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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 71-1
Part A

REPORT OF ACTIVITIES,

Part A: April to October, 1970

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CANADA

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DEPARTMENT OF ENERGY, MINES AND RESOURCES

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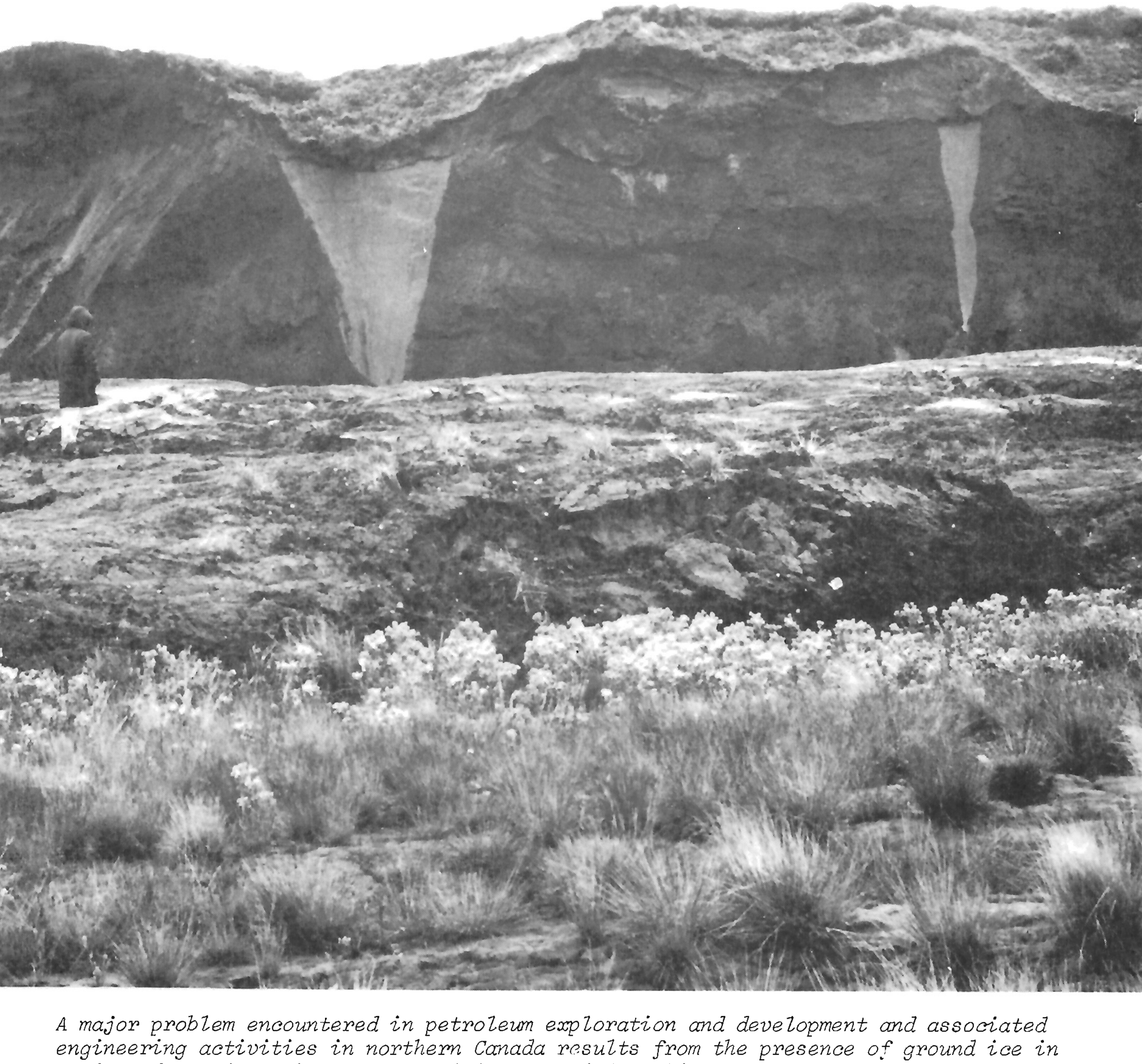
ABSTRACT

This report, containing 132 short papers, some illustrated by page-size maps and figures, presents the preliminary results of field work carried out under the auspices of the Geological Survey of Canada between April and October 1970.



A major problem encountered in petroleum exploration and development and associated engineering activities in northern Canada results from the presence of ground ice in various forms in much of the surficial material. This photograph illustrates ice wedges about 12 feet high in ice-rich clayey colluvium and till along the southern edge of Liverpool Bay about 100 miles northeast of Inuvik. In the foreground is a series of stabilized mud-flow lobes resulting from thermokarst erosion. Photograph by V.N. Rampton (GSC photo 201547).

REPORT OF ACTIVITIES,
Part A: April to October, 1970

INTRODUCTION

The Geological Survey, one of Canada's oldest scientific organizations, maintains a capability in mapping, detection, interpretation, research, and advice in the earth sciences, including mineralogy and paleontology, and in complementary aspects of geophysics, geochemistry, physical geography and other disciplines. It co-ordinates these to provide a national and regional inventory of formations of rocks and surficial materials, their structures, minerals, landforms, and conditions of stability, and to develop concepts and techniques to maintain the standard of the inventory and to increase its usefulness and effectiveness. A major aspect of the Survey's work is concerned with the description and exploration of our main geological provinces to provide basic geological data to forecast, discover and evaluate our mineral resources, to provide an understanding of the physical environment and to support the administration and policy formulation in mineral and energy resources. In support of this work the Survey is engaged in improving the methods by which it acquires its data and in developing new concepts, instrumentation and in establishing physical, chemical and paleontological standards.

In support of these objectives the Geological Survey has 473 active projects in 1970-71; of these about 174 had a field component and the papers that comprise this publication present the preliminary results of many of these studies. Submissions for inclusion in this report were accepted until October 30, 1970. Many of the conclusions presented are based on a preliminary assessment of the data collected and are therefore subject to confirmation or revision in the light of more detailed office and laboratory studies. To expedite publication illustrations are reproduced directly from material submitted by the authors and the text has been given a minimum of editorial attention. The 132 papers that make up this publication are arranged according 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; for branch use project numbers are included with each paper. Requests for geological information, announcement cards concerning publication release dates, maps, reports, or information on specific areas should be addressed to: Geological Survey of Canada, Department of Energy, Mines and Resources, 601 Booth Street, Ottawa 4, Canada.

This publication (Paper 71-1, Part A) describes the activities of the Geological Survey between April and October, 1970. Paper 71-1, Part B to be published in mid- 1971 will include brief reports on work done between November 1970 and March 1971. These reports, together with reports on isotopic and radiocarbon dating, the annual index of publications and the volume of abstracts of papers published by Geological Survey personnel in non-Survey publications, provide a comprehensive accounting of the scientific work of the organization.

APPALACHIAN GEOLOGY

12 I/11
12 P/28.9
2M/12

1. OPERATION STRAIT OF BELLE ISLE, NEWFOUNDLAND AND LABRADOR

Project 680130

L. M. Cumming

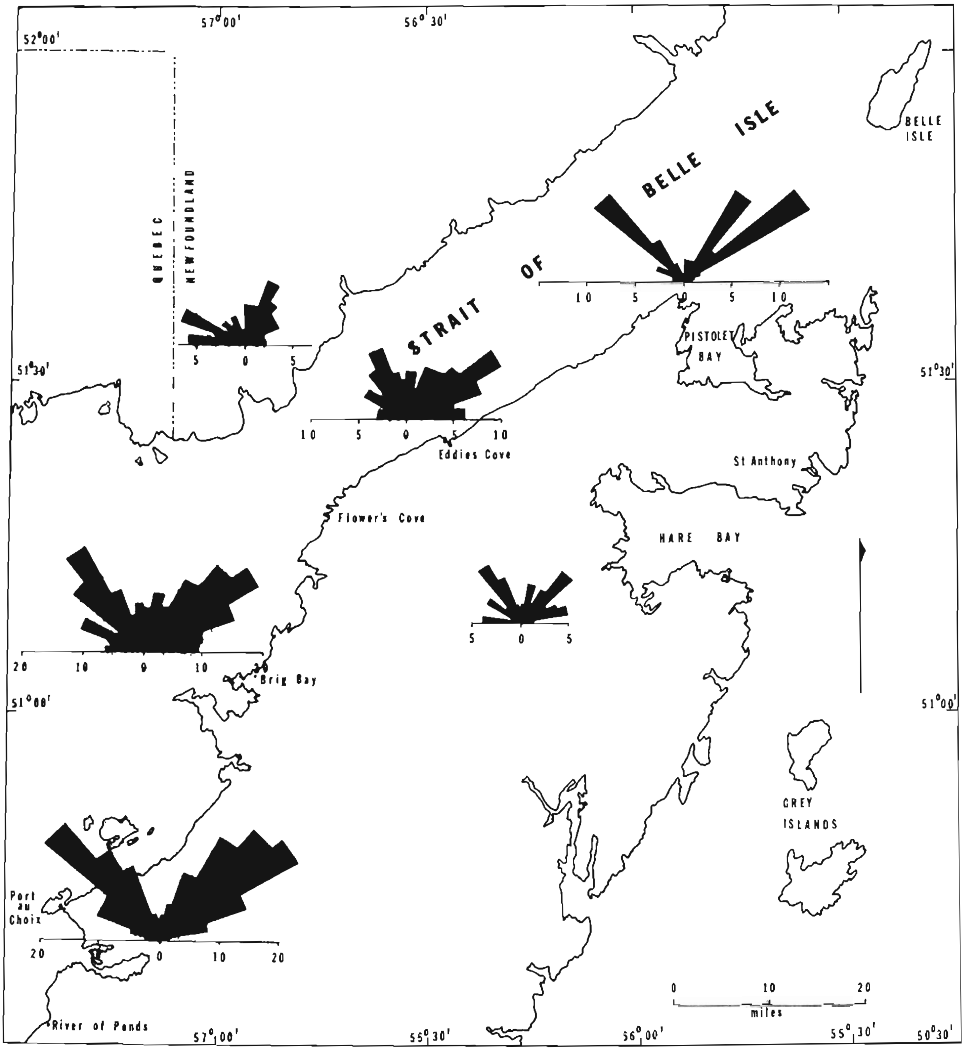
Study of joint and fault systems in the Paleozoic rocks of western Newfoundland and southern Labrador was undertaken during the summer of 1970. The area lies between $50^{\circ}30'$N to $51^{\circ}40'$N and $55^{\circ}30'$W to $57^{\circ}30'$W and is underlain largely by Cambro-Ordovician platformal facies autochthonous rocks which have been subdivided into the following formations:

Middle Ordovician	Goose Tickle Formation Table Head Formation ... Disconformity ...
Lower Ordovician	St. George Formation
Cambrian	Hawke Bay Formation Forteau Formation Bradore Formation .. Unconformity ...
Precambrian	Granitic gneisses

The jointing observed gives a consistent regional picture. Two well-developed joint sets belong to one joint system. This is indicated by the maintenance of constant angle (90°- 100°) between the sets (see Figs. 1, 2, 3). This jointing appears to represent extensional jointing. Supporting evidence has been observed at numerous localities within the St. George Formation where elliptical chert blebs and nodules, which are flat and lie in the planes of bedding, show tension cracks or fractures normal to the long axis of the ellipsoid. These tension fractures show parallel orientation (both strike and dip) with the regional joints and indicate a genetic relationship between them. The joint system may have formed as a result of release of residual stresses following uplift of the platformal region.

Large- and small-scale vertical and steeply dipping normal faults have been observed in the Port Saunders area (12I/11). Of particular interest are three northeast-trending faults - (1) Back Arm Fault, (2) a fault offshore northwest of the twin peninsulas at Port au Choix and (3) a fault exposed at Port Saunders village. Increase in dolomite content towards the fault, extensive shattering of the rock and steeply pitching slickensides are clear evidence for the first two faults. Extensive megabreccia development west of Port Saunders village is the best evidence for the third fault. At this locality, St. George and Table Head Formations are adjacent to one another and the presence of steep to vertical plunging slickensides indicate that the last movement on the fault plane is of dip slip nature.

Two minor faults of strike slip nature, one at Port au Choix Cove and another at Barbace Cove (12 I/11), both trending northwesterly, appear to



Rosette diagrams, proceeding from south to north, represent measurements at:

207 localities from Port Saunders area (12 I/11);
204 localities from Brig Bay (12 P/2) and Flower's Cove (12 P/7) areas;
59 localities from Salmon River area (12 P/1);
97 localities from Eddies Cove (12 P/8) and Big Brook (12 P/9) areas;
61 localities from Labrador (12 P/6, 12 P/7) and
65 localities from Raleigh area (2 M/12 west half).

Figure 1. Distribution of joints in Palaeozoic rocks in the Strait of Belle Isle region.

Figure 2.

View across Strait of Belle Isle near Eddies Cove showing typical widely spaced joint system in the St. George Formation. Iceberg in the background is grounded along the Labrador coast.
GSC photo 201500-M

Figure 3.

Joint system in mud-cracked dolomite of the St. George Formation, west side of Pistolet Bay.
GSC photo 201500-O

postdate the northeast-trending Back Arm Fault. Left laterally displaced, vertically dipping dolomitized bands, five feet wide, are the clear evidence for the Port au Choix Fault. Presence of horizontal to shallow plunging slickensides near these faults suggests that the fault movement is essentially strike slip.

Evidence for two other northeast-trending faults, one east of Hawke Bay Flats and the other in the southeast of Port Saunders village (12 I/11 east half) is the steep to vertical dip of the beds near the faults. The otherwise undeformed beds show evidence of open to light folding near the faults and are thought to have originated as a result of drag along the fault planes.

No major faults have been noticed in the Eddies Cove and Big Brook areas (12 P/8, 12 P/9). One minor fault noticed along the shore (approximately 3.3 miles northeast of Green Island Brook, 12 P/8) shows vertical movements on the fault plane. Locally the beds are dragged into the fault plane (Fig. 4), the southern block being the upthrown block. The fault plane has a variable trend (045° to 075°).

Numerous major and minor faults have been noticed in the Brig Bay map-area (12 P/2) where most of them are marked by well developed lineaments. Ten Mile Lake is probably a fault lineament. Although evidence to determine the movement direction on this fault is lacking, Forteau Formation and St. George Formation exposed on opposite sides of the lake suggest dip slip or oblique slip movements.

In the Cape Norman and Pistolet Bay areas two northeasterly trending faults, well exposed on the shore, show evidence of vertical movements on the fault planes. Strata adjacent to these faults are highly shattered and broadly folded. Tightly folded layers are also common. Steep to vertically plunging slickensides are well developed along the joint planes which are filled

Figure 4.

Minor fault trending northeast 1.3 miles west of Eddies Cove, Newfoundland.
GSC photo 201500-N

with carbonate veins. Horizontal slickensides observed at some places along the shore suggest that some blocks have experienced strike slip movements, but the majority of faulting is of normal type.

A megabreccia developed at Green Cove (2 M/12), containing silicified oolitic carbonate blocks, is probably a collapse breccia as evidence for extensive faulting at this point is lacking. No slickensides were observed at this place. A similar megabreccia occurs at Plum Point (12 P/2).

Numerous normal faults cut the Paleozoic strata north of Strait of Belle Isle[1]. Additional evidence in support of normal faulting was found during the present study. Steep to vertically plunging slickensides were observed on most of the fault planes.

The shoreline east of L'Anse Clair is a zone of faulting which trends northeasterly. The zone does not appear to extend far inland and probably dies out halfway between the shore and Forteau Bay. Steep to vertically plunging slickensides are common along the shoreline and the majority of minor faults show vertical displacements ranging from one to ten feet. The amount of displacement decreases with increasing distance from the major fault and obviously these minor displacements must have been associated with the major fault movement.

Evidence which suggests that the regional joint system predates the regional fault system is found in the Cape Norman area. There, joint planes adjacent to two faults show evidence of movement along the planes. Slickensides are well developed along these planes. Away from the faults, the joint planes show no evidence of movement but maintain their regional trend. From this it is inferred that, at least locally, the regional joint system predates the fault system and faulting itself, has taken place along the pre-existing fracture planes.

---

[1] Cumming, L.M.: Operation Strait of Belle Isle, Quebec and Newfoundland-Labrador; <u>in</u> Report of Activities, Part A: April to October 1969, Geol. Surv. Can., Paper 70-1, Pt. A, pp. 3-8 (1970).

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2. STRUCTURAL EVOLUTION OF THE BATHURST-NEWCASTLE DISTRICT, NEW BRUNSWICK

21 O, P,

Project 690015

Herwart Helmstaedt

During the final field season of this project mesoscopic structures were mapped in the Clearwater Stream area, between the North and South branches of the Sevogle River, and in the area surrounding the Brunswick No. 12 and 6 mines from Ninemile Brook in the west to the Nepisiguit River in the east. Although there are important regional variations in orientations of fabric elements the sequence of deformation is similar in both areas and corresponds to that of other areas in the district[1,2].

The following preliminary conclusions emerge for the Bathurst-Newcastle district as a whole:

1. The oldest unit of the Tetagouche Group is a sequence of quartzite and phyllite in which the quartzite becomes increasingly argillaceous upwards in the stratigraphic sequence as well as laterally from west to east. This sequence was probably laid down on a sialic basement.

2. In most areas of the district the earliest volcanic products are rhyolitic tuffs and flows. Rhyolitic volcanism was later accompanied and then superceded by andesitic to basaltic volcanism. Most sulphide deposits occur near the bottom of the volcanic pile close to the contact between the underlying quartzose sediments and the overlying, generally porphyritic rhyolitic volcanics.

3. Three phases of deformation are of regional significance in the Tetagouche rocks. The first and most penetrative event, resulted in a regional foliation, local mineral lineation, and isoclinal folds on all scales. It was accompanied and in part outlasted by a greenschist metamorphism. Whereas assemblages of the chlorite subfacies with local transitions to blueschist assemblages are common in the northern and northeastern part of the district, biotite is common in the central and southern part. The second phase of deformation caused a relatively penetrative crenulation cleavage, but folding on the macroscopic scale is apparently not associated with this phase. The third phase is responsible for large regional folds that plunge steeply in the eastern part, but gently in the western part of the district.

4. The first two phases of deformation are pre-Late Silurian events (Taconian Orogeny). The third phase can presumably be correlated with the Acadian Orogeny, because faults related to this phase offset porphyritic dykes of probable Middle Devonian age.

5. The major control of the sulphide orebodies is stratigraphic. The sulphide deposits have been deformed by all three phases of deformation and their shape is mainly a consequence of the first phase. However, in some deposits the fluence of later phases is important. The 'shear zones' identified near some deposits are the effects of the first phase of deformation and are not related to the emplacement of the ore. The sulphides are generally conformable to bedding or to the first cleavage along which bedding has been transposed. Locally, where orebodies have been isoclinally folded, the first cleavage cuts across the sulphides.

6. A systematic mapping of mesoscopic fabric elements may be a significant aid in the exploration for new orebodies.

---

[1] Helmstaedt, H.: Geology of Map-area 0-6 Head of Middle River and Wildcat Brook (Northern New Brunswick); Mineral Resources Br., Dept. Nat. Resources, New Brunswick, Map-series 70-1 (1970).

[2] Helmstaedt, H.: Structural geology of Portage Lakes area, Bathurst-Newcastle district, N. B.; Geol. Surv. Can., Paper 70-28 (in press).

NB

3. SUBSURFACE OIL AND GAS STUDIES IN EASTERN CANADA

Project 600456

R.D. Howie

In southern New Brunswick, a field examination of the Albert Formation, started in 1969, was completed[1]. The Albert Formation, a local facies of the Upper Devonian and Mississippian Horton Group, comprises an assemblage of grey, greenish grey to black shale, sandstone and conglomerate, which in part is highly bituminous and contains commercial quantities of gas and oil in the Stony Creek field.

An examination of well cutting from the Stony Creek field, and from a number of wells in the Moncton-Sussex area exhibit a change in stratigraphy from area to area. Differences in interpretation of published maps of the Albert Formation[2 to 7], and changes in facies indicate future progress in the search for petroleum will depend on basinal analysis of the formation.

The Albert Formation overlies the predominantly red shale to conglomerate of the Memramcook Formation and is overlain by red shale and red and green sandstone and conglomerate of the Moncton Group. The upper and lower contacts of the Albert Formation may show a rapid change from red to grey and from grey to red or may be transitional over hundreds of feet. In a road-cut 1.8 miles west of Norton on Highway No. 1,[2] the transition from the Moncton Group to the Albert Formation is accomplished in a few feet. In the Mount Pisgah to Kinner settlement area[4], the section mapped as Albert Formation is a sequence of hundreds of feet of sandstone and shale, that is for the most part red, with green interbeds disclosing a very gradual transition between the Albert Formation and the Moncton Group.

Green conglomerate in the Albert Formation at Elgin[5], Walker Settlement[3], Mapleton[5], Stuart Mountain[6], and Rosevale[6] are similar to green Memramcook conglomerate at Elgin, south of Parkindale[6], and green Moncton conglomerate at Waterford. In the Sussex Corner-Parlee Brook area[3] outcrop originally mapped as Moncton Group, and later remapped as Albert Formation is now shown to belong to the Moncton Group. However, north of a southwest-trending fault, between Parlee Brook and Waterford, outcrop mapped as Moncton Group and later changed to Albert Formation, is considered to belong to the Albert Formation.

---

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

[3] Evans, C.S., and Alcock, F.J.: Waterford; Kings and Saint John counties; New Brunswick; Geol. Surv. Can., Map 829A (1945).

[4] Stewart, J.S.: Petitcodiac (west half); Kings and Westmorland counties; New Brunswick; Geol. Surv. Can., Map 643A (1941).

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[7]Gussow, W.C.: Carboniferous stratigraphy and structural geology of New Brunswick, Canada; Am. Assoc. Petrol. Geol., vol. 37, No. 7, pp. 1713-1816 (1953).

General
A.S.

4. GRAPTOLITES, COPPER AND POTASSIUM-ARGON IN GOLDENVILLE FORMATION, NOVA SCOTIA

W.H. Poole

Graptolites were discovered in 1968 by P.E. Schenk and the writer in the Cambro-Ordovician Meguma Group on the southeast coast of Nova Scotia. The find is the first outside of that relatively restricted, northwestern part of the Meguma terrane which heretofore has yielded the few localities upon which the designated age of the Meguma depends.

Schenk[1] in a recent regional study of the Meguma has summarized the paleontological evidence for the age of the group and referred to this new graptolite occurrence. The occurrence is sufficiently important to publicize its location in the hope that the area of the locality will be thoroughly searched for additional better-preserved graptolite specimens.

The graptolites were found in loose fragments of dark grey slate, freshly bulldozed from low outcrop along Highway 7 at Tangier, 45 miles east of Halifax. The locality is less than one mile east of the Tangier River bridge, or 0.3 mile east of the turn-off to Mason Cove, near pits and concrete foundations of an old gold mining operation.

The black slate is lithologically typical of the mainly(?) Lower Ordovician Halifax Formation, the upper part of the Meguma Group but the locality is shown on an old geological map by Faribault[2] to fall on an anticlinal axis within the older Goldenville Formation, of the lower part of the Meguma Group, many thousands of feet stratigraphically below the Halifax. Schenk[1] has favoured the Goldenville rather than Halifax interpretation of these rocks.

Bernd-D. Erdtmann, Department of Geology, Indiana University at Fort Wayne, in December 1969 examined the collection and commented as follows:

GSC Loc. 82925.

"Identifications: Graptolite branches probably belonging to Didymograptus, but possibly rhabdosomes of Monograptus.

"Comments: The sample indicates at least a medium grade metamorphism (phyllitic slate). The specimens are almost completely obliterated. One can only state with certainty that there are no Diplograptids in the sample which excludes Middle Ordovician for a stratigraphic position. However, both a Canadian (Arenigian) and Silurian age are possible, the first being the more likely."

The locality and other slate outcrops in the general vicinity should be thoroughly searched for better preserved graptolites. A more precise identification would help in our understanding of the age of the two formations.

Copper stain was noted by P.E. Schenk, I.M. Harris and the writer in greywacke-quartzite of the Cambro-Ordovician Goldenville Formation along the southeast coast of Nova Scotia, 48 miles east of Halifax. The locality is on the shore of Phoenix Island, at Dipper Point, 4.5 miles south-southwest of the village of Spry Bay.

Small diffuse spots of malachite are scattered irregularly and sparsely on a few tight fractures within a few inches of greywacke-quartzite beds containing much detrital muscovite. Examination of a thin section of a specimen bearing malachite failed to reveal copper or iron sulphides within the rock, and thus the immediate origin of the copper stain is unknown. An analysis of several malachite-bearing specimens by the geochemical laboratory of the Geological Survey using an atomic absorption spectrophotometric method yielded 0.016 per cent copper.

This copper mineralization, however lean, raises the speculation that economically important low-grade deposits of disseminated copper sulphide-bearing quartz veins and of dykes or sills at the locality from which the copper could have been derived. To speculate further, there may exist deposits in the Goldenville terrane similar to those found in the late Precambrian Purcell Group of southeastern British Columbia[3] and the belt terrane of Montana and Idaho[4], to which the Meguma has been broadly compared[5].

Potassium-Argon. The source of the Goldenville sediments has been shown convincingly to be a metasedimentary and meta-igneous terrane lying to the south-southeast[1]. Knowledge of the age of the detrital muscovite in the Goldenville undoubtedly would aid interpretation of the provenance. To this end, I.M. Harris and the writer collected two samples of muscovitic Goldenville, one on Phoenix Island at the malachite locality described above and the other 3 miles on strike to the east, in possibly the same sequence of beds, on the peninsula leading to Taylor Head. One muscovite concentrate, impure with 17 per cent chlorite, from Dipper Point yielded by potassium-argon analysis in the laboratories of the Geological Survey, 476 ± 19 m.y., while the other concentrate, with only 5 per cent chlorite, yielded 496 ± 20 m.y. (R.K. Wanless, pers. comm. 1970). The range of age of the two determinations, considering the experimental error limits, spans the interval 457 m.y. to 516 m.y., Late Cambrian and Early Ordovician according to the Geological Society of London's Phanerozoic time-scale, 1964. This age of course is precisely the most favoured for the age of deposition of the Goldenville. The age presumably cannot represent the age of the source area, and is probably the age of that collection of processes related to transport, deposition, diagenesis, compaction, de-watering and possibly cleavage formation.

---

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[2]Faribault, E.R.: Tangier Sheet; Geol. Surv. Can., Sheet No. 39, Map No. 565 (1896).

[3]Minister of Mines and Petroleum Resources, British Columbia, Annual Report, 1968, p. 270.

[4]Trammell, J.: Stratabound base metal sulphides in the Belt Supergroup of Montana (abstract); Geol. Soc. Am., Abstracts with Programs, vol. 2, No. 5, p. 352 (1970).

[5]Poole, W.H.: Tectonic evolution of Appalachian region of Canada; Geol. Assoc. Can., Spec. Paper No. 4, pp. 9-51 (1967).

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5. URANIFEROUS MINERAL IN THE CARBONIFEROUS, GASPÉ PENINSULA

Project 700038

W.H. Poole

A uraniferous mineral, clarkeite $(Na_2, Ca, Pb)O \cdot 8UO_3 \cdot 6H_2O$ was discovered in the Bonaventure Formation of Carboniferous age at Percé, easternmost Gaspé Peninsula, Quebec. The locality is on the beach at Percé below the lookout on Highway 6 at Côte Surprise, near White Head (Cap Blanc). The occurrence serves to emphasize that all late Paleozoic clastic strata from upper Devonian to Permian of the Atlantic region are potential host rocks of uranium deposits.

The Bonaventure Formation comprises a calcite-cemented polymictic red conglomerate of probable early Pennsylvania age which is exposed around the edge of Chaleurs Bay bordering southern Gaspé Peninsula and northern New Brunswick. The formation is essentially flat lying and rests with angular unconformity upon strata of many ages which have been folded during Devonian and earlier periods. It appears to be a fluviatile deposit derived locally from highlands located inland from the present Chaleurs Bay. The deposits have partly buried an irregular erosion surface.

At the Côte Surprise locality, the Bonaventure rests upon steeply dipping ribbon limestone of the Matapedia (White Head) Group of late Ordovician and early Silurian age. From the shore, the unconformity rises in the seacliff in a southerly direction. A peculiar limestone bed, varying from 5 to 10 feet in thickness, forms the base of the Bonaventure and underlies the red conglomerate. The limestone is almost structureless. It is buff, grey and reddish grey, finely crystalline, and lacks bedding. Some parts are oolitic. Bedding parting planes in the underlying ribbon limestone, reddish coloured for several feet below the unconformity, appear to continue upward through an indistinct unconformable surface into the lower part of the Bonaventure limestone. Thin irregularly curving and discontinuous veins of chalcedony (agate) generally less than a few inches thick cut the limestone. The chalcedony is thinly banded, reddish, grey, buff and black. Similar chalcedony appears as pebbles in the overlying conglomerate. Both contribute to agate pebbles found on the beach and admired by amateur collectors[1].

Some small pods of drusy quartz within medium crystalline dolomite contain tiny millimetric blades of black hematite (specularite). Pinhead-sized equant crystals of black clarkeite are distributed sparsely in the dolomite. Extent and concentration are unknown.

The hematite and clarkeite were identified by M. Bonardi, mineralogy laboratory of Geological Survey of Canada, using X-ray diffraction methods, from specimens collected by the writer. The clarkeite X-ray pattern became quite distinct after heating of the mineral. The mineral has been identified from only Spruce Pine, North Carolina and from India[2]. If it is like that from Spruce Pine, its composition would be $(Na_2, Ca, Pb)O \cdot 8UO_3 \cdot 6H_2O$ and contains about 80 per cent UO_3. In both localities, and perhaps also at Côte Surprise, it is an alteration product of uraninite.

The origin of the clarkeite appears to be related to the alteration of limestone to dolomite and perhaps to the formation of the drusy quartz and hematite pods. The limestone itself must certainly be a sedimentary product of Bonaventure age and presumably of marine origin; in another locality, near St-Jules in Maria Township[3], limestone about 20 feet thick occurs within the Bonaventure Formation and is quarried. Perhaps, groundwater action during subsequent fluviatile deposition of immediately overlying conglomerates may have produced the veinlets of chalcedony and zones (?) of dolomitization in the limestone and at the same time deposited the clarkeite (? after uraninite) and quartz-hematite.

