

[1] McGrath, P.H.: Magnetic susceptibility and natural remanent magnetization of selected rock outcrops in southern New Brunswick; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 93-97 (1969).

[2] Geological Survey of Canada: Aeromagnetic Maps 7291G, 7030G, 7031G, 7032G, 7033G, 7034G, 7035G (1965, 1966, 1968).

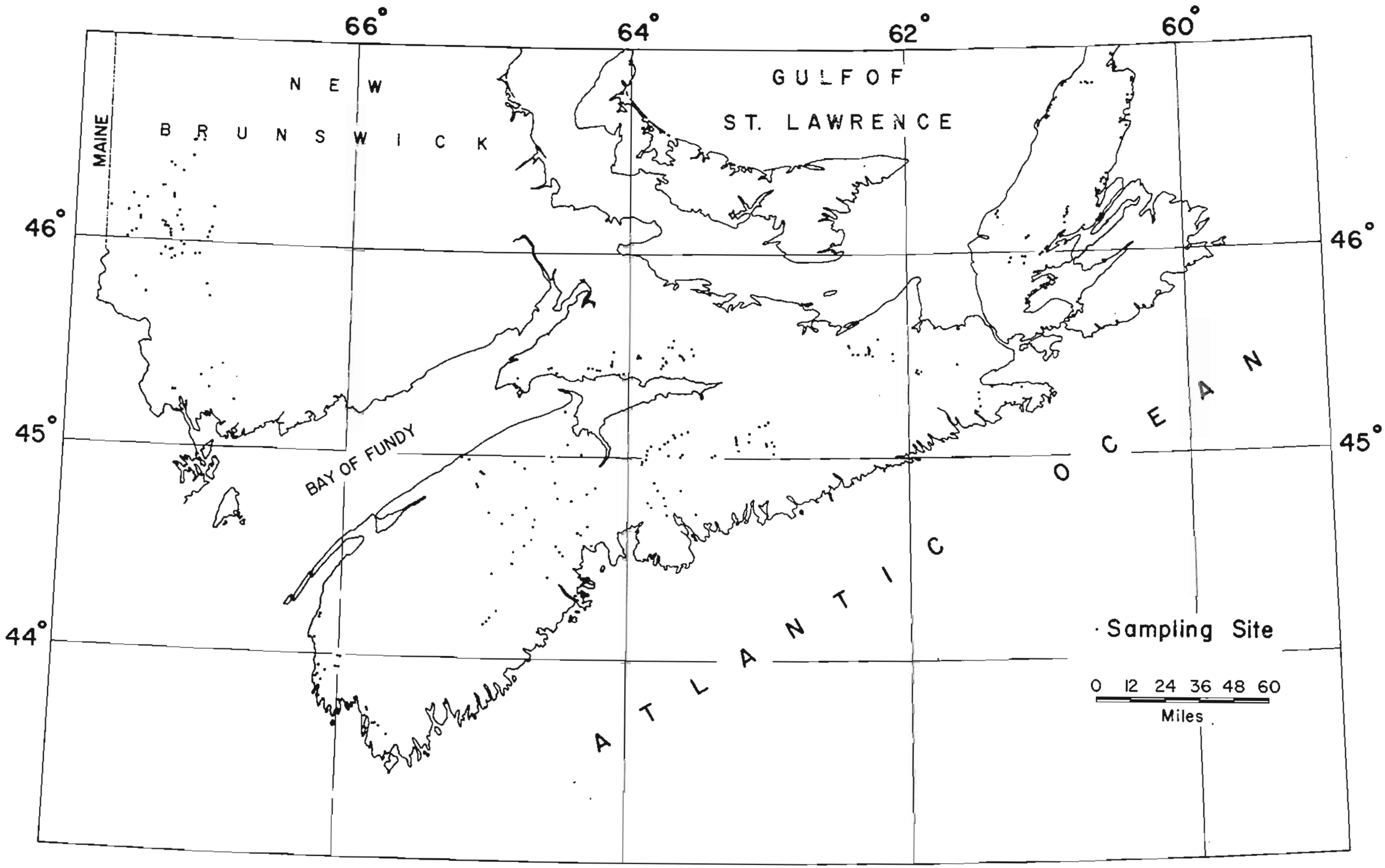


Figure 1. Outcrops sampled during 1969.

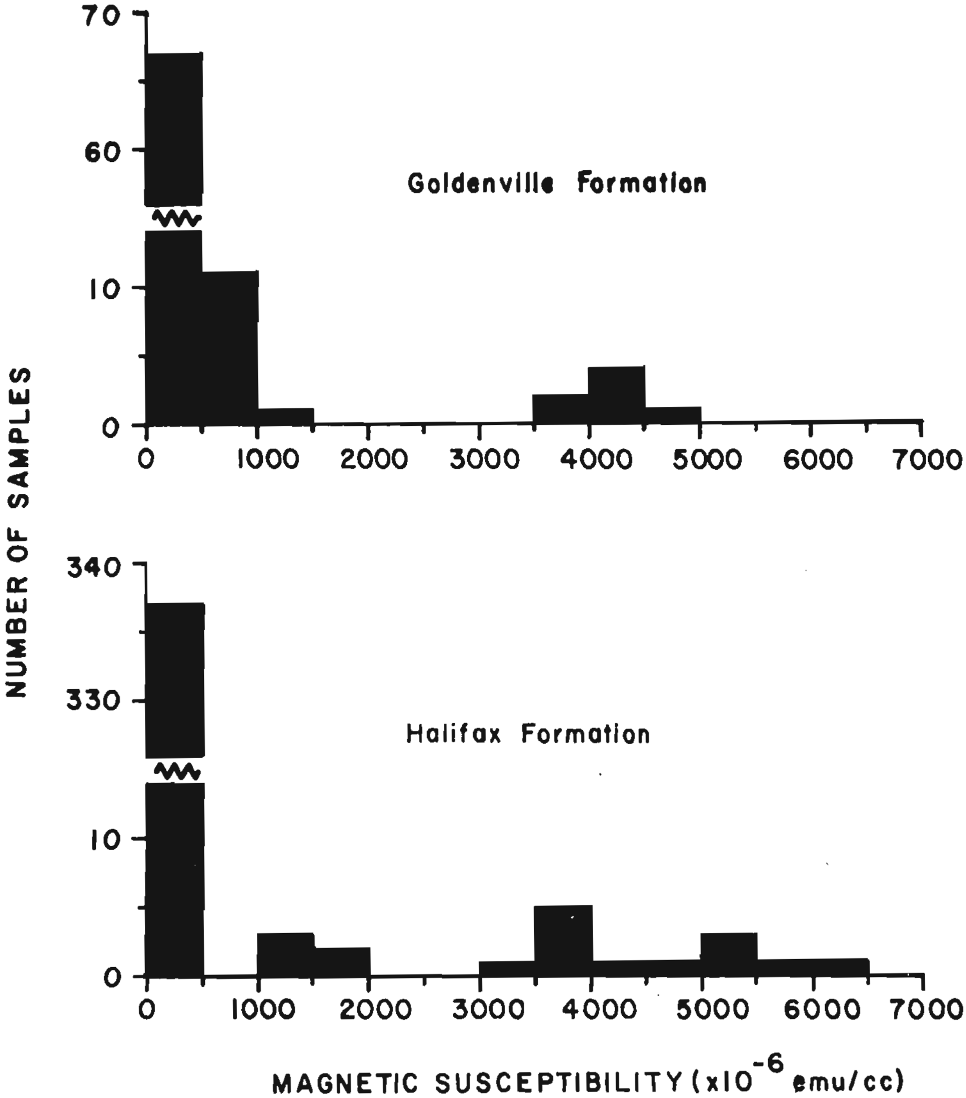


Figure 2. Frequency distribution of in situ magnetic susceptibility determinations - Meguma Group.

[3] Hood, Peter, J.: Magnetic surveys of the Continental Shelves of Eastern Canada; in Continental Margins and Island Arcs; Geol. Surv. Can., Paper 66-15, pp. 19-32 (1966).

[4] Neumann, Henrich: Pseudomorphs of pyrrhotine after pyrite in the Ballachulish slates; Mineral. Mag., vol. 29, No. 210, pp. 234-238 (1950).

[5] Stevenson, I.M.: Shubenacadie and Kennetcook map-areas, Colchester, Hants and Halifax counties, Nova Scotia; Geol. Surv. Can., Mem. 302, p. 13 (1959).

[6] Crosby, D.G.: Wolfville map-area, Nova Scotia (21 H 1); Geol. Surv. Can., Mem. 325, p. 18 (1962).

[7] Taylor, F.C.: Reconnaissance geology of Shelburne map-area, Queens, Shelburne and Yarmouth counties, Nova Scotia; Geol. Surv. Can., Mem. 349, p. 15 (1967).

---

48. RADIOISOTOPE METHODS, BRITISH COLUMBIA (82 N)

Project 670053

L. Ostrihansky and A.G. Darnley

In support of an investigation being undertaken by R. Mulligan at Snowflake Regal silver mine, near Albert Canyon, British Columbia, a Hilger & Watts Ltd. portable radioisotope X-ray fluorescence analyzer was used to evaluate tin concentration in situ. The instrumentation and technique has been previously described[1].

Measurements were made underground on natural rock surfaces primarily to select material for laboratory analysis. Visible stannite was subsequently noted in samples which gave the highest readings.

---

[1] Darnley, A.G. and Leamy, C.C.: The analysis of tin and copper using a portable radioisotope X-ray fluorescence analyzer; in Radioisotope Instruments in Industry and Geophysics, IAEA, Vienna, 1966.

---

49. PALEOMAGNETISM OF TRIASSIC BASALTS, NOVA SCOTIA (21 A, B, H)

Project 680077

G.W. Pearce

The purpose of this study of the Triassic basalts along the west coast of Nova Scotia and especially in the Annapolis Basin and the Minas Basin is to determine accurately the paleomagnetic characteristics of the North Mountain basalts in order to relate them with geotectonic features.

The preliminary results showed systematic discrepancies in the directions of remanent magnetization among different units. For that reason, sampling of contact zones of the flows and of more sites were required for a more detailed paleomagnetic investigation. The fifteen collecting sites of this year were situated between Digby and Cape d'Or. Over one hundred cored samples, oriented both with the Brunton compass and the solar compass were taken from different lava flows. The paleomagnetic measurements are carried on with the high sensitivity astatic magnetometer of the Geological Survey of Canada.

50. PALEOINTENSITIES AND IDENTIFICATION OF NRM COMPONENTS, SUDBURY, ONTARIO (41 I)

Projects 670554 and 670566

E.J. Schwarz

Additional detailed sampling of a section of the felsic norite was carried out just north of Sudbury. The oriented drill cores were cut into three cylinders. Two of these were used in the comparison of the blocking temperature spectra of the Natural Remanent Magnetization and a remanent magnetization of the thermomagnetic type acquired during cooling in the laboratory in a constant magnetic field. The third cylinder of each core was used in the comparison of the microcoercivity spectra of the Natural Remanent Magnetization and the laboratory Thermoremanent Magnetization. Further work will include thermomagnetic analyses and microscope work on the opaques. The purpose of the study is (1) to compare the results of the demagnetization tests, (2) to improve the experimental methods used, and (3) to investigate the possibility of variations in paleomagnetic intensity during the cooling of the norite through its blocking temperature range.

51. LOW-FREQUENCY PHASE-SENSITIVE RESISTIVITY MEASUREMENTS, MANITOBA (62 H, K) QUEBEC (21 E)

Project 670040

W.J. Scott

Phase and amplitude measurements were made using low-frequency A.C. resistivity equipment designed and built for the purpose. Frequencies employed ranged from 10 Hertz to 0.01 Hertz.

Readings were taken over one tabular sulphide body and two buried sand and gravel aquifers, and in no case were phase shifts observed that could not be attributed to electromagnetic coupling between transmitter and receiver dipoles.

52. MULTISPECTRAL PHOTOGRAPHY

Project 630031

V.R. Slaney

Three weeks in August were spent at Uranium City in a program shared with the gamma-spectrometer. The visit was aimed at obtaining colour and false-colour film which, in an area of high outcrop density, might be expected to help in the recognition of rock types. Seventy millimetre Hasselblad cameras were used to photograph an area 16 miles by 10 miles, which was flown at heights of 10,000 feet and 5,000 feet above sea level. Selected lines were also flown at 1,000 feet above ground level. Colour, colour-infrared and panchromatic films were exposed. Most of the film has been processed. The film will be evaluated when processing is complete.

The Department of National Defence agreed to provide a number of high altitude flights using a CF 100 jet aircraft modified for aerial photography. The Geological Survey have contributed a closed circuit television system to assist in the navigation of the aircraft. Engineering modifications to the aircraft, however, delayed the start of the program which is now scheduled to begin in October.

Proposals to mosaic small-scale, low sun-angle photographs of a test area near Bancroft may have to be postponed unless suitable weather occurs before mid-October. Three early morning flights produced sufficient information to decide on the film to be used.

53. INFRARED SCANNING

Project 670054

V.R. Slaney

Thirty-six flights were made over the Almonte-Ottawa River test strip between May 1968 and May 1969, at heights of 1,000 feet to 7,000 feet above ground level. Most of the flights were concentrated into 24-hour-periods at different seasons of the year. The strip was also photographed with colour and colour-infrared film, and a limited number of thermistor and radiometer measurements were taken on the ground during two of the series of flights.

Because of the automatic gain system built into the scanner, it is not possible to relate ground temperature measurements to density measurements made on the film from the scanner. However, over short lengths of scanner film, density changes do indicate relative radiation differences on the ground.

Flights carried out in the late evening and at dawn record the greatest range in ground temperatures. Limestone and granite gneiss rocks can be recognized by the scanner where the overburden is thin or absent. The two rock-types can be separated by their characteristic fracture and drainage pattern. Areas of drift and of alluvium can also be separated.

The effect of water is particularly striking. Streams and bodies of standing water are displayed more prominently than on aerial photographs. Variations in the water content of soils are also shown in some detail.

In September the Skyvan was provided with a new nose bubble capable of carrying the IR scanner, to be tested in October. The mount is rotatable so that corrections can be made for aircraft drift.

54. PALEOMAGNETIC STUDIES OF RADIOMETRICALLY DATED IGNEOUS ROCKS IN THE CORDILLERA, SOUTHWESTERN BRITISH COLUMBIA (92, 93)

Project 690042

D. T. A. Symons

About 870 oriented samples from 180 sites were collected from (a) the Tertiary intrusives of Vancouver Island, (b) the Coast intrusives (Jurassic) of Vancouver Island, (c) the Karmutsen volcanics (Triassic) of Vancouver Island, (d) the Squamish batholith north of Vancouver, (e) the Chilliwack batholith near Hope, (f) the Copper Mountain batholith near Princeton, (g) the Tulameen ultramafic structure near Tulameen, (h) the Guichon batholith near Ashcroft, and (i) the Topley intrusives near Fraser Lake.

The paleomagnetic properties of these samples will be studied to examine Cordilleran tectonics, dating of intrusive phases, and correlation. Six weeks were spent in the collection of these samples.

55. BURIED MISSOURI AND RED RIVER VALLEYS IN MANITOBA (62 G, H, J)

Project 690062

J.E. Wyder

A project for the purpose of delineating the courses of the preglacial Missouri and ancestral Red Rivers in south-central Manitoba was initiated in late June, 1969. The project is based in part on previous work in map-areas 62 F (Virden)[1] and 62 H (Winnipeg)[2] and in part on bedrock elevation data provided by B. Bannatyne, L. Gray and A. Pederson of the Manitoba Department of Mines and Natural Resources.

The survey method consisted of surface resistivity profiles, with stations every mile, across the suspected trends of the buried valleys. Results of the resistivity survey were used to locate drillholes which were sidewall sampled and geophysically logged.

Results of the survey indicate the preglacial Missouri River valley trends easterly through a gap, less than 4 miles wide, at Brandon, continues to Carberry where it swings in a broad arc until it trends due north near Gladstone. Beyond Brandon the valley appears to be greater than 10 miles wide.

Attempts to delineate the ancestral Red River valley were not successful. Surface resistivity anomalies appear to be caused by decreases in water salinity. This geophysical phenomenon may be of some value both in locating freshwater supplies in the Lake Agassiz plains and in detecting lateral changes in lithology. None of the test holes drilled this year encountered the bedrock surface at elevations less than 550 feet asl. These elevations are appreciably higher than bedrock elevations of 435 and 470 feet asl previously determined in the buried valleys. Further stratigraphic drilling and, possibly, geophysical work is required to determine whether or not the presently known bedrock surface elevation-lows are actually associated with the ancestral Red River.

---

[1] Klassen, R.W. and Wyder, J.E.: Bedrock topography and character of drift in Manitoba part of Virden map-area; Geol. Surv. Can., Paper (in press).

[2] Collett, L.S. and Wyder, J.E.: Drilling, Sidewall sampling and DC resistivity, Winkler area, Manitoba; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A (1968).

56. BOREHOLE AND RELATED GEOPHYSICAL TECHNIQUES, ALBERTA AND BRITISH COLUMBIA (72 L, 82 H, I, G)

Project 680035

J.E. Wyder

A drilling, sidewall sampling, and borehole geophysical logging program was conducted as a co-operative project with A. MacS. Stalker close to several Pleistocene sections exposed in the banks of the South Saskatchewan River near Medicine Hat, Alberta. The purposes of the program were to determine the feasibility of detecting the stratigraphy of the exposed sections in boreholes and to investigate the possibility of using borehole geophysical measurements to correlate the geological units between drillholes. Results from this program will be analyzed during the 1969-70 winter season.

A co-operative program with L. A. Bayrock (Research Council of Alberta) initiated in November, 1968 was continued in June, 1969. Three surface resistivity profiles were completed which cross the assumed position of the buried preglacial North Saskatchewan River. Results of this program will be contributed to a Research Council of Alberta publication authored by Bayrock.

A borehole geophysical logging project in co-operation with Cominco Ltd. geologists at Kimberley, British Columbia was initiated in March, 1969. This project has the objective of investigating potential applications of small diameter borehole geophysical logging equipment to stratigraphic problems in the mining industry in general and to the Kimberley area in particular. The initial results while interesting, cannot be evaluated until further work, tentatively planned for October 1969, is completed.

57. SIDEWALL SAMPLING AND GEOPHYSICAL SERVICE, WESTERN CANADA

Project 680036

J.E. Wyder and R.A. Hodge

Under the general direction of T. Berg (Research Council of Alberta), routine surface resistivity surveys were conducted on and near the Suffield Experimental Station at Ralston, Alberta. The purpose of the work on the station was to locate an area approximately 1,000 metres square which would be geologically uniform to a depth of approximately 35 metres. An electrically-uniform area of these dimensions was located. Drilling is required, however, to confirm geological uniformity. Resistivity surveys near the Suffield Station were oriented to cross known and/or suspected buried river valleys.

Sidewall sampling services were provided for: a Research Council of Alberta drilling program near Consort, Alberta; R. W. Klassen (Geological Survey of Canada) in the Duck Mountain area (NTS 62 N) Manitoba; and to University of Manitoba personnel near Portage la Prairie, Manitoba.

Borehole geophysical logging services were also provided the Research Council of Alberta for the project in the Consort area.

MINERAL DEPOSITS

58. GEOLOGY OF CANADIAN NICKEL AND PLATINUM GROUP DEPOSITS, ONTARIO AND QUEBEC (32D, 35F, G, 41I, 42A)

Project 630037

O.R. Eckstrand

Nickel and platinum group deposits in the following districts of Ontario and Quebec were examined: Sudbury, the Timmins-Kirkland Lake-Noranda-Val d'Or belt, and Ungava (Cape Smith-Wakeham Bay belt). Particular attention was directed toward the regional geological setting, details of occurrence of the mineralization, and collection of specimen material for laboratory studies. Such examinations constitute the field component of a continuing documentation and study of the occurrence of nickel and platinum group metals in Canada.

Nickel deposits in the Cape Smith-Wakeham Bay belt occur as massive, disseminated, and vein sulphides localized in the basal portions of moderately folded ultramafic sills. To date, the higher grade deposits have been discovered in the northern belt of ultramafic sills, but substantial mineralized zones are known in the southern belt as well. The deposits appear similar to those at Rankin Inlet and in the nickel belt of Western Australia.

59. PEGMATITIC URANIUM DEPOSITS IN THE GRENVILLE PROVINCE, ONTARIO AND QUEBEC

Project 680088

M. Fratta

Field study of the uranium deposits in the Grenville Province carried out in 1969, concluded a project begun in 1968. The localities visited in 1969 were:

- Mont Laurier area
- Baskatong Reservoir area
- Otter Lake and Grand Calumet Island area
- Kipawa area
- St. Lawrence North Shore area

All these localities are in the Province of Quebec.

The <u>Mont Laurier area</u> was the site of an intense exploration effort in 1969. More than 25 companies have staked ground in this area; however, of these only a few had done enough work to warrant a visit. The properties visited were:

- The Mekoos claim group of Johns Manville Company
- Scandia Mining Company of the Malouf Group
- Guardian Mines Ltd.
- The Mac Dee Central Group of Phelps Dodge of Canada

Most of the mineralization is localized in granitic pegmatites that bear variable amounts of magnetite, biotite and sphene as accessory minerals. The pegmatitic dykes were emplaced into high grade metamorphic rocks. Quartzite, biotite gneiss and small sheet-like intercalations of granite were the most common rocks observed in the drillcores and in the vicinity of the mineralization.

The Baskatong Reservoir area is southwest of the Mont Laurier area. Capri Mining Corporation Ltd. was the only company engaged in active exploration, but other companies had acquired ground in the area and had begun preliminary exploratory work. The occurrences described by Shaw[1] were revisited and many samples collected.

In this area a variety of occurrences have been observed. In addition to pegmatitic uranium deposits, radioactivity was observed in metamorphic pyroxenite in association with sulphides. Most of the area is underlain by marble or calcium-rich metasediments; in addition, some granite and pegmatite are also present. Diopside is the main constituent (50-100 per cent) of the pyroxenite and is relatively abundant in the gneisses and in the pegmatite. The presence of large amounts of diopside (up to 25 per cent) in the pegmatite would appear to be a clear case of contamination. The main radioactive mineral is uranothorite, but allanite, thorianite and/or uraninite are also present in some deposits.

In Otter Lake and Grand Calumet Island area, where exploration for uranium was done in 1954-56, there has been renewed activity. Some of the old properties described by Shaw[1] and two new properties, the Clock and the M. Adams claims were examined and sampled.

On the Clock Group, the radioactive zones are concentrated in marble that contains variable amounts of calc-silicates (in places the calc-silicates exceed the calcite), whereas on the Adams property, radioactivity is confined to granitic pegmatite dykes.

Allanite is the most common radioactive mineral in deposits of this area, but uraninite, betafite, U- and Th-bearing zircon, thorite and thorianite were also found and identified by M. Bonardi of the Geological Survey of Canada.

In the Kipawa area, the multi-mineral property at Hunters' Point was visited as were two properties of the Sturdy-Talisman Mines Company near Grindstone and Sheffield lakes.

The Kipawa area is underlain by Precambrian metasediments (biotite-hornblende paragneiss; quartzite; pyroxenite), syenite, granite gneisses, migmatite (injection gneiss), pink granite and pegmatite. With the possible exception of some pegmatite dykes, all the rocks underwent metamorphism.

At the Hunters' Point occurrence, the mineralization is caused by veins of radioactive material filling fractures in the impure quartzite. The radioactive mineralizations on the Sturdy-Talisman properties of Grindstone and Sheffield lakes are localized in calc-silicate rocks, ranging from metamorphic pyroxenite to hornblende and diopside gneisses, which in places contain up to 5 per cent thorite and as much as 20 per cent eudialyte, with minor fluorite and apatite. The thorite is in crystals up to 3 centimetres long but is found also in shapeless masses. Where it occurs in discrete crystals in the hornblende gneiss, the elongated prisms lie in the planes of gneissosity.

A short visit was made to the uranium deposits of the St. Lawrence North Shore area. The St. Augustine property of the Boylen Group was briefly studied and several samples collected from the blasted trenches. Here considerable radioactivity was detected in quartz-biotite gneisses, only where they are variously cut and injected by small dykes of pegmatite, a few inches in width. The pegmatite dykes are also somewhat radioactive. Some metasomatic processes would appear to be responsible for the radioactivity in the metamorphic rocks.

Other uranium occurrences in the Baie Johan Beetz area that were not seen last year were visited in 1969. Additional data were collected on these properties which confirmed some of last year's general observations on this area.

Certain generalizations can be made regarding the pegmatitic uranium deposits of the Grenville Province. The rocks are mainly metamorphic rocks of sedimentary origin that are intruded by granites and pegmatites. During examination of the uraniferous pegmatites, the following observations have been made by the writer:

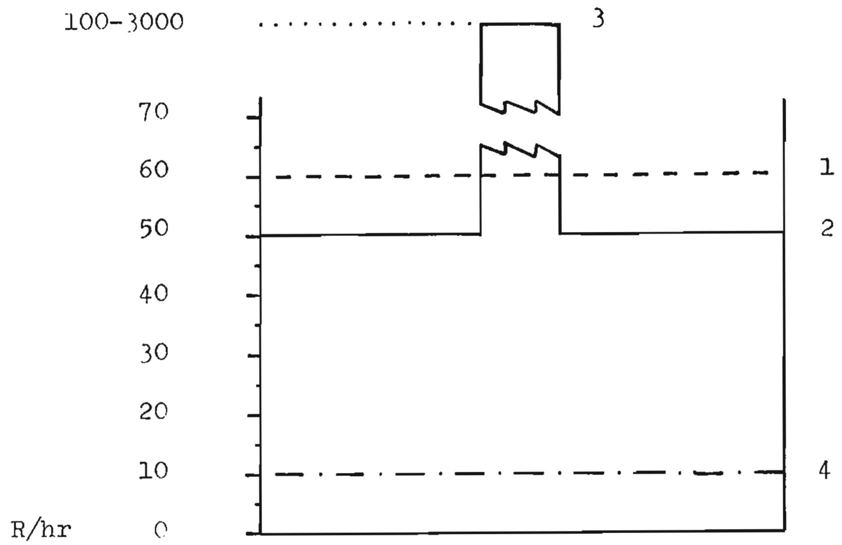
1. The pegmatites may be genetically related to the large volume of granite which is present in all areas.
2. Most of the pegmatites contain either muscovite or biotite and magnetite but some contain all three minerals.
3. Muscovite-bearing pegmatite everywhere has little radioactivity.
4. Pegmatites with abnormal concentrations of biotite and/or magnetite are abnormally radioactive, but in general biotite-magnetite pegmatites are less radioactive than the granites they cut.
5. In granites and pegmatites, the thorium content is less than that of uranium.

In the Baie Johan Beetz area especially, the two types of pegmatite seem to be the products of different stages of the same magmatic process rather than the product of two different magmas.

The biotite pegmatite was most likely emplaced first. Although observations of field relationships are inconclusive, the fact that muscovite usually crystallizes at a lower temperature than either biotite or magnetite suggests that muscovite-bearing pegmatites are younger.

According to Fersman[2], uranium is precipitated during his phases B and C which coincide with the crystallization of granite and pegmatite, provided the total pressure is high; otherwise uranium escapes as a volatile uranyl compound and is later precipitated in the hydrothermal stage. The early precipitation of uranium as uraninite or other oxides, such as euxenite or betafite, takes place during the late phase of granite crystallization or at the beginning of the pegmatite crystallization. This may explain why the muscovite pegmatite has such low radioactivity whereas the medium-grained biotite granite shows, on the contrary, a remarkably high background.

Uranium appears to be concentrated in the biotite granite and in the immediately subsequent biotite pegmatite. Figure 1 explains graphically the modality of concentration of uranium.



1. Assumed radioactivity level of granite and pegmatite magma.
2. Radioactivity level of barren biotite-magnetite pegmatite.
3. Radioactivity of uraniferous biotite-magnetite pegmatites.
4. Radioactivity of muscovite pegmatite.

Figure 1. Concentration of uranium.

It is assumed here that there was no enrichment of uranium in the pegmatite phase; the granite and the pegmatite 'magmas' contained the same proportion of uranium. In the course of crystallization, certain local concentrations of uranium took place within the pegmatite. This, in turn, slightly depressed the overall radioactivity level of the biotite-magnetite pegmatite relative to that in the original magma.

---

[1] Shaw, D.M.: Radioactive mineral occurrences of the Province of Quebec; Que. Dept. Mines, Geological Rept., No. 80 (1958).

[2] Fersman, A.Y.: Les Pegmatite, leur importance scientifique et practique. Leningrad, URSS, Academie des sciences de l'URSS, 3 vols. (1931).

60. GEOLOGY OF IRON MANGANESE DEPOSITS, NORTHEASTERN ONTARIO AND NORTHWESTERN QUEBEC (31NW, 32SW, 41NE, 42SE)

Project 570029

G.A. Gross and R.H. Ridler

Field study of Algoma type iron-formation and related mineral occurrences in Archean volcanic rocks was continued during the season in the southern part of the Canadian Shield. An iron range west of the Harricanaw River in Montgolfier Township, Quebec was examined where exploration drilling, sampling and evaluation work was being carried out after a lapse of about 10 years since the previous drilling program on this iron-formation. The thin-banded magnetite-rich beds are interlayered in a sequence of greywacke sediments and andesite flows and tuffs. The oxide facies of iron-formation consists of very fine grained magnetite disseminated in thin (1-5 millimetre) layers of quartz, chlorite, dark green mafic constituents and mica. The iron-formation appears to consist of a mixture of chemically precipitated magnetite, minor hematite and chert with a high proportion of fine-grained clastic material composed of argillaceous mud or volcanic ash. This mixed facies of iron oxide and chert with clastic material is extensively developed in iron-formations in the belt of volcanic rocks which extends east to Chibougamau.

Geological information was collected on a number of occurrences of iron-formation in southwestern Quebec including a highly metamorphosed deposit of iron-formation near the village of Miquelon in Bossé Township. Plans have been prepared for the production of a high quality magnetite concentrate from this deposit.

Magnetite-quartz iron-formation occurs in a group of hornblende-biotite-quartz gneiss and amphibolite rocks which are surrounded and intruded by granite. The magnetite in the iron-formation was recrystallized during metamorphism and is fine- to medium-grained and although the deposit is small the iron-formation can be processed to give a high quality iron concentrate.

Iron-formation Facies in the Southern Part of the Abitibi Basin, Ontario and Quebec

Field work was done by Dr. R.H. Ridler, Research Fellow at the University of Western Ontario, as part of a detailed study of iron-formation facies and related precious metal occurrences along the southern margin of the Abitibi greenstone-belt and was sponsored by the Geological Survey of Canada as part of the project on iron and manganese deposits. This study of iron-formation follows previous work in the area by Dr. Ridler on Archean volcanic stratigraphy that was part of a broader study of volcanic rocks in the Abitibi belt led by A.M. Goodwin.

Field study of the various facies of iron-formation in the southern margin of the Abitibi belt was carried out with the purpose of defining the stratigraphic and areal distribution of each of the iron-formation facies, outlining compositional and mineralogical variations within and between the various facies, and to determine the effects and extent of polyphase deformation and metamorphism of each facies.

The iron-formation occurs within one restricted stratigraphic zone in the thick succession of volcanic and sedimentary rocks. It is composed of a great variety of lithological facies but major carbonate and minor sulphide facies are correlative with the oxide facies that is extensively developed in the iron-formation in Boston Township.

All facies of the iron-formation and particularly the carbonate facies are highly deformed by folding, shearing, and recrystallization of mineral constituents during metamorphism but many primary sedimentary features still preserved in the iron-formation are evidence of its syngenetic origin and that of many carbonate and siliceous zones related to it. Economic concentrations of gold are found in each of the major facies of iron-formation and the carbonate and sulphide facies are highly favourable host rocks for its occurrence. A large proportion of the gold occurrences of the area are within or very close to rocks representing a facies of the iron-formation or its stratigraphic equivalent and it is strongly suspected that various facies of the iron-formation were 'source-beds' for the gold distributed in later veins, shears and fault zones. Other gold deposits occur in trachyte-syenite rocks that are part of the complex of volcanic rocks which contain the iron-formation.

The lateral and symmetrical distribution of different facies of iron-formation in relation to the centre of volcanism in the Noranda area is being studied in some detail. A zonal distribution of auriferous base metal massive sulphide deposits, auriferous carbonate facies and oxide facies of iron-formation around centres of volcanic activity supports the concept that all of these different types of deposits are products of volcanism. Considerable detailed information has been marshalled to test and develop concepts of the volcanic origin of the deposits and to analyze conditions in the depositional environments where the various deposits formed.

61. COPPERMINE RIVER COPPER DEPOSITS, DISTRICT OF MACKENZIE (86N, O)

Project 600009

E.D. Kindle and R.V. Kirkham

Most of the known copper deposits of the Coppermine River area were visited during July and August, 1969.

Mineral suites for laboratory study were collected by the junior author. Dominant fault line lineaments visible in the air photographs of the district were studied and the presence of faults, shear zones and shattered zones in the vicinity of and as loci of mineralization at many of the copper lodes, was confirmed.

One new type of copper deposit was noted (15 types found in the area were enumerated previously)[1]. The Cal 3 deposit (Lat. 67° 38'; Long. 116°59') is a sandstone dyke-copper-lode situated 1 1/2 miles west of Cliff

Lake in ground owned by Hearne Coppermine Limited. The sandstone dyke ranges from 5 to 7 feet wide and is well exposed for a length of 250 feet. The strike is N70°E and the dip is vertical. The overall length of the dyke is about 600 feet; it abuts on the east against a fault which strikes N27°W and on the west it abuts against a fault that strikes N30°W. The western part of the dyke is concealed beneath a small lake and the latter mentioned fault follows the northwest side of this lake which is about 200 feet wide. The dyke has been lightly shattered and is replaced by veinlets, pods and grains of chalcocite so that the mass contains between 1 and 3 per cent chalcocite. In some places pockets of chalcocite up to 2 inches in diameter were seen. The sandstone dyke occurs within the thick Precambrian Coppermine River Series basalt sequence with amygdaloidal basalts dominant locally in surface exposures. The dyke is a clastic filling of a tension fissure.

Widespread copper mineralization in the sedimentary rocks of the Coppermine River Series was investigated on the Bud 942-947 claims about 7 miles northwest of the junction of Husky Creek and Coppermine River. The claims are owned by G. Leliever. Presence of the mineralization was brought to our attention by W.R.A. Baragar who encountered it during the course of regional mapping. Scattered copper minerals occur in easterly-trending bluffs for over one mile and probably extend farther to the east, north and northwest.

Chalcopyrite, bornite and chalcocite occur disseminated in dark mudstones, siltstones, silty sandstones, and silty pebble conglomerates and also in small quartz veinlets and along fractures in quartz sandstones and quartzites. These minerals seem to be most abundant in a zone about 10 to 50 feet above an unconformity, especially in beds that are rich in hematite and magnetite. Eight samples taken for assay across widths ranging from 6 inches to 8 feet were found to contain from 0.02 to 0.44 per cent copper. The sample that contains 0.44 per cent copper was a chip sample taken across a 3-foot-thick bed that contains about 10 to 15 per cent specular hematite.

The sedimentary rocks have been indurated and metamorphosed to varying degrees by a gently northerly dipping diabase sill over 100 feet thick that lies between 10 and 40 feet stratigraphically above the main copper-bearing horizons. However, the sill does not appear to have been responsible for the mineralization.

Copper mineralization at this locality is not of immediate economic interest but it is possible that a higher copper content may be found elsewhere near this general stratigraphic horizon.

---

[1] Kindle, E.D.: The nature of the Coppermine River deposits; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 112 (1969).

62. CERTAIN COPPER DEPOSITS IN JURASSIC VOLCANIC ROCKS OF CENTRAL BRITISH COLUMBIA (93L, M, 94D, 103L)

Project 600009

R.V. Kirkham

A brief examination was made of several copper deposits in Jurassic volcanic rocks of central British Columbia. This project was an extension of studies which the writer had been carrying out for the British Columbia Department of Mines and Petroleum Resources.

Copper occurrences in the Hazelton and Takla volcanic sequences have been known for over 50 years, but only relatively recently have they received considerable attention as possible sources of copper and silver.

These deposits have a variety of structural, stratigraphic, and mineralogical features. The only features that they seem to have in common are that the main metals in them are copper and silver and the host rocks are mainly Lower Jurassic volcanic rocks or interlayered sediments. In the Smithers area, with which the writer is most familiar, this type of mineralization has not been found in rocks younger than Bajocian. However, there is a distinct possibility that such mineralization occurs in older sedimentary and volcanic rocks and younger intrusive rocks of the Terrace area[1,2]. This possibility remains to be checked.

At some deposits there is unequivocal evidence that mineralization is epigenetic, being controlled by prominent fault or fracture systems. However, at other deposits there are very prominent stratigraphic controls with little evidence of important structural controls.

Chalcopyrite, bornite, and chalcocite are the most important ore minerals. In some deposits pyrite, hematite, and/or magnetite are also abundant but in others they are absent. Minor amounts of native copper, galena, sphalerite, and tetrahedrite (?) have been observed at a few localities.

Alteration in many of these deposits is inconspicuous while in others, epidote, chlorite, potash feldspar, and/or quartz are common alteration products.

The genetic affinities of this type of deposit are not at all clear. The writer in his study of the zonal distribution of ores on Hudson Bay Mountain decided that this type of mineralization was simply a special type of outer zone deposit related to the emplacement of Upper Cretaceous-Lower Tertiary porphyritic intrusions in the central part of the district[3] (p. 20). It is however, difficult to reconcile such a hypothesis with the fact that this type of mineralization is very widespread in the lower volcanic division of the Hazelton Group and that it shows no apparent spatial relationship to silicic intrusions of the area as do most other metalliferous deposits. It is also significant that this type of mineralization has not been found in younger formations (post-Bajocian) of the Hazelton and Smithers area. There are two main possible origins for this type of deposit: 1. they were formed as a result of hydrothermal activity related to Hazelton and Takla volcanism or, 2. they were formed preferentially in certain Hazelton and Takla volcanic rocks by hydrothermal activity during some later geological episode(s). At present there is little evidence available to favour either hypothesis.

[1] Duffell, S. and Souther, J.G.: Geology of Terrace map-area, British Columbia; Geol. Surv. Can., Mem. 329 (1964).

[2] Kindle, E.D.: Mineral Resources of Terrace area, Coast District, British Columbia; Geol. Surv. Can., Mem 205 (1937).

[3] Kirkham, R.V.: A mineralogical and geochemical study of the zonal distribution of ores in the Hudson Bay Range, British Columbia; unpubl. Ph.D. Thesis, Univ. Wisconsin (1969).

63. URANIUM IN CANADA

Project 670029

H.W. Little and V. Ruzicka

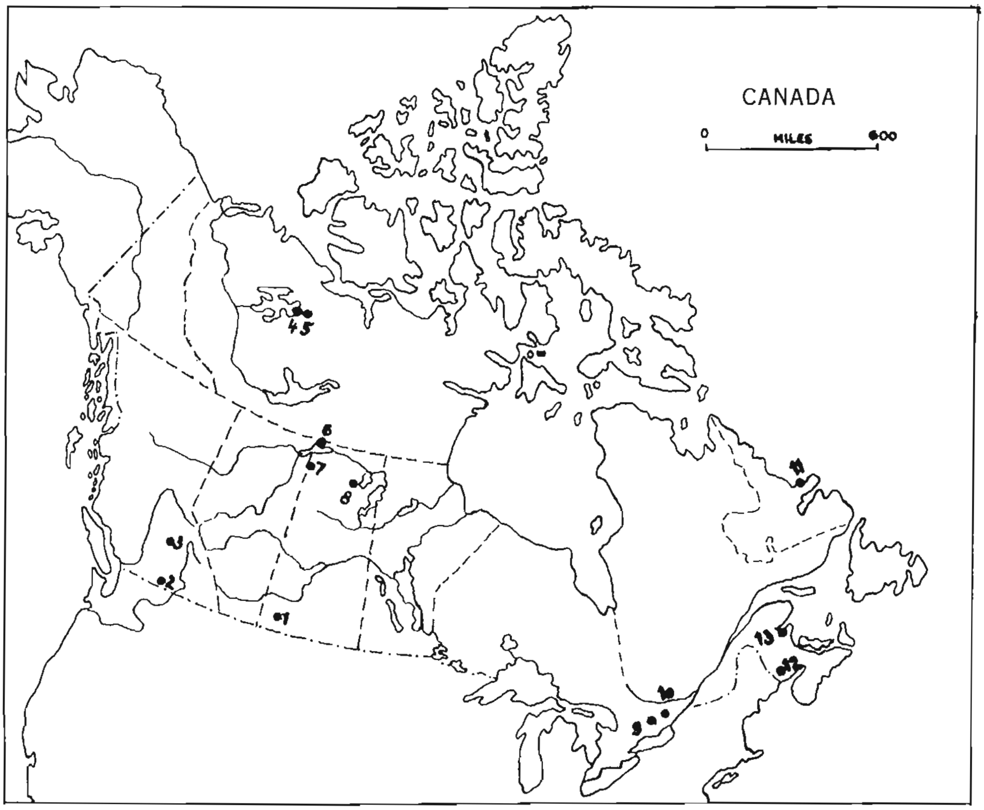
Brief examinations of exploration activity for uranium were made in many parts of Canada (see Fig. 1) and a visit was made to lignitic uranium deposits in North and South Dakota under the guidance of officers of the United States Atomic Energy Commission. Reports of activity in Elliot Lake area and Grenville Province, by T.J. Bottrill and M. Fratta respectively, are published elsewhere in this volume.

In Cypress Hills near Eastend, Saskatchewan, uraniferous lignites that had been tested previously by pits for Scoteire Explorations were tested by churn drilling followed by radiometric logging. This program had barely begun at the time of our visit but some uraniferous lignite in the Oligocene Ravenscrag Formation had been intersected. Depth of cover on such lignites ranges to 200 feet but mainly is much less.

In southern British Columbia a prospect owned by the Power Reactor and Nuclear Fuel Development Corporation of Japan is on Dear Creek about 32 miles north of Rock Creek. The deposit consists of uraniferous conglomerate which comprises a heterogeneous assemblage of roundstones of pre-Tertiary rocks in a sandy matrix with some carbonaceous material and limonite. It is overlain by flat-lying olivine basalt of Miocene (?) age[1]. Such conglomerate is rarely exposed in the region in road-cuts only, where protected from erosion by the basalt and olivine basalt. It is not known, therefore how extensive the conglomerate is. At the time of our visit trenching had exposed several feet of radioactive conglomerate at two localities about 100 feet apart, and a diamond-drill had just been put into operation.

At Rexspar property[2, 3], two zones containing secondary uranium minerals, purple fluorite and much pyrite in sheared Permo-Carboniferous(?) trachyte had been delineated in the 1950s. Denison Mines are currently exploring some 300 claims. Their initial program consists of geological mapping, geophysical testing of radon and uranium in soils, and IP surveys. Samples from the old workings were taken for study.

In Northwest Territories at Port Radium, Echo Bay Mines are producing silver and copper concentrates from their property which is east of and adjacent to the old Eldorado Mine. On the property the No. 2 vein



1. Cypress Hills
2. Dear Creek
3. Rexspar
4. Port Radium
5. Contact Lake
6. Beaverlodge
7. Carswell Dome
8. Wollaston Lake
9. Bancroft
10. Sharbot Lake
11. Makkovik-Kaipokok
12. Mount Pleasant
13. Campbellton

Figure 1. Location map

carries locally much pitchblende but to date it has not proved economically feasible to produce a uranium concentrate, but a new bulk sample has been sent to a laboratory for further tests. No. 2 vein is similar to the mineralogically complex veins that were mined on the Eldorado property.

Nine miles southeast of Port Radium, the Contact Lake Mine[4], now owned by Ulster Petroleums Limited, was unwatered in July, 1969 and the workings rehabilitated. Although primarily a silver prospect the veins contain in places interesting values in uranium, but the distribution appears to be spotty.

About 2 miles east of Contact Lake 9 trenches cut in 1967 by Precambrian Explorations expose a narrow vein cutting greywacke intermittently for 200 feet. A little pitchblende was seen in the vein. One-half mile west-southwest on the shore of Contact Lake a short adit and drift explore a copper-cobalt vein. In a pit above the adit some pitchblende was seen in the vein.

In northern Saskatchewan in Beaverlodge area[5] the Fay, Verna, Bolger, and Hab properties of Eldorado Nuclear were examined. The Verna Mine is being phased out of operation temporarily in line with the cut-back in production announced by the Company. The Bolger orebody has yielded some 40,000 tons of rich carbonate ore, including some secondary ore. A second, larger, orebody was discovered below by vertical drilling and at the time of our visit waste was being removed from the open pit to expose it for mining.

At the Hab property, which is about 5 miles north of the Verna, crosscuts are being driven from the shaft on three levels to intersect the two orebodies, which are not yet accessible for inspection.

The Scope property of Enex Mines Limited, which has been extensively drilled, is adjacent to and west of Lake Cinch Mine. The main ore zone strikes N70°E, lies south of the Crackingstone River Fault, and comprises red carbonate breccia ore with pitchblende. Mineralization is spotty and some spectacular values are reported. South of, and parallel to the main zone is the Pardee zone which contains a narrow vein. North of Crackingstone Fault the Mac zone is similar mineralogically to the main zone.

A short visit was made by Little to the Carswell dome area where Mokta and Numac are carrying out exploration programs, which the latter company had barely begun. In Carswell area[6] weak gamma ray anomalies have been found in the Archean basement rocks. Stronger anomalies occur in outcrops of Cluff breccia. Near Cluff Lake basal coarse, hematitic, polymictic conglomerate is exposed and locally is more radioactive than the breccia, but the uranium content there must nevertheless be low.

The Gulf Minerals discovery at Rabbit Lake near Wollaston Lake[7] was examined in early July. The writers were given full access to the diamond-drill cores and visited some of the outcrops south of the deposit. However, because they were not permitted to take any specimens, tentative identifications of minerals and rocks can not be subsequently confirmed or refined in the laboratory.

The company has released the following description of the deposit, prepared by Dr. J.W. Hoadley:

"The deposit is structurally controlled and occurs in an area underlain by granitic and sedimentary gneisses of the basement complex of rocks. These are cut by several major and numerous minor faults, which within and near the mineralized zone, have been strongly brecciated and hydrothermally altered. Carbonatization, argillization and silicification are the chief types of alteration. Hematization is common, but not necessarily directly related to the uranium mineralization. Minor syngenetic pyrite is a common accessory. Galena and, to a lesser extent, sphalerite are present in very minor amounts. Sooty pitchblende or uraninite is the principal uranium mineral. Massive lustrous pitchblende is also present in some parts of the deposit."

In Bancroft area[8, 9, 10], Ontario at Faraday Mine no further underground exploration is being done but the mine workings are being kept unwatered. Ore intersections have been made 200 to 300 feet below the 1,200-foot level.

Cam Mines Limited owns the Croft property in Cardiff Township and is exploring the belt of layered amphibolites that extends southward to the old Bicroft Mine, in which ore-bearing pegmatites were mined. They also drilled seven exploratory holes on the Moly Group which they have optioned. In Duncannon Township, near Egan Chute seven anomalies were explored by trenches and drilling but the pegmatites there contain excessive thorium.

Amalgamated Rare Earths are actively exploring by diamond drilling the Halo property, near Wilberforce, where two adits had been driven. A new zone, the Northwest, has been outlined. They own also the Blue Rock where the main adit penetrates a large body of red pegmatite ore in layered amphibolite. The Cavendish property which they also own was not examined.

Fidelity Mining Investments Limited own a number of claims in northwestern Faraday Township on which some trenching and diamond drilling is in progress. Host rocks are granitic gneiss, marble and amphibolite which contain red, uralite-bearing pegmatites in which crystals of uraninite were identified.

North of Sharbot Lake in Palmerston Township[11] the property of Rexdale Mines was visited. A number of anomalies have been found in six zones, some of which have been investigated by trenching and drilling. Magnetite, pyrite, gummite, and some uraninite and molybdenite occur in flesh-coloured, biotite-bearing pegmatites that cut granitic gneiss and biotite schist. The highest radioactivity occurs where coarse biotite is most abundant.

In Makkovik-Kaipokok area, Labrador[12] Brinex are engaged in further exploration of mineral concessions. Recent work has been concentrated in the southwestern part and has resulted in promising discoveries of pitchblende-bearing veins and disseminations which occur mainly in a zone of tuff, quartzite, and argillite that extends southwestward from the Kitts deposit. The veins and disseminations contain quartz, carbonate, magnetite, some pyrite, and are commonly hematitized.

In New Brunswick the Mount Pleasant[13] polymetallic deposit was visited. In the Fire Tower zone greissenized porphyry and tuff is intersected by a west-trending fracture that showed strong radioactivity. Magnetite, purple fluorite, and patches of red hematite, but no uranium minerals, were seen.

Near Campbellton, about 1 mile west of Sugarloaf Mountain on claims owned by W.M. Miller and D.H. Johnson radioactive anomalies in red andesitic lavas and grey medium-grained granitic rocks in scattered outcrops were sampled.

---

[1] Little, H.W.: Kettle River, east half, British Columbia; Geol. Surv. Can., Map 6-1957 (1957).

[2] Joubin, F.R. and James, D.H.: Rexspar uranium deposits; Can. Mining J., vol. 77, No. 7, pp. 59-60 (1956).

[3] Campbell, R.B.: Adams Lake, British Columbia; Geol. Surv. Can., Map 48-1963 (1963).

[4] Lang, A.H., Griffith, J.W. and Steacy, H.R.: Canadian deposits of uranium and thorium; Geol. Surv. Can., Econ. Geol. series, No. 16 (2nd edition), pp. 196-198 (1962).

[5] Tremblay, L.P.: Geology of the Beaverlodge mining area; Geol. Surv. Can., Mem 367 (Adv. Ed.) (1968).

[6] Currie, K.L.: Geological notes on the Carswell circular structure, Saskatchewan; Geol. Surv. Can., Paper 67-32 (1969).

[7] Fahrig, W.F.: Wollaston Lake, Saskatchewan; Geol. Surv. Can., Map 27-1957 (1958).

[8] Hewitt, D.F.: Geology of Cardiff and Faraday townships; Ont. Dept. Mines, Ann. Rept., vol. LXVI, Pt. III (1959).

[9] Hewitt, D.F. and James, W.: Geology of Dungannon and Mayo townships; Ont. Dept. Mines, Ann. Rept., vol. LXIV, Pt. VIII (1957).

[10] Satterly, J.: Radioactive mineral occurrences in the Bancroft area; Ont. Dept. Mines, Ann. Rept., vol. LXV, Pt. VI (1957).

[11] Smith, B.L.: Geology of the Clarendon-Dalhousie area; Ont. Dept. Mines, Ann. Rept., vol. LXV, Pt. VII (1957).

[12] Beavan, A.P.: The Labrador uranium area; Proc. Geol. Assoc. Can., vol. 10, pp. 137-145 (1958).

[13] Van de Poll, H.W.: Carboniferous volcanic and sedimentary rocks of the Mount Pleasant area, New Brunswick; N.B. Mineral Resources Br., Rept. of Invest. 3 (1967).

---

64. METALLOGENIC STUDY, NORTHERN CASSIAR BATHOLITH BRITISH COLUMBIA (104, O, P, 105B)

Project 650012

R. Mulligan

This is a region containing numerous and varied mineral deposits including tungsten and molybdenum, and many occurrences and concentrations of beryllium and tin[1].

Results of sampling and other work are expected to enhance understanding of the interrelationships of the mineral deposits and their relationship to the geological environment.

In Wolf Lake area (105B) heavy mineral concentrates were collected from streams draining the western fault-contact zone of the Cassiar Batholith in the vicinity of Daughney Lake and the Upper Rancheria River. This zone is considered especially favourable for tin and/or tungsten concentration.

In McDame area (104P) specimens and samples of the mineralized material and host granitic rocks were taken from the newly completed adit at the Cassiar molybdenum property. Showings of molybdenum mineralization and their granitic host-rocks, also of zinc-rich pyrrhotite skarns were examined and sampled at the property of Della Mines Limited on the lower west slope of Haskins Mountain. Placer concentrates were obtained from a recently worked section of McDame Creek, which locally contains significant tin concentrations.

[1] Mulligan, R.: Metallogeny of the region adjacent to the northern part of the Cassiar Batholith, Yukon Territory and British Columbia; Geol. Surv. Can., Paper 68-70 (1969).

65. GEOLOGY OF CANADIAN LITHOPHILE METALS

Project 530014

R. Mulligan

About two months of field work was done in the Cordilleran Region in 1969 including time devoted to the metallogenic study in the vicinity of the northern Cassiar Batholith (see previous report). The work consisted mainly in sampling and concentration of stream sediment deposits and examination and sampling of granitic bodies and associated molybdenum, tungsten and base-metal occurrences in various parts of the Cordilleran tin belt[1]. The results of analytical and other work are expected to further define the belt and to confirm its continuity, nature, and strength as a geochemical province.