This new uraniferous mineral occurrence enlarges the prospective area of Carboniferous rocks for uranium deposits in the Atlantic Provinces. This discovery adds Quebec to the three Maritime Provinces whose Carboniferous strata bear uranium minerals[4, 5, 6]. And the occurrence also adds limestone of the Bonaventure type at least, to the various lithologies bearing uraniferous minerals.

---

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21 J/14

6. PLASTER ROCK MAP-AREA, NEW BRUNSWICK

Project 700016

R. Skinner

Geological mapping of the bedrock of the Plaster Rock map-area for publication on a scale of 1:50,000 was started in 1970 and the east half was completed.

The map-area lies on the western flank of the Miramichi Highlands of New Brunswick about 40 miles southwest of the Bathurst mining camp. The eastern half is underlain by moderately folded Silurian and/or Devonian volcanic and sedimentary rocks and most of the western half is underlain by flat-lying Mississippian continental and marine sedimentary rocks.

Unit 1 underlies the southeast corner of the map-area and consists of grey, fine- to medium-grained quartz-feldspar-biotite paragneiss, a rock that is widespread to the east in the adjoining Tuadook Lake map-area[1].

Unit 2 is deformed and altered granite that is intimately associated with unit 1. It is a greenish pink, foliated, medium-grained, in places porphyritic, biotite granite, and is also widespread to the east in the adjoining Tuadook Lake map-area.

Silurian and/or Devonian map-units 3 to 5 are lithologic units that become younger to the west; in the northern part of the area they are in stratigraphic order, but in the southern part unit 3 and the small body of unit 4 to the west of it are younger than the main body of unit 4.

Unit 3 consists of greenish grey, aphanitic to fine-grained, massive basalt intercalated with minor grey slate and siltstone.

Unit 4 forms the highest hills in the area and consists of pink, red and grey aphanitic to finely porphyritic rhyolite with intercalations of slate (some of which is fossiliferous) and basalt. In places, particularly in the northern part of the area, the red rhyolite is distinctly laminated.

Unit 5 is the thickest and most widespread of the Silurian and/or Devonian units and for the most part overlies the volcanic units. It consists mostly of grey slate and siltstone, but contains intercalated rhyolite and basalt flows and agglomerates, and is cut by numerous diabase dykes of unit 6. The siltstone is commonly distinctly graded.

Unit 6, grey, fine- to medium-grained, massive diabase, is widespread and occurs as northeasterly trending dykes from a few feet to a few thousand feet thick that cut the Silurian and/or Devonian units, particularly unit 5.

Unit 7 consists chiefly of flat-lying Mississippian continental red beds. Only the eastern, or basal part of unit 7 was examined; there it consists of flat-lying red pebble conglomerate and coarse sandstone. The clasts are well rounded pebbles of Silurian and/or Devonian volcanic and sedimentary rocks of Devonian diabase and of vein quartz. According to Rose[2] the Mississippian sequence in the Plaster Rock map-area is about 2,000 feet thick. From base to top, it consists of 500 to 1,000 feet of red conglomerate, sandstone and shale with shale predominating in the upper half; about 130 feet of limy shale and limestone; about 100 feet of gypsum-bearing shale (which outcrops at Plaster Rock); and about 800 feet of red friable shale capped by 25 feet of conglomerate.

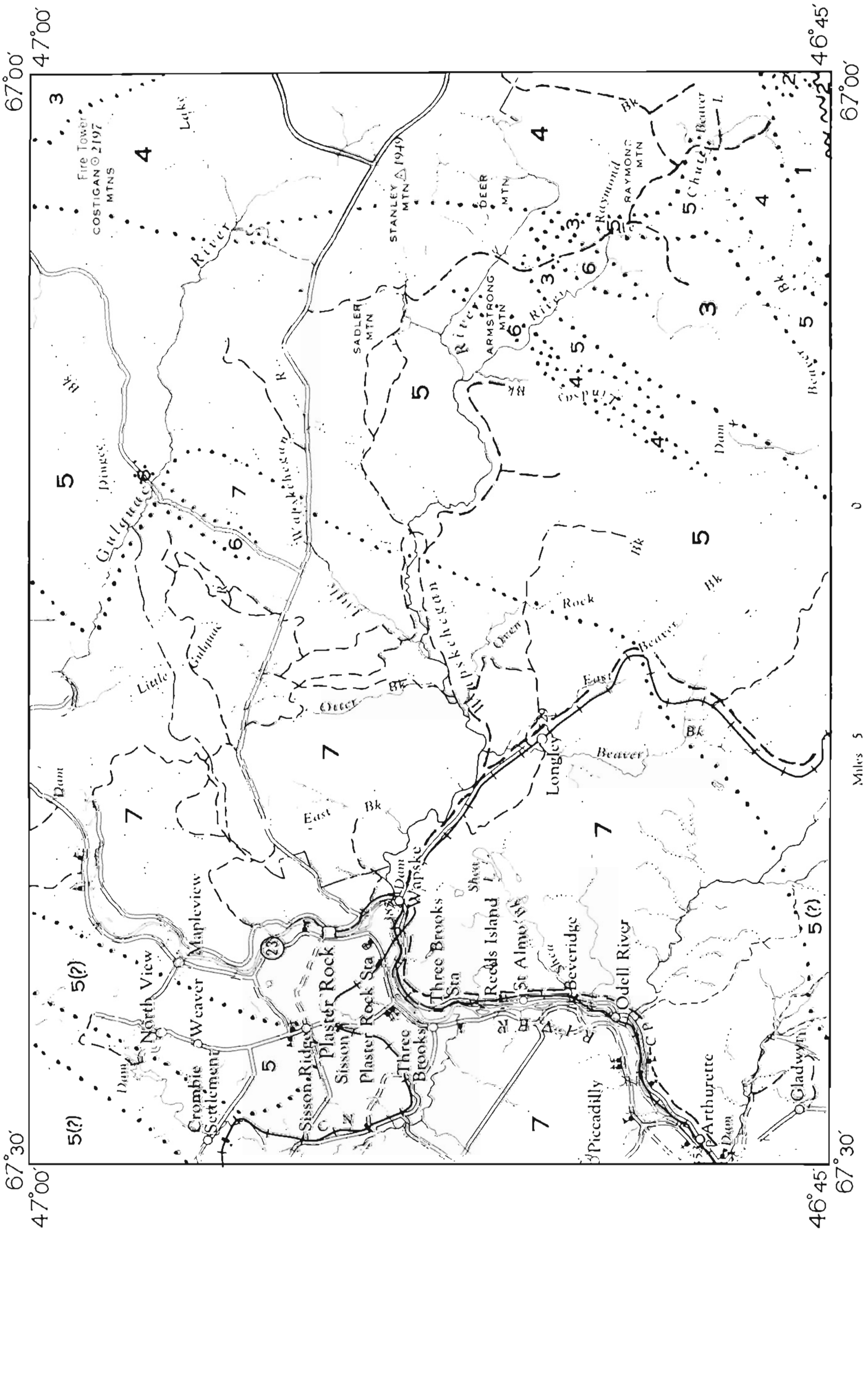

Figure 1. Sketch map of Plaster Rock map-area.

LEGEND

MISSISSIPPIAN

7 Red conglomerate, sandstone, shale, limestone, gypsum

DEVONIAN

6 Diabase

SILURIAN AND/OR DEVONIAN

5 Slate and siltstone, minor rhyolite and basalt (cut by numerous diabase dykes (6))

4 Rhyolite, slate, basalt

3 Basalt, minor slate and siltstone

UPPER ORDOVICIAN OR SILURIAN

2 Pink foliated granite

CAMBRO-ORDOVICIAN

1 Paragneiss

The contact between the Cambro-Ordovician paragneiss and the Silurian and/or Devonian volcanics is presumably unconformable. The Catamaran Fault, which trends westerly across McKendrick Lake[3] and Tuadook Lake map-areas cuts the southeastern corner of Plaster Rock map-area, and then swings southerly. The Silurian and/or Devonian in the east half of the map-area occupies the east limb of a large north-northeasterly trending syncline whose axis passes near Plaster Rock.

No significant metallic mineral occurrences are known with Plaster Rock map-area. However, silver, lead, and zinc geochemical anomalies have been reported from the Costigan Mountains. Gypsum was mined at Plaster Rock in the late 1800's and the product was used for fertilizer and cement; Hamilton[4] examined the deposits and estimates that about 5 million tons of gypsum are available in the immediate Plaster Rock area.

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

[2] Rose, Bruce: Plaster Rock area, New Brunswick, Geol. Surv. Can., Paper 36-19 (1936).

[3] Anderson, F.: McKendrick Lake, New Brunswick; Geol. Surv. Can., Paper 69-12 (1970).

[4] Hamilton, J.B., and Barnette, D.E.: Gypsum in New Brunswick; Report of Investigation No. 10, Mineral Resources Br., Dept. Nat. Resources, New Brunswick, pp. 12-16 (1970).

82 G.J.
General

COAL RESEARCH

7. STUDIES BY THE COAL RESEARCH SECTION, 1970

Projects 610269, 680102, 680105, 690026

P.A. Hacquebard and A.R. Cameron

Field work by the Coal Research Section consisted of a month spent by a two-man party in coal localities of western Canada. Many of these localities are presently sites of intensive exploration and development and the trip provided an opportunity to meet with personnel of the companies involved and to become acquainted with the geology and problems of particular areas. Areas visited ranged from the Crowsnest Pass of southern Alberta and British Columbia to Carmacks in the Yukon Territory. Samples for petrological study were collected during the trip.

Project 610269. Petrographic Examination of Coking Coals from the Crowsnest Coalfield, Alberta and British Columbia.

Two increment samples representing the Nos. 9 and 10B seams and one column sample representing the No. 10A seam were collected on Line Creek Ridge, north of Natal, B.C. A total thickness of about 37 feet of coal is represented by these three seams which along with the No. 8 seam figure largely in the development plans of the company exploring this area. In addition the number and position of "tonstein" or clay layers were checked in the No. 10 seam mined in the Harmer Knob Pit near Natal. These layers are thought to have considerable value in seam correlation.

Project 680102. Rank Studies of Coal and Carbonaceous Matter.

This study involves the microscopic evaluation of rank. To this end a total of 108 samples were collected in the field season of 1970. The sample sites were selected with three objectives in mind: (1) to study the vertical change within a given section, (2) to study the lateral variation in rank on a regional basis within a given formation, and (3) to study the variation in rank among coals of different formations.

In line with these objectives good sectional coverage of Kootenay Formation coals was provided by samples collected at Line Creek and Fording River in the upper Elk River field north of Natal, B.C. Samples were collected at Canmore, Alberta to complete coverage of the Kootenay Formation coals from that area. Additional samples of Kootenay coals were collected in the Blairmore, Burmis and Frank areas of Alberta.

Coal-containing sections of the Luscar Formation (lower Cretaceous) were sampled in the Mountain Park and Smoky River areas of Alberta while coals of the Gething Formation (also lower Cretaceous) were sampled in the Peace River Canyon area of British Columbia. Coals in a section of the Brazeau Formation (upper Cretaceous) exposed along McLeod River in Alberta were also collected. In addition samples of coal were collected from the Belly River and St. Mary Formations of upper Cretaceous age in the Hill Spring, Lundbreck and Coleman, Coal Valley, Sterco, Robb and Hinton areas, also in Alberta.

Project 680105. Petrography of Coal Seams in the Rocky Mountain-Foothills Belt, north of the Crowsnest area. Samples for detailed petrological studies were collected in the following areas:

1. Luscar, Alberta. The main seam (90 feet thick at point of sampling) collected in 2-foot increments.

2. Smoky River, Alberta; (a) No. 10 seam (12 feet 7 inches thick) on Grande Mountain, collected in 6-inch increments, (b) No. 4 seam (20 feet thick); upper 15 feet collected as a column sample in No. 5 mine.

3. Sukunka Creek south of Chetwynd, B.C. Chamberlain seam (8 feet 7 inches thick) collected as a column from a drill core.

Project 690026. Petrographic Correlation of Coal Seams of Carmacks, Yukon Territory.

A 17-foot-thick seam, freshly exposed on the south bank of the Yukon River at Carmacks, was collected in 6-inch increments for detailed analysis. The exposure is about 2 miles south of Tantalus Butte where coal is presently being mined for the drying of base-metal concentrates.

/ 106A, C,

CORDILLERAN GEOLOGY

8. OPERATION STEWART, YUKON TERRITORY AND DISTRICT OF MACKENZIE

Project 680119

S.L. Blusson

Regional mapping on a scale of 4 miles to one inch was completed for the entire project area including the southwest corner of Mount Eduni area (106A). Preliminary maps for these areas are presently in preparation. Stratigraphic detail was confined to several sections in the Lower Cambrian (see W.H. Fritz elsewhere in this publication) and to Siluro-Devonian strata. The northwest part of Nadaleen River map-area (106C) is extensively underlain by the Proterozoic strata which bear little resemblance to the sub-Cambrian section in areas to the east and possibly represent the oldest strata in the Mackenzie or Selwyn Mountains. The basal unit, seen in the vicinity of Fairchild Lake, comprises about 4,000 feet of thin-bedded and banded argillaceous and calc-silicate hornfels. The Lower Proterozoic section is block faulted, locally tightly folded, and overlain with marked angular unconformity by Upper Proterozoic purple argillite possibly correlative with the lower part of the Rapitan Group. This unconformity is best exposed west of Pinguicula Lake where it was first reported by Wheeler[1]. The Proterozoic "Grit" unit, so extensive south and west of Nadaleen River map-area, nowhere in that map-area comes in contact with the Upper Proterozoic argillite. The "Grit" unit probably represents a western facies of the Upper Proterozoic unit and has been thrust appreciably to the north and east.

A new area of Paleozoic volcanism was found northeast of Bonnet Plume and Misty Lakes. Well jointed, thin basic flows and very coarse chaotic breccias total as much as 3,000 feet on the Yukon-Northwest Territories boundary at the head of Bonnet Plume River. These rocks are well dated by graptolites as Middle Ordovician and are thus contemporaneous with volcanism in the Sunblood Formation of Glacier Lake map-area[2].

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[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] Gabrielse, H. et al.: Flat River, Glacier Lake, and Wrigley Lake, District of Mackenzie and Yukon Territory; Geol. Surv. Can., Paper 64-52, (1965).

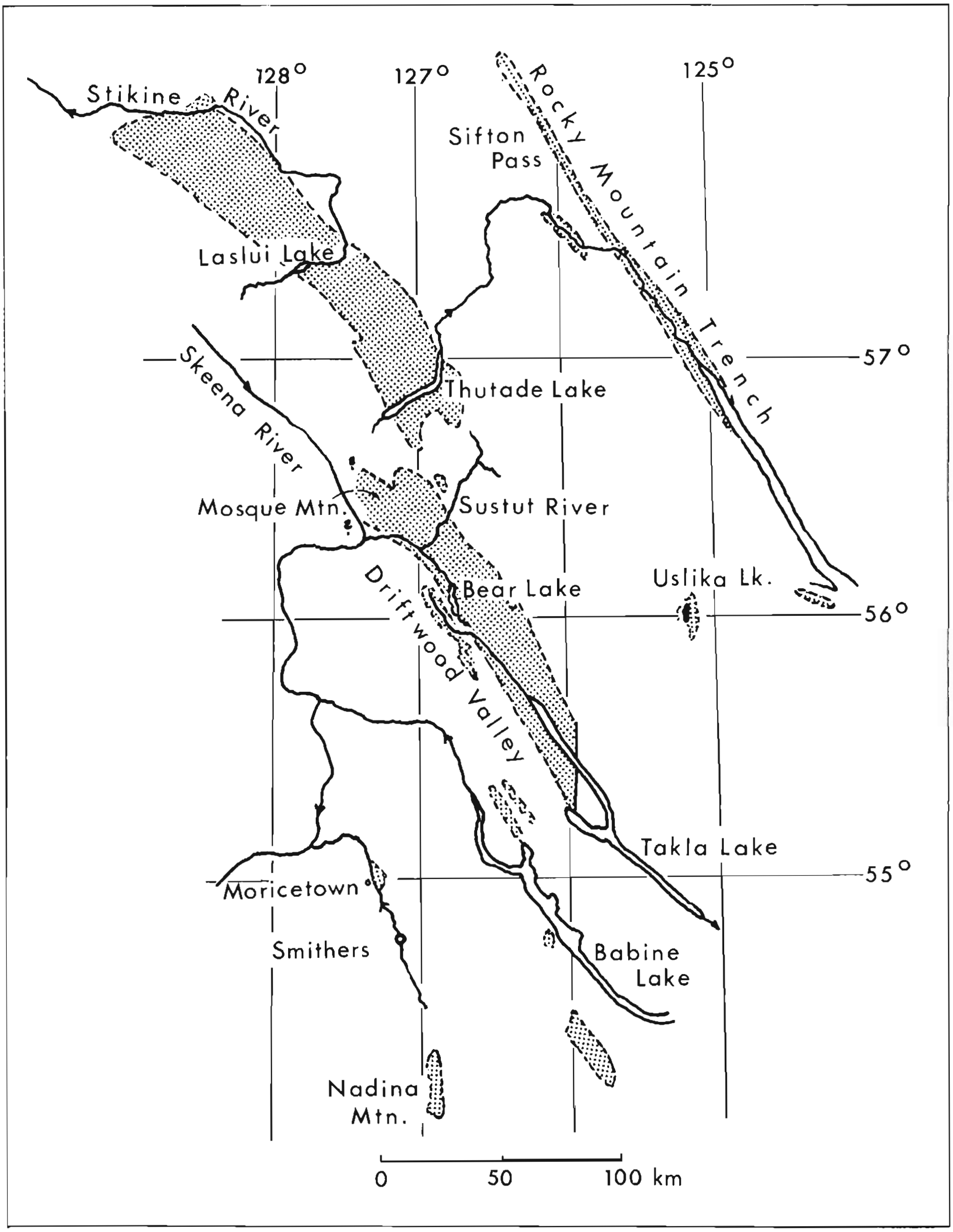

Figure 1. Presently known distribution of Late Cretaceous-Early Tertiary continental deposits in north-central British Columbia.

94D,E;
104 H ✓

9. TECTONIC FRAMEWORK OF SUSTUT AND SIFTON BASINS, BRITISH COLUMBIA

Project 690032

G.H. Eisbacher

Field work concentrated on the study of continental Upper Cretaceous-Lower Tertiary Sustut Group rocks between Sustut River and Thutade Lake[1, 2]. Reconnaissance was carried out between Bear Lake and Takla Lake. Outliers of Upper Cretaceous-Lower Tertiary continental deposits were inspected near Moricetown[3], Nadina Mountain and Babine Lake[4], Uslika Lake[5], and in part of the Rocky Mountain Trench (Sifton Formation[6]).

On Mosque Mountain, northwest of Bear Lake, a large hitherto unknown outcrop area of Sustut Group was discovered which may possibly extend into the northwesterly trending Skeena River valley (see Fig. 1).

The stratigraphic succession between Sustut River and Thutade Lake is similar to the one reported from the area between Thutade Lake and Laslui Lake[2] except for a higher proportion of conglomeratic members below the first appearance of acid tuff sheets. The upper part of the Sustut Group contains many such waterlain acid tuffs for which no definite source area has yet been identified.

The Late Cretaceous-Early Tertiary flood plains were located close to major present day topographic lineaments (Driftwood Valley, Rocky Mountain Trench). Sedimentary facies vary rapidly from coarse- to fine-grained assemblages across these northerly to northwesterly trends; much less pronounced changes are found along strike.

Paleocurrent data suggest progressive growth of folds and faults in underlying rocks during sedimentation of the Sustut Group. It seems that the basal units of the Sustut Group were deposited unconformably onto pre-existing northerly to north-northwesterly trending structures within the underlying Triassic-Jurassic volcanics and sedimentary rocks. During and after deposition of the Sustut Group this older tectonic fabric was redeformed together with the overlying Sustut rocks along strong northwesterly trends, particularly in the sector southwest of the Omineca Fault (see Fig. 2). The Omineca Fault[1] is on trend with the Kitchener Monocline. The latter may represent a distinct hinge of the Late Jurassic Bowser Basin[2].

The Omineca-Quenada-Pinchi Fault Zone therefore probably constitutes an inherited structural weakness within the regional tectonic framework which reversed its sense of displacement during the late pulses of the Cordilleran Orogeny.

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

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

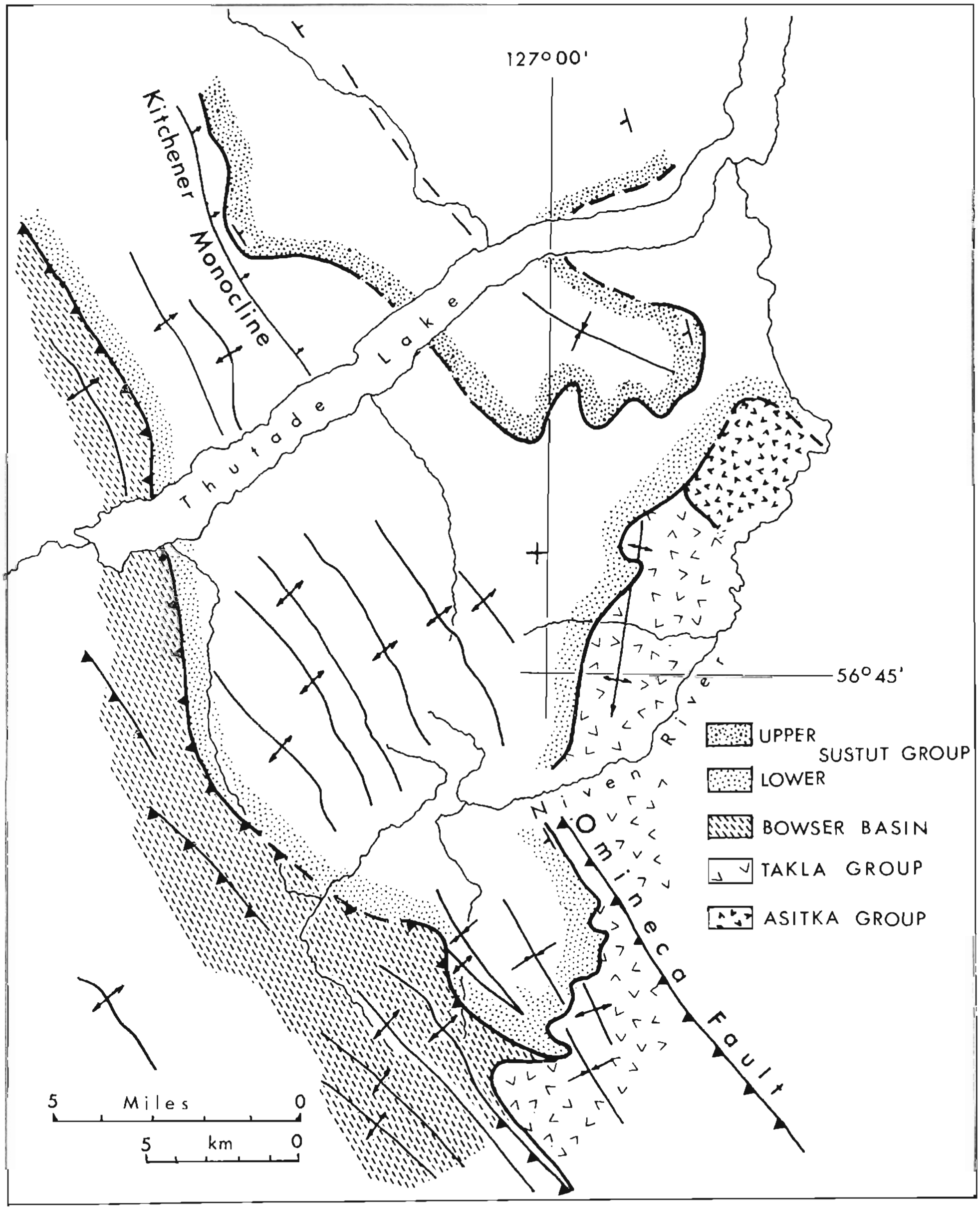

Figure 2. Sketch map of the Thutade Lake area illustrating the relationship of Sustut Group to upper Paleozoic and Triassic-Jurassic volcanic and sedimentary rock units.

[3]Sutherland Brown, A.: Geology of the Rocher Deboule Range; B.C. Dept. Mines Petrol. Resources, Bull. 43 (1960).

[4]Geol. Surv. Can. Map 671A – Houston Sheet (1942).

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

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

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10. OPERATION FINLAY, NORTH-CENTRAL BRITISH COLUMBIA

94 C/E½
94 F/W½
94 E ✓

Project 700047

H. Gabrielse

Operation Finlay is designed to complete the geological reconnaissance mapping of Fort Grahame east half (94 C E 1/2), Ware west half (94 F W 1/2), and Toodoggone (94 E) map-areas. During the 1970 field season mapping was completed in Fort Grahame E 1/2 map-area. In addition, detailed studies were carried out in northeastern Fort Grahame W 1/2 and in southwestern Ware map-areas as part of a thesis project concerning stratigraphy, sedimentation, and structure of the Ingenika Group (see J.L. Mansy, this report).

Fort Grahame E 1/2 map-area embraces parts of Omineca and Rocky Mountains and is bisected diagonally by the north-northwesterly trending Rocky Mountain Trench. The floor of the Trench in the map-area is now flooded by Williston Lake created by the W.A.C. Bennett dam on Peace River. Some of the more important aspects of the geology are given below.

Stratigraphy

Strata of the Tenakihi and Ingenika Groups[1] appear to be almost entirely of Precambrian age. It is probable that only a resistant quartzite member exposed in northeasternmost Aiken Lake map-area (Fort Grahame W 1/2) and a few small occurrences of archeocyathid-bearing limestone are of Early Cambrian age. The remaining strata are similar to those of the Upper Proterozoic Kaza, Miett, and Windermere rocks of the southern Cordillera.

Carboniferous and Permian strata exposed in the southwestern part of the map-area seem to overlie unconformably Cambrian and possibly minor younger rocks. In places, as little as 300 feet of strata separate Proterozoic and Carboniferous beds.

Rocks of the Misinchinka Group east of lower Ospika River are similar to those of the Ingenika Group. North of lower Ospika River three members, the upper two possibly lying unconformably on the lower, are, in ascending order:

a. interbedded chloritic slate and impure feldspathic gritty quartzite, more than 500 feet thick, and similar to rocks south of lower Ospika River;

b. calcareous slate and slaty, platy limestone; green and black phyllite; sandy limestone; includes one member of conglomerate as much as 40 feet thick with cobbles of quartzite and limestone to 1 foot in diameter in a phyllitic matrix; pure white quartzite, possibly 100 feet thick (total thickness of member more than 500 feet);

c. green, grey, and black phyllitic slate; a thick, monotonous, highly cleaved sequence with local members of limestone and dolomite. Impure carbonates of member b change facies, at least in part, northerly into phyllitic slates comprising the lower part of member c; (total thickness of member probably exceeds 2,000 feet).

West of upper Ospika River more than 2,000 feet of dominantly clastic rocks contain an Early Cambrian fauna in the upper part. These rocks are overlain by dolomites and siltstones containing a rich Middle Cambrian fauna.

Several thousand feet of well-bedded, wavy banded, silty, nodular limestone and dolomite underlies the most rugged mountains west of upper Ospika River. These rocks are probably of Early Ordovician age and are overlain by more than 2,000 feet of siltstones, slates, limestones, and quartzites of Ordovician and Silurian ages[2].

Structure

Strata northeast of Rocky Mountain Trench are involved in typical Rocky Mountain structures displaying a northeasterly sense of tectonic transport (see Fig. 1). Possibly four or five thrust sheets are evident, the more westerly generally exposing older rocks. Tight folds, locally overturned to the east, and well developed southwesterly dipping cleavage commonly occur in the footwall rocks of major thrust faults. In general, however, cleavage is much more pervasively and intensely developed towards the southwest, and, in the Proterozoic phyllite belt flanking the Rocky Mountain Trench, bedding is commonly obscured.

In contrast to the structural style in the Rocky Mountains, strata southwest of Rocky Mountain Trench in the Butler Range are involved in structures that show a southwesterly sense of tectonic transport. The Butler Range is interpreted as an anticlinorium flanked to the southwest by a major syncline that in its northern part is strongly overturned to the southwest. The zone of southwesterly overturned structures, coinciding approximately with the Mesilinka River valley, apparently becomes much wider to the northwest, and north of Ingenika River in Aiken Lake map-area involves a belt of rocks at least 15 miles wide in which isoclinal folds and relatively shallow dipping thrust faults are dominant (see J.L. Mansy, this report).

Symmetrical folds in Proterozoic rocks are present southwest of Mesilinka River. Two well-defined faults in the southwesternmost part of the area show an apparent sinistral sense of movement. Along the southern boundary of the area and in adjacent northernmost Manson River map-area these faults locally trend more northerly than the strata and effect a repetition of westerly dipping sections of Carboniferous limestone.

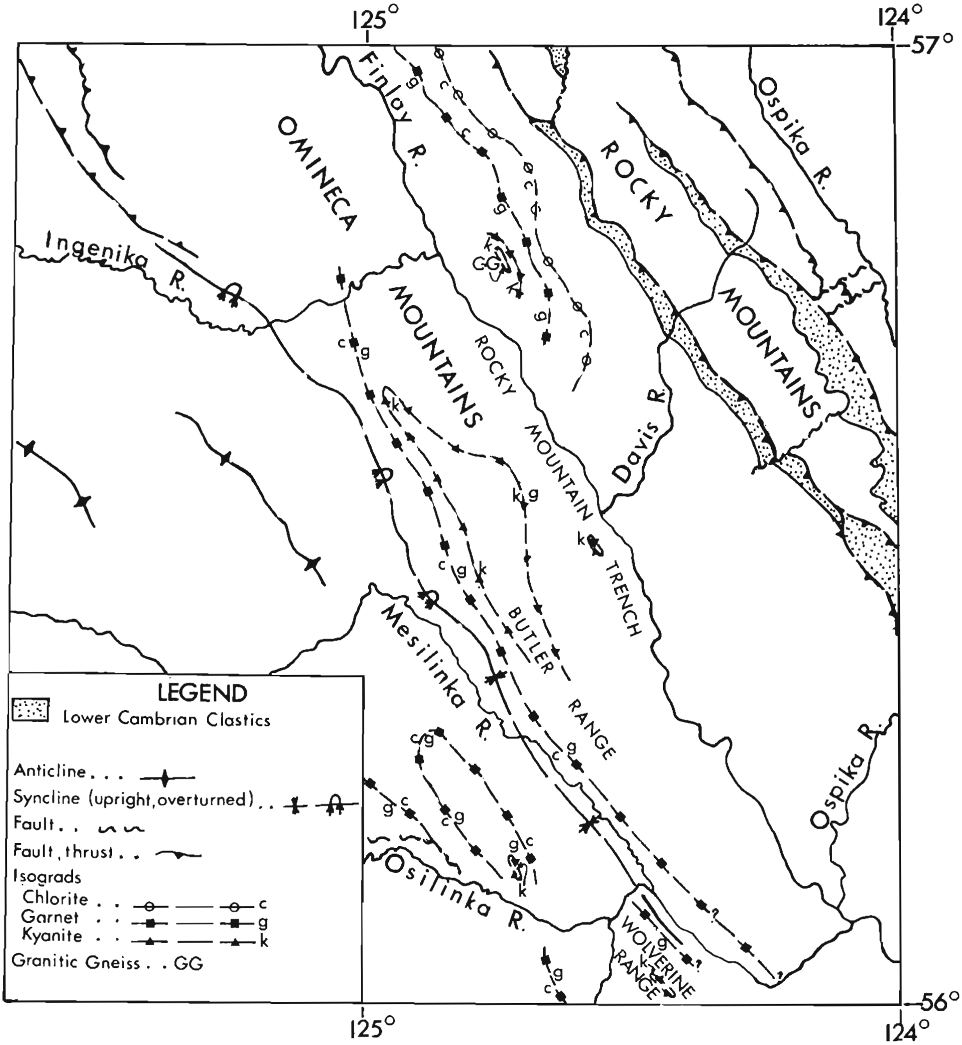

Figure 1. Sketch map of Fort Grahame east-half map-area (east of longitude 125) and part of Aiken Lake map-area (west of longitude 125) showing some of the major structural elements and the approximate positions of metamorphic isograds.

Metamorphism

The entire succession of Proterozoic rocks southwest of the Rocky Mountain Trench has been regionally metamorphosed to grades ranging from chlorite in the synclinoria to kyanite in the anticlinoria. In general, as noted by Roots[1] there is an increase in metamorphic grade with increasing stratigraphic depth. It is clear, however, that within the Ingenika Group, rocks of equivalent stratigraphic position are much more highly metamorphosed in the anticlinoria than in the synclinoria. Feldspar-quartz-muscovite pegmatites are common, though not quantitatively important, in Wolverine and Butler Ranges. Nowhere are the rocks so altered or migmatized that primary aspects of the stratigraphy cannot be recognized.

Upper Proterozoic phyllitic slates, carbonates, and possibly some volcanic rocks are regionally metamorphosed in a belt as much as 8 miles wide on the northeast side of Rocky Mountain Trench north of latitude 56°40' (see Fig. 1). The following remarkably well defined succession from east to west is as follows:

1. drab, grey to dark grey, phyllitic slate;
2. glossy, green, fine-grained, chloritic phyllitic slate;
3. strongly crenulated, coarse-grained chloritic schist;
4. garnet-amphibole-sericite and muscovite schist; amphibolite;
5. kyanite-garnet-muscovite schist bordered to the west by a medium-grained granitic gneiss.

This regional metamorphism bears little relation to stratigraphic level as revealed in a major anticline trending through the high mountains northeast of the mouth of Ingenika River.

Near the mouth of Davis River a marked discordance in metamorphic grade occurs across Rocky Mountain Trench, the rocks to the southwest being of much higher grade.

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

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

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94 C E/2
94 F

11. THE INGENIKA GROUP

Project 700047

J. L. Mansy

A detailed study of the Ingenika Group[1] was begun in the 1970 field season as a thesis project designed to provide information on stratigraphy, sedimentation, and structure of the thick and widespread Upper Proterozoic and Lower Cambrian sequence of rocks in north-central British Columbia. Work was confined mainly to the western part of Russel Range in northeasternmost Aiken Lake map-area (94 C E 1/2) and its northerly continuation in Ware map-area (94 F) (see Fig. 1).

Three formations are easily recognized and serve to elucidate the structural style. They are, in ascending order:

1. limestone, well-bedded, ivory and cream coloured, interbedded in upper part with green phyllite; locally includes reddish weathering and pisolitic beds; possibly as much as 500 feet thick.

2. phyllite and schist, dominantly chloritic and green weathering, locally purple, buff, and black, in places contains considerable pyrite; rock is commonly mylonitized and displays rod-like and boudinage structures; grades upward into unit 3.

3. quartzite, impure, phyllitic, and rusty weathering in lower part, pure and white weathering in upper part; upper part more than 300 feet thick, lower part more than 1,000 feet thick.

All strata are intensely deformed and the structural style indicates relative tectonic transport to the west-southwest (see Fig. 2).

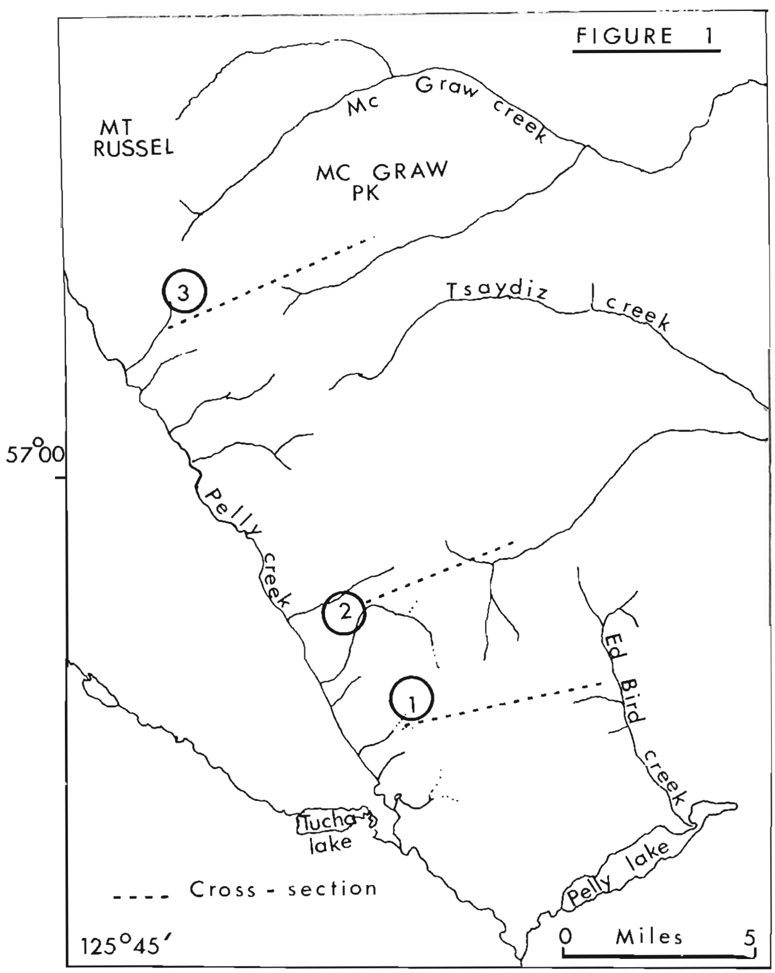
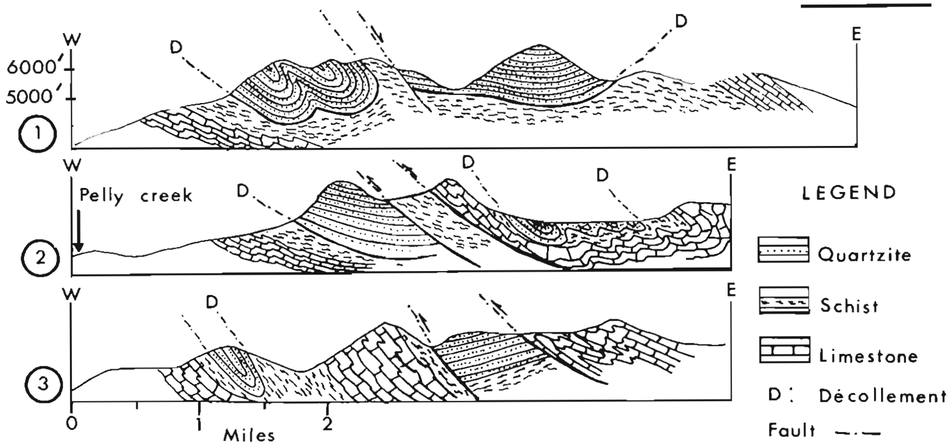


FIGURE 2



CROSS - SECTIONS OF RUSSEL RANGE

The limestone member is tightly folded and in many places axial planes are nearly horizontal or dip gently to the east. The apparent great thickening of limestone south of Pelly Lake is the result of stratigraphic repetition in strongly overturned folds.

The phyllite and schist unit is strongly deformed and shows marked tectonic thickening and thinning. In most places the contact with overlying quartzite is a tectonic boundary interpreted as a décollement.

The competent quartzite member occurs either in tight, almost isoclinal folds or as nearly flat panels overlying highly deformed underlying rocks.

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

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12. NOTES ON THE GEOLOGY OF SOUTHERN VANCOUVER ISLAND

92C, E, F, K, L ✓

Project 680038

J.E. Muller

Fieldwork in the 1970 field-season was restricted to about 5 weeks of preliminary work for the Vancouver Island part of an International Geological Congress 1972 tour of the Southern Cordillera. Special attention was given to the southeast part of the island in an effort to integrate the mapping of C.H. Clapp[1, 2] with recent work farther north, in order to give a unified presentation of Vancouver Island geology.

The south tip of the island is transected by two important faults: Leech River Fault, marked by the valleys of Loss, Wye, Bear Creeks, Leech and Goldstream Rivers, and San Juan River Fault, marked by San Juan River and probably extending southeastward to meet Leech River Fault east of Langford Lake. These two faults appear to separate two narrow strips of different geological composition from the main part of Vancouver Island.

The region including Victoria, Saanich Peninsula and the Malahat-Sooke Lake area is underlain by rocks similar to those known in other parts of the island, but more compressed and disturbed than anywhere else.

In this region Clapp[1, 2] mapped a complex of basic and intermediate crystalline rocks as Wark gabbro-diorite gneiss and Colquitz quartz diorite and granite gneiss. These rocks appear to be incompletely recrystallized volcanic and volcanoclastic rocks, including diabase sills which the writer considers similar to the Westcoast Crystalline Complex of the Vancouver Island west-coast[3]. McLellan[4] equated the Wark and Colquitz rocks with the "Turtleback Complex" of San Juan Islands, also a mixture of many types of crystalline rocks, mainly basic in composition. According to these writers the rocks were derived from or intrusive into Paleozoic and Mesozoic rocks and themselves are of probable Jurassic age.

On the other hand Danner[5] and others have considered the Turtleback Complex to be a pre-Devonian complex, unconformably overlain by Devonian and younger sedimentary and volcanic rocks. The writer recently examined several key-localities in San Juan Islands and found that indeed the Wark-Colquitz and Turtleback complexes have much similarity. However, no evidence was found on Vancouver Island for an unconformity above the Wark-Colquitz complex and for the present it is considered to be the recrystallized equivalent of mainly Paleozoic volcanic, volcanoclastic and basic intrusive rocks, presumably of the Sicker Group.

Probably the oldest bedded rocks in the area are a sequence of thinly bedded to laminated light green altered dacite porphyry, silicified tuffs and greywacke that is complexly folded. They are exposed in the Oak Bay area between Harling Point and Gonzales Point and northwest of Goldstream on Skirt Mountain and on Mount Finlayson. In places they grade into Wark hornblende-plagioclase gneiss. They apparently represent Sicker Group volcanic rocks in the Victoria area.

A succession of highly folded greywacke and argillite is well exposed on Malahat Highway and on Finlayson Arm. It may be equivalent to a similar greywacke-argillite sequence in Alberni map-area, that on Ballenas Islands yielded Middle Pennsylvanian fusulinids in enclosed limestone pods[3]. Another Pennsylvanian occurrence of limestone in argillite was discovered south of Cowichan River (approx. 48°44' north, 123°58' west). B.E.B. Cameron (pers. comm.) determined from this limestone a microfauna, containing "*Palaeotextularia* sp., *Climacammina* sp., *Endothyra* sp., *Polytaxis* sp., *Microcheilinella* sp., *Amphissites* sp., bryozoa, and *Tetrataxis* sp. This fauna is clearly Permo-Pennsylvanian, but the range of *Polytaxis* indicates a tentative Pennsylvanian age".

Ribbon-chert, in a sequence less than 100 feet thick, consists of 2-inch beds of black, light grey weathering chert, separated by black argillaceous laminae, well exposed on Malahat Highway and Finlayson Arm, north of and probably stratigraphically overlying the argillite-greywacke sequence. Similar rocks, less than 20 feet thick are exposed on Buttle Lake between underlying Permian Buttle Lake limestone and the overlying Triassic

Karmutsen volcanics. Rocks of similar lithology were also described by Fyles[8] from Sicker Group rocks in Cowichan Lake area and are abundantly exposed on San Juan Islands where they are of Permian age according to Danner[5].

All bedded rocks described so far may be assigned to the upper Paleozoic Sicker Group. Clapp named the "Malahat Volcanics" and used the term Sicker Group for a belt of rocks north of Duncan that he believed to be Jurassic in age. The latter are now known to be also late Paleozoic and "Malahat" and "Sicker" Volcanics are therefore apparently two names for the same rock sequence.

A younger sequence of volcanics consists of maroon and green coloured tuffs and breccias, flows and light coloured sills of dacite-porphyry and minor pillow lava. They were mapped by Clapp[1,2] as "Vancouver Volcanics". Judging by lithologies both Karmutsen (Triassic) and Bonanza (Jurassic) Volcanics may be represented, the latter more abundantly. Fine-grained limestone enclosed in the volcanics at Bamberton and Todd Inlet (Butchart Gardens) is probably equivalent to Upper Triassic (Quatsino) limestone, but coarsely crystalline crinoidal limestone in the quarry southwest of Cobble Hill is more likely correlative with the Permian limestone exposed on Cowichan Lake.

These rocks are intruded by "Saanich Granodiorite" of probable Jurassic age and all are unconformably overlain by Upper Cretaceous Nanaimo Group beds.

The Leech River Formation is exposed in a belt between the southeastward converging San Juan River and Leech River Faults. The formation consists of greywacke, argillite, sheared conglomerate and minor volcanic rocks, commonly isoclinally folded and with axial-plane slaty cleavage. At Goldstream Park these rocks are phyllitic slates and minor greenschist, but westward towards Jordan River they have become garnet- and staurolite-bearing quartz-biotite schist and gneiss and hornblende-plagioclase gneiss. Locally the schists contain grey, rod-shaped porphyroblasts to one-inch in length of an almost completely sericitized silicate that is probably andalusite rather than sillimanite, as reported by Clapp.

The Leech River schists may be equivalent to the upper Paleozoic sediments and volcanics north of San Juan River that have been described in the foregoing section, or as suggested by Sutherland Brown[6] they may be an Upper Jurassic to Lower Cretaceous clastic sequence. Such a sequence, lithologically similar to the less metamorphosed parts of Leech River Schist, is present on San Juan Islands and there tentatively correlated with the Upper Jurassic to Lower Cretaceous Nooksack Group of Cascade Mountains[5].

South of Leech River Fault the Eocene Metchosin Formation consists of pillow-lavas, aquagene breccia, and basaltic flows almost identical to those of the Triassic Karmutsen Formation. They are locally overlain by the Miocene Sooke Formation of sandstone, shale and conglomerate.

Leech River Fault is undoubtedly a fundamental fault. It appears prominently as a steep northward sloping gradient in gravity on the gravity-map of Steacy and Stephens[7]. Together with San Juan River Fault it cuts off the Vancouver Island geological province of Paleozoic and Mesozoic volcanic, sedimentary and intrusive rocks. South of it rocks belong to the geological province of Olympic Peninsula containing mainly Tertiary volcanic and sedimentary rocks on a substratum of (upper Mesozoic ?) highly folded clastics.

The latter could perhaps be equivalent to the Leech River Schist and in that event San Juan River Fault would be the major break between Vancouver Island and Olympic Peninsula geological provinces.

Both faults have curved, northward convex traces and are vertical to steeply northward dipping. Mylonitic zones are exposed in valleys following the faults. Folds and fold-axes of Leech River rocks are strictly parallel to the fault, suggesting simultaneous faulting and folding that must have occurred in Tertiary time. Judging by slickensides it is probable that the movement had both vertical and horizontal components. The metamorphism of Leech River rocks, apparently highest near the fault, indicates perhaps temporary high temperature and moderate pressure.

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[1] Clapp, C.H.: Geology of the Victoria and Saanich map-area, Vancouver Island; Geol. Surv. Can., Mem. 36 (1913).

[2] Clapp, C.H., and Cooke, H.C.: Sooke and Duncan map-areas, Vancouver Island; Geol. Surv. Can., Mem. 96 (1917).

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

[4] McLellan, R.D.: The geology of the San Juan Islands; Univ. Wash. Publ. in Geol., vol. 2 (1927).

[5] Danner, W.R.: Limestone resources of Western Washington; Wash. Divn. Mines and Geol., Bull. 52 (1966).

[6] Sutherland Brown, A.: Tectonic history of the insular belt of British Columbia; Can. Inst. Mining Met., Spec. Vol. 8, pp. 83-100 (1966).

[7] Steacy, R.A., and Stephens, L.E.: An interpretation of gravity measurements on the west coast of Canada; Can. J. Earth Sci., vol. 6, pp. 463-474.

[8] Fyles, J.T.: Geology of the Cowichan Lake area, Vancouver Island, British Columbia; B.C. Dept. Mines, Bull. 37 (1935).

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92 F, J, K

13. COAST MOUNTAINS PROJECT

Project 630016

J.A. Roddick and W.W. Hutchison

Reconnaissance mapping of the Coast Mountains was extended into Bute Inlet (92 K), northeastern Alberni (92 F) and eastern Pemberton (92 J) map-areas. Work was conducted by helicopter spot examination and selected ground traverses in the interior parts of the map-areas. The shoreline will be examined in a subsequent season.

Although broadly similar to the geology to the north[1] that of Bute Inlet map-area suggests a slightly higher structural level. It is marked by several parallel, northwest-trending, narrow belts of metavolcanic and metasedimentary rocks separated by broader areas of quartz diorite and granodiorite. Unlike pendants farther north in the Coast Crystalline Belt, those in Bute Inlet map-area are characterized by large volumes of silicic volcanic breccias, and comparatively few, substantial exposures of granitoid gneiss. High-level feldspar porphyry intrusions, also more common there than to the north, may be related to the breccias. Appreciable areas between Toba and Bute Inlets are underlain by apparently young, possibly upper Tertiary, acid volcanic rocks. That area and the islands to the west are cut by numerous westerly trending intermediate to rhyolitic dykes. Georgia Lowland[2] in both Bute Inlet and Alberni map-areas is characterized by a dioritic complex that has undergone pervasive low temperature alteration that produced much epidote and chlorite. Karmutsen (Upper Triassic) basalt flows, common on northeastern Vancouver Island[3], are exposed on the southwesternmost islands commonly in fault contact with the Coast Crystalline Complex.

As the northeastern part of Pemberton east-half map-area is underlain by strata that form the northeast flank of the Coast Crystalline Belt, plutonic rocks are much less abundant than in the Bute Inlet map-area. The oldest known and most extensive stratigraphic unit in that part of Pemberton map-area is the upper (?) Paleozoic Ferguson Group. It consists mainly of ribbon-chert, greenstone, argillite and isolated pods of crystalline limestone. J.W.H. Monger spent about three weeks examining this sequence for the Coast Mountains Project. As it is tightly folded, complexly faulted and lacking in persistent marker horizons, the structure is not understood. Apart from small crinoid ossicles no macrofossils were found, but laboratory examination of unrecrystallized oolitic limestone may reveal microfossils.

The Camelsfoot Range, northeast of Yalakom River, was examined by J.A. Jeletzky. Except near Yalakom River where the strata are much faulted, the structure is an open syncline that plunges gently northwesterly. Slices of Lillooet Group (equivalent to the mid-Kimmeridgian to Valagninian part of the Relay Mountain Group) consisting mainly of argillite with minor greywacke and conglomerate are found near Yalakom River. A very thick sequence of Jackass Mountain Group[4] underlies most of the Camelsfoot Range. It consists chiefly of greywacke, argillite and conglomerate, and ranges in age from possible Hauterivian to Albian. The Jackass Mountain Group is overlain by a poorly exposed sequence of greywacke, arkose and shale that is thought to be a sedimentary facies of the Kingsvale Group of Albian (?) and/or later age.

In the vicinity of Upper Nahatlatch River in the southeast corner of Pemberton Lake map-area, a previously unknown occurrence (about 40 square miles) of silicic volcanic breccia was discovered. It is almost certainly Tertiary but its precise age is not known. Small remnants of very young but pre-glacial, flat-lying basalt flows were found on several ridges between Bralorne and Lillooet Rivers. The map-area contains two northwest-trending belts of serpentine, one is in the Cadwallader Creek area and the other in the Shulaps Range. North and northwest trending faults are abundant in the northern part of the map-area, especially near the major Yalakom transcurrent fault.

[1] Roddick, J.A., and Hutchison, W.W.: Coast Mountains Project, B.C.; in Report of Activities, Part A: May to October 1967, Geol. Surv. Can., Paper 68-1, Pt. A, pp. 37-41 (1968).

[2] Holland, S.S.: Landforms of British Columbia; B.C. Dept. Mines, Bull. 48 (1964).

[3] Muller, J.E.: Northern Vancouver Island, B.C.; in Report of Activities, Part A: April to October 1969, Geol. Surv. Can., Paper 70-1, Pt. A, pp. 44-49 (1970).

[4] Duffell, S., and McTaggart, K.C.: Ashcroft map-area, B.C.; Geol. Surv. Can., Mem. 262 (1952).

104 G

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14. STRATIGRAPHY OF MESOZOIC VOLCANIC ROCKS, NORTHWESTERN BRITISH COLUMBIA

Project 690063

J.G. Souther

An investigation of the Mesozoic volcanic succession, begun last year in Telegraph Creek area[1], was extended north to Atlin. Selected volcanic sections were sampled for chemical and petrographic study in order to establish the degree of variation along and across the principal volcanic belts of the Stikine-Taku regions. The study confirms earlier interpretations[2] that Jurassic volcanic rocks diminish north of the Stikine River whereas Upper Triassic volcanic rocks, principally augite andesites, form a continuous, very thick unit that extends throughout the entire region.

The stratigraphic work was coordinated with selection of a route and stops for I.G.C. field trip A12, "Volcanic Rocks of the Northern Cordillera".

[1] Souther, J.G.: Cordilleran volcanic study 1969, Telegraph Creek, B.C.; in Report of Activities, Part A: April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 50-53 (1970).

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

115 I

15. OPERATION SNAG, YUKON TERRITORY

Project 700025

D.J. Tempelman-Kluit

Exposure in the project area is extremely poor except along river valleys and in some ridges in the Dawson Range and southern Aishihik map-area. Field work during 1970 was therefore confined to a reconnaissance traverse across Dawson Range and to examination of outcrops accessible from the Yukon, White, Donjek, Ladue, Klotassin and Nisling Rivers. River travel by inflatable rubber boats powered by 33 h.p. outboard jets proved efficient. Owing to an early drop in the water level in late July the upper reaches of Nisling and Klotassin Rivers were not explored. Three weeks were spent in the vicinity of Aishihik Lake examining outcrop accessible from the road and lake.

Highlights of the geology of the region have been outlined by Green[1]. Much of the area is underlain by granitic rocks and metamorphic rocks classed broadly as "Yukon Group" that are locally overlain unconformably by Mesozoic and younger volcanic and sedimentary strata. Of the metamorphic rocks included in the Yukon Group none seen this season resemble those of the late Precambrian "Grit Unit" elsewhere in the Territory; on the contrary, some of the rocks are lithologically like upper Paleozoic strata found in the Yukon Territory east of the project area. A layered ultrabasic body, roughly equidimensional in plan and about 10 miles across accounts for the aeromagnetic high zone in central Snag map-area (115 K).

A helicopter reconnaissance of the region is planned to complete the project. It is expected that because of the paucity of exposures much of this work will involve looking for rather than at outcrops.

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[1] Green, L.H.: Reconnaissance of Aishihik Lake, Snag, and a portion of Stewart River map-areas, Y.T.; in Report of Activities, Part A: May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 30-31 (1968).

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93 L

16. SMITHERS MAP-AREA, BRITISH COLUMBIA

Project 690009

H.W. Tipper

The re-examination of Smithers map-area (93 L) was begun in 1969[1] and continued in 1970. The reconnaissance geology is known from published maps of the Geological Survey[2,3,4,5] and the British Columbia Department of Mines and Petroleum Resources[6,7]. The 1970 work was mainly in the east half of the map-area (Houston map-area of Lang, 1942) and unless otherwise indicated, the following remarks refer to the east half.

The oldest known rocks of the area are an Upper Triassic group described by Carter and Kirkham[6] as "Triassic and older?" that consist of massive grey limestone, dark green pyroxene-bearing basaltic breccias and tuffs, minor argillite, conglomerate, and andesitic feldspar porphyries or breccias. Fossils tentatively indicate a Late Triassic age and the group is lithologically similar to rocks of the Nicola and Takla Groups of the Quesnel Trough[8]. The group underlies most of an area from a line four miles south of the east half of Fulton Lake, northward along Babine Lake to the north margin of the map-area.

The Hazelton Group was divided by Armstrong[2] into five main units that were retained, in general, by Carter and Kirkham (ref. 6, units 4 to 8). Although these units can be recognized in a rough way in parts of the area, the group cannot be everywhere subdivided so simply. Facies changes within the sediments and volcanics are rapid and profound so that lithologic correlations are meaningless without paleontologic control. Although some units yield few, if any, fossils others have abundant diagnostic forms and a reasonable areal distribution of the fossils provides good stratigraphic control.

Lower Jurassic bedded, green, grey, and purple fragmental volcanic rocks underlie much of the low country north of Highway 16 between Houston and the eastern margin of the map-area and extend to the north boundary of the map-area. They are mostly andesitic or basaltic breccias with lesser amounts of bedded tuffs, and minor massive or vesicular and amygdaloidal flows. Interlayered with these volcanic rocks are thin impure limestone lenses, shales, greywackes and, rarely, cobble and pebble conglomerate; these sediments in places may be several hundred feet thick and have in the past been confused with Middle Jurassic sediments. Fossils indicate that these rocks range in age from Sinemurian to Pliensbachian; earlier or late Lower Jurassic rocks may also be present. The Tachek Group on Tachek and Matzehtzel Mountains are correlative with the Lower Jurassic volcanics of the Hazelton Group.

Middle Jurassic rocks are varied. Fossiliferous interbedded tuffs, breccias, shale, and greywacke are overlain by green and grey coarse andesitic to basaltic breccias and tuffs. These apparently are mainly or entirely of early Middle Jurassic (Bajocian) age and are exposed northwest of Dome Mountain and along the west side of Babine Mountains. Younger Middle Jurassic (Callovian) sediments overlie the Bajocian volcanics but the nature of the contact is unknown. These sediments are mainly black to dark grey shale with minor greywacke and rare conglomerate lenses. Stratigraphically higher sediments are interlayered with andesitic and basaltic tuffs, breccias, and flows and these volcanics form the highest unit of the Babine Mountains; they are thought to be late Middle Jurassic in age.

The Topley Intrusions, previously believed to be pre-Jurassic ?[5] or Lower Jurassic[9], were found to be intrusive into the Tachek Group and therefore, in the writer's interpretation, younger than Early Jurassic. This is in accord with recently published radiometric age dates[10] that indicate a Late Jurassic age.

The Tertiary rocks of the area lying mainly south of Highway 16 are divisible into three or more mappable units. The Ootsa Lake Group of early Tertiary age is made up of rhyolitic, dacitic, and lesser andesitic and basaltic breccias, tuffs, flows, dykes, sills, and stocks with minor sediments or waterlain volcano-clastic rocks. Many small intrusions scattered throughout the area, particularly the feldspar porphyries and those with rounded quartz phenocrysts, show a strong lithologic similarity to Ootsa Lake volcanic rocks and may be genetically related. Overlying the Ootsa Lake Group, in places unconformably, is the Endako Group that is further divisible into two lithologically and structurally distinct units. The "Lower" Endako Group is made up mainly of reddish and brownish, vesicular and amygdaloidal basaltic to andesitic breccias, tuffs, and flows that are thinly layered and warped into very broad, open folds; near the base dacitic to rhyolitic rocks are interbedded. The "Upper" Endako Group rests with angular discordance on the "Lower" and is made up of grey to dark grey, glassy massively bedded basalt breccias and flows with minor interbedded sediments. The "Upper" Endako Group, except locally, consistently dips eastward or northeastward at 5 to 15 degrees whereas the "Lower" Endako dips up to 20 degrees easterly or westerly. The structure of the Ootsa Lake Group is unknown. "Lower" Endako Group volcanics occur also in small areas near Babine Lake, southeast of Topley Landing on Newman Peninsula, on the west side of Babine Lake near Bear Island, and approximately 15 miles east of Chapman Lake; these rocks include some dacitic rocks that may belong to either the Endako or Ootsa Lake Groups. The Endako Group is believed to be no younger than early Miocene.

Apparently the Mesozoic rocks were deformed only slightly over wide areas. Broad open folds are suggested north of Houston and Perow and northward but along the west side of Babine Mountains, Lower Jurassic volcanics are thrust northeasterly onto Middle Jurassic sediments and volcanics. Mount Cronin and Mount Hyland are mainly late Middle Jurassic volcanic rocks that display a series of imbricate thrusts from the southwest. The structural picture is complicated further by repeated, closely spaced block faulting which is sufficient in places to obscure all earlier structural features. The pattern of faulting, readily seen in air photographs, is clearly suggested on Carter and Kirkham's map[6], particularly around Babine Lake and Hudson Bay Mountain, but the closeness of the spacing of the faults can only be shown adequately in detailed mapping. Two exceptionally prominent faults cross the area in a northwesterly direction, one follows the east side of Bulkley valley east of Smithers and the other follows the east side of Babine Mountains southeasterly towards Rose Lake on the east margin of the area. These faults mark fairly profound and abrupt east-west changes in lithology and possibly structure but the nature of the movement is not known. Other major faults parallel these faults but are not as continuous. Northwesterly trending faults appear to be the more dominant and persistent.