Areas examined included:

1. The upper Hess River Region, Yukon (105N, O). This is an area containing numerous small granitic intrusions and some tungsten occurrences and is on the hypothetical southeastward extension of the tin-tungsten belt from the McQuesten-May district.
2. Favourable parts of the Tintina Trench west of the McQuesten district, Yukon.
3. Upper Ruby Creek area, Atlin district, B.C. Molybdenum-tungsten occurrences in this area are on the projection of a line of tin-bearing tungsten occurrences that passes through the Black Diamond Mine.
4. The Cassiar district.
5. The upper Fraser River section of the Rocky Mountain Trench, McBride area (93H) (reconnaissance sampling of stream-sediment concentrates). At the Snowflake-Regal Silver Mine near Albert Canyon, reopened last year by Stannex Minerals Limited, several days were spent with Dr. Ostrihansky of the Exploration Geophysics Division. Numerous readings were taken with a Portable X-ray fluorescence analyzer in search of tin concentrations in potentially favourable parts of the lower workings, and samples were collected for further examination and analyses where some appreciable concentrations were indicated.

[1] Mulligan, R.: Geology of Canadian tin occurrences; Geol. Surv. Can., Paper 64-54 (1966).

66. CERIUM AND YTTRIUM IN MONTEREGIAN INTRUSIONS, QUEBEC (21D, E, 31A)

Project 670028

E.R. Rose

The Monteregian Intrusions are a well known group of alkaline igneous rocks that intrude both undeformed and deformed sedimentary rocks of Paleozoic age, in the St. Lawrence platform and Appalachian orogen areas, in a belt lying generally east of Montreal. An inlying niobium and rare earth-bearing carbonatite complex in the Canadian Shield, around Oka west of Montreal, is also believed to be related, and many other carbonatite masses elsewhere in Eastern Canada may also be related to Monteregian igneous activity.

Brief field trips were made to the main Monteregian Hills and to the Oka carbonatite complex to sample and check these rocks for cerium and yttrium, using the methods described previously[1]. Rare earths were detected in 35 out of 37 samples of igneous rocks and in 4 out of 8 of sedimentary or metamorphic contact rocks tested. Strong traces of cerium and yttrium were given by 4 samples of intrusives (nepheline syenite, sodalite syenite and alkaline syenite pegmatite) from Mount St. Hilaire, and by 4 samples of various intrusives (sovite, alnoite and carbonatite) from Oka. Traces of cerium and yttrium were given by 2 samples of essexite from Mount Johnson, by 2 samples of intrusives (gabbro and laurdalite) from Brome Mountain and by 1 sample of hornfels from the contact zone of Mount St. Hilaire. Faint tests for either cerium or yttrium were given by single samples of tinguaite from Ste-Dorothee, breccimatrix from Isle Ste-Helene, intrusive okaite and contact Grenville gneiss near Oka, intrusive peridotite and contact hornfels from Brome Mountain, intrusive gabbro and contact hornfels from Mount Rougemont, nepheline syenite dyke from Mount Johnson, essexite from Mount Yamaska, nordmarkite and syenite from Mount Megantic.

These tests suggest that dispersions of rare-earth elements in faint trace amounts are widely associated with the intrusive rocks of the Monteregian alkaline suite, and related carbonatite complexes. These rocks may be hosts to concentrations of rare-earth elements as well as other rare elements such as uranium, thorium, scandium, zirconium, titanium, vanadium, tungsten and niobium, and they should be carefully investigated for possible economic concentrations of these elements.

---

[1] Rose, E.R.: A progress report on experiments with chemical field tests for the detection of the rare-earth elements cerium and yttrium; Geol. Surv. Can., Paper 69-15 (1969).

67. VANADIUM-BEARING TITANIFEROUS MAGNETITE AND ANORTHOSITE OF THE DORE LAKE COMPLEX, CHIBOUGAMAU, QUEBEC (32G)

Project 630039

E.R. Rose

At the invitation of Dr. Gilles Allard, who is continuing detailed geological mapping in the Chibougamau area for the Quebec Department of Natural Resources, a trip was made to examine titaniferous magnetite deposits in rocks of the Dore Lake Complex, in Rinfret and Lemoine townships, southeast of Lake Chibougamau. With the expert guidance and assistance of Dr. Allard and members of his party, the writer was shown good sections across and along the strike of the deposits, which occur as extensive and persistent zones within ancient and metamorphosed bands of pyroxenite, gabbro and anorthosite in the northeast-trending south limb of the anorthosite member of the Dore Lake Complex. The titaniferous magnetite occurs in concordant, nearly vertical, nearly massive bands, as much as 5 feet or more in width and in disseminations throughout these rocks, that together form large tonnages of low-grade material. Dr. Allard has mapped three separate, but closely associated zones of titaniferous magnetite in the Dore Lake Complex and has suggested that there is a marked similarity in these banded rocks to those in the Bushveld Complex in South Africa, from which iron, titanium and vanadium are now being commercially recovered. Samples were taken by the writer to determine the nature of the vanadium-bearing ore minerals and to ascertain how the vanadium content of the titaniferous magnetite varies across strike and along strike in these mineralized zones in Rinfret and Lemoine townships.

A trip underground permitted an examination of the 2-mile-long drift being driven southeasterly on the 900-foot level under Dore Lake between the Jaculet and Bateman Bay shafts. The drift is almost entirely in metamorphosed chalky white anorthosite that is interbanded in places with darker metagabbro and gabbroic anorthosite. Dark dykes and inclusions, and zones of shearing with light sulphide mineralization are common in these rocks. In places the anorthosite is banded and shows a cumulate texture with a gradation from anorthosite to grabbroic anorthosite in bands 1 foot or less in thickness. The strike of the banding is generally northeasterly with a moderately steep dip northwesterly. A section of anorthositic rocks more than 10,000 feet thick is exposed in the drift under Dore Lake, and this section is flanked on both the northwest and southeast sides of the lake by bands of metagabbro that carry disseminations of titaniferous magnetite. About 6 miles to the east, at Magnetite Bay on Lake Chibougamau, thick zones of titaniferous magnetite occur in serpentinized peridotite and dunite, and near Cache Lake, about 10 miles to the southeast, titaniferous magnetite occurs in gabbroic anorthosite and pyroxenite bands in anorthosite. A comparison of the magnetite from these various zones will be made to assist in understanding their origin and to aid in their development.

68. GEOLOGY OF LEAD AND ZINC DEPOSITS OF CANADA

Project 650056

D.F. Sangster

Lead - and/or zinc-bearing stratabound deposits were examined at Buttle Lake (Vancouver Island), Pine Point (District of Mackenzie), Flin Flon-Snow Lake areas (Manitoba), Manitouwadge and Timmins areas (Ontario), Noranda (Quebec), Bathurst-Newcastle area (New Brunswick), Buchans and Daniel's Harbour (Newfoundland).

All deposits examined (except a few vein deposits in the Bathurst area) are conformable in the sense that their long axes are parallel to local foliation and/or bedding. With the exception of the Pine Point and Daniel's Harbour deposits, all are contained in volcanic, volcanic sedimentary, or siliceous sedimentary host rocks; most have been modified to some degree by regional and/or thermal metamorphism. Where metamorphic grade is low or moderate, and in the absence of shearing, primary textural and structural features are commonly obliterated in the massive sulphide ore but may still be preserved in the host rocks.

From these field investigations, the following preliminary observations emerged for conformable deposits in noncalcareous rocks:

1. The most common host rocks appear to be volcanic flow rocks and coarse pyroclastic as volcano-sedimentary rocks such as fine- to medium-grained tuffs. Less commonly, stratabound deposits were found to be associated with metasedimentary rocks such as greywacke or highly siliceous rocks tentatively identified as impure quartzites.

2. Deposits in volcanic rocks are very frequently closely associated with the more acidic (dacite to rhyolite) phase of volcanism. This phase may consist of massive acidic flows, acid pyroclastics, or, rarely fine-grained acidic tuffs. A common ore occurrence is at the contact between basaltic or andesitic flows and more acidic flows or pyroclastics. Also where the orebodies are associated with acidic pyroclastic rocks, there is a tendency for a rather marked spatial association of ore with that part of the ore-bearing pyroclastic horizon that contains the greatest abundance of larger fragments. In some areas, the larger fragments may be only one inch in diameter whereas in other areas the largest fragments may be several inches in size. Nevertheless, in defining potential mineralized areas, it may prove useful to record average sizes of clasts in acidic pyroclastics.

3. Alteration, or 'feeder' pipes characterized by an abundance of chlorite or, less commonly, sericite, are a well-known feature of deposits in massive volcanic rocks. Lacking a well-defined pipe in the footwall of the ore zone, many deposits instead have a more-or-less continuous and roughly conformable chloritized zone in the footwall which is lacking or more poorly defined in the hanging wall. Other deposits merely show a relatively sharp hanging wall contact with country rock and more diffuse or irregular footwall contact. Footwall chloritic zones or feeder pipes are apparently much less common in deposits enclosed in volcano-sedimentary and normal sedimentary

rocks although there is good evidence of chloritic feeder pipes at Stall Lake and Anderson Lake mines in Manitoba which are largely enclosed in metasedimentary rocks.

4. Orebodies with feeder pipes tend to be zoned with copper enriched in the stratigraphic footwall and zinc (with or without lead) in the hanging wall of the ore zone.

5. Where deformation has not modified their original shape, there is a marked tendency for orebodies in the massive volcanic rocks to be stubby or ovoid in shape; deposits in the more layered rocks tend to be more plate-like or blanket shaped.

Deposits at Pine Point and Daniel's Harbour, wholly-contained in dolomite, are confined to specific lithologic horizons (which may or may not be equivalent to stratigraphic horizons in the case of diagenetic or secondary dolomitization). Local ore controls, however, appear to be subtle tectonic features, such as joints or faults of small displacement, which are co-incident with the larger, more obvious, structural elements of these areas.

Sericitic wall-rock alteration adjacent to the Nigadoo River Mines lead-zinc-silver vein in the Bathurst area, was sampled for possible K-Ar dating of the time of mineralization.

PALEONTOLOGY AND BIOSTRATIGRAPHY

69. SILURIAN-ORDOVICIAN MACROBIOSTRATIGRAPHY OF ANTICOSTI ISLAND, QUEBEC (12E, F)

Project 570015

T.E. Bolton

Biostratigraphic studies of Ordovician and Silurian rocks of Anticosti Island were continued during 1969, with particular emphasis on the rocks exposed in the south-central and eastern parts of the island. Sufficient data on the various formational boundaries are now available to complete a geological map on the scale of 1 inch to 4 miles at least for the western half of the island.

Diagnostic trilobite and echinoderm faunal assemblages are being established for several of the formations recognized. The Upper Ordovician Vauréal Formation contains in subsurface shales a trilobite assemblage composed of odontopleurids (Primaspis), trinucleids (Tretaspis and Cryptolithus), raphiophorids (Lonchodomas) and olenids (Triarthrus)[1]. Exposures of the Vauréal Formation along the northern part of the island contain a Flexicalymene-Ceraurus-Remipyga-Encrinurus assemblage, and in addition associations of Paraharpes-Brachyaspis? and Amphilichas-Chasmops-Calyptaulax. Amphilichas ranges up into the shaly Member 3 of the Ellis Bay Formation, Chasmops into Members 4 and 5, and Paraharpes into Member 4[2]. Primaspis and Lichas are typical forms within the basal 'off-reef' beds of Member 6. Thus on the basis of trilobites, at least five members (with a total thickness of 115 feet) are of late Ordovician rather than early Silurian age. The Silurian assemblage within the Jupiter Formation, in contrast, is characterized by Acernaspis-Arctinurus-Diacalymene-Encrinurus.

A varied echinoderm fauna is present within the lower beds of the Vauréal Formation. The cystid Pleurocystites anticostiensis Billings (composed of minute periproct plates of the P. squamosus group) and crinoids Reteocrinus, Carabocrinus, Cupulocrinus, and Dendrocrinus form the earliest association. Reteocrinus ranges into Member 2 of the Ellis Bay Formation; Glyptocrinus? and an undetermined Cyathocrinoidea both occur in Member 6. Within the Silurian, Dendrocrinus minutus Springer, originally assigned to the Vauréal Formation, is present in the Gun River Formation. A Dimerocrinites-Sagenocrinites-Eucalyptocrinites assemblage characterizes the Jupiter Formation, and Eucalyptocrinites-Periechocrinites are essential elements within the crinoidal limestone of the uppermost, Chicotte Formation.

Samples for whole rock age determination were collected in the De Puyjalon area on the north shore of the island from two diabase dykes intruding Upper Ordovician Vauréal limestone. A previous determination on the more westerly dyke indicated a whole rock, K-Ar age of 138$\pm$ 28 m.y.[3], The southerly continuation of the eastern dyke was recently discovered 2 miles inland on the Squaw Cove road. Paleomagnetic properties of both dykes at De Puyjalon are being determined.

A collection of Mya-Macoma-Hiatella shells from postglacial sediments located on the Becscie River some 4 miles inland, at an elevation of 125 feet, should provide additional information on the postglacial history of the island[4]. An age of 12, 940 ± 180 B.P. previously was determined for a similar assemblage collected from 180 feet above sea level in the airport area northeast of Port Menier.

---

[1] Bolton, T.E.: Subsurface Ordovician fauna, Anticosti Island, Quebec; Geol. Surv. Can., Bull. (in press).

[2] Bolton, T.E.: Stratigraphy of Anticosti Island; in Report of Activities, Field, 1964; Geol. Surv. Can., Paper 65-1, p. 113 (1965).

[3] Wanless, R.K. et al.: Age determinations and geological studies, K-Ar isotopic ages, Report 7; Geol. Surv. Can., Paper 66-17, p. 101 (1967).

[4] Bolton, T.E. and Lee, P.K.: Postglacial marine overlap of Anticosti Island, Quebec; Proc. Geol. Assoc. Can., vol. 12, pp. 67-78 (1960).

---

70. MICROPALEONTOLOGY, ANTICOSTI ISLAND, QUEBEC (12E, F)

Project 640040

M.J. Copeland

Collections for microfauna were made from the central interior, southern and eastern shores of Anticosti Island. These stratigraphically located samples (Upper Ordovician and Silurian) are being processed for contained Ostracoda. Additional rock samples were obtained for acid extraction of Foraminifera by Professor H.A. Ireland, University of Kansas.

Ostracodes in the oldest, Vauréal Formation (Upper Ordovician)[1] indicate the continuation eastward of the tripartite microfaunal zonation previously established[2]. Species of Jonesites and Eoleperditia are common in the uppermost zone. The occurrence of tetradellid ostracodes in microfaunas from all members of the overlying Ellis Bay Formation indicates a pre-Silurian age for all or most of this unit.

East of Jupiter River road, shale of the upper Becscie Formation contains a new genus of beyrichiid ostracode[3], the earliest known North American representative of the Zygobolbidae. These forms are associated with the brachiopod Virgiana, indicating possible correlation with lower Clinton (Niagaran) strata of the mid-continent region. Samples of the overlying Gun River Formation have not yielded extensive ostracode faunas.

Sections of the Jupiter Formation were examined on Jupiter, Brick, and Chicotte rivers and Heath and East points. The Brick and Chicotte rivers section revealed the presence of Jupiter strata nearer the southern coast of the island than previously known and disclosed the thin, breached, veneer-like relationship of the overlying Chicotte Formation. The presence of a typical Upper Jupiter ostracode fauna exemplified by Zygobolba decora (Billings), Bolbineossia sp., and Bolbibollia labrosa Ulrich and Bassler has now been established from near Jupiter River east to Heath Point.

The uppermost, poorly known crinoidal and coral limestone of the Chicotte Formation was sampled in three areas: Southwest Point and Brick River roads, and Chicotte River. Samples of microfauna from this formation have not previously been available and appear to contain an unusual ostracode fauna from this specialized depositional environment.

---

[1] Bolton, T.E.: Ordovician and Silurian formations of Anticosti Island, Quebec; Geol. Surv. Can., Paper 61-26 (1961).

[2] Copeland, M.J.: Ostracoda from the Vauréal Formation (Upper Ordovician) of Anticosti Island, Quebec; Geol. Surv. Can., Bull. (in press).

[3] Copeland, M.J.: Two new genera of beyrichiid Ostracoda from the Niagaran (Middle Silurian) of Eastern Canada; Geol. Surv. Can., Bull. (in press).

---

71. MIDDLE PALEOZOIC BIOSTRATIGRAPHY, GASPÉ, QUEBEC, AND MARITIME REGION

Project 690006

W.T. Dean

During May two weeks were spent working with members of the U.S. Geological Survey in Ohio and Kentucky. The work formed part of a larger project aimed at establishing type sections for the 'Series' which constitute the Ordovician in Eastern North America, and at ascertaining the vertical distribution of various invertebrate guide fossils within those sections.

From the beginning of July to the end of August, lower Paleozoic fossils were collected from several parts of the Appalachian region, namely southern Quebec, the Maritimes, Gaspé Peninsula, and various areas of Newfoundland. Particular attention was paid to rocks of Cambrian and Ordovician ages and their included trilobites with a view to future researches.

In September additional collections were obtained from the Ordovician rocks of the Philipsburg Region, southern Quebec. The strata, mostly limestones and shales, include also the Mystic Conglomerate, of approximately Middle Ordovician age. The latter contains numerous limestone boulders, some of which are fossiliferous, and it is proposed to study the trilobites of the boulders as well as those of the limestone sequence at Philipsburg.

72. CAMBRIAN BIOSTRATIGRAPHY IN THE CANADIAN CORDILLERA

Project 650024

W.H. Fritz

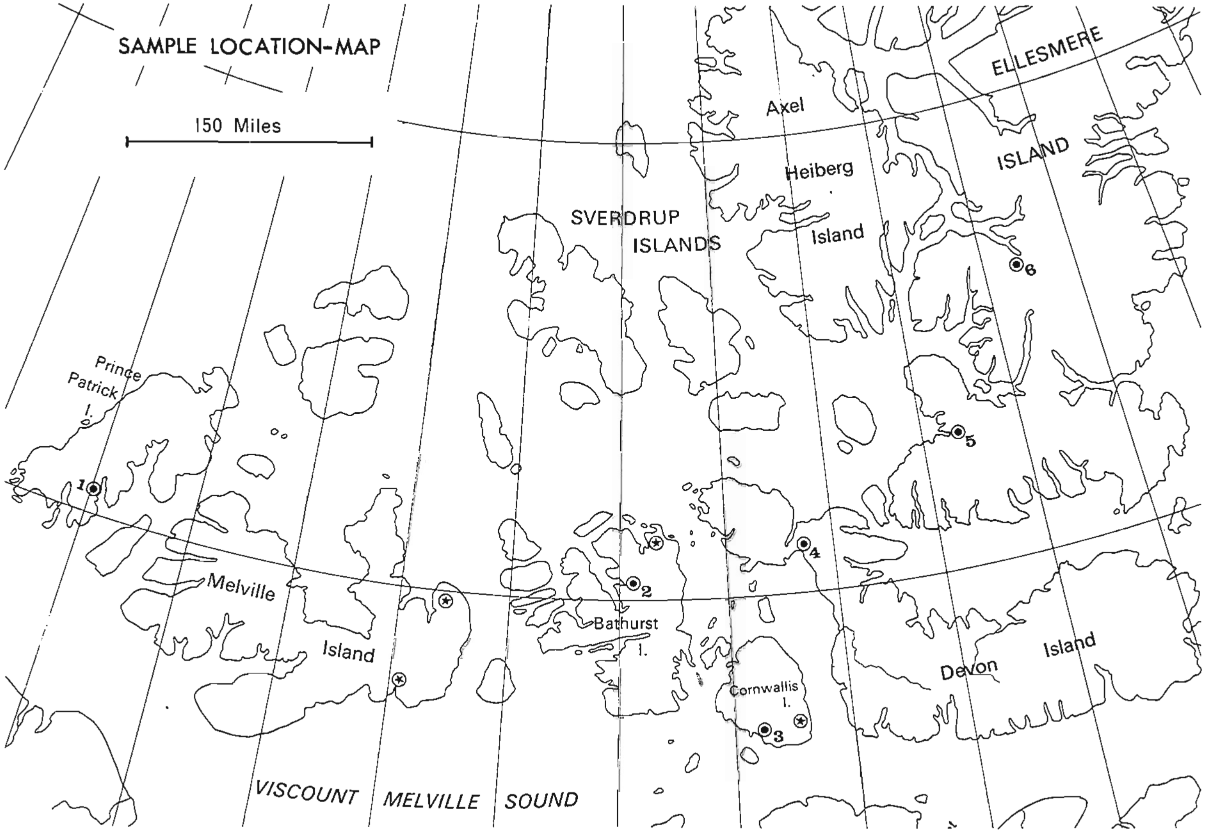
One week was spent near Field, British Columbia checking Burgess Project data used in an oral and written presentation to the North American Paleontological Convention in Chicago, September, 1969. A short visit to Operation Norman, Mackenzie Mountains, District of Mackenzie was made to study the type Macdougal Group in Dodo Canyon and other outcrops. Thicknesses in the Macdougal were measured up-section from the top of the 'chocolate-coloured' shale which Hume included as the basal unit. At 179 feet and 190 feet trilobites are present that belong to the late Lower Cambrian. Fossils collected at 230 feet and 235 feet belong to the Middle Cambrian Albertella Zone, possibly to the later part of this zone. Collections between 294 feet and 337 feet need further study, but part of these can be assigned to the Glossopleura Zone. It is postulated tentatively that an unconformity exists at 191 feet, and that the Plagiura-Poliella and early Albertella Zone is missing. Strata below the 'chocolate-coloured' shale were searched extensively for fossils. None was found except for algal mounds just below this unit. One and one-half weeks was spent on Operation Stewart, located immediately west of Operation Norman. A 4,400-foot Lower Cambrian section was measured between the headwaters of the Mountain and Arctic Red rivers. Here the Sekwi Formation is 3,605 feet thick with approximately 55, 920 and 2,630 feet belonging to the early, middle, and late Lower Cambrian, respectively. Overlying the Sekwi is an unnamed black shale unit that is 835 feet thick. Collections indicate that at least the lower 405 feet of this unit belongs to the late Lower Cambrian.

73. SILURIAN-DEVONIAN BIOSTRATIGRAPHY OF THE ARCTIC ISLANDS, DISTRICT OF FRANKLIN (49C, 49E, 58F, 59B, 69A, 89B)

Projects 680101 and 680113

T.T. Uyeno and D.C. McGregor

Samples were collected for palynomorph and conodont analyses from the Franklinian miogeosyncline and the Prince Patrick uplift, Queen Elizabeth Islands. The objectives of the project, begun in 1968, are to set up zonal standards for spores of mid-Paleozoic age in the Canadian Arctic, and to correlate the palynomorph zones with the conodont zones established in the classical areas of Germany and Austria, and in parts of North America. (See Figure on page 106.)



⊛ Sampled in 1968 (see McGregor and Uyeno, 1969). ⊙ Sampled in 1969:
1. Griper Bay Fm. 2. Cape Phillips, Bathurst Island, Stuart Bay, Eids, Blue Fiord, and Bird Fiord Fms. (Twilight Creek). 3. Allen Bay Fm. 4. Douro, Devon Island, Sutherland River, Prince Alfred, and Blue Fiord Fms. 5. Eids, Blue Fiord, Bird Fiord, and Okse Bay Fms. 6. Allen Bay/Read Bay, Cape Phillips, Eids, Blue Fiord, and Okse Bay Fms.

Six stratigraphic sections of Silurian and Devonian rocks on Prince Patrick, Bathurst, Cornwallis, Devon, and Ellesmere islands were measured and sampled in 1969 (Fig. 1). Taken together with four sections obtained in 1968[1], these sections provide data over 600 miles of the Arctic Archipelago, from Mould Bay to Strathcona Fiord.

Samples were obtained from the Allen Bay*, Read Bay, Douro, Devon Island*, Sutherland River*, Prince Alfred*, Cape Phillips, Bathurst Island*, Stuart Bay*, Eids, Blue Fiord*, Bird Fiord*, Griper Bay, and Okse Bay Formations. Those formations sampled at their type sections, or in their type areas, are designated with an asterisk.

Well-preserved spores occur in all samples so far examined of the Weatherall, Blue Fiord, Bird Fiord and Okse Bay formations. Less well preserved spores are present in some samples from the Bathurst Island, Stuart Bay, Eids, and Hecla Bay formations. Laboratory results are not available yet on the spore content of the other formations sampled. The trilete spores discovered in the Bathurst Island, Stuart Bay and Eids formations, the first of Early Devonian age ever reported from the Canadian Arctic, bear some similarity to Siegenian and Emsian spores of Eastern Canada and Europe.

Spiny plant axes and other megascopic plant compression remains were discovered near the base of the Stuart Bay Formation and in the topmost beds of the Bathurst Island Formation on northern Bathurst Island. They are the first Early Devonian megascopic plant remains to be found in the Canadian Arctic.

From collections made in 1968, generally sparse conodont faunas have been obtained thus far from the Stuart Bay, Eids, Blue Fiord, Bird Fiord, and Weatherall Bay formations. More varied faunas occur in the Read Bay and Griper Bay formations.

---

[1] McGregor, D.C. and Uyeno, T.T.: Mid-Paleozoic biostratigraphy of the Arctic Islands (58F, 69A, 78H); in Report of Activities, Part A, April to October 1968, Geol. Surv. Can., Paper 69-1, Pt. A, pp. 134-135 (1969).

PETROLOGY

74. LAKE ST. MARTIN STRUCTURE, MANITOBA (62 O)

Project 680071

K. L. Currie

An unusual structure in the region of Lake St. Martin, Manitoba contains mildly alkaline volcanic rocks of Permian age. This structure has been extensively shallow drilled by the Manitoba Department of Mines in collaboration with the FRED program. In collaboration with H. R. McCabe and B.B. Bannatyne of the Manitoba Department of Mines, the cores were examined, and a field examination of the structure was made. The structure appears to be a near circular depression approximately 14 miles in diameter with an uplifted central core about 4 miles in diameter. The Paleozoic rocks surrounding the depression appear to be anomalously high out to a distance of about 2 miles, forming a rim around the structure. The central core, centred 4 miles east of Gypsumville, consists of a complex of amphibolitic rocks with layers of granite gneiss, graphic granite and pegmatite. It appears to be coherent rather than brecciated, but plastic squeezing is abundantly evident. Large amounts of maskelynite are present, locally in spectacular schlieren-like masses. The quartz in the graphic interbeds is intensely cleaved, and shows abundant lamellar structures. The central core appears to be raised up about a thousand feet above its normal position, presumably along an almost vertical ring fault. The region around the core is filled with suevitic breccia with rare thin volcanic beds. The fragments are commonly unaltered basement rocks; intensely hydrothermally altered material is rare. Strongly shocked fragments are extremely rare or absent. Drilling shows at least 1,000 feet of breccia just outside the central core. Around the northern half of the structure the breccia is overlain by dolomite, anhydrite, and gypsum, which presumably formed in the closed basin formed by the annular depression around the uplifted core. Vesicular volcanic rocks, with rare basement inclusions, are found around the outside of the structure. A thin layer of breccia, less than 10 feet thick, occurs at the base of this sequence. Drilling shows the volcanic rocks to underlie the breccia, and to thin toward the centre, virtually disappearing less than half way across the 'moat'. The evidence clearly shows Lake St. Martin structure to be a crater very similar to Mistastin Lake[1]. Of particular interest is the clear evidence that the volcanics underlie the breccia, and occur only at the margin of the crater.

---

[1] Currie, K. L.: Mistastin Lake, Labrador; A new Canadian crater, Nature, vol. 220, pp. 776-777 (1968).

75. ICE RIVER ALKALINE COMPLEX, BRITISH COLUMBIA (82 N)

Project 680071

K. L. Currie and J. Ferguson

The Ice River alkaline complex, approximately 15 miles south of Field, British Columbia, is one of the largest and most complex alkaline masses in Canada. A comprehensive study of this intrusion, made classic by J.A. Allan[1] was commenced this year. The intrusion is shaped like a north-facing U. The northeasterly arm is the least altered, and comprises an approximately flat-lying stratiform intrusion, with an estimated thickness of about 2,000 feet. Alkaline pyroxenite (jacupirangite) is exposed at the extreme northern tip of this arm, but the basal layer elsewhere is composed of a saturated syenite, at least 200 feet thick, the upper part of which has been intensely carbonated. This carbonation disguises the transition from syenite to ijolite which occurs somewhere within the carbonated layer. A thick sequence of brecciated ijolite, urtite and jacupirangite overlies the syenite. By analogy with the northwestern arm, this is believed to represent a layered ijolite-urtite sequence, but the rocks are now agmatitic with a matrix of nepheline syenite. The upper half of the stratiform mass is composed of coarse aegirine nepheline syenite showing little foliation. The northwest arm of the intrusion is entirely composed of a layered complex of ijolite, urtite and carbonatite, with minor jacupirangite at the northwestern tip, and a thin layer of saturated syenite along the base of the complex. In addition to the carbonatite plug previously recognized[2], many hundreds of carbonatite sheets and dykes were identified. The character of the central mass of nepheline syenite is radically different from the arms. It closely resembles nepheline gneisses of the Bancroft and Copeland Mountain areas. Strong gneissosity is everywhere present, and in many areas the rocks resemble migmatite. Remnants of basic rocks are occasionally present, possibly representing the breccia zone found to the northeast. The structural relations between this central gneiss and the arms are uncertain, but faulting is certainly present to the northeast, and is assumed to be present to the northwest. The complex is tentatively concluded to be a funnel-shaped layered intrusion folded and metamorphosed during the Laramide Orogeny. The sodalite characteristic of this district does not come from the main part of the intrusion, but occurs in sills and veins of syenite, and along fractures, all younger than the main mass. Sodalite has been identified as veinlets in the Paleozoic rocks more than 30 miles from the intrusion in the Blaeberry District, suggesting a widespread occurrence of alkaline igneous activity. Support is given to this hypothesis by the discovery of phonolitic sills on Mount King 10 miles north of the Ice River complex. Specimens of these rocks have kindly been donated by Mr. D. Foskett of Yoho National Park.

As part of the study of alkaline rocks in this district a brief examination was made of the nepheline gneisses at Copeland Mountain, 14 miles northwest of Revelstoke. These gneisses, remarkably similar in appearance to the gneissic syenitic portion of the Ice River complex, occur as an apparently conformable layer in a quartzite-calc-silicate-marble-biotite gneiss sequence. A rim of saturated syenite occurs around the main mass of nepheline rich rocks, but small lenses of nepheline-bearing biotite gneiss occur hundreds of feet beyond the margin of the main body, some within a few inches of surrounding quartzite beds. Skarn bands, apparently of sedimentary origin are conformable within the nepheline gneiss, and the nepheline-bearing rocks appear completely conformable with their surroundings. Sodalite occurs in rocks surrounding the main mass, but not within the nepheline gneisses. Pegmatoid lenses within the nepheline gneiss commonly contain giant sphene crystals, and less commonly contain eudialyte. The general appearance of the deposit is remarkably similar to that at Bigwood, Ontario (40 miles south of Sudbury), where molybdenite and sodalite are also associated with pegmatitic segregations within a conformable lens of nepheline syenite gneiss.

[1] Allan, J.A.: Field map-area, British Columbia and Alberta; Geol. Surv. Can., Mem. 55 (1914).

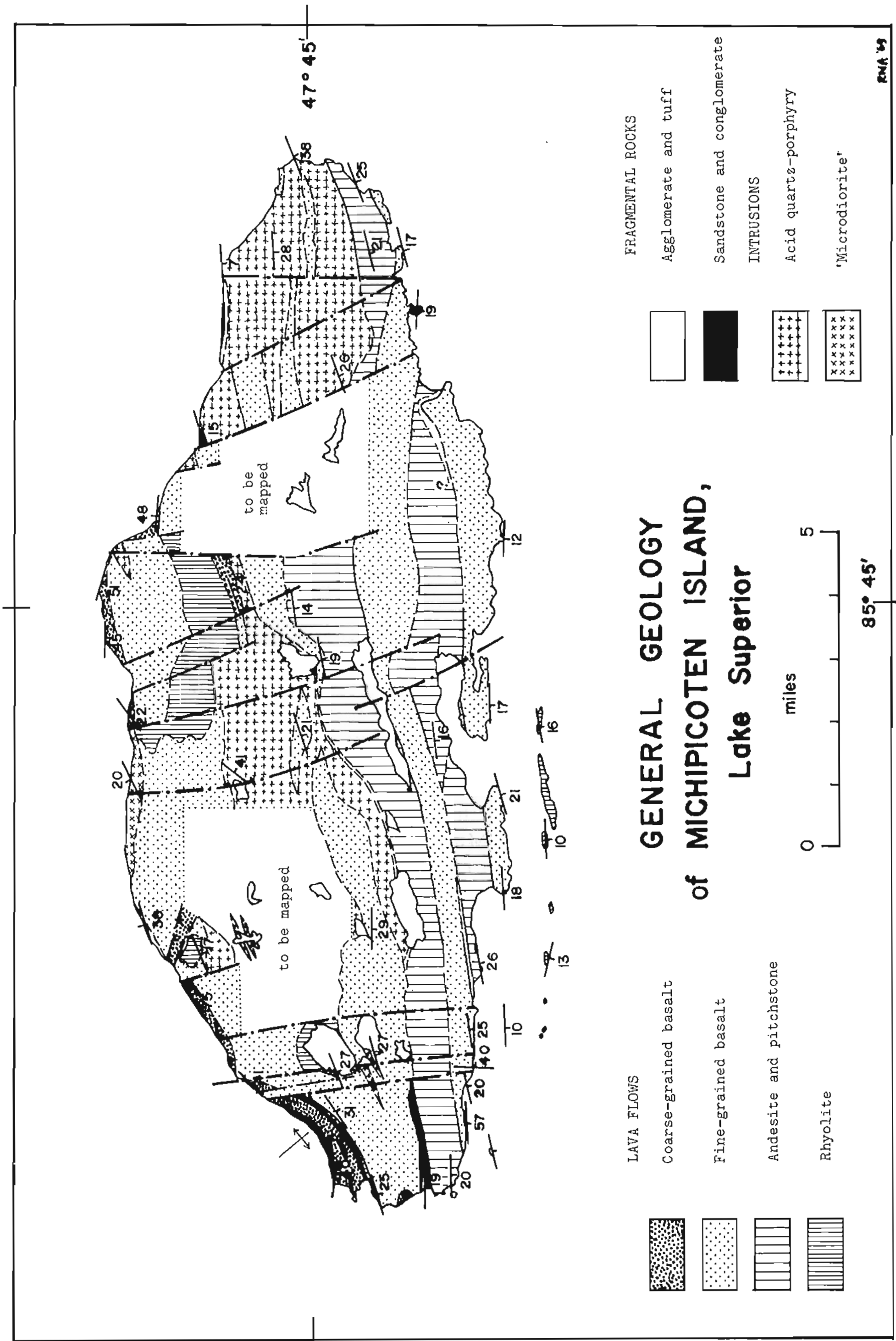
[2] Rapson, J.E.: Carbonatite in the alkaline complex of the Ice River area; Proceedings of the International Mineralogical Association, New Delhi meeting, 1964 (1966).

76. CALLANDER BAY ALKALINE COMPLEX, ONTARIO (31 L/1)

Project 680071

J. Ferguson and K. L. Currie

Continuing the study begun last year, a detailed examination was made of the dyke swarms around the bay. Three main types of dykes were recognized, lamprophyres, felsic dykes, and carbonatites. The lamprophyres range in width from 1/2 inch to 5 feet, with the most common width around 8 inches. A considerable range in composition is evident from very olivine-rich types to olivine-free types. Feldspar is rare or absent in the matrix of the rock. Ocelli are almost universally present, their size depending on the size of the dyke. Internal zoning, complete with chilled margins, concentration of ocelli, and other features is a common and prominent feature of the dykes. Geometrically the dykes pinch and swell markedly along strike, and may pinch out entirely in outcrop. More or less marked sinuosity of strike is common. A particularly characteristic feature of the dykes is offsetting. The dyke may be displaced along a planar surface as much as three times its own width, though offsets less than the width of the dyke are most common. The outer edges of the offset parts commonly show thin horn-like projections which together with the complete lack of disturbance in the host rocks show the offsetting to be a feature of the intrusive mechanics of the dykes, and not due to later structural disturbance. The felsic dykes display a greenish or brownish aphanitic matrix, commonly with large phenocrysts of pink feldspar. In outcrop the rocks have a characteristic fractured to shattered appearance. The dykes thicken and thin in extraordinarily rapid fashion, locally thinning from 5 feet to 6 inches within 10 feet. Both lamprophyres and felsic dykes show little or no marginal alteration of the country rocks. Carbonatite dykes, commonly pale pink in colour, and from 2 to 8 inches wide are common near the bay. They are notably constant in width, and undulate gently along strike. Locally intense fenitization is present on the margins, but other dykes show little or no effect. Members of each of the three sets of dykes were found cutting members of the other sets, so that intrusion of the dykes was presumably roughly contemporaneous. No example of a fenitized dyke was definitely identified, so intrusion of the dykes post-dated all or most of the fenitization.


GENERAL GEOLOGY
of MICHIPICOTEN ISLAND,
Lake Superior
miles
0
5
47° 45'
85° 45'
to be mapped
to be mapped
LAVA FLOWS
Coarse-grained basalt
Fine-grained basalt
Andesite and pitchstone
Rhyolite
FRAGMENTAL ROCKS
Agglomerate and tuff
Sandstone and conglomerate
INTRUSIONS
Acid quartz-porphyry
'Microdiorite'
RMA '69

PRECAMBRIAN GEOLOGY

77. VOLCANIC STUDIES ON MICHIPICOTEN ISLAND, ONTARIO (41 N)

Project 680115

R.N. Annells

The study is part of a larger program of investigation of the Keweenawan lava flows and related rocks in eastern Lake Superior.

During the summer the entire Michipicoten Island coastline was mapped in detail, and 8 measured traverses were made from north to south across the island; the shores of the larger lakes on the island were also examined. Fresh samples were collected from all the flows exposed on the shoreline; a representative selection of these will be chemically analyzed for the major and 13 minor elements. Other studies will be made of the petrography and phenocryst mineralogy of the lavas, and the possible presence of disseminated ore minerals in the lavas will also be investigated.

A generalized stratigraphic section through the lavas mapped on the island is given below; some of the units in this section represent groups of flows rather than single flows:

	Unit	Thickness (feet)
15	Pink rhyolite, flow-banded	620
14	Fine-grained grey basalt with a few silty intercalations	970
13	Acid tuff	0.90
12	Fine-grained grey and reddened basalts, lustrous black pitchstone	960
11	Acid tuff	80
10	Fine-grained dark grey vitreous basalt	835
9	Dark grey vitreous andesite bearing abundant feldspar microphenocrysts	565
8	Dark vitreous andesite with feldspar microphenocrysts	595
7	Medium-coarse-grained holocrystalline basalt	280
6	Acid tuff	0.55
5	Conglomerate with red-brown matrix	255

	Unit	Thickness (feet)
4	Pink rhyolite with granular texture	900
3	Fine-grained dark grey vitreous and holocrystalline basalts	2,275
2	Dark red rhyolite with some flow-banding	0.100
1	Coarse-grained ophitic and doleritic basalts with intercalated conglomerates and acid tuffs	2,780 (down to lake level)

This preliminary compilation gives a thickness of 11,360 feet for the Michipicoten lava pile.

The lava flows on Michipicoten Island dip in a southerly direction (see map, Fig. 1); these dips decrease from about 45 degrees on the north coast to about 12 degrees on the south coast and the small island chain south of the main island. Dips were found to increase locally to 75 degrees on the north shore of Michipicoten Island and one flow on the southwest corner of the island was found to be vertical near a fault zone.

A number of normal faults trending between north and north-northwest cut the lavas, and the rocks are sometimes hydrothermally altered along these fracture zones; this alteration contrasts strikingly with the generally very fresh appearance of the lavas, and can be seen at intervals in the andesite (unit 9) which alters to a pale green-grey rock specked with pyrite. Narrow fracture zones up to 6 feet wide cut the basalts on the south coast of the island; these fractures trend roughly parallel to the coastline and are often filled by carbonate, quartz, chalcedony and agate.

The fine-grained basaltic rocks on the north shore of the island are cut by what appears to be a lenticular intrusion of medium-grained holocrystalline red rock which has been tentatively identified as a microdiorite. The lower part of the lava sequence (units 1-9) is often cut by sheet-like or lenticular intrusions of pink acid quartz-porphyry bearing large phenocrysts of feldspar (up to 1 inch) and quartz (up to 0.3 inch). These quartz-porphyry bodies are frequently discordant to the lava flows.

Several outcrops of volcaniclastic rocks were found on Michipicoten Island, the most notable being an agglomerate bearing large angular and rounded blocks of island lava types in a chaotic red or green matrix; this agglomerate outcrops on the northwest shore of the island, and acid tuffs of smaller fragment size were found at five different stratigraphic levels elsewhere on the island.

The occurrence of a highly varied basalt-andesite-rhyolite sequence and associated fragmental rocks on Michipicoten Island is felt to represent a central volcanic origin rather than a flood basalt origin for these mid-Keweenawan lava flows; the general lava sequence on the island shows much similarity to the successions encountered in the Icelandic central volcanoes.

No obvious examples of pillow lavas were found on the island and it thus seems possible that many of the flows were extruded subaerially;

however, the occurrence of conglomerates bearing well-rounded rock fragments is taken to suggest that this volcanism proceeded in close proximity to a body of water.

78. PRECAMBRIAN SHIELD OF THE RIVIÈRE GATINEAU MAP-AREA, ONTARIO (31 SW AND PARTS OF 31 NW)

Project 680030

A.J. Baer

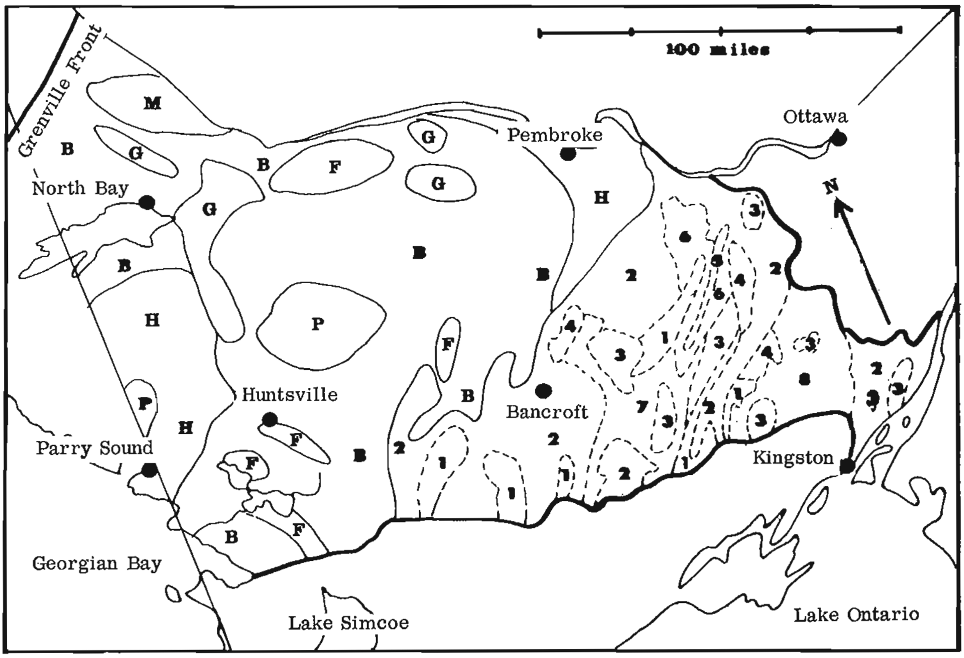
The writer and an assistant undertook a survey of the Grenville Province in southeastern Ontario, east of longitude 80°W. This survey included reconnaissance mapping of geologically unknown areas and control of existing maps against field observations. Traverses were made along roads, and about 1,500 stations were established, at one-mile intervals where practicable. Similar operations were started in 1968 in adjacent parts of the Province of Quebec and are preliminary towards compilation of a geological map of NTS 31 at the scale of 1:1 million.

The area (see Fig. 1) can be divided in two by a line passing approximately through Lake Simcoe, Bancroft and Pembroke. This line is about the northwestern limit of rocks of the Grenville Group (marble, paragneiss, quartzite) and of dominant northeasterly or northerly structural trends. The region southeast of this line has been extensively studied and mapped by previous authors and reconnaissance work in 1968 essentially confirmed data already published. This region will therefore not be dealt with further in this report. Although some areas northwest of the Lake Simcoe-Pembroke line had previously been mapped in detail, large regions are still virtually unmapped or described as gneiss and granite, undivided.

Lithologies

In order of decreasing abundance, the main rock-types of the area northwest of the Lake Simcoe-Pembroke line are biotite gneiss, quartzofeldspathic gneiss, hornblende gneiss, garnet-hornblende and garnet-pyroxene gneiss, metamorphosed granitic rocks and leucocratic mica gneiss.

Biotite gneiss is as common as it is variable in composition and can be found practically anywhere in the area. It typically contains over 60 per cent feldspar, 5-20 per cent quartz, 10-20 per cent biotite, minor hornblende and accessory minerals. Garnet has rarely been encountered. The rock is commonly grey, more rarely pink or white. It is medium- to fine-grained and generally well-layered. The layers vary in thickness from a few millimetres to a few metres, and in colour from white to black. The rock may contain up to 20 per cent of interlayered amphibolite. Although varieties of biotite gneiss have been distinguished and mapped separately, the rock as a whole gives an impression of great uniformity and monotony.



Western Part
B: Biotite gneiss
F: Quartzofeldspathic gneiss
G: Granitic rocks
H: Hornblende gneiss
M: Leucocratic micagneiss
P: Garnet-hornblende and garnet-pyroxene gneiss

Eastern Part*
8: Granulite and charnockite
7: Volcanic rocks
6: Amphibolite
5: Schist
4: Gabbro and diorite
3: Granite and allied plutonic rocks
2: Gneiss and schist
1: Granitic gneiss

* Geology of the Eastern Part modified after G.S.C. Map 1250A, 1969.

Figure 1. Major rock-units in the Grenville Province of southeastern Ontario.

Quartzofeldspathic gneiss is common between North Bay and Lake Simcoe and in the Haliburton-Bancroft area. It contains less than 15 per cent mafic minerals (hornblende, less commonly biotite), 10-40 per cent quartz and 45-75 per cent feldspar. Colour of the rocks varies from light to dark pink, with occasional greyish horizons. The rock is commonly fine-grained, rarely medium-grained; it is well layered, in layers 10 centimetres to 2 metres thick. In some areas the quartzofeldspathic gneiss contains thin but continuous layers of amphibolite.

Hornblende gneiss is abundant east of Parry Sound and between Pembroke and Bancroft. Elsewhere it represents a minor component of the biotite gneiss and of the quartzofeldspathic gneiss. The rock generally contains over 25 per cent hornblende, up to 75 per cent feldspar and minor amounts of biotite. It is commonly dark green, and medium to fine grained. Layering varies from excellent to very poor. However many of the poorly layered outcrops display a good gneissosity due to the parallel orientation of irregular lenses of feldspathic material. Isolated lenses of marble are associated with the hornblende gneiss northeast of Parry Sound.

Garnet-hornblende and garnet-pyroxene gneiss is common in Algonquin Park and northeast of Parry Sound, but rare elsewhere. These rocks contain about 10 per cent garnet, 10 per cent pyroxene and/or hornblende, and 80 per cent quartzofeldspathic material. Because feldspar is clear and has a greasy luster, it is difficult to tell from quartz. The rock is typically greenish grey and becomes rusty-brown by weathering. It is commonly medium grained, homogeneous, and rarely layered. A granular texture due to distribution of garnet and pyroxene and/or hornblende in small isolated grains is typical of most outcrops. Field evidence indicates that some of the grey biotite gneiss described above grades into garnet-hornblende and garnet-pyroxene gneiss by increasing metamorphism. The transition probably corresponds to that between the amphibolite facies and the granulite facies of metamorphism. Large bodies of granitic rocks (granodiorite, granite) are confined to the western part of the area examined. Few of them are to be found east of 79°W. In spite of great variability in texture and mineralogy, most are pink and homogeneous. Some are well foliated, others are massive, or show alternating foliated and massive zones. A common mineralogy is 45-60 per cent feldspar, 30-40 per cent quartz and 10-15 per cent biotite. Hematite is a common accessory mineral, and garnet may be present. Other phases lack biotite and hematite, but they contain 15-20 per cent hornblende and pyroxene, and 5-10 per cent garnet. In these phases feldspars are greenish and the rocks appear to be in the granulite facies of metamorphism. All bodies of granitic rocks appear to have been recrystallized after their emplacement and many of them have been strongly deformed.

Leucocratic, muscovite- and biotite-bearing gneisses are common west and southwest of Temiscaming, but absent from most other areas. They may contain up to 50 per cent quartz, 50 per cent feldspar or more, 20 per cent light green mica and 15 per cent biotite. Orthoquartzites are associated with these gneisses in some localities.

Other rock-types have been encountered, but they do not appear to have regional significance at the scale of the present study. They include for instance small bodies of gabbroic rocks (mainly dykes), leucocratic biotite-garnet-hornblende gneiss, small granite bodies and pegmatites.

Structure

Northwest of the Lake Simcoe-Pembroke line, structural trends are commonly southeasterly and lineations generally plunge to the southeast. In the Huntsville-North Bay area, a south-southeasterly trend can be distinguished from an east-southeasterly trend but it is not yet known if they correspond to two distinct phases of deformation. Northeasterly trends are dominant in an 8- to 10-mile-wide belt along the Grenville Front and they also appear with increasing frequency as the 'line' is approached from the north and northwest. Close to the 'line' northeasterly trends are younger than southeasterly trends. Northwest of the 'line', gneisses dip to the south or southeast at low to intermediate angles (less than 50 degrees), in contrast with steep attitudes southeast of the Lake Simcoe-Pembroke line.

Metamorphism

Although all Precambrian rocks in the area are metamorphic, their grade of metamorphism varies from the greenschist facies to the granulite facies. Most rocks are in the amphibolite facies, and the greenschist facies is only represented in the Hastings 'basin'. Field observations suggest that in addition to previously known occurrences of the granulite facies in the Frontenac axis, this facies also occurs east of North Bay, northeast of Parry Sound and in Algonquin Park.

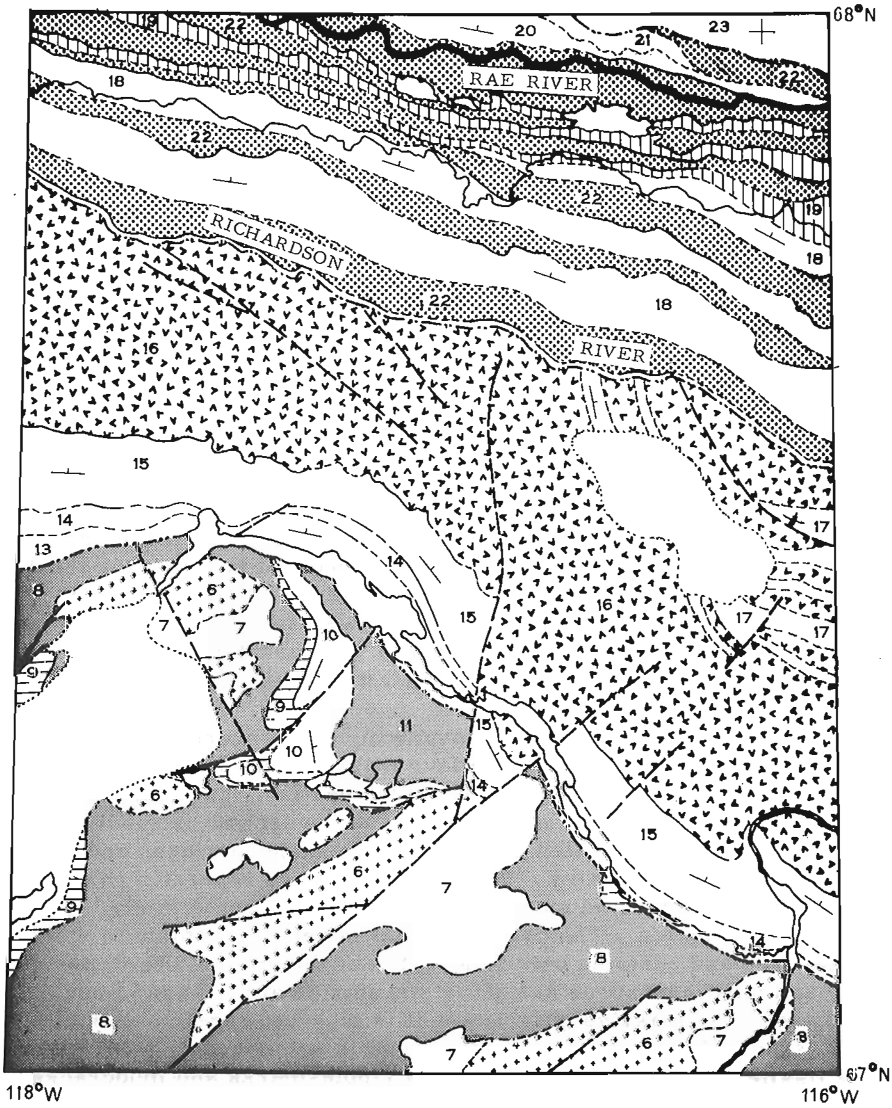
79. COPPERMINE AND DISMAL LAKES MAP-AREAS, DISTRICT OF MACKENZIE (86 O AND N)

Projects 660007 and 690025

W. R. A. Baragar and J. A. Donaldson

The two map-areas, about 7,500 square miles, were mapped during the summer by means of helicopter traverses spaced about 3 or 4 miles apart and supplemented in places by ground traverses. The areas are in the north-central District of Mackenzie and were previously mapped at a scale of 8 miles to 1 inch by Fraser[1]. Donaldson extended his previous work on the Hornby Bay Group[2] by additional work near Dease Arm, Great Bear Lake, and Baragar mapped and sampled a section across the Coppermine River lavas between the two major faults of the Dismal Lake sheet. This supplements the five sections of Coppermine River lavas previously mapped and sampled[3]. John Worth began sedimentological and stratigraphic studies of sediments overlying the Coppermine River flows by detailed examination of sections along, and west of, Coppermine River.