The Smithers map-area has undergone intensive mineral exploration by mining companies in recent years. The writer encountered no new economic mineral occurrences except possible traces of chalcopyrite in Lower Jurassic volcanic rocks at one or two places a few miles south of Fulton Lake. The association of many mineral occurrences in the area, particularly copper and molybdenum, with small feldspar and quartz porphyry intrusions has suggested a genetic relation to the Tertiary volcanics and hence a Tertiary age for the mineralization. This may be true for many deposits such as Granisle mine and Kennco's Goosly Lake property which are in or near large Tertiary volcanic and intrusive complexes. However, as the volcanic rocks of Tachek and McRea Mountains are now known to be intruded by the Topley Intrusions of probable Upper Jurassic age, the mineral deposits on these mountains may be a result of Jurassic mineralization. Furthermore, granitic clasts have been found in Middle Jurassic and probably Lower Jurassic conglomerate indicating one or more older periods of intrusions in the region. Two or more periods of mineralization may also be expected in parts of the map-area.

[1]Tipper, H.W.: Smithers map-area, British Columbia; in Report of Activities, Part A: April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A (1970).

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

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

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

[5]Hanson, G., and Phemister, T.C.: Topley map-area, B.C.; Geol. Surv. Can., Summ. Rept., 1928, Pt. A, pp. 50-77 (1929).

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

[7]Carter, N.C.: Northern Babine Lake area; B.C. Dept. Mines Petrol. Resources, Ann. Rept. 1965, pp. 90-99 (1966).

[8]Campbell, R.B., and Tipper, H.W.: Geology and mineral exploration potential of the Quesnel Trough, British Columbia; Bull. Can. Inst. Mining Met., vol. 63, No. 699, pp. 785-790 (1970).

[9]Tipper, H.W.: Nechako River map-area, British Columbia; Geol. Surv. Can., Mem. 324 (1963).

[10]White, W.H., Sinclair, A.J., Harakal, J.E., and Dawson, K.M.: Potassium-argon ages of Topley Intrusions near Endako, British Columbia; Can. J. Earth Sci., vol. 7, No. 4, pp. 1172-1178 (1970).

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82 N/W½,
82 M/E½.

17. BIG BEND MAP-AREA, BRITISH COLUMBIA

Project 620017

J.O. Wheeler

The Lardeau Group east of Columbia River between Downie and La Forme Creeks[1] was subdivided into the Windermere (?) phyllitic grit and pelite of the Broadview Formation to the west and the lower Paleozoic black, carbonaceous phyllite of the Index Formation to the east. The two units, which are separated by a unit of greenstone, dip moderately to gently to the east. Thus the Index lies structurally above the Broadview. This structural relationship results from an episode of westward-directed "backfolding" and thrusting in the western Selkirk Mountains. This event resulted in the overturning of earlier (pre-Late Mississippian, apparently eastward-directed thrusts, well-developed in Lardeau west half map-area[2], whereby the

Broadview Formation (a westerly greenstone-bearing facies) of the Windermere Horsethief Creek Group was thrust over lower Paleozoic rocks, including the Index Formation.

Nepheline syenite gneiss, known to contain significant concentrations of molybdenite[3] and locally some pyrochlore[4], occurs as concordant sheets within the mantling gneisses south and west of the core gneisses of Frenchman's Cap Dome. It occurs in the mantling gneiss north of the dome south of the head of Sibley Creek and west of Columbia River.

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[1] Wheeler, J.O.: Big Bend map-area, British Columbia; Geol. Surv. Can., Paper 64-32 (1965).

[2] Wheeler, J.O.: Lardeau (west half) map-area; British Columbia; in Report of Activities, Part A: May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 56-58 (1968).

[3] Fyles, J.T.: Knox Group, Revelstoke Mining Division; Minister of Mines and Petroleum Resources, British Columbia, Annual Report, 1967, pp. 261-263 (1968).

[4] McMillan, W.J.: West flank, Frenchman's Cap Gneiss Dome, Shuswap Terrane, British Columbia; Geol. Assoc. Can., Spec. Paper No. 6, pp. 99-106 (1970).

~~General~~ 32D ✓

18. RADIO WAVE MAPPING OF STRUCTURAL FEATURES

Project 670041

A. Becker and W.F. King

The experimental work performed during the summer of 1970 concludes the preliminary series of measurements [1, 2, 3] of the distortion of VLF electromagnetic waves by faults and shear zones.

The recent data obtained in the Ottawa basin and across two major features in the Noranda area (Smoky Creek Fault, Lois Lake shear) confirms the earlier results which indicated the suitability of VLF methods for the mapping of near surface geological features.

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

[2] Becker, A.: Radio wave mapping of Gloucester Fault, Ontario; in Report of Activities, Part A: May to October 1967; Geol. Surv. Can., Paper 68-1, Pt. A, p. 67 (1968).

[3] Becker, A.: Radio wave mapping across the Gloucester Fault, Ontario; in Report of Activities, Part A: April to October 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 67-68 (1970).

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19. ARES-AIRBORNE RESISTIVITY ELECTROMAGNETIC SYSTEM

Project 680089

General ✓

A. Becker

The current work on the project of designing a variable frequency airborne electromagnetic system was restricted to the construction of a scale model for this new, recently patented airborne electromagnetic method. As outlined in the patent[1] the frequency of operation varies in concert with the apparent resistivity of the ground beneath the instrument. The most important feature of the new system however is its ability to maintain a constant depth of penetration irrespective of ground conductivity.

The initial trials were directed towards the verification of theoretical principles. The experiments were carried out using horizontal layers of aluminium foil for the ground model. The results of this work indicate that the theoretical foundations are valid.

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[1] Becker, A.: Airborne apparatus for and a method of determinining electrical conductivity and overburden; Can. Patent No. 789,691 (1968).

20. HIGH RESOLUTION AEROMAGNETIC DATA, ONTARIO AND DISTRICT OF MACKENZIE

~~#2A~~ General ✓

Project 680140

B.K. Bhattacharyya and M.T. Holroyd

Total field contour maps to a scale of 1:25,000 with a basic contour interval of two gamma, over the area in Ontario extending from 81° W to 81° 45'W and from 48° 22.5'N to 48° 45'N, have been published by Geological Survey of Canada. The data were compiled and the maps drawn by automatic machine methods devised by the Theoretical Geophysics Section.

A similar survey being carried out in the Northwest Territories over an area extending from 60° N to 60° 30'N and 116° W to 118° W, delayed by flying conditions and diurnal variation, is to be completed in October-November 1970.

21. GAMMA-RAY SUPPORT, DISTRICT OF MACKENZIE

Project 670052

75 D, E ✓

B.W. Charbonneau

One of the more interesting results of the airborne cross-country gamma-spectrometric profile work conducted during the 1969 field season[1,2] was the realization that the general area between Fort Smith, N.W.T. and the east arm of Great Slave Lake (NTS sheets 75 D, E) contained abnormally high overall radiometric values as well as some local concentrations.

Groundwork was undertaken on three of the more interesting anomalies during July and August 1970 (see Fig. 1). The purpose of this work was to provide ground values for reconfirming airborne sensitivities established in work at Bancroft and Elliot Lake, Ontario[3,4] and as well to provide some insight into the geological cause of the anomaly pattern which would aid in the later interpretation of the airborne survey of sheets 75 D, E (see Darnley this publication). An advantage of the Fort Smith area from the point of view of anomaly variation was that high U/Th ratios existed in places (e.g. locality 3) and it was deemed desirable to determine these ratios at ground level.

The work was accomplished by traverses with a station spacing of 200 feet. Geological observations and readings with a CPD 153-C gamma spectrometer (manufactured by Atomic Energy of Canada Ltd.) were taken at each station. Samples were taken approximately every third station in order to make K, U, Th determinations in the laboratory. A variety of anomaly types were investigated. From north to south these were:

Anomaly (1): Thubun River area has moderately high uranium count rate and a moderately high U/Th ratio (Fig. 2 airborne profile 36 fiducials 5 1/2-6 1/2 marked by solid lines). This anomaly is underlain by a pink medium-grained equigranular to subporphyritic granite, 25 per cent quartz, 70 per cent potash feldspar, 5 per cent altered hornblende. As the core of the anomaly is approached the granite becomes more reddish and slightly more coarse grained, uranium and thorium count rates generally increase and the uranium to thorium ratio also increases. Dark chloritic porphyroblastic

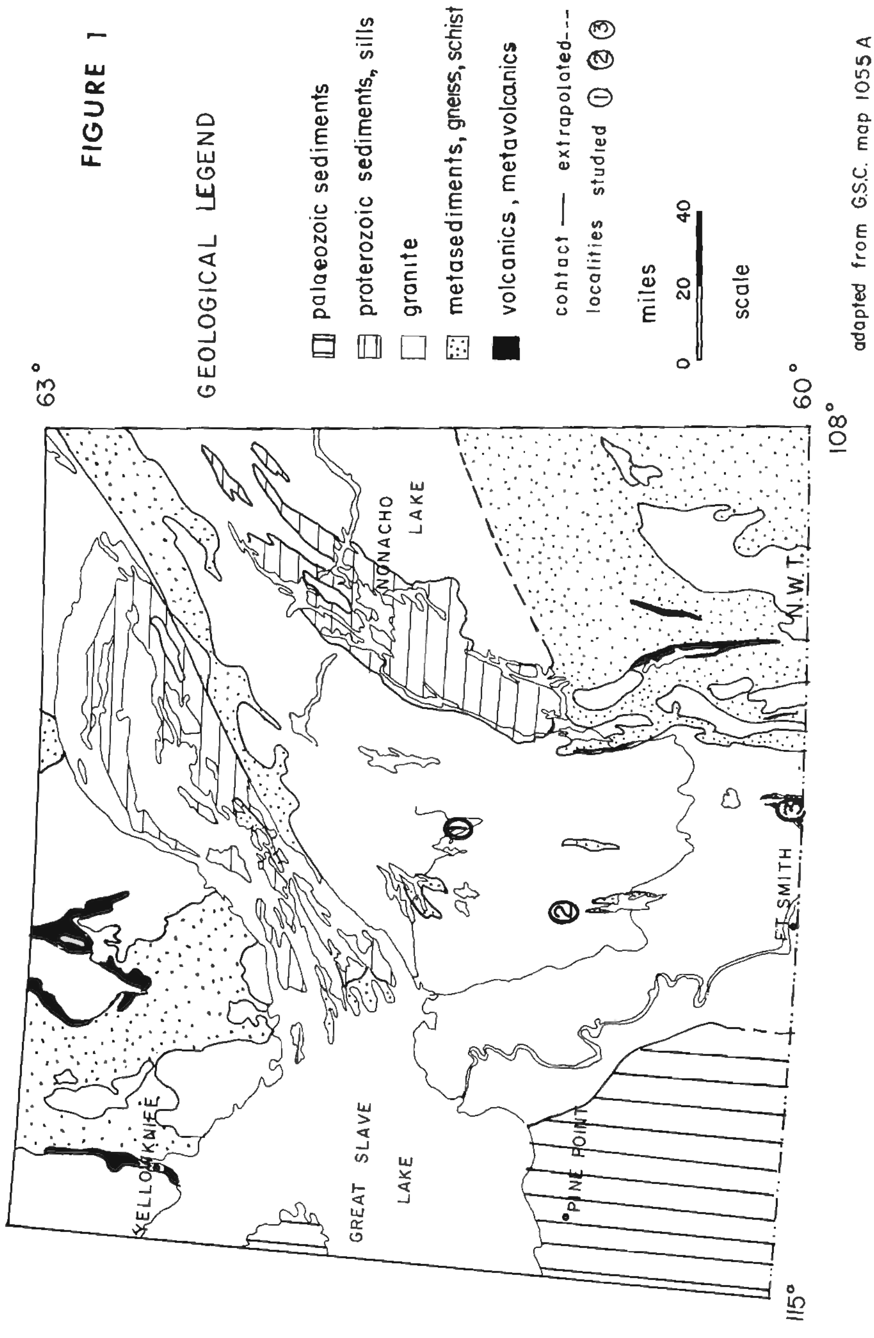
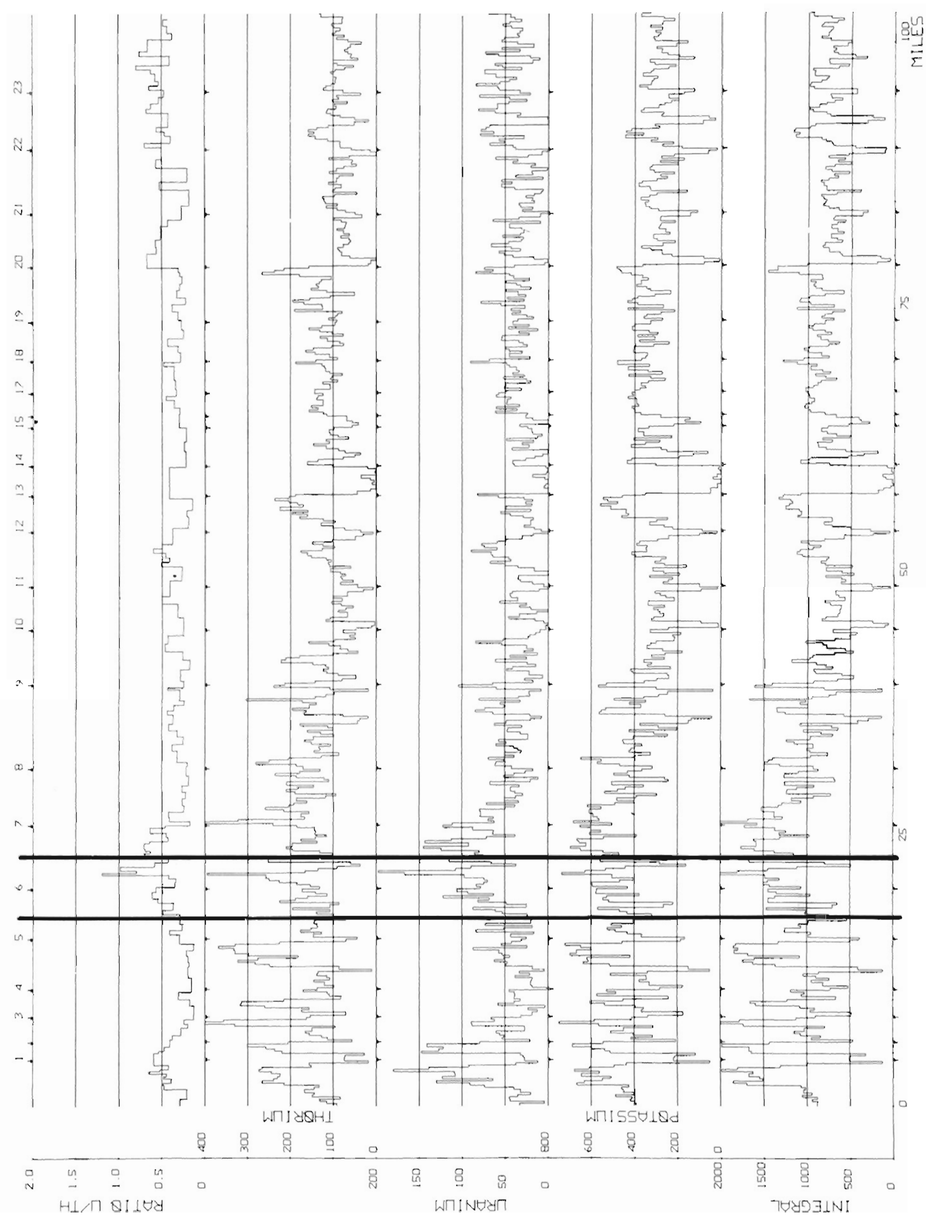

GEOLOGICAL LEGEND
palaeozoic sediments
proterozoic sediments, sills
granite
metasediments, gneiss, schist
volcanics, metavolcanics
contact —— extrapolated - - -
localities studied ① ② ③
miles
0 20 40
scale
adapted from G.S.C. map 1055 A
63°
60°
115°
108°
GREAT SLAVE LAKE
NONACHO LAKE
KELLOWKNIFE
PINE POINT
FT. SMITH
N.W.T.
1
2
3

FIGURE 1

FIGURE 2

CROSS-COUNTRY PROFILE 1969

O CONNOR LAKE TO HALLIDAY LAKE - 36



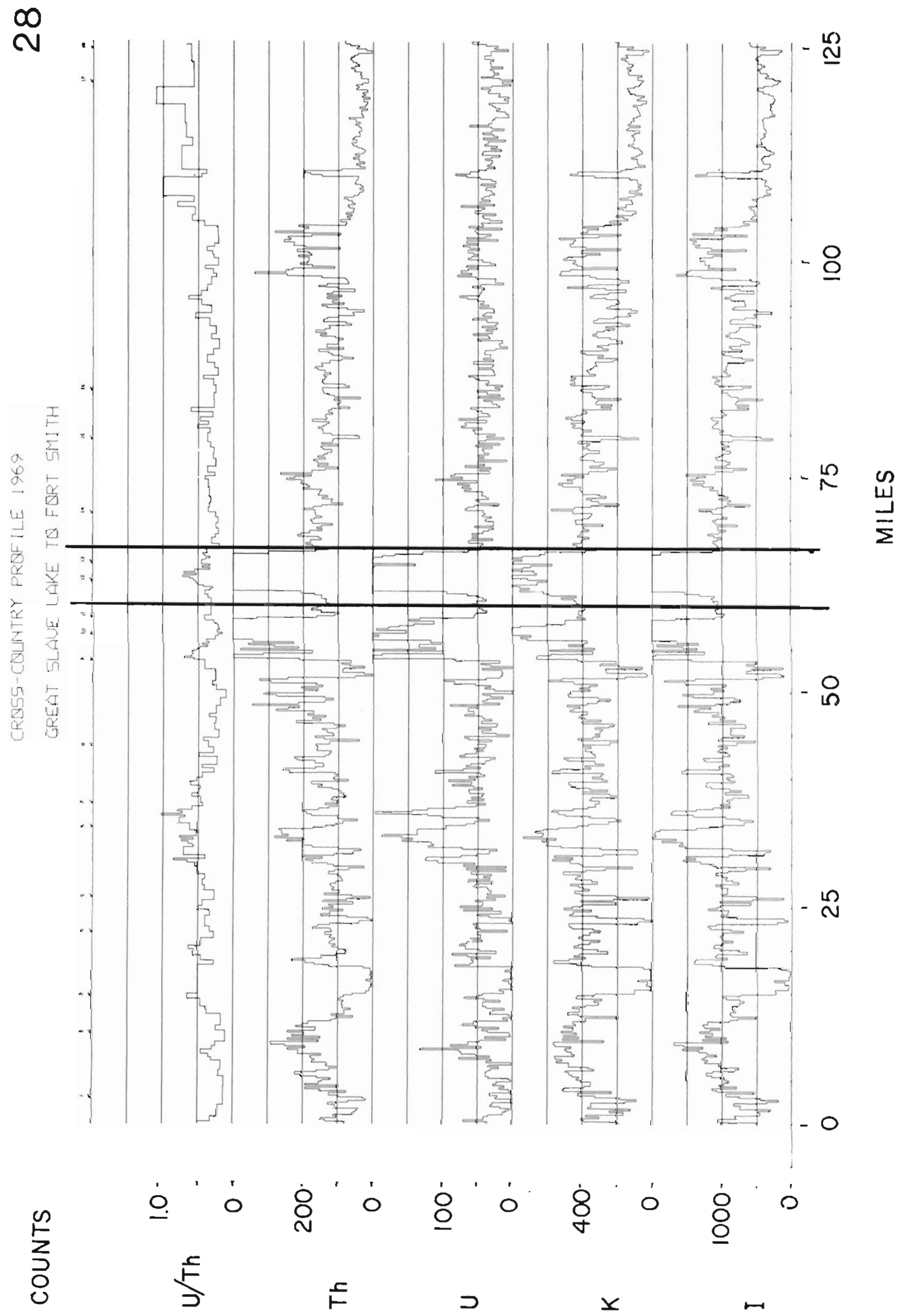
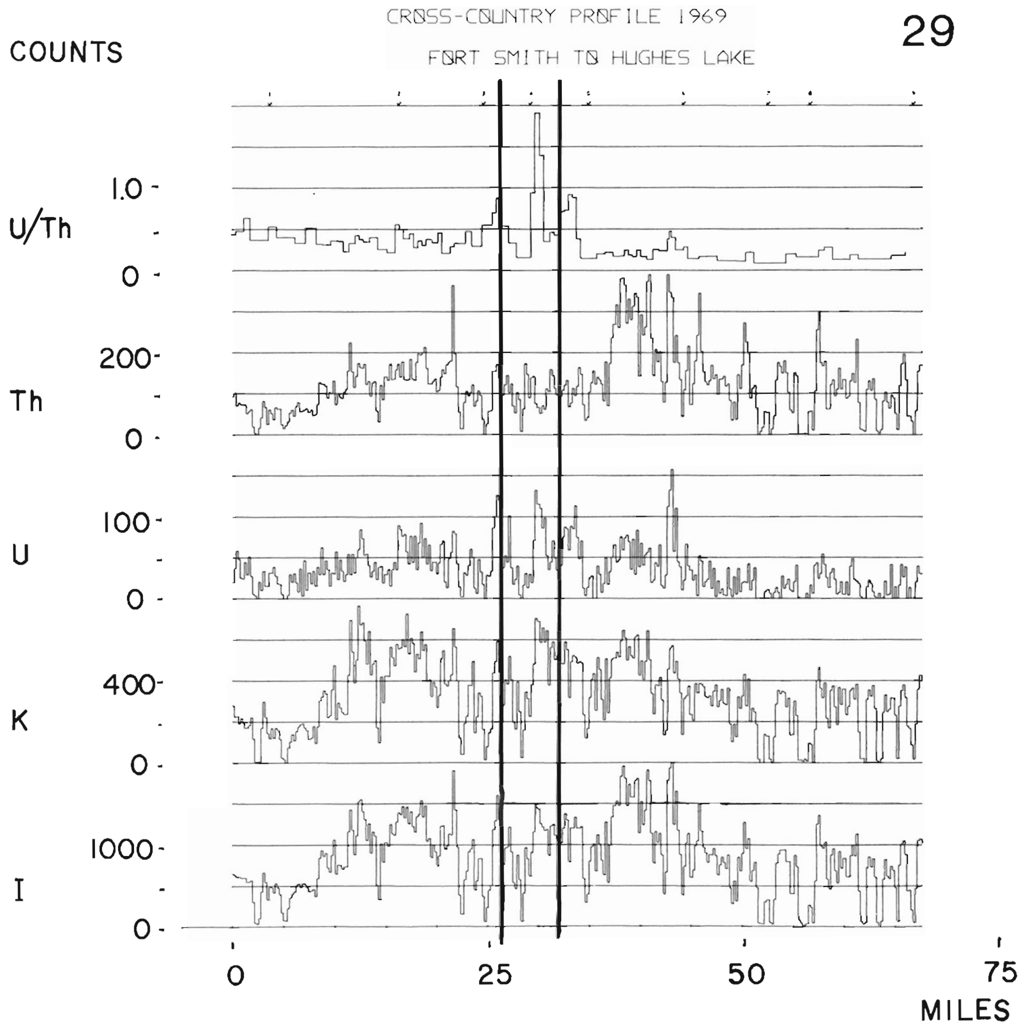

CROSS-COUNTRY PROFILE 1969
GREAT SLAVE LAKE TO FORT SMITH
28
COUNTS
U/Th
Th
U
K
I
1.0
0
200
0
100
0
400
0
1000
0
0
25
50
75
100
125
MILES

FIGURE 3

FIGURE 4



shears striking east-west in the core of the anomaly have values of >50 ppm uranium and >250 ppm thorium. A few almost completely digested paragneiss bands can be identified in the granite. Several thin diabase dykes striking north-northwest cut all the above rocks.

Anomaly (2): North Star Lake area has a very high uranium count rate but a fairly low U/Th ratio (Fig. 3 airborne profiles 28 fiducials 11 1/2-13 marked by solid lines). This anomaly is underlain by a foliated porphyritic granite 80 per cent grey to pink potash feldspar crystals up to 1 1/2 inches long, 10 per cent blue-grey quartz and 10 per cent altered hornblende. This porphyry is approximately 3 1/2 miles long by 1 mile wide and elongated in a north-south direction. The enclosing rocks are 10 per cent pink, medium-grained 10 per cent quartz, 85 per cent potash feldspar, 5 per cent hornblende granites with minor zones of inclusions of paragneiss and amphibolites.

Diabase dykes cut the surrounding granites but were not observed within the granite porphyry. North-south linears which are interpreted as faults transect the structure along the western margin of the porphyritic mass. Quartz stockworks are generally found within these faults. Another granite porphyry mass lies about 3 miles farther north in the zone (see profiles) but we did not examine it.

Radiometrically the surrounding granites are uniformly low in uranium and thorium. The granite porphyry on the other hand is everywhere quite high in uranium and thorium with average values of the order of >25 ppm uranium and >75 ppm thorium. An interesting feature is that minor north-south shear zones which cut the granite porphyry and average some 2-3 feet in width by a few hundred feet long are considerably enriched in uranium and thorium with values of >100 ppm uranium and >1000 ppm thorium being observed. Higher grade material exists in the area with one sample provided by private interests giving a much higher uranium value, with the causative material tentatively identified as uraninite (Steacy pers. comm.).

This zone and its extensions to the north and south along the fault system warrants further investigation. In particular the large fault zones which are topographic depressions filled with overburden may carry higher uranium and thorium values. As gamma radiation is attenuated by only a few feet of overburden gamma spectrometric equipment would not pick up this type of concentration. Radon measurement on soil gas in the depressions which cover the traces of the north-south linears especially in or near the confines of the granite porphyry would be interesting.

Anomaly (3): Donovan Lake area (Fig. 4 airborne profile 29 fiducials 3 1/2-4 1/2 marked by solid lines) has a moderate uranium count rate but a very high U/Th ratio. This anomaly is underlain by a pink sugary granite comprising 15 per cent quartz, 80 per cent potash feldspar, 5 per cent hornblende and traces of graphite. Sometimes a reddish alteration is found especially around quartz and potash feldspar grains. The rock unit is nearly one mile wide and strikes north-northeast on the east side of Donovan Lake. The uranium contents are not high, some 10-15 ppm, but the thorium values are very low, about 1 ppm, which results in the very high U/Th ratio. A band of quartzite a little more than a mile wide underlies Donovan Lake and the shores. This quartzite has minor amphibolite members, garnetiferous zones, some gossaniferous pyrite bands, and is granitized in part. Radiometric values are low. Another band of the high U/Th ratio granitoid described above is found on the west of the quartzite as well.

In conclusion, groundwork validated the airborne values (concentrations, ratios, etc.) with the added complexity which is to be expected at ground level. In addition to the work mentioned above, we visited a few previously known uranium localities in the area such as the Tsu Lake showing and the north shore of Pilot Lake.

Quite a bit of ground follow-up by private companies on the various anomalies from the profile data was noted with all areas we visited having been examined by at least one company with extensive staking resulting at the locality No. 2.

Regionally the whole granitoid belt from south of Fort Smith to the La Loche fault, and lying approximately between longitudes 111° W and 112°W seems to be remobilized with respect to its flanks and this zone is the axis of the radiometric high (see separate report by Darnley).

[1] A.G. Darnley, R.L. Grasty, B.W. Charbonneau: Cross country airborne gamma-spectrometric profiles, 1970, Geol. Surv. Can.; Open File Item 22.

[2] A.G. Darnley, R.L. Grasty, B.W. Charbonneau: Highlights of GSC airborne gamma-spectrometry in 1969; Can. Mining J., April 1970.

[3] A.G. Darnley: Airborne gamma-ray spectrometry; Can. Mining Met. Bull., February 1970.

[4] A.G. Darnley, and M. Fleet: Evaluation of airborne gamma-ray spectrometry in the Bancroft and Elliot Lake areas of Ontario; Fifth annual symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 1968.

22. ELECTRICAL CONDUCTIVITY OF LUNAR SAMPLES

Project 680005

L.S. Collett

Attempts to evaluate sample conductivity on the basis of magnetic absorption by means of Q-drop in the resonant circuit of a marginal-type Colpitts oscillator resulted in only partial success. The difficulty stems directly from the physical constitution of the lunar samples. Here, the presence of metallic (Fe-Ni) particles in a dielectric matrix, effectively precludes the detection of eddy currents in the sample matrix since these are much weaker than the eddy currents in the metallic inclusions. Inductive measurements thus do not yield an estimate of the sample conductivity but permit an estimate of the total, volumetric, free metal content of the sample under test. The results of the measurements on Apollo 11 sample 10084,83 (fines) gives a volumetric free metal content of 0.76 per cent. Both these figures compare in order of magnitude with the estimated 0.5 - 1 per cent free iron estimated by Muir _et al._[1] over the frequency range from $0.5 - 2.0 \times 10^6$ Hz.

Thus, our efforts turned to the contact electrode method of the capacitance type on the lunar samples maintained in a dry nitrogen atmosphere at room temperature. Two samples 10065,22 (breccia) and 10084,83 (fines) from Apollo 11 and three samples 12002,84, 12002,85 (crystalline rocks) and 12070,107 (fines) from Apollo 12 were measured for dielectric conductivity, relative permittivity and loss tangent in the frequency range of 10^3 to 10^7 Hz. Due to the absence of moisture, the samples behave as dielectric material. The investigations revealed the following general characteristics: (1) The dielectric conductivity increases from below 10^{-7} mhos/m for all samples at 10^3 Hz to almost 10^{-4} mhos/m for the rocks and to 10^{-5} mhos/m for the fines at 10^7 Hz, (2) the relative permittivity is 7.3 ± 5 per cent and 8.1 ± 5 per cent for Apollo 11 breccia and Apollo 12 crystalline rocks respectively at the higher frequencies, with an increase of 10 to 20 per cent for the lower frequencies and is 3.8 for Apollo 11 fines and approximately 3.0 for the Apollo 12 fines, (3) the loss tangent ranges from 0.14 to 0.02 for the breccia and from 0.05 to 0.01 for the crystalline rocks decreasing most rapidly above 10^6 Hz and from 0.13 to 0.005 for the fines decreasing gradually over the frequency range.

The collaboration of Drs. A. Becker and T.J. Katsube and Mr. R.H. Ahrens and the staff of the Electrical Methods Section is gratefully acknowledged.

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[1] Muir, A.H. Jr., Horesley, R.M., Grant, R.W., Abdel-Gawad, M., and Blander, M.: Mossbauer spectroscopy of moon samples; Science, vol. 167, No. 3918, pp. 688-690, 30 January, 1970.

General

23. AFMAG SURVEYS

Project 680123

L.S. Collett

During 1970, no AFMAG flying was conducted during the summer. The results of the 1968 flying in the upper Nelson River area, Manitoba, and Uranium City area, Saskatchewan[1] and of the 1969 flying in the St. Mary's River area, Nova Scotia[2], have been prepared for publication. Profiles of the two frequency (140 and 510 Hz) profiles were digitized. With the aid of the computer and plotter, the profiles of the two frequencies have been plotted to the scale of 1:50,000 and will be overprinted on photo-map bases, where available, and otherwise on half-tone topographic map bases. Now in publication stage are 26 map sheets for Manitoba, 4 for Saskatchewan and 4 for Nova Scotia.

A paper on selected areas in Manitoba was prepared and presented by L.S. Collett and C.K. Bell at the Canadian Institute of Mining and Metallurgy annual meeting, Toronto, in April, 1970 and will be published in their bulletin.

The AFMAG results over the Thompson Belt and the area to the northeast in Manitoba have been donated to the Geological Survey of Canada by AMAX Exploration Ltd. Compilation of these data are in progress and will be published by the Survey.

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[1] Collett, L.S.: AFMAG/VLF surveys Uranium City area, Saskatchewan, Upper Nelson River area, Manitoba; in Report of Activities, Part A: May to October 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 79 (1969).

[2] Collett, L.S.: AFMAG survey, St. Mary's River area, Nova Scotia; in Report of Activities, Part A: April to October 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 70-71 (1970).

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24. AIRBORNE GAMMA SPECTROMETRY SURVEYS IN THE AREAS OF ELLIOT LAKE, ONTARIO AND FORT SMITH, NORTHWEST TERRITORIES

Project 670050

General ✓

A.G. Darnley

Two experimental area-surveys were undertaken in July and August 1970.

A detailed survey was flown over a block approximately 36 by 15 miles with Pronto Mine at its southeast corner. The area of 550 square miles was selected to avoid the man-made radiometric features which dominate the Huronian syncline east of Elliot Lake. Lines with a spacing of 0.5 km extended from the North Channel to the pre-Huronian basement north and west of Rawhide Lake.

The main purpose of the survey was to investigate if lower Huronian sediments possess recognizable radiometric features in areas several miles from known economic occurrences. Such information would give guidance in recognizing comparable sediments elsewhere in the Shield. Also because of the detail in which conventional geological mapping has been carried out in the area it is a good test of the general usefulness of gamma spectrometry as a mapping tool. During and subsequent to the period of the airborne survey ground control gamma spectrometer measurements were undertaken over a number of test sites within the area by T.J. Bottrill (see separate report, this publication). Until compilation of all the data is complete no firm conclusions are possible, but a preliminary assessment of the analogue chart records leads to the following observations.

The Matinenda sediments are characterized on most profiles by small but recognizable increases in both uranium and thorium. On comparing one line with another the persistence of this feature is apparent. Occasionally there are obvious anomalies with more marked increases in the concentration of U and Th, accompanied in some cases by an increase in the U:Th ratio. However, it seems that if a survey was conducted with widely spaced lines over this area and especially if low sensitivity equipment was used, its importance might not be recognized.

The most prominent radiometric anomalies in the area surveyed are due to thorium in parts of the Lorraine Formation. Granitic rocks in the northern portion of the area do not show any unusual concentration of radioelements compared with granitic rocks from other areas.

The second area flown was selected in order to follow-up the very high radioactivity revealed by reconnaissance profiles flown in 1969 in the region between Fort Smith and Great Slave Lake[1]. A preliminary survey, which will be suitable for compilation on a scale of 1:250,000, was made over an area of approximately 15,000 square miles. Lines were flown east-west with a spacing of 5 km. Unlike the reconnaissance profiles of the previous year the maximum detector volume (12 9x4 in. NaI (Tl) crystals) of the Skyvan system was employed. The area covered is bounded approximately by 59° 45' N and 62° 25' N, 109° 50' W and 112° 15' W.

It was not clear from the 1969 work whether a single or several discrete areas of high radioactivity were involved.

It now seems that there is a prominent radiometric high extending southwards from the La Loche River structure (which parallels the MacDonald Fault) to the southern margin of the area surveyed, in Alberta, where it is becoming noticeably weaker. This distance is approximately 160 miles. The average east to west width of the "high" is about 30 miles and it is very approximately bounded between 111° W and 112° W. It appears to coincide closely with a prominent magnetic "low" shown in the 1:5,000,000 Magnetic Anomaly Map of Canada[2]. The belt consists largely of granitic rocks with porphyritic zones and minor vestiges of metasedimentary material and it appears to be at least partially remobilized with respect to its flanks (see separate report by Charbonneau, this publication). It is the largest area of above-average radioelement content (K, U and Th) that has been encountered in the current radiometric program. Within the "high" and associated with certain prominent lineaments there are large and continuous areas with up to five times average granitic abundances of uranium and thorium. Although in general the U:Th ratio over the anomalous region is low there appear to be zones with north or north-northeast trends, mostly near the east and west margins, where the U:Th ratio is quite high and possibly of some economic significance.

The magnitude of anomalies is not necessarily a reliable guide to economic significance in either geophysics or geochemistry, but it should be noted that the dimensions of this anomalous region appear greatly to exceed anything associated with known uranium areas such as Elliot Lake, Bancroft, Uranium City or Wollaston Lake. Certain zones within it and adjacent to it would appear to have better-than-average potential for radioactive mineral deposits, and probably for other elements also. One of the most important features about this region could be its potential as a source area for important sedimentary uranium deposits. Younger clastic sediments along its north and west margins would seem to be particularly worthy of close examination because of their proximity. Neither should the possibility be overlooked of finding uraniferous phosphatic limestones in chemical precipitates of the region to the west. It should be noted that although there are some relatively weak thorium anomalies in the vicinity of Nonacho sediments there are no strong anomalies in this part of the area surveyed. Closer inspection of computer reduced data when it becomes available may however show something of significance, since by analogy with the Elliot Lake situation mineralization of this type may have only a subtle radiometric expression.

Cross-country reconnaissance profiles have been flown during 1970 between Thunder Bay, Kenora, Red Lake, Norway House, Flin Flon, Lac La Ronge, Buffalo Narrows, Fort Chipewyan and Fort Smith, and between Yellowknife and Great Bear Lake. Only the last sector contains any ground comparable to that between Fort Smith and Great Slave Lake.

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[1] Darnley, A.G., Grasty, R.L., Charbonneau, B.W.: Highlights of GSC airborne gamma-spectrometry in 1969; Can. Mining J., April, 1970.

[2] Morley, L.W., MacLaren, A.S., Charbonneau, B.W.: Magnetic Anomaly Map of Canada, Geol. Surv. Can., Map 1255A (1968).

25. HAMMER SEISMIC SURVEYS, ONTARIO AND QUEBEC

Project 680037

31 G ✓

R.M. Gagne and G.D. Hobson

Three hammer seismographs operating in the Ottawa area for a total period of 26 crew weeks surveyed 2155 locations between Quyon and Buckingham on the Quebec side and between Mississippi Lake and Russell south to Winchester in Ontario. Depth to bedrock was obtained at all locations. An attempt will also be made with such an abundance of data to correlate seismic velocity with overburden material and with bedrock lithology. These data were acquired in conjunction with Project 700040 (J.S. Scott). Geographically the area surveyed lies between 45° 00' and 45° 45'N and between 74° 45' and 76° 45'W.

26. RADIOISOTOPE METHODS

Project 670053

41 I ✓

R.L. Grasty

Dr. L. Ostrihansky visited the Sudbury area and carried out in situ measurements for copper, iron and nickel using an EKCO portable X-ray fluorescence analyser. Approximately 70 stations were analyzed and hand specimens collected for laboratory analysis using the solid state X-ray silicon detector. Fifty samples were also collected and analyzed in the Elliot Lake area of Ontario. To investigate the problem of radioactive disequilibrium in the uranium decay series a selection of small cores were drilled from surface outcrops, also in the Elliot Lake area. Sections of these cores will be analyzed using the laboratory solid-state X-ray germanium detector. Gamma-ray spectra were also taken at these sites using an A.E.C.L. portable field instrument and hand specimens collected for comparison of laboratory analysis.

27. MARINE SEISMIC STUDIES IN THE GREAT LAKES AREA

Project 660054

30 M, N ✓
40 I, J, A ✓
41 A, B, C, D ✓

G.D. Hobson

A program of detailed seismic surveying using a repetitive source was conducted in the vicinity of Centre Island along the Toronto waterfront Objectives of the program were to delineate stratification within the unconsolidated sediments overlying bedrock and to define the bedrock surface.

A compilation of all data acquired in Lakes Ontario, Erie and Huron in previous years has been undertaken. The biggest and most onerous task has been the transfer of all data to a common projection and scale.

28. SEISMIC REFRACTION PROGRAM, WELLAND – PORT COLBORNE, ONTARIO

30 L, M ✓

Project 670074

G. D. Hobson

The last map sheet near Fort Erie was completed during May and June 1970 completing this project which was begun in 1967. An FS-3 hammer refraction seismograph has been used to determine the thickness and nature of the overburden and the configuration of bedrock. The project was initiated to complement the studies associated with the development of the new Welland Canal channel and tunnel approaches and to complete the Pleistocene mapping and bedrock topography of adjacent areas. The investigation of the area of the Niagara Peninsula east of the present Welland Canal to the Niagara River is now complete with a report in preparation.

29. SEISMIC REFRACTION PROGRAM, BEAUFORT SEA – MACKENZIE DELTA

Project 690040

General ✓

G. D. Hobson

A limited program of shallow seismics was undertaken in the Mackenzie Delta near Tuktoyaktuk using a Huntec FS-3 seismograph. The purpose was to acquire some permafrost velocities (which appear to be lower than previously encountered near Dawson, Yukon Territory) and to test both refraction and reflection techniques in an attempt to define the base of the permafrost. Permafrost in two drillholes was known to be about 200 feet deep. Both seismic and resistivity methods appear to yield usable results. The reflection technique appears to be able to define the base of the permafrost.

An acoustic technique was also applied over Ice Lake near Tuktoyaktuk. These data are presently being processed and will be correlated with drill logs.

A side scan sonar instrument was installed aboard M.V. Richardson and later on C.S.S. Hudson in the Beaufort Sea to investigate bottom surficial materials. The records acquired during these surveys have not been viewed to date due to the lateness of return of the vessels.

30. HIGH RESOLUTION AEROMAGNETIC SURVEY OF THE ST. MARY'S RIVER GRABEN, NOVA SCOTIA

11 E, F ✓

Project 680081

P. J. Hood and P. Sawatzky

A high resolution aeromagnetic survey of the St. Mary's River graben which lies west of Chedabucto Bay in Nova Scotia was carried out between September 14 and October 18, 1970. The survey magnetometer used was a single-cell self-orienting rubidium-vapour magnetometer mounted in a ten-foot tail stinger of a Beechcraft Queenair B80 aircraft owned by the Geological Survey of Canada. The magnetic survey data, time, Doppler cross- and along-track, and flight elevation were digitally-recorded on seven-track magnetic tape. The survey area was bounded by the following co-ordinates 61° 30'W to 63° 15'W and 45° 15'N to 45° 30'N, and the lines were spaced one-quarter nautical mile apart and flown in a horizontal plane 1,500 feet above mean sea level. Double control lines were flown in an east-west direction approximately six miles apart. Approximately 5,000 line miles of high resolution aeromagnetic data were thus obtained with only minor breakdowns in the equipment.

This relatively magnetically flat area was flown to throw more light on this geologically-interesting area over which an AFMAG contract survey had been flown by the Geological Survey in 1969. One of the objectives of the survey was to see whether the Pennsylvanian gabbroic bodies which intrude the Horton Group to the northeast of the graben may be detected within the graben. As this was the first survey away from the Ottawa area, another objective was to thoroughly field test the aeromagnetic survey equipment, ascertain any weaknesses in survey procedure and support functions such as post-survey checking of the digital data and flight path accuracy. It would seem that the field operation would run more smoothly if the survey operation was more self-contained by having an in-field computer printout and film development capability.

During the course of the main survey, the opportunity was taken of obtaining eight lines over the Roslin salt dome whose top is some 900 feet below the surface. This diapir coincides with a thirty-gamma positive anomaly (see Geol. Surv. Can. Map 825G) and a gravity survey by the Nova Scotia Research Foundation showed a distinct gravity low as would be expected since salt has a lower density than the surrounding sedimentary rocks. A direct comparison will be made with the ground magnetic survey results carried out by the Nova Scotia Research Foundation to try to establish the approximate geometry of the causative bodies. Investigations of this feature may have importance in the delineation of such features on the continental shelf because of the well-known association of salt-domes and petroleum.

The airborne equipment was operated throughout the survey by P. Sawatzky who designed and built the magnetometer system; he also acted as party chief for the operation. K. Owens was the survey navigator responsible for keeping within the flight specifications, and H. Knapp operated the ground diurnal base station. For the duration of the survey Spartan Aero Services Limited of Ottawa maintained the aircraft and supplied the pilot of the aircraft, A. Lambros, under contract.

31. REGIONAL MAGNETIC SUSCEPTIBILITY SURVEY IN SASKATCHEWAN, ALBERTA AND DISTRICT OF MACKENZIE

Project 660042

L. J. Kornik

A third field season of a continuing regional magnetic susceptibility survey[1,2,3] in northern Saskatchewan, northeastern Alberta and the southern portion of the District of Mackenzie was completed. Sample sites on selected outcrops of Precambrian rocks between Lake Athabasca and Great Slave Lake were visited during this past summer utilizing a float-equipped Cessna 180 aircraft. In situ magnetic susceptibility determinations, oriented diamond-drill core and notes on the geology were made at 268 locations. To date a large portion of the Churchill(Structural)Province of Manitoba, all of northern Saskatchewan, the northeast corner of Alberta and an area between Lake Athabasca and Great Slave Lake in the District of Mackenzie have been visited during different years of the survey.

The data have not been interpreted but will be incorporated into a report in the near future. It is anticipated that these results will assist in the regional interpretation of aeromagnetic data.

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[1] Kornik, L. J.: Regional magnetic susceptibility survey in Manitoba and Saskatchewan; in Report of Activities, Part A, May to October, 1966, Geol. Surv. Can., Paper 67-1, Pt. A, pp. 126-128 (1967).

[2] Kornik, L. J.: Regional magnetic susceptibility survey in Manitoba and Saskatchewan; in Report of Activities, Part B, November 1967 to March 1968, Geol. Surv. Can., Paper 68-1, Pt. B, pp. 18-22(1968).

[3] Kornik, L. J.: Regional magnetic susceptibility survey in Manitoba and Saskatchewan; in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 92 (1969).

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32. SEISMIC REFRACTION STUDIES OF THE INTERIOR PLATEAU OF BRITISH COLUMBIA

General ✓

Project 660051

H. A. MacAulay and G. D. Hobson

During four days in August short refraction profiles were shot at selected points along profiles previously shot during September and October 1966. The purpose of this additional work was to obtain more information on the velocities of the near surface layer to aid in the interpretation of the original data.

33. AEROMAGNETIC INTERPRETATIONS – CANADIAN APPALACHIAN REGION

11 D
21 P/12
Nfld ✓

Project 680121

P.H. McGrath

Continuing the field surveys of 1968[1] and 1969[2], in situ magnetic susceptibility measurements were obtained at three hundred and five sites in the Canadian Appalachian Region during the summer of 1970. Fifteen sites are located in the Bathurst area (21 P/12) of New Brunswick, nine sites on the

Meguma Group in Nova Scotia (11 D), and the remaining two hundred and eighty-one sites occur on the island of Newfoundland in the environs of (1) St. Anthony and (2) the Trans-Canada Highway between Port aux Basques and Terra Nova National Park.

In addition to the in situ susceptibility measurements, oriented drill cores were collected from 88 sites. Each of the sites sampled possessed an appreciable component of induced magnetization. The magnetic susceptibility and the intensity and direction of the natural remanent magnetization of these cores will be determined during 1970-71 by the rock magnetism laboratory of the Geological Survey of Canada.

All of these data will be incorporated into a continuing program of magnetic interpretation of crustal structure in the Canadian Appalachian Region.

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[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] McGrath, P.H.: Aeromagnetic Interpretation - Appalachia; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 79-82 (1970).

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34. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS

Projects: 690066, 690068, 690070, 690071, 690072, 690073

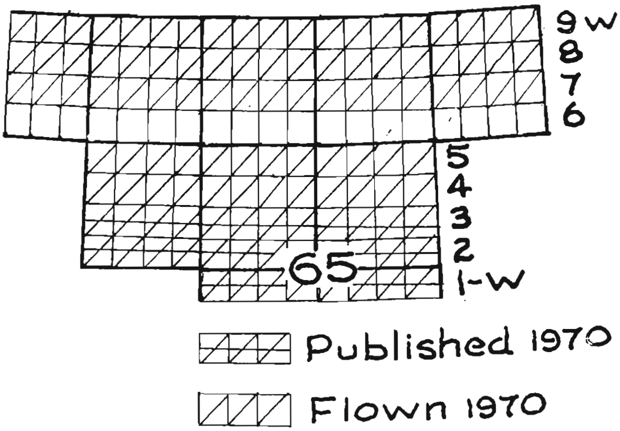
Canada ✓

A.S. MacLaren

The federal-provincial aeromagnetic survey plan, started in 1962, was designed to cover the remainder of the Canadian Precambrian Shield and adjacent areas, not flown at that time. The estimated cost was 18 million dollars and the aeromagnetic surveys were estimated to continue for a period of 12 years.

Prior to 1962 flying completed by the Geological Survey and some provinces amounted to 543,000 square miles. Since 1962 the accelerated program has covered approximately 1,300,000 square miles.

There remain several years' work to complete the following areas: Labrador and southern Baffin Island, the District of Keewatin and the District of Mackenzie and the Yukon Territory. British Columbia still requires several years' work in rough terrain to complete the aeromagnetic coverage.

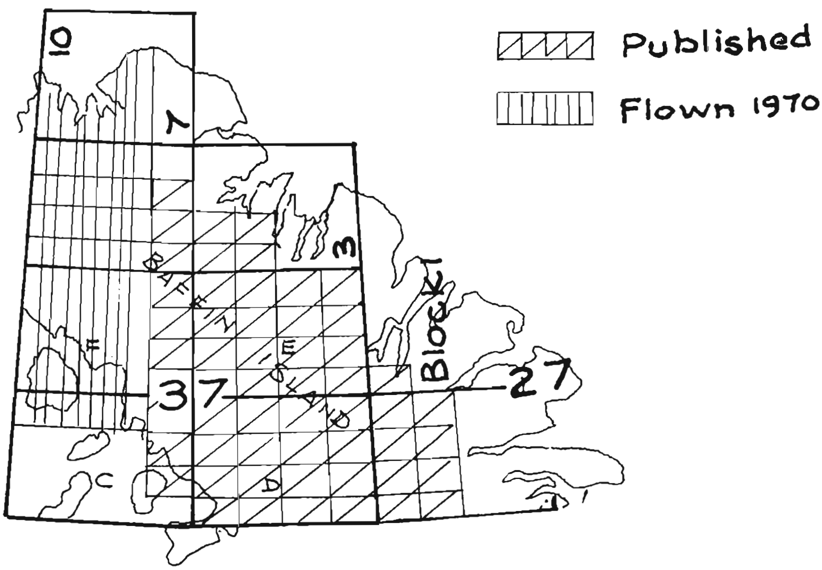


Project 690068

During the 1970 field season 35,000 square miles of survey were completed in blocks 1, 2, 4, 5, 7, 8 and 9 and block 3 was published.

It is expected that blocks 1 and 2 will be published by January 1971, 4 and 5 by the end of April and 7, 8 west and 9 west by June 1971.

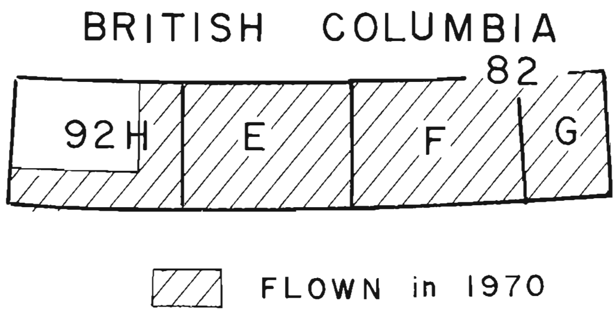
This contract was inspected in the field during the month of July.



Project 690071

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

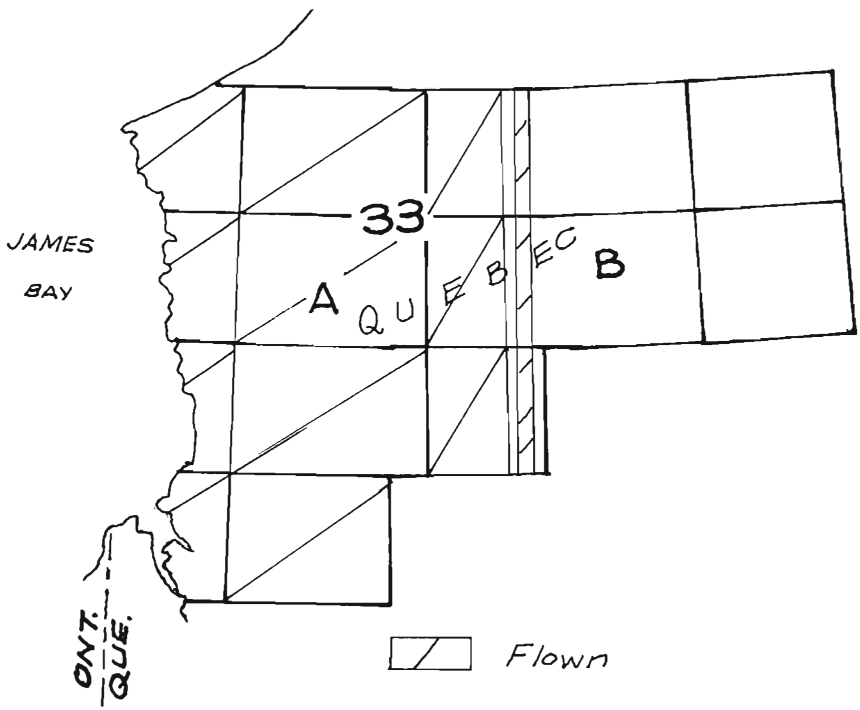
During 1970, 11,000 line miles were flown by Aero Photo Inc. on this contract to complete all the flying in Baffin Island and block 7 (10 maps) were published. It is expected that all the maps on this contract will be printed and published by March 1971 to complete the whole contract.



Project 690066

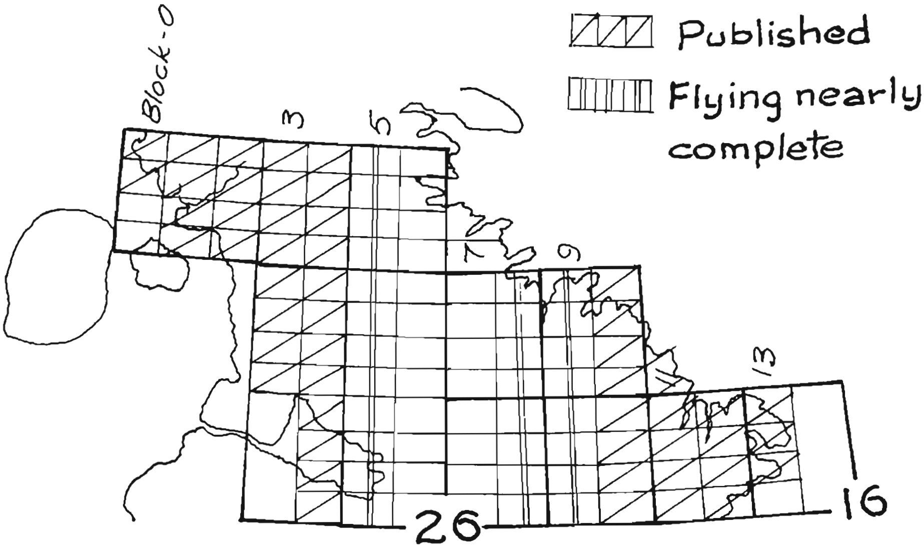
Twelve thousand five hundred square miles of aeromagnetic surveys were flown using a helicopter in 1970 in blocks B 2, 3 and 4 and A 3 and 4.

It is expected that twenty-four one-mile maps will be published by April 1971. The magnetometer survey will continue from October through the winter into April or May 1972.



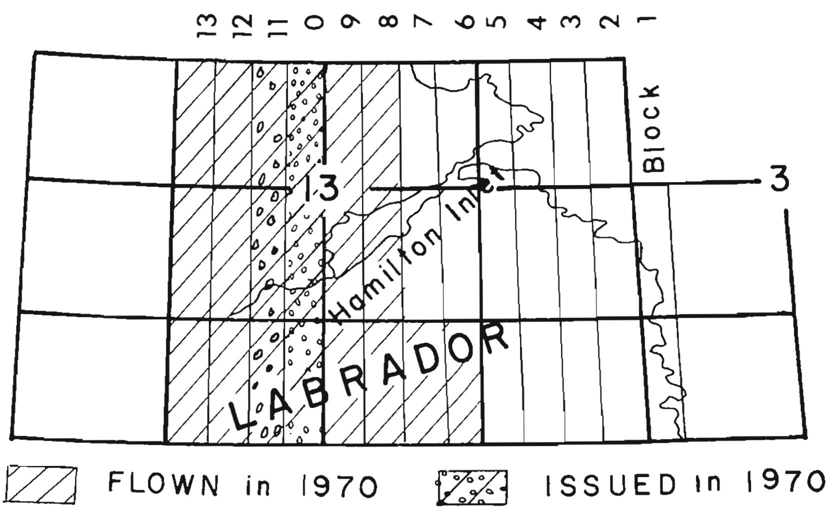
Project 690073

At the end of September 55,000 square miles of surveying on this contract had been flown and partially compiled over a 2-year period. It is anticipated that flying on this contract will proceed next winter and that some of the maps will be published in 1971 starting on the west side of the area along the east shore of Hudson Bay.



Project 690070

During the field season 11,800 line miles (5,900 square miles) of aeromagnetic surveying were carried out in blocks 6, 7, 8 and 9 but none of these blocks were completed due to bad weather and excessive variations of the earth's magnetic field. Block 5 will be published by April 1972. There remain approximately 11,000 line miles to be done in 1972 to complete the contract. This contract was inspected during September by E. J. Derouin.



Project 690072

Twenty-five thousand square miles of aeromagnetic survey flying were achieved in Labrador during the field season using Goose Bay as a base.

Block 10 was printed in October and it is anticipated that block 11 will be printed by the end of December 1970. Blocks 12 and 13 are scheduled for printing in May 1971 and blocks 8 and 9 in April.

35. SEISMIC SURVEY OF THE DUBAWNT GROUP — (55 NW, 65 NE, NW)

Project 700061

A. Overton

Conventional refraction seismic surveys were conducted at selected locations around Baker Lake and the Thelon Plain, Northwest Territories to determine the thickness of rocks comprising the Dubawnt Group.

An Otter aircraft was used to transport crew and equipment to each location during April and May. The locations were selected on frozen lakes and rivers to facilitate landing of the aircraft, and also shooting of small dynamite charges in holes drilled in the ice or in the underlying water. Seismic detectors were set on the ice for recording these shots. Some experiments with reflection shooting were also conducted in a similar manner. Results have been interpreted and mapped, showing the depths computed. In the vicinity of Baker Lake, the presence of volcanics at some locations may have prevented penetration to basement; in this area the greatest thickness calculated is about 4,200 feet near the north end of Pit Lake. On the Thelon Plain the greatest thickness calculated is about 6,300 feet at a location four miles south of Hornby Point.

36. THERMOMAGNETIC STUDIES OF ROCKS; SUDBURY, ONTARIO AND HALIFAX, NOVA SCOTIA

Project 700054

E. J. Schwarz

Sampling for thermomagnetic studies was done near Sudbury, Ontario and Halifax, Nova Scotia. Approximately 200 oriented drill cores were collected from a part of the Sudbury norite (with D. T. A. Symons). A dense sampling pattern was designed in an attempt to (1) trace variations in both direction and intensity of the local paleomagnetic field during cooling of the norite, (2) distinguish between variations in the dipole and non-dipole components of the paleomagnetic field, (3) locate "paleoisotherms" in the norite, and (4) estimate the cooling rate of the norite. This new approach requires a detailed and precise analysis of the remanent magnetization and thermomagnetic properties.

The Meguma Formation around Halifax was sampled (drill cores and hand specimens totalling about 100) with P. H. McGrath for thermomagnetic and other work. The objectives are to investigate (1) the origin of the strong elongated aeromagnetic anomalies locally occurring over the formation, and (2) the possibility of the occurrence of natural phase relations between FeS_2 (weakly magnetic Meguma), $Fe_{1-x}S$ (magnetic Meguma) — Fe_3O_4 (contact metamorphism around granite intrusions).

37. MULTISPECTRAL PHOTOGRAPHY

General.

Project 630031

V. R. Slaney

The four-week period from mid-August to mid-September was spent in the Northwest Territories flying the Geological Survey's Skyvan out of Fort Smith and Yellowknife. Equipment consisted of an RC8 camera, a pack of four Hasselblad 70-mm cameras and an I. R. thermal scanner.

The photography was designed to determine the usefulness of colour and false colour film in the recognition of rock types in well exposed areas of northern Canada. It was also designed to provide additional information to support gamma-ray and thermal infrared studies which were being carried out in the same area.