Sketch maps of the geology of the Dismal Lakes and Coppermine map-areas appear in Figures 1 and 2 respectively. The most interesting features are: (1) an unconformity not previously recognized was found to exist within the Hornby Bay Group as it is presently defined; (2) the unconformity previously reported between the Coppermine River Group and a younger sedimentary group[3] was traced across the two map-areas; and (3) the unconformity between Hornby Bay sandstones and underlying granites and rhyolites was observed in outcrops. These, together with the long recognized unconformities between the Yellowknife and Epworth groups and the post-Coppermine River sediments and Paleozoic limestones, make a total



LEGEND

23 Paleozoic dolomite
unconformity
22 Diabase
21 shale
20 Massive quartzite
19 Dolomite-limestone
18 Shale and sandstone

unconformity
Coppermine River Group
17 Red sandstones
16 Basalts
15 Dolomite
14 Red mudstone - shale
13 Sandstone - black shale
unconformity

Geological boundary; approximate, assumed
Unconformity

0 5 10 miles

Figure 1. Geology of Dismal Lakes map-area.

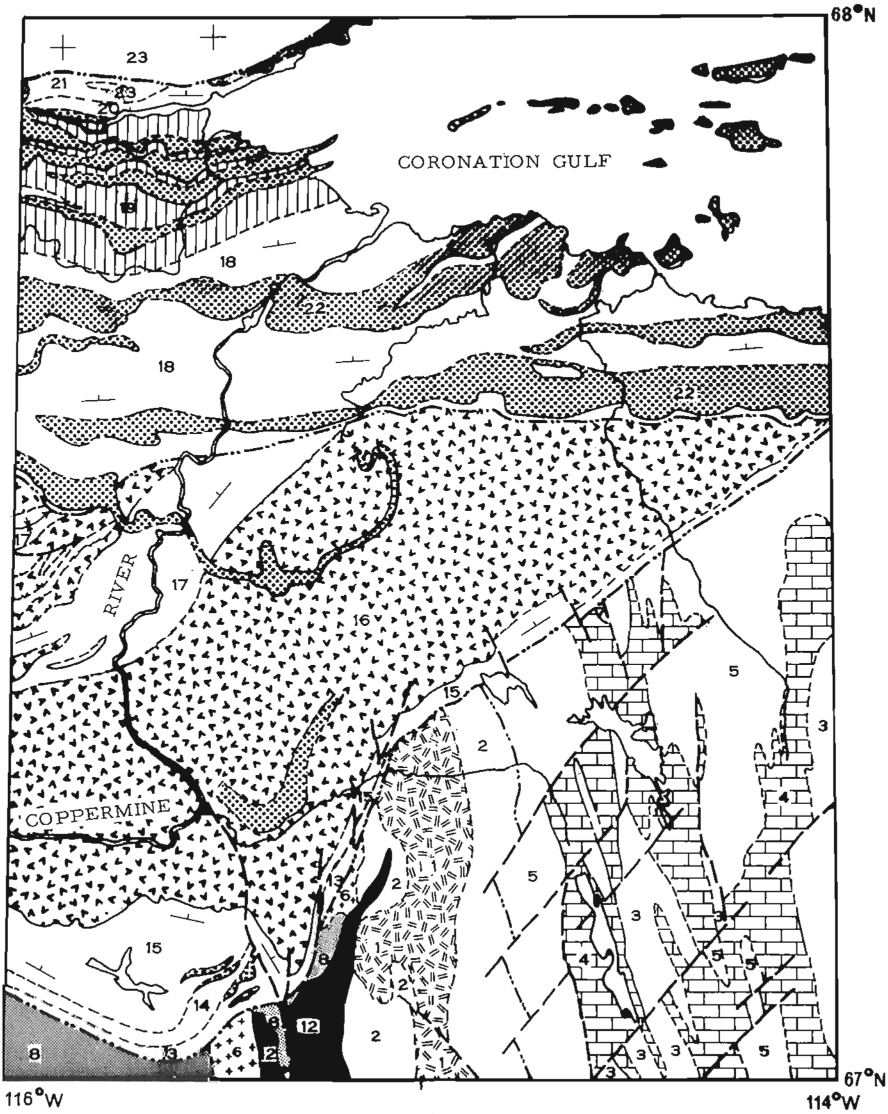
of five unconformities present in the two map-areas. In the interests of simplicity only three are distinguished in the sketch maps. Following is a brief summary of the geology of the two map-areas.

The oldest rocks are greenstones (1), locally pillowed; and metasediments (2), mainly slates and phyllites of, presumably, the Yellowknife Group. The metasediments show one or more cleavages and various combinations of intersection - and crinkle-lineations. The Epworth Group, composed of reddish sand - and siltstones (3) dolomite (4) greywacke (5) and shale, is moderately folded along northerly-trending axes and is cut by numerous faults many of which strike parallel to the folds. The relationship of granite (6) and feldspar phyric rhyolite (7) to the Epworth Group is unknown, but all are unconformably overlain by the Hornby Bay Group which is here restricted to rocks below the newly recognized unconformity reported above. The Hornby Bay Group consists of sandstones and conglomerates (8, 11), dolomite (9), and a sandstone - shale unit (10). These rocks, which have been gently warped and faulted, are unconformably overlain by a sequence of sandstones and black shales (13), red mudstones and shales (14) and several dolomite units[2]. For most of its exposed length this sequence dips 4 to 10 degrees northerly and is conformably overlain by the Coppermine River Group consisting of a lower volcanic and an upper sedimentary and volcanic division. The volcanic rocks are aphyric subaerial basalts (16) occurring as sheet-like flows with individual thicknesses of mainly 25 to 75 feet. Pyroclastic rocks are exceedingly rare. The lower division is 8, 000 to 10, 000 feet thick. The upper division consists of red sandstones and shales, typically crossbedded, interlayered with basaltic flows. It is a minimum of 4, 000 feet thick.

The sedimentary group overlying the Coppermine River Group unconformably is here divided into four map-units as follows (older to younger): thinly layered shales and sandstones (18), carbonate rocks (19), massive quartzite (20), and shale (21). The lowest unit is subdivisible into dark shales, thinly laminated quartzites with shale partings, and very friable, thin bedded, red shales. These have not been separated in the sketch maps. Ripple-marks and mudcracks are abundant in the thinly layered quartzites and shales. The carbonate unit is generally thinly to moderately thick layered and contains both limestone and dolomite. The units outcrop poorly and most exposures are along streams or at the base of cuestas capped by diabase. The massive quartzite unit is pink and rarely shows distinguishable bedding. The upper unit of this group is composed of greenish grey, thinly fissile shales exhibiting in places ripple-marks and mudcracks. The group dips generally about 5 degrees northward.

A dozen or more diabase sills (22) ranging from about 25 to about 300 or 400 feet thick intrude the post-Coppermine River sedimentary succession but are overlain unconformably by lower Paleozoic dolomites (23) that appear at the northern boundaries of the map-areas. One sill extends into the Coppermine River Group at a point where the unconformity swings sharply northward near Coppermine River. A differentiated sill within the Coppermine River lavas just east of the big bend in Coppermine River may be of the same age as the lava flows.

The Muskox Complex (12) which was thought to post-date the Hornby Bay Group[4] may now be considered to post-date only that part of the previously-defined Hornby Bay Group that lies below the newly-recognized unconformity (T.N. Irvine, pers. comm.). Of uncertain age and relationship



LEGEND

12 Muskox complex
Hornby Bay Group
11 Sandstones
10 Sandstone – shale
9 Dolomite
8 Sandstones – conglomerate
unconformity

7 Rhyolite
6 Granite

Epworth Group
5 Greywacke
4 Dolomite
3 Red sandstones – siltstones

unconformity
Yellowknife Group
2 metasediments
1 basalts

0 5 10 miles

Figure 2. Geology of Coppermine map-area.

are a group of previously unmapped diabase sills that intrude the sandstones (13) and shales (14) just northwest of Muskox Complex.

The Coppermine River flows have been intensively explored for copper in the last four summers and a number of prospects have been worked on by several exploration companies (see Kindle and Kirkham, this publication). In the course of our field work this summer a new copper showing was located in black shales at the base of the younger sedimentary group (18) a short stratigraphic distance above the unconformity. Its location is 67°32'4"N, 115°54'21"W. Two grab samples gave assays of 1.70 and 0.26 per cent copper. Other assays and further descriptions of this occurrence are provided by Kirkham (Kindle and Kirkham, this publication) who later visited this showing. A polished section of the copper-bearing shale showed that the mineralization is mainly very finely (.02-.05 mm) disseminated bornite and less commonly coarser blebs (2-3 mm) of chalcocite. Magnetite forms about 10 per cent of the rock. This showing is more significant as an indicator of possible sedimentary copper ores elsewhere in the poorly exposed post-Coppermine River sediments than as a specific copper prospect.

---

[1] Fraser, J.A.: Geology, north-central District of Mackenzie; Geol. Surv. Can., Map 18-1960 (1960).

[2] Donaldson, J.A.: Stratigraphy and sedimentology of the Hornby Bay Group, District of Mackenzie (parts of 86 J, K, L, M, N, and O); in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 154-157 (1969).

[3] Baragar, W.R.A.: Volcanic studies: Coppermine River basaltic flows; in Report of Activities, Part A, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 26-28 (1967).

[4] Smith, C.H., Irvine, T.N. and Findlay, D.C.: Muskox Intrusion; Geol. Surv. Can., Maps 1213A and 1214A (1967).

---

80. HURWITZ GROUP, DISTRICT OF KEEWATIN (55J, K, L, 65 I, PARTS 55 E, F, AND PARTS 65 G AND H)

Project 670004

R.T. Bell

Approximately three weeks were spent visiting scattered outliers of the Hurwitz Group from Rankin Inlet to Wallace River on Hudson Bay and westward to Watterson Lake. Unfortunately ice and open water conditions precluded a visit to the important Marble Island locality.

New information includes the following observations:

(1) Sedimentary strike in the ripple-marked orthoquartzites is northeasterly

throughout the area with direction of transport from the southeast, including information from outcrops on the northside of Rankin Inlet and Watterson Lake[1].

(2) Granitic rocks invade the Hurwitz Group near Wallace River and north of McConnell River.

(3) Polymict conglomerates and slightly pyritic impure quartz arenites were discovered in a narrow north-trending belt just west and northwest of Carr Lake. These sedimentary rocks may be Archean in age or may be equivalent to the Montgomery Lake and Padlei belt sedimentary rocks previously described[2]. No anomalous radioactivity was detected.

(4) Hurwitz G unit[1] is present near Wallace River and is separated from Hurwitz D unit by about 300 feet or less of grey phyllites.

(5) At Watterson Lake the ripple-marked orthoquartzites (Hurwitz D) directly overlie metadiorites and granitic gneiss.

---

[1] Bell, R.T.: Preliminary notes on the Proterozoic Hurwitz Group, Tavani and Kaminak Lake areas, District of Keewatin; Geol. Surv. Can., Paper 68-36 (1968).

[2] Bell, R.T.: Study of the Hurwitz Group in the eastern part of the Rankin-Ennadai belt, District of Keewatin; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 147-148 (1969).

---

81. PRECAMBRIAN ROCKS, LONG RANGE MOUNTAINS, NORTHWEST NEWFOUNDLAND (12 I)

Project 680130

H. H. Bostock

A part of the Long Range in the Great Northern Peninsula, Newfoundland, lying west-northwest of Hooping Harbour-Williamsport, was mapped at a scale of 1 mile to 1 inch (Fig. 1). Glacial striae indicate easterly ice movement towards the coast from the topographic divide in the western part of the mapped area. Erratics are very common and appear to be entirely locally derived. A reconnaissance study of the geology of the Great Northern Peninsula is reported by Clifford and Baird[1].

Bedrock within the area mapped consists chiefly of granitic, amphibolitic and quartzitic gneisses. One body of massive granite and several small bodies of metagabbro are present within these gneisses. Basic dykes are abundant in the eastern and central parts of the area but none were observed in the west. These dykes consist chiefly of northeast-trending, steeply dipping, greenish diabase and are up to 200 feet wide. Other basic dykes in varying stages of alteration to biotite-amphibole-plagioclase gneiss are well exposed only along the sea coast.

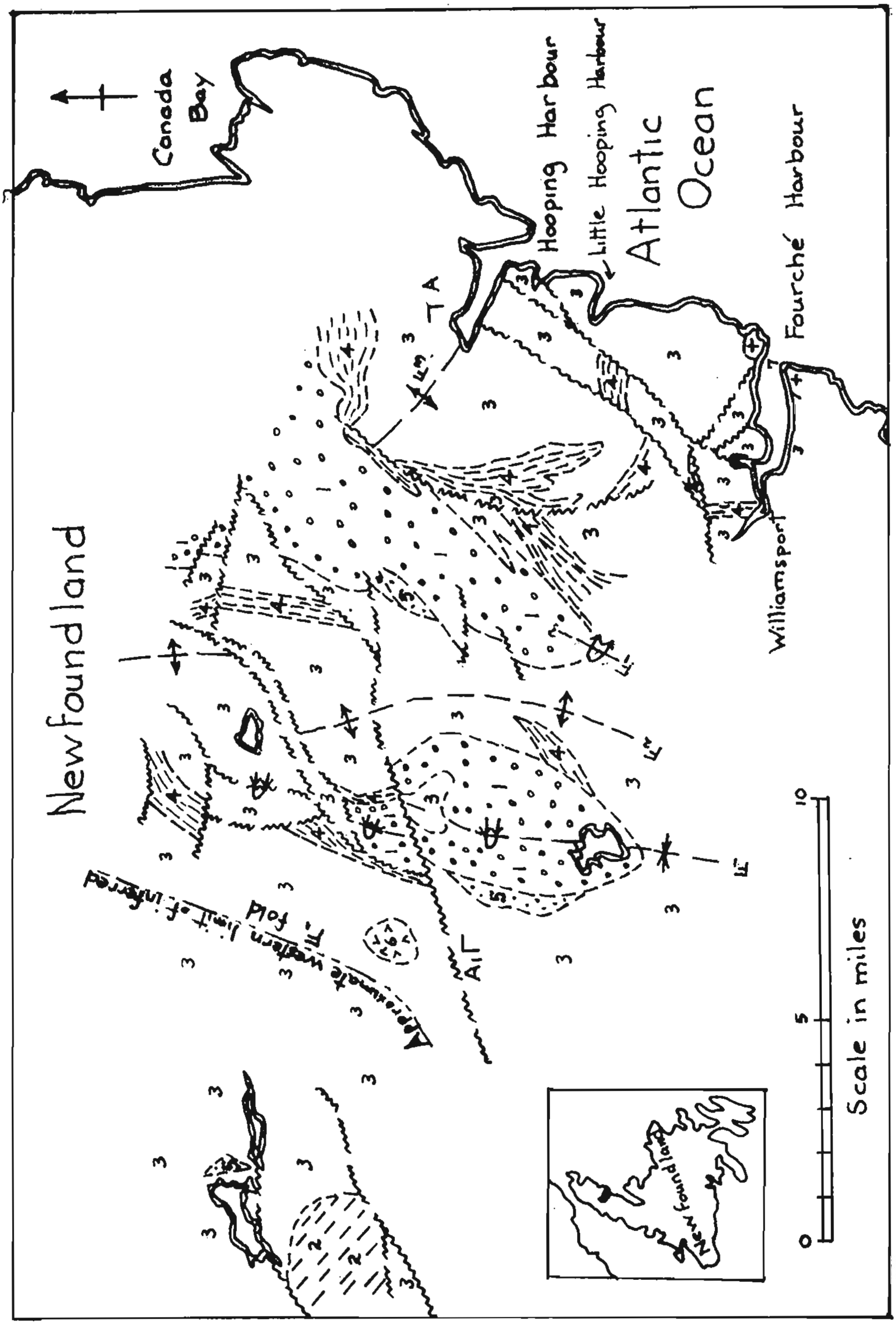

Newfoundland
Canada Bay
Hooping Harbour
Little Hooping Harbour
Atlantic Ocean
Fourché Harbour
Williamsport
0
5
10
Scale in miles
Newfoundland

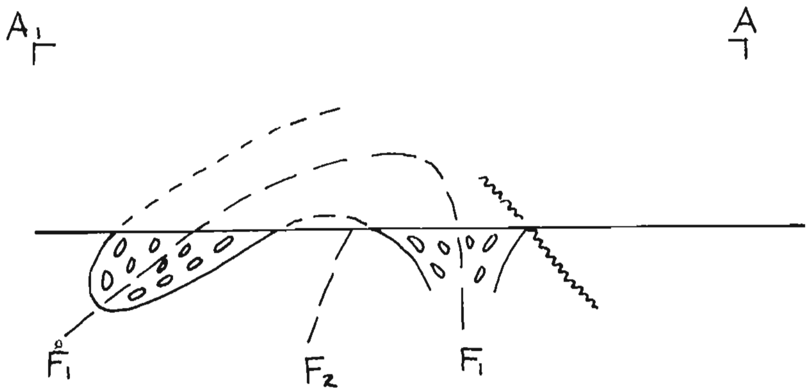
Figure 1.

Precambrian rocks of the Great Northern Peninsula Newfoundland

Lithologies	Symbols
7. Massive chlorite granite	Geological contact
6. Hornblende-biotite metagabbro	Faults
	approximate
5. Sillimanite-bearing gneiss	assumed
	Fold Axes
4. Mesocratic gneiss	antiformal
3. Leucocratic gneiss	(overturned)
2. Lineated granitic gneiss	synformal
	(overturned)
1. Augen gneiss	

Simplified Section

Showing F_1 and F_2 folds in the southern part of the central domain



A preliminary subdivision of the gneisses into augen-gneiss (1), lineated granitic gneiss (2), leucocratic gneiss (3), mesocratic gneiss (4), and sillimanite-bearing gneiss (5) has been made. These rocks are predominantly medium grained (1 to 3 mm) except that the augen-gneiss (1) contains potash feldspar augen commonly 2 or more centimetres in length. Biotite is the most widespread mafic mineral but magnetite is common in leucocratic gneiss and amphibole in mesocratic gneiss. Medium-grained potash feldspar is a constituent in some parts of the leucocratic gneiss and may provide a basis for further subdivision.

Bedding surfaces, evident chiefly through the presence of minor impure quartzite beds, have been the only sedimentary features recognized. Secondary structures consist principally of schistosity, gneissosity, and lineation, but locally simple or compound, small scale folding is evident. The appearance of the latter in nearly flat-lying gneisses indicates that the rocks have been intensely deformed.

For purposes of description and discussion the area is divided somewhat arbitrarily into three domains: eastern, central and western. The eastern domain is bounded by the Atlantic Ocean and a small massive granite body (7) near Fourché Harbour on the east, and on the west by a narrow fault block extending between Williamsport and Hooping Harbour. The central domain extends west from there to a northward-trending structural discontinuity (see Fig. 1) that lies some 18 miles inland from the coast. The western domain includes the area lying west of the central domain and is the least known of the three.

The eastern domain between Fourché Harbour and Little Hooping Harbour, is characterized by leucocratic gneiss (3) with southeast to south dipping foliation. Angles of dip in the south range from 45 to 70 degrees but are typically somewhat less in the north. Along the north coast of Fourché Harbour, lineations formed by wrinkles along contacts between thin bands (metadykes) of mesocratic gneiss and leucocratic host, plunge as much as 28 degrees east-northeast.

The central domain includes two large bodies of augen-gneiss (1) surrounded by leucocratic (3) and mesocratic (4) gneiss with sillimanite-bearing mesocratic gneiss (5) along their western margins. In the north mesocratic gneiss (4) exists within leucocratic gneiss possibly as a single layer about 500-600 feet thick. Farther south, lithologic continuity is less evident. Gneisses in the northern part of the domain are typically shallow-dipping (0 to 35 degrees) and are cut by faults of significant displacement. Farther south, dips are commonly steeper and deformation appears to have been more penetrative. The western boundary of the central domain is marked by progressive steepening of westward dips which eventually pass through the vertical. Lineations, defined by quartz elongation, and to a lesser extent by elongate biotite lenses, are evident at widely scattered localities in the northern part of the domain where the gneisses are gently dipping. These lineations trend southwesterly and most plunge at about 10 degrees or less.

The western domain, west of the zone of vertical dips, is dominated by a body of lineated granitic gneiss (2) about which leucocratic gneisses (3) wrap with outward dips. Lineations within this body, made evident through elongation of quartz and irregular mullions, plunge chiefly from 15 to 30 degrees southeast. Foliation appears to be rare or absent throughout most of the central part of the body, but along its unfaulted margins both lineation and foliation are present. A small body of sillimanitic-rich gneiss (5) is present in the northern part of the domain apparently surrounded by rocks devoid of sillimanite.

A preliminary hypothesis relating the geometry of the rocks in the central and eastern domains has been developed during field work and is presented below. This will undoubtedly be revised by further study.

It may be supposed that the rocks of the central domain exist in a major westward overturned recumbent anticline, F_1, the core of which is occupied by augen-gneiss (1). The western limit of this fold follows the zone of vertical dips; and the fold axis is marked by the cores of the augen-gneiss bodies (1). The westernmost of these bodies is thus viewed as a rootless synformal anticline. Evidence for this fold lies in the persistence of nearly horizontal lineations within the equigranular gneisses across the northern part of the central domain where the gneisses are gently dipping, and within the augen-gneiss (1) where the orientation of augen appears to be parallel with quartz elongation in the surrounding gneisses. These lineations are assumed to be 'b' axis lineations of the F_1 fold. Presence of the fold is compatible with structural-lithologic units in the gneisses, in so far as these are known, provided that the necessary faults and displacements are assumed. Some uncertainty arises from the fact that the orientation of the western F_1 fold axis (apparently south-southwest, see Fig. 1) is obscured by faulting in the northwestern part of the central domain where lineations, which strike slightly more westerly, are best exposed.

The recumbent fold, F_1, has been arched along an axis, F_2, subparallel to F_1. Foreshortening of the F_1 fold at right angles to the F_2 axis has occurred, mostly along isolated faults in the north, but in the south similar foreshortening has been more penetrative. The northern part of the eastern (upper) limb of the recumbent fold F_1 has been broadly warped along a west-northwest-trending axis F_3. The southwest limb of this F_3 fold, at its southwest margin, has been detached from the more highly deformed southern continuation of the east limb of the F_1 fold along a curved (gently dipping?) fault.

Rocks of the eastern domain form a largely isoclinal, southeasterly dipping sequence that is separated from predominantly southwesterly to southerly dipping gneisses of the central domain by a narrow fault block. Dips of the gneisses become more shallow on both sides of this fault block as Hooping Harbour is approached from the south. It is therefore possible that the boundary faults die out in unmapped territory farther north.

Small amounts of malachite, pyrite, and calcite occur in veins within sheared diabase at the waterfall 1/2 mile north of Williamsport. Veins at the base of the falls have been excavated, but high tide at the time of the writer's visit prevented their examination.

---

[1] Clifford, P.M. and Baird, D.M.: Great Northern Peninsula of Newfoundland-Grenville inlier; Trans. Can. Inst. Mining Met., vol. 45, pp. 95-102 (1962).

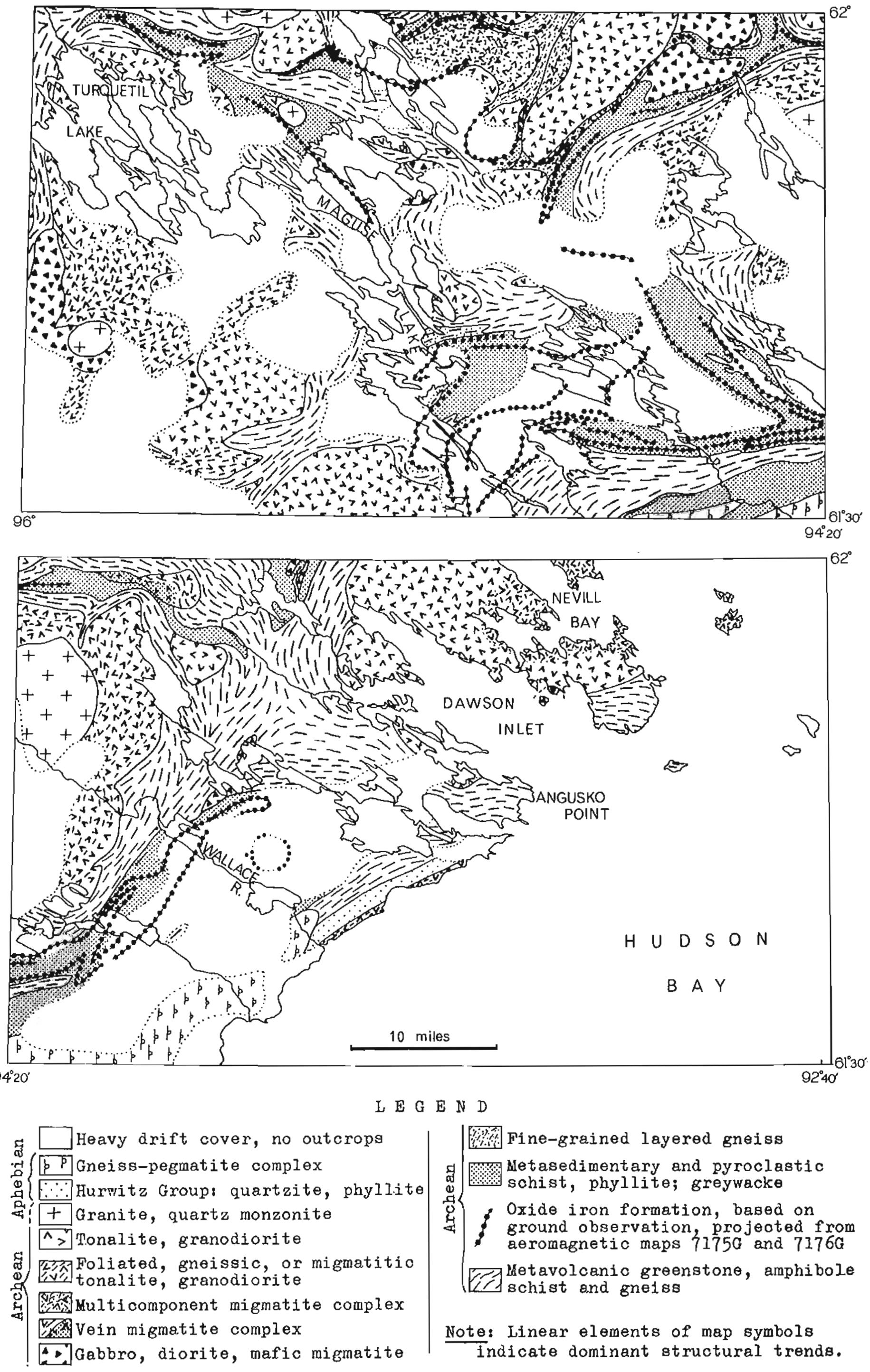


Figure 1. Sketch map of the geology of the north parts of the Eskimo Point and Dawson Inlet map-areas.

82. ESKIMO POINT AND DAWSON INLET MAP-AREAS, DISTRICT OF KEEWATIN (55 E, NORTH HALF, 55 F, NORTH HALF)

Project 660006

A. Davidson

The northern halves of the Eskimo Point and Dawson Inlet map-areas were traversed by helicopter in June 1969 for publication of geological maps at a scale of 1 inch to 4 miles. This mapping was undertaken in order to extend geological knowledge recently obtained in the adjacent Tavani (55K), Kaminak Lake (55L), and Henik Lakes (65H) map-areas[1, 2, 3]. The present map-area covers the southern part of the northeast end of the Ennadai-Rankin Inlet greenstone belt[4], and is notable in that it contains extensive, linear, high aeromagnetic anomalies[5, 6], formerly presumed and now known to be caused by sedimentary iron-formations. Figure 1 is a geological sketch map of the area mapped.

Large, lake-strewn, drift-covered areas entirely obscure the bedrock in about one third of the map-area. Elsewhere the amount of outcrop varies from sparsely scattered to plentiful; outcrop is virtually continuous in places north and west of Dawson Inlet.

The oldest rocks are massive or pillowed greenstones, in places much deformed. These are locally intercalated with or overlain by intermediate to felsic metavolcanic rocks, chiefly of pyroclastic origin. This volcanic assemblage appears to be overlain conformably by metasedimentary rocks that locally contain thick tuff and agglomerate units. Thinly bedded magnetite and magnetite-hematite iron-formation forms part of the sediment-tuff assemblage. Much more sedimentary rock is present in the map-area than to the north. The greatest preserved thickness is probably in the complex structural trough between Maguse Lake and Wallace River. In this trough linear aeromagnetic anomalies, ranging from 3,000 to 20,000γ above background (3,500γ), are continuous for many miles. Rock exposure in this region is extremely sparse. Thinly interbedded iron-formation and siltstone is present in most outcrops, but nowhere was outcrop observed precisely where the highest magnetic anomalies occur; however, angular blocks of black, very fine grained, thick bedded magnetite iron-formation are common in the overlying drift. It seems likely that there is more than one iron-formation unit within this structural trough, but it is possible that one unit is repeated at the surface by folding. Steep dips prevail everywhere in the volcanic and sedimentary rocks.

A variety of plutonic rocks have invaded the older strata, forming complexes containing several rock types that appear to represent successive stages of plutonic activity. Parts of five complexes occur within the map-area: (1) at and south of Turquetil Lake; (2) south of Maguse Lake; (3) along the northern map boundary west of 94°30'W (the southern extension of the complex around Carr and Kaminak Lakes[2]); (4) around the upper reaches of Wallace River; (5) in the vicinity of Dawson Inlet and Nevill Bay. These complexes differ internally in structure and arrangement of plutonic units, but contain a similar diversity of rock types. In general they are surrounded by a shell of mafic metavolcanic rocks that in places penetrate the complexes as screens separating different plutonic units. An exception is north of Maguse Lake where sedimentary rocks, including iron-formation, are converted to irregularly folded gneisses and invaded by several granitoid types to form migmatite. The plutonic complexes are composed predominantly of hornblende tonalite and hornblende-biotite granodiorite. Hornblende diorite and gabbro bodies usually occur near the margins of the complexes, are considerably altered, and represent the earliest intrusive phase; an exception is the small pluton on the north shore of Dawson Inlet, which is composed of fresh, layered norite and leucogabbro, and appears to cut the adjacent tonalite. The core of the Wallace River complex is occupied by a large pluton of massive, coarse-grained, pink quartz monzonite and granite with large K-feldspar megacrysts; dykes of similar type invade the surrounding tonalite which, in addition, is much deformed. A smaller pluton of massive cream granite intrudes gneissic tonalite south of Turquetil Lake. Small satellite plutons of various types occur between the large complexes.

Northerly trending diabase dykes cut the plutonic rocks. Between Angusko Point and the mouth of Wallace River, a narrow belt of steeply dipping sediments, including ripple-marked orthoquartzite, phyllite, and micaceous or feldspathic meta-sandstones with thin conglomerate interbeds, is assigned to the Hurwitz Group (see R. T. Bell, this publication).

Metamorphism in the Archean volcanic and sedimentary rocks is probably no higher than lower to middle greenschist grade where these rocks are well removed from the plutonic complexes, as west and southwest of Dawson Inlet, east of Maguse Lake, and northwest of Turquetil Lake. These rocks have attained higher metamorphic grade close to the outer margins of the complexes, and in places form narrow zones of contact migmatite. Where the country rocks form indentations or narrow screens between individual plutons of the complexes, they are converted to medium-grained schist and gneiss, commonly migmatitic.

Near the southern map boundary west of Maguse Lake, the plutonic rocks are deformed and recrystallized, as are the diabase dykes that cut them. Similarly east of Maguse Lake, the regional metamorphic grade increases southwards; mafic volcanic rocks are converted to medium- and coarse-grained hornblende schists, sediments to biotite schists with garnet and local cordierite. Pegmatitic granite pervades these rocks to form a gneiss-pegmatite complex. Near the mouth of Wallace River, quartzite of the Hurwitz Group is invaded by pegmatitic granite and is converted to glassy quartz. Thus it appears that the southerly increase in metamorphic grade and the introduction of pegmatitic granite are effects of post-Hurwitz (Hudsonian) Orogeny, and are distinctly later than the plutonic complexes which are known to be pre-Hurwitz[2, 3].

An annular magnetic anomaly, 2 1/2 miles in diameter, is located just north of Wallace River near its mouth (see Fig. 1). There is no outcrop in this vicinity, so the nature of bedrock is not known. The anomaly is similar in form and size to anomalies associated with some alkalic plutons and carbonatites.

---

[1] Heywood, W.W.: Tavani map-area, District of Keewatin; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, p. 139 (1968).

[2] Davidson, A.: Kaminak Lake map-area, District of Keewatin; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 122-125 (1968).

[3] Bell, R.T.: Ferguson Lake and Henik Lakes areas, District of Keewatin; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 149-151 (1969).

[4] Wright, G.M.: Geology of the southeastern barren grounds, parts of the Districts of Mackenzie and Keewatin; Geol. Surv. Can., Mem. 350 (1967).

[5] Geol. Surv. Can., Aeromagnetic Map 7175G (1966).

[6] Geol. Surv. Can., Aeromagnetic Map 7176G (1966).

---

83. PLUTONIC COMPLEXES IN THE NORTHEAST PART OF THE ENNADAI-RANKIN INLET REGION (PARTS OF 65 H, I, 55 E, F, K, L)

Project 660006

A. Davidson

The Ennadai-Rankin Inlet greenstone belt[1] may best be described as a region containing Archean volcanic and sedimentary rocks, invaded by a variety of Archean plutonic rocks, with both overlain by Aphebian sediments (among them the Hurwitz Group) that are preserved in structural basins and fault troughs. The northeast-trending belt is gradationally bounded by regions of higher metamorphic grade in which the effects of Hudsonian (post-Hurwitz) Orogeny dominate. Mapping[2, 3, 4], has shown that the various plutonic rocks within the belt are associated in large complexes made up of several plutons. Detailed work, concentrated in areas of plentiful outcrop, was undertaken last summer within and around the large complex centred about Kaminak Lake (55 L). This work and continued regional mapping (see Davidson, this publication) permit the following tentative summary description of the plutonic complexes in the northeast part of the Ennadai-Rankin Inlet region.

Metamorphic grade in the volcanic and sedimentary rocks between the plutonic complexes varies with distance between the complexes. Separate satellite plutons of various types are present between some complexes. Screens of country rock penetrate the complexes, and serve to separate distinct plutonic units. In the central parts of some complexes these screens are preserved as narrow belts of gneiss or zones of migmatite, commonly deformed into arcuate structures. Radiating from the central parts are more or less bulbous plutons whose 'heads' are homogeneous and well-defined, but whose 'tails' merge indistinctly with the central mixed zone. Later, homogeneous plutons, oval in plan, are present within some complexes, and transect the core structures.

The earliest phase of plutonism is represented by bodies of gabbro or diorite. This was followed by introduction of large masses of tonalite and granodiorite that appear to have both pushed out the earlier mafic plutons so that the latter are now marginal to the complexes, or to have penetrated through them to form well-defined plutons that protrude from the cores of the complexes. Mixed rocks (vein and inclusion migmatites) are a common feature where plutonic masses have invaded the country rocks along their structural grain, and also where leucocratic plutonic phases have intruded earlier mafic plutons. More variably structured, multicomponent migmatites are found in the central parts of the complexes, suggesting that country rock remnants and earlier plutonic phases were rendered mobile during continued and intensifying plutonism. Interaction between these mobilized rocks and magma ranging in composition from tonalite to quartz monzonite has given rise both to a great variety of complex, foliated rocks, and to gradational changes in gross rock composition. Magma of quartz monzonite or granite composition seems nearly everywhere to have been the last active phase of plutonism, forming all gradations between extensive vein and dyke networks and homogeneous plutons either within or marginal to the complexes. It is probable that the several pluton complexes in the region are now exposed at different levels.

Outwards from the core of the Ennadai-Rankin Inlet greenstone belt, Hudsonian Orogeny has increasingly affected both plutonic and country rocks. Northerly-trending pre-Hurwitz diabase dykes cut all the plutonic complexes and are useful in outlining the extent of Hudsonian metamorphism within the belt. Only sporadically along the core of the belt are they essentially unaltered; from there they become metamorphosed both northward and southward, attaining amphibolite grade before structural involvement renders them indistinct within the bordering regions of intense Hudsonian Orogeny. Mineralogical and textural changes in the plutonic rocks can be evaluated by using these dykes as a control to distinguish between the effects of Hudsonian Orogeny and of pre-diabase plutonism.

---

[1] Wright, G.M.: Geology of the southeastern barren grounds, parts of the Districts of Mackenzie and Keewatin; Geol. Surv. Can., Mem. 350 (1967).

[2] Heywood, W.W.: Tavani map-area, District of Keewatin; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1A, Pt. A, p. 139 (1968).

[3] Davidson, A.: Kaminak Lake map-area, District of Keewatin; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 122-125 (1968).

[4] Bell, R.T.: Ferguson Lake and Henik Lakes areas, District of Keewatin; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 149-151 (1969).

84. KAMINAK LAKE ALKALIC COMPLEX, DISTRICT OF KEEWATIN (55 L)

Project 660006

A. Davidson

A small pluton of unusual alkalic rocks occurs at the northeast side of Kaminak Lake, and was first reported in 1968[1]. Because such rocks are potentially of economic significance, this pluton was revisited last summer. Ground and boat traversing enabled nearly every outcrop to be examined in five days.

About 35 per cent of the pluton lies beneath an arm of Kaminak Lake. Some 90 per cent of the rest is buried by drift; in places the cover is relatively thin, and angular blocks at the surface probably represent the underlying bedrock. Figure 1 is a revised sketch map of the pluton and shows the distribution of major rock types as deduced from the sparse outcrop.

Field work has definitely confirmed the presence of two major and distinct types of rock: (1) an ijolitic series, rich in nepheline and aegirine-augite; (2) a syenitic series, with and without nepheline. Dykes of syenite cut ijolitic rocks in many places. In addition to dykes, syenitic rocks form a lens-shaped mass along the northwest side and at the north end of the pluton. A pyroxene-rich phase in the southern part of the pluton is gradational to ijolite. Crude, steeply dipping layering in the ijolitic rocks conforms to the outline of the pluton.

Along the northeast side, the volcanic country rocks are altered to dense, fine-grained, pink syenitic fenites with blue amphibole and aegirine in a zone as much as 1/2 mile wide. Crosscutting dykelets of syenite are common in this zone. The bordering tonalite at the northeast end of the pluton is similarly altered. Magnetite in the fenitized rocks, apparently formed during alteration, presumably accounts for the magnetic anomaly that partly surrounds the pluton[1]. Apart from several dyke-forming phases, mostly of fine-grained, nondescript green or grey rocks, dykes and lenses of carbonatite were noted both within the pluton and in the bordering fenite zone. Commonly composed predominantly of pink or cream calcite, the carbonatites also contain various proportions of apatite, biotite, magnetite, pyrite, blue amphibole, and yellow-green pyroxene. Thin sections have not so far revealed the presence of pyrochlore or other rare minerals.

A Rank Model NE 148A Scintillometer was used to take readings on outcrop surfaces. Results are summarized in Table I. Average ranges given for the three main groups of rocks apply to the whole complex. They are not significantly different to readings obtained on the granitic rocks elsewhere in the vicinity of Kaminak Lake. Readings at two localities, A and D (see Fig. 1), are in excess of three times higher than 'normal' for the alkalic rocks in general. The cause of these high readings is not at present known.

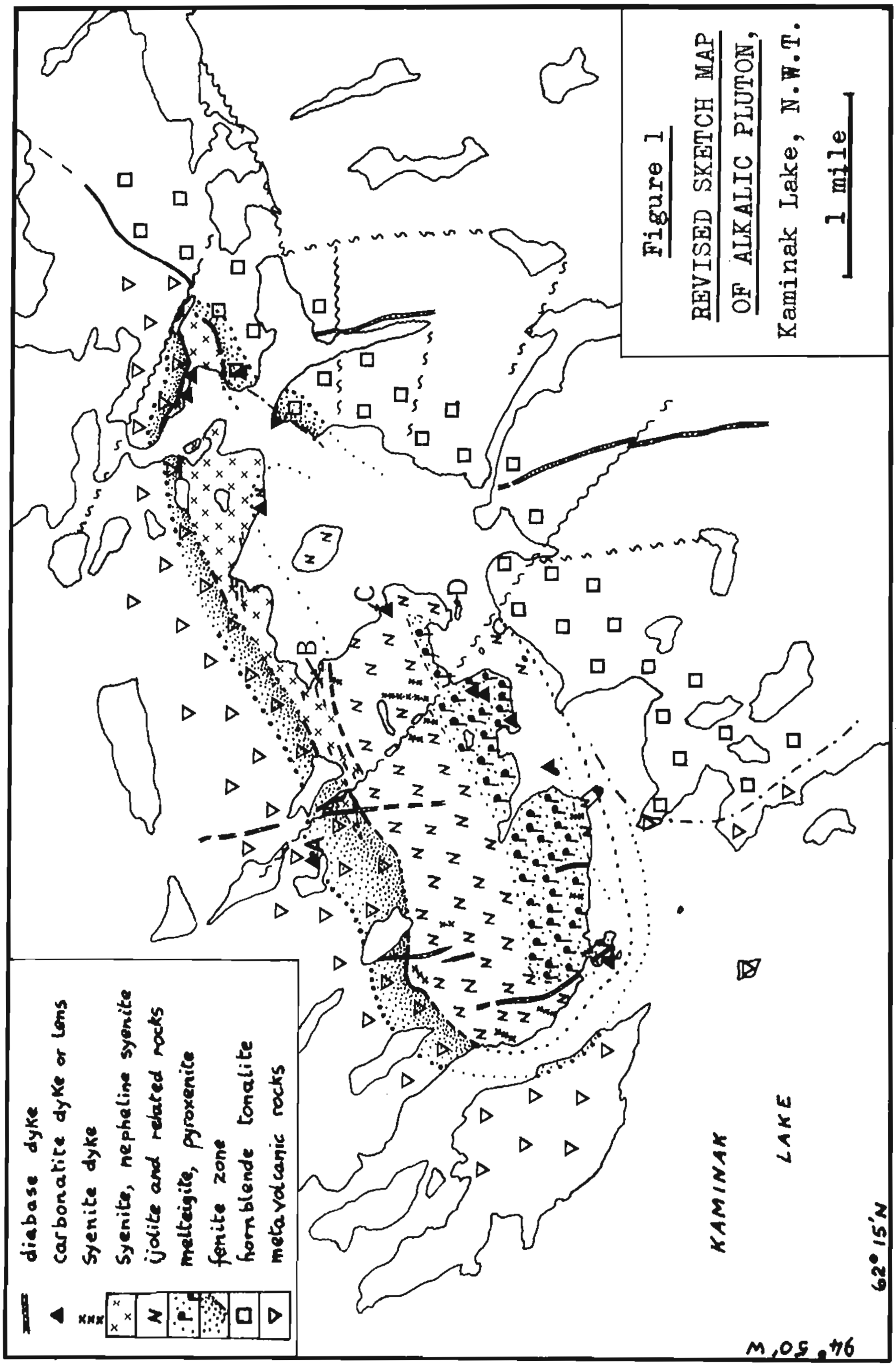


Figure 1
REVISED SKETCH MAP
OF ALKALIC PLUTON,
Kaminak Lake, N.W.T.

1 mile

TABLE I

Scintillometer Readings in μR/hr

Background over lake	1.5 - 2
Background over muskeg	5 - 8
Background over gravel, sand, till	6 - 10
Average range, pink fine-grained fenite	11 - 15
Average range, syenitic rocks	9 - 15
Average range, ijolite and related rocks	11 - 17
9-inch carbonatite dyke, locality A	28 - 45
Mixed ijolitic and syenitic rocks, B	12 - 23
Carbonatite, C	9 - 12
Altered rocks with carbonate, D	12 - 42

[1] Davidson, A.: An occurrence of alkali syenite, Kaminak Lake map-area, District of Keewatin; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 126-129 (1968).

85. ENNADAI LAKE AND NUELTIN LAKE MAP-AREAS, DISTRICT OF KEEWATIN (65 C AND 65 B WEST HALF)

Project 680085

K.E. Eade

An investigation of the stratigraphy and structure of the Aphebian sedimentary rocks was carried out in conjunction with reconnaissance mapping of these adjoining areas (for publication on a scale of 1 inch to 4 miles) by means of a combination of helicopter and ground traverses. This project was started in the 1968 field season[1]. The region has been previously mapped on a scale of 1 inch to 8 miles[2,3].

Although the Aphebian sedimentary rocks in these areas are not contiguous with type Hurwitz Group rocks to the north, northeast or east, the lithology and stratigraphy indicate that, in part, they are correlative. In the Ennadai Lake area however, rocks equivalent to the Hurwitz Group are overlain unconformably by polymictic conglomerate and arkose to subgreywacke containing scattered pebbles. The stratigraphic subdivisions in these areas as compared with the type Hurwitz Group of the Kognak River area[4] are as follows:

Ennadai-Nueltin Lakes areas	Hurwitz Group, Kognak River area
Arkose, subgreywacke	
Conglomerate	
Unconformity	
Arkose, subgreywacke, impure quartzite	Impure quartzite, quartz-sericite schist
	Greywacke; minor siltstone
Dolomite, limestone, intercalated argillite	Dolomite, argillite, siltstone
Argillite, fine-grained greywacke; minor gabbro sills and flows of andesite to dacite	Slate, shale, siltstone; gabbro sills
Orthoquartzite, quartzite	Orthoquartzite; boulder conglomerate

In the Ennadai Lake area the lower part of the section, including the orthoquartzite and much of the overlying argillite, is commonly absent, apparently eliminated by faults that are the contacts of most occurrences of the sedimentary rocks with older rocks. Primary structures are rare in these rocks but scattered observations in the Ennadai Lake area on cross-bedding in the arkose below the unconformity and in the uppermost arkose formation, indicate transport direction from the northeast in both units. The sedimentary rocks are folded along northeast trending axes and numerous faults of various trend cut the rocks, particularly in the eastern part of the Ennadai Lake area. Regional metamorphism has affected the sedimentary rocks almost everywhere, but seems to be more intense in the southeastern part of the Ennadai Lake area. Contact metamorphism, associated with younger plutons, also affects these rocks.

Postorogenic plutons, ranging in composition from granite to granodiorite intrude the sedimentary rocks. The rocks are mostly coarse grained, porphyritic, and commonly fluorite-bearing, but some are medium grained felsic granodiorite.

Underlying the sedimentary rocks in the few places where normal, unfaulted contacts are present, are basic volcanic rocks or quartz-feldspar-biotite gneiss, the latter a part of the older mixed complex of granodiorite gneisses and massive granodiorite.

In the extreme south of the Nueltin Lake (W 1/2) area and the adjoining southeast part of the Ennadai Lake area, drift is extensive but scattered outcrops of paragneiss are present. The relationship is not clear between these gneisses of sedimentary origin and the above-described sedimentary rocks but it is suggested that the gneisses are probably derived from an older group of sedimentary rocks.

No mineral occurrences of economic interest were discovered. Scintillometer readings were made on the orthoquartzite, conglomerate and arkose formations in a number of places but values observed were background or only slightly above. Readings on the younger intrusive, coarse-grained granite to granodiorite were commonly 15 to 20 μR/hour (Rank type ND148A scintillometer) and in some localities up to 40 μR/hour. In the vicinity of

60°32'N, 100°11'W, small, rusty shear zones containing pyrite occur in meta-andesite and nearby are abundant boulders of pyritized sheared meta-andesite.

---

[1] Eade, K.E.: Ennadai Lake map-area, District of Keewatin; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 157-158 (1969).

[2] Lord, C.S.: Geological notes on southern District of Keewatin, Northwest Territories; Geol. Surv. Can., Paper 53-22 (1953).

[3] Wright, G.M.: Geology of the southeastern barren grounds, parts of the Districts of Mackenzie and Keewatin; Geol. Surv. Can., Mem. 350 (1967).

[4] Eade, K.E.: Preliminary report, Kognak River map-area (east half), District of Keewatin; Geol. Surv. Can., Paper 64-27 (1964). Kognak River (west half), District of Keewatin; Geol. Surv. Can., Paper 65-8 (1966).

---

86. BERENS RIVER - DEER LAKE MAP-AREA, MANITOBA AND ONTARIO (53 D, WEST HALF, 63 A, EAST HALF)

Project 690010

I.F. Ermanovics

Field work has been completed this year in the Berens River-Deer Lake map-area thus concluding reconnaissance remapping in the Superior Province of eastern Manitoba begun in 1968[1] between 51 and 53°N, 95 and 97°W. The area comprises a complex, compositional (mainly quartz monzonite to granodiorite) and structural melange ('root' area) of elongated magmatic bodies surrounded by envelopes of differentiated 'granitic' gneiss (orthogneiss and altered paragneiss). A part of the area, illustrating these features, is shown in Figure 1. Structural trends change from northwest (130° to 110° azimuth) in the eastern portion to westerly (080° to 110° azimuth) in the western portion of the area; both foliation trends are superposed on shear-folded rocks in the central portion of the area extending along an axis striking 040 degrees.

Volcanic rocks of Horseshoe Lake (52°51'N, 95°45'W) comprise various textural varieties of 'hornfelsed' dacite and small, irregular pockets of rhyodacite. A sequence of layered gneiss (8 miles long, 2,300 feet thick) at the same locality consists, in decreasing order of abundance of black, biotite-spotted greywacke, spotted traps, diopside-feldspar-quartz banded gneiss, garnetiferous mica gneiss, and thin laminae of quartzite. Retrograde

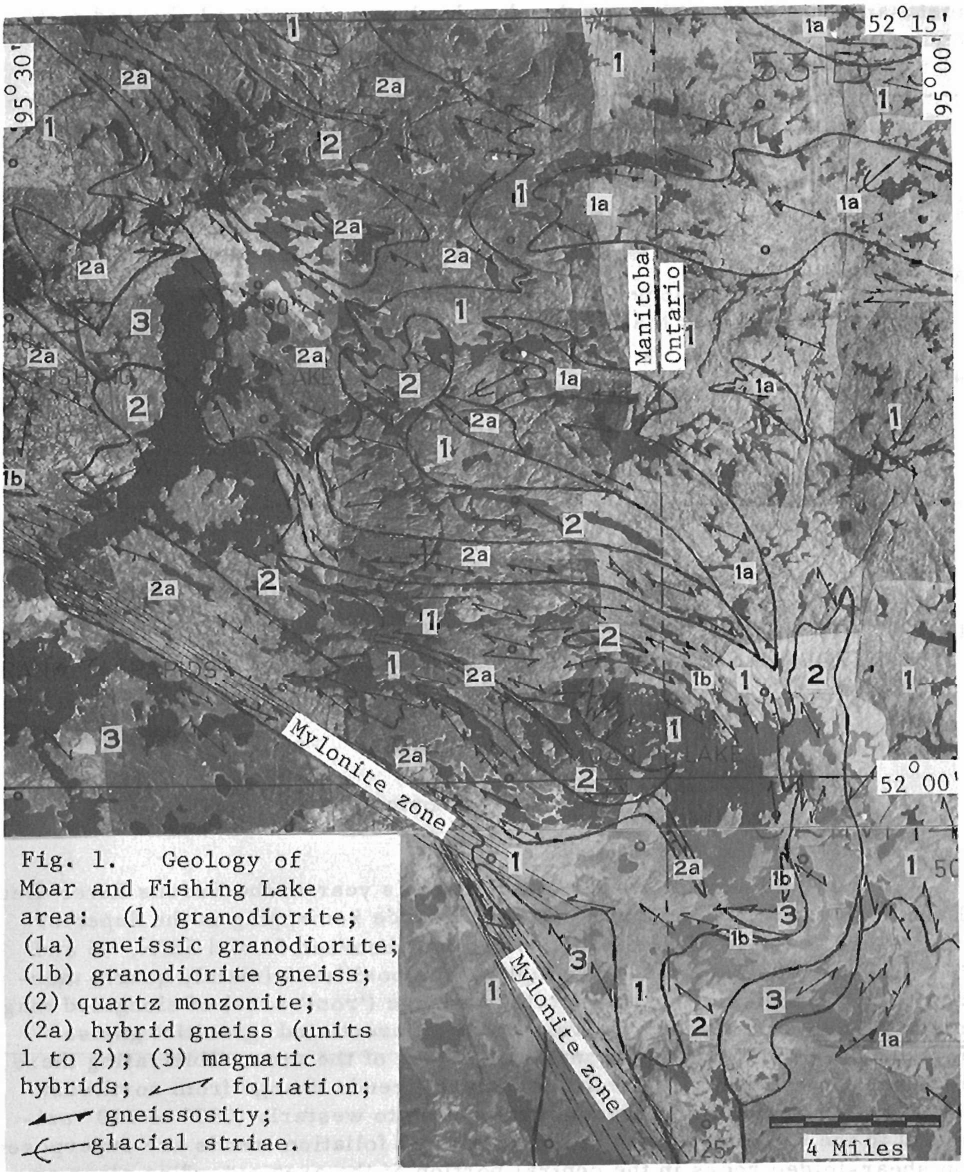


Fig. 1. Geology of Moar and Fishing Lake area: (1) granodiorite; (1a) gneissic granodiorite; (1b) granodiorite gneiss; (2) quartz monzonite; (2a) hybrid gneiss (units 1 to 2); (3) magmatic hybrids; ⟋ foliation; ⟶ gneissosity; ⟵ glacial striae.

alteration from amphibolite to greenschist facies of metamorphism, typical of volcanic and metasedimentary rocks of the Rice Lake Group and other greenstone belts is absent.

Continuing work on rocks of this region will comprise (a) an areal modal mineral analyses of plutonic rocks to provide quantitative information for provenance studies of sedimentary rocks of greenstone belts elsewhere, (b) Rb/Sr isochron studies to separate times of major chemical diversification from times of recrystallization of gneisses (Dr. A. Turek, Manitoba Mines Branch, collaborator), (c) a multistage hierarchal analysis of variance design to test various hypothesis of variance in rock-types over an area of 5,000 square miles using major oxides, 'metals' and trace elements (Dr. E.M. Cameron, Geochemistry Section, Geological Survey of Canada, collaborator) and (d) a pilot study for the feasibility of developing 'chemical modes' for broad regions of the Canadian Shield from hand specimens collected during the course of geological mapping.

---

[1] Ermanovics, I.F.: Geology of Hecla-Carroll Lake map-area, Ontario and Manitoba; Geol. Surv. Can., Paper 69-42 (in press).

---

87. BASIN ANALYSIS OF THE ATHABASCA SEDIMENTARY BASIN, SASKATCHEWAN (74)

Project 680135

W.F. Fahrig

Three weeks were spent logging diamond-drill cores from the Athabasca Basin. Several of these holes penetrate the entire preserved thickness of this formation.

Material suitable for determining a minimum age for the Athabasca was obtained from a dyke that cuts the formation on the south shore of Lake Athabasca and material that may be useful for directly determining the age of sedimentation by the Rb/Sr method was obtained from several of the drill-cores.

88. DIABASE DYKES OF THE CANADIAN SHIELD, LABRADOR (13)

Project 610044

W.F. Fahrig

Six weeks were spent sampling diabase and related rocks at 60 sites in the area between Seal Lake and the Labrador Coast. It is expected that the measurement of various parameters of these samples along with field relationships will yield data useful in solving local geological problems as well as contributing data relating to the correlation of rocks between the coasts of Labrador and Greenland.

89. ARTILLERY LAKE MAP-AREA, DISTRICT OF MACKENZIE (75 O, EAST HALF)

Project 670005

J.A. Fraser

Mapping of the area for publication on a scale of 1 inch to 4 miles was begun and completed in 1969. The project was undertaken because of the current interest of the mining industry in mineral occurrences along the Thelon Front[1] (boundary between the Slave and Churchill (structural) Provinces) and is part of a continuing study of the geology along the Front. Coverage of the area was accomplished by helicopter traverses run east and west at intervals of 2 1/2 miles supplemented by ground traverses from Smart and Sifton lakes and from the north shores of Campbell Lake and Mary Frances Lake. Bedrock is moderately well exposed in the northern two thirds of the map-area and poorly exposed in the remainder.

The northwest corner of the map-area lies within the Slave Province[2] and is underlain by massive muscovite granite. The rest of the map-area lies within the Churchill Province[2] and is underlain principally by a heterogeneous assemblage of composite and cataclastic gneisses, by schist, and by granite, granodiorite, diorite, and gabbro.

Hornblende schist and amphibolite are the most common mafic components of the gneisses but mafic minerals in gneiss may include biotite, garnet, clinopyroxene and orthopyroxene. The felsic layers show considerable variation in thickness and abundance from place to place so that gradation of gneiss across or along strike into schlieren migmatite and granite is not uncommon. Micaceous schists, some of which contain sillimanite, are associated locally with the gneisses and constitute a minor component of the migmatites. Biotite-quartz schist with interlayered garnet-hornblende schist and gneiss forms a well-defined belt, approximately 4 miles wide, that runs from Smart Lake through the western part of Sifton Lake to the north boundary of the map-area. On the regional aeromagnetic map[3] this belt appears as a pronounced low. Calc-silicate lenses and layers, consisting chiefly of pale green diopside, occur in mafic gneisses along the southeastern arm of Smart Lake.

Massive to foliated granite and granodiorite are found throughout the map-area. Granitic rocks are particularly characteristic of the area south and west of Smart Lake. In the southern third of the map-area they constitute the bulk of the rocks exposed.

Medium- to coarse-grained massive to foliated diorite and gabbro occur in a northerly-trending belt that crosses the southeastern arm of Smart Lake. These rocks are locally granitized.

Three sets of diabase dykes, oriented northerly, easterly, and northeasterly, intrude the granitic rocks and gneisses. The northeasterly dykes are most altered but in all sets the chief mafic mineral is hornblende.

The schists and gneisses are strongly foliated in a north-northeasterly direction and are steeply inclined. Small, tight folds in schist exhibit shallow plunges north and south. All major rock units in the area have been displaced to the right along northeasterly trending faults. The faults are marked by strong topographic lineaments and are bordered by zones of breccia and mylonite. The McDonald Fault, the most prominent of these structures, runs through Campbell and Mary Frances lakes and is known to extend in both directions many miles beyond the borders of the map-area. Zones of mylonite that trend north, parallel with the foliation in the adjacent gneisses, probably predate the northeasterly faults.

Numerous claims have been staked since the beginning of 1968 in an area that extends from Campbell Lake northwards to Moraine Lake. In general the distribution of claims follows the trend of magnetic anomalies[3] which, in turn, are roughly parallel with the Thelon Front. Hornblende-garnet schist and gneiss and associated mafic rocks of this belt contain several rusty-weathered zones characterized by disseminated pyrite and graphite. Selected specimens from these gossans are to be analyzed.

---

[1] Wright, G.M.: Geology of the southeastern barren grounds, parts of the Districts of Mackenzie and Keewatin (Operations Keewatin, Baker, Thelon); Geol. Surv. Can., Mem. 350 (1967).

[2] Stockwell, C.H.: Structural provinces, orogenies, and time classification of rocks of the Canadian Precambrian Shield; Age determinations by the Geological Survey of Canada, Report 2, Isotopic Ages; Geol. Surv. Can., Paper 61-17 (1961).

[3] Stockwell, C.H.: Artillery Lake; Geol. Surv. Can., Aeromagnetic Series Map 7192G (1968).

90. GEOLOGICAL RECONNAISSANCE OF SOUTHAMPTON ISLAND, DISTRICT OF KEEWATIN (45 M, N, O, P, 46 A, B, C, F; PARTS OF 46 D, E, G)

Project 680092

W.W. Heywood

The reconnaissance geological mapping of Southampton Island was completed in the 1969 field season using one Bell 47 B-2 helicopter from the base camp at Coral Harbour. W.L. Davison assisted with the Precambrian mapping, and B.V. Sanford was responsible for the areas underlain by Paleozoic rocks. A summary of his field work will be found elsewhere in this publication.

The Paleozoic and Precambrian areas have produced contrasting landscapes resulting from their widely dissimilar rock types. The Paleozoic rocks for the most part form flat to gently undulating plains. The Precambrian, on the other hand, rises gently from sea level in the south to form a high plateau bounded by fault scarps that extend from Cape Welsford southeasterly to Seahorse Point, and southerly from Duke of York Bay to South Bay.

Most of the area is underlain by massive to foliated granitoid rocks, migmatite, gneiss and paragneiss. Amphibolite, quartzite and lime silicate gneiss are present and a few small gabbroic bodies occur. These rocks are probably of Aphebian age and represent continuations of the types present on the mainland. Pegmatite dykes are common on Bell Peninsula and Cape Welsford. Diabase dykes are small and widely spaced. Variations in metamorphic grade are apparent and granulite facies rocks in the central highlands are probably prograded equivalents of the adjacent rocks.

The general structural trends are northeasterly to east. The northeast coast is in part both a fault scarp and a fault line scarp.

Graphite-rich schist and gneiss in zones as much as 400 feet wide occur on Bell Peninsula between Gore Point and Mount Minto. These contain traces of molybdenite. Molybdenite also occurs in pegmatite dykes in the Terror Point and Cape Welsford areas. Rusty zones occur in the gneissic rocks, however no minerals of economic interest were noted.

91. STUDY OF THE EPWORTH GROUP, COPPERMINE RIVER AREA, DISTRICT OF MACKENZIE (86 G, H, I, J, O, P)

Project. 690024

P. Hoffman

The stratigraphy, paleocurrents, sedimentology, stromatolites and structure of the Epworth Group (Aphebian) in the Coppermine River area were studied in an extension of a similar project on Aphebian rocks of the Great Slave Lake area[1, 2]. The purpose of the project is to:

1. Assess the probability of stratiform copper or Mississippi Valley type lead-zinc mineralization.
2. Establish lithostratigraphic correlations between the Epworth and Great Slave areas.
3. Confirm or reject, by paleocurrent analysis, the hypothesis of a north-northwest - trending geosyncline as advanced on the basis of data from the Great Slave area[2].
4. Determine whether the main structural features of the Epworth belt are consistent with the hypothesis.
5. Continue detailed studies of selected formations to elucidate the paleo-environments of Precambrian carbonate sediments.
6. Evaluate the usefulness of Aphebian stromatolites for long-range bio-stratigraphic correlation by contrasting them with established Riphean (Helikian-Hadrynian) stromatolite zonation in the U.S.S.R.

Economic Potential

Favourable horizons for stratiform copper mineralization are the dark coloured argillaceous sediments of the lower Odjick Formation and the basal Recluse Formation[3]. Minor nonstratiform copper mineralization is associated with northwest-trending structural breaks containing diabase dykes.

Lead-zinc mineralization is more probable in the Rocknest Formation[3] than in other stratigraphic units, but favourable depositional settings (e.g. porous carbonate banks adjacent to saline basinal sediments) have not as yet been located.

Stratigraphic Correlation

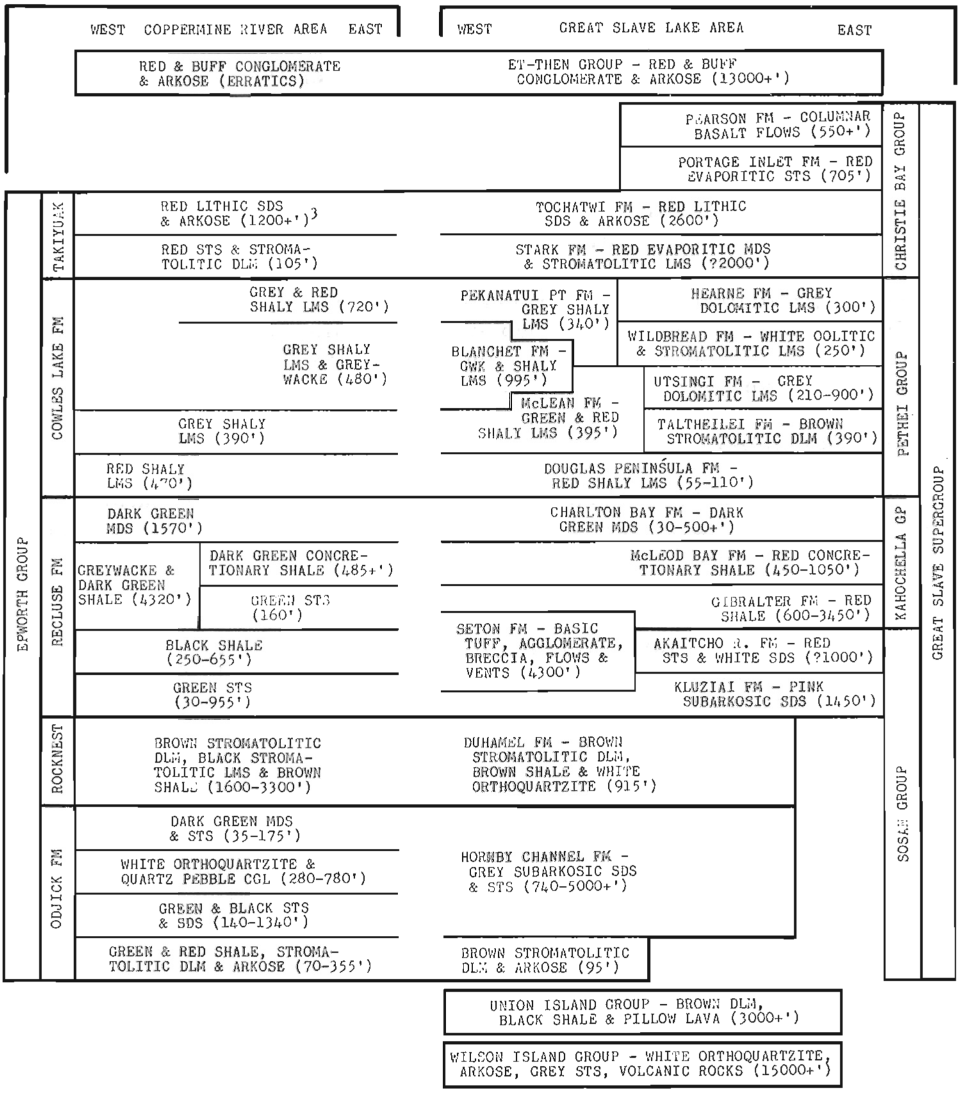
Correlation of many formations, and even members, in the Epworth and Great Slave sequences was established by identity of lithology, stratigraphic sequence, depositional environment and paleocurrent trend. A tentative correlation chart is shown in Figure 1.

Paleocurrent Analysis

Paleocurrent data, summarized in Figure 2, confirms the geo-syncline hypothesis[2] with the following modifications. The trend of the geo-syncline (i.e. depositional strike) is arcuate rather than straight. It trends north-northwest through the Great Slave Lake area, northerly at the south end of the Epworth belt, and north-northeast at the north end of the belt. The first appearance of exogeosynclinal greywacke turbidites (flysch) occurs lower in the Epworth succession (in the Recluse Formation) than in the Great Slave (Blanchet Formation).

Thrust Faulting

Regional west-dipping, north-trending thrust faults occur in a belt at least 30 miles wide in the central and western parts of the Epworth Basin. The thrust planes parallel bedding, have little or no topographic expression,



Lithologic Designations

SDS - sandstone
MDS - mudstone
DLM - dolomite
STS - siltstone
LMS - limestone
CGL - conglomerate

Figure 1. Correlation chart of Aphebian strata in the Epworth and Great Slave basins.

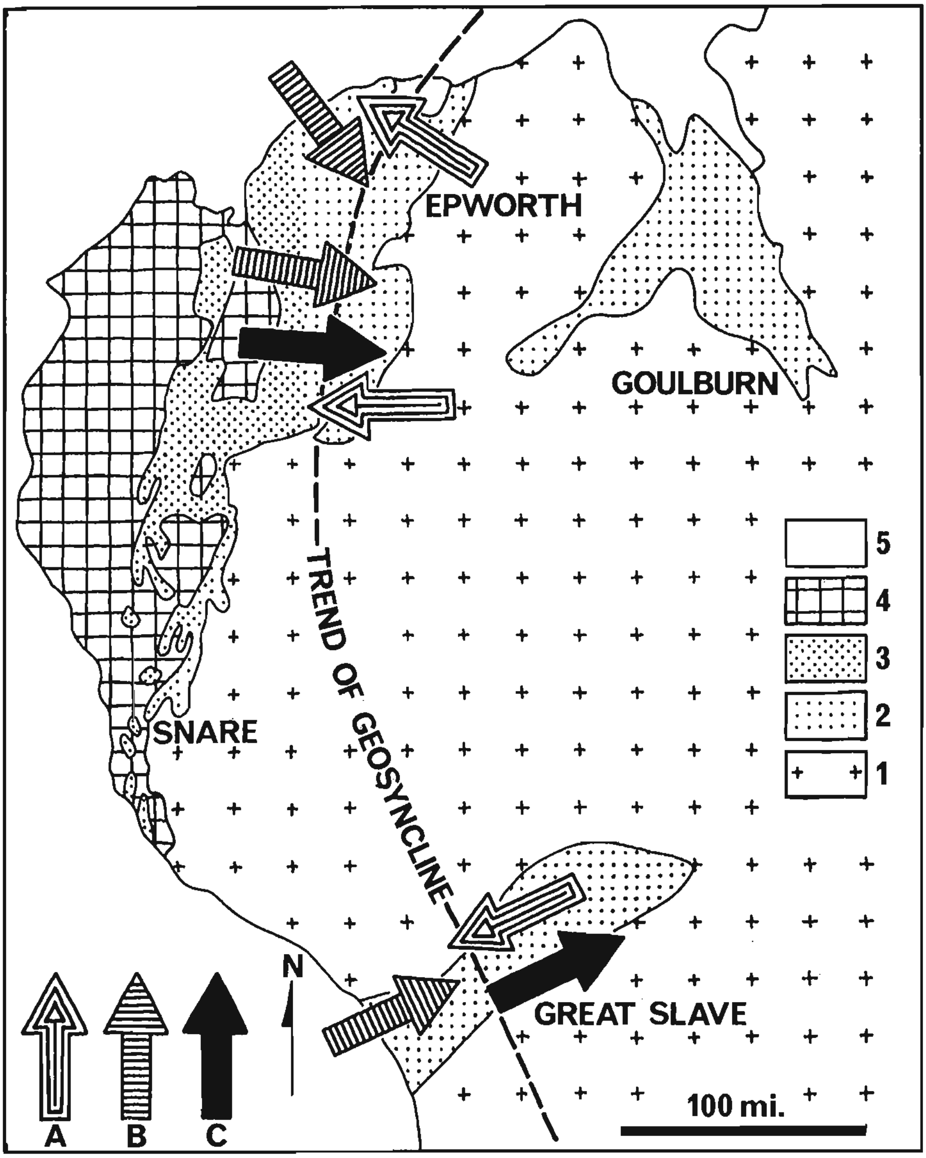


Figure 2. Geological sketch map of the northwesternmost Canadian Shield showing paleocurrents in the Epworth and Great Slave basins. Paleocurrent arrows: A. Miogeosynclinal nonmarine sandstone (Odjick Formation and Sosan Group); B. Exogeosynclinal marine turbidites (Recluse and Blanchet formations); C. Exogeosynclinal nonmarine sandstone (Takiyuak and Tochatwi formations). Map units: 1. Archean granitic and metamorphic rocks (Slave and Churchill provinces); 2. Unmetamorphosed Aphebian sedimentary and volcanic rocks; 3. Metamorphosed Aphebian and Archean(?) strata; 4. Late Aphebian (Hudsonian) granitic rocks (Bear Province); 5. Helikian and younger cover strata. Note the arcuate trend of the geosyncline. In Aphebian times, the craton was to the east and the orogenic belt to the west.

and are accompanied by breccia and contorted zones that in many cases are less than 20 feet thick. Nevertheless, displacement is such that entire formations are repeated several times in what otherwise appear to be simple homoclines. Recognition of the thrust faults is essential for correct interpretation of maps and stratigraphic sections. The thrust belt is structurally analogous to the Alberta Foothills and Front Ranges of the Cordilleran geosyncline.

The thrust planes are themselves folded about northeast-trending axes which persist eastward of the thrust belt. The northeast folds parallel those in the Goulburn and Great Slave sequences.

Shallow Water Shale-Carbonate Cycles

The Rocknest Formation consists of 1, 600-3, 300 feet of repeated shale-dolomite-limestone cycles, each 10-50 feet thick. Superimposed on the small cycles are grand cycles, 100-500 feet thick, defined by variation in the proportions of shale and carbonate. The carbonate contains stromatolites and the shale mudcracks, indicating that both are of shallow water origin. The cycles closely resemble those in the lower Paleozoic rocks of Alberta[4] and the Mackenzie Valley[5]. Stratigraphic sections (100 per cent exposed) were measured bed-by-bed and will be analyzed paleo-environmentally to determine the causal mechanism of the cyclicity.

Stromatolites and Algal Microflora

Columnar stromatolites in some beds near the top of the Rocknest Formation belong to the form supergroup 'Gymnosolenida'[6] and have well developed 'wall structure'. Such stromatolites are diagnostic of the Upper Riphean (about 950-675 m. y. B. P.) in the U. S. S. R. Their appearance in Epworth rocks (about 2, 500-1, 700 m. y.) indicates that the Soviet stromatolite zonation may not be applicable to the Canadian Precambrian.

Dark grey stromatolitic limestone with black chert of early replacement origin is common in the Rocknest Formation. The chert is a likely host for preserved cellular microflora. Such microfossils are of critical importance to the study of the evolution and ecology of Precambrian life.

---

1 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).

2 Hoffman, Paul: Proterozoic paleocurrents and depositional history of the East Arm fold belt, Great Slave Lake, District of Mackenzie; Can. J. Earth Sci., vol. 6, pp. 441-462 (1969).

3 Fraser, J.A. and Tremblay, L.-P.: Correlation of Proterozoic strata in the northwestern Canadian Shield; Can. J. Earth Sci., vol. 6, pp. 1-9 (1969).

4 Aitken, J.D.: Middle Cambrian to Middle Ordovician cyclic sedimentation, Southern Rocky Mountains of Alberta; Bull. Can. Petrol. Geol., vol. 14, pp. 405-441 (1966).

5 Macqueen, R.W.: Lower Paleozoic stratigraphy, Operation Norman, 1968; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 238-241 (1969).

6 Raaben, M.E.: Columnar stromatolites and Late Precambrian stratigraphy; Am. J. Sci., vol. 267, pp. 1-18 (1969).

---

92. GEOLOGIC AGE AND STRUCTURAL RELATIONS OF THE MUSKOX INTRUSION

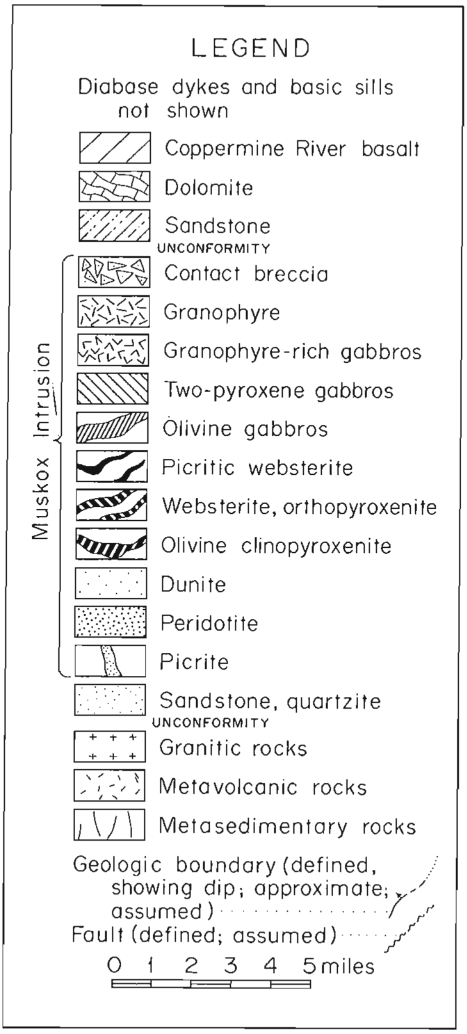
Project 590283

T.N. Irvine

The original mapping of the Muskox Intrusion[1,2] showed that is emplaced close to and, in part, along a major unconformity between a basement complex of predominantly metasedimentary and granitic rocks and a relatively undeformed succession of sandstone, dolomite and plateau basalt (Fig. 1). Of the latter rocks, the sandstone and dolomite are presently assigned to the Hornby Bay Group, and the basalt to the Coppermine River Group[3]. The Muskox Intrusion is clearly transgressive to some of the sandstone which it locally has metamorphosed to quartzite. However, it is not in exposed contact with the dolomite and basalt, and although it was tentatively assumed to be younger than these rocks (or, perhaps, coeval with the basalt), this relation was not established. A further field examination of the problem was prompted when a petrographic study of the available samples of the dolomite failed to reveal any metamorphism attributable to the intrusion. The findings indicate that the dolomite and basalt are younger than the intrusion, the essential reasons being as follows:

(1) The dolomite, which is generally siliceous and therefore especially susceptible to metamorphism, shows no contact metamorphism due to the intrusion. This is particularly critical in the area immediately west of the Muskox north drillhole (Fig. 1) where the dolomite overlies the intrusion, apparently within only a few hundred feet of its roof contact. From heat conduction theory and phase equilibria data it would be expected that if the dolomite was older than the intrusion, this part (even if 1,000 feet above the roof contact) would be heated to temperatures at which it should be considerably metamorphosed. The theoretical aspects of this criterion have some support in the present situation in that the diabase dykes that cut the dolomite have contact metamorphosed it (to calcite-serpentine rock) through widths consistent with the heat flow theory.

(2) The dolomite and basalt show very little displacement due to the Canoe Lake fault even though the fault, which trends directly towards them, is a major structure where it cuts the intrusion only a short distance to the south (Fig. 1). In the intrusion, the fault causes a strike separation of 4-5 miles and a fairly constant stratigraphic separation of about 1,700 feet. However, as shown in Figures 1 and 2, it has no northward extension



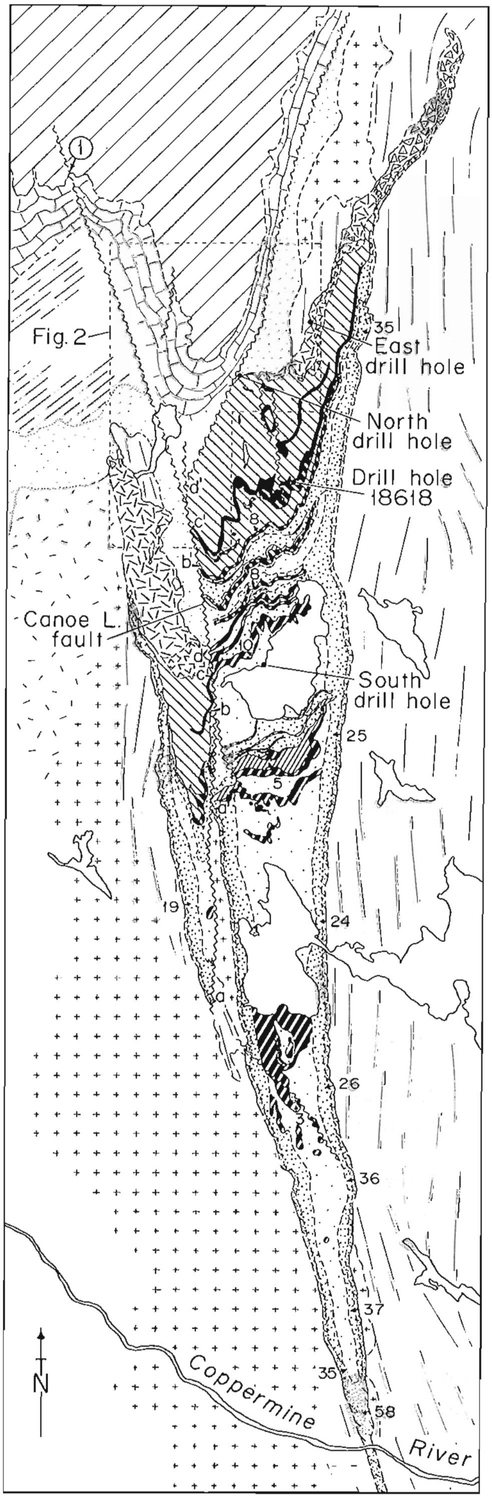


Figure 1.
Geology of the Muskox Intrusion, modified from Smith, Irvine and Findlay[2]. The strike separation along the Canoe Lake fault is indicated by the correlations a-a', b-b', c-c' and d-d'. Note that the assumed northward extension of the fault to Locality 1 shows almost no separation where it crosses the basalt-dolomite contact (the contact dips 5-10°N at this locality). The upper sandstone unit is distinguished on the basis of work by Baragar and Donaldson (this publication); it appears conformable with the dolomite and therefore is shown to be younger than the Muskox Intrusion.

that causes a strike separation of more than a few hundred feet at mappable horizons within the dolomite-basalt succession. Moreover, the map relations suggest that the extension labelled A in Figure 2 may have opposite displacement to that evident in the intrusion: in the intrusion the east block of the fault appears to be raised relative to the west, whereas the dolomite along the east side of the extension A looks to be depressed. The above relations might be due to rotational (hinge) movements on the fault, but these would have to be largely confined to a short segment in the vicinity of All Night Lake. The relations are more readily explained if most of the displacement evident in the intrusion occurred before the dolomite was deposited. In this case, the fault might also have been a controlling structure for the formation of the syncline in the dolomite and basalt directly north of the Muskox Intrusion (Fig. 2).

Accepting the above, the general history of the area subsequent to deposition of the sandstone unit invaded by the Muskox Intrusion was probably as follows:

(a) Emplacement and solidification of the Muskox Intrusion.

(b) Tectonic deformation, marked in particular by the main displacement on the Canoe Lake fault.

(c) Erosion, probably to the extent that the Muskox Intrusion was exposed at the surface.

(d) Deposition of the dolomite and of the quartzose sediments that underlie it (see Fig. 1). This early part of this stage could be concurrent with (c).

(e) Eruption of the Coppermine River basalt, accompanied and followed by emplacement of numerous diabase dykes and sills.

(f) Mild folding of the dolomite and basalt and further faulting, including minor adjustments on the Canoe Lake fault and its branches.

This sequence has three important implications:

(i) There is a major unconformity within the Hornby Bay sandstone-dolomite succession marking a significant period of igneous and tectonic activity. The unconformity is probably the same one mapped by Baragar and Donaldson (see this publication).

(ii) The Muskox Intrusion is sufficiently older than the Coppermine River basalt that they can have no immediate genetic relation. The amount of the age difference is not known quantitatively, but the time required for deposition of the dolomite alone was undoubtedly long enough to preclude a direct plutonic-volcanic connection. The dolomite is about 500 feet thick near the Muskox Intrusion and thickens westward to about 4,000 feet[3].

Figure 2. (opposite)
Detailed geology along the roof contact of the Muskox Intrusion (cf. Fig. 1). Faults A and B denote the most likely directions in which the Canoe Lake fault might extend. Note there is no appreciable separation of the dolomite and basalt due to B.
Faults C, D and E follow topographic lineaments. D and E are suggested in that the lower part of the dolomite appears to be missing along their northwest sides. The unusual strike of the dolomite at Locality 2 probably represents deformation due to D. Locality 3 is an outcrop of breccia composed of quartzite fragments in an igneous matrix, similar to breccia at the top of the Muskox Intrusion. The dotted contact at Locality 1 is the approximate position of the unconformity found in the Hornby Bay Group by Baragar and Donaldson (this publication).

(iii) There is a possibility that the only cover over the axial part of the Muskox Intrusion when the intrusion solidified was the sandstone it intrudes. The thickness of the sandstone is variable, but its maximum value is of the order of 4,000 feet[3]. Such a relatively thin cover is consistent with the presence of tridymite pseudomorphs in the quartzite and granophyre along the roof contact of the intrusion[4], and with the crystallization characteristics of the Muskox magma[5].

---

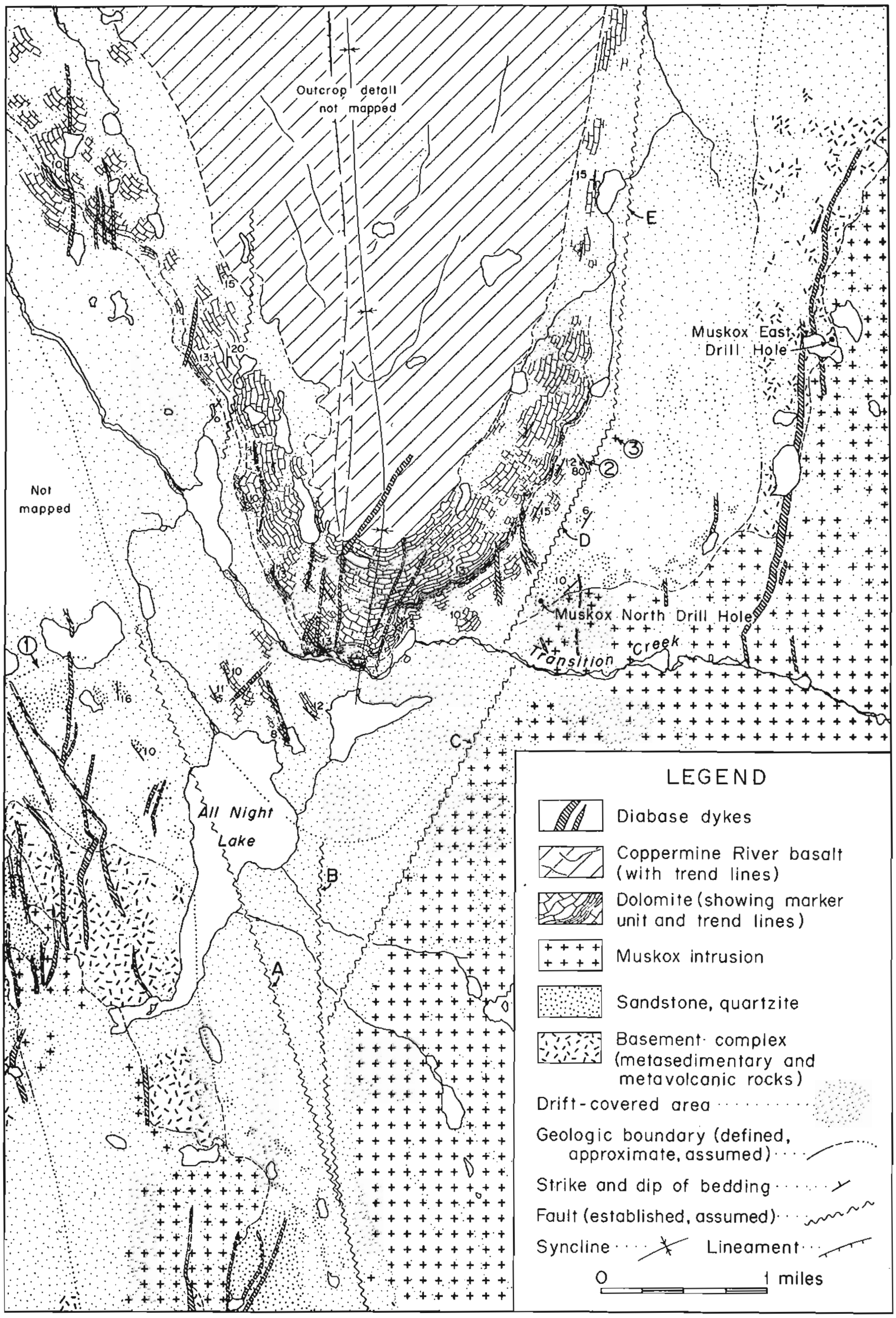
[1] Smith, C.H.: Notes on the Muskox Intrusion, Coppermine River area, District of Mackenzie; Geol. Surv. Can., Paper 61-25 (1962).

[2] Smith, C.H., Irvine, T.N. and Findlay, D.C.: Geology, Muskox Intrusion; Geol. Surv. Can., Map 1231A (1967).

[3] Fraser, J.A.: North-central District of Mackenzie, Northwest Territories; Geol. Surv. Can., Map 18-1960.

[4] Pouliot, G.: Paramorphisme du quartz dans le granophyre de l'intrusion de Muskox, T.N.O.; Naturaliste can., vol. 95, 1277-1292 (1968).

[5] Irvine, T.N.: Crystallization sequences in the Muskox Intrusion and some other layered intrusion. Olivine-pyroxene-plagioclase relations; Geol. Soc. S. Africa, Symposium volume on layered intrusions (in press).


Outcrop detail not mapped
Not mapped
Muskox East Drill Hole
Muskox North Drill Hole
Transition Creek
All Night Lake
A
B
C
D
E
LEGEND
Diabase dykes
Coppermine River basalt (with trend lines)
Dolomite (showing marker unit and trend lines)
Muskox intrusion
Sandstone, quartzite
Basement complex (metasedimentary and metavolcanic rocks)
Drift-covered area
Geologic boundary (defined, approximate, assumed)
Strike and dip of bedding
Fault (established, assumed)
Syncline
Lineament
0
1 miles

93. STUDY OF THE NONACHO GROUP OF SEDIMENTARY ROCKS, NONACHO LAKE, TALSTON AND RELIANCE AREAS, DISTRICT OF MACKENZIE (PARTS OF 75 E, F, K)

Project 650008

J. C. McGlynn

The study of the Nonacho Group of sediments and its regional setting was continued and this year work was concentrated in parts of 75 F, 11, 12, and 13 in the Nonacho and Hjalmar Lakes area. The objectives of the work are: to study the stratigraphy, structure and sedimentary petrology of the Nonacho strata; to correlate these rocks with groups of Aphebian or younger rocks in the region; and to establish their age relationships to the metamorphic and igneous rocks with which they are in contact.

The Nonacho Group comprises a conformable sequence of arkoses and lithic sandstones, polymictic conglomerates and conglomeratic arkoses and shales. In the Hjalmar Lake area the basal units are maroon-grey arkoses and chocolate brown shales. Shales with thin interbeds of arkose constitute up to half of the lower part of the succession. These rocks grade upwards and possibly laterally into thick-bedded arkoses or lithic sandstones with thin interbeds of shale. In the western part of Nonacho Lake area the lower part of the sequence comprises thinly bedded grey shales and light grey arkoses that again grade upwards and possibly laterally to thickly bedded light grey arkoses with thin grey shale interbeds. These rocks are overlain by thickly bedded light grey arkoses with very thin shale interbeds or intervening shale chip conglomerates. Conglomerate bands and conglomeratic arkoses occur in the lower part of the sequence in the western part of Nonacho Lake. Clasts that occur in such conglomerates near the base of the sequence are dominantly granitic lithologies similar to granitoid rocks that form the margin of the basin. Conglomerate bands higher in the sequence are polymictic with clasts of white quartzite, basic to intermediate volcanic rocks, maroon and grey sandstones, and vein quartz in addition to a variety of granitic rocks. Single pebble bands, pebble clusters, and isolated pebbles occur within the arkoses or lithic sandstones higher in the sequence. Cross-bedding, parallel laminations, cross-laminations and ripple-marks occur in the same horizons of arkose and convoluted laminations, slump structures and sandstone dykes are common in the interbeds of shale. Along the south shore of the central part of Nonacho Lake is exposed a sequence of very thickly bedded arkose (up to 6 feet) in which each bed has a thin (3-6 inches) silty shale top. The arkose grades into the silt over a narrow zone so that each unit is a graded bed. Both arkose and silty shale are massive and structureless with no crossbedding or pebbles and only rare parallel laminations. Contacts between strata are sharp and smooth. These rocks appear to be lateral equivalents of the normal sandstones. All Nonacho strata are essentially unmetamorphosed.

Evidence from contact areas on both sides of the basin indicate that all granitic rocks observed in the study area are older than the Nonacho sediments and are therefore part of the basement of the basin in which the sediments were deposited. Basal units of the sediments are commonly a sedimentary breccia of variable thickness comprising unsorted angular boulders of underlying granitoid rock in an arkosic matrix. This rock grades upward and possibly outward from the basin margin to arkoses containing the odd angular granitoid clast and beds or lenses of coarse grit composed of fragments of granite. Between the breccia and basement there may be a zone composed of granitoid rock broken into large blocks that have been only slightly moved from their original position and which are separated by seams of arkosic sand or mud. In one exposure, arkose was in sharp contact with what appears to be a 'rotten' granite in which all mafic minerals have been altered to chlorite and feldspar to clay. In many parts of the contacts, particularly along the western margin, the evidence of unconformity has been destroyed or obscured by faulting.

Preliminary analyses of over 600 crossbed orientations collected from 27 sites indicate a complex pattern. Taken together they display no dominant trend of current direction. Those in the west half of the basin indicate a variety of paleocurrent trends also, but are dominantly from northeast to southwest whereas those from the east half of the basin in the study area yield a mean direction from southwest to northeast. Preliminary work suggests that in part this scatter of paleocurrent orientation relates to a stratigraphic and facies variation. The lower shaly part of the sequence has, on both sides of the basin, different paleocurrent directions than the upper clastic units.

The oldest rocks in the area in the basement of the Nonacho strata consist of mafic-rich, mixed gneisses, granitic gneiss or porphyroblastic gneiss with bands, lenses and irregularly shaped masses of very acidic, massive and locally pegmatitic granodiorite or granite. Bands of amphibole gneiss and meta-gabbro occur within the granitoid rocks. The mafic minerals are commonly altered to chlorite.

The Nonacho strata are thrown into broad folds about axes that in the western part of the area trend northeast but in the eastern part of the area strike east-northeast. Fold axes dip steeply and folds plunge gently, usually to the northeast. Cleavage is intensely developed along axial zones, and in sequences of massive arkose movement occurs along faults that occur in the axial zones parallel to the fold axes. Faulting is concentrated along the margin of the basin and is particularly intense along the western margin. In the basement, broad northeast-trending mylonite zones are common as are zones of intense brecciation and shearing. Sediments are also sheared in the contact zone along the western margin. A major fault underlies the northwest arm of Nonacho Lake and extends into both basement rocks and Nonacho strata. Boulders of mylonite in Nonacho conglomerates indicate that some of this faulting was pre-sedimentation. These faults probably are boundary faults that formed the original basin and movement on these continued during sedimentation and, at a higher level, after sedimentation both during and after the folding of the Nonacho strata.

A number of uranium showings and copper prospects have been discovered in the region. Most of them occur in the basement near contacts with Nonacho rocks in shear or breccia zones. Attention of prospectors is therefore directed to the contact zones of Nonacho sediments and basement particularly where faulting has been intense. Consideration should also be given to searching for sedimentary or fossil placer deposits within the Nonacho sediments.

94. OPERATION TORNGAT, NORTHEASTERN QUEBEC, NORTHERN LABRADOR (24 A, H, 14 C, D, E, F, L)

Project 660013

F. C. Taylor

Helicopter reconnaissance in northeastern Quebec and northern Labrador, started in 1967, was continued. Although inclement weather prevented completion of the project, the following map-areas were covered: 24 A, H; 14 C, D, E, F and L. Drs. E. W. Reinhardt, E. Froese and W. C. Morgan of the Geological Survey staff formed a most capable geological team.

The bedrock is entirely Precambrian with the possible exception of two outcrops of sandstone, arkose and pebble-conglomerate reported by Wheeler[1]. The oldest rocks are Archean and these form a coastal strip, ranging from 10 to 30 miles wide, extending southward from Saglek Fiord to south of Nain. These are an extension of Archean rocks mapped in 1967[2]. Migmatite is the commonest rock type but gneissic granite and granodiorite, amphibolite, granulite, pegmatite, metasedimentary rocks and ultrabasic inclusions are also present. Diabase dykes are abundant, but lack characteristic trends.

Metamorphic rocks of Proterozoic age form the largest part of the area. Migmatite and granitic or granodioritic gneiss underlie large areas in 24 A and 24 H and most of the southwest quarter of 14 D. Scattered throughout these rocks are small areas of metasedimentary rocks consisting chiefly of biotite-rich paragneisses with lesser amounts of amphibolite. Small ultrabasic bodies occur locally. A large area of quartzite, up to 4 miles wide, lies 1 to 2 miles east of Indian House Lake. Porphyritic granodiorite underlies a large part of the northwestern two-thirds of 24 A. Garnet-quartz-feldspar gneiss and granulite, shown on Map 13-1968[2] in the east half of 24 I and the west half of 14 L, extends south to approximately the Fraser River in 14 D where they in part pass into migmatite through a broad transitional zone and in part are intruded by quartz monzonite, granodiorite and anorthosite.

Major intrusions of anorthosite, with lesser amounts of gabbroic anorthosite and gabbro intrude both the Archean and Proterozoic rocks in 14 C, D, E and F. These rocks are in turn intruded by larger plutons of quartz monzonite and granodiorite.

Unmetamorphosed rocks of the Ramah and Mugford groups lie unconformably on the Archean rocks in separate localities. Sedimentary rocks of the Ramah Group, occupying a small area south of Saglek Fiord form an extension of those shown on Map 13-1968. The Mugford Group, consisting chiefly of volcanic rocks but with appreciable quantities of sedimentary strata, forms the Kaumajet Mountains along the coast between Hebron Fiord and Okak Bay.

No major economic mineral occurrences are known in the area.

[1] Wheeler, E.P. II: Unmetamorphosed sandstone in northern Labrador; Bull. Geol. Soc. Am., vol. 75, pp. 569-570 (1964).

[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).

95. QUATERNARY GEOCHRONOLOGY AND PALEONTOLOGY

THE VERTEBRATE FAUNAS OF SURPRISE, MITCHELL, AND ISLAND BLUFFS, NEAR MEDICINE HAT, ALBERTA (72L)

Project 650027

C.S. Churcher

Elsewhere in this publication Stalker describes field work conducted by himself and the writer during 1969. The present paper lists vertebrate fauna found and identified to the end of 1968, mainly at Surprise Bluff (S 1/2 sec. 34, tp. 12, rge. 6, W 4th mer.), Mitchell Bluff (NE 1/4 sec. 32, tp. 13, rge. 5, W 4th mer.), and Island Bluff (SW 1/4 sec. 4, tp. 14, rge. 5, W 4th mer.). The animals recorded below are listed according to the units in which they were found. The unit names are used as given by Stalker[1], who also describes the stratigraphy of the three bluffs. To date more than 45 species of vertebrate animals belonging to 9 orders have been recognized, of which more than 25 species have been found in the Upper Sands at Mitchell Bluff alone.

	Surprise Bluff	Mitchell Bluff	Island Bluff	Other Bluffs
Postglacial Deposits				
Canis lupus (wolf)				x
Mammuthus primigenius (Siberian mammoth)				x
Mammuthus imperator (imperial mammoth)				x
Equus conversidens (Mexican ass)				x
Camelops hesternus (western camel)				x
Highest Intertill Deposits				
Smilodon californicus (sabre-toothed cat)				x
Lepus cf. *townsendii* (hare)				x
Equus conversidens (Mexican ass)	x			x
Equus cf. *giganteus* (giant horse)				x
Tanupolama stevensi? (? Steven's long-legged llama)				x
Odocoileus sp. (Nearctic deer)				x

	Surprise Bluff	Mitchell Bluff	Island Bluff	Other Bluffs
Lowest Intertill Deposits				
Mammuthus primigenius (Siberian mammoth)			?x	x
Equus conversidens (Mexican ass)				x
Equus cf. *giganteus* (giant horse)			?x	x
Camelops hesternus (western camel)	x			
Upper Sands and Gravels				
Canachites ?canadensis (spruce grouse)		x		
Megalonychidae ?Megalonyx sp. (ground sloth)		x		
Sylvilagus sp. (rabbit)		x		
Lepus cf. *townsendii* (hare)		x		
Thomomys cf. *talpoides* (pocket gopher)		x		
Cynomys cf. *ludovicianus* (prairie dog)		x	x	
Citellus ?richardsoni (ground squirrel)		x	x	
Microtus sp. (vole)		x	x	
Ondatra zibethecus (muskrat)		x		
Erethizon dorsatum (porcupine)		x		
Mustela vison (mink)		x		
Canis lupus (wolf)		x	x	
Vulpes vulpes (red fox)		x	x	
Procyon lotor (racoon)		x	x	
Lynx canadensis (lynx)		x		
Felis ?atrox (giant jaguar)		x		
Mammuthus jeffersoni (Jefferson's mammoth)	x	x	x	
Equus conversidens (Mexican ass)	x	x	x	
Equus niobrarensis (Niobrara horse)		x	x	?x
Amerhippus sp. (southern horse)		x		
Tanupolama sp. (long-legged llama)		x		
Camelops hesternus (western camel)		x	x	
Odocoileus sp. (Nearctic deer)		x		
Cervus canadensis (wapiti)		x	x	
Rangifer tarandus (caribou)		x	x	

	Surprise Bluff	Mitchell Bluff	Island Bluff	Other Bluffs
Antilocapridae cf. *Antilocapra americana* (prongbuck)		x		
Bison cf. *latifrons* (extinct bison)		x		
Lower Sands				
Cynomys cf. *ludovicianus* (prairie dog)				x
Mammuthus columbia (Columbian mammoth)				x
Mammuthus jeffersoni (Jefferson's mammoth)		?x	x	
Mammuthus imperator (imperial mammoth)				x
Mammuthus i. haroldcooki (Cook's mammoth)		x		
Equus conversidens (Mexican ass)		x		
Camelops minidokae (Irvingtonian camel)			?x	x
Ovis cf. *canadensis* (mountain sheep)			x	
Basal Gravel and Sand				
? *Nothrotherium* sp. (ground sloth)				x
Canis sp. *s.l.* (dog)				x
Mammuthus i. haroldcooki (Cook's mammoth)			x	x
Equus conversidens (Mexican ass)		?x		
Equus cf. *calobatus* (stilt-legged ass)		?x		
Equus scotti (Scott's horse)		x	x	x
Camelops minidokae (Irvingtonian camel)		x	x	x

[1] Stalker, A.MacS.: Quaternary stratigraphy in Southern Alberta, Report II: Sections near Medicine Hat; Geol. Surv. Can., Paper 69-26 (1969).

96. PEAT DEPOSITS AND FOSSIL MOSSES IN THE ARCTIC (97G, 97H, 98B, 107B)

Project 690044

Marian Kuc

Interglacial Flora at Worth Point, Banks Island (72°15'N, 125°40'W)

This project is a continuation of work initiated by J.G. Fyles who discovered organic beds in coastal cliffs at Worth Point on the west coast of Banks Island in 1960. At that time willow twigs, dated at more than 49,000 years (GSC-367)[1], were obtained from a 6-foot-thick bed of uncompressed peat at the top of the 30-foot-high, but eroded, coastal cliff. In 1969 another coastal section was investigated near Worth Point. A layer of plant remains occurs about 55 to 60 feet a.s.l., and this layer is believed to correspond to the dated layer sampled by Fyles. The plant layer is overlain by organic deposits containing tree trunks and thick Sphagnum peats, and it lies above a horizon of compressed wood associated with moss peat. The plant layer studied is separated from the organic layers above and below by heavy grey clays.

Complete plant remains have been perfectly preserved in situ in this layer. Material identified to date includes 46 species: (1) vascular plants; Alnus, Betula, Carex, Empetrum, Equisetum, Larix, Ledum, Pyrola, Salix, Vaccinium and many others; (2) mosses such as Aulacomnium, Bryum, Camptothecium, Climatium, Ditrichum, Hylocomium, Mnium, Rhitidium, Thuidium, etc.; (3) numerous liverworts; (4) lichens of the genera Cetraria, Cladonia, Peltigera and some others; and (5) fungi in rotten wood.

In a paleoecological sense this vegetation is that of a parkland. The floristic composition is typical of the colder part of the Boreal Forest Zone.

Postglacial Deposits, Masik River Area, Banks Island (71°34'N, 123°30'W)

Field work was completed in the Masik River area, southwestern Banks Island. Knowledge of the surficial deposits and the history of events here has special significance because during the last glaciation the plateau areas adjacent to the Masik River valley were covered by ice caps, yet the valley itself does not appear to have been filled by ice. The main unglaciated area of Banks Island is farther north. Particular attention is being paid to thick (9- to 18-foot) peat deposits, dominated by willow (with Salix alaxensis as the main species) and mosses, deposited in the valley bottom and to finely-bedded fluvial deposits deposited between ice lobes on the adjacent plateau. Such peat deposits are the product of shrub-tundra, and they are characteristic of the Low Arctic.