In all, 1,200 line miles of photography were completed using the RC8 camera, and 400 line miles using the Hasselblad cameras. Four areas were investigated:

1. Two east-west lines, 80 miles long crossed each of map-sheets 75 D and 75E.
2. Two areas, each 40 square miles in area were photographed for preparing mosaics. One area lies north of Tsu Lake and the other south of Pilot Lake. Both are located on map-sheet 75 D.
3. A section across major rock types in the area of the East Arm of Great Slave Lake.
4. An area of 50 square miles about Yellowknife.

Colour and false colour film was exposed in all areas with the RC8. In the Yellowknife and Great Slave Lake areas, Hasselblad cameras were used to expose monochrome film combined with a variety of narrow band filters.

Computer Analysis

It is very difficult to predict the response of a film in terms of density or colour to a range of objects making up a typical ground scene. The problem becomes more acute when narrow band filters are applied to the optical system of the camera or scanner. A number of computer programs for the treatment of radiometric data were prepared during the summer by a student supervised by H. Gross.

The most useful program was one which carries out a point by point multiplication of 2 spectra (wavelength vs. % transmittance or reflectance) producing a plot of the product. Up to 6 spectra can be multiplied together in sequence to give a curve which describes the product of all of the spectra.

In practice, large numbers of curves can be produced which represent varying combinations of a particular atmosphere, subject, filter and lens or optical system. Further work is needed to incorporate the effect of incident illumination and the sensitivity of the detecting system.

38. INFRARED SCANNING

Project 670054

General /

V. R. Slaney

A thermal infrared scanner was leased from Daedalus Incorporated for airborne tests in the area about Fort Smith, Northwest Territories. The tests were to attempt to distinguish different rock types in areas of high incidence of outcrop. Airphotos were also obtained for comparative studies.

The scanner was operated with a 4.0 to 5.5 micron filtered detector. It has a D.C. coupled system designed to give information about the relative temperature of ground objects. Information was recorded on magnetic tape. The playback system reproduces the image on 70 mm film for examination in the field. The scanner was installed in a rotating mount to allow corrections to be made for aircraft drift.

Some 300 line miles of imagery were recorded on tape before an electrical fault halted the survey.

Three east-west lines, each 80 miles long were flown across map-sheets 75 D and 75 E.

Two other areas, each about 6 miles by 6 miles, were also flown. It is hoped to construct a thermal mosaic of each area. One area lies south of Pilot Lake and the other north of Tsu Lake, both within map-sheet 75 D.

39. PALEOMAGNETIC STUDIES OF RADIOMETRICALLY DATED IGNEOUS ROCKS IN THE CORDILLERA, BRITISH COLUMBIA

Project 690042

92 B ✓
103 I, J ✓

D. T. A. Symons

Oriented core samples were collected from 3 areas in British Columbia. A total of 135 cores were collected from 27 sites in the Cenozoic Sooke gabbro on the southern tip of Vancouver Island in an attempt to locate a magnetic normal-to-reverse polarity zone indicated in samples collected during the previous field season. A further 132 cores from 23 sites were collected from the Aiyansh lava flow which outcrops in the Nass River valley some 60 miles north of Terrace, British Columbia. This flow was extruded about 220 years ago, and it provides a chance to compare the direction and intensity of the Earth's magnetic field as measured from its remanence to observatory records of the time. Finally, 125 cores were collected from 25 sites in 6 early Cenozoic intrusive phases in the Coast Ranges. The sites are located for the most part along the north shore of the Skeena River some 10 to 50 miles inland from Prince Rupert, British Columbia. This suite is being studied to determine if the available radiometric ages of the phases correspond to the paleomagnetically-determined ages.

Two weeks were spent in the collection of those cores. The paleomagnetic properties of the cores are currently being examined.

GEOCHEMISTRY

40. REGIONAL GEOCHEMICAL EXPLORATION OF THE COPPERMINE BASALTS: COPPER AND ZINC IN LAKE AND STREAM WATERS AND SEDIMENTS UNDER CONTINUOUS PERMAFROST CONDITIONS

Project 700046

R. J. Allan

Canada

Objectives

This study is a continuation of a program to develop regional geochemical exploration techniques, employing surficial materials as the sample media, in Canada's zone of continuous permafrost. The study involved both a regional program and a detailed control study for the regional program, and was carried out in the central part of the Coppermine basalts during late June, July, August and early September, of 1970. The objectives of the regional study were: to outline on a regional scale a Cu-rich basalt group; to delineate within this group, members, or areas of members, with greater Cu mineralization; to show the position of those structures in which Cu may have accumulated; to evaluate sites of known mineralization; and to evaluate the Cu distribution in areas where considerable diamond drilling has been carried out based on geological and geophysical exploration methods. The objectives of the detailed control study involving a total of 22 lakes were to determine: the variations in Cu concentration in lake waters during the entire sampling season, as determined by climatic changes, mainly rainfall; the variations in Cu concentration in lake water with position in the lake; the effect of changes in Cu concentration of water in inflowing and outflowing streams on the Cu concentration of the lakes; the variation in Cu concentration in the lake bottom sediments with position around the lake; the Cu distribution in waters and sediments from selected lakes which were found to be anomalous with respect to Cu, in the regional study.

Sample Media

The samples collected were of lake and stream waters and lake and stream sediments. The use of lake waters for regional geochemical exploration in the Coppermine Group was indicated by a pilot study during the summer of 1969[1].

Area Covered, Sample Site Density and Helicopter Efficiency in the Regional Program

The regional program was experimental in that only a guess could be made at the site density required to fulfill the objectives outlined above. Because of this, the site density varied for adjoining 1-mile map-sheets.

The total area covered was 6 one-mile map-sheets (Table 1). Total lake sites visited in the regional program was 637. Total water samples collected was 945 and sediments 706. Total helicopter time used was 114 hours.

TABLE I

Nts[1] Sheet	Approx. Area	No. of[2] Sites	Site Density	Regional[3] Site Density	Helicopter Time Per Sheet	Helicopter[4] Time Per Site
	Sq. Miles		Sq. Miles Per Site	Sq. Miles Per Site	Hours	Minutes
86-0-12	240	38	6.2	25	8	12.6
86-N-1 & 86-0-4	240	22	10.7	25	4.75	12.9
86-N-7	240	75	3.1	9	15	12.0
86-0-5	240	138	1.5	4	25	10.9
86-N-8	240	271	0.9	1	40	9.9

[1] 93 water and 45 sediment samples were also collected from sheet 86-N-9. Helicopter time on this sheet was 20 hours, as the base camp was moved to Coppermine because of the weather. The water samples were collected regionally at one site per 3 square miles. Sediments came from lakes in two strips; one in the basalts, below the unconformity to the overlying sediments and one in the overlying sediments above the unconformity.

[2] At every site a lake water and lake bottom sediment was collected.

[3] This is the density that will be used to assess the sample densities that may be used in other areas. The actual site density is much greater due to the fact that samples were also collected along all major structures, aeromagnetic lineaments and in the vicinity of known mineralization.

[4] Time per site is very low and is attributed to the fact that the helicopter pilot assisted with the sampling and in essence was an integral member of the sampling team. Under normal circumstances this rate of sample collection could not be maintained.

Detail Control Study for the Regional Program

There were 3 types of detail study involved:

1. One anomalous lake closest to the 47-Zone Cu deposit, and one lake in a background area, were studied. At these lakes sediment samples were collected from all the inflowing and outflowing streams and from the lake bottoms at intervals around the lakes. Water samples were taken from all the streams and from the lakes at the point of inflow or outflow of all streams every 4 days during the period July 2 to September 15.

2. Seventeen lakes were selected, ranging in concentration from background to anomalous. These were 17 of the 25 lakes for which water analyses for Cu were available[2]. Sediments were collected from the lake bottoms around each of these lakes.

Water samples were taken at an outflowing stream if one existed every 10 days during the period July 4 to September 15. On July 1, ice had not completely melted on some of the lakes and on September 15, the ground was snow covered and many of the lakes were frozen over.

3. Of the 22 lakes which were eventually found to have anomalous Cu concentrations in both their water and sediment samples, 3 were selected for detailed study. This involved collection of lake waters and sediments from around the lake, and stream waters and sediments from inflowing streams.

To assist in interpretation of the detailed results, a daily climatic record was maintained from July 1 to September 15.

Analytical Methods

All samples of waters and sediments, except for those from sheet 86-N-9 were analyzed in the field. Sediments were dried and sieved in the field to $<$80 mesh ($<177\,\mu$). For both types of samples, the field determination of Cu was made with 2-2' biquinoline; the sediments were leached with cold HCl. The field concentrations found for Cu in both water and sediments are for extractable Cu only; the total Cu, and Zn contents have been determined in Ottawa for the sediments and will be determined for the waters. Sieved sediment samples were returned to Ottawa by air-mail as soon as they were analyzed in the field. No Zn analyses were done in the field.

Field Results and General Conclusions

Eventually all the results will be placed on computer punch cards along with the co-ordinates of each sample site on the sample grid. The data will include: 1) partial determinations for Cu in waters and sediments made in the field laboratory; 2) total determinations for Cu and Zn in waters and sediments made in the Ottawa laboratory; 3) pH of the water samples determined in the field laboratory 4) data concerning the sample site, namely bedrock geology, glacial geology, positions on geologically or geophysically inferred structures and proximity to known mineral showings.

Table 2

Site Density	Approx. Area
Sq. Miles Per Site	Sq. Miles
25	1500
10	1000
5	750
1	250

From these data, computer-drawn contour maps will be constructed from sites selected randomly by the computer, at site densities as listed (Table 2) and for other controls, e. g. all lakes on faults.

At this stage, however, no computer drawn contour maps are available but, based on the field determinations of Cu in waters and sediments and the Cu and Zn concentrations in sediments determined in Ottawa, the following general conclusions can be drawn.

1. The concentration of Cu in lake sediments as determined in the field (partial Cu) reflects the Cu concentration in the underlying bedrock. This is attributed to the fact that although the drift cover is extensive, it is often not deep and there are numerous outcrops. The range in Cu concentrations is in the order: underlying dolomite $\leq$ overlying sediments < lower basalt member $\leq$ middle basalt member < upper basalt member. This variation in the Cu concentrations for the basalt members was previously demonstrated by analysis of rock chip samples[3].

2. The concentration of Cu in lake sediments as determined in the laboratory at Ottawa (total Cu) reflects the same pattern as outlined under (1), but seems on rough inspection to produce a more even pattern (more easily contoured).

3. The concentration of Zn in lake sediments as determined in Ottawa (total Zn) shows that this element is distributed over a greater thickness and therefore greater area of the basalts.

4. A zone with greater Cu and Zn concentrations in the sheets studied runs from the northeast corner of sheet 86-N-7 diagonally across the middle of sheet 86-N-8 and dies out in the southwest corner of sheet 86-0-5. This zone is crudely oval in shape with a major axis of about 20 miles long running northwest and a minor axis of about 10 miles long, running northeast.

5. The concentration of Cu in lake waters, as determined in the field, only shows the presence of the Cu-rich zone in the upper basalt member. The Cu concentrations for the waters, at least those obtained in the field, do not distinguish between the other rocks mentioned in (1). It is expected that the total Cu determinations made by atomic absorption spectroscopy in Ottawa will provide some degree of differentiation.

6. Because of (5), it could be said from a purely exploration viewpoint that the Cu-rich zone in the upper basalts could have been crudely located by analysis of lake waters alone. Had the sample density been dropped even to 1 sample for 10 square miles, this would probably still be true, although the final computer-drawn contour maps will determine this without bias. Of course, it is assumed that once 3 or 4 lakes with higher copper concentration are located adjacent to each other in 10-square-mile grid intersections, more detailed sampling would be carried out before conclusions were drawn.

7. In the total 1,500-square-mile area covered, 22 highly anomalous lakes i. e. as anomalous or more anomalous that the 2 lakes at the 47-zone, were found. These lakes were separated on the basis of combined

anomalous Cu in both water and sediment. There were, in addition, 23 lakes that were anomalous for Cu in either water or sediment, within the 1,500 square-mile-survey area. The majority of these anomalous lakes are located in the upper basalt member.

8. Of the 22 anomalous lakes, (a) 4 were in the immediate vicinity of known copper mineralization i.e. 2 at the 47-Zone, 1 at the Lars showing, 1 at the East Grid; (b) another 8 were approximately 1 mile or less from known minor sites of mineralization; (c) 10 anomalous lakes could not be explained by any known Cu occurrences. The exact position of 20 of the lakes is shown on Figure 1. Accurate locations can be obtained by placing this figure directly over a 4-mile to one inch map-sheet. The 2 anomalous lakes not shown are located in the extreme southwest corner of sheet 86-0-5 at approximate positions 67° 19'N, 115° 38'W and 67° 16'N, 115° 36'W respectively. There were many sites of known mineralization, outside the zone described in (4) which did not produce anomalous Cu concentrations in either waters or sediments of nearby lakes. This was especially true for the lower and middle basalt members where on diamond drilling most of these showings were found to be only very minor occurrences.

9. Of the three anomalous lakes studied in detail (Fig. 1) the one to the north was the most interesting. The high Cu concentration of the one to the west was found to be due to some influence from its northern end. The high Cu concentration in the one to the east was found on detail study to be related to the extensive occurrence of Cu mineralization in pieces of a breccia or more likely a mineralized flow top in which the lake was situated. The remaining lake, that to the north, was found to have the highest Cu content in its lake water of all 637 lakes analyzed, including those at the 47-Zone. The high concentration in the lake water was found to be due to high concentrations in the water of streams entering this lake from its eastern side. These streams flowed from a scarp slope trending south-southwest at the very probable position of a major fault. This lake would definitely merit the use of ground geophysics in its vicinity.

10. The detailed control studies both (1) and (2) showed that in larger lakes there could be a considerable variation in the Cu concentration of lake sediments at different points around the lake bottom. On small lakes, about 1,000 feet in diameter, this was not the case or at least it was less serious. It did show that a direction towards a showing could be obtained from samples collected around the lake bottom. It also implies that lakes with only anomalous Cu in the water should be revisited to check the bottom sediments before they are discounted. Both detailed control studies showed that Cu concentration in lake waters remained virtually constant during the entire sampling season. Exceptions to this were anomalous lakes which increase the Cu concentration in their waters after heavy rainfall.

11. The following conclusions on weathering in this high latitude cold desert can be drawn from the data of the detailed studies: (a) copper is moved very quickly into lakes after heavy rainfall; (b) this copper is transported in stream waters; probably as carbonate-bicarbonate complexes and fed by run off above the permafrost table; (c) considerable quantities of soluble copper must be available for transport in the streams and it is likely that

the form of this is copper sulphate; (d) weathering of outcropping and sub-outcropping sulphide deposits in the permafrost environment is considerable. Much of this movement of economic elements from sulphide deposits in permafrost conditions, in the form of sulphates, has been recently hinted at in the U.S.S.R.[4].

12. There appears at first glance to be no relationship between type of glacial deposits and Cu or Zn distribution. This is attributed to two facts: (1) although the drift cover is fairly complete, there is reasonable outcrop in most areas of the basalts surveyed and (2) the till in the area is usually "reworked" and the outwash is often "dirty", the net result being that the textural and mineralogical differences in the surficial cover are only slight.

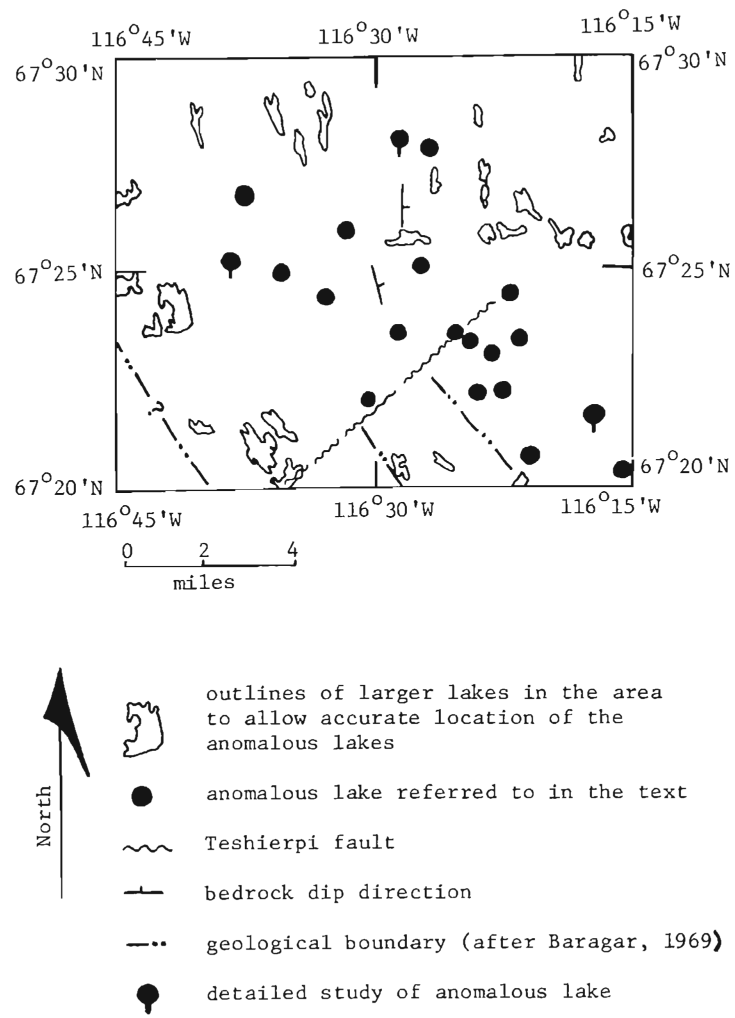


Figure 1. Location map of the 20 anomalous lakes referred to in the text.

13. There are numerous sites in favourable geological structures or elsewhere, particularly in sheet 86-N-7, where considerable, largely unsuccessful, diamond drilling has been carried out, based on ground geophysical surveys. These areas were shown to be essentially barren of Cu, especially when compared with the Cu-rich zone described under (4).

14. The field-determined pH values of the lake waters were all alkaline. They ranged from 7.1 to 9.2 with most around the 8.2. There appears to be very little relationship, if any, between pH of the lake water and its concentration of Cu.

15. This method apparently works in the Coppermine basalt group. Where else can it be applied? Assuming that those exploration companies wishing to use this method regionally did a small initial pilot study and also a control study during the sampling season, it should be possible to apply this method to the volcanics of Bathurst Inlet, Victoria Island, Borden Peninsula, Cape Smith-Wakeham Bay belt and Labrador Trough. Applications of similar methods for other types of rocks will necessitate more detailed pilot projects. Two or three such studies could probably be done during one summer now that we have considerably more numbers relating to geochemical dispersion in the surficial permafrost environment.

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[1] Hornbrook, E.H.W., and Allan, R.J.: Geochemical exploration feasibility study within the zone of continuous permafrost, Coppermine River Region, N.W.T.; Geol. Surv. Can., Paper 70-36, 35 pp. (1970).

[2] Allan, R.J., and Hornbrook, E.H.W.: Development of geochemical techniques in permafrost, Coppermine River Region; Can. Mining J., April, pp. 45-48 (1970).

[3] Baragar, W.R.A.: The geochemistry of Coppermine River Basalts; Geol. Surv. Can., Paper 69-44, 43 pp. (1969).

[4] Pitul'ko, V.M., and Shilo, N.A.: Geochemistry of frozen terrain and prospecting for ore deposits. Translations of the Northeastern Multidisciplinary Scientific Section, Academy of Sciences of the U.S.S.R., Magadan, 33 pp.(1970).

41. STUDIES OF THE FREQUENCY DISTRIBUTION OF ORE ELEMENTS IN CERTAIN ROCK UNITS OF THE CANADIAN SHIELD

32D /

Project 690050

E.M. Cameron

The frequency distribution by size of genetically related ore deposits within a given area or rock unit obeys probability laws; often this approximates a lognormal distribution. The writer has previously argued that these observed distributions are but the artificially truncated tail of a more general probability distribution of ore minerals within the given geological unit[1]. By determining the frequency distribution of the smaller and more frequent size components ("microdeposits") of this general distribution, important clues to the ore potential of a given geological unit may be obtained. This approach has already been applied with encouraging results to a comparison of the copper-bearing Coppermine Group and portions of the Yellowknife Group[1] where no copper deposits or showings are known; and to the discrimination of ultramafic rocks associated with nickel-copper sulphide ores from barren ultramafic intrusions[2].

In the case of the Coppermine Group, copper in samples of these volcanic rocks has been shown to be distributed lognormally, with a high log variance, the frequency distribution curve being continuous into the thousands of ppm Cu. On the evidence of this curve, it has been suggested that the copper sampled in the volcanic rocks and the copper of the copper deposits and showings were formed and distributed by the same geological process, namely magmatic segregation. The copper contained in the ore deposits may, however, have been secondarily redistributed. Since the copper of the rocks and the copper of the ore deposits are so closely related, the frequency distribution of Cu in the rocks may be used to predict ore potential. For the Archean volcanic rocks of the Yellowknife Group, which were compared with the Coppermine samples, the frequency distribution of copper is normal rather than lognormal; only one sample exceeds 273 ppm Cu. For the ultramafic study it has been similarly possible to separate ore-associated ultramafics from barren rocks. The former have distribution curves for copper and/or nickel sulphides which are continuous into higher ranges than is the case with the barren ultramafics.

These favourable results encouraged a comparison of the frequency distribution of copper in the rocks of a mineralized Archean greenstone belt with the previously analyzed Yellowknife Group samples. Thus 701 samples of volcanic rock were collected from two traverses in the Noranda camp. The first traverse, nine miles in length, is immediately south and east of the town of Noranda. The second, 19 miles long, is an east-west traverse 8 miles north of Noranda. The distribution of copper in the samples from Noranda and from the Yellowknife Group has been found to be basically similar. Both groups of analyses are principally composed of a normal frequency distribution of moderate and similar dispersion. It is tentatively suggested that this distribution is that of copper sulphide in the volcanics which is unrelated to any copper ore deposits. For the Noranda data, there is mixed with this distribution a second and distinct distribution of high copper values. This second frequency distribution, which has a high variance, is believed to be related to the ore deposits of the area. It comprises about 5 per cent of the Noranda samples.

The results very briefly outlined above have important implications apart from that of relating frequency distribution of ore elements to the ore potential of the sampled geological unit. The Geochemistry Section of the Geological Survey has been attempting to devise reconnaissance methods of geochemical exploration within the Canadian Shield using lake waters and muds and stream sediments. Studies carried out by R. J. Allan and E. H. W. Hornbrook[3] in 1969 and by Allan[4] in 1970 have shown that at Coppermine the area containing the known copper deposits and showings can be readily outlined using widely-spaced samples of lake waters or muds. A spacing of 1 sample per 10 square miles has been suggested as adequate (R. J. Allan, pers. comm.). At this spacing the geochemical pattern for copper in the lake waters or muds is not due to the ore deposits; it represents primarily the areal variation of copper in the bedrock. This highly efficient spacing is possible in the Coppermine area because copper in the bedrock is directly related to copper in the ore bodies and showings; all are part of the same frequency distribution. On the basis of the data from the Yellowknife Group and the Noranda belt, this is not the case for the volcanic rocks enclosing the massive sulphide deposits of the Archean greenstone belts. The copper (and presumably zinc and other "ore" elements) contained in the majority of rock samples taken from these belts is unrelated to the massive sulphide ores. In terms of a volcanic-exhalative origin for the massive sulphides, copper values directly associated with these deposits are likely to be confined to the walls of the pipes through which the mineralized solutions passed and to the stratigraphic zones in the volcanics and associated sediments where the metals were precipitated. Thus in the Archean greenstone belts, geochemical sampling of surficial materials must rely on discovering anomalies due to mineralized pipes and stratigraphic zones. In the Noranda traverses these mineralized pipes and zones account for approximately a twentieth of the rock sampled. Thus it appears that reconnaissance geochemical sampling in these greenstone belts must be made at a considerably closer spacing than is the case with the Coppermine Group.

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[1] Cameron, E. M., and W. R. A. Baragar: Distribution of ore elements in rocks for evaluating ore potential: Frequency distribution of copper in the Coppermine Group and Yellowknife Group volcanic rocks, N. W. T., Canada. Proc. Third Intern. Geochem. Explor. Symp., Toronto, April, 1970 (1970).

[2] Cameron, E. M., G. Siddeley, and C. C. Durham: Distribution of ore elements in rocks for evaluating ore potential: Nickel, copper, cobalt, and sulphur in ultramafic rocks of the Canadian Shield. Proc. Third Intern. Geochem. Explor. Symp., Toronto, April, 1970 (1970).

[3] Hornbrook, E. H. W., and R. J. Allan: Geochemical exploration feasibility study within the zone of continuous permafrost; Copper River region, N. W. T. Geol. Surv. Can., Paper 70-36 (1970).

[4] Allan, R. J.: Regional geochemical exploration of the Coppermine Basalts: Copper and zinc in the lake and stream waters and sediments, above the Arctic Circle, under continuous permafrost conditions (this publication No. 40).

42. GEOLOGY OF CANADIAN NICKEL AND PLATINUM GROUP DEPOSITS

Canada ✓

Project 630037

O.R. Eckstrand

The field component of this project was continued by visiting nickel deposits in the northern Labrador Trough, at Lake Renzy in the Grenville subprovince, in the Sudbury, Wawa, Thunder Bay, and Kenora - Fort Frances areas of Ontario, in the Werner Lake - Bird River area of western Ontario and eastern Manitoba, and in the Thompson and Lynn Lake areas of northern Manitoba. The general aim in each instance was to gain an appreciation of the general geological environment and the nature of mineralization, and to sample the ores and host rocks for various supplementary laboratory studies and comparison purposes.

Because they represent such a distinctive but little known type of nickel occurrence, and because they are receiving renewed exploration interest, some deposits of the Labrador Trough are described here in preliminary form.

Disseminated nickel-copper mineralization in "blotchy" metagabbro sills of the northern Labrador Trough

General Geology - Numerous deposits of low-grade disseminated nickel-copper mineralization occur in "blotchy" metagabbro sills that are common in the northern Labrador Trough between the Koksoak River and Hopes Advance Bay. The sills intrude the predominantly basaltic volcanic rocks of the Kaniapiskau Group, generally seeking out the thin, shaly interflow sediments or their contacts with the volcanic rocks. The sills themselves range in thickness from a few tens of feet to about 200 feet, and are relatively extensive. They have been folded into very elongate synclines and metamorphosed along with the enclosing rocks.

The actual "blotchy" metagabbro appears to be the central portions or cores of larger intrusive units, the border zones of which are a more basic and normally textured hornblende metagabbro. Minor interlayering of "blotchy" metagabbro and normal metagabbro is common. Some occurrences of "blotchy" metagabbro are structurally more complex, with re-entrant embayments of border zone metagabbro, and isolated blocks or tongues of "blotchy" metagabbro in the border zone metagabbro. Most of these features are believed to be primary.

The "blotchy" metagabbro is made up of about 50 to 75 per cent 1/2 inch to 1 1/2 inch equant or slightly lenticular "blotches" of felsic material. Originally these were probably pure feldspar, but now they are a fine-grained metamorphic assemblage that probably involves albite-clinozoisite-sericite. The boundaries of the blotches are only moderately sharp, apparently rendered "fuzzy" by metamorphic recrystallization. Mafic minerals in the interstitial gabbroic material are sensibly the same as those in the border zone metagabbro, and may include hornblende, biotite, chlorite and pyroxene (?, olivine?, serpentine?) depending on regional metamorphic grade.

Mineralization - Pyrrhotite, pentlandite and chalcopyrite appear to be the principal sulphide minerals, and these are disseminated in the gabbroic matrix interstitial to the feldspathic "blotches". Sulphide content of the "blotchy" metagabbro ranges from as high as 25 per cent to less than 1 per cent, and distribution tends to be somewhat erratic. However the sulphides consistently tend to be more abundant in the "blotchy" core of the sill than in the non-"blotchy" border zones. Within the "blotches", sulphides occur only in sparse seams and cleavage cracks. Not uncommonly, the disseminated mineralization extends into the adjacent metagabbroic border zones, but the majority is in the "blotchy" metagabbro.

In several of the occurrences, roughly conformable sinuous veins of massive sulphides constitute a second mode of mineralization. Their mineralogy and grades are similar to the disseminated mineralization despite the much higher sulphide content. They range in size from a few inches to a few feet in width and a few tens to a few hundreds of feet long. The massive sulphide veins usually occur along the contact between "blotchy" metagabbro and bordering metagabbro.

A moderate amount of drilling has demonstrated that tonnage in individual presently known deposits attains the order of tens of million tons, with grades of about 0.8 to 1.0 per cent combined nickel plus copper. Ni:Cu ratios range from 1:2 to 1:4 and average about 1:3. Eventual production feasibility would seem to depend on the discovery of several deposits close enough to each other to be treated in a single mill.

Genetic Speculations - The "blotchy" gabbro itself bears many similarities to orbicular anorthosite sills in the Bird River and Cross Lake areas of Manitoba. An appealing model is that the "blotches" were derived from a crystallized anorthositic mass which existed in a deep magmatic chamber. Upon tectonism, the anorthosite suffered fragmentation and the fragments were caught up in the gabbroic magma. The latter, in its upward transport, abraded and sorted the anorthosite fragments to produce a well-sized collection of "blotches". The process of flow differentation[1] could have led to their segregation as central cores in the sills which were eventually emplaced.

It seems fairly clear that the mineralization is intimately related to the "blotchy" metagabbro, and therefore must be magmatic in origin. Less clear is the control of its distribution, both disseminated and massive. However, it seems reasonable that the sulphur content expressed by the sulphides was originally dissolved in the magma.

There is a contrasting theory that the sulphur is derived by assimilation of iron sulphides of apparent syngenetic origin which are in many cases observed in the adjacent interflow sediments. However, cases are also known where sulphides were essentially lacking in these sediments adjacent to mineralized "blotchy" metagabbro sills, and conversely, where abundant sulphides were present in the sediments, but the immediately adjacent "blotchy" metagabbro sill was unmineralized. The rather common co-occurrence of disseminated nickel-copper sulphides in the sills and closely adjacent iron sulphides in the sediments may result simply from the facts that sulphides in interflow sediments are common, and the sills preferentially intrude the interflow sediments rather than the massive and pillowed flows of the volcanic pile.