In the valley of the Masik River the following zones have been distinguished: deltaic, areas of older peat (at least 10,000 years old; cf. GSC-240, 10,660 ± 170)[2], younger peats (presently developing), and a marginal zone with glacial landforms. In numerous profiles gravel is exposed in the valley bottoms, overlain successively by peats, stratified slope deposits, alluvium, disturbed and drained surface peat deposits, etc.

Tundra-pond Deposits, Thesinger Bay, Banks Island (71°48'N, 124°38'W)

Investigations of peat-forming tundra communities were initiated in 1967 in the Expedition River area, Axel Heiberg Island and continued in 1968 near Mould Bay, Prince Patrick Island. In 1969 work was carried out along the coast of Thesinger Bay, western Banks Island. The profile investigated has 28 layers which can be grouped in 3 distinct sections: (1) aquatic horizons with fossil plankton and allochthonous remains of land plants, often with shells of freshwater molluscs; (2) strata resulting from wet tundra successions around the margins of lakes and by their submerged variants; (3) layers of different inorganic materials (sand, fine gravel, colluvium, etc.) with remains of plants that grew on post-lake substrata. The profile studied shows all stages in the development and filling of a tundra pond.

Peat Deposits, Twin Lakes, Inuvik, N.W.T. (68°21'50"N, 133°44'10"W)

A peat profile at Twin Lake near Inuvik, from which palynological samples had been studied previously by J. Terasmae[3], was revisited. Plant macrofossils were collected to supplement the earlier investigation.

---

[1] Dyck, W., Lowdon, J.A., Fyles, J.G. and Blake, W., Jr.: Geological Survey of Canada radiocarbon dates V; Radiocarbon, vol. 8, pp. 96-127 (1966).

[2] Dyck, W., Fyles, J.G. and Blake, W., Jr.: Geological Survey of Canada radiocarbon dates IV; Radiocarbon, vol. 7, pp. 24-46 (1965).

[3] Mackay, J.R. and Terasmae, J.: Pollen diagrams in the Mackenzie Delta area, N.W.T.; Arctic, vol. 16, pp. 228-238 (1963).

---

97. QUATERNARY PALYNOLOGY

Project 690064

R.J. Mott

Bottom sediments of several lakes in southeastern Quebec were cored in connection with the Quaternary mapping project of W.W. Shilts (Project No. 660035) to provide material for radiocarbon dating and palynological studies. It is hoped that radiocarbon age determinations on basal organic lake sediments will provide minimum dates for deglaciation of the region. Palynological studies of these cores should reveal the late-glacial and postglacial vegetation and climatic history of the region.

Organic sediments from lakes on three of the Monteregian Hills: Mount Yamaska, Mount Bruno, and Rougemont, were cored in co-operation with Pierre LaSalle of the Québec Department of Natural Resources. This project is a continuation of previous work done by LaSalle and J. Terasmae on Mount St. Hilaire and will provide material for radiocarbon dating and palynological studies. Dates on sea levels at various elevations will be obtained by dating basal freshwater organic sediments of lakes isolated from the sea at successively lower levels. Study of the microfossils (especially diatoms) in the sediments should indicate whether or not the lake basins were subsequently inundated again by a relative rise in sea level.

Cores of bottom sediments from three lakes in the North Bay-Mattawa Region were obtained in connection with a mapping project by J.E. Harrison (Project No. 680067). Basal organic sediment in Kilrush Lake located near the bedrock sill of the Fossmill Outlet should give a minimum age for the end of the 'Fossmill Phase' of Glacial Lake Algonquin. A kettle hole farther north is believed to have become ice-free at about the same time as the Sobie-Guillmette Lake Spillway began operating. This spillway lowered Lake Algonquin from the level at which it was held while draining through the Kilrush Lake channel. Basal organic sediment from the lake now occupying the kettle hole should date the time when the Sobie-Guillmette Lake Spillway became operable. Basal organic sediment from a third lake in the Mattawa River valley should provide a minimum date for the end of the Stanley Stage of Lake Algonquin and the beginning of the Nipissing Great Lakes.

98. DENDROCHRONOLOGICAL INVESTIGATIONS

Project 680026

M.L. Parker

Dendrochronological specimens were collected from more than 700 coniferous trees of 19 different species from 52 sites in British Columbia, Alberta, Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia. The primary objective of this field work is to build tree-ring width chronologies and tree-ring density chronologies to be used for the following purposes: (1) dating of geological events, (2) evaluation of the dendrochronological quality of tree-ring specimens of various species from different ecological sites, (3) comparison of tree-ring chronology characteristics with climatic variables in order to determine the relationships between radial tree growth and climate, and (4) establishing a network of tree-ring stations throughout Canada to observe climatic changes through time and space.

Cross-sections from submerged logs and stumps were collected from the tidal zone of the Bay of Fundy to supplement those collected with D.R. Grant in October, 1968. Many of these well-preserved specimens, ranging in age to 4,000 years B.P.[1], contain tree-ring series of datable quality. Dendrochronological dates cannot be obtained from these specimens, however, until a regional master chronology of the required length is available. Tree-ring chronologies built from living-tree and archeological specimens may eventually overlap the ring series of the more recently submerged trees. Increment cores were taken from living eastern hemlock and red spruce trees in Nova Scotia that are several hundred years old. Cores were also taken from construction beams at Fort Beausejour, New Brunswick, which was built in 1750-1751.

Several weeks were spent in central British Columbia collecting tree-ring samples with J.A. Heginbottom. Excellent quality Douglas-fir and ponderosa pine specimens were obtained in and around the Fraser River valley. Three days were spent collecting cores and cross-sections from trees on and between the moraines at Tchaikazun and Friendly glaciers.

Large Douglas-fir, western red cedar, and other species of trees were sampled on Vancouver Island for the dual purpose of building long tree-ring chronologies and testing the power-driven increment borer being developed with G.A. Meilleur. Three samples from large Douglas-fir trees, collected near Duncan, British Columbia, have been prepared and counted, and each contains more than 1,200 annual rings. The power-driven borer was used successfully in extracting 3/4-inch diameter cores up to 5 feet in length from large Douglas-fir trees.

In addition to the traditional dendrochronological techniques of ring width analysis, we are investigating a new method of tree-ring research which has been developed recently in France[2]. Techniques for the production of X-ray negatives of wood samples have been developed with K. Meleskie, Non-Destructive Testing Laboratory, Mines Branch. A tree-ring scanning densitometer has been developed with F.W. Jones for the Geological Survey of Canada. This machine will produce tree-ring density plots, measure ring widths, produce bar graphs of ring widths, and print and punch the data on perforated tape for computer analysis. The ring series of some species of trees that have been investigated, such as Engelmann spruce and white spruce, are more variable in density of latewood than in ring width. The usefulness of tree-ring specimens for dating purposes and climatic analysis is greatly improved by the use of annual ring density measurements.

---

[1] Grant, D.R.: Recent submergence in Nova Scotia and Prince Edward Island; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 162-4 (1968).

[2] Polge, Hubert: Etablissement des courbes de variation de la densité du bois par exploration densitométrique de radiographies d'échantillons prélevés à la tarière sur des arbres vivants; Ann. des Sciences Forestières, XXIII, Fas. 1 (1966).

QUATERNARY GEOLOGY: INVENTORY MAPPING AND STRATIGRAPHIC STUDIES

99. QUATERNARY GEOLOGY, BIG BEND-CANOE RIVER, BRITISH COLUMBIA (PARTS OF 82M, 82N, 83C, D)

Project 690011

René A. Achard

A study of the Quaternary history of the area has been undertaken in advance of the completion of the Mica dam, a Columbia River treaty dam, and of possible future engineering developments along the Columbia River between Mica Creek and Revelstoke. This study includes the mapping of the surficial deposits of the affected valleys at the scale 1:50, 000.

Most of the Mica reservoir is situated in the Rocky Mountain Trench, extending from near Valemount on the Canoe River to near Donald on the Columbia River. In this section, most surficial deposits are directly related to Pleistocene glaciation, particularly to the last recession of valley ice tongues. The major modifications of valley geomorphology after glaciation have been construction of talus, alluvial and debris fans, initially much more active than at present, and the building or cutting of low terraces. Following deglaciation, two lakes, Bush and Kinbasket, occupied parts of the Rocky Mountain Trench. The presence of each was essentially controlled by bedrock structure, but both seem to have been at least partially dammed by fronto-lateral morainic bodies. Bush Lake has now been nearly filled by the Columbia, Gold and Bush rivers, and the Columbia, Sullivan and Kinbasket rivers continue to push large deltas into Kinbasket Lake.

In the section of the Columbia River valley situated downstream from the Trench and from the Mica dam towards Revelstoke, and in addition to an evident glacial imprint, various glaciofluvial and glaciolacustrine processes have been active during the last stages of glaciation. These resulted locally in the deposition of large volumes of silt, sand and gravel, particularly near the mouths of the main tributaries. The presence and distribution of these various deposits suggest that they were formed by the disintegration of stagnant ice, whereas the surficial deposits of the Rocky Mountain Trench suggest deposition rather by active alpine ice.

In this same section of the Columbia River valley, it appears that at certain times during, and possibly shortly after deglaciation, the main valley was blocked by the buildup of glacial and glaciofluvial debris at the mouth of the largest tributaries: the Goldstream River, Downie Creek and Jordan River. This permitted the formation of shallow lakes, probably short-lived, in which sand with some silt and clay have been deposited.

Many valley walls, oversteepened by glaciation, have subsequently readjusted to more stable angles by means of slides. Most of these occurred probably soon after the melting of the retaining ice tongues. However, some slides occurred also more recently on heavily fractured rock slopes. Wood from a tree picked up by a recent slide in the Canoe River valley opposite Dawson Creek, and collected from amongst slide debris, has been radiocarbon dated as not older than 140 years (GSC-1231; 0± 140 years).

Postglacial fluvial downcutting appears to have amounted to no more than 15 metres. Most of this entrenchment took place soon after deglaciation, as the Mazama volcanic ash, which is 6,600 years old, was deposited on terraces as low as 3 metres above present high water levels. The stream profiles and gradients have been altered little from those existing at the end of the last glaciation. Throughout the area, practically all the main tributaries of the Columbia have a rather low main gradient towards their mouth and often contain meandering reaches a short distance upstream from the Columbia. But these relatively flat levels are all slightly above the Columbia Valley, so that the streams drop rapidly in gorge-like rapids cut into bedrock over the last few kilometres. Most of this downcutting was probably initiated under pressure below the glaciers. In many cases, this is suggested by the diversion of these channels downstream, along what must have been the main direction of the ice flow. In some places, it appears that this main ice flow was contrary to the present drainage. Other indicators, particularly the petrography of the glacial deposits, will afford a more accurate interpretation of the direction of the most active or of the last main ice flows.

Observations relative to the Quaternary and glacial history of the area were also made during two reconnaissance trips above the timberline. One of these trips was in the northern Selkirks, from Bachelor Pass to the Adamant Range, and the other across the Jordan Range in the Monashee Mountains. The formation of moraine ridges and of other glacial deposits were observed in place on and around different ice tongues. In general, dead ice and dead-ice layers in glacial deposits were seen to play a more important role than running waters in producing the final structure of the deposits.

It appears that during the last postglacial advance, initiated throughout the area 200 to 300 years ago, and having reached its maximum near the end of last century, most accumulation areas were no more extensive than at present.[1] However, the longitudinal profiles of lateral moraines built during this advance indicate that the gradients of the glaciers within the ablation zone were lower and the tongues were much thicker than they are in present-day glaciers farther up-valley.

Numerous faults and fissures, probably essentially of tectonic origin, crisscross the Monashees along the Columbia between Revelstoke and the Canoe River. Evidence that movement along these faults and fissures may still be active was observed. More pertinent observations relative to the causes and especially to the rate of these inferred movements will have to be made at appropriate locations.

Wheeler, J.O.: Selkirk and Monashee mountains: recent glacier fluctuations; in Glacier Research; Can. Geophys. Bull., vol. 17, pp. 126-127 (1964).

---

100. LAST ICE-AGE DEPOSITS IN THE PORT STANLEY MAP-AREA, ONTARIO (40 I/11)

Projects 680043, 690052

A. Dreimanis

Field work was begun in the eastern half of the map-area in 1964[1] and in the western half in 1968[2]. In 1969 main attention was paid to the stratigraphy, as type sections of nine rock-stratigraphic units of the last ice age, ranging from the Early Wisconsin Lower Bradtville Drift to the Late Wisconsin Port Stanley Drift (Table 1), occur in this area. Almost continuous geologic profile section was measured along the 45-kilometre-long Lake Erie bluffs, and clarification was achieved on the two stratigraphic units, the Plum Point Interstadial and the Southwold Drift, which previously were not sufficiently well known.

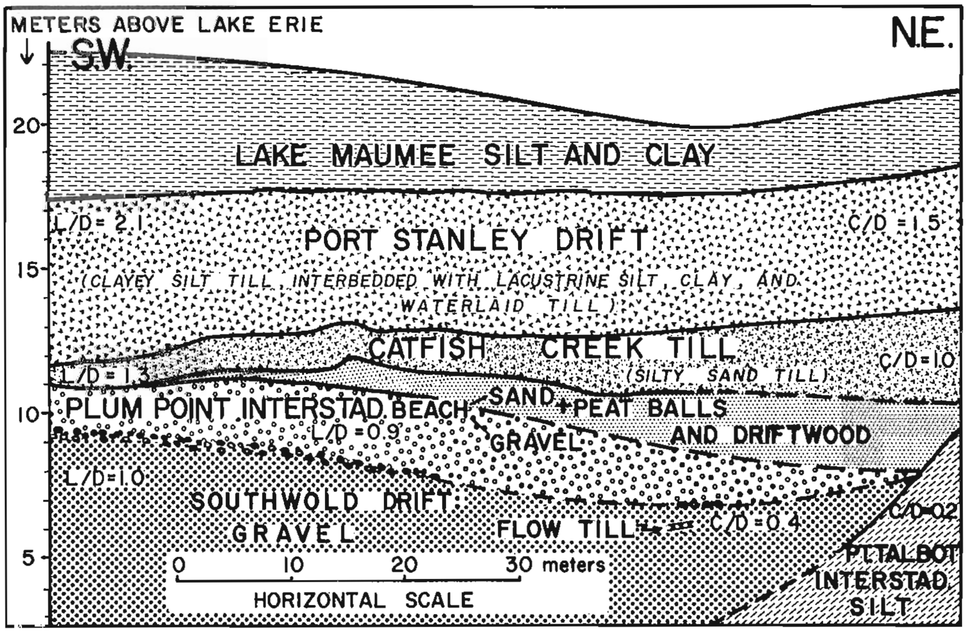
When the name of the Plum Point Interstadial was first introduced in 1957[2], its existence was based mainly upon finding of wood, 25,000 to 28,000 radiocarbon years old, in the base of the Catfish Creek Till. A type section is now established (Fig. 1) for the Plum Point Interstadial, containing beach deposits of a lake which must have had an outlet across the Niagara Peninsula into Lake Ontario basin.

TABLE I

Stratigraphy of the last ice-age deposits in the Port Stanley map-area

Radiocarbon years B. P.	Time-stratigraphic units	Rock-stratigraphic units
	Holocene	Recent alluvial, palludal, littoral and mass-movement deposits (no names assigned)
10,000		
	Late or Main Wisconsin	Late-glacial lake deposits (Lake Maumee to Early Lake Erie) Port Stanley Drift Catfish Creek Drift
22,000		
	Mid-Wisconsin	Plum Point Interstadial Beds Southwold Drift Port Talbot II Interstadial Beds Dunwich Drift Port Talbot I Interstadial Clay
53,000		
	Early Wisconsin	Upper Bradtville Drift Lower Bradtville Drift

The Southwold Drift was considered first (then called the till No. 2)[3] to separate the Port Talbot from the Plum Point interstadial deposits, but later[4] it was placed stratigraphically at the base of the Catfish Creek Drift. Last summer's field investigations proved that an interval of severe periglacial climate, followed by a warmer episode, separated the deposition of these two drift sheets. The periglacial climate is suggested by numerous frost wedges, up to 16 metres long, which cut through the Southwold Drift and the underlying Port Talbot II Interstadial silts in the type area of these deposits, 3 kilometres southwest of Port Talbot. The following relatively warmer episode (Plum Point Interstadial) caused deep oxidation of the Southwold Drift; the overlying Catfish Creek Till is nonoxidized. Laboratory investigations of the pebble lithology and the carbonate content of the till matrix shows (Fig. 1) that the lithologic composition of Southwold Drift differs from that of the Catfish Creek Drift.



Legend for lithologic composition

L/D - ratio of limestone to dolostone pebbles,
C/D - ratio of calcite to dolomite in the less than 0.063 millimetre fraction.

Figure 1. Profile section at the western end of the gravel pit, Lake Erie shore near Plum Point, 4.5 kilometres southwest of Port Talbot, Ontario.

Laboratory investigations of all the Wisconsin glacial and interstadial deposits are in progress. The first set of granulometric analyses of 20 Port Stanley till samples show that the waterlaid type of this till usually contains more silt, probably incorporated from the silty meltwaters, than the predominantly more clayey basal till in the same sections.

---

[1] Dreimanis, A.: Pleistocene geology of the London-St. Thomas and Port Stanley area; Ont. Dept. Mines P.R. 1964-6, pp. 52-53 (1964).

[2] Dreimanis, A.: Surficial geology, Port Stanley map-area, Ontario (40 I/11, West Half); in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 190-191 (1969).

[3] Dreimanis, A.: Stratigraphy of the Wisconsin glacial stage along the northwestern shore of Lake Erie; Science, vol. 126, pp. 166-168 (1957).

[4] McKenzie, G.D.: The type section of the Port Talbot Interstadial; unpubl. M.Sc. thesis, Univ. Western Ontario, London, Ont.

---

101. QUATERNARY GEOLOGY INVENTORY, SOUTHERN LABRADOR (13F, H, PARTS OF 3E, 13C, E, G, I, 23H)

Project 690043

R.J. Fulton and D.A. Hodgson

Inventory mapping of the Quaternary geology of Labrador south of the 56th parallel was begun during the 1969 field season. Field mapping of 13F, 13H and 3E, the north half of 13C and parts of 13E, 13G and 23H was completed at a scale of 1:125,000. This season's work is looked on as a pilot-feasibility study. Two more field seasons will be required to complete the project. The work was requested by the Newfoundland Department of Mines, Agriculture and Resources which plans a forest inventory-land capability study of the area. Mining companies active in the area have taken an interest in the project as much of the area is drift-covered and the Quaternary deposits may hold the key to locating valuable mineral deposits.

This is the first Quaternary geology mapping project undertaken by the Geological Survey that has made full time use of helicopter support. Basic mapping was by airphoto interpretation with helicopter traverses to check problem areas, to investigate variability of map-units and to examine exposures. Difficulty was experienced finding landing sites in heavily forested areas that are common along the major valleys. As most exposures occur along the main streams it was not possible to check all exposures on the ground.

No Quaternary deposits predating the last glaciation were found. Exposures are uncommon in the area and largely limited to glaciofluvial and glaciolacustrine tills deposited in the major valleys during final stages of deglaciation. A peaty layer up to 30 centimetres thick mantles the surface in most of the area and bogs occupy closed depressions and poorly drained areas. Maximum depth of a sounded bog was 3 metres. Palsas occur in coastal bogs from Rigolet to Spotted Island (the area north of Rigolet was not investigated) but these indicators of permafrost were not found more than a few miles inland. Beaches occur up to 70 metres above sea level in the Cartwright area. There is, however, no evidence that this is the limit of submergence and no marine shells were found to date this period of inundation.

102. QUATERNARY GEOLOGY, SOUTHWEST NEW BRUNSWICK (21G)

Project 670037

N.R. Gadd

Reconnaissance mapping of parts of the area not previously covered by detailed studies[1, 2, 3, 4] was completed.

Glacial phenomena such as striations, drumlins and erratic boulders indicate that at the maximum of the last glaciation continental ice moved across the map-area generally from northwest and north towards southeast and south. The southerly trends are characteristic of the area east of Fredericton and St. George, the southeasterly trends of the area to the west. Local deviations from these general trends reflect local topographic controls during late stages of glaciation during retreat of the ice margin.

Large moraines and associated outwash deposits in the Fundy Coast areas between St. George and St. John were formed by the continental ice sheet that overrode the hills in the coastal part of the map-area. Large discontinuous ridges of boulder gravel and till trending east-northeast along the coast are associated with channel deposits and fans of outwash gravel deposited more or less directly at the ice margin. It is not yet clear whether the presence of ice at these moraines and marine submergence of the Fundy Coast were contemporaneous because of the lack of well-developed glaciomarine features. Examination of new extensive exposures in a feature of this coastal morainic system, which was previously described by Lee[1] as a glaciomarine delta, suggests that the feature is a submerged end moraine modified by marine deposition and wave action. Therefore, radiocarbon dates on marine shells at this site in St. John (I(GSC)-72, 13,235 $\pm$ 500 years B.P.)[5] and at Pennfield (GSC-882, 13,000 $\pm$ 240 years B.P.)[6] relate to the marine sediments but are a minimum date for the age of the modified moraine. Lacustrine organic material (gyttja) from a kettle lake in unmodified glacial features at Pennfield has an anomalous age of 16,500 $\pm$ 370 years B.P. (GSC-1063). Although this age is greater than might have been anticipated for deglaciation of the coastal region of New Brunswick, it suggests that the ice margin may have retreated prior to marine submergence in the area, and may represent the time of deglaciation. The limit of marine submergence is about 250 feet above sea level; wave washed bedrock is more common in the zone below that level than are marine bottom sediments and shore deposits.

After the formation of the coastal morainic systems, an ice lobe probably occupied the St. Croix valley and Passamaquoddy Bay, flowing southeasterly along the valley and spreading peripherally in the bay and across the Mascarene Peninsula. On the peninsula levelled glacial flutings show that the last ice movement in that area was from west to east. Large moraines that may be traced from St. John to St. George appear to be truncated in the Mascarene Peninsula and adjacent Passamaquoddy areas, suggesting that a lobe of ice moving southeast and east out of Passamaquoddy Bay either prevented the formation of, or destroyed, moraines that might have formed across the chain of islands that separated Passamaquoddy Bay from the Bay of Fundy proper. Radiocarbon dates on marine shells in St. Croix valley indicate that Passamaquoddy Bay was ice free and the ice margin had retreated from the area northwest of St. Stephen and that the sea occupied positions some 100 feet above present sea level some 12,400 years ago (GSC-795, 12,300 ± 160[7]; GSC-886, 12,300 ± 160[6]; GSC-1067, 12,600 ± 270).

Coastal moraine and marine submergence phenomena of New Brunswick appear to be related to the Cherryfield-Eastport morainic system in coastal Maine[8], but the relationship is not yet quite clear. Evidence from the region of granitic and volcanic hills just north of the Bay of Fundy indicates that as the ice thinned meltwater was carried to the coast first in transcurrent eskers and then in outwash channels. Finally, however, when the ice margin had retreated north of the range of hills, drainage became ice marginal and flowed both northeast and southwest towards the major valleys flowing to the Bay of Fundy; the St. Croix, Digdeguash, Magaguadavic, Douglas, Nerepsis, and lower St. John valleys.

Subsequent recession of the continental ice sheet, as reconstructed from the distribution of moraines, position of outwash fans, and the pattern and orientation of esker systems in the region, was characterized by the existence of an arcuate margin concave northwesterly and with its axis along a line between Fosterville and St. Stephen in the international boundary area. In this axial zone the terrain is characterized by a field of drumlins whose orientation is southeasterly. Discontinuous moraines and other ice marginal features judged to be contemporaneous swing east and northeast from the boundary area towards the southerly and easterly trending parts of the St. John River in a series of arcs. It is suggested that counterparts may exist in adjacent areas of Maine.

The construction of gravelly moraines and morainic accumulation of boulders in several places across the southwest part of New Brunswick indicates the activity of the ice sheet when the margin stood north of the Bay of Fundy. Segmented eskers or alternating esker and glacial valley train deposits along a major glacial drainageway indicate fluctuations in the rate of melting and hence in the rate of ice margin retreat, possibly due to climatic variations during the late Wisconsin in New Brunswick. Most eskers in the area are relatively short and are oriented radially in relation to an arcuate ice margin. Larger eskers that are continuous across one or more morainic belts have radially oriented segments north of each moraine. Along its length an esker may have one or more changes in orientation, southerly to southeasterly at the south end of the system and southeasterly to easterly at the north end, with abrupt changes in direction at or near a moraine. Such changes also occur in places where the ice flow direction during the last stages of glaciation was under topographic control. The pattern of esker orientation in much of southwest New Brunswick reflects the changing pattern of ice flow in a condition of lobate ice margin retreat over irregular terrain.

---

[1] Lee, H.A.: Surficial geology of Fredericton, York and Sunbury counties, New Brunswick; Geol. Surv. Can., Paper 56-2 (1957).

[2] Lee, H.A.: Surficial geology of Canterbury, Woodstock, Florenceville and Andover map-areas; York, Carleton and Victoria counties, New Brunswick; Geol. Surv. Can., Paper 62-12 (1962).

[3] Gadd, N.R.: Quaternary geology, St. George, New Brunswick; Geol. Surv. Can., Paper (in press).

[4] Gadd, N.R.: Quaternary geology, St. Stephen, New Brunswick; Geol. Surv. Can., Paper (in press).

[5] Walton, A., Trautman, M.A., and Friend, J.P.: Isotopes, Inc., radiocarbon measurements I; Radiocarbon, vol. 3, p. 50 (1961).

[6] Gadd, N.R.: St. Stephen, New Brunswick; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 195 (1969).

[7] Lowdon, J.A., and Blake, W., Jr.: Geological Survey of Canada radiocarbon dates VII; Radiocarbon, vol. 10, pp. 207-245 (1968).

[8] Borns, H.W., Jr.: Field trip guide for the friends of the Pleistocene 30th annual reunion, Machias, Maine (1967).

---

103. QUATERNARY GEOLOGY, GREAT NORTHERN PENINSULA, ISLAND OF NEWFOUNDLAND (2M, PARTS OF 2 L: 12 I, P)

Project 690065

D.R. Grant

Reconnaissance of landforms and surficial deposits on the terminus of the Northern Peninsula, Newfoundland, commenced and completed in 1969, was undertaken to aid regional geological, geochemical, and forest capability and engineering feasibility surveys.

Abundant directional striae indicate at least four glacial events:
1. Laurentide ice from Labrador advanced southeast over at least the lowland portion of the Northern Peninsula, as evidenced by unidirectional grooving, roches moutonnées and Labrador erratics on the uplands near Roddickton

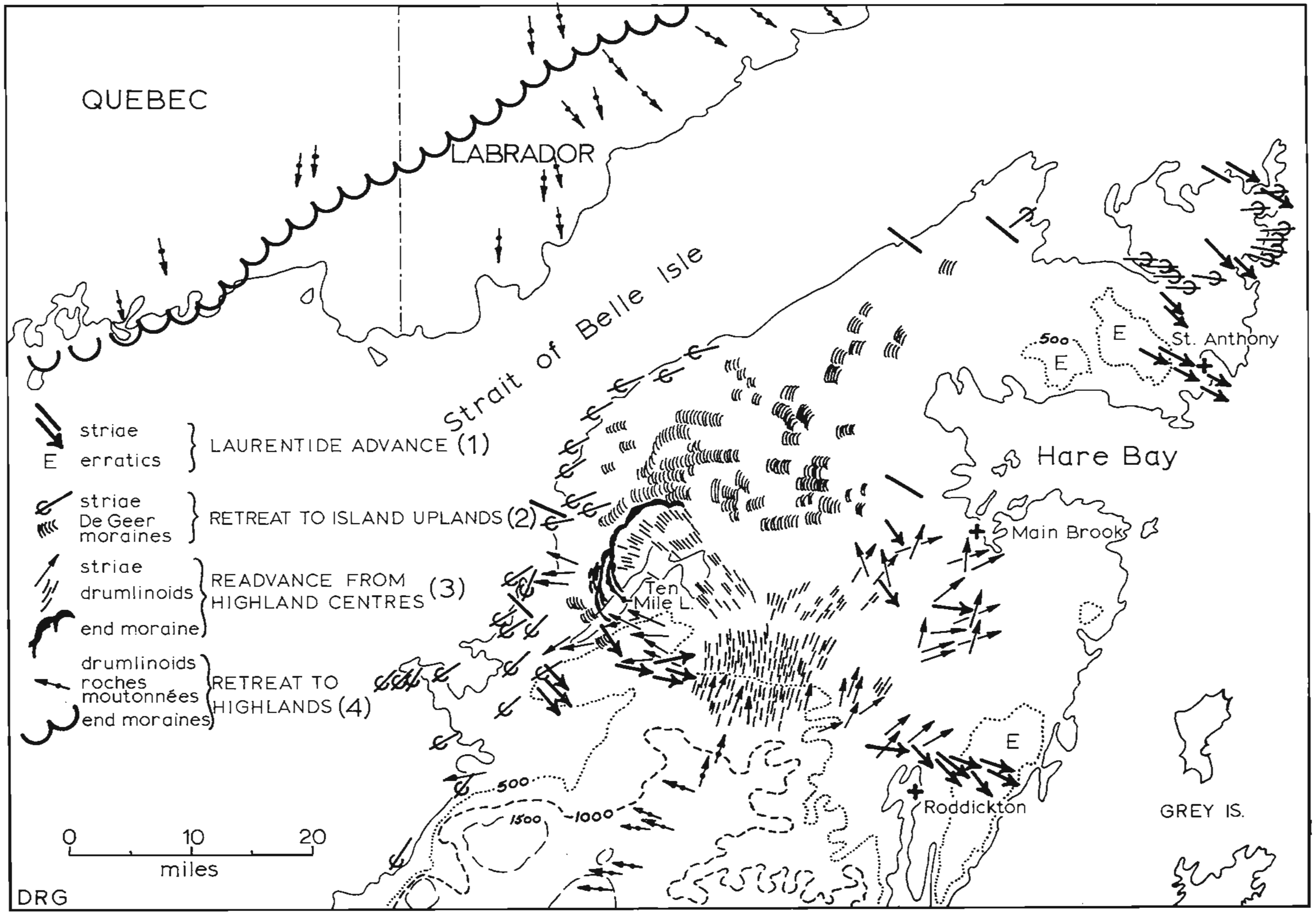


Figure 1. Glacial features, Great Northern Peninsula, Newfoundland, and adjacent Quebec-Labrador.

and St. Anthony, and a shelly drift derived from marine sediment in Strait of Belle Isle that was spread widely over the area.

2. Subsequent retreat, influenced mainly by a calving bay migrating northeastward along Strait of Belle Isle, proceeded concentrically inland from the present coast to an ice divide near Hare Bay, as indicated by striations and De Geer moraines.

3. Ice readvanced down into the sea over the lowlands, from the north flank of the Long Range plateau, fluting and drumlinizing the marine deposits. A lobe deploying westward into the basin of Ten Mile Lake was free to build a massive, multiple-ridged end moraine whereas on the northern and eastern margins the advancing ice probably abutted against the still-wasting older lowland ice-cap. Crossing striae near Main Brook suggest wastage again took place differentially as the sea calved the western flank.

4. Final retreat was up onto the Long Range plateau where the latest ice cap flowed actively westward as well as eastward over the height of the land, leaving abundant striated roches moutonnées.

The peculiar surficial geology will be a decisive factor in future development. The disjunct glacial pattern and atypical deposits have particular relevance to the interpretation of geochemical anomalies and the provenance of mineralized erratics. Plans to consolidate runoff for hydro-electric power must contend with meagre overburden, and underground drainage shown by sink-holes, disappearing rivers and intermittent lakes. Thin soils and poor drainage are also factors limiting forest capability. On the other hand, geological mapping is facilitated by abundant outcrops, estimated at one per mile of random air traverse, because of shallow drift and abundant lakes.

104. MARINE BEACH INVESTIGATIONS IN THE RICHMOND GULF AREA, EASTERN HUDSON BAY, QUEBEC (PART OF 34C)

Project 690082

G.M. Haselton

Detailed reconnaissance field work was carried out on foot and by boat along the prominent coastal peninsula that separates Hudson Bay from Richmond Gulf. This peninsula is a massive west-dipping cuesta composed of Proterozoic sedimentary rocks which lie on a basement of Archean gneisses and related metamorphic rocks. Arkose and carbonates dominate the lithology of the modern beach along much of the eastern side of the Richmond Gulf Cuesta.

Well-developed flights of marine beaches are preserved in protected transverse valleys on both the dip and scarp slopes of the cuesta. Several species of marine shells, including, whole, paired bivalves buried in place, were collected in a number of localities. The highest shells were found at an elevation of approximately 565 feet above present sea level. Radiocarbon age determinations on this and other samples are in progress.

Shells probably exist above 565 feet even though they were not encountered during the five weeks spent in the field area. This idea is occasioned, in part, by the fact that the shells at 565 feet are so well preserved.

Altimetry measurements indicate that the limit of postglacial marine submergence on the Richmond Gulf Cuesta, immediately north of Gulf Hazard, is of the order of 860 feet above sea level, a figure which agrees closely with the elevation shown on the Glacial Map of Canada[1]. There is a drop in the elevation of the marine limit toward the northwest corner of Richmond Gulf; here it was found to be ca. 765 feet above sea level. The elevations of the marine limit at the north end of the Nastapoka Islands, given as 800 feet for Broughton Island and 600 for McTavish Island on the Glacial Map of Canada[1], are incorrect, as the highest elevations on these two islands barely exceed 400 feet. Stanley recorded a marine limit of 875 feet[2] south of Gulf Hazard, but farther south the elevation of the marine limit increases. Archer reported that the highest beach ridges near Little Whale River occur at 937 feet[3].

The highest beach materials are found in association with large boulder ridges. Boulders occur up to several feet in diameter and are well rounded. The size and rounding of the boulders and the continuous nature of the ridges indicate that they are marine, as the fetch of ice dammed lakes would not be adequate to produce such material.

Most striae on the tops of the high basalt ridges have a bearing of 340 degrees (true). On a small island in the middle of Richmond Gulf two well-developed sets of striae were observed. The younger set bears 325 degrees and the older 350 degrees. These striae are at sea level. It is suggested that this divergence in ice direction is the result of topographic control during downwasting of the ice sheet and not the result of two separate advances.

An examination of ice-molded forms indicates that the last direction of ice flow was from east to west. This is supported by the lithology of erratics, as gneissic boulders from the Archean basement to the east of Richmond Gulf rest on Proterozoic basalts of the cuesta. All of the perched boulders are part of the ablation (ground) moraine which is preserved above the marine limit. Some boulders are underlain by a sandy till. The contrast between ground moraine, or perched ablation boulders, and marine boulder-ridge beaches is striking.

In some deflation hollows small ventifacts occur, but they are now covered by black encrusting lichens or are being encroached upon by patches of vegetation. Random observations indicate that the best faceting of these stones is on the east side. If this is indeed the case it suggests they were produced by katabatic winds from an ice cap to the east. Dunes, recently active, have been stabilized by vegetation for the most part.

---

[1] Prest, V.K., Grant, D.R. and Rampton, V.N. (compilers): Glacial map of Canada; Geol. Surv. Can., Map 1253A (1968).

[2] Stanley, G.M.: Raised beaches on east coast of James and Hudson bays; Bull. Geol. Soc. Am., vol. 50, No. 12, Pt. 2, pp. 1936-1937 (1939).

[3] Archer, D.R.: The upper marine limit in the Little Whale River area, New Quebec; Arctic, vol. 21, No. 3, pp. 153-160 (1968).

105. QUATERNARY GEOLOGY OF THE TASEKO LAKES MAP-AREA, BRITISH COLUMBIA (92O)

Project 680129

J.A. Heginbottom

Mapping of Quaternary deposits and landforms from aerial photographs and ground traverses at a scale of 1:250,000 was extended to cover the southeast quarter of the map-area. Much of this part of the map-area is similar to the northeast quarter, described previously[1]. However, to the southwest the rolling plateaus of Tertiary volcanics give way to mountain ranges separated by glacierized troughs. The mountains rise to between 6,000 and 9,000 feet a.s.l., and form the eastern limits of the Coast Ranges. The valley of the Fraser River in general is narrower south of the map-area.

In late June, three days were spent with an ARDA soil survey party correlating descriptions of Quaternary deposits and soil parent materials in the northeast quarter of the map-area.

In July, four days were spent assisting M.L. Parker in the collection of tree cores for dendrochronological work, and in company with Mr. Parker, a brief visit was made to the glaciers at the head of the Tchaikazun Valley to collect tree cores and other samples from an area of some recent alpine moraines (of Neoglacial age?).

---

[1] Heginbottom, J.A.: Quaternary geology of the Taseko Lakes map-area, British Columbia (92-0); in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1A, p. 201 (1969).

---

106. QUATERNARY GEOLOGY, KINGSTON, ONTARIO (31C, North Half)

Project 680062

E.P. Henderson

Striae and other associated ice-flow features indicate ice movement slightly south of southwest in the eastern part of the map-area, a more southerly and later flow of about south 25 degrees west in the Kaladar-Mazinaw region, and about south 10 degrees west in the Madoc-Bancroft region, almost perpendicular to the extensive Dummer moraine[1] that runs along the southern boundary of the area.

Glacial deposits 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 or in morainic areas. In the southern quarter of the region several irregular areas are underlain by Paleozoic limestones rather than by the mixed Precambrian rocks present over the rest of the region. Stony knobs and ridges of Dummer terminal moraine are present in the limestone areas, though the bulk of this large moraine lies south of the mapped area. In areas of well developed morainic topography local relief may exceed 40 feet, with till accumulations that must exceed 50 feet in thickness. North of Clareview and the Clare River numerous De Geer moraines have formed over an area of four or five square miles, evidently as the result of crevassed ice calving into the waters of Lake Iroquois. They are up to 800 feet long, 400 to 600 feet apart, and most are 4 to 6 feet high, though the largest rises to a height of 10 feet. The De Geer moraines usually form straight ridges with only faint, wavy irregularities, and are confined, as is the Dummer moraine, to areas underlain by limestone. Several atypical isolated drumlins, the largest of which was 80 feet high and two miles long, were mapped in areas where till was otherwise scant.

Glaciofluvial sediments are generally present as small isolated kames or esker segments of short to moderate lengths, but in two places have formed tabular outwash deposits of considerable extent. One is the series of large gravel flats extending along a major spillway system from Mazinaw and Marble lakes through North Brook to south of Flinton, the other a network of spillway deposits in the northwest corner of the area in the vicinity of Paudash Lake. In two or three other places northwest of Coe Hill smaller tabular gravel deposits, separated by winding bedrock valleys, indicate where melt-water has for brief periods escaped across the rugged Shield landscape. Although esker and kame deposits have been more extensively exploited to date for gravel and sand than have the flat-lying outwash, the larger reserve of commercial materials should be found in the latter type of deposit.

Glacial Lake Iroquois expanded across most of Eastern Ontario as the Wisconsin ice sheet retreated to the north and northeast. Subaerial outwash deposits between Mazinaw Lake and Flinton northwest of Kaladar occur at elevations below the maximum recorded for Lake Iroquois and indicate that lake levels in the Ontario Basin had fallen below that level, when the damming ice stood south of the area between the Dummer moraine[1] and a few miles south of Kaladar and five miles northwest of Flinton.

As deltaic deposits near Flinton are probably some 60 to 100 feet below the level of the Lake Iroquois water plane, meltwater must have entered a lower level lake that formed soon after the Lake Iroquois stage. This water body was probably Lake Frontenac, considered by Mirynech[2] as the shortest-lived post-Iroquois stage in the Ontario Basin.

Deltaic deposits north of Plevna[3], previously thought to represent a more northerly shore feature of Glacial Lake Iroquois, were found to have been deposited in a separate water body held up by a sill at the south end of Marble Lake and since largely drained by tilting during isostatic recovery of the area from its glacial load. Meltwater from this lake also entered Lake Frontenac at Flinton.

---

[1] Chapman, L.J. and Putnam, D.F.: The physiography of southern Ontario; Univ. Toronto Press (1951).

[2] Mirynech, Edward: Pleistocene geology of the Trenton-Cambellford map-area, Ontario; unpubl. Ph.D. thesis, Univ.Toronto, 176 p. (1962).

[3] Henderson, E.P.: Quaternary geology, Kingston (North Half), Ontario; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 203 (1969).

107. QUATERNARY RECONNAISSANCE, NORTHWEST DISTRICT OF MACKENZIE (86C, D, E, 96A-H, 106A, G, H)

Project 690046

O. L. Hughes

A reconnaissance examination was made of the Quaternary geology of the area covered by Operation Norman II. Field work was concentrated on the area west of Mackenzie River, particularly in determining the upper limit of Laurentide glaciations along the flank of Mackenzie Mountains, and in delimiting the former extent of valley glaciers that originated in those mountains.

Recognizable ice-marginal features (moraines, ice-marginal channels, kame terraces) indicate an advance of Laurentide ice against the east flank of Mackenzie Mountains to elevations over 4,000 feet in the southern part of the area, declining to about 3,000 feet in the northwest. Glacial erratics found above recognizable ice-marginal features to elevations over 5,000 feet in the southern part of the area, and to 3,500 in the northwest, indicate an older and more extensive Laurentide advance.

Distribution of glacial erratics indicates an early stage of valley glaciation in which major valleys on the east flank of Mackenzie Mountains were occupied by large glaciers. Subdued moraines indicate a later much-restricted advance of valley glaciers, and relatively fresh moraines indicate a still more restricted advance in which glaciers were mostly confined to tributary valleys that headed in glacial cirques. Numerous 'spurs' along the Mackenzie Mountain front, lying between valleys formerly occupied by the early extensive valley glaciers, and lying beyond the limit of Laurentide advance, are unglaciated. The Plains of Abraham, a plateau mostly 4,500 to 5,000 feet in elevation between Carcajou and Little Keele rivers, comprises the largest such area.

Major ice-marginal channels occur along the Mackenzie Mountain front from Keele River north and west to Arctic Red River and beyond. Numerous extensive outwash gravel deposits are closely associated with the channels. Less extensive channel systems (also with associated outwash) are found in Norman and McConnell ranges but glaciofluvial gravel is lacking in extensive plains areas bordering Mackenzie River.

Major rivers such as Keele, Mountain and Arctic Red, and numerous lesser streams that drain northeast and north from Mackenzie Mountains contain thick deposits of glaciolacustrine silt, laid down when Laurentide ice lay against the mountain front, impounding glacial lakes. Extensive deposits of glaciolacustrine silt, overlain by sand of variable thickness, occupies extensive areas along Mackenzie River, especially along the lower reaches of Hume River, Snafu Creek, and Connolly, Hanna, Mountain, Little Bear and Great Bear rivers. Areas underlain by such deposits are characterized by abundant thermokarst lakes or irregular outline.

Although drift thickness locally attains 400 feet or more in thickness in exposures along Mackenzie Mountain front, glacial deposits are mostly thin in the plains part of the studied area, except for areas covered by glaciolacustrine silt and sand (mentioned above), that commonly is 50 feet or more thick.

With local exceptions, permafrost is found throughout the area. Organic deposits from a few feet to 10 feet thick are widespread in major valleys and in the plains.

108. QUATERNARY GEOLOGY OF THE DUCK MOUNTAIN AREA, MANITOBA-SASKATCHEWAN (62N)

Project 640029

R.W. Klassen

Reconnaissance mapping of the surficial deposits begun in 1968[1] was completed.

The drift stratigraphy was investigated by means of some 4,500 feet of rotary drilling, electrical logging and side-wall sampling (19 holes), and 1,000 feet of power-auger drilling (28 holes).

The average drift thickness on the Manitoba part of the upland is 600 feet (4 holes) and a maximum thickness of more than 750 feet is indicated. The upper zone of the shale bedrock in this area in places includes a greenish, noncalcareous sand 15 feet to 25 feet thick.

The drift of the upland comprises about 50 per cent till, 30 per cent gravel and sand and 20 per cent silt and clay. Eight till units were recognized in the thickest drift penetrated in the northeastern part of the upland. Two or three till units about 40 feet thick overlain by about 15 feet of dense, lacustrine clay that is covered by some 5 feet of silt and/or sand occur within the Lake Agassiz Basin around Dauphin. A somewhat similar, but thicker (more than 100 feet) stratigraphic succession occurs along the outer margin of the Swan River Delta in the northwestern part of the area.

---

[1] Klassen, R.W.: Quaternary geology of the Duck Mountain area, Manitoba (62N); in Report of Activities, Part A, April to October 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 213-214 (1969).

109. QUATERNARY GEOLOGY, ARNPRIOR MAP-AREA, ONTARIO AND QUEBEC (31F/8)

Project 690055

Gretchen V. Minning

Mapping of the Quaternary geology of the Arnprior map-area (31F/8 east and west half) at a scale of 1:50,000 was begun in the summer of 1969. The project was undertaken in part to provide information for an Ontario Department of Mines environmental geology study in the Ottawa-Carleton area.

The Arnprior area is located along the boundary of the Canadian Shield and the Ottawa-St. Lawrence Lowland. Precambrian igneous and metamorphic rocks of the Shield and lower Paleozoic rocks of the Lowland are exposed at the surface and also underlie unconsolidated Pleistocene deposits.

Glacial and nonglacial Pleistocene deposits are thickest in areas underlain by flat-lying Paleozoic rocks. In many places well drilling has indicated at least 100 feet of unconsolidated sediments over bedrock.

Most of the unconsolidated material that appears at the surface consists of postglacial marine sediments, both reworked and primary. Mottled, noncalcareous, nonfossiliferous, grey-brown clay (reworked from marine clay deposited in the postglacial Champlain Sea) fills topographic depressions and blankets bedrock, glacial deposits, and primary marine sediments. The grey-brown clay is the major component of tillable land and also supplies raw material for a drain tile industry in Arnprior.

Medium- to fine-grained, well-sorted, nonfossiliferous sand, reworked by water from primary marine sand and gravel deposits, is found along former channels of the Ottawa and Madawaska rivers. In some areas, i.e., near Constance Bay, this alluvial sand has been reworked further by wind into stabilized sand dunes.

Primary marine clay, sand, and gravel are present in minor amounts at the surface and also occur beneath the reworked marine sediments. Grey, calcareous, fossiliferous marine clay is found at depths of 6 to 10 feet in excavations near Carp. Marine sand and gravel, with fossils in growth position, are exposed at lower elevations, but are more commonly found as beach deposits (up to 500 feet above sea level) along bedrock highs.

Glacial sediments are present throughout the map-area. Although the glacial drift is covered by thick deposits of marine and reworked marine sediments at lower elevations, till occurs at the surface on and near bedrock highs. Outwash sand and gravel in many places forms a thin, discontinuous drift cover on Precambrian bedrock highs, especially in the vicinity of Mount Pakenham. Ice-contact stratified drift, an important source of sand and gravel for the construction industry, is present in substantial quantities in moraines near Arnprior and northwest of Stittsville.

Glacial sediments, moraines, and ice-scoured bedrock indicate that ice of the last Wisconsin glaciation covered the entire area and ice movement was from northwest to southeast.

Recent deposits include fluvial material (sandy clay, sand, and gravel) forming terraces along the Ottawa, Madawaska, and Mississippi rivers and bog deposits overlying alluvium in old river channels and occupying lows on bedrock surfaces.

110. QUATERNARY GEOLOGY, MACKENZIE DELTA AND ARCTIC COASTAL PLAIN, DISTRICT OF MACKENZIE (PARTS OF 107B, 117A, C, D)

Project 690047

V.N. Rampton

The early part of the field season was spent reconnoitering the region east of the Mackenzie Delta as far as Malloch Hill to assess the amount and nature of investigations required to supplement those previously made by Fyles[1, 2], Hughes[3], and Mackay[4] in order to (1) map the Quaternary deposits and landforms of the region and (2) establish their sequence and age. More detailed investigations were made of the Pleistocene stratigraphy along the East Channel of the Mackenzie River between Reindeer Depot and Tununuk and along the southern edge of Liverpool Bay.

Along the East Channel correlation of individual stratigraphic units from section to section is difficult because of slumping and the discontinuity of the units. However, in many sections the following generalized sequence is apparent from top to bottom; (1) till-like material, (2) cross-bedded gravel and light grey sand (glaciofluvial in origin) (3) brownish horizontally bedded silts and fine-grained sands, and (4) grey sands and brownish grey silts characterized by crossbeds, beds of peat, and an abundance of organic detritus.

Along the southern edge of Liverpool Bay stratigraphic units can be correlated easily from exposure to exposure because of their continuity. Brownish sands showing deltaic sedimentary structures are capped by colluvium, lacustrine sediments, and patches of ground ice and clayey till. East of 129°45'W some of the organic lacustrine deposits, which are wood free, may predate the classical-Wisconsin. Channel deposits of grey sand and gravel, which occasionally contain wood and organic detritus, are present within the upper part of the brownish sands. West of 130°30'W grey sands also were found to underlie the brownish sands (similar observations were previously made by Mackay[4]). Along the Anderson and Kugulak rivers gravel and sand terraces are present in valleys cut into the above deposits.

Three days were spent mapping surficial deposits by helicopter along the Arctic Coastal Plain between the International Boundary and the Aklavik Range (coastal exposures were excluded because they have been examined in some detail by Fyles[1] and Mackay[5]). Erosion surfaces, which have sporadic occurrences of gravel upon them, are present beyond the limit of glaciation and in glaciated areas away from the coast. River terraces whose bases are cut into bedrock have up to 150 feet of gravel overlying the bedrock. Till on surfaces away from the coast is very thin and patchy. Along the outer edge of the coastal plain between Firth and Blow rivers, till overlies silts, sands, and gravels. Glaciofluvial deposits are present throughout this belt. The large valley between Peak Lake and the Babbage River, which is occupied by Deep Creek for most of its length, is filled with fine-grained sediments and peat.

---

[1] Fyles, J.G.: Quaternary stratigraphy, Mackenzie Delta and Arctic coastal plain; in Report of Activities, May to October, 1965; Geol. Surv. Can., Paper 66-1, pp. 30-31 (1966).

[2] 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).

[3] Hughes, O.L.: Surficial geology, northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper (in preparation).

[4] Mackay, J.R.: The Mackenzie Delta area, N.W.T.; Geograph. Br., Mem. 8 (1963).

[5] Mackay, J.R.: Glacier ice-thrust features of the Yukon coast; Can. Dept. Mines Tech. Surv., Geograph. Bull., No. 13, pp. 5-21 (1959).

---

111. PALEOSOL STUDIES IN CENTRAL YUKON (115P)

Project 690048

N.W. Rutter

Detailed sampling and field investigation of soils developed in six sections located off the highway between Dawson and the vicinity of Stewart Crossing in central Yukon were carried out during a ten-day period in September. The objective is to identify, characterize, and determine the genesis of certain soils developed on surfaces of varying age in order to reconstruct paleoclimate, to determine relative time of development and to use as an aid in deciphering the Quaternary history of the area. A secondary objective is to compare soil development in till and gravelly glacial outwash where other soil forming factors are essentially the same. Profile samples were taken from gravelly glacial outwash of Wisconsin, probable Illinoian and pre-Illinoian age (Hughes, pers. comm.) and from overlying loess, silt or sand. Soils developed in Wisconsin, probable Illinoian till and overlying finer material were also collected.

The use of a tractor-mounted back hoe and blade were necessary in order to obtain complete and fresh sections. Investigation revealed a complex pedologic and depositional history, indicated by the presence of composite and polygenetic soils, loess over the outwash deposited at various times as indicated by various stages of soil development, weathering zones over 8 feet deep in the oldest soils with the possibility of in situ clay production, and sand and silt filled wedge-like features in outwash with soil development less extensive than the adjacent material.

112. QUATERNARY GEOLOGY, PINE PASS, BRITISH COLUMBIA-JASPER, ALBERTA (PARTS OF 83, 93)

Project 690049

N.W. Rutter

Reconnaissance Quaternary geology was carried out in the eastern slopes of the Rocky Mountains and Foothills of British Columbia from Pine Pass in the north and the Wapiti River in the south. Investigations were confined to the major river valleys including the Pine River from Azouzetta Lake to East Pine; the Sukunka River from its headwaters to the Pine River including Burnt River, one of its tributaries; the Murray River from its headwaters to the Pine River and its tributaries – Bull Moose River and Wolverine and Flatbed creeks. Parts of West Kiskatinaw River were also investigated.

Postglacial stream erosion and deposition has resulted in a paucity of glacial deposits within the valleys of the mountains and most of the foothills. One exception to this is extensive late glacial lacustrine silts and deltaic deposits found well up the valleys. Near the headwaters of the Sukunka River, less than five miles from the Continental Divide, late glacial lacustrine silts are found on the valley floor at elevations of over 3,500 feet. Farther downstream lacustrine sands are found on the valley sides at elevations of over 4,000 feet and 1,500 feet above the present valley floor.

The most complete glacial geological sections are along the north-flowing Murray River. The river has incised deeply into bedrock since final deglaciation of the area. One section near Lone Prairie has at least 40 feet of Cordilleran till overlain by oxidized sands and gravels which are about 40 feet thick there but much thicker in other locations. The sands and gravels may be equivalent to the extensive oxidized sands and gravels thought to be interglacial found throughout the Rockies of northeast British Columbia. These in turn are overlain by 10 feet to 15 feet of Cordilleran till overlain at the surface by lacustrine silts.

Reconnaissance Quaternary geology will be continued next field season from the area discussed, south, to the vicinity of Jasper National Park.

113. QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF THE TAWATINAW AREA, ALBERTA (83 I)

Project 680027

D.A. St-Onge

Systematic mapping of landforms and surficial deposit of the Tawatinaw area was almost completed. During previous seasons stratigraphic studies were carried out by boat traverses along the Athabasca River and its major tributaries. Because of the lack of good exposures within the map-area a drilling program was undertaken in order to supplement surface information. Twenty-nine holes were dug to a maximum depth of 150 feet using a truck-mounted continuous auger.

Information from drillholes and from road-cuts along the recently completed highway between Clyde and Athabasca has made it possible to determine the presence of a thin upper till occupying the broad shallow depression which extends southward from Athabasca. The Tawatinaw Valley was carved in the central part of this depression which merges southward with a northwest- southeast-trending depression drained by Dapp Creek and Redwater River. The surface expression of the thin upper till is an exceptionally well developed complex of morainic and crevasse filling ridges.

A series of five C^{14} dates obtained from organic remains relate to the postglacial history of the area.

GSC-1049 11,400 ± 190 yrs. B.P.

Date from lower 5 centimetres of a 554-centimetre core of algal gyttja and banded marl. Lofty Lake, ca. 32 miles E of Athabasca, LSD 8, sec. 22, tp. 66, rge. 17, W 4th mer. Palynological studies are being made of this core.

GSC-1093 10,700 ± 170 yrs. B.P.

Date from lower 5 centimetres of a 385-centimetre and core of algal gyttja and marly algal gyttja. 'Alpen Siding' Lake ca. 2 miles NW of Alpen Siding. LSD 12, sec. 8, tp. 63, rge. 20, W 4th mer.

GSC-1205 10,000 ± 160 yrs. B.P.

Date from bones of Bisons sp. Athabasca Landing Co. gravel pit. North side of river from town of Athabasca, approximately 135 feet above river level. Gravels mark first river phase following draining of glacial lake. LSD 5, sec. 21, tp. 66, rge. 22, W 4th mer.

GSC-1207 5,900 ± 140 yrs. B.P.

Date from bones of Bison sp. in terrace sandy silts of North Saskatchewan River. Terrace is each 70 feet above river level, bones are from 5 feet below the surface; ca. 8 miles SE of Smoky Lake village LSD 1, sec. 29, tp. 58, rge. 16, W 4th mer.

GSC-1195 2,700 ± 140 yrs. B.P.

Date from bones of Bison sp. in sandy silts of a lower terrace of North Saskatchewan River. Terrace is ca. 40 feet above river level and the bones are from 5 feet below the surface; ea. 5 miles SSW of Bellis Alta.; LSD 6, sec. 31, tp. 58, rge. 15, W 4th.

114. INDICATOR STUDIES; PLEISTOCENE GEOLOGY; LAC MEGANTIC REGION, QUEBEC

Project 660035

W.W. Shilts

Mapping of surficial deposits at a scale of 1:50,000 was completed for the Canadian portion of the Sherbrooke (21E) sheet. The results of this study were presented as a dissertation at Syracuse University.

Detailed study of surface erratic dispersal, surface till pebble dispersal, heavy mineral dispersal, and potassium and plagioclase feldspar dispersal for the 2 to 3 portion of surface till combined with many striation and till fabric data permitted the following conclusions concerning ice movements and deposition during the final glaciation to be drawn:

1. As ice entered the area, a broad lobe confined between Mount Ste-Cécile and Mount St-Sebastien and the Boundary Mountains advanced south-southwest up the Chaudière Valley depositing a granite-poor clay till.
2. Flow during the glacial maximum varied from 100 degrees to 150 degrees; topography influenced glacier flow very little during this phase as pronounced flow maxima at 110 degrees, 120 degrees, and 140 degrees are recorded in all parts of the area. Indicator trains trend between 120 degrees and 130 degrees.
3. During deglaciation, a broad lobe again occupied the Chaudière Valley; although ice flow was south-southwest up the valley, the lobe was generally retreating.
4. An ablation deposit of large boulders was 'let down' on the surface of the lodgment till as ice melted away; large boulders rarely occur in the till; the ablation deposit was largely derived from high areas.

Geochemical prospectors should take into account the intricate patterns of drift dispersal in this region when evaluating geochemical anomalies. As an example, 50 per cent of the cobbles in streams just east of Mount Rond Top are molybdenum, copper, and iron-sulphide-bearing granodioritic rocks derived largely from Mount Ste-Cécile, 15 miles to the northwest.

Thick till (up to 40 feet) which covers ore bodies in parts of the Mount Scotch-Mount Scotch Cap area may mask geochemical anomalies anticipated in near-surface samples. Sampling should be done near the till-bedrock contact for geochemical studies of till.

Extensive ice-contact and deltaic gravel deposits may exist beneath till in the gravel-poor region north of Drolet. Ice-contact deposits related to an early glaciation[1] have recently been utilized for aggregate northeast of Eugénie River and in the east branch of Bras River, east of La Guadeloupe. Subtill, deltaic gravel and sand with groundwater and aggregate potential may be found near altitudes of 1,250 feet and 1,400 feet in major Chaudière River tributaries. These altitudes correspond to inferred water planes of an extensive and long-lived proglacial lake which existed in the Chaudière Valley prior to the last glaciation.

Thick, calcareous clay deposits in the vicinity of Drolet are >70 per cent finer than 4μ. The -4μ fraction is composed almost exclusively of well-crystallized chlorite and 10Å hydromica. These deposits or clay till derived from them should be suitable for brick manufacture or other ceramic uses.

---

[1] Shilts, W.W.: Pleistocene geology, Lake Mégantic Area, southeastern Quebec; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1A, p. 184 (1968).

---

115. QUATERNARY STRATIGRAPHY, MOOSE RIVER BASIN (42)

Project 690045

Robert G. Skinner

A detailed study of Quaternary events and stratigraphy in the Moose River Basin was begun this season with the traverse of several rivers in northern Ontario. Many new exposures of interglacial organic sediments were discovered, and numerous samples were collected for palynological study. The Missinaibi interglacial interval is represented by fossiliferous marine sands, fluvial sands and gravels with rare freshwater molluscs, lacustrine strata at least ten metres thick, and peat. Highly calcareous till below the Missinaibi deposits is commonly leached to a depth of up to fifty centimetres. Interglacial marine sands were discovered at the mouth of Big Cedar Creek (42I).

Evidence suggesting at least four tills was found in the Moose River Basin. Mechanical analyses and examination of heavy minerals and carbonate content, planned for samples from all tills in the basin, may aid in determining provenance and the stratigraphic relationships of the tills.

Many marine shell collections were made. Although most were below 400 feet elevation one came from a raised beach at Otter Rapids at an elevation of 440 feet above sea level. These highest shells probably relate to a sea level just below the marine limit for that area, and their dating should provide an important datum point.

At the end of the season, two days were spent at the site of the lower Notch Hydroelectric Power dam on the Montreal River. Waterworn sticks and twigs, seeds and cones were collected from deltaic sands beneath till. These sediments, preserved in an ancestral Montreal River gorge and exposed by construction activities, may be southern equivalents of the Missinaibi beds. Radiocarbon dating of the organic material will provide critical evidence.

116. QUATERNARY STUDIES IN THE SOUTHWESTERN PRAIRIES, ALBERTA (72L EAST HALF)

Project 650027

A. MacS. Stalker

During the summer of 1969, Dr. C.S. Churcher of the Department of Zoology, University of Toronto, and the writer continued their studies of Quaternary stratigraphy and vertebrate paleontology in the Medicine Hat area of Alberta. Some results of this work have been reported previously[1, 2, 3, 4] and a report by Dr. C.S. Churcher on the vertebrate fauna identified up to the end of 1968 is given elsewhere in this publication. As in previous years the archeological work was undertaken by a party from the Department of Archaeology, University of Calgary, this year directed by Mr. J. Elliott with supervision by Dr. B. Reeves.

An invaluable addition to the work was the successful drilling and logging of some holes, with an aggregate footage in excess of 2,000 feet, by a party under direction of J.E. Wyder. This work was undertaken primarily to compare results of drilling and sidewall sampling with sections that could be observed visually, to obtain undisturbed sections through the deposits, and to obtain accurate thicknesses of the various units. In most cases the drift was 200 to 300 feet thick, but one hole on high land in LSD 13 of sec. 36, tp. 13, rge. 5, W 4th mer. pierced nearly 500 feet of surficial material before reaching bedrock; this thickness was totally unexpected and is the thickest section of such material yet reported from southeast Alberta.

Results of the drilling program have yet to be appraised, but there were several unexpected windfalls. One was the discovery in the deep hole mentioned above of approximately 270 feet of lake deposits beneath the lowest till. This is by far the thickest section of lacustrine material yet found in southern Alberta, and it apparently was laid down in a proglacial lake developed during advance of the first glacier to reach the area. No fossils have been found in this material. Also, results of the drilling indicate that preglacial Oldman River may have flowed directly eastward past Medicine Hat towards Saskatchewan, rather than striking northeast towards Empress from near Taber as previously assumed.

Bones were collected from most of the sites previously found in the Medicine Hat area, but most of the excavation work and collecting was in the Sangamon (?) beds at Mitchell Bluff (NE 1/4 sec. 32, tp. 13, rge. 5, W 4th mer.), which continue very productive. Two sites of assumed mid-Wisconsin Age (Reservoir Gully in NE 1/4 sec. 27, tp. 12, rge. 6, W 4th mer.; Galt Island Bluff in SW 1/4 sec. 18, tp. 13, rge. 6, W 4th mer.) were bulldozed and prepared for future work, and collection of fossils was started at them. These two sites also appear prolific. To date, bones have been collected in large number from four, and in lesser number from five, separate horizons, ranging in age from near the Pliocene-Pleistocene boundary to near the present.

[1] Stalker, A.MacS.: Quaternary studies in the southwestern Prairies; in Report of Activities, Part A, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 113-114 (1967).

[2] Stalker, A.MacS.: Quaternary studies in the southwestern Prairies; in Report of Activities, Part A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 184-186 (1968).

[3] Stalker, A.MacS.: Quaternary studies in the southwestern Prairies; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 220-221 (1969).

4 Stalker, A.MacS.: Quaternary stratigraphy in southern Alberta, Report II: Sections near Medicine Hat; Geol. Surv. Can., Paper 69-26 (1969).

QUATERNARY SEDIMENTOLOGY AND GEOMORPHOLOGY

117. LANDSLIDES IN SOUTHERN BRITISH COLUMBIA

Project 690012

René A. Achard

The purpose of this project was to assess the needs for specific geological studies of past and potential slide areas in southern British Columbia.

Particular attention has been given to steep or seemingly unstable rock slopes along the main transportation routes. Brief field investigations showed that stability studies should be begun and geological information collected on selected areas along the Hope-Princeton highway and along the Trans-Canada highway through the Selkirk and the Monashee mountains. The magnitude of such a task could probably be greatly reduced by developing a theoretical evaluation scheme which would group systematically the interacting factors inducing large rockslope failures.

118. PROGLACIAL GEOMORPHOLOGY, GENERATOR LAKE, BAFFIN ISLAND, DISTRICT OF FRANKLIN (27C)

Project 680040

D.M. Barnett

Investigation of the proglacial geomorphology of Generator Lake, Baffin Island was continued toward the development of a process-response model of a cold ice-dammed lake.

Three preliminary radiocarbon dates suggest that the chronological framework of the lake basin based on lichenometry requires revision, hence considerable effort was devoted to locating further datable material and resampling earlier sites where possible. Five new detrital vegetation samples were found, all in deltaic sands. The resulting dates will offer potentially good chronological control for assessing the speed with which processes have operated and possibly some clues as to any significant variation in speed over the time span involved.

Sediment samples were taken from five streams tributary to Generator Lake and also from its spillway, with metering by an Ott current meter for discharge calculations. A meteorological observing program was maintained to relate short term process intensity to prevailing weather patterns, where appropriate. Continuous recording of pressure, temperature, relative humidity and total wind was augmented by 12 hourly (0000, 1,200 hrs. GMT) observations of cloud height, type and cover, wind speed and direction, precipitation, maximum and minimum temperatures, stream and lake surface temperatures and lake level.

Fossil and modern ice pushed ridges were examined in some detail to identify the significant variables in their formation; some small ones were observed during or immediately after formation.

Slope and elevation data on cross valley moraines and raised deltas were collected in order to calculate volumes with a view to estimating rates of till generation and sedimentation.

Sample till fabric data were collected from six paired pits in three cross-valley moraines.

The ice cliffs were rephotographed from the air at the end of a very warm summer. Considerable change was apparent with further retreat and an increase in cliffing contrasting with a general decrease in recent years.

A small number of line soundings in key areas added to echo-sounding data gathered earlier.

119. GEOMORPHOLOGICAL INVESTIGATIONS: NORTHERN AND SOUTHERN BANKS ISLAND DISTRICT OF FRANKLIN (98)

Project 640004

H.M. French

Work initiated during 1968[1] on the Beaufort Plain of northwest Banks Island was extended to the dissected regions of northern and southern Banks Island. As before, transport in the north of the island was by Nodwell RN21 vehicles.

Soil mapping was completed for an area adjacent to Ballast Brook and the relationship of the soils to the asymmetry of the valleys[1] established. Investigation of the Beaufort Surface suggests that it is of a composite nature consisting of (1) high level fluviatile terraces, (2) small areas of silty clay loam, (3) large areas of Beaufort materials in situ and much modified by solifluction. Polar Desert Soils (Storkerson Series) occur widely but on some of the higher terraces materials resembling the Beaufort Sandy Loam[2] are present. The higher levels of the Beaufort Plain are currently being dissected by a series of north-flowing streams. Several stages of dissection are evident. A summit surface of fluviatile origin is represented by pebble gravel-capped hills which range from 800 feet in the south to 500 feet in the north. A more widespread and undulating surface is also recognized in this part of the island and is called The Lowland Surface. It is characterized by (1) a gradual decline in height northwards from 600 feet to 450 feet, (2) undulating topography developed in Eureka Sound. Formation with solifluction slopes commonly of 3 to 8 degrees, (3) extensive peat deposits in the swales and depressions together with misfit streams. This Lowland Surface is tentatively thought to be subaerial in origin and associated with Wisconsin ice

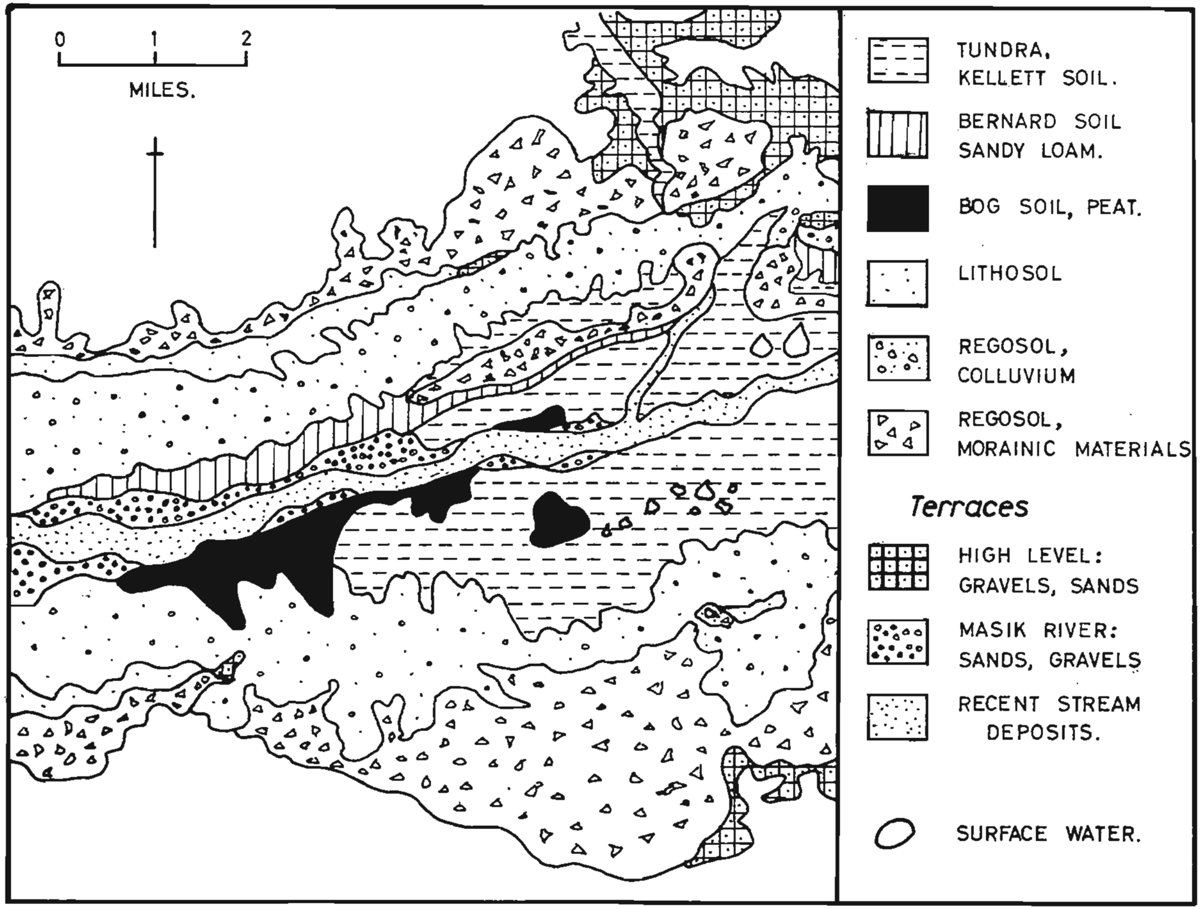


Figure 1. Preliminary soils and materials map of part of the Masik Valley, southern Banks Island.

present in McClure Strait to the north. Slope studies were carried out in the southern half of the island. At Sachs Harbour, tin foil markers were inserted on slopes of 3 degrees to measure rates of solifluction movement. In the Masik Valley considerable time was spent investigating the northern slopes where extensive thick slope deposits occur producing gentle rectilinear slopes of between 3 and 7 degrees. This colluvium is derived essentially from weak shale of the Christopher Formation which is exposed in the upper sections of the valley slopes. Field observations suggest that the most probable mode of slope development has been one of rectilinear slope recession. Soils and materials were mapped in the field and their relationship to slope form investigated. The following soils are most widespread (Fig. 1): (1) Kellett Series, occupying the poorly drained flat areas of the valley bottom, (2) Bernard Series, occurring as the gentle (< 8-degree) slopes developed on either glacial or well-drained colluvium materials, (3) Bog Soils, in limited areas of extensive peat accumulation, especially on the south side of the valley, (4) Regosols, widely developed as terraces, morainic ridges and the upper colluvium slopes. At least two soil-slope sequences can be recognized.

The time when these extensive slope materials were produced is not clear. At present the Masik River and its tributaries are dissecting these deposits. It is probable that these slopes are unrelated to present conditions and are related to a part period of geomorphic activity when slope development was proceeding at a faster rate.

---

[1] French, H.M.: Geomorphological investigations, Beaufort Plain, District of Franklin (98); in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A., p. 192 (1969).

[2] Tedrow, J.C.F. and Douglas, L.A.: Soil investigations on Banks Island; Soil Science, vol. 98, pp. 53-65 (1964).

---

120. MASS WASTING STUDIES IN THE OGILVIE AND WERNECKE MOUNTAINS, CENTRAL YUKON TERRITORY (106D, E, 116B, G)

Project 670033

J.T. Gray

The field work for the project was completed in 1969. The research on talus and pro-talus debris forms in the Bear River valley in the Wernecke Mountains (Nash Creek map-area, 106D) and in Tombstone Region in the Ogilvie Mountains (Dawson map-area, 106B, C) is being prepared as a Ph.D. thesis for submission to the Department of Geography, McGill University. Solifluction forms in the two regions were also studied and the findings will be published subsequently. The results obtained in 1969 are reported briefly below.

Erosion of rock walls has been calculated by estimating talus volumes and the rock wall areas from which talus is derived (a method modified after Rapp)[1]. The following figures for erosion per square metre were calculated.

TABLE I

	Lithology	Mean thickness of rock eroded per square mile (metres)	Maximum Erosion	Minimum Erosion
Cone 6821	Diorite	0.099	0.171	0.046
Cone 6824	Quartzite with minor slate	0.625	No estimates yet available	
Cone 6825	Quartzite with minor slate	0.660	No estimates yet available	
Cone 6801	Quartzite and slate	0.774		

Cones 6824, 6825 and 6821 are below rock-walls within two miles of each other in the Tombstone Region, in a situation where the time available for talus accumulation since deglaciation has been roughly equivalent for all three. Deglaciation here occurred about 10,000 years B.P., a C^{14} date of 9,650 ± 200 years B.P. having been obtained from the lowest organic material in a palsa bog in the vicinity (GSC-1172). Cone 6801 is on a west facing slope in the Bear River area where regional evidence indicates deglaciation 10,000-14,000 years ago.

Maximum possible error limits for these figures of erosion have to be calculated and results from two additional metasedimentary rock-walls and one igneous intrusive rock-wall have to be analyzed. The results so far suggest a mean erosion rate in the order of 0.1 to 1 metre for the postglacial period which is of the order of 10,000 to 14,000 years in length. They also tentatively suggest that the long term erosive processes have operated more effectively on the metasediments than on the igneous hypabyssal rocks of which cone 6821 is composed, although analysis of more data is necessary to confirm this conclusion.

Debris accretion over short term periods was examined for igneous intrusive rocks and for metasediments. Three methods were used.

(1) the measurement of debris on snow fringing the base of the igneous intrusive rock walls. This revealed the extremely small quantity of debris eroded from the smooth steep slabs and also indicated the extreme localization of fallen debris below narrow infrequently occurring chimneys.

(2) the measurement of lichen free debris among older debris below an igneous rock-wall. This procedure was designed to assess an order of magnitude of erosion for this wall over a period of 10 to 20 years (the time interval found to be necessary for lichen establishment on gold tailings in the vicinity of Dawson, and subjectively extrapolated to the talus zone). A minimum of 71 cubic metres of fresh debris was found below a wall area of 80,000 square metres. This yields an extrapolated rate

of 0.585 metre/10,000 years. The value of these short term measurements, however, is in the information they yield on the distribution of the fallen debris with relation to the zones of weakness on the wall. A tremendous concentration of debris accretion below a major diagonally sloping joint was noted.

(3) the measurement of freshly fallen debris on netting which runs down the length of one talus zone in the igneous intrusive zone and a second in a zone of a thin bedded dolomite. On the former the netting covers 9.3 per cent of the surface area of the cone; on the latter it covers 12.4 per cent. Table II shows the total weights of debris and weight per unit area on the two nets after the winter of 1968-69 and after given time intervals during the summer of 1969.

TABLE II

	Cone 6820	Cone 6830
Area of Cone	1,791 sq.m.	11,216 sq.m.
Area of netting	222 sq.m.	1,042 sq.m.
Period 1: No. of days since previous observations	340	296
Period 1: Weight of debris	221 kg.	173 kg.
Period 2: No. of days since previous observations	22	53
Period 2: Weight of debris	13 kg.	180 kg.
Period 1 and Period 2: No. of days since previous observations	362	349
Total weight of debris for period 1 and period 2	234 kg.	353 kg.
Total weight of debris per unit area of netting	1.052 kg./sq.m.	0.339 kg./sq.m.

The greater weight per unit area of netting on cone 6820 probably indicates greater debris accumulation on the metasedimentary cone over the year 1968-69. It is thought unlikely that much debris was moved onto the netting by avalanches from uncovered talus because minimal disturbance was noted along the edges of the netting.

Large pro-talus rock glaciers in the Bear River area were studied. These forms are horizontal or subhorizontal extensions of talus slopes outward over low gradient valley floors and considered to be postglacial in origin. This conclusion is based on the fact that they exist in valleys glaciated during the McConnell glaciation and show no evidence of disturbance such as would be expected if they had been in the path of a major valley glacier.

Three rock glaciers and four talus cones initially surveyed in 1967 and re-surveyed in 1968 were again surveyed in 1969 to determine the extent of mass movement due to internal processes. Results are not yet processed but indications are that movements are slight and may not be detectable.

Solifluction forms initially surveyed in 1967 were re-surveyed in 1969. Three tube profiles placed in lobes were re-excavated. One of the

Figure 1. Solifluction profiles in Bear River valley Wernecke Mountains, central Yukon Territory. GSC photo 154288.

profiles exhibited downslope movement of 18 centimetres near the surface over the two-year period (Fig. 1). The parabolic profile of movement exhibited both by the tube and by the polycylinder profile on the right of the photograph is characteristic[2]. The latter profile indicates that there are no zones of locally excessive shearing within the unfrozen boulder clay mantle.

[1] Rapp, A.: Talus slopes and mountain walls at Tempelfjorden, Spitsbergen. A geomorphological study of denudation slopes in an Arctic locality; Norsk. Polarinstitutt Skrifter, vol. 119, 96 pp. (1959).

[2] Williams, P. J.: Downslope soil movement at a sub-Arctic location with regard to variations with depth; Research Paper No. 300, Division of Building Research, N.R.C. Publication 9306 (1966).

121. EROSION IN A PERMAFROST ENVIRONMENT, DISTRICT OF MACKENZIE (107B)

Project 690054

J.A. Heginbottom

The object of this study is to develop an understanding of the nature, extent and rate of erosion in permafrost areas disturbed by the activities of man. Attempts are being made to assess the importance of surficial material, geomorphology, snow cover, vegetation, depth of active layer, ground ice distribution and other factors on controlling erosion. In 1969 investigations were largely confined to the area of the 1968 Inuvik fire, and were concerned with determining parameters to be measured and procedures to be followed to achieve the project objectives. The project is planned to continue for another two field seasons.

Visits were made to the study area in May-June, just as the ground was beginning to thaw, and again in September, when the active layer was at its deepest. Various experiments were set up in May-June. These were inspected in September and a general survey of the burned area and its surroundings was made. The experiments included one to measure movement of the surface material on a hillslope, one to measure changes in ground height caused by the growth or decay of ground ice, two to monitor changes in the thickness of the active layer, and the installation of thermocouple cables to record ground temperatures.

Some data on the thickness of the active layer under different conditions are presented in Table I. From the September observations it can be seen that burning alone has had no effect on the median thickness of the active layer, but that removal of the surface organic material has caused the active layer to increase in thickness by nine inches in this one summer.

TABLE I

Terrain type		Date of observation	Depth of active layer (inches)	observation	Depth of active layer (inches)
Unburned area	Min.	8 June '69	0.0	18 Sept. '69	0.0
	Med.		3.9		17.0
	Max.		9.1		30.0+
Burned area	Min.	30 May '69	0.0	16 Sept. '69	7.0
	Med.		2.8		16.5
	Max.		7.8		30.0+
Scarified (fire break) area	Min.	30 May '69	0.0	17 Sept. '69	15.0
	Med.		4.1		25.5
	Max.		8.4		30.0+

Apart from this, the only changes seen to have occurred during the summer of 1969 are a series of fresh earth flows on the south-facing side of Boot Creek Valley, and the melting out of some ice wedges to the east of the Inuvik gravel pits. The earth flows are on a slope of between 10 and 12 degrees, and so many have occurred, 10 in one mile, that they must be considered a result of the fire. On lower angled slopes and outside the burned area no erosion was seen, however other incidents of erosion and change may become apparent after a longer period of time.

122. GEOMORPHIC PROCESSES, MACKENZIE VALLEY - ARCTIC COAST, DISTRICT OF MACKENZIE (107 B, C, D, 117 D)

Project 680047

J. Ross Mackay

Permafrost

The Reindeer D-27 temperature cable (2,000 feet) near Tununuk has not reached an equilibrium temperature three years after drilling. Undisturbed permafrost depths of Richards Island and Tuk Peninsula are estimated at 1,000 to about 1,300 feet or more. The low distal alluvial islands of the Mackenzie Delta (e.g. Ellice Island) have permafrost depths of 100 to 200 feet or more away from water bodies.

Tundra polygon ice-wedges (107C)

Observations carried out over several years show that ice-wedges tend to crack yearly at nearly the same place. Crack depths may exceed 15 feet. The summer-winter differential displacement across many wedges in 1968-69 exceeded 0.1 to 0.2 inch.

Glacially deformed structures (107C)

Deformed structures on Pelly, Hooper, Rae, Kendall and Garry islands indicate an ice thrust generally towards the northwest.

Pingos (107C, 107D)

Bench marks were established on 6 pingos in order to determine if they are growing. Pingos have tended to form in drained lakes whose water depths were usually 5 feet or more.

Environmental disturbances (107B, 107C, 107D)

The depressions along seismic lines on Richards Island and Tuk Peninsula have been due primarily to thermokarst effects and not thermal erosion. Subsidence is largely a function of the season when the line was bulldozed, the presence or absence of ice-wedges, and the amount of segregated ice below the active layer. Thermal erosion has been far less effective than thermal (thermokarst) melting in producing seismic 'troughs'. Seismic lines below the spring and fall flood level of the Mackenzie are soon obscured.

The depths of thaw in the 1968 burnt over areas around Inuvik were up to 20 per cent greater (in 1969) on some flats; 30 per cent on a 20-degree slope. Rivulets are transporting some sediment down the burnt over slopes. Settling, due to thermokarst effects, is greatest in the interhummock areas.

123. SEDIMENTOLOGY OF ESKERS NEAR PETERBOROUGH, ONTARIO AND WINDSOR, QUEBEC (31D/8, 31H/9)

Project 660030

B.C. McDonald and I. Banerjee

Field work was carried out as part of a continuing study of the geology of eskers[1, 2, 3]. Two weeks were spent completing work on the Peterborough esker[3] of Ontario and two weeks were spent beginning a detailed sedimentological study of the esker at Windsor, Quebec.

Measurements of stratigraphic cross-sections, cross-stratification dips and pebble orientations were continued in gravel pits on the Peterborough esker. The objective was to construct a facies model of the esker based on these data. A special project was detailed measurement of pebble orientations from various layers of a very thickly crossbedded unit[3] to ascertain whether such crossbedding is indicative of antidune bedforms.

The Windsor esker is approximately 13 kilometres long and occupies the floor of the St. Francis River valley. Sixteen of 25 gravel pits along the length of the esker were examined. Three morphologic types are well developed in the esker: beads, long straight ridge, and double ridge. The beads appear to result from primary sedimentation and not from subsequent erosion. In beads, sequences of sandy pebble gravel pass downstream into sequences of ripple-laminated sand by interfingering over distances of only a few metres. The sedimentation environment appears to have been that of a subaqueous fan. Long, straight ridges are underlain in places by cycles comprising crossbedded sandy gravel fining upward into crossbedded sand. The rapid downstream fining that is characteristic of beads is not evident in the long ridges. Double ridges may have a more complex sedimentation history than either beads or simple ridges. Fault structures indicate that the trough between the ridges is a result of the melting of a former ice mass. Paleocurrent determinations from pebble orientations and cross-stratification measurements indicate that stream flow was southward and generally parallel to the main esker trend, although some divergences from the local trend of the ridge were noted. Laboratory examination of field data is in progress and study of this esker will continue.

[1] Fyles, J.G.: Eskers west of Hudson Bay in Districts of Keewatin and Mackenzie; in Report of Activities, Part A, May to October 1966, Geol. Surv. Can., Paper 67-1, Pt. A, p. 25 (1967).

[2] McDonald, B.C.: Esker geology, District of Keewatin; in Report of Activities, Part A, April to October 1968, Geol. Surv. Can., Paper 69-1, Pt. A, pp. 67-68 (1969).

[3] Banerjee, I.: Sedimentology of an esker north of Peterborough, Ontario; in Report of Activities, Part B, November 1968 to March 1969, Geol. Surv. Can., Paper 69-1, Pt. B, pp. 61-62 (1969).

124. SEDIMENTOLOGY STUDIES ON THE OUTWASH PLAIN BELOW PEYTO GLACIER, ALBERTA (82N/10)

Project 660030

B.C. McDonald and I. Banerjee

Ten days were spent examining sedimentary structures and facies of the Peyto Glacier outwash. Comparison of these features with those in other localities was made by brief study of: (1) Bow Glacier outwash, (2) sediments of the braided North Saskatchewan River east of Mount Amery, (3) sediments of a steep mountain stream (No-See-Um Creek), and (4) sediments of older outwash exposed in gravel pits 2.2 miles northwest of Lake Louise.

General slopes of the two outwash plains varied between 0.016 and 0.022. Sediment types varied from cobble gravel to silt. Shallow stratigraphic sections were measured, and some pebble orientation data were gathered.

Particular attention was given to the following bedforms:

(1) 'Transverse ribs' - These are regularly spaced, linear concentrations of pebbles and/or minor ridges oriented at right angles to the axes of the riffle portions of shallow channels. Spacing of the ribs varies directly with the b-axis dimension of the largest pebbles in the rib;

(2) Ripples - A wide variety of ripple forms were observed. Generally these were associated with the pool portions of shallow channels;

(3) Current crescents - These forms are ubiquitous in the shallow channels but are more evident in the pools. Regressive ripples were noted occupying the zones of separation in the lees of larger cobbles;

(4) Bars - Transverse and tributary bars of sandy gravel and pebbly sand are prevalent on the braided reaches examined; their development appears to be an integral part of the braiding mechanism.

125. GLACIOFLUVIAL SEDIMENTATION OF THE BRAMPTON ESKER, ONTARIO (30M/12)

Project 660030

H.C. Saunderson and A.V. Jopling

The Brampton esker is situated approximately 15 1/2 miles west of Toronto and 1 1/4 miles east of the town of Brampton. Nine sand and gravel pits have been opened in the esker, and two of these pits are abandoned. The esker serves as an aquifer for Brampton (population 38,000).

The esker extends in a northwest-southeast direction for a distance of 2 1/2 miles with an average width of 1/3 mile and a maximum height of approximately 105 feet. The southeastern half is a subdued ridge with a featureless surface, whereas the northwestern half has a pitted surface. The total range in elevation is between 700 feet and 880 feet above sea level.

The deposits were formed within a re-entrant of the southerly-wasting ice front of the Ontario lobe at the close of Wisconsin time. An anastomosing network of meltwater channels fed into, and sheet-flooded, the re-entrant from the east, west and south. To date, 2,000 azimuths of the maximum dip direction of ripple cross-lamination and dune crossbedding, sampled at various stratigraphic horizons, have been taken to ascertain the spatial and temporal variation in paleocurrent direction.

The stratigraphy of the deposit can be subdivided into: (a) a lower unit composed of partly-cemented gravels and sands, (b) a middle unit of sand with intercalations of channel-fill gravels and (c) an upper unit composed primarily of sand. These units are gradational in character.

The lower unit is composed predominantly of sheet deposits of medium-sized gravel, probably formed as a series of kames. The middle unit consists of fine to coarse sand traversed by channel sands and gravels deposited by trunk streams which were flowing through a sandy floodplain environment. Channel scour-and-fill structures can be identified, as can micro-environments of deposition such as levee, interchannel of floodplain and shallow pond (lacustrine) environments. The upper unit reflects a waning flow regime marked by the deposition of sand, silt and clay in shallow ponds. Varves are present locally in this unit.

In addition to these main stratigraphic units, a discontinuous diamictic deposit with a maximum thickness of 3 feet overlies the stratified material, especially in the southeastern portion of the esker. A second diamicton, 6 to 7 feet in maximum thickness and bluish grey in colour, has been found at two locations where it is overlain and underlain by glaciofluvial material. It contains smaller clasts and has a higher percentage by volume of fines than the first diamicton.

Twenty-two stratigraphic sections have been measured to show the characteristics of the esker both in longitudinal and transverse cross-section. Different types of samples have been collected, channel samples to show the spatial pattern of size sorting and stream competency, and others from specific structures to reconstruct local hydraulic parameters of the paleo-flow regime.

Deformational structures include normal and high angle reverse faults, slump structures and clastic dykes. The esker lacks a distinctive pattern of faulting along the flanks. The clastic dykes are composed of silt and fine-grained sand, crudely stratified parallel to the boundary surfaces of the dykes, and are associated with faulting in the upper sand facies.

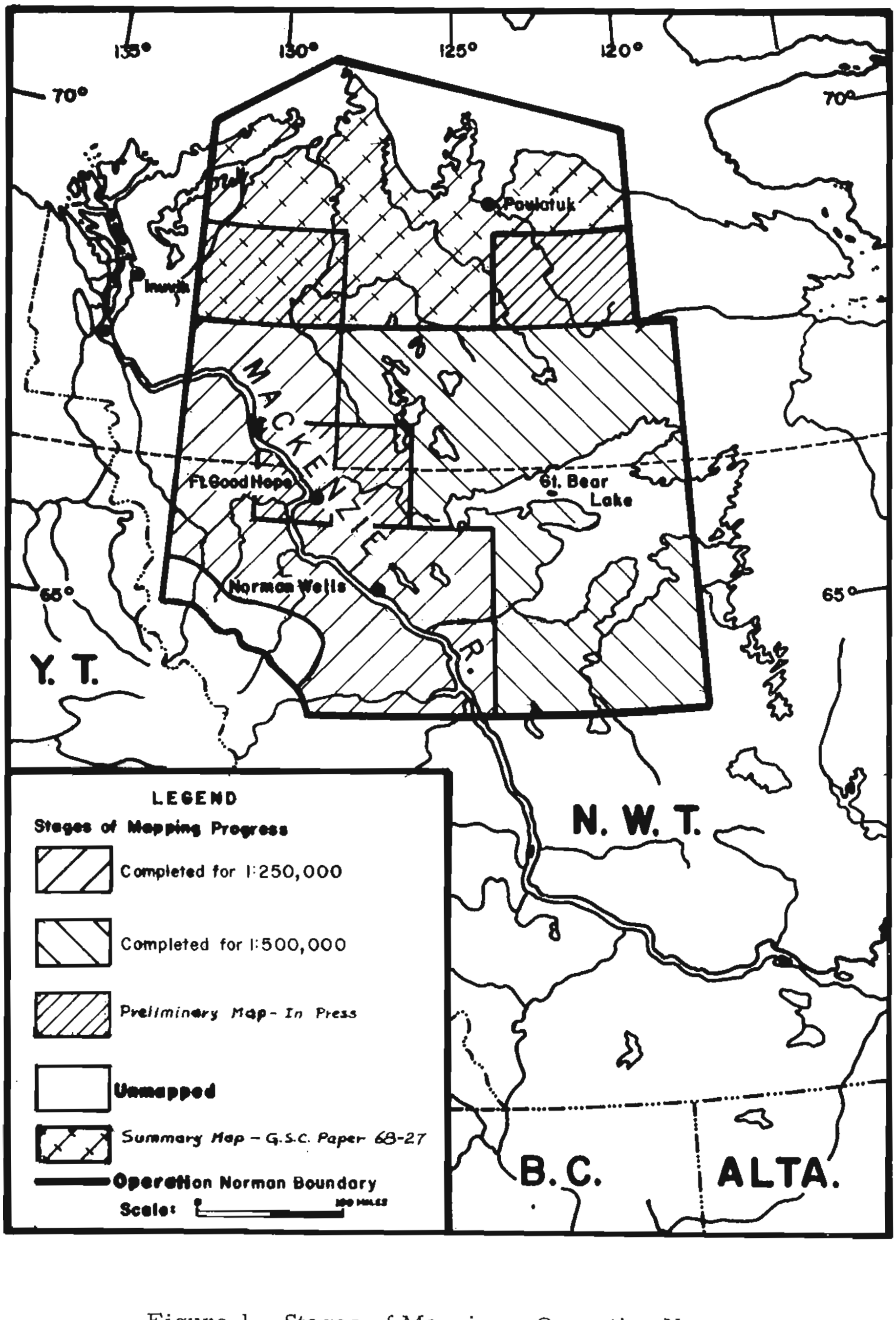


Figure 1. Stages of Mapping - Operation Norman

STRATIGRAPHY

126. OPERATION NORMAN, DISTRICT OF MACKENZIE (86 D, E, L, M; 87 B, C; 96; 106 A, B, G, H, I, J, O, P; 107 A, D, E)

Project 670068

J. D. Aitken, D. G. Cook, H. R. Balkwill

Operation Norman, a regional geologic study of the lower Mackenzie River area (Fig. 1), under the direction of J. D. Aitken, combines reconnaissance bedrock mapping, stratigraphic studies, and investigation of surficial Quaternary deposits. The bedrock program is being carried out by the Institute of Sedimentary and Petroleum Geology; Quaternary studies are by the Division of Quaternary Research and Geomorphology. The operation will cover about 145, 000 square miles, most of the area between 64°N and the Arctic Ocean, and between 119 and 132°W (Fig. 1). Although Figure 1 indicates the area examined to date, including publications released and in press, this report summarizes only the work completed in the 1969 field season.

Field studies during 1969 were confined mainly to the Mackenzie Mountains, the Mackenzie River valley, the McConnell Range of the Franklin Mountains, and the plains area south of Great Bear Lake. It was intended that field work for Operation Norman would be completed during this field season; this was prevented by a combination of bad weather and operational difficulties.

Reconnaissance mapping and regional structural investigation were done by J. D. Aitken, H. R. Balkwill, and D. G. Cook. In conjunction with mapping, detailed stratigraphic and paleontologic studies were carried out by J. F. Usher, Queen's University (Proterozoic and Cambrian stratigraphy); R. W. Macqueen (Cambrian, Ordovician, and Silurian stratigraphy); W. Fritz (Cambrian biostratigraphy); W. S. MacKenzie (Devonian stratigraphy); A. E. H. Pedder (Devonian biostratigraphy); C. J. Yorath (Cretaceous stratigraphy, including reconnaissance mapping in areas underlain predominantly by Cretaceous rocks). Quaternary surficial deposits were examined by O. L. Hughes. Reports on stratigraphy and Quaternary geology appear elsewhere in this publication under individual authorship. Discussion of the broader findings of Operation Norman are presented below.

Thirty-one stratigraphic units (Table I), some of which are lateral facies of others, were mapped. The season's studies established the relationships of units mapped in Operation Mackenzie[1], with those mapped by the authors in the Franklin Mountains and Anderson Plain[2]. Pronounced regional unconformities occur at the base of the Cretaceous, Devonian, Upper Ordovician to Lower Silurian, and Middle Cambrian to Lower Ordovician, sequences. All four are apparent from regional truncation of underlying units. The sub-Middle Cambrian unconformity truncates earlier structures as well. Tertiary non-marine strata unconformably overlie Devonian and Cretaceous rocks in the Mackenzie River valley in the southern part of the area. Local faulting and tilting of the Tertiary beds show that compressive deformation continued into the Tertiary.

In the plains area south of Great Bear Lake, flat-lying Cambrian and Ordovician sediments unconformably overlie Proterozoic rocks, and are unconformably overlain by Cretaceous strata. Significant deformation was noted only in tilted Proterozoic sediments which form a northeast-trending Precambrian hill south of Great Bear Lake and near the eastern edge of the area. This hill is onlapped by Cambrian strata.

The McConnell Range forms part of the Franklin Mountains but differs from the rest of the mountains in that rocks older than the Cambrian Saline River Formation are exposed. Hence, the décollement which seems to occur in or below the Saline River Formation beneath most of the Franklin Mountains[2] must cut deeper into the stratigraphic sequence in the McConnell Range. A high-angle westward-dipping reverse fault marks the eastern boundary of the McConnell Range and is lost beneath overburden to the north. The St. Charles Range, on strike farther north, is bounded on the west by an eastward-dipping reverse fault. Such pairs of faults, opposed in sense of transport but more or less on strike with each other, are characteristic of the Franklin Mountains north of Great Bear River[2]. In the north part of the McConnell Range, a number of domes or doubly plunging anticlines occur. These commonly have a core (present erosion level) of Mount Clark quartzite. The largest such dome forms Mount Clark.

The Mackenzie River valley is underlain principally by Cretaceous strata. Broad folds occur, but are difficult to map because exposure is poor.

In the Mackenzie Mountains, there is generally a close relationship between structure and topography. The frontal ranges are a series of three parallel, broad, flat-topped ranges from 6 to 24 miles across, and each formed by a broad box-anticline exposing mainly resistant Precambrian or Cambrian quartzite and Cambro-Ordovician dolomites. Devonian carbonates and clastic rocks occur in the synclines which are much narrower (2 to 4 miles) than the anticlines. Because these rocks are more easily eroded, the synclines form the loci of subsequent major streams and rivers. This simple pattern is complicated in places by high angle reverse, and thrust faults. The series of anticlines and synclines is succeeded abruptly to the southwest by a belt of thrust imbrication and related folding. Mapping of this belt is complicated by abrupt stratigraphic changes - both facies changes and the sudden appearance and disappearance of units at the sub-Devonian and sub-Middle Cambrian unconformities. The unsurveyed portion of Operation Norman (Fig. 1) is the northwestward extension of this complex belt.

Pre-Tertiary, pre-Cretaceous, pre-Devonian and pre-Upper Ordovician; uplifts, indicated by the above-mentioned unconformities, appear to have been epeirogenic, whereas the pre-Middle Cambrian uplift appears to have been orogenic. A thrust fault involving only sub-Middle Cambrian strata is truncated by the sub-Middle Cambrian unconformity. Furthermore, northerly and north-northwesterly transverse or normal faults may in part predate Middle Cambrian strata. Some of these affect rocks beneath the sub-Middle Cambrian unconformity, but not those above. Many faults in this set, however, cut the entire exposed sequence (up to and including Upper Devonian); these may have resulted from reactivation of older structures. Steeply dipping diabase dykes, also striking northerly, cut only the rocks beneath the sub-Middle Cambrian unconformity.

TABLE I

TABLE OF STRATIGRAPHIC UNITS

	Mackenzie Mountains in southwestern part of area (includes mountain front at Arctic Red River)		Mackenzie Mountain front, Mackenzie River valley Franklin Mountains	
	UNIT	THICKNESS IN FEET	UNIT	THICKNESS IN FEET
QUATERNARY	unconsolidated surficial deposits		unconsolidated surficial deposits	
	regional unconformity		regional unconformity	
TERTIARY			Fluvial gravels, sandstones, coal, tuff	0-1, 500
			unconformity	
CRETACEOUS			East Fork Formation	0-200
			Little Bear Formation	500-1, 000
			Slater River Formation	0-1, 000
			Sans Sault Formation	1, 400-7, 800
			regional unconformity	
UPPER DEVONIAN	Imperial Formation	3, 000	Imperial Formation	2, 000
	Canol Formation	0-50	Canol Formation	400
			disconformity	
MIDDLE DEVONIAN			Ramparts-Kee Scarp Formation	0-360
	Hare Indian Formation	0-800	Hare Indian Formation	800
	Hume Formation	400	Hume Formation	400
LOWER AND MIDDLE DEVONIAN	Landry Formation	300-600		
	Arnica Formation	300-600	Bear Rock Formation	700
	Camsell Formation	240-900		
SILURIAN AND LOWER DEVONIAN	Delorme Formation	450		
	regional unconformity		regional unconformity	
ORDOVICIAN AND SILURIAN	Mount Kindle Formation	350-1, 500	Mount Kindle Formation	350
	regional unconformity		regional unconformity	
CAMBRIAN AND ORDOVICIAN	Ronning Group (2 mappable units)	1, 000-1, 400	Ronning Group (3 mappable units)	800-1, 800
CAMBRIAN	Purple sandstones	0-400		
	Saline River Formation	0-200	Saline River Formation	0-550
			Mount Cap Formation	0-200
	regional unconformity		regional unconformity	
CAMBRIAN OR PROTEROZOIC	Diabase dykes			
	Varicoloured dolomite and limestone	0-2, 150		
	Shale with limestone and dolomite	0-900		
	Quartzite, shale and dolomite	0-2, 200		
	Quartzite	1, 200-3, 000	Quartzite	2, 500
PROTEROZOIC	Diabase sills		Diabase sills	
	Argillaceous quartzite with siltstone, shale and dolomite	1, 450	Argillaceous quartzite with siltstone, shale and dolomite	600+
	Shale with silty dolomite	1, 200'		
	Grey dolomite with chert	1, 200+		

The geology of the Mackenzie Mountains is pertinent to oil exploration in the region. Remarkable exposures provide concrete stratigraphic data regarding the degree to which stratigraphic units are cut out beneath prominent unconformities. Furthermore, facies changes, most notably in the Middle Devonian Bear rock and Ramparts-Kee Scarp formations, may be well documented. Precambrian sediments intruded by diabase dykes and sills provide rocks with potential for base metal exploration. No metallic minerals of economic significance were noted, however.

---

[1] Douglas, R.J.W. and Norris, D.K.: Dahadinni and Wrigley map-areas, District of Mackenzie; Geol. Surv. Can., Paper 62-33 (1963).

[2] Aitken, J.D., Yorath, C.J., Cook, D.G. and Balkwill, H.R.: Operation Norman, District of Mackenzie; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 223-229 (1969).

---

127. EASTERN DEVON ISLAND AND SOUTHERN ELLESMERE ISLAND, DISTRICT OF FRANKLIN (38 F, G; 39 B, C, F, G, H; 48 E-H; 49 A, B, D)

Project 680015

R.L. Christie

Geological reconnaissance of the eastern coast of Devon Island was conducted using motor toboggans during April and May. This completed a project begun in 1968, during which season travel was hampered by early departure of the coastal ice. The westernmost exposures of 'basement' rocks of the north coast, in Sverdrup Inlet, also were visited in 1969. During the summer season, certain stratigraphic sections were studied and mapping was carried out on Ellesmere Island.

The Precambrian rocks of the east coast of Devon Island are mainly grey, granulose quartz-feldspar gneisses of a granitoid aspect. The dark mineral in most places is biotite, but pyroxenitic or amphibolitic bands of various widths occur, these bands conforming to the local structural trends. Leucocratic, garnet-bearing gneisses of metasedimentary aspect occur north of Philpots Island and west of Cape Sherard.

Gneissic foliation in the granitoid rocks is nearly everywhere distinct, the foliation usually being due to common orientation of flakes or lensoid patches of biotite. Alignment of feldspar grains also contributes to the gneissic structure. Banded structure due to variations in composition or texture is relatively rare. Such banded rocks prevail in the vicinity of the north coast of Philpots Island.

The gneisses of the south coast of Devon Island, between Cape Warrender and Cape Sherard, are 'stretched' in appearance, and evidently have undergone a period of cataclasis. Dark bodies of dioritic-appearing rock, some smaller ones resembling stretched inclusions, also occur in this region. Cataclastic textures were observed also at scattered localities on the east coast.

Pegmatitic rock as veins, anastomosing stringers, and irregular bodies, both conforming and crosscutting, forms a minor proportion of the gneiss in the northern part of the east coast. Pegmatite is most abundant at Sverdrup Inlet, where in places it is one-third of the rock.

A generally eastward structural trend prevails on eastern Devon Island, with, however, significant variation at certain localities. Well-banded gneisses of the north coast of Philpots Island are folded into an open 'nose' structure, and banding is flat lying there and at Cape Hodgeson, to the west. Variable attitudes are characteristic of the south coast of Devon Island, west of Cape Sherard, where trends vary from northerly through easterly to southeasterly, and darker gneisses and inclusion-like bodies are mixed in with the biotitic, subgranitic gneisses.

Irregular, dyke-like bodies of dark grey, dioritic to gabbroic rock, in some cases schistose, occur at widely scattered localities. These bodies, usually conforming to the local structural trend, are evidently synkinematic structures.

Diabase or basalt dykes definitely of post-kinematic origin were found in the northern part of the east coast and on the south coast of Devon Island. Most of these dykes are less than 40 feet wide. A tabular intrusion of coarse-grained gabbro on the south coast is about 1/4 mile wide. Dykes of this type were found both conforming to and crosscutting the local structural trends.

Several flat-topped hills resembling monadnocks form a distinctive physiographic feature of Philpots Island. The hills are elongate with an easterly trend, and stand up to about 600 feet above the surrounding Precambrian lowland. The hills are entirely Precambrian rock. They appear to be glaciated, the tops probably remnants of an elevated, near-planar physiographic surface.

A positive Bouguer anomaly of 100 milligals has been found at Cape Sherard by the Gravity Division of the Dominion Observatory. The shape and exact location of this anomaly are uncertain because gravity mapping is incomplete, but there is no doubt about its substantial size. No unusual rocks were found at Cape Sherard, and the northeast structural trend there is compatible with the regional trends. Dips of gneissossity vary from southeast to northwest, but variability of both trend and dip is characteristic of much of the south coast of the island.

A 45-degree deflection of the compass needle was observed both in 1968 and 1969 at the mouth of a small, north-trending valley about 4 miles east of Cape Newman Smith, on the north coast of Devon Island. A strong, local distortion of the magnetic field is suggested, but again, the exposed rocks are evidently typical of the region.