The disseminated nickel-copper sulphides probably separated out of the gabbroic magma as immiscible sulphide droplets. The fact that these sulphides occur principally in the "blotchy" core of the sill suggests that the immiscible droplets (like the felsic "blotches") were segregated by flow differentiation during magma transport so that they became concentrated in the central portion of the sill. It is possible that the massive sulphide veins represent further segregation of the droplets to the point where a significant body of homogeneous liquid sulphide formed. This sulphide melt would then act as a separate unit in the moving fluid system represented by the gabbroic magma and its load of anorthositic "blotches". Because of its distinctive physical properties (mainly the probably lower viscosity), the sulphide melt may be localized at the juncture of the "blotchy" core and the border zones. The fact that the massive sulphide veins are quasi-conformable rather than sharply cross-cutting features supports the view that they were emplaced while the magma or part of it was still appreciably fluid.

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43. REGIONAL GEOCHEMICAL CENSUS OF PLUTONIC ROCKS IN EASTERN YUKON TERRITORY

Project 690036

R.G. Garrett

All the major bodies of acid plutonic rocks, 74 intrusives, northeast of the Tintina Trench and between 62° 40'N and 64° 40'N were sampled. In addition representative collections were made of the host rocks of the intrusives. A detailed sampling program was carried out around the AMAX Mount Allan property in order to investigate the relationships between the intrusive, the host sediments and the skarn tungsten deposits. The information yielded by the detailed study will be used in aiding the interpretation of the regional data. In total, some 2,800 samples were collected and these are being analyzed for a wide range of elements.

The intrusives are predominantly quartz monzonite and granodiorite; some true granite occurs and syenite was observed in three areas (Tombstone Mountain area, Syenite Range and Rogue Range). Two gross regional features are of interest, firstly, disseminated sulphides within the intrusives are most commonly found in the southeast of the area investigated, i.e. the McMillan Pass area; secondly, tourmaline, as knots and veins, was commonly found only in the McMillan Pass area.

Sulphide mineral showings were noted in several areas and are listed in Table 1. These showings were all minor and are presented as it is believed they have not been noted previously.

Table I

Mineral(s)	Association	Host	Map Sheet	UTM
molybdenite	on joint faces	quartz monzonite	105 M	08 481100 7039700
trace molybdenite	tourmaline vein	granite	105 O	09 428100 6999100
galena, sphalerite, arsenopyrite, pyrite	quartz vein	granodiorite	105 I	09 475100 6984600
galena, pyrite	tourmaline vein	granite	105 I	09 504400 6976000
trace molybdenite	in granite sill	granite	105 O	09 435900 7036600

44. DEVELOPMENT OF BIOGEOCHEMICAL EXPLORATION METHODS FOR WINTER USE FOR METALLIC MINERAL DEPOSITS

Project 700062

Dist of Keewatin ✓

E.H.W. Hornbrook

Field studies were conducted in the vicinity of Kaminak Lake in the Ennadai-Rankin belt of volcanic and sedimentary rock, Keewatin District, Northwest Territories.

The objective of the study was to determine the effectiveness of regional geochemical methods, particularly hydrogeochemistry, in delineating large (in excess of 100 square miles) anomalous areas within the 2,300-square mile study area. More detailed studies were carried out to examine geochemical dispersion haloes in the vicinity of known metal element occurrences. Further, manual and electrical pumping systems were developed and tested to increase the sample collection rate with resultant reduced operational costs.

Approximately 1,000 water samples and 400 sediment or soil samples were collected.

The results of an examination of the field area and of a few copper and zinc determinations completed in a field analytical laboratory revealed the following: The existence of large geochemical haloes in the drainage waters is doubtful and the waters, contrary to expectations, contain only low zinc and little or no copper in solution (see report by A. Nigrini, this publication No. 46). Analysis of all samples collected for several elements will confirm or modify the above preliminary findings.

The manual pumping system attached to the float of the helicopter was successfully used all summer, permitting a collection rate of one lake water sample per 4 to 7 minutes respectively with sample collection densities of one sample per square mile or 10 square miles. The electrical system was installed, tested, and proven to be operationally successful but a pump free from internal contamination and with a higher pumping capacity will be required.

45. GEOCHEMICAL DISTRIBUTION OF MERCURY AND ASSOCIATED METALS IN SOIL SAMPLES FROM CLYDE MAP-AREA, ONTARIO

Project 690091

I. R. Jonasson

Soil sampling over a small anomaly in an area where mercurial tetrahedrite and cinnibar have been found has been completed. The property, prospected by Carndesson Mines and located near Clyde Forks, Lanark Co., covers a number of small disseminated sulphide prospects associated with barite veins in Grenville marbles. Soil samples taken at a given site included humus and organic materials, B horizons and where available, C horizons. These were analyzed for mercury by a newly modified atomic absorption technique and for 26 other elements. Humic samples were used subsequently for a series of extraction studies designed to elucidate the nature of the mercury compounds present. Similar work is in progress on other types of soil samples.

The elements which best map the location of mineralization include mercury; zinc, arsenic, barium, boron, manganese and copper. Mercury levels in this area range from a background for humus of about 100 ppb up to anomalous values of 2 ppm with a high in one location of 250 ppm. In B and C horizons corresponding values at the same site are generally lower by factors of 2 (in background areas) to 10 (for anomalies).

Current field work encompasses a sampling program for soil gases in the same site areas.

46. TRANSPORT AND DEPOSITION OF ORE INDICATOR ELEMENTS IN STREAMS AND SEDIMENTS

Project 690039

A. Nigrini

Sampling of waters and sediments near known mineral occurrences, near gossans, and in anomalous lakes and streams was undertaken in the Bathurst area (21 O/7E, 21 O/9W) of New Brunswick, and the Hope Lake (86N/8, 9) and Kaminak Lake (55L) areas of the Northwest Territories. Water chemistry was investigated in order to evaluate its effect on ore element dispersion haloes in these regions. Temperature, pH, Eh, Cu^{++} and HCO_3 were measured in the field. Water samples were returned to Ottawa for detailed analysis for the major cations and anions as well as Fe, Mn, Cu, Pb and Zn.

In the Bathurst area, where groundwaters were observed equilibrating with the atmosphere, copper values were found to decrease, with increasing pH (from pH 3 to pH 7) until a maximum of about 1 ppb was achieved at pH 7. Concomitant copper precipitation suggests that Cu^{++} concentrations in water are buffered by copper minerals in the sediments. In the Kaminak Lake area pH values average about 7 and it is probable that a similar buffering action is maintaining low copper values in these waters.

Copper levels in the waters of the Hope Lake area are generally higher than those in the Kaminak Lake and Bathurst areas. These levels correlate with higher pH values which, in the Hope Lake area, average approximately 8 and suggest that the copper is carried as a hydroxyl complex in the water. Thermodynamic considerations indicate that hydroxyl complexes of copper dominate at pH's greater than 7.3 and allow higher total copper levels with increasing pH.

The foregoing observations suggest that for regional geochemical exploration programs based on water sampling, pH measurements are critical. In this instance, low copper values (on the order of 1 ppb) in waters having pH's of 7 to 7.5 should not be interpreted negatively since these low levels represent the thermodynamic maxima in this pH range. Similar restrictions may also apply to other ore elements, but probably not at the same maximum levels or in the same pH range. Further work in this direction is continuing.

GEOCHRONOLOGY

47. THE SELECTION OF SAMPLES FOR ISOTOPIC AGE INVESTIGATIONS

Projects 540028, 650466

General ✓

R.K. Wanless and R.D. Stevens

A seven-day collecting expedition in June 1970 was organized to collect samples for geochronological study in four areas of Quebec as follows:-
1. Rouyn-Noranda: (a) Bulk samples of boulders and pebbles from Temiskaming and Cobalt conglomerates were collected to obtain zircon concentrates for U-Pb dating. Also, bulk samples of Pontiac schist, the Kinojevis Lake "granite", and the Cléricy syenite were collected for zircon separation. (b) The Flavrian and Dufault "granites" were extensively sampled for Rb-Sr isochron study. Sufficiently fresh hornblende for K-Ar dating was found in four of these samples.

The Rouyn-Noranda sampling is directly related to our study of the subdivision of the Precambrian in this area. At this time sample preparation and mineral separations are still in progress.
2. Senneterre-Desmarisville-Chapais: Sampling of granitic, gabbroic and metamorphic rocks was carried out along the Senneterre-Chibougamau road. Biotite, muscovite and/or hornblende concentrates from these samples will provide K-Ar dates in this geochronologically unstudied area. The specimens have been petrographically examined and mineral concentrates are in preparation.
3. Chibougamau: A bulk sample for zircon separation was collected from the locality on Lac la Dauversière (Obatogamau) which has consistently yielded anomalously old (3800 m.y.) biotite ages. A greater quantity of muscovite and biotite will also be obtained from this sample so that more experimental investigation of the nature and reasons for the anomaly can be carried out by the K-Ar, Rb-Sr and U-Pb methods[1, 2].

In addition, further samples were collected from the Dauversière area and from islands within the lake in order to determine the areal extent of the anomalous age phenonemon. Boat traversing on the lake was very satisfactory, but the high water level in the bush this summer prevented effective penetration to the south between the lake and the Grenville Front.

The samples have been petrographically examined and selected, and mineral concentrates are in preparation.
4. Lac St. Jean-Chicoutimi-Bagotville: Samples of anorthosite from Hébertville, syenite from Shipshaw/Chicoutimi-Nord, gneiss from Arvida, granite from Bagotville and gneiss from near Chicoutimi were collected for K-Ar age determination to obtain data for this area where not much geochronological work has been done in the past.

Petrographic examination and selection has been carried out and mineral concentrate preparation is in progress.

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2 Wanless, R.K., Stevens, R.D., Loveridge, W.D.: Anomalous parent-daughter isotopic relationships in rocks adjacent to the Grenville Front near Chibougamau, Quebec; Eclogae geol. Helv., vol. 63/1, pp. 345-364 (1970).

MINERAL DEPOSITS

48. URANIFEROUS CONGLOMERATES OF THE CANADIAN SHIELD

41J ✓

Project 690014

T.J. Bottrill

1. The Stratigraphic Relationships of Uraniferous Conglomerates, Associated Strata, and Volcanic Units at Elliot Lake, Ontario

The Elliot Lake Group which contains the uraniferous oligomictic conglomerates also contains substantial thicknesses of volcanics, but the internal stratigraphy of the group was known only for the area of the Quirke Lake syncline in Townships 137, 138, 143, 144, 149, and 150. A field program was undertaken to investigate the distributions of the various units over an area to the west of these six townships. It was found that there are probably two separate volcanic units, and that these are the possible stratigraphic equivalents of the two major ore-bearing sandstone members in the Quirke Lake syncline. The lower volcanic unit is found subsurface over a large area between Iron Bridge and Elliot Lake, and exposed on the southern edge of the Quirke Syncline in Township 143 where it is seen to be underlain by a polymictic conglomerate and was originally considered as being part of an Archean greenstone belt. This lower volcanic unit may be correlative with the metamorphosed Pater volcanics on the north channel of Lake Huron, south of the Murray Fault. The volcanic unit is locally overlain by the basal Stinson polymictic conglomerate which occurs over a large area to the west of Elliot Lake. The Ryan sandstone unit is overlain unconformably by the basal Stinson polymictic conglomerate, such that the author considers the lower volcanic and the Ryan as at least in part correlative.

The upper volcanic unit includes, firstly the Thessalon volcanics, and secondly, a series of volcanic units exposed along the north limb of the Quirke Syncline (Fig.1) which are thought from a study of diamond-drill core to be connected. This second series has in part previously been mapped as Archean[2, 3], but is considered as part of the same unit mapped as Huronian in Townships 157 and 163[4, 5]. These volcanics are seen to be underlain by a quartz-pebble conglomerate where they overlie Algoman granites, such as on Dolyberry Lake and immediately to the west of Highway 634 in Township 150 at the unconformity of volcanics mapped as Archean and granites which locally are seen to develop a paleosol. Where they overlie Archean greenstone belts the exact position of the boundary is problematic. The upper volcanic member is seen locally in Township 163 to be underlain by sediments considered by the author as part of the Elliot Lake Group, and are probably correlatable with the sandstones underlying the Thessalon volcanics[6, 16]. The upper volcanics are overlain by the Ramsay Lake Formation polymictic conglomerate; however, conglomerates interbedded with volcanics are seen to grade into the Ramsay Lake Formation where it contains abundant angular volcanic clasts and a mafic matrix of possible volcanic derivation. It would

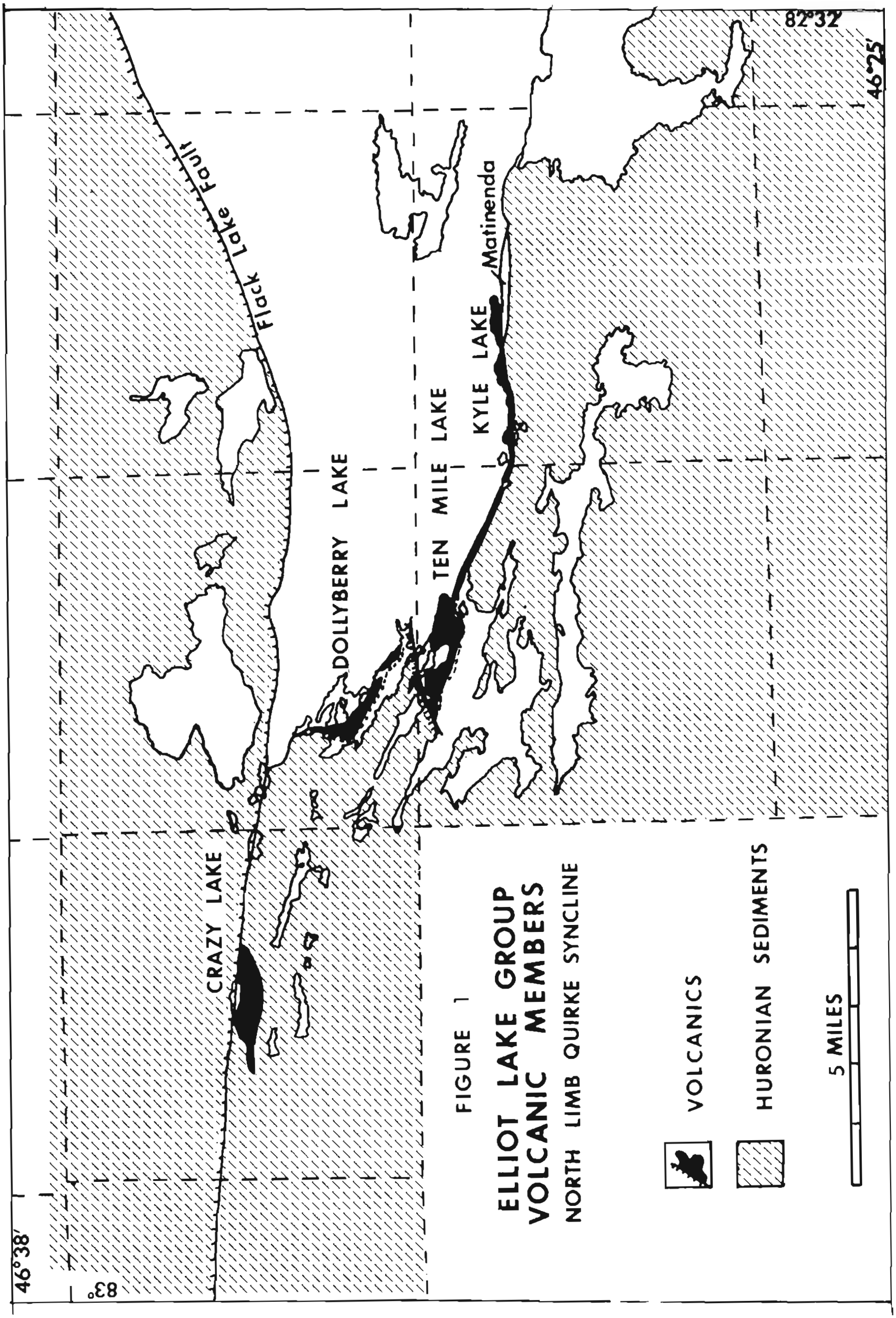

FIGURE 1
ELLIOT LAKE GROUP VOLCANIC MEMBERS
NORTH LIMB QUIRKE SYNCLINE

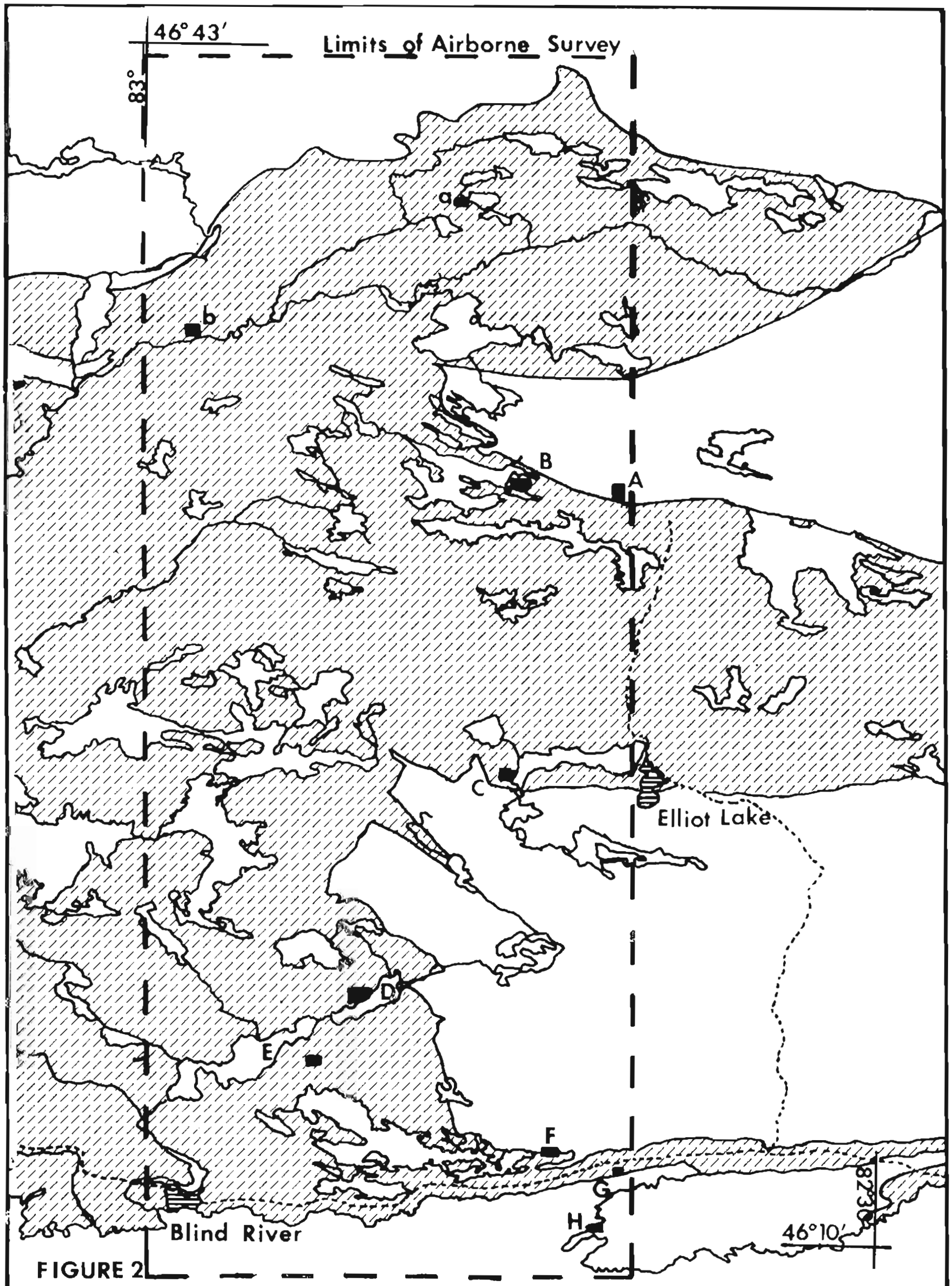

FIGURE 2
GAMMA SPECTROMETER SURVEY
ELLIOT LAKE 1970

10 Km

Ground Surveys (table 1)

Huronian

TABLE 1

GAMMA - SPECTROMETER SURVEY ELLIOT LAKE 1970

GROUND SURVEYS: PRELIMINARY RESULTS

Grid Code (as on Fig. 2)	Name	Uppm	Thppm	K%	No. of stations in survey	Stratigraphic Unit	Lithological Type
A	Algoman	0.6	4.1	1.9	72	Algoman	Granite
B	Ten-mile	7.2	32.8	3.2	63	Mississagi	Sandstone/Arkose
C	Elliot Lake	4.3	20.3	1.5	47	Matinenda (Ryan)	Sandstone/Arkose
D	Magog	1.5	8.1	1.8	43	Matinenda (Stinson)	Sandstone/Orthoquartzite
E	McKim	5.4	26.8	2.5	12	McKim	Sandstone/Subgreywacke
F	Pronto	21.3	17.6	4.4	39	Algoman	Granite
						Matinenda-Pronto	Sandstone/Arkose Conglomerate
G	Spragge	1.0	1.7	0.3	10	Spragge	Metasediment
						Pater	Metavolcanic
H	Cutler	4.8	19.2	3.5	44	Cutler/Middle Aphebian	Granite
9	Armore	2.2	418.0	4.2	11	Lorrain	Sandstone Conglomerate
6	White River	11.5	54.7	4.2	15	Mississagi	Sandstone Conglomerate

therefore seem possible that the upper volcanic unit is in part correlative with the Manfred sandstone unit, and in part the mutually overlying Ramsay Lake Formation.

The stratigraphic correlation of volcanics and sandstones that contain ore-bearing conglomerates below petrographically similar polymictic conglomerates would add substantial support to the statement of Roscoe[7] that "the thick volcanic sequences must have had considerable influence on Matinenda sedimentation", and would suggest that volcanics form a necessary component at Elliot Lake of the environment for ore formation.

2. Radio-Element Geochemistry of Huronian and Related Strata

In co-ordination with the airborne gamma-spectrometer-survey of an area west of Elliot Lake (Fig. 2) undertaken by the Exploration Geophysics Division (see Darnley, this publication) readings of various Huronian units and of Algoman granites were taken with a portable gamma-spectrometer for their uranium, thorium and potassium contents. Preliminary data (Table 1) would suggest that the radio-element distribution is similar to that of sediments in the Phanerozoic and thereby support the contention of Pliler[8] that the sedimentary geochemistry of uranium and thorium in the Huronian is actualistic.

Thirty-two gamma-spectrometer readings taken randomly on Algoman granitic rocks in an area similar to that sampled by Roscoe and Steacy[9] gave mean values as follows:

Uranium (ppm)	Thorium (ppm)	Potassium (per cent)
5.1	29.1	3.43

Grid A (Table 1, Fig. 2) gave mean values as follows:

Uranium (ppm)	Thorium (ppm)	Potassium (per cent)
0.6	4.1	1.9

These two sets are substantially lower in the uranium content than those reported by Roscoe and Steacy[9] and are close to the clark values. The difference is possibly the result of the sampling techniques, and larger volumes of material measured by the writer.

3. Lower Proterozoic Clastic Strata and possible Uraniferous Conglomerates in the Northwest Territories

It has been suggested[10, 11, 12] that uraniferous conglomerates as found in the Huronian could occur elsewhere in the Canadian Shield in Lower Proterozoic strata of similar age.

Occurrences of pyritic quartz-pebble conglomerate in the Montgomery sediments were examined near Padlei, District of Keewatin. Though largely similar in appearance to the conglomerates at Elliot Lake, Ontario they occur in a different sedimentary suite associated with subgreywacke rather than gritty arkose; this difference is probably related to the prevenance lithologies. If however it is indicative of a different sedimentological environment[13] then the exploration potential of the unit is somewhat lessened.

Occurrences which are related to coarse clastic strata, in which the source of the radioactivity may be stratiform were examined in the Sosan Group on the East Arm of the Great Slave Lake[14]. A number of radioactive zones have been outlined by Vestor Explorations Limited (Northern Miner, Sept. 24, 1970). The radioactive clastic strata occur in association with minor volcanics, including pyroclastics, mudstones, dolomite sands and polymictic conglomerates. The strata are sometimes steeply dipping, dissected by high-angle faults, and frequently show a disrupted fabric or brecciation[15]. The Sosan rests upon granites with a possible paleosol at the unconformity. The presence of coarse clastic strata, preserved paleosol and association with pyroclastic volcanics may indicate a similar environment of ore formation to the uraniferous conglomerates at Elliot Lake, Ontario.

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49. GEOLOGY OF IRON AND MANGANESE DEPOSITS IN CANADA

Project 570029

G. A. Gross

Labrador Geosyncline, Newfoundland, and Quebec

Iron ore producing mines in the Schefferville, Wabush Lake and Gagnon areas were visited to up-date geological information. Further field studies were made of iron deposits which are to be mined in the course of the new development programs and the large expansion of iron ore production from the region which is to take place during the next few years.

In the Schefferville area attention was given to revision of detailed stratigraphic information on the iron-formation around Timmins Mine and Irony Mountain where the stratigraphy differs from that in the type section in Ruth Lake Mine area.

New detailed information on the stratigraphy and lithological facies of the iron-formation in the Wabush Lake area was studied which has considerable significance in management of "ore grade control" in the large mines of the area.

Work is underway in the Mount Wright area for development of a large mine and ore beneficiation plant on the western part of this iron range. The results from an extensive drilling program on the Mount Wright deposits were reviewed which confirm the size and depth of the large iron-formation structure that was predicted from results of exploration work carried out on these deposits in 1953 and 1954.

It is expected that iron ore production from the Labrador geosyncline may be doubled by 1975 when the expansion programs at the various mine properties are completed.

Superior Province, Northwest Ontario

A number of iron-formation occurrences were visited to obtain information from recent exploration and development work and to obtain specimens for study of minor elements and composition of various lithological and sedimentary facies. In the Geraldton area hematite, magnetite and carbonate facies of iron-formation intimately associated with fine-grained clastic rocks are being studied to define mineralogical and petrological features in this potential iron ore and to provide geological information relevant to beneficiation and concentration of the iron-bearing minerals. Iron-formation was examined in the Lake St. Joseph area to obtain further geological data pertinent to the evaluation of these large deposits of potential iron ore.

Melville Peninsula, District of Franklin

Iron-formation was examined on the eastern side of Melville Peninsula near Parry Bay and on the west side near Selkirk Bay[1]. The iron-formation in both areas is predominantly a magnetite quartz facies of Algoma type and is directly associated with intermediate to basic metavolcanic rocks. Iron-formation is repeated in tight steeply plunging fold structures where it forms very impressive deposits that contain large tonnages of potential iron ore. The iron-formation in the western area is more uniform in composition containing 30 to 35 per cent iron and is up to 1,000 feet wide in some structures. The iron-formation of the eastern area has considerable metasedimentary and metavolcanic rock interlayered and infolded with it and individual bands or structural units of iron-formation may not exceed a few hundred feet in width. The iron-formation of this region can be beneficiated without difficulty and provide magnetite concentrates of high quality.

The belts of metavolcanic rock containing the magnetite iron-formation are of particular interest for exploration for base metal sulphide deposits. Numerous small gossan zones were observed which are formed by oxidation of pyrite and pyrrhotite disseminated in the volcanic rocks. Traces of chalcopyrite were observed in some of these mineralized zones. In places the sulphide minerals occur in thin bands of black mica schist which appear to be derived from carbonaceous fine-grained sediments interlayered in tuff, pyroclastics and a variety of volcanic rocks. A large proportion of the metavolcanic rocks are intermediate to acidic in composition and indicate that considerable differentiation took place in the magma from which they were produced. It is highly probable that base metal sulphide deposits were deposited in these volcanic belts along with the iron-formation.

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

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50. INTERNATIONAL SYMPOSIUM ON THE GEOLOGY AND GENESIS OF PRECAMBRIAN IRON AND MANGANESE FORMATIONS AND ORE DEPOSITS, KIEV AND KRIVOY ROG, UKRAINE S.S.R., U.S.S.R.

G.A. Gross

Two weeks were spent in attendance at this scientific conference and field study of the Krivoy Rog iron ranges which was sponsored by UNESCO and the Ukrainian Academy of Sciences. About 60 specialists on the various major iron and manganese producing regions of the world presented papers on recent geological work on iron and manganese deposits and discussions centered on new concepts being developed on their genesis. Field work at Krivoy Rog included study of mine geology at the two largest open pit mines where magnetite quartz iron-formation is being mined and concentrated, at the two largest underground mines where hematite ore derived from iron-formation is produced, and study of the geological setting of the famous Krivoy Rog iron belt in several outcrop areas in the Ukrainian Shield. Papers and proceedings of the symposium will be published in a special UNESCO publication. The symposium was of particular value as it brought together representatives from major iron and manganese producing areas of the world and established a working liaison for correlation and comparison of geological information of global significance in the development of iron and manganese resources.

51. GEOLOGY OF COPPER AND MOLYBDENUM DEPOSITS

Project 700059

R.V. Kirkham

A general study of copper deposits in Canada was initiated. Copper mines and prospects in parts of British Columbia, Yukon Territory, Northwest Territories, Ontario, Quebec, New Brunswick, and Nova Scotia were visited. Besides this general work more specific studies were carried out in a few areas. Preliminary results of the work are as follows:

1. Granisle Mine, British Columbia - Nine days were spent examining intrusion - vein relationships at the Granisle porphyry copper deposit in central British Columbia. Even though an overall pattern of distribution of sulphide and alteration minerals appears to exist within the deposit, it was established that there has been a very complex history of veining and intrusive activity. There is abundant evidence (truncated veins, vein fragments, etc.) indicating that periods of intrusive and hydrothermal activity overlapped.

2. Copper deposits in the Mush Lake Group, Yukon Territory - It has been known for many years that there are numerous copper occurrences in Mush Lake volcanic rocks of southwestern Yukon. They have been described by Knopf[1], Cairnes[2], Kindle[3], Muller[4], Green[5], Findlay[6,7], and others. The writer examined briefly showings on Rabbit Creek (Canyon City Mines Ltd.), Discovery property (Silver City Mines Ltd.), Quill Creek property (Quill Creek Mines Ltd.), showings south of Pickhandle Lake, showings northeast of Tatamagouche Creek (Alice Lake Mines Ltd.), Johobo property (Johobo Mines Ltd.), and Jack Pot property (Jack Pot Copper Mines Ltd.). Most of these deposits occur in volcanic rocks typical of the Mush Lake Group. However, because of their different host rocks and possible different genetic affinities the showings on Rabbit Creek and those on the Jack Pot property should not be considered as "Mush Lake copper occurrences."