128. TRIASSIC STRATIGRAPHY, PINE PASS REGION, NORTHEASTERN BRITISH COLUMBIA (93 O, 94 B)

Project 680084

D. W. Gibson

In 1969, field work consisted of detailed measuring and sampling of several stratigraphic sections in the vicinity of Pine Pass on the John Hart Highway, between Peace and Sukunka rivers in northeastern British Columbia. This investigation, part of a continuing project and a phase of Operation Smoky, is an extension of work begun in the summer of 1968.

In the Foothills Region, between Peace River and the Hart Highway, Triassic strata have been divided tentatively into five map-units which are, in ascending order: (1) Toad-Grayling Formation, (2) Liard Formation, (3) 'Grey Beds', (4) Pardonet Formation, and (5)'post-Pardonet Beds'. A brief description of these lithostratigraphic units has been published[1].

Most of the above units can be recognized and extended into the Foothills Region south of Hart Highway, at least as far as Sukunka River. However, facies changes are apparent between the two regions. South of Hart Highway, Unit 1 (Toad-Grayling Formation), consisting of dark brown- to black-weathering siltstone, limestone, and minor sandstone, can be divided readily into two distinct members. The lower member consists of very dolomitic siltstone, silty shale, and minor limestone, whereas the upper member consists of very calcareous siltstone, and silty limestone. The contact between these two lithofacies is conformable and distinct, and corresponds to the contact between the Vega Siltstone and Whistler members of the Sulphur Mountain Formation in the Jasper-Banff Region of Alberta[2]. Furthermore, at some sections the lower member of Unit 1 may be divided into two subfacies, corresponding to the Vega and Phroso Siltstone members of the Sulphur Mountain Formation in the Jasper-Banff Region. The contact between these two subfacies is gradational and placed only with difficulty. These lithostratigraphic divisions in Unit 1 are not recognizable north of the highway. Units 2 and 3, consisting of brown- and grey-weathering sandstone, siltstone, and limestone, and grey- to buff-weathering dolomite, siltstone, sandstone, and limestone respectively, are similar between the two regions north and south of Hart Highway. However, the twofold subdivision noted in Unit 3[2] north of the highway is less apparent although still present to the south, at least as far as Burnt River. Unit 4 (Pardonet Formation) was observed at only one locality south of the highway. It consists of massive to platy-weathering, silty limestone, bioclastic limestone, and carbonaceous siltstone. Unit 4 thins and disappears to the south and east, such that the overlying Jurassic Fernie Formation rests unconformably on the limestones and dolomites of Unit 3. Unit 5, a light grey- to white-weathering limestone facies recognized north of the Hart Highway and south of Peace River, was not observed to the south. It, therefore, has a limited areal distribution. At Pine River bridge on the Hart Highway, the Jurassic Fernie Formation rests unconformably on Unit 4 (Pardonet Formation) and Unit 5 is absent.

[1] Gibson, D.W.: Triassic stratigraphy of the Rocky Mountain Foothills, northeastern British Columbia; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 235-236 (1969).

[2] Gibson, D.W.: Triassic stratigraphy between the Athabasca and Smoky Rivers of Alberta; Geol. Surv. Can., Paper 67-65 (1968).

129. MESOZOIC STRATIGRAPHY OF NORTHERN AND EASTERN PARTS OF VANCOUVER ISLAND, BRITISH COLUMBIA (92 E, F, L, 102 I)

Project 670064

J.A. Jeletzky

About two and one-half weeks in July and August 1969 were spent in the study of Mesozoic sections of northern and eastern parts of Vancouver Island. The following results were obtained.

Nanaimo Group of Comox area

Trent River Section

Typical representatives of Pachydiscus (Canadoceras) newberrianus (Meek) were found at GSC loc. 60845 near the top of upper Trent River shale (=Cedar District Formation) in its Trent River section. This confirms the previously suggested (ref. 1, p. 45, Table 2) correlation of the upper Trent River shale with the Cedar District Formation of Nanaimo Basin and Sucia Island.

The upper Trent River shale extends upstream for 850 to 900 yards past the mouth of Bloedel Creek. At the latter point it overlies gradationally the 18 to 40+ feet thick 'Tsable River conglomerate' (ref. 1, p. 45, Table 2). This unit consists of fine to coarse pebble-conglomerate rich in sandy to silty matrix and, in places grading into pebbly mudstone. 'Tsable River conglomerate' (=Extension Formation) overlies discordantly the deeply eroded surface of the lower Trent River shale (Pachydiscus perplicatus beds of Inoceramus naumanni zone). Angular discordance of 10 to 15 degrees was measured at this contact in the left bank of Trent River where 'Tsable River conglomerate' overlaps a northwest-trending anticline of the lower Trent River shale. This fact and the presence of an adjacent broadly synclinal structure containing lower Trent River shale beneath the overlapping 'Tsable River conglomerate' indicate the occurrence of a pre-upper Trent River (i.e. early Campanian) orogenic phase in the Comox Basin at least.

Metaplacenticeras sanctaemonicae fauna was found at Usher's (ref. 2, p. 106) fossil locality 107 (GSC loc. 83909) near the visible base of the Denman Island section of the upper Trent River shale. The basal beds of this section are, therefore, younger than the topmost beds of the Trent River section (i.e. GSC loc. 60845) and are correlative with the upper part of the Cedar District Formation (Metaplacenticeras cf. pacificum subzone) of the Nanaimo Basin. The younger part of Denman Island section of the upper Trent River shale has yielded only Baculites chicoensis Gabb sensu Usher, 1952 and Schlueteria selwyniana. It is placed tentatively in the Metaplacenticeras cf. pacificum subzone.

Quatsino Sound

Jeune Landing area

Baculites cf. chicoensis Gabb sensu Usher, 1952 was found in unit 2 of the Nanaimo Group section (ref. 3, p. 127) occurring in headwaters of Lippy and Kwokwesta creeks 2 1/2 to 3 miles north of Jeune Landing. This suggests that the Nanaimo Sea only flooded the Neroutsos Inlet area in the early Cedar District time (i.e. Hoplitoplacenticeras vancouverense time).

The rhyolite of unit 1 of the same section was found to be a sill, 15 to 20 feet thick, overlain by at least 250 feet of Nanaimo Group greywacke (top concealed near the top of the slope).

The Bonanza Group section beneath the Cretaceous rocks consists of at least 150 feet (top concealed) of greenish grey, mostly coarse, waterlain volcanic breccia and pebble to boulder volcanic conglomerate of the Waterlain Breccia unit of the Volcanic Division interbedded with and laterally replaced by coarse-grained, spherically and locally pillow-like weathering, augite porphyry (lava flows?). This Waterlain Breccia unit overlies, apparently disconformably, at least 250 feet of upper Norian, fine- to medium-grained, in places tuffaceous, and locally gritty and pebbly greywacke interbedded with considerable amounts of argillite and impure limestone near the top and visible base of the unit. The following fauna (identified and dated by E. T. Tozer) was found in this section. The topmost 20 feet contain a species of Monotis (GSC locs. 83930 and 83910) which is almost certainly of an Upper Norian age. Monotis salinaria Brown abounds in the interval 20 to 200 feet below the top (GSC locs. 83911, 83913, 83912, 83917, 83916, 83915, 83914). The basal 25 feet have yielded only a poor Sagenites - like ammonite (GSC loc. 82960) and poor Monotis - like shell fragments (GSC loc. 83919) that are probably Upper Norian.

The Sutton limestone is absent in this section in spite of its widespread occurrence in a similar stratigraphic position on the west side of Neroutsos Inlet on Drake Island. The Monotis - bearing Upper Norian rocks of Jeune Landing area appear to be an arenaceous eastern facies of the Sutton limestone of Quatsino Sound (Upper Suessi zone according to E. T. Tozer; see GSC loc. 24333).

North shore of main Quatsino Channel

A Cenomanian (earliest Upper Cretaceous) marine fauna including Desmoceras (Pseudouhligella) ex aff. ezoanum Matsumoto, Baculites

(Sciponoceras) n. sp. ex aff. kossmati (Nowak), Eogunnarites sp. indet. and Inoceramus ex aff. I. crippsi Mantell (GSC loc. 83932) was found in the conglomeratic interbeds occurring at the base of the 'Upper Shales' of Dawson (ref. 4, p. 88B). This fauna, found about 600 feet west-southwest of the mouth of Bish Creek, indicates that the underlying (contact covered) more than 2,000-foot-thick Aptian conglomerate unit (ref. 5, pp. 72, 73) may include rocks of Albian age. Alternatively, the Albian time may be represented only by the inferred unconformity between the Aptian and (?)Albian conglomerate unit and the Cenomanian (and ?later) 'Upper Shales'. Whichever hypothesis applies, the sea apparently did not reinvade the northern part of Vancouver Island until Cenomanian time.

Northern End of Vancouver Island

Lower Cretaceous outlier at Christensen Point

The central part of the outlier including the tip of Christensen Point was found to consist of a plug- or (?)dyke-like intrusive body, several hundred yards wide, composed of granodiorite to (?)diorite porphyry. This intrusive has apparently destroyed the contact between the Barremian greywacke unit to the east, which is at least 1,000 feet thick, and the badly faulted and contorted variegated clastic rocks to the west, which are at least 200 feet thick. The latter consist of calcareous and sandy siltstone with numerous interbeds and pods of calcareous greywacke, grit and mostly fine pebble-conglomerate. No diagnostic fossils were found in these predominantly marine, southwest-dipping, rocks on the west side of Christensen Point. However, these variegated beds are believed to be Cenomanian rather than Barremian in age because of their lithological similarity to the reliably dated (see in previous section) arenaceous to conglomeratic basal beds of the 'Upper Shales' exposed in Quatsino Sound, and because of the gradational contact with the overlying late Cenomanian (or ?basal Turonian), medium grey to dull brown shale and siltstone. The latter unit is equivalent to the upper part of the 'Upper Shales' and to the shale-siltstone unit (at least 1,000 feet thick) of the western limb of the outlier (ref. 3, pp. 130, 131) which was tentatively dated as of Albian or (?)Cenomanian age.

The shale-siltstone unit of Christensen Point syncline is at least 1,500 feet thick on the eastern limb. This unit has a general southwesterly dip and is commonly distorted. Tetragonites ex aff. T. jacksonense Anderson (GSC locs. 83927, 83926) and Eucalycoceras? ex aff. shastense Reagan (GSC loc. 83229) of late Cenomanian or (?)basal Turonian age were found in the middle third of the unit but its lower and upper thirds did not yield any diagnostic fossils.

Approximately 1,400 yards east of the mouth of Laura Creek this shale-siltstone unit is overlain, apparently conformably, by at least 100 feet of dark grey, friable, flaky-weathering siltstone commonly containing specifically indeterminate, concentrically ribbed Inoceramus shells and fragments. This considerably faulted and dyke-infested siltstone unit appears to be synclinally bent within the next 500 yards along the shore. A Turonian age is suggested for this Inoceramus - bearing siltstone unit because of its apparently gradational relationships with the underlying Cenomanian shale-siltstone unit. The top of this siltstone unit is not reached in the axis of Christensen Point syncline.

The Cenomanian shale-siltstone unit reappears west of the Inoceramus-bearing siltstone outcrops at a point about 900 yards east of the mouth of Laura Creek. Farther west this unit outcrops continuously with prevalent northeasterly to northerly dips. Those outcrops, just east of the mouth of Laura Creek, were studied previously (ref. 3, pp. 130, 131).

Northeast Coast of Vancouver Island

Nanaimo Group of Suquash Basin

Contrary to previous estimates, the exposed thickness of the basal coarse-grained greywacke unit underlying the fossiliferous greywacke bed with Inoceramus subundatus Meek, etc. (GSC loc. 82952; see ref. 3, p. 132), does not exceed 340 feet. The base of the unit is concealed (faulted?) and it may be repeated in part by at least two west-trending faults of which the direction and amount of displacement are unknown.

The upper part of the richly fossiliferous, calcareous greywacke bed (GSC loc. 82952) has yielded Baculites chicoensis Gabb sensu Usher, 1952 (GSC locs. 83923, 83922) in addition to numerous pelecypods and gastropods. The bed is about 50 feet thick. This confirms the previously suggested (ref. 3, p. 132) correlation of the Basal greywacke unit with the lower part of the Cedar District Formation (i.e. Hoplitoplacenticeras vancouverense zone) of Nanaimo Basin and Sucia Island. The fossiliferous bed (GSC loc. 82952) is flexed in a number of small, east-west trending, gentle folds for about 3/4 of a mile southwest of its first appearance. It gradually becomes more coarse-grained, gritty and pebbly in this direction. At the point about 3/4 of a mile northwest of the mouth of Koegh River, marine fossils disappear from the coarse-grained, gritty and pebbly facies (beach deposits?) of bed 82952 and are replaced by fossil wood, carbonized plant fragments and some 1-inch to 4-inch thick inclusions and lenses of impure coal. Like its marine facies, this nonmarine facies of bed 82952 is flexed into a number of small and gentle east-west trending folds and continues to outcrop to the mouth of Keogh River. Within the last few hundred feet before the mouth of Keogh River the non-marine facies interfingers with strongly and intricately crossbedded and ripple-marked subgreywacke and (?)arkose of deltaic type previously believed to overlie it (ref. 3, pp. 132, 133). The younger beds of this Variegated sandstone unit begin to outcrop in the bed of Koegh River where the top of the nonmarine equivalent of bed 82952 finally plunges beneath the sea.

About 250 feet of the Variegated sandstone unit outcrop on the seashore between the mouth of Keogh River and the base of the Metaplacenticeras occidentale siltstone (ref. 3, p. 133) and its total thickness (including non-marine equivalent of bed 82952) does not exceed 300 feet.

The discovery of Metaplacenticeras sanctaemonicae fauna near the base of the Denman Island section of Trent River shale (see in the previous section) seems to favour the correlation of the Metaplacenticeras occidentale siltstone with the upper part of the Trent River shale (i.e. with the upper part of Cedar District Formation) rather than the previously proposed correlation (ref. 3, p. 133) with the lower Lambert and the lower Northumberland formations of the Comox and Nanaimo basins.

No outcrops of the Metaplacenticeras occidentale siltstone were found between 1/4 and 3/8 of a mile above the mouth of Keogh River. Poor outcrops of unfossiliferous siltstone occurring in this interval were found to be of Pleistocene age when studied in detail at an exceptionally low water level. The holotype of Metaplacenticeras occidentale must, therefore, have been found in younger beds outcropping farther upstream. Because no intercalated marine beds are known in the Bluish-grey, coarse- to fine-grained, hard greywacke unit (ref. 3, p. 133), it could have been found in the Upper siltstone unit outcropping on the second right confluent of Keogh River as suggested by J. E. Muller (written communication of January 21, 1969). The two upper units of the Suquash Basin succession (ref. 3, p. 133) may be, therefore, still in the Metaplacenticeras pacificum zone. Their previously suggested correlation with the upper part of Northumberland and the lower part of the upper Lambert Formations appears to be unnecessary.

Only about 150 feet of fine- to coarse-grained greywacke and (?)arkose containing numerous intercalated beds of coaly siltstone and some 1- to 4-inch-thick pods and lenticular interbeds of impure coal, outcrop on the seashore in the interval 7/8 of a mile to 2 1/8 miles southwest of the mouth of Keogh River. These synclinally bent rocks appear to represent the upper part of the Bluish-grey, coarse-grained greywacke unit of Keogh River section (ref. 3, p. 133). No outcrops of the Upper siltstone unit have been observed but it may be concealed in the completely covered interval of the shoreline, more than 1,200 feet wide, in the syncline's axis. This shallow, approximately east-west trending syncline, is complicated by a few east-west to northwest-trending, minor folds and disrupted by east-west trending faults with undetermined direction of movement and displacement. The northern side of the major east-west trending fault limiting this synclinal structure from the north is believed to be relatively upthrown. Another major, southeast-trending fault is believed to limit this synclinal structure to the south. This fault appears to cut into the shore about 1 mile northwest of False Head, to follow the bed of an unnamed, minor creek for about 1 1/2 miles upstream, and then to cut across the adjacent part of the Keogh River bed. The southeastern side of this fault appears to be relatively upthrown because the Nanaimo rocks outcropping southeast of it (i.e. between the nameless creek concerned and Port McNeill) are lithologically unlike those of the Bluish-grey, coarse-grained greywacke unit, but resemble closely those of the Basal coarse-grained greywacke unit.

The synclinally bent rocks of the Bluish-grey, coarse-grained greywacke unit of the above described seashore section and their equivalents in the Keogh River section (ref. 3, p. 133) appear to be confined to a graben in the middle part of Suquash Basin.

No intercalated marine beds were seen in the apparent equivalents of the Basal coarse-grained, greywacke unit in the relatively upthrown southern part of Suquash Basin. Those rocks are flexed in a considerable number of minor, mostly east-west to northwest-southeast trending, gentle folds that are probably related (pressure ridges?) to several major, east-west to northwest-southeast trending faults disrupting the rocks. Progressively older beds of the unit appear to come to the surface in the southeasterly direction in spite of the apparent absence of an overall synclinal structure in this part of the basin. This gradual wedging out of the Basal coarse-grained greywacke unit appears to be caused by a progressively stronger relative upthrow of the individual fault blocks in the southeasterly direction.

The observed disappearance of marine interbeds toward the southeast and the prevalence of northwest-dipping foreset beds in the Nanaimo rocks of Suquash Basin suggest that the sea advanced from the north or northwest and did not penetrate beyond False Head and the middle course of Keogh River. These observations support Sutherland Brown's (ref. 6, Figs. 6-7) idea about the continuous presence of a wide isthmus separating the Suquash-Neroutsos Inlet embayment of the Nanaimo Sea from its southern (Oyster River-Texada Island) embayment.

---

[1] Müller, J.E. and Jeletzky, J.A.: Stratigraphy and biochronology of the Nanaimo Group, Vancouver Island and Gulf islands, British Columbia; in Report of Activities, Part B, November 1966 to April 1967; Geol. Surv. Can., Paper 67-1, Pt. B (1967).

[2] Usher, J.L.: Ammonite faunas of the Upper Cretaceous rocks of Vancouver Island, British Columbia; Geol. Surv. Can., Bull. 21 (1952).

[3] Jeletzky, J.A.: Mesozoic and Tertiary stratigraphy of northern Vancouver Island (92 E, 92 L, 102 I); in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A (1969).

[4] Dawson, G.M.: Report on a geological examination of the northern part of Vancouver Island and adjacent coasts; Geol. Surv. Can., Ann. Rept. 1886, Pt. B (1887).

[5] Jeletzky, J.A. and Tipper, H.W.: Upper Jurassic and Cretaceous rocks of Taseko Lakes map-area and their bearing on the geological history of southwestern British Columbia; Geol. Surv. Can., Paper 67-54 (1968).

[6] Sutherland Brown, A.: Tectonic history of the Insular Belt of British Columbia; in Tectonic history and mineral deposits of the Western Cordillera; Can. Inst. Mining Met., Special vol. 8, pp. 83-100 (1966).

---

130. LOWER CRETACEOUS AND LATE UPPER JURASSIC BIOCHRONOLOGY AND FACIES OF MANNING PARK AREA, BRITISH COLUMBIA (92 H)

Project 670064

J. A. Jeletzky

In August 1969, ten days were spent in the detailed paleontological-stratigraphical study of some Lower Cretaceous and late Upper Jurassic

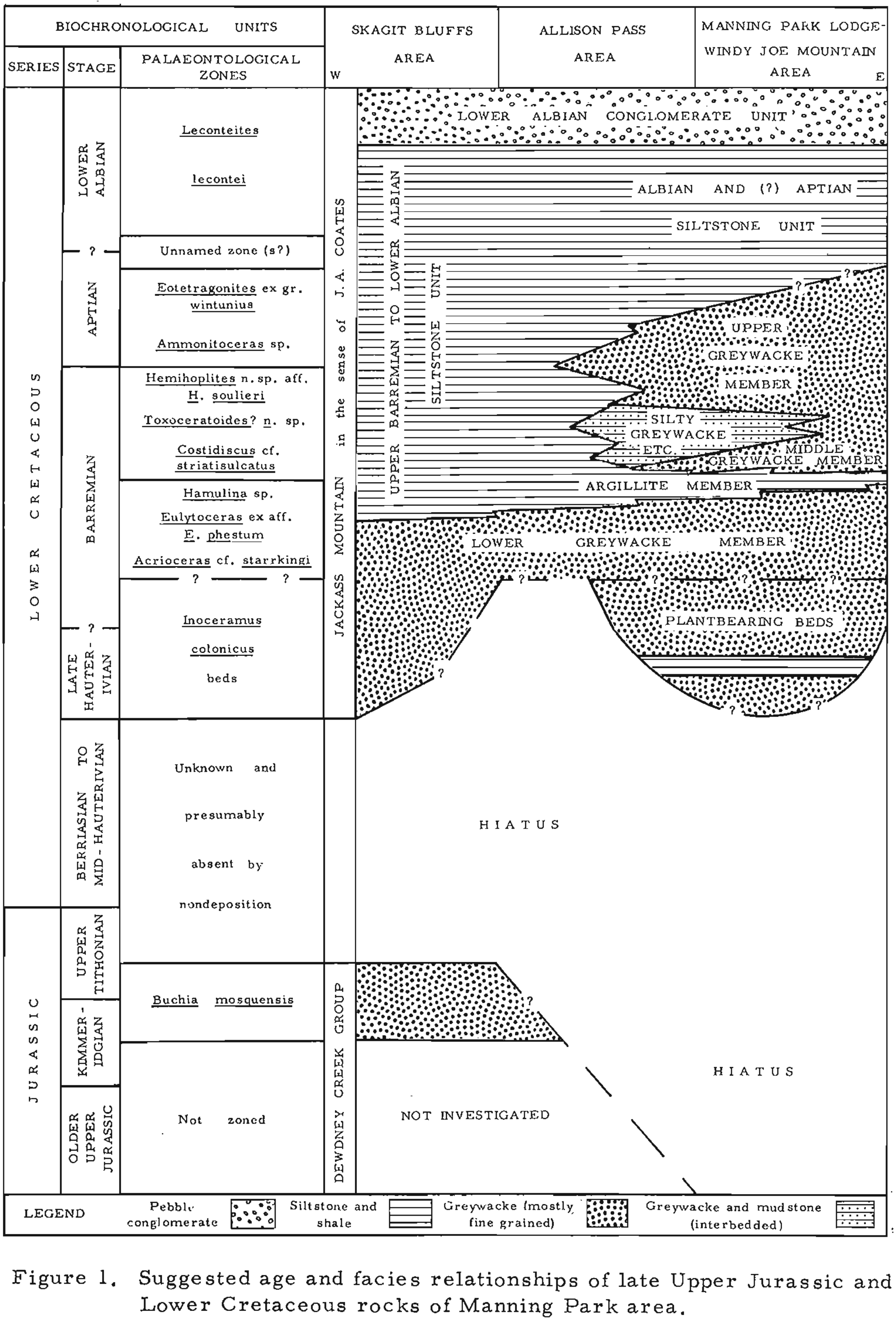


Figure 1. Suggested age and facies relationships of late Upper Jurassic and Lower Cretaceous rocks of Manning Park area.

sections discovered by the late J.A. Coates (refs. 1, 2, 3 and unpubl. data) in the Manning Park area of the eastern Cascade Mountains. The following results were obtained.

Lookout Road North of Manning Park (=Pinewoods) Lodge and Windy Joe Mountain

Neocomian? nonmarine greywacke

The Cretaceous succession is assumed to begin with the plant-bearing, presumably nonmarine greywacke assigned a Neocomian? age by J.A. Coates (unpubl.). All observed contacts of this unit appear to be faults but it is believed to underlie conformably the marine middle Barremian rocks and to be equivalent to the late Hauterivian to ?early Barremian Inoceramus colonicus beds of more easterly and southeasterly sections (see below and Fig. 1).

Marine Barremian to Aptian unit

Lower greywacke member This member consists of at least 295 feet of light green-grey, mostly fine-grained, commonly silty greywacke. Some interbeds of medium- to coarse-grained, gritty and pebbly greywacke occur in the upper 65 feet of the member. Numerous intercalated beds of similarly coloured, massive-looking mudstone and some beds of fissile, pure shale occur throughout the member. The base is invariably covered. The upper contact is abrupt but apparently comformable.

No fossils were found in the basal 130 feet of the member but its upper 65 feet have yielded a diagnostic Barremian fauna including (GSC locs. 83941, 83942): Partschiceras infundibulum (d'Orbigny), Hypophylloceras? sp., Eulytoceras ex aff. E. phestum Matheron, Hamulina sp., Hoplocrioceras sp. indet., Acrioceras cf. starrkingi Anderson, Shasticrioceras ex gr. pontiente Anderson, Lythancylus? n. sp., Boreioteuthis ex gr. impressa (Gabb), Quoiecchia ex gr. aliciae Crickmay. This fauna is tentatively placed in the middle part of the Barremian because of its stratigraphic position and the absence of all diagnostic upper Barremian cephalopods which dominate the fauna of the overlying members of the unit. E. ex aff. E. phestum, Acrioceras cf. starrkingi, and Hamulina sp. appear to be diagnostic of this fauna.

Argillite member This member consists of dark grey, dark brown-weathering, locally silty or sandy argillite with 6- to 10-inch-thick, concretionary bands and concretions of rusty-weathering impure limestone. Partial sections of this member are up to 155 feet thick and its total thickness is believed to be in the order of 400 feet. The contact with the overlying Middle greywacke member was not seen.

The Argillite member has yielded the writer only (GSC loc. 83943) Boreioteuthis n. sp. as well as nondiagnostic pelecypods and gastropods. J.A. Coates, however, found some large Ancyloceras-like ammonites (GSC loc. 62321) suggestive of its late Barremian age.

Middle greywacke member This member consists of ash grey, brownish grey-weathering, mostly fine-grained and massive-looking greywacke with minor amounts of dark grey mudstone and fine pebble-conglomerate rich in granitic pebbles. The longest partial section exposes about 180 feet of the member but its total thickness is believed to be in the order of 250 feet. The lower contact was not seen. The contact with the overlying Silty greywacke-sandy mudstone member is conformable and apparently gradational in spite of the presence of lenticular, gritty to conglomeratic interbeds.

Only very rare nondiagnostic pelecypods have been seen in the Middle greywacke member.

Silty greywacke-sandy mudstone member This member is characterized by interbedded, irregular, but mostly thin (1- to 10-inch) beds of dark grey to dark brown-grey weathering, fine- to very fine grained, more or less silty, friable greywacke with similarly coloured, sandy to very sandy mudstone containing some inclusions of orange-weathering, ferruginous mudstone. The thickness of this member varies from 76 to 97 feet in the best exposed complete sections studied. The upper contact appears to be gradational.

The member is notable for its large content of small fragments of fossil wood and comminuted plant remains. However, it contains rare marine pelecypods, gastropods, and ammonites at most levels. Most of the fossiliferous beds occur in the basal 8 to 10 feet and also in the middle part of the member (GSC locs. 83933, 83945, 83950 and 83951. These have yielded: Partschiceras infundibulum (d'Orbigny), Hypophylloceras? sp., Lytoceras spp., rare Eotetragonites ex gr. wintunius (Anderson), Hemihoplites n. sp. ex aff. H. soulieri (Matheron), Shasticrioceras ex gr. pontiente Anderson, Toxoceratoides? n. sp., Hoplocrioceras? sp., Boreioteuthis ex gr. impressa (Gabb), Quoiecchia ex gr. aliciae Crickmay, Heterotrigonia? ex gr. newcombei Packard, neritid gastropods, nerineid gastropods and irregular echinoids. This fauna is placed in the late Barremian in spite of the presence of Eotetragonites ex gr. wintunius (Anderson) (see below).

Upper greywacke member This member consists of at least 400 feet of light to medium grey, brownish grey-weathering, fine- to coarse-grained, hard, resistant greywacke. Numerous intercalated beds of gritty and pebbly greywacke, fine to coarse grit, and fine pebble-conglomerate occur in the intervals 160 to 195 feet and 250 to 262 feet above base of the member. Less numerous beds of pebbly and gritty, coarse-grained greywacke occur in its basal 8 to 10 feet. Rare 1- to 5-foot-thick beds of silty, fine-grained greywacke or very sandy mudstone were seen locally.

Only the lower 262 feet of the Upper greywacke member are exposed on Lookout Road. The Aptian part of the member, at least 130 feet thick, was seen only on the eastern slope of Windy Joe Mountain.

The contact with the overlying Lower Albian shale was not seen in any of the studied sections and the complete thickness of the Upper greywacke member may exceed 400 feet.

At most levels marine fossils are either absent or occur rarely. Small to large wood fragments and comminuted plant debris are, in contrast, abundant in most beds. Several 1- to 6-inch-thick beds of coquina, replete in marine fossils, are scattered throughout the member. It seems likely that the member consists largely of beach to lagoonal deposits interfingered with a smaller number of marine deposits.

The marine fauna occurring in the lower 204 feet of the member appears to be quite uniform and almost identical with that of the underlying Silty greywacke-sandy mudstone member. It includes (GSC locs. 83935, 83936, 83946, 83947, 83948, and 83956); Partschiceras infundibulum (d'Orbigny), Hypophylloceras cf. onoense (Stanton), Lytoceras sp. ind., Eulytoceras sp. indet., Eotetragonites ex gr. wintunius (Anderson), Aconeceras sp. indet., Hemihoplites n. sp. aff. H. soulieri (Matheron), Shasticrioceras cf. hesperium Anderson, S. ex gr. pontiente, Hoplocrioceras? sp. indet., Hemibaculites? sp. indet., Ancyloceras? ex aff. durrelli Anderson, Costidiscus cf. striatisulcatus (d'Orbigny), Toxoceratoides? n. sp., genus novum aff. Dissimilites Sarkar, 1954, Quoiecchia ex gr. aliciae Crickmay (in lower 130 feet only?), Heterotrigonia? ex gr. newcombei (Packard), Yaadia cf. lewisagassizi Crickmay, nerineid gastropods, neritid gastropods, naticid gastropods, and irregular echinoids.

The presence of Hemihoplites n. sp. aff. H. soulieri, Hemibaculites? sp. indet., Costidiscus cf. striatisulcatus and Quoiecchia ex gr. aliciae indicates a late Barremian age for the Upper greywacke member. It is placed tentatively in the late (latest?) Barremian zone of Hemihoplites n. sp. aff. H. soulieri together with the underlying Silty greywacke-sandy mudstone member (Fig. 1). Eotetragonites ex gr. wintunius (Anderson) appears to be a long-ranging species group beginning in the late Barremian and ranging through the Aptian.

The upper 196 feet or more of the Upper greywacke member have yielded only long-ranging marine pelecypods and gastropods. Because of their stratigraphic position these beds are correlated with the Aptian part of the Upper Barremian to Lower Albian siltstone unit of Allison Pass and Skagit Bluffs (Fig. 1).

Lower Albian and (?)Aptian siltstone unit

The Upper greywacke member is overlain by at least 700 feet of dark grey to black, brownish grey-weathering, micaceous, mostly silty shale with numerous intercalated beds of lighter grey, greenish tinged, more or less sandy siltstone and minor amounts of fine-grained greywacke. Concretionary bands and scattered concretions of hard, impure limestone and calcareous siltstone abound locally. The lower contact was not seen. The contact with the overlying Lower Albian conglomerate unit is abrupt but relatively even.

The early Lower Albian Leconteites lecontei (Anderson) fauna occurs 175 feet below the top of the unit in the Lookout Road section (GSC loc. 83993). Poor ammonites, including indeterminate phylloceratids and lytoceratids and some forms similar to Leconteites ex gr. lecontei (Anderson), were found several hundred feet down section in the interval 185 to 245 feet stratigraphically above its visible base (GSC locs. 83936, 83940, 83937). No fossils were found in other sections of the unit.

An interval, several hundred feet wide and almost completely covered, separates the visible base of the Lower Albian and (?)Aptian siltstone unit from the top of adjacent exposures of the Upper greywacke member in the Lookout Road section. The complete thickness of this unit may, therefore, reach 1,000 feet. It is possible that the unfossiliferous or concealed lower part of the unit is older than the early Lower Albian *Leconteites lecontei* zone, and contemporary with the Aptian part of the Upper Barremian to Lower Albian siltstone unit (*see* below).

Lower Albian conglomerate unit

A thick unit of predominantly coarse (pebbles 2 to 7 inches across predominate) pebble-conglomerate overlies the Lower Albian and (?)Aptian siltstone unit in all sections studied. This hard, ridge-forming conglomerate unit includes numerous interbeds of fine to medium (1 1/4- to 2-inch pebbles predominate) or cobble (9- to 12-inch pebbles predominate) conglomerate; it includes, also, beds up to 50 feet thick of fine- to coarse-grained, often gritty and pebbly greywacke, and of dark grey to black siltstone and shale. The well to moderately rounded pebbles are closely packed and surrounded by sandy to gritty matrix. Granitic pebbles predominate but various volcanic and chert pebbles are common. No complete sections of the Albian conglomerate unit were seen and its upper contact was not reached. However, its total thickness reaches 2,000 feet in the Lookout Road-Windy Joe Mountain area according to Coates (ref. 1, p. 55).

Ammonites closely resembling *Cleoniceras* (Grycia?) *perezianum* (Whiteaves) or the strongly ribbed variant of *Brewericeras hulenense* (Anderson) have been found by J.A. Coates (GSC loc. 61139) stratigraphically above the Albian conglomerate units in a nameless creek canyon entering Similkameen River from the south, south of the Administration Building of Manning Park Lodge. *Leconteites* cf. *lecontei* (Anderson) and *Aucellina* aff. *gryphaeoides* (Sowerby) have been found (GSC loc. 74807) 130 feet stratigraphically above the top of the unit on the mountain spur between Buckhorn and Gambie creeks. The conglomerate unit is, therefore, early lower Albian in age.

Skagit Bluffs-Allison Pass Area

Unlike the Lower Cretaceous rocks of Lookout Road-Windy Joe Mountain area (i.e. east flank of synclinorium of J.A. Coates; *see* ref. 1, p. 55), those of the Skagit Bluffs-Allison Pass area are largely represented by poorly fossiliferous, dark grey siltstones with minor interbeds of fine-grained, silty greywacke. Only the Lower greywacke member of the Barremian to Aptian marine unit retains its characteristic lithology throughout the investigated part of the western flank of the synclinorium (Fig. 1). Another distinctive feature of the west flank is the presence of marine Upper Jurassic rocks beneath the Lower greywacke member (ref. 3, p. 43, Fig. 6). The marine, Upper Jurassic rocks are completely absent and apparently were never deposited on the eastern flank of the synclinorium (ref. 3, l. cit.; this paper Fig. 1).

Upper Jurassic marine rocks

This unit was studied only at the eastern end of Skagit Bluffs in the road-cuts of Hope-Princeton highway. In this section it is several hundred feet thick and consists of dull to bluish grey, laminated to very thinly bedded, very fine grained, hard and dense, quartzite-like greywacke which often grades laterally into very sandy siltstone. This unit is interbedded with considerable amounts of very hard, cherty siltstone and minor amounts of medium- to coarse-grained greywacke, grit and fine to coarse pebble-conglomerate. The greywacke unit is underlain, apparently conformably, by a great thickness of dull blue to dark grey, laminated to thinly bedded, hard and dense, mostly cherty argillite with some beds of coarse clastics. This older Upper Jurassic (and older?) unit was not studied in any detail.

Middle to late Kimmeridgian forms of Buchia mosquensis (Buch), Cylindroteuthis (Cylindroteuthis) sp. indet. and perisphinctid ammonites were collected 4 1/2 to 5 feet (GSC loc. 83953) and 40 feet (GSC loc. 83954) stratigraphically below the assigned top of the Upper Jurassic marine rocks.

In the Skagit Bluffs section the contact of the Upper Jurassic marine greywackes with the overlying, lithologically similar greywackes of the Lower greywacke member appears to be a fault of unknown displacement striking toward the north and dipping 75 to 80 degrees east. However, marine fossils of the late upper Tithonian (Buchia piochii zone) to mid-Hauterivian (Hollisites-Speetoniceras zone) age are invariably absent in the numerous fossil collections of J.A. Coates on the western flank of the synclinorium and the late Hauterivian to Barremian fossil localities are often situated next to those of Buchia mosquensis and Buchia cf. blanfordiana zones. This suggests the unconformable overlap of the early upper Tithonian (Buchia cf. blanfordiana zone) by the late Hauterivian or early Barremian rocks. The late upper Tithonian to mid-Hauterivian marine rocks, which are widespread in the western and northern parts of Tyaughton Trough (ref. 4, pp. 64-69), apparently were not deposited on the western limb of the Manning Park synclinorium because the Lower Cretaceous sea only flooded the area in late Hauterivian or (?)early Barremian time.

Marine ?late Hauterivian to Lower Albian rocks

Lower greywacke member So far as known, the Lower greywacke member of the western flank of the Manning Park synclinorium only differs from its previously described equivalent on the eastern flank in the considerably greater amount of secondary induration and silicification. About 280 feet of the member are exposed in the faulted Skagit Bluff section but its complete thickness may be in excess of 400 feet judging by less disturbed but incomplete sections measured by J.A. Coates (unpubl.) and the writer on the upper slopes (elevation 4, 800 to 5, 000 feet) of Skagit River valley north and northeast of Skagit River campsite.

The contact with the underlying Upper Jurassic marine rocks was not seen but is believed to be unconformable for previously given reasons. The contact with the overlying Upper Barremian to Lower Albian siltstone unit is conformable and gradational.

The upper part of the Lower greywacke unit (uppermost 100 feet?) is characterized by the common presence of Eulytoceras ex aff. E. phestum (Matheron), Lythancylus n. sp., Boreioteuthis ex gr. impressa (Gabb), and Quoiecchia ex gr. aliciae Crickmay (GSC locs. 83952, 67923, 67921, and 69345). This fauna is equivalent to that occurring in the uppermost 65 feet of the member on the east limb of the synclinorium.

Some other fossil localities (e.g. GSC loc. 67922) have yielded a different fauna including Crioceratites (s. lato)? sp. indet., Hoplocrioceras?

sp. indet., Acroteuthis? sp. indet., Inoceramus colonicus Anderson, I. cf. ovatus Stanton, Neritina? sp. indet. and other long-ranging pelecypods and gastropods. This Inoceramus colonicus fauna (Fig. 1) is widespread on the western flank of the Manning Park synclinorium. So far as known (ref. 4, pp. 9, 72), I. colonicus ranges through most of the Hauterivian and into the Lower Barremian stage. However, the affinities of ammonites associated with it at GSC loc. 67922 suggest a late Hauterivian to (?)early Barremian age for this fauna. The stratigraphical analysis of fossil localities of the late J.A. Coates and personal observations of the writer agree with this suggestion as the Inoceramus colonicus fauna appears to be largely confined to the basal beds of the Lower greywacke member underlying those with Eulytoceras ex. aff. E. phestum.

No traces of Inoceramus colonicus fauna have been found by J.A. Coates and the writer on the eastern slope of Manning Park synclinorium probably because of the lateral replacement of these richly fossiliferous, shallow-water marine beds by the Neocomian? nonmarine greywacke and(?) the nonfossiliferous lower part of the Lower greywacke member (Fig. 1).

Upper Barremian to Lower Albian siltstone unit The Lower greywacke member of the Skagit Bluff-Allison Pass area is overlain by a thick unit of extremely monotonous dark grey to black, sandy siltstone. This siltstone unit is apparently devoid of any prominent greywacke beds corresponding to the Middle and Upper greywacke members of the Lookout Road-Windy Joe Mountain area. Only a few beds (1 inch to a few feet thick) of dull to dark grey, fine- to very fine grained, silty greywacke were seen in this siltstone unit, except on the eastern side of Allison Pass where it seems to pass laterally into a more sandy facies.

Relatively short (as much as 1,200 feet), partial sections of the dark grey siltstone unit were measured and its complete thickness is unknown. The width of the apparently little disturbed outcrop areas of the unit between those of the Lower greywacke member below and the Lower Albian conglomerate unit above suggests, however, that it is between 2,000 and 2,500 feet thick.

Hemihoplites n. sp. aff. H. soulieri (Matheron) and Toxoceratoides? n. sp. (GSC locs. 83963, 83967, 64810, 70471, 75147) occur rarely in a thick interval (several hundred feet thick) of dark grey, mostly sandy siltstone a few hundred feet above the base of the unit. This part of the unit is, therefore, the offshore, silty facies of the upper Barremian part of the Marine Barremian to Aptian unit of the Lookout Road-Windy Joe Mountain area (Fig. 1). The argillite member of the latter unit appears to be a tongue of this siltstone facies in the predominantly littoral to nonmarine facies of the late Barremian sea on the eastern limb which reflects the farthest eastward advance of this sea.

The middle part of the unit (at least 725 feet thick) immediately overlying the Hemihoplites-bearing beds has yielded an entirely different fauna including Eotetragonites ex. gr. wintunius (Anderson), Ammonitoceras sp. indet., Aconeceras sp. indet., and a peculiar ammonite resembling Subpulchellia (GSC locs. 83958, 83959, 68697, 83965, 83968, 83972, 83966, 83971). It is devoid of all Upper Barremian ammonites such as Boreioteuthis and Trigoniidae which characterize the underlying part of the Upper Barremian to Lower Albian siltstone unit and its predominantly sandy equivalents farther east (Fig. 1). These beds are, therefore, assigned a general Aptian age and correlated with the upper part of the Upper greywacke member of the eastern limb of Manning Park synclinorium.

The Aptian part of the Upper Barremian to Lower Albian siltstone unit appears to be represented almost entirely by dark grey siltstone between Skagit Bluffs and Skaist River valley. Farther east, on the western side of Allison Pass, its upper 440 feet are largely represented by dull grey to bluish grey, brown-weathering, fine to very fine, silty greywacke laterally replacing the dark grey siltstone of the more westerly sections. This section is obviously transitional to the sections of the Lookout Road-Windy Joe Mountain area consisting largely of greywacke (see preceding section and Fig. 1).

The upper part of the dark grey siltstone unit (which is at least 500 feet thick) has yielded ammonites referable to or comparable with Leconteites lecontei (Anderson) (GSC locs. 73543, 74802, 68692, 72888 and 72890). It is, therefore, contemporary with the Lower Albian and ?Aptian siltstone unit of the eastern flank of the Manning Park synclinorium.

Lower Albian conglomerate unit

The Upper Barremian to Lower Albian siltstone unit is overlain by the Lower Albian conglomerate unit in the interval between the western side of Allison Pass and the point about 2.7 miles east of Skaist Creek bridge. The lithology and thickness of the unit in these sections do not seem to differ materially from those in the Lookout Road-Windy Joe Mountain sections (see previous section).

No sections of the Lower Albian conglomerate unit were studied west of or in the Skaist Creek valley. According to J.A. Coates (ref. 1, p. 55 and unpubl.) the unit rapidly thins westward and northward to a few tens of feet in this part of the area.

Paleogeographical and Structural Implications

The silty marine rocks of the western limb of Manning Park synclinorium are gradually replaced eastward by partly (e.g. Lower, Middle, and Upper greywacke members) or(?) entirely (e.g. Neocomian? plant-bearing unit, Lower Albian conglomerate unit) nonmarine, coarser grained clastics. This indicates that the middle to late Lower Cretaceous seas of the Manning Park area advanced from the east and/or northeast and did not penetrate far beyond the line of Lookout Road-Windy Joe Mountain.

The inferred presence of the late Hauterivian and/or early Barremian marine greywackes on the western flank of Manning Park synclinorium and their apparent replacement by nonmarine rocks on the eastern flank, suggests that the gradual advance of the middle Lower Cretaceous sea began in the late Hauterivian time. This transgression apparently continued well into late Barremian time judging by the increased ratio of siltstone and shale (Argillite and Silty greywacke-sandy siltstone members) to coarser clastics on the eastern flank during this time interval (Fig. 1).

The deposition of the latest Barremian to Aptian Upper greywacke member and the Lower Albian conglomerate unit obviously reflects strong uplifts east of the area. These uplifts have caused considerable but short-lived regressions in the Manning Park area proper. The resumption of siltstone deposition on the eastern flank of Manning Park synclinorium following these tectonic pulses indicates that they did not terminate the Lower Cretaceous transgression there, and that the latter progressed well into Albian time. The presence of Albian marine interbeds farther east in the upper part of the otherwise nonmarine Pasayten Group (ref. 2, p. 57) supports this conclusion.

There is no evidence favouring the orogenic nature of the latest Barremian or early Lower Albian tectonic movements in the Manning Park area, though the early Lower Albian uplift probably resulted in a short-lived interval of nondeposition and intense erosion.

The presence of sandy and conglomeratic interbeds in the Hauterivian-Lower Albian succession of the western flank of Manning Park synclinorium and the inferred absence of the late Upper Tithonian to mid-Hauterivian rocks there (Fig. 1) indicates that this area did not represent the central part of the Tyaughton Trough of the Western Cordillera. This circumstance and the presence of much more complete late Upper Jurassic and Lower Cretaceous sections in the Nooksack and Harrison Lake areas (ref. 4, pp. 74-75) invalidates J.A. Coates (ref. 2, p. 56) conclusion that the Jurassic-Cretaceous Basin of deposition of Manning Park area was: "a trough whose borders correspond approximately to the present map boundaries of the group". The entire Manning Park area apparently formed part of the eastern flank of the Tyaughton Trough at least in late Jurassic and early Cretaceous time (ref. 4, pp. 74-75). The present day synclinal structure of the area and the separation of the Manning Park and Harrison Lake outcrop areas of Lower Cretaceous rocks by the belt of Hosameen metamorphic rocks appear to be the result of the post-Lower Cretaceous (Tertiary?) inversion of the Tyaughton Trough. The post-Lower Cretaceous orogenic movements have strongly uplifted the central part of the trough and transformed it into a horst-like structure. This resulted in an almost complete removal of the Mesozoic sedimentary cover from this uplifted part of the trough. The Mesozoic cover was, in contrast, preserved in the relatively depressed, graben- or syncline-like, marginal parts of the trough.

---

[1] Coates, J.A.: Manning Park area, Cascade Mountains; in Report of Activities, May to October, 1965; Geol. Surv. Can., Paper 66-1, pp. 55-56 (1966).

[2] Coates, J.A.: Manning Park area (92H), Cascade Mountains; in Report of Activities, Part A, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 56-57 (1967).

[3] McTaggart, K.C., Carr, J.M., Ney, C.S., Rouse, J.A., Coates, J.A. and Schau, M.: Field trip Vancouver to Kamloops and return; Guidebook for Geol. Field Trips in southwestern British Columbia, Dept. of Geol., Univ. British Columbia, Rept. No. 6, pp. 39-62, Figs. 6-10 (1968).

[4] Jeletzky, J.A. and Tipper, H.W.: Upper Jurassic and Cretaceous rocks of Taseko Lakes map-area and their bearing on the geological history of southwestern British Columbia; Geol. Surv. Can., Paper 67-54, 218 pages, 14 Figs. (1968).

131. DEVONIAN STRATIGRAPHY, DISTRICT OF MACKENZIE

Project 670068

W.S. MacKenzie

Two months of field work were spent on this project in association with Operation Norman (see Aitken, Cook, and Balkwill, this publication). Devonian stratigraphical studies carried out in the McConnell Range and Mackenzie Mountains revealed that lithologic units formerly established in the Camsell Bend and Root River map-areas to the south, for example, the Delorme, Camsell, Arnica, and Landry formations are persistent along a trend some 40 miles southwest from and parallel to the mountain front (Fig. 1). They are, however, absent or thin in the vicinity of Mountain River headwaters and cannot be recognized within the partly equivalent Bear Rock Formation breccias along the mountain front.

The oldest strata of probable Devonian age consist of yellow-weathering, finely crystalline, silty dolomites of the Delorme Formation which, south of Keele River, comprise a sequence about 900 feet thick underlain by Ordovician beds. Near Mountain River headwaters, the formation, which has thinned to about 425 feet, rests on Cambrian strata and west of Arctic Red River only about 175 feet of the Delorme Formation is present above the Ordovician. The Camsell Formation, about 900 feet thick south of Keele River, is absent from the Mountain River headwaters region and only about 240 feet thick near Arctic Red River. The Arnica and Bear Rock formations combine to form about 800 feet of section between the Delorme and

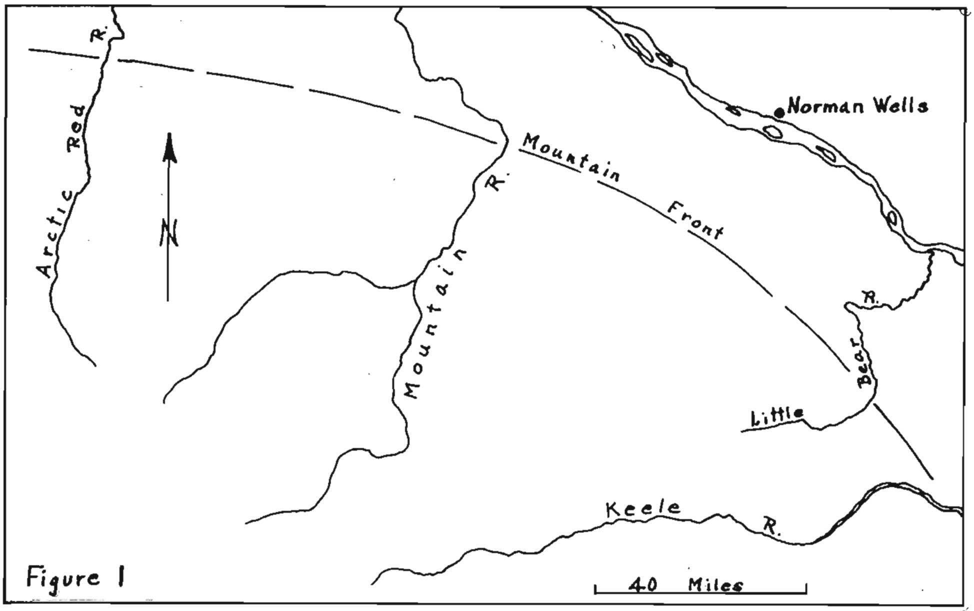


Figure 1

overlying Hume Formation. Stratigraphic equivalence of the Landry and Gossage formations can be demonstrated near Arctic Red River. The stratigraphic position of the Landry Formation and its lithologic similarity to the Gossage Formation elsewhere suggests that this correlation is valid within the report area.

The Hume Formation maintains its characteristic lithology and relatively uniform thickness throughout the report area even where the Hare Indian and Canol formations are absent and the Imperial Formation is in direct contact with the underlying Hume. In the southern part of the report area, in the vicinity of Little Beaver River, medium to dark grey, calcareous and silty mudstones, which overlie siliceous shales of the Canol Formation, are tentatively correlated with the Fort Simpson Formation. The maximum exposed thickness of overlying Imperial Formation strata within the report area is 3,580 feet.

132. LOWER PALEOZOIC STRATIGRAPHY AND SEDIMENTOLOGY; EASTERN MACKENZIE MOUNTAINS, NORTHERN FRANKLIN MOUNTAINS (96 C, D, E, F; 106 G, H)

Project 670068

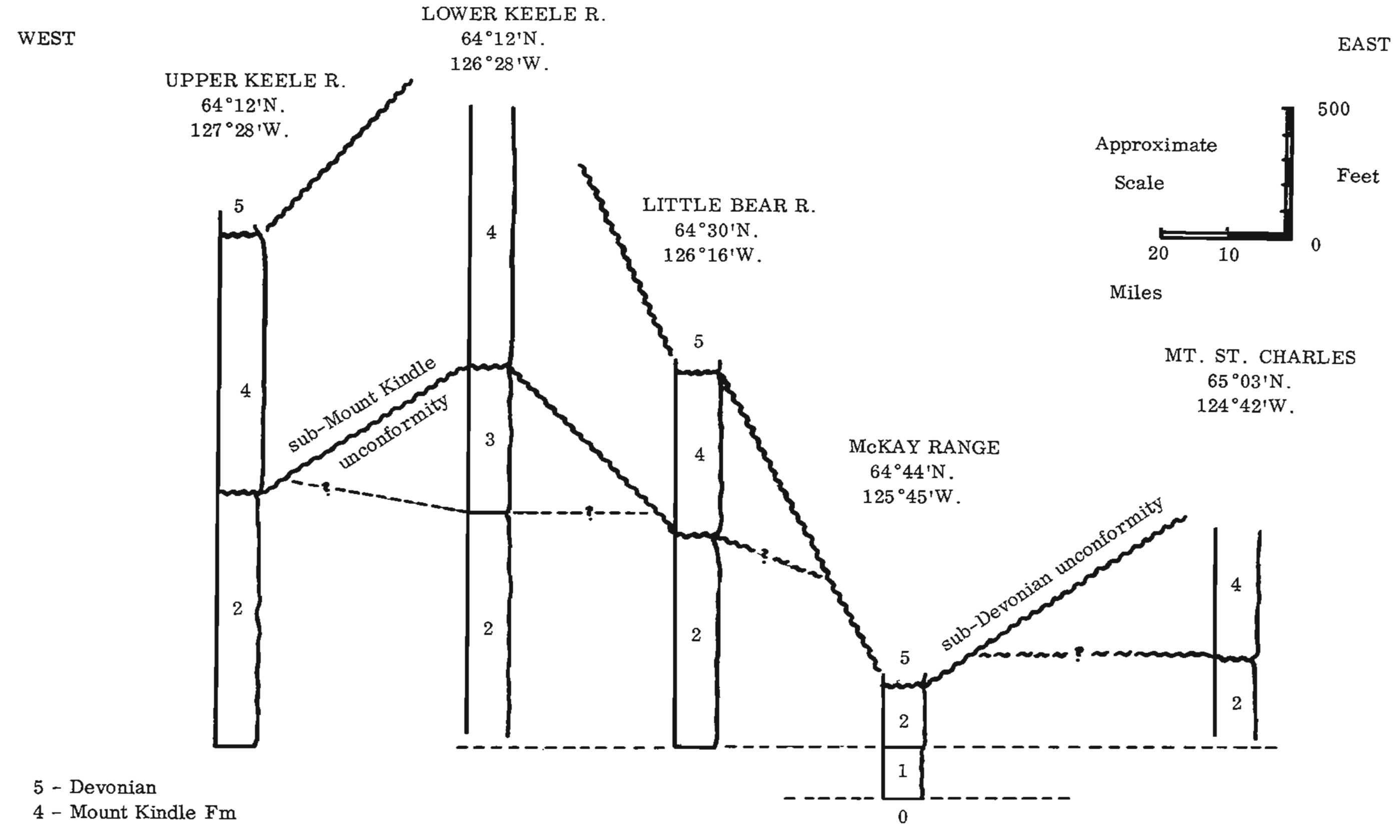
R.W. Macqueen

Introduction

Four, widespread, lower Paleozoic shelf carbonate units are mappable in the plains east of the lower Mackenzie River[1, 2]. From the base these include the informal 'cyclic', 'rhythmic', and 'cherty' units, and the overlying Mount Kindle Formation. All of these are known now to extend into much of the northern Franklin and eastern Mackenzie Mountains with relatively few facies changes. Within any local area of either plains or mountains, the presence or absence of particular post-Saline River lower Paleozoic units are dependent on the degree of erosion associated with several regional unconformities, including the present erosion surface, the sub-Devonian unconformity, and the sub-Mount Kindle unconformity (see Fig. 1).

'Ronning Group'

Based on 1968 and 1969 field work by members of Operation Norman, the term 'Ronning Group' is here used only in a reconnaissance sense, because: (1) the four distinct stratigraphic units which comprise the type 'Ronning Group' on the south side of Dodo Canyon[3] (96 D) along the Mackenzie Mountain front can be mapped separately wherever they occur throughout most of the Operation Norman area[1, 2, 4, 5, 6]; and (2) the Mount Kindle Formation, part of which is the uppermost of the four units in the type 'Ronning Group', is everywhere underlain by a regional unconformity



5 - Devonian
4 - Mount Kindle Fm
3 - "Ronning" cherty unit
2 - "Ronning" rhythmic unit
1 - "Ronning" cyclic unit
0 - Saline River Fm

Figure 1. Diagrammatic cross-section illustrating Lower Paleozoic stratigraphic relationships, Mackenzie Mountains to Franklin Mountains.

separating Upper Ordovician basal Mount Kindle beds (containing fossils identified by Norford as part of the Bighornia-Thaerodonta fauna[7]) from underlying Lower Ordovician rocks (age based on silicified gastropods identified by Norford) or older beds. Thus, the Middle Ordovician succession is missing at the 'Ronning' type locality and, probably, over the entire Operation Norman area. Except where exposure is poor (eastern part of the Lac Belot sheet[1], and locally in the northern Franklin Mountains), the Mount Kindle can be easily differentiated from older rocks wherever it is found in the Operation Norman area.

Basal contact A gradational contact is present between the dolomites and gypsiferous, red and green shales of the upper Saline River Formation, and the overlying basal or 'cyclic' unit of the 'Ronning Group' throughout most of the northern Franklin Mountains and their vicinity (e.g. Saline River, 96 C; Bear Rock, 96 D; and Norman Range, 96 E), and along the Mackenzie Mountain front between the Keele and Imperial rivers. Within the Mackenzie Mountains to the west, however, the cyclic unit of the 'Ronning Group' is missing. There the lowest 'Ronning' beds, which are assigned to the rhythmic unit, are considerably richer in clastic quartz than to the east. These quartz-rich lower 'Ronning' beds are in contact with progressively lower stratigraphic units to the west, ultimately directly overlying Cambrian or Proterozoic quartzites[4] near Arctic Red River (106 G).

Cyclic unit The distinctive, pale yellowish orange-weathering, 150- to 250-foot-thick dolomite unit of the lower 'Ronning' is clearly recognizable throughout its area of outcrop in the plains (Orl[1,2]), most of the northern Franklin Mountains, and along the Mackenzie Mountain front. Although the unit is informally termed the 'cyclic unit', individual lithic cycles, which are so well-developed in the Norman Range[5], are difficult to identify along the Mackenzie Mountain front and south of the Norman Range. Near the mouth of Saline River (96 C) the unit consists of rhythmic alternations of olive-grey, argillaceous dolomites and pale yellowish orange, very finely crystalline dolomites, and lacks the characteristic wafer-like, flat-pebble conglomerates and stromatolitic dolomites typical of the Norman Range. The upward disappearance of argillaceous dolomites characteristic of the cyclic unit and the appearance of finely to medium crystalline, porous, brownish grey-weathering dolomites (commonly oolitic; or oolitic limestones) characteristic of the overlying rhythmic unit[5] is gradational, indicating no significant break in sedimentation.

Rhythmic unit The dolomite rhythms observed in the plains east of the lower Mackenzie River, the northern Franklin Mountains, and at Dodo Canyon along the Mackenzie Mountain front[5] (Or2a[1,2]) are now known to be characteristic of this 500- to 1,400-foot-thick unit throughout much of the Operation Norman area. Because they consist of alternations of two types of dolomite, one very finely crystalline and greyish orange to brownish grey (light grey beds in Fig. 2), the other finely to medium crystalline and brownish grey or light brown[5] (medium or dark grey beds in Fig. 2), the rhythms of the northern Franklin Mountains and the plains east of the lower Mackenzie River are subtle in character, especially where exposures are incomplete. The rhythms do, however, provide a lithologic correlation for the lower 'Ronning' of the plains, northern Franklin Mountains, and eastern Mackenzie

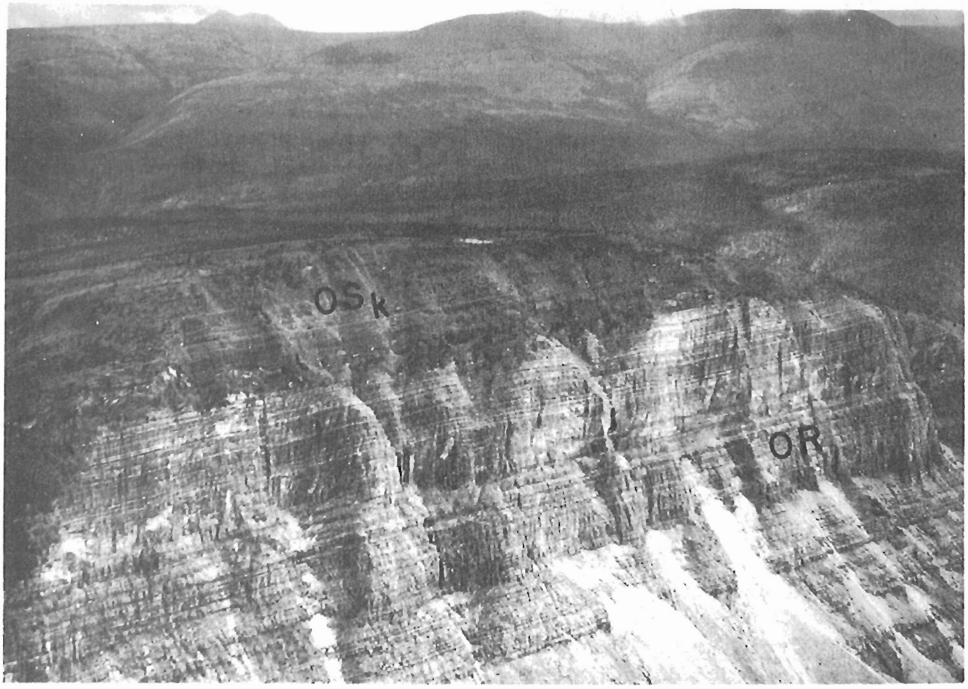


Figure 2. View from helicopter of lower Paleozoic units exposed on north side of upper Keele River valley, 6 miles downstream from mouth of Nainlin Brook (96 D). Lower part of photograph shows pronounced banding in 'Ronning' rhythmic unit (OR), of which approximately 900 feet are shown. Dark grey beds above are Mount Kindle Formation (OS_k), basal 300 feet of which are seen in disconformable contact with rhythmic unit, on scarp face. Sub-Mount Kindle unconformity shows several tens of feet of relief. GSC photo 201285.

Mountains. The distinctive banding of the rhythmic unit is immediately apparent in the eastern Mackenzie Mountains (Fig. 2). Along the lower part of Keele River (96 D), the rhythms are striking because those portions represented by finely to medium crystalline dolomite elsewhere consist here of grey-weathering, dominantly oolitic limestones, locally containing trilobites. At one section along the lower Keele River the rhythmic unit is about 850 feet thick, and contains at least 63 individual rhythms ranging in thickness from 5 to 26 feet, and averaging about 9 feet in thickness (including both oolitic limestone and very finely crystalline, greyish orange dolomite). Many features displayed by these rhythms[5] suggest an intertidal origin for the oolitic limestones and their dolomitized equivalents, and a supratidal origin for the very finely crystalline dolomites. Re-examination of this unit in the Norman Range (96 E), along with studies in the McKay Range and McConnell Range (96 C), revealed that many of the mottled red, finely to medium crystalline dolomites, which have fair to good intercrystalline porosity, are dolomitized oolites.

Along the Mackenzie Mountain front (except the more westerly exposures near Arctic Red River), and in the northern Franklins, the rhythms appear to extend throughout the entire unit rather than only the lower part as earlier suggested[5].

Only the basal 100 to 200 feet of the unit, however, is rhythmic in the most westerly localities examined near Arctic Red River (106 G) and along the upper Keele River about 5 miles above the mouth of Nainlin Brook (96 D). In this western area, strata equivalent to the middle and upper parts of the rhythmic unit are uniform, finely crystalline, slightly porous and cherty, brownish grey-weathering dolomites, which appear to represent replaced calcarenites. This westward facies change takes place fairly abruptly, for excellent rhythms are observable only 6 miles downstream from Nainlin Brook along upper Keele River (Fig. 2).

The lower part of the rhythmic unit near Arctic Red River contains brachiopods and echinoderm ossicles dated by Norford as Late Cambrian (possibly Franconian). Based on this evidence and on collections below and above this unit, its indicated age is mainly Late Cambrian, with the Cambro-Ordovician boundary at or somewhere near the top.

Where the overlying cherty unit is present, the contact is conformable.

Cherty unit In the Mackenzie Mountains this unit is sporadically distributed as remnants from pre-Mount Kindle erosion (Fig. 1), and ranges considerably in thickness from 0 to about 550 feet. It is composed of grey-weathering, thick-bedded finely to medium crystalline dolomite, generally with lesser amounts of drusy quartz, chert, silicified stromatolites, and silicified oolites, all of which are common to very abundant in the plains east of the lower Mackenzie River[5, 6] ($Or2b^2$). Silicified gastropods collected by Macqueen and others in 1968 from this unit are thought by Norford to be Early Ordovician in age.

Mount Kindle Formation The Mount Kindle is widely distributed in the northern Franklin and eastern Mackenzie Mountains, except where removed by pre-Devonian erosion (Norman Range, 96 E; McKay Range and Bear Rock, 96 C). It consists of a monotonous succession of uniform, medium to dark brownish grey, finely to medium crystalline dolomites with very abundant chert and silicified halysitid, favositid, and horn corals and orthoconic cephalopods. Facies changes appear to be minimal across the Operation Norman area, but throughout the area of outcrop of the Mount Kindle, considerable changes in thickness occur from less than 300 feet to about 1,500 feet, and are related to pre-Devonian erosion. In general the formation is thinnest along the Mackenzie Mountain front and in the northern Franklin Mountains, and thickest in the southern and southwestern part of the Operation Norman area in the Mackenzie Mountains. Dolomites composing the Mount Kindle are commonly fetid, and very rarely contain traces of bitumen. The presence of well-developed intercrystalline and vuggy porosity, combined with a penetrative fracture system oblique to bedding, make this unit the most promising carbonate hydrocarbon reservoir within the lower Paleozoic rocks of the area.

Collections identified by, and in part made by Norford, indicate that the Mount Kindle of the Operation Norman area is Late Ordovician in its lower part (see above), and Early Silurian in its upper part in the thicker sections. The presence of an appreciable thickness of Upper Ordovician beds in the Mount Kindle is in agreement with the earlier conclusions of Douglas and Norris[8] and others for the type Mount Kindle of the Franklin Mountains in the Wrigley area.

---

[1] Aitken, J.D. and Cook, D.G.: Geology, Lac Belot, District of Mackenzie, 96 L; Geol. Surv. Can., Map 6-1969 (in press).

[2] Cook, D.G. and Aitken, J.D.: Geology, Erly Lake, District of Mackenzie, 97 A; Geol. Surv. Can., Map 5-1969 (in press).

[3] Hume, G.S. and Link, T.A.: Canol geological investigations in the Mackenzie River area, Northwest Territories and Yukon; Geol. Surv. Can., Paper 45-16 (1945).

[4] Aitken, J.D., Cook, D.G. and Balkwill, H.R.: Operation Norman, District of Mackenzie; Geol. Surv. Can. (this volume).

[5] Macqueen, R.W.: Lower Paleozoic stratigraphy, Operation Norman, 1968; in Report of Activities, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 238-241 (1969).

[6] Yorath, C.J., Balkwill, H.R. and Klassen, R.W.: Geology of the eastern part of the Northern Interior and Arctic Coastal Plains, Northwest Territories; Geol. Surv. Can., Paper 68-27 (1969).

[7] Norford, B.S.: The Beaverfoot-Brisco Formation in the Stanford Range, British Columbia; J. Alta. Soc. Petrol. Geol., vol. 10, pp. 443-453 (1962).

[8] Douglas, R.J.W. and Norris, D.K.: Dahadinni and Wrigley map-areas, District of Mackenzie, Northwest Territories; Geol. Surv. Can., Paper 62-33 (1963).

---

133. STRUCTURAL AND STRATIGRAPHIC STUDIES, BLOW RIVER AREA, YUKON TERRITORY AND WESTERN DISTRICT OF MACKENZIE (117 A, EAST HALF, 107 B)

Project 690005

D.K. Norris

Approximately two months were devoted to field work in northern Yukon Territory and western District of Mackenzie between Mackenzie Delta and Barn Mountains to supplement field data and photo interpretation from

Operation Porcupine[1]. Camp facilities and air support were made available at the invitation of Union Oil Company of Canada Limited. Their assistance and cooperation and that of Geophoto Services Limited are deeply appreciated. In spite of unusually bad weather and the onset of winter conditions in July some objectives were met. New information gathered in 1969 and in the intervening years since Operation Porcupine will result in significant changes in maps 10-1963 and 1250A.

The region of Arctic Plateau and Coastal Plain lies at the cross-roads of the Franklinian, Cordilleran and Alaskan geosynclines. In contrast to the uniformly stratified shelf type sediments so widespread through the east-central Cordillera of Canada, the sedimentary succession is highly variable laterally as well as vertically and is punctuated by a series of orogenic deformations, uplifts and periods of erosion. Sandstone and carbonate bodies are discontinuous primarily because of lateral facies changes, nondeposition and removal at unconformities.

Structurally the area between Mackenzie Delta and Barn Mountains is characterized by ovate domes and long north-trending folds bounded or cut by near-vertical faults on which the displacements appear to have been largely strike slip. The tectonic style, therefore, contrasts with that of the Cordillera farther south where inclined folds are intimately associated with thrust or high-angle reverse faults[2].

In the sequence of resistant chert and dark grey siltstone beds a few miles south of the headwaters of Johnson Creek, Early Devonian (probably Siegenian) graptolites (R. Thorsteinsson, pers. comm., 1969) were discovered. There much of the succession previously assigned to Unit 2C on Map 10-1963 represents the upper part of the Road River Formation. It provides the connecting link between the occurrence of similar marine Road River facies on Porcupine River[3] and in southeastern Barn Mountains[3, 4]. Relatively deeper water marine conditions would appear to have been widespread in Arctic Plateau and Coastal Plain in Late Silurian and Early Devonian time. Road River Formation has been removed at least locally by erosion at the sub-Permian and sub-Mesozoic unconformities. Thirteen miles north of Bonnet Lake, for example, olive grey, slaty argillites of Precambrian (?) Neruokpuk Formation are overlain with angular unconformity by Mesozoic rocks. The problem of forecasting the whereabouts of possible carbonate banks of Road River age in the subsurface is accordingly difficult.

Above this unconformity rests a prominent pebble and cobble conglomerate comprised largely of chert and quartzite phenoclasts but with some slaty argillite. This unit is considered the lateral equivalent of the Brat Creek Formation[5]. Above the conglomerate is a lithologically gradational succession from conglomeratic sandstones, to interbedded sandstone and shale to interbedded shale and coal. In an attempt to date the conglomerate and immediately overlying rock, carbonaceous shale and siltstone stringers were sampled for palynological study. According to W.S. Hopkins (Interdepartmental Report, 1969) organic material was present in the form of bits of tissue; tracheids with bordered pits were common. Microfossils may have been present but their condition is such that no identification was possible. The presence of spores in the coal is yet to be determined so that there are no additional data to support the assignment of these rocks to the (?) Late Triassic and Early Jurassic series[6].

Late Paleozoic carbonate rocks appear to be absent beneath the unconformity north of Bonnet Lake and the areal distribution of the lateral equivalents of the Lisburne Group must be considered with this in mind. Several hundred feet of cherty and dolomitic limestone are present, however, immediately north of Driftwood River approximately where the river crosses 138°W (see Geol. Surv. Can., Map 10-1963). These outcrops in conjunction with the fault bounded cherty dolomites ten miles southeast of Bonnet Lake, reported by Gabrielse[7] to contain crinoid stems, suggest that similar rocks may occur at least locally still farther east. In White Mountains E.W. Bamber (pers. comm., 1969) assigns 82 feet of limestone to the Pennsylvanian system. This limestone is known to contain Middle Pennsylvanian (Desmoinesian) fusulinids[8].

A regional unconformity separates Pennsylvanian rocks from Early Permian carbonates and clastics. In White Mountains the Permian succession rests on the unnamed 82-foot limestone unit; and in northern Richardson Mountains in the vicinity of Rat Pass it rests on Ordovician-Silurian Road River Formation[9], and on Upper Devonian clastics (ref. 10, p. 282). A clastic sequence occurring on Porcupine River between Bell and Driftwood rivers is of a Permian age as it has yielded Pseudogastrioceras sp. and Spiriferella saranae (identified by P. Harker, Interdepartmental Report, 1960). This unit rests on Early Devonian and older cherts and shales[3,11]; Basset and Stout (ref. 12, p. 750) however would tentatively assign much of this conglomerate succession to the late Upper Devonian (Famennian). With the exception of the localities cited in the vicinity of Rat Pass and depending on the age assignment of some of the clastic rocks on Porcupine River, the base of the Lower Permian is disconformable. Where the unconformity is angular the pre-Permian structures trend 30 to 60 degrees east of north and are believed to be Variscan in age. They appear to be confined to a narrow belt trending east-northeast through the localities cited on Porcupine River and northern Richardson Mountains. They may be extrapolated across Mackenzie Delta to the Campbell Lake uplift. Where they are buried beneath younger sediments as in the delta, they may have provided potential hydrocarbon traps.

In White Mountains and the headwaters of Cache Creek, 400 to 800 feet of limestone, locally with interbedded quartzite, are overlain by 1,500 to 2,500 feet of rusty weathering, concretionary shale. Brachiopod and ammonoid faunules collected from this sequence are of Early Permian age (E.W. Bamber and W.W. Nassichuk, pers. comm., 1969).

Overlying the Permian clastic-carbonate sequence in the Blow River area is a widespread blanket of Jurassic and Lower Cretaceous shales and sandstones coeval with the Bug Creek and Husky formations. The Triassic system does not appear to be represented. Westward from its type locality in Aklavik Range the sandstones of the Bug Creek are more argillaceous, apparently discontinuous, variable in stratigraphic position or may be absent. Between Barn and British Mountains for example, the interval from the 'Lower Sandstone Division' (ref. 12, pp. 6-7; ref. 1B, p. 5) is represented by a recessive unit, presumably shale. Sandstones characteristic of the Bug Creek Formation are not evident.

Perhaps the most prominent and widespread rock unit in the region is the 'Lower Sandstone Division'. It forms a resistant and readily mappable formation throughout Arctic Plateau and Coastal Plain as well as in Ogilvie Mountains west of Eagle Plain. Below it is the largely Jurassic sequence of clastic rocks of the Brat Creek, Bug Creek and Husky formations. Above it is a complex framework of cleaved, faulted and folded siltstones, shales, and sandstones of Early Cretaceous age, subdivisible locally into mappable units referable to Jeletzky's stratigraphic subdivisions of the Lower Cretaceous between Blow and Bell rivers (ref. 15, p. 5). Additional biostratigraphic studies will doubtless lead to considerable refinements in the stratigraphy and consequently in the structure of the region.

Unconformably overlying the Lower Cretaceous is a succession of relatively undeformed, gently north-dipping, dark grey, marine siltstones probably more than a thousand feet thick on lower Fish River and Cache Creek. These are overlain conformably (?) by at least 5,000 feet of Upper Cretaceous and Tertiary, graded, fluted and load-casted sandstones, conglomeratic sandstones and siltstones to the margin of Mackenzie Delta. Grey and green chert and grey quartzite pebbles are common in the conglomerates and suggest a provenance in uplifted Neruokpuk and Road River terranes. The discovery of igneous pebbles ranging from quartz latites to porphyritic andesites and comprising less than one per cent of the phenoclasts, is suggestive moreover of sources well removed from the immediate area, possibly in Alaska. No detritus of porphyritic granite characteristic of the Mount Fitton, Mount Sedgwick or Old Crow stocks was found.

Because of the implications regarding the hydrocarbon potential of igneous intrusions or extrusions of Late Cretaceous and Tertiary age in the area a careful search was made for the dykes reported by Kent and Russell (ref. 16, p. 588) at Coal Mine Lake, approximately 8 miles northwest of the mouth of Fish River, and in Caribou Hills (R. de Caen, pers. comm., 1966)*. In neither instance could the presence of these igneous rocks be substantiated although red and brown clinker believed to be associated with coal seams burned by spontaneous combustion were common in the areas.

The hydrocarbon potential of the Blow River area would appear to be promising on both stratigraphic and structural grounds. First, there is the possibility of carbonate banks comparable to the Vunta Formation of White Mountains (ref. 3, p. 10) buried beneath Arctic Coastal Plain and Mackenzie Bay. Second, the thick Pennsylvanian and Permian carbonate and clastic succession may be widespread in lower Fish River area and beneath Mackenzie Bay. If both these potential intervals are present there, however, they would appear to be buried beneath more than ten thousand feet of Mesozoic clastic rocks. Third, within the Mesozoic succession there are a number of prospective sandstones, especially adjacent to and quite possibly beneath Mackenzie Delta. Pinchouts and erosional truncations demonstrated in the outcrop may well be present at depth and may have served to localize migrating hydrocarbons.

The broad domes and appressed anticlines so evident at the surface in Arctic Plateau may reflect the style of deformation for an unknown distance northward beneath the cover of Late Cretaceous and younger sediments in Arctic Coastal Plain and Mackenzie Bay. The fact that the domes involve strata as old as Early Cambrian (see Geol. Surv. Can., Map 10-1963) immediately north of Rat Pass, assumed Cambrian in White Mountains (ref. 3, p. 10), and Precambrian (?) metamorphic rocks north of Bonnet Lake (this report) would suggest that their control is still more deep-seated.

---

* The writer is indebted to R. de Caen, Triad Oil Company Ltd., for providing precise locations for these reported occurrences.

The anticlines, on the other hand, may terminate downwards in lateral equivalents of the Cambrian Saline River Formation as evaporites are present in the Donna River fault zone. Both domes and anticlines contain potential hydrocarbon source and reservoir rocks.

---

[1] Norris, D.K.: Operation Porcupine; in Summary of Research: Field, 1962, Geol. Surv. Can., Paper 63-1, pp. 17-19 (1963).

[2] Jeletzky, J.A.: Eastern slope, Richardson Mountains: Cretaceous and Tertiary structural history and regional significance; Proc. First Internatl. Symp. on Arctic geology; Alberta Soc. Petroleum Geologists, Calgary, pp. 578-582 (1961).

[3] Norford, B.S.: Reconnaissance of the Ordovician and Silurian rocks of northern Yukon Territory; Geol. Surv. Can., Paper 63-39, (1964).

[4] Martin, L.J.: Stratigraphy and depositional tectonics of north Yukon – lower Mackenzie area, Canada; Bull. Am. Assoc. Petrol. Geol., pp. 2399-2455 (1959).

[5] Jeletzky, J.A.: Jurassic and (?) Triassic rocks of the eastern slope of Richardson Mountains, northwestern District of Mackenzie; Geol. Surv. Can., Paper 66-50 (1967).

[6] Jeletzky, J.A.: Pre-Cretaceous Richardson Mountains Trough: its place in the tectonic framework of Arctic Canada and its bearing on some geosynclinal concepts; Trans. Roy. Soc. Can., Ser. 3, sec. IV, vol. 56, pp. 55-83 (1963).

[7] Gabrielse, H.: Geological reconnaissance in the northern Richardson Mountains, Yukon and Northwest Territories; Geol. Surv. Can., Paper 56-6 (1957).

[8] Ross, C.A.: Upper Paleozoic Fusulinacea: Eowaeringella and Wedekindellina from Yukon Territory and giant Parafusulina from British Columbia; Geol. Surv. Can., Bull. 182, pp. 129-134 (1969).

[9] Knipping, H.D.: Late Paleozoic orogeny – north Yukon; Frontiers of exploration in Canada, A.A.P.G.-A.S.P.G. Regional Meeting, Banff, Alberta, Canada (1960).

[10] Norris, A.W.: Reconnaissance Devonian stratigraphy of northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 67-53 (1968).

[11] Jackson, D.E. and Lenz, A.C.: Latest Silurian graptolites from Porcupine River, Yukon Territory; Geol. Surv. Can., Bull. 182, pp. 17-29 (1969).

[12] Bassett, H.G. and Stout, J.G.: Devonian of Western Canada; in International symposium on the Devonian system, Vol. 1, Alberta Soc. Petroleum Geologists, Calgary, Canada, pp. 717-752 (1968).

[13] Jeletzky, J.A.: Uppermost Jurassic and Cretaceous rocks of Aklavik Range, northeastern Richardson Mountains, Northwest Territories; Geol. Surv. Can., Paper 58-2 (1958).

[14] 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).

[15] 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).

[16] Kent, P.E. and Russell, W.A.C.: Evaporite piercement structures in the northern Richardson Mountains; Geology of the Arctic, Vol. 1, Proc. First Internatl. Symp. on Arctic Geology, Alberta Soc. Petroleum Geologists, Calgary, Canada, pp. 584-595 (1961).

---

134. STRUCTURAL-STRATIGRAPHIC STUDIES IN THE SOUTHERN FOOTHILLS OF ALBERTA (82 O)

Projects 690017, 690018

N.C. Ollerenshaw

Structural and stratigraphic data were collected and field mapping completed in the foothills part of Scalp Creek east map-area (82O/13E).

A photogeological revision of the Wildcat Hills east (82O/7E) geological map was checked in the field.

Preliminary field work was undertaken for the revision of the Morley (82O/2W) and Jumpingpound (82O/2E) map-areas.

Fabric studies were made on several exposures of Cretaceous conglomerate, to provide data on the source areas, depositional and tectonic environments of the Cretaceous rocks.

135. PALEOZOIC STRATIGRAPHY OF SOUTHAMPTON, COATS AND MANSEL ISLANDS, DISTRICT OF KEEWATIN (45J, M, N, O, P; PART OF I; 46A, B, C, F, PARTS OF D, E, G)

Project 680092

B.V. Sanford

Field work for the project 'Geology of Southampton Island', under the leadership of W.W. Heywood, was begun in 1968, and completed in 1969. The writer was responsible for the study and mapping of the Paleozoic terrane and traversed Southampton, Coats, and Mansel islands briefly during August and early September, 1968. During the summer of 1969, Paleozoic strata of Southampton Island were examined in more detail, and mapped on a scale of 1:250, 000.

Much new information concerning the stratigraphy and depositional environment of the Paleozoic succession was obtained. In addition, Paleozoic deformation, hitherto unreported, will help to shed new light on the tectonic history of the northern Hudson Bay Basin and adjacent areas of the Canadian Shield.

The various formations exposed on Southampton, Coats, and Mansel islands are lithologically similar to those of comparable age in the Hudson Bay Lowlands mapped during the course of Operation Winisk (1967)[1] and consequently, the same nomenclature with the addition of Red Head Rapids Formation is tentatively adopted for this more northern region, as follows:

SILURIAN	Niagaran	Attawapiskat	175'+
		Ekwan River	300'
		Severn River	500'
		disconformity	
ORDOVICIAN	Richmondian	Red Head Rapids	200'+
		Churchill River	175'
		disconformity (?)	
	Edenian	Unnamed oil shale unit (not reported in Hudson Bay Lowlands)	7+
		Bad Cache Rapids	150'
		unconformity	

Precambrian crystalline rocks

Comparable Paleozoic sequences about 1, 500 feet thick and which range in age from Late Ordovician (?) to Middle Silurian have been determined on both Southampton and Coats islands; on Mansel Island, only about 300 feet of strata are exposed which comprise the Ekwan River and Attawapiskat formations.

Except for a coarse clastic member locally developed at the base of the Bad Cache Rapids, the entire Paleozoic succession is composed of carbonate rocks, limestones and dolomites, which were deposited in environmental conditions, varying from normal marine to evaporitic. Extensive biohermal reefs flourished during deposition of the Attawapiskat and Red Head Rapids formations, and to a lesser extent in Ekwan River time. Whereas the Red Head Rapids of Hudson Bay Lowlands was by error included in the Severn River Formation, its stratigraphic significance and economic potential are well displayed on Southampton and Coats islands. Some of the algal bioherms that occur in the Red Head Rapids appear to have suitable reservoir characteristics and significant structural closure. Similar reefs if found in subsurface at adequate depth could be prospective of oil and gas. The Attawapiskat, containing algal and stromatoporoid reefs, form the youngest rocks on the southern extremities of each of the three islands, and may be prospective in the immediate offshore regions of Hudson Bay.

An unnamed Ordovician oil shale unit lying between the Bad Cache Rapids and Churchill River is highly petroliferous, and may be worthy of future exploration.

Major fracture systems established in the Paleozoic as a result of post-Silurian uplift of Precambrian rocks should be investigated for possible base metal occurrences. These systems are best developed along the Paleozoic-Precambrian contact; and they also intersect Paleozoic strata in numerous other parts of Southampton Island.

---

[1] Sanford, B.V., Norris, A.W. and Bostock, H.H.: Geology of the Hudson Bay Lowlands (Operation Winisk); Geol. Surv. Can., Paper 67-60 (1968).

---

136. ORDOVICIAN OF THE OTTAWA VALLEY - HAWKESBURY TO PEMBROKE, ONTARIO (31F-H)

Project 690027

H. Miriam Steele

During the 1969 field season work was begun on a paleoecological study of Wilderness Stage (Middle Ordovician) of the Ottawa Valley.

Outcrops spread over an area of 3 square miles near Braeside, Ontario, were located, and the area was surveyed. About 250 feet of stratigraphic section were measured and fossils and lithologic samples were collected. Preliminary studies indicate that the Wilderness section is complete in the Braeside area.

The stratigraphic section exposed at the Fourth Chute of Bonnechere River, also was measured and fossils and lithologic samples were collected.

137. JURASSIC AND CRETACEOUS ROCKS OF ROCKY MOUNTAIN FOOTHILLS, NORTHEASTERN BRITISH COLUMBIA AND ALBERTA (83E, L, 93I, O, P, 94B, G)

Project 680084

D.F. Stott

Studies of Jurassic and Cretaceous rocks were continued in the Foothills and Plains, and were concentrated mainly in Halfway River (94B), Pine Pass (93O), and Dawson Creek (93P) map-areas. This investigation forms part of Operation Smoky (see G.C. Taylor, this publication).

The Jurassic Fernie Formation is not well exposed in Pine Pass map-area although its thickness along the western Foothills is in the order of 1,900 feet. The lower part, including all beds between the base of the formation and a prominent glauconitic marker bed, has about the same thickness as equivalent beds in sections near Sikanni Chief and Halfway rivers[1]. However, the upper part of the formation shows a very pronounced increase in thickness in the Pine Pass Region.

The Minnes Group was traced southward to Goodrich Peak where its thickness is about 4,000 feet. The Late Jurassic to Early Cretaceous Monteith Formation composed of fine-grained, argillaceous sandstone and fine- to coarse-grained, quartzose sandstone is well developed in that region. The Valanginian Beattie Peaks Formation, consisting of interbedded silty mudstone and siltstones in the Carbon Creek Region, contains much more sandstone to the south. The quartzose sandstones of the overlying Monach Formation were not found in the vicinity of Goodrich Peak, although a prominent succession of sandstone strata at that locality is assigned to the formation.

The Lower Cretaceous Bullhead Group is recognized throughout the region. A conglomeratic succession was found along the axes of many synclines within the Pine Pass map-area and was traced southward into a prominent conglomerate previously mapped as Cadomin in the vicinity of Bullmoose Mountain and Murray River[2]. The Gething Formation, along the west bank of the Peace River canyon, was re-examined and the fault repetition that was suggested in a previous report[3] is not present. Its thickness there is, therefore, in the order of 1,800 feet. Both the Cadomin and Gething formations occur west of Sukunka River in the vicinity of Burnt River.

The Fort St. John Group[2] and the Smoky Group[4] were examined and fossils collected at many new localities as part of the mapping program to revise the Dawson Creek map-area[5].

---

[1] Stott, D.F.: Fernie and Minnes strata north of Peace River Foothills of northeastern British Columbia; Geol. Surv. Can., Paper 67-19, Parts A and B (1967, 1969).

[2] Stott, D.F.: Lower Cretaceous Bullhead and Fort St. John groups, between Smoky and Peace rivers, Rocky Mountain Foothills, Alberta and British Columbia; Geol. Surv. Can., Bull. 152 (1968).

[3] Stott, D.F.: The Gething Formation at Peace River canyon, British Columbia; Geol. Surv. Can., Paper 68-28 (1969).

[4] Stott, D.F.: The Cretaceous Smoky Group, Rocky Mountain Foothills, Alberta and British Columbia; Geol. Surv. Can., Bull 132 (1967).

[5] Stott, D.F.: Dawson Creek map-area, British Columbia; Geol. Surv. Can., Paper 61-10 (1961).

---

138. DAWSON CREEK AND PINE PASS MAP-AREAS, BRITISH COLUMBIA (93P, O)

Project 680084

G. C. Taylor

Revision of the Dawson Creek[1] and Pine Pass[2] map-areas was accomplished during summer operations by staff geologists G.C. Taylor, D.F. Stott, D.W. Gibson, E.W. Bamber, E.T. Tozer, and N.W. Rutter (see elsewhere this publication for separate reports).

More than 50,000 feet of stratigraphic section, with representative segments of all systems from Proterozoic to Cretaceous (except Pennsylvanian), were examined and described. Significant facies changes occur between northern and southern successions of most units reflecting the influence of the Peace River arch, superimposed on the major east to west facies changes common to most stratigraphic units.

A major change in structural style is also evident. North of Hart Highway most structural elements have significant southward plunges and relate to structures more typical of the northern Rocky Mountains where folding is the dominant mode of deformation. South of Hart Highway large thrust elements, with little internal deformation, become prominent although Front Range structures retain the northern habit. Folding is the predominant type of structural deformation of the Foothills. Very steep flanks in combination with moderate structural relief suggest that these folds are detached from the deeper elements.

---

[1] Stott, D.F.: Dawson Creek map-area; Geol. Surv. Can., Paper 61-10 (1961).

[2] Muller, J.F.: Pine Pass, British Columbia; Geol. Surv. Can., Map 11-1961 (1961).

139. UPPER PROTEROZOIC TO MID-CAMBRIAN STRATIGRAPHY, DISTRICT OF MACKENZIE (96D, 106A, G, H)

Project 670068

John L. Usher

Sub-Ronning strata were studied and measured at a limited number of localities in the Mackenzie Mountains, District of Mackenzie, between Keele River and Arctic Red River, in conjunction with Operation Norman, 1969 (see Aitken et al.,[1] this publication).

The sections are located at the following coordinates, and the units and their thicknesses at each locality are shown in Table 1.

A. Little Bear River, Long. 126°55'W, Lat. 64°29'N (96D)
B. Imperial Canyon, Long. 128°03'W, Lat. 65°6'N (106H)
C. Dodo Canyon, Long. 127°13' W, Lat. 64°52'40"N (96D)
D. Deca Creek, Long. 128°27'W, Lat. 64°13'N (106A)
E. Arctic Red River, Long. 130°40'W, Lat. 65°4'N (106G)
F. Arctic Red River, Long. 131°00'W, Lat. 65°15'N (106G)

Rocks of the Macdougal and Katherine groups[2] underlie the Ronning Group, and are the oldest exposed strata in this part of the Mackenzie Mountains. The lithologic succession from the base of the Ronning, stratigraphically downward, may be conveniently summarized as follows; the numbers that are affixed to the units are also a convenience for tabulation of thicknesses in Table 1 and for discussion purposes hereinafter, and are not intended to be precursors of future formation or member names.

(xii) Varicoloured shales, siltstones, sandstones, and argillaceous to sandy dolostones, thin- to medium-bedded.

(xi) Pink, grey, and white gypsum interbedded with grey and pale green, gypsiferous shale; thin dolostones in upper and lower parts of unit.

(x) Red and grey shales, black shales, sandstones, siltstones, with thin dolostones, limestones, and gypsum. Collapse breccias in Deca Creek area (Section D).

(ix) Grey and rusty brown-weathering quartzites, cherty, sandy shales and siltstones.

(viii) Thick- to very thick bedded, grey, stromatolitic limestones and/or red-orange dolostones. Thin-bedded, argillaceous limestone and shale comprise the lower part of the unit.

(vii) Brick red, nodular, calcareous shales (the 'Chocolate Shales'[2]) underlain by thick-bedded, grey, stromatolitic limestone, in turn underlain by thin-bedded, grey limestones, dolostones, and sandy dolostones, interbedded with laminated sandstones, siltstones and grey, green, red, and black shales.

(vi) White to red and purple, thick-bedded orthoquartzite (130 feet thick along the mountain front) underlain by thin-bedded siltstones, sandstones, and shales. The bottom third of the unit consists of three orange-weathering dolomites separated by grey, silty or sandy shales. The lowest dolostone is sandy and argillaceous; the upper two dolostones contain flat-pebble conglomerates and stromatolitic beds. Chert is common in the middle dolostone.

(v) White orthoquartzite, in places hematitic; thick- to very thick-bedded.
(iv) Purple shale; rare, thin sandstone beds.
(iii) White, pink, and pale green orthoquartzite, with grey and green shales and siltstones; some pale orange-weathering dolostones in the upper part.
(ii) Dark brown-weathering shale with less abundant ribs of orange-weathering, silty dolostone.
(i) Pale grey, dense, hard dolostone with abundant grey and black chert.

	A	B	C	D	E	F
(xii)		75	) 424	(		
(xi)		200	)	(425		
(x)		50	142	(		
(ix)	n.p.	100	275	n.p.		
(viii)	595	n.p.	n.p.	2,150(2)		
(vii)	440	n.p.	480(1)	870	650(4)	
(vi)	520	350(1)	490	2,180(3)	945	
(v)		775				645
(iv)		120				225
(iii)		1,200				1,975
(ii)						+1,200
(i)						+1,200

Table 1. Thicknesses (in feet) of units measured at sections localities. (n.p. - not present).

Footnotes to Table 1.

(1) An unconformity, or complex of unconformities, underlies the gypsum-bearing units (xii), (xi), and (x) (Saline River Formation, Williams, 1923[3]). At Imperial River canyon (section B) the sub-Saline River Formation unconformity separates units (x) and (ix). A second unconformity is clearly exposed at the base of unit (ix). Units (viii), (vii), and the upper part of unit (vi) are absent beneath this unconformity. At both unconformities there is an indication, in outcrop, of slight angular discordance.

Immediately to the southeast in Dodo Canyon (section C), unit (vi) is complete, and is succeeded in turn by 480 feet of unit (vii). Lying disconformably above unit (vii) are 275 feet of beds probably equivalent to unit (ix). These beds at Dodo Canyon contain late Early Cambrian and Middle Cambrian trilobite faunas[4]. Unit (x) is 142 feet thick, and is overlain by a 424-foot interval which is mainly covered, but is believed to be equivalent to units (xi) and (xii) (R.W. Macqueen, pers. comm., 1969). Thus, it appears that fossiliferous Lower and Middle Cambrian strata, unit (ix), were at one time widespread in the area but, of the sections studied, only Dodo Canyon and probably Imperial River have a remnant of these strata sandwiched between Saline River and older, nonfossiliferous rocks. It is concluded tentatively that Lower and Middle Cambrian rocks were removed by erosion prior to Saline River 'time' from a large part of the northeastern Mackenzie Mountains. It is, of course, possible that units (viii), (vii) and (vi), or older, may be unfossiliferous Cambrian strata, but limestones of unit (viii) and the shales and limestones of unit (vii), the lithologies of which are most amenable to fossil preservation, were carefully scrutinized and no trace of invertebrate life was discovered in them. It is, therefore, tentatively suggested that all units older than unit (ix) are Proterozoic in age.

(2) On Deca Creek (section D), a 600-foot-thick unit of brown-weathering, thin-bedded dolostones lies above the grey limestones of unit (viii) and beneath the gypsum-bearing strata of units (xii), (xi), and (x), and has been included in unit (viii) at this locality.

(3) The lower 800 feet of unit (vi) in the Deca Creek section consist predominantly of shale and sandy shale with, midway, one orange-weathering dolostone, 200 feet thick, containing flat-pebble conglomerate and stromatolitic layers.

(4) The 'chocolate shale' upper part of unit (vii) in the Arctic Red River area is in the order of 500 feet thick. Isolated, massive, structureless, stromatolitic bioherms occupy the entire interval, vary from circular to elongate shape, and are surrounded on all sides by the nodular shales. In the 'off-reef' shales the nodular character is everywhere retained, but the brick red colour may be replaced by grey and black. These colour variations are probably related to reef distribution, but more detailed areal study would be required to determine the nature of that relationship.

Indeed, further work is necessary not only to establish the lithofacies within the rocks under discussion, but also to unravel their age and stratigraphic relations with the thick Cambrian and Proterozoic sections lying westward in the Yukon.

---

[1] Aitken, J.D., Cook, D.G., and Balkwill, H.R.: Operation Norman, District of Mackenzie; Geol. Surv. Can. (this publication).

[2] Hume, G.S.: The Lower Mackenzie River area, Northwest Territories and Yukon; Geol. Surv. Can., Mem. 273 (1954).

[3] Williams, M.Y.: Reconnaissance across northeastern British Columbia and the geology of the northern extension of Franklin Mountains, N.W.T.; Geol. Surv. Can., Sum. Rept. 1922, Pt. B., pp. 65-87 (1923).

[4] Fritz, W.H.: Cambrian biostratigraphy in the Canadian Cordillera; Geol. Surv. Can. (this publication).

140. CRETACEOUS AND TERTIARY STRATIGRAPHY, DISTRICT OF MACKENZIE (96C, D, E; 106G, H)

Project 670068

C. J. Yorath

Cretaceous

The Cretaceous and Tertiary rocks of the Mackenzie Plains Region lying between 64° and 68°N were examined during the 1969 field season as part of Operation Norman.

Cretaceous rocks outcrop in numerous river valleys that extend from the Mackenzie Mountains to Mackenzie River. Exposures are generally poor, macrofossils are rare, and facies changes are common. The succession consists of sandstones, mudstones and shales which are structurally concordant with, but separated by a regional unconformity from, underlying Devonian rocks. Anticlines exposing Devonian and older rocks occur beyond the mountain front and these show steeply dipping Cretaceous strata on their flanks.

Cretaceous nomenclature used in this report is that of the Canol investigations as reported by Hume and Link[1] and later summarized by Hume[2]. Conclusions expressed here are tentative until micropaleontological studies are complete.

Cretaceous deposition appears to have occurred within a deep, northwesterly trending, narrow basin, bounded by probable source areas to the south and southwest, in the region presently occupied by the Mackenzie Mountains. To the north and northeast lay a broad, shallow shelf region.

Basinal deposition began with the accumulation of the Sans Sault Formation which, adjacent to the mountain front, consists of an alternating sequence of dense, fine-grained, argillaceous, locally calcareous sandstones and sandy mudstones. Toward the centre of the basin the succession is composed predominantly of mudstone with minor thin sandstones and siltstones. This northward change in facies is well displayed on Arctic Red River and Ramparts River. The basal 50 to 160 feet of the formation, informally called the 'Basal Cretaceous Sandstone', consists of medium-grained, well sorted, commonly clean, glauconitic quartz sandstone with conglomerate beds near the middle and at the base. These strata are exposed at many localities along the mountain front and are believed to be equivalent to the clean, cross-bedded quartz sandstones that appear as a thin veneer over much of the Great Bear Plains Region[3].

To the southeast, in the region of Keele, Redstone and Little Bear rivers, dark grey sandy mudstones were observed lying beneath the Little Bear Formation. Those have been assigned tentatively to the Sans Sault Formation.

The Sans Sault Formation was examined in detail on Hume River, Mountain River and at its type section at Sans Sault Rapids; measured thicknesses were 7,800, 3,500 and 1,400 feet respectively. The section at Sans Sault Rapids is faulted and part of the middle mudstone unit is missing.

On Slater River and Loon Creek about 200 feet of black, plastic shales containing numerous bentonite laminae were assigned to the Slater

River Formation[2]. Other exposures of what were assumed to be equivalent beds were seen along Imperial River, Mountain River and Carcajou River and at those localities the unit lies directly on the Sans Sault Formation. However, at each of the mountain front localities the exposures consist of about 1,000 feet of mudstones, sandy mudstones and, locally, thinly interbedded mudstone and sandstone and hence are more similar in lithology to the underlying Sans Sault Formation. Thus, the Slater River Formation, at Slater River and Loon Creek may represent a less sandy facies of the Sans Sault Formation.

The type locality of the Little Bear Formation is on Little Bear River and there the formation can be subdivided into a lower sandstone, a middle mudstone and upper sandstone. Its total thickness is 560 feet. A distinguishing feature of the sandstones, particularly the upper unit, is the presence of distinct white grains which appear in most exposures of the formation.

The Little Bear Formation is the most widespread unit of the Cretaceous succession. In the plateau region, westward from Hume River, the unit appears to grade laterally into the Trevor Formation[4] which consists of an alternating succession of heavy, fine- to medium-grained, ferric sandstones and shales. Although the basal contact of the Trevor Formation was nowhere observed owing to lack of exposure, the typical sandstones of the Sans Sault Formation were seen to be less than 100 feet stratigraphically beneath the lowest sandstones of the Trevor Formation.

The East Fork Formation is best exposed near the mouth of the East Fork of the Little Bear River. There, about 200 feet of black plastic shales with minor amounts of coal and local basal conglomerate rest on the Little Bear Formation. The unit is very local in extent and was not recognized north of Little Bear River. Within the core of a syncline at Link Bend on Imperial River, and resting on sandstones assigned to the Little Bear Formation, is a 160-foot-thick succession of mudstones and sandstones. This unit may be a sandy facies of the East Fork Formation lying closer to the source of the clastics.

On the east flank of the Mackay Range, which exposes Devonian and older rocks in an eastwardly overturned section, are 480 feet of brown-weathering, thin-bedded to massive, fine- to medium-grained, clean to argillaceous sandstones. No fossils were found in this unit and the potential for microfauna recovery appears poor. All that can be said at present is that the unit is post-Devonian and pre-Tertiary although its lithologic similarity to the Sans Sault Formation can not be overlooked.

Tertiary

Tertiary continental deposits are well exposed along the Mackenzie River near Fort Norman and in the plateau country north of Keele River and east of the Mackenzie Mountain front. Additional exposures are located on the east side of Mackay Range and along Brackett River.

Near Fort Norman 210 feet of fluvial sands, gravels and coal are well displayed along the Mackenzie River bank. Some pale yellow-weathering ash beds, 'fire clays' and one bocanne were observed.

In the plateau region north of Keele River 1,500 feet of conglomerates, crossbedded sandstones, coals and ash beds were measured near

Tertiary Creek. A few plant remains were collected from this locality and from isolated outcrops on the east side of Mackay Range.

---

[1] Hume, G.S. and Link, T.A.: Canol Geological investigations in the Mackenzie River area, Northwest Territories and Yukon; Geol. Surv. Can., Paper 45-16 (1945).

[2] Hume, G.S.: The Lower Mackenzie River area, Northwest Territories and Yukon; Geol. Surv. Can., Mem. 273 (1954).

[3] Aitken, J.D. and Cook, D.G.: Geology of Lac Belot, District of Mackenzie, 96L; Geol. Surv. Can., Map 6-1969 (in press).

[4] Mountjoy, E.W. and Chamney, T.P.: Lower Cretaceous (Albian) of the Yukon: Stratigraphy and Foraminiferal subdivisions, Snake and Peel rivers; Geol. Surv. Can., Paper 68-26 (1969).

---

141. CRETACEOUS AND TERTIARY STRATIGRAPHY, CARIBOU HILLS, DISTRICT OF MACKENZIE (107B)

Project 690020

C.J. Yorath and W.S. Hopkins

During the latter part of August 1969 the writers initiated work in the Beaufort-Mackenzie area. The stratigraphy was examined and samples collected from the Lower Cretaceous 'Bentonitic zone' and Tertiary Reindeer Formation which are exposed in the Caribou Hills on the east side of the Mackenzie Delta. Field work was hampered by poor weather and the section was not completed.

Generally, the Reindeer Formation consists of very poorly exposed and unconsolidated gravels and sands with minor amounts of shales and carbonized wood zones. Three dark maroon 'burnt' intervals were noted. The Reindeer Formation rests on the 'Bentonitic zone' which consists of homogeneous black, plastic shales containing several concretionary horizons.

The section dips toward the northwest; south of Reindeer Depot the dips are small but farther north along the exposure dips become steeper.

GENERAL

142. STUDY OF CONTINENTAL DRIFT

Project 680039

J. William Kerr

A field and literature study of northern regions is in progress to interpret Continental Drift in the Arctic. In 1969, several regions of Alaska were studied during a one month visit to U.S. Geological Survey field parties.

In the Panhandle region of southeastern Alaska the unusual lower Paleozoic eugeosynclinal succession was examined along with transcurrent faults. Lower Paleozoic rocks were also studied in the Alaska Range where a continuous Cambrian to Middle Silurian section was discovered for the first time. Lower Paleozoic cores from the Naval Petroleum Reserve on the North Slope were examined for possible correlation with the Canadian Arctic Islands.

143. MINERAL COLLECTING IN CANADA

Project 640048

Ann P. Sabina

About 200 mineral and rock occurrences were investigated between Ottawa and North Bay. The occurrences are accessible by automobile and by boat. They are within about 80 miles of highways 17 in Ontario and 8 in Quebec. The purpose of the trip 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. Most of the localities visited are in Renfrew County. Except for the Dominion magnesium mine (Haley's Station), none of the deposits is currently in operation. Specimens of feldspar, peristerite, amazonite, dolomite, graphic granite, corundum, molybdenite, apatite, mica, beryl, marble, fossiliferous limestone, magnetite, celestite and garnet may be collected. In the North Bay area, the most interesting specimens (for collectors) furnished by the deposits include: jaspery iron-formation, garnet, amazonite, peristerite, kyanite, pyroaurite and brucite. A feldspar quarry at Mackey yields an abundance of pink peristerite. On the north side of the Ottawa River, there are deposits of magnetite, uranium, mica, brucite, cordierite, feldspar, fossiliferous limestone, asbestos, and molybdenum. The Hilton Mine is the only active operation. It was noted that in southwestern Renfrew County a number of the localities popular with collectors including the Kuehl Lake zircon and Quadeville beryl occurrences are no longer accessible to them.

AUTHOR INDEX

LOCATION INDEX

PROJECT NUMBER INDEX