The writer visited these properties to determine if the deposits in the Mush Lake Group have many features in common with those in the Hazelton and Takla Groups of central British Columiba[8], and those in the Coppermine River Group of the Northwest Territories. The writer is convinced that deposits in these three areas have sufficient similarities to suggest that they have had somewhat similar origins. There appears to be an important group of epigenetic copper deposits in volcanic sequences that has not been widely recognized as a separate major genetic class of copper deposits.

In these three areas none of the deposits examined to date has proven to be economic, but in many cases exploration of this type of deposit has not been extensive. Although it is not unreasonable to expect that economic deposits of this type might exist somewhere in the southwestern part of the Yukon, exploration for this type of deposit is complicated by the fact that there has been very extensive post-ore deformation in the Kluane Ranges. Many of the deposits are cut by minor and probably also major faults. In the Quill Creek area there appears to be a melange of fault blocks. Major low angle thrust faults and high angle block faults are common. In areas where there are encouraging showings there seems to be little hope that the mineral deposits are still intact or that their dislocated portions can be found.

3. Copper deposits in the Coppermine River Area, District of Mackenzie

About two weeks were spent in the Coppermine River area as part of a study of copper deposits being carried out by E. D. Kindle and the writer[9].

Work was concentrated on the Teshierpi fault system and mineral deposits related to it. Copper sulphides have been found at several localities along the fault system; however, only at the 47 Zone has it been possible for exploration companies to outline a significant tonnage of mineralized rock. Controls on the sulphide distribution are not at all clear. Nevertheless, it is probably in some way related to the amount of open space that existed along the fault system. In the case of the 47 Zone open space was provided by extensive fault brecciation.

Systematic samples were also collected to study the distribution of copper in a flow that is particularly rich in disseminated native copper. From the abundance of native copper in hand specimens it appears as if the copper content varies considerably both vertically and along strike.

4. Stratiform copper deposits in Mississippian rocks of Cape Breton Island and part of mainland Nova Scotia

It has been known since 1966 that chalcopyrite and malachite are present in uppermost conglomerate and sandstone beds of the Grantmire Formation and basal limestone beds of the overlying Windsor Group in the Frenchvale area west of Sydney, Nova Scotia[10]. Diamond drilling has been used to demonstrate that minor, subeconomic chalcopyrite is present in these beds at widely scattered localities near Frenchvale. For many years it has been known that copper minerals in minor quantities occur at this stratigraphic horizon at many places in Cape Breton Island. For instance Kelley, in reference to the A_1 limestone of the Windsor Group states: "The conglomerate underlying the limestone at Grand Narrows has malachite stains on some of the pebbles, a common feature of several outcrops of conglomerate underlying the A_1 limestone"[11]. Similar mineralization has also been observed in the Antigonish area at the contact between the Horton and Windsor Groups[12]. The writer examined this type of mineralization in the quarry at Christmas Island, the Frenchvale area, and the Kaiser Celestite deposit at Enon. W. Potter of the Nova Scotia Department of Mines is presently studying the Grantmire Formation and its associated mineral deposits in the Boisdale and Frenchvale areas.

In general chalcopyrite occurs interstitially in minor amounts in the upper few feet of the Grantmire Formation where the beds are grey rather than the characteristic red colour. Malachite is typical in weathered outcrops. Minor disseminated chalcopyrite has also been noted at some localities in the dark, very fine grained basal limestone beds of the Windsor Group. In most places examined to date the mineralized beds are very low grade and less than five feet thick.

Even though known copper tenors are low and widths are narrow, the apparent wide areal extent and consistent stratigraphic relations of this mineralization indicate an intriguing possibility that major stratiform copper deposits exist somewhere in the area. Certainly from both economic and scientific points of view, it would be highly desirable to know much more about the nature and distribution of this mineralization. It should be kept in mind that it has already been established that there are major concentrations of base metals in Carboniferous rocks of Cape Breton Island[13]. For example, a Pennsylvanian sandstone bed has been found that is 37 feet thick and averages 3 to 3 1/2 per cent lead for more than one mile along strike and greater than 1,000 feet down dip.

Several features of the copper mineralization suggest a syngenetic rather than an epigenetic origin: (1) extremely wide areal extent (2) constant stratigraphic position (3) presence of many areas between copper occurrences of this type that were probably positive during and after Grantmire and Windsor deposition. It is difficult to envisage any epigenetic process or series of processes far removed from the rocks themselves that could adequately account for these features. The fact that the main host rocks are poorly sorted, coarse-grained continental clastic sediments would appear to be inconsistent with syngenetic origin. However, it should be remembered that in places the basal limestone beds of the Windsor Group contain disseminated chalcopyrite. Marine transgression over very permeable continental beds could adequately explain the distribution of chalcopyrite in the underlying coarse clastic sediments. If this were the case it becomes immediately apparent that the sedimentological conditions existing during the deposition of the lower Windsor "Macumber lithology"[14] were of primary importance in controlling the distribution of copper in these rocks.

The mineralization in Mississippian rocks of Nova Scotia is yet another example of stratiform copper mineralization occurring where marine beds overlie continental "red beds" or basement. Other examples are at White Pine, Michigan; Creta, Oklahoma[15]; Redstone River area, Northwest Territories[16]; Coppermine River area, Northwest Territories[17]; Mansfeld area, Germany; and, at least in part, the Zambian Copperbelt. Hoffman[18] made somewhat similar observations. It would appear that, regardless of how these copper deposits formed, the relationship of marine beds overlying continental beds is fundamental. It should be emphasized that if this relationship can be established with certainty it offers a very powerful exploration tool for this type of deposit. It should be pointed out, however, that most areas cited above also contain evaporites in the sequence and that copper mineralization is present in the underlying basement rocks; hence, many factors could be equally as important in determining whether or not this type of copper mineralization is present, its extent, and concentration.

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Canada

52. URANIUM IN CANADA

Project 670029

H. W. Little

Dr. V. Ruzicka completed a major work comprising a geological comparison of Canadian and East European uranium deposits with emphasis upon regularities in their distribution. He also proposed a genetic classification of these deposits. His paper is now in press.

The writer in June visited Elliot Lake area where visits to Denison and Quirke II mines were made, as well as to the Agnew Lake mine some 50 miles to the east, where underground development is in progress.

In the early part of the field season visits were made to uranium showings in the Paleohelikian Kazan quartzite, in post-Kazan volcanic and associated intrusive rocks, in Early Aphebian Hurwitz sediments, and in Archean rocks, in Baker Lake area, District of Keewatin. Although little development had been done at the time, either by Aquitaine Company of Canada Limited or by New Continental Oil Company of Canada Limited, and the deposits seemed to show some degree of stratigraphic preference, but some are definitely related to north-trending faults and in the writer's opinion the available evidence in most deposits points to an epigenetic origin.

At Rabbit Lake, Saskatchewan, a few miles west of Wollaston Lake, development of the Gulf Minerals deposit will soon begin, according to a recent announcement. The deposit is irregular in shape, but is roughly lenticular, the longest axis plunging moderately northeasterly. The shortest axis is vertical. Near the core is a large mass of massive pitchblende which appears to grade outward into a body containing only sooty pitchblende as the ore mineral. This sooty pitchblende occurs mainly along tiny fractures but is also disseminated within the brecciated material. Minor uranophane is present. The host rocks are of pre-Athabasca age and consist of heterogeneous rock types including medium-grained biotite granitic gneiss, medium- to coarse-grained actinolite-bearing gneiss, coarse-grained red arkose, minor red argillite, red silicified, dolomitic marble, impure quartzite, and calc-silicate rocks. These rocks are intruded by white to grey medium-grained granite and red medium- to coarse-grained granite and minor pegmatite. The host rocks are sheared and locally brecciated, and have undergone chloritization, sericitization, carbonatization, silicification, and argillization. The first four are widespread, but the last apparently is largely confined to an envelope about the orebody. Within the orebody kaolonization of gneiss is virtually complete in small pods. Quartz and dolomite have been introduced, both replacing other minerals and veining the rocks. Sooty pitchblende is mainly, if not entirely earlier than white to transparent dolomite and quartz, but later than kaolin.

Zones of reduction of ferric oxide occur in the red arkose and argillite. Paucity of hematitization in the deposit is striking, being only local and weak, and apparently not directly related to uranium mineralization. Sulphides are not abundant. Pyrite is widely scattered and mainly, or entirely, earlier than the mineralization. Minor galena and sphalerite and a few crystals of chalcopyrite have been reported, but the paucity of sulphides in the deposit is striking.

The deposit lies almost entirely within a wedge of brecciated rock bounded on the west by a steeply dipping, north-trending fault, on the south by a steep fault striking northeasterly, and to the north and below by a fault that strikes about 70 degrees and dips 30 degrees S, steepening to 40 degrees at depth. Beyond the faults the rocks are similar to those within the wedge, but are little brecciated or altered.

In Uranium City area properties of Eldorado Nuclear Limited were examined. The Verna mine has been closed; most production is currently from the Fay mine. Development has proceeded to the 24th level, and a pilot hole drilled to 2,000 feet below this level intersected ore grade vein material near the end. Ore is therefore known to have a minimum vertical extent of 5,000 feet.

The upper Bolger orebody, which is 2,000 feet east of the Verna shaft, in the hanging wall of the St. Louis fault, has been completely mined and at the time of the writer's visit intervening waste had been removed to expose the lower Bolger orebody. This consists of a tabular stockwork of pitchblende-bearing carbonate-quartz veins in epidotized amphibolite.

Development of the Hab mine, which is about 3 1/2 miles north of the Bolger pit, is proceeding on three levels on which both the 038 and 039 zones are intersected. The 038 zone consists of a high grade disseminated orebody in porphyroblastic granite locally mylonitized. The 039 zone is a carbonate-quartz vein that strikes westerly and dips steeply to vertically. The host rock where the vein was examined is mylonitized amphibolite. The rocks in the vicinity of the mine are granitic gneiss, porphyroblastic amphibolite, boudinaged granitic dykes and some other rocks typical of the Tazin Group.

The Nesbitt property at Reed Bay was also visited but flooding at the face of the adit due to a pump failure prevented examination of the best mineralization. This consists of red carbonate pitchblende-bearing veinlets in sheared amphibolite which overlies quartzite, and lies on the west limb of a syncline. A sample was taken from the dump for mineralogical examination.

The exploration camps of Mokta (Canada) Limited at Fond du Lac and Cluff Lake were visited. Samples of pitchblende-bearing material from veins in the basement rocks, and from the Athabasca Formation were obtained at the latter locality for mineralogical examination and isotopic age determination.

A visit was made to Philipsburg area, Quebec, where brecciated phosphatic dolomite of Lower Cambrian age, underlying argillaceous rocks, is impregnated by a uranium mineral, possibly uraninite, and some pyrite, fluorite and sphalerite, on ground held by SOQUEM. The uranium mineral is closely associated with collophane in the dolomite.

The writer is grateful to the mining and exploration companies for their co-operation and hospitality. At the time of writing further field work is planned.

53. TIN-MOLYBDENUM-TUNGSTEN OCCURRENCES IN NEW BRUNSWICK

Project 530014

R. Mulligan

A brief visit to the property of Brunswick Tin-Mines Ltd., at Mount Pleasant, N.B. was made in September, 1970. Most of the previous underground work had been done in the north "zone" of the property with the object of developing economically mineable tin deposits. Recent work has been concentrated in the "south" and "Fire-Tower" zones, where the concentrations of molybdenum and tungsten is generally higher and that of tin generally lower than in the north zone. Two adits have been driven in this part of the property, one at about 900 feet elevation on the north side of the Fire-Tower summit, and another at about 750 feet elevation on the west side. Drifting and diamond drilling has indicated a zone of molybdenum-tungsten mineralizations and several zones with zinc, lead, copper, and tin mineralization.

54. GEOLOGY OF LEAD AND ZINC DEPOSITS IN CANADA

Project 650056

D.F. Sangster

Lead and zinc-bearing deposits were examined in the northern and southern Cordillera, Churchill Province, Grenville Province, and the Arctic Islands. Of the deposits visited, the following warrant special mention at this time:

I. Tom Group, Y.T. (N.T.S. 105 0/1) This lead-zinc-barite deposit, owned by the Hudson Bay Mining and Smelting Co. Ltd., is a bedded, stratiform body within a thick series of thin-bedded argillite, siltstone, conglomerate, and minor limestone. The age of the host rocks was tenatively identified as Ordovician-Silurian, mainly on lithologic evidence[1]. A distinctive lithologic unit in the sequence near the deposit is a chert-pebble conglomerate. However, chert-pebble conglomerate has been reported both in Ordovician-Silurian and Devono-Mississippian rocks to the southwest[2]. Recently Blusson (this publication) has correlated it with Devono-Mississippan strata. Elsewhere in the western Cordillera, stratiform lead-zinc mineralization is relatively common in the Carboniferous but rare to lacking in the Ordovician-Silurian. If host rocks at the Tom Group are indeed lower Paleozoic, this would present a rather anomalous situation from a metallogenic standpoint whereas a Devono-Carboniferous host would be consistent with occurrences elsewhere in the western Cordillera. Two methods are currently underway to determine which of the two age possibilities is the most likely: (1) fossil-like forms, found in the host argillite, are being examined; (2) the S-isotopic composition of barite in the ore is being determined in order to relate it to the compositions of ancient seawater sulphates[3].

II. Bathurst-Norsemines Group (N. T. S. 76 F/16) Currently being explored by Cominco Ltd., this Cu-Zn-Ag body lies within a large area of metasediments, chiefly micaceous quartzite with minor limestone, of assumed Yellowknife Group (Archean) age[4].

An unusual feature of this deposit is that, although it lies within a thick sequence of metasediments with little or no evidence of extensive volcanism, the orebody itself appears to have many of the characteristics of the so-called "volcanogenic" or massive sulphide deposits so common elsewhere in the Shield, particularly the Superior Province [5,6]. Features present at the Bathurst-Norsemines main zone are: (i) a sharp hanging-wall and diffuse footwall contact between ore and country rock; (ii) zoning of the orebody zone (Cu-Zn(-Pb)) and a lower, disseminated sulphide zone (Cu) (see Northern Miner, April 16, 1970); (iii) typical chlorite-biotite (-sericite) alteration associated with, and apparently confined to, the disseminated chalcopyrite-type ore in the footwall. Little or no alteration appears to be present on the hanging-wall.

Another unusual feature of the area is the presence of limestone, apparently conformable and at least several tens of feet thick, interlayered with the quartzites. The carbonate reacts to hydrochloric acid indicating the presence of calcium carbonate. Analyses of this rock will be carried out to determine the exact nature of the carbonate. Inasmuch as limestone of Archean age is rare, muscovite and biotite from the quartzite will be analyzed by the K-Ar method to determine its metamorphic age.

III. Grenville Province As an aid toward a better evaluation of the lead-zinc potential of the Canadian Grenville Province, the writer spent a day examining the Balmat zinc deposit and surrounding geology in northern New York State[7]. As a result of this brief visit two features of the Balmat area would appear to be directly applicable to the Canadian Grenville Province. These are (i) the position of the orebody close to the eastern edge of the "marble belt" in the Grenville Group sedimentary basin; and (ii) the close association between the zinc mines and the talc-tremolite mines, occurring as they do in different (but sometimes adjacent) stratigraphic horizons within a thick carbonate sequence. The coincidence of these two features together with the numerous zinc deposits in the area, raises the possibility that the ores lie in the same position relative to the Grenville Sedimentary Basin as Pine Point does to the Elk Point Basin i.e. at the edge close to a "shale-out"[8].

The dolomites of the Presqu'ile Formation find their counterpart in the dolomitic marbles at Balmat. The talc, tremolite, and serpentine in the Balmat area (respectively 31.7, 24.7 and 43.0% MgO) are similarly consistent with a high-magnesian rock. In the Canadian Grenville, calcitic and dolomitic marbles have not, as a rule, been mapped separately. However, in the writer's opinion, the Balmat-Edwards zinc-bearing carbonates find their northern equivalents in the extensive marble sequence occurring in the southwest quarter of the Mont Laurier-Kempt Lake map-sheet[9], and the southwestern extension of this belt. This conclusion, subject to later modification as studies proceed, is based on the following observations: (i) the southwest corner of the map-area contains within it the eastern edge of the main marble unit; (ii) it is on strike with the Balmat-Edwards marble belt; (iii) it is characterized by an abundance of high-Mg mineral occurrences.

For example, of the approximately 50 mica localities recorded in the entire Mont Laurier-Kempt Lake sheet, over 45 occur in the southwest quarter and of these approximately 75 per cent occur exclusively within the marble belt. Such mica deposits are generally composed of biotite (about 20% MgO) or phlogopite (29% MgO). Furthermore, the marble belt in the southwest corner contains the only dolomite (22% MgO), talc (32% MgO), and serpentine (43% MgO) occurrences recorded in the entire map-area. There is thus indirect evidence that perhaps this area contains more silicated dolomite (the host rock at Balmat-Edwards) than has been recognized to date. Consequently, in the writer's opinion, the carbonates of this area warrant further investigation of their lead-zinc potential.

IV. Arctic Islands Only two significant base metal sulphide deposits are presently known in the Arctic Archipelago. These are the Bankeno Mines Ltd. property on Little Cornwallis Island (NTS 68 G/8) and the Texas Gulf Sulphur deposit on northern Baffin Island (NTS 48 C/1).

The Bankeno deposit occurs in the Thumb Mountain Formation of Middle to Late Ordovician age. Botryoidal sphalerite and coarse galena replace dolomite "pseudo-breccia" resulting in a typical Mississippi Valley type deposit[8].

The Texas Gulf Sulphur main ore zone (Pb-Zn-Ag) was examined in both outcrop and underground in a 1,000-foot adit completed in 1969. Mineralization consists of sphalerite, galena, and pyrite widely interlayered with coarse white dolomite. Host rocks are dark, fine-grained dolomite of the Proterozoic Society Cliffs Formation[10]. The deposit appears to be somewhat sinuous in plan, is roughly 9,000 feet long, and cuts across bedding in the host dolomite at a shallow angle. An unusual feature of the deposit are vertical, pipe-like pyrite "roots" extending downward from the main ore lens at several points along its length. One of these pipes, where exposed, consists of fine-grained pyrite in which the bedding and brecciation texture of the adjacent dolomite is clearly preserved. The deposit is quite unlike anything seen by the writer elsewhere in Canada.

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55. GEOLOGICAL STUDY OF SILVER DEPOSITS IN CANADA

Canada

Project 680060

R.I. Thorpe

Field work was initiated by visiting silver-bearing deposits in the Thunder Bay area, Ontario, the Great Bear Lake area, Northwest Territories, in southern British Columbia, and in the Yukon. Approximately 160 deposits were visited in order to observe their general geological setting and the nature of the mineralization. A total of 335 samples were collected for mineralogical, ore microscopic, chemical, isotopic and/or trace element studies.

Thunder Bay Area

The silver-bearing veins of the Thunder Bay area are generally of simple type. The presence of fluorite as an important gangue mineral in some veins and its absence in others is the most striking difference in the veins. The veins are generally located very near the upper or lower contacts of the regional Logan diabase sills and a genetic relationship seems likely. This has also been suggested by Franklin[1] who considers that the metals were derived from the Rove shale through contact metamorphism.

Southern British Columbia and Yukon

Many silver-bearing veins in southern British Columiba which contain high-grade silver minerals (native silver, argentite, pyrargyrite) appear to be very closely related to granitic intrusive rocks. Examples are as follows:

1. Veins at the Highland Bell mine, Beaverdell, within or near the diorite of the West Kettle stock.
2. Veins in the Slocan-New Denver area within or near granite and granodiorite of the Nelson batholith.
3. Veins at Utica Silver Mines, Keremeos, within diorite.

Veins containing argentiferous tetrahedrite, freibergite, and/or argentiferous galena are apparently located farther from granitic bodies (e.g., veins in the Lardeau, Milford and Kaslo Groups in the Ainsworth-Kaslo area and most of those in the Slocan Group sediments in the Slocan-New Denver area). Mineral stabilities may be one important determining factor for this zoning; Keighin and Honea[2] have inferred that pyrargyrite can only be formed at temperatures above 192°C. In the Slocan area the higher grade veins within the Nelson intrusive rocks have apparently been generally found to be smaller and more discontinuous than somewhat lower grade veins in the Slocan sediments. Other differences between the vein types probably exist and will be studied further.

A number of important questions regarding the genesis and classification of silver-bearing vein deposits will require further investigation. These include the following:

1. The causes of vertical zoning in which veins containing abundant galena in their upper portions become sphalerite-and pyrite-bearing at depth. Many veins in the Slocan area, B.C., show this type of zoning[3, 4], as do those at Keno Hill, Yukon.
2. The question of whether or not silver veins may be gradational into at least one type of gold-bearing vein. Arsenopyrite-bearing silver-gold veins as represented, for example, by the Venus, Arctic and Mount Nansen deposits, all in the Yukon, could be an intermediate class. At the Highland Bell mine the silver veins pass downdip into arsenopyrite-bearing veins which are richer in gold.

Silver Deposits in the Great Bear Lake area, N.W.T.

A study of the genesis of the Great Bear Lake silver deposits, integrating the results of previous and current studies, is planned. Samples have been collected from the Echo Bay, Terra, Norex and Silver Bay deposits. Two weeks were spent at Echo Bay mine collecting samples and making observations as to mineralization stages, megascopically evident paragenesis of the vein minerals, and general geological relationships. Samples were collected for study of the vein mineralogy, lead isotope composition, chemical nature of wall-rock alteration, composition of fluid inclusions in gangue material, age dating of the underlying diabase sill, and possibly for oxygen isotope and trace element investigations. Some of these investigations will be conducted jointly with Dr. S.D. Scott of the University of Toronto.

Examination of the rocks and geological relationships at the Terra property helps greatly in understanding geological events in the Echo Bay area. At Echo Bay a sequence of recrystallized tuffaceous rocks, which consists of alternating reddish and dark green bands, is of questionable origin. However, their fine-grained equivalent at the Terra property is clearly of tuffaceous origin and shows, curiously, diffuse contacts between the alternating beds. A magnetite-apatite pipe (which is largely intrusive but also shows evidence of a replacement origin) at Terra appears to have its equivalent in a replacement zone of magnetite and associated amphibole-apatite-magnetite veins at Echo Bay. Some magnetite is also present in pyroclastic rocks on the Norex property suggesting that magnetic anomalies could possibly serve as a primary guide to favourable areas for silver mineralization in the Great Bear Lake area. Sulphide-bearing zones, apparently of syngenetic origin, are present at both the Terra and Echo Bay properties. At Echo Bay conformable pyrite bands occur throughout a considerable thickness of black siliceous sediment, while at Terra a more concentrated zone of marcasite-chalcopyrite mineralization is present. The silver-bearing veins could have some genetic relationship to these sulphide zones.

At the Terra property the obvious sequence of geological events is as follows: (1) volcanism, deposition of tuffaceous sequence, (2) deposition of water-lain sediments, probably largely of volcanic derivation, which grade upward to red argillite, (3) formation of magnetite pipe, (4) intrusion of quartz porphyry dyke, and (5) intrusion of diabase dyke. However, further work will be required to place two other events, the intrusion of a body of syenite, and formation of the silver-bismuth-arsenide veins, relative to events (3), (4) and (5).

Preliminary mineralogical work indicates the presence of three bismuth sulphosalt minerals, emplectite, $CuBiS_2$ (Port Radium), schirmerite, $PbAg_4Bi_4S_9$ (Terra), and wittichenite, $Cu_3 Bi S_3$, (Norex). Previously Kieller[5] identified schirmerite, wittichenite (klaprothite), and guanajuatite, $Bi_2 (Se, S)_3$ in one of the Port Radium veins.

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PALEONTOLOGY AND BIOSTRATIGRAPHY

General ✓

56. TYPE SPECIMENS OF SPECIES OF FOSSILS DESCRIBED BY C.H. CRICKMAY

A number of important type specimens of Cambrian, Devonian, Triassic, Jurassic and Pliocene species have been deposited by C.H. Crickmay in the Type Collections of Invertebrate Fossils of the Geological Survey of Canada. The species were described from western and northwestern Canada and from the western United States of America in a number of papers between 1928 and 1968. The material from the United States is included in order to keep together the suite of specimens. The type specimens are stored at the Institute of Sedimentary and Petroleum Geology in Calgary.

The types include most of those described for the following taxa. These specimens are the originals of the indicated illustrations; some comments by Dr. Crickmay are added to amend errors within the original publication or to bring attention to subsequent taxonomic and stratigraphic revisions.

DEVONIAN, WESTERN AND NORTHWESTERN CANADA

Corals

Endophyllum barbatum: 1960a, p. 12, Pl. 7, Figs. 6-7; parts of the holotype.
Exilifrons exilis: 1968b, pp. 3-4, Pl. 1, Fig. 11, Pl. 2, Figs. 1, 2, 9, Pl. 3, Fig. 5, Pl. 4, Fig. 1; holotype (2 pieces) and two paratypes.
Exilifrons excavata: 1968b, p. 5, Pl. 1, Figs. 7-8, Pl. 2, Figs. 3-6; holotype (2 pieces) and one paratype (3 pieces).
Exilifrons Horiae: 1968b, pp. 5-6, Pl. 1, Figs. 9-10, Pl. 4, Figs. 2-4, holotype and two paratypes.
Exilifrons ogilviensis: 1968b, p. 4, Pl. 1, Figs. 5-6; holotype and one paratype.
Spongonaria parca: 1968b, pp. 1-2, Pl. 1, Figs. 1-2, Pl. 2, Figs. 7-8; holotype.
Spongonaria philoctetes: 1968b, p. 2, Pl. 3, Figs. 1-2; holotype (2 pieces).
Spongonaria richardsonensis: 1968b, pp. 2-3, Pl. 1, Figs. 3-4, Pl. 3, Figs. 3-4; holotype (3 pieces).

Brachiopods

Acutatheca (Minutilla) decoris: 1967, p. 11, Pl. 4, Figs. 8-13; holotype, three paratypes and two unfigured specimens; the originals of Pl. 2, Figs. 27-41 have not been preserved.
Acutatheca (Minutilla) layeri: 1967, p. 10, Pl. 4, Fig. 6; holotype and two unfigured paratypes; the originals of Pl. 2, Figs. 30-36 have not been preserved.
Devonoproductus secundus: 1963, p. 26, Pl. 14, Figs. 18-20; three paratypes.
Eleutherokomma impennis: 1953, p. 3, Pl. 2, Fig. 5; a paratype.
Eleutherokomma scymnus: 1967, p. 12-13, Pl. 4, Figs. 1-3; holotype and one paratype; the originals of Pl. 1, Figs. 23-29 have not been preserved.
Emanuella caligatae: 1967, p. 8, Pl. 3, Figs. 1-6; holotype and one paratype; the originals of Pl. 2, Figs. 8-12 have not been preserved.

Emanuella sluzari: 1967, p. 8, Pl. 3, Figs. 16-20; Middle Devonian, Alberta; holotype and one paratype; the originals of Pl. 2, Figs. 20-24 have not been preserved.
Emanuella vernilis: 1967, pp. 8-9, Pl. 2, Fig. 19, Pl. 3, Figs. 7-9; Middle Devonian, District of Mackenzie; holotype and two paratypes; the originals of Pl. 2, Figs. 13-18 have not been preserved.
Innuitella innuitana: 1968a, pp. 5-6, Pl. 2, Figs. 1-14; Pl. 6, Figs. 1-5; holotype and three paratypes.
Ladjia landesi: 1967, p. 9, Pl. 2, Figs. 25-28, Pl. 3, Figs. 10-15; basal Upper Devonian, northern Alberta; holotype and three paratypes; the original of Pl. 2, Fig. 29 has not been preserved. The types of this species are from the KCL-Midwest Otter Lake No. 10-20 well, not the 10-10 well.
Spirinella collina: 1968a, pp. 6-7, Pl. 3, Figs. 1-8, Pl. 4, Figs. 1-9, Pl. 6, Figs. 6-8, 12-13; holotype and four paratypes.
Stringocephalus aleskanus: 1962, p. 12, Pl. 9, Fig. 1; a paratype (3 pieces).
Stringocephalus asteius: 1963, pp. 28-29, Pl. 6, Figs. 5-7, Pl. 16, Figs. 4, 7; three paratypes (all represented by sectioned material).
Stringocephalus chasmognathus: 1960b, pp. 884-885, Textfigs. B6-10, C1-4; two paratypes (one represented by sectioned material). The paratype shown by Textfigs. B6-10 probably is mistakenly assigned to the species.
Stringocephalus ciconia: 1968a, pp. 9-10, Pl. 7, Figs. 1-6, Pl. 13, Figs. 1-4, Pl. 14, Figs. 1-5; holotype (4 pieces) and three paratypes.
Stringocephalus noctua: 1968a, p. 10, Pl. 8, Figs. 1-7, Pl. 9, Figs. 1-8, Pl. 14, Figs. 6-7, Pl. 15, Figs. 1-5, Pl. 16, Figs. 1-7, Pl. 17, Figs. 1-4; Pl. 16, Fig. 7 is a reversed print; holotype and eight paratypes (some represented by sectioned material). The original of Pl. 15, Figs. 1-5 is paratype No. 4, not No. 1; that of Pl. 16, Fig. 7 is paratype No. 7, not No. 3; that of Pl. 17, Figs. 1-3 is paratype No. 8, not No. 2.
Stringocephalus parasulcatus: 1968a, p. 11, Pl. 6, Figs. 16-19; holotype (represented by sectioned material). The species now can be referred to Parastringocephalus Struve.
"Tenticospirifer keleticus": 1952, p. 591, Pl. 73, Figs. 10-19; the paratype, an unknown form, mistakenly assigned to this species.
Warrenella timetea: 1963, p. 17, Pl. 11, Figs. 14-18; two topotypes. The species now can be referred to Reticulariopsis Frederiks.

TRIASSIC AND JURASSIC, WESTERN AND NORTHWESTERN CANADA

Corals

Kraterostrobilos bathys: 1930, p. 40, Pl. 2, Figs. f, g, i; holotype and the paratype (both represented by pieces).

Brachiopods

Euidothyris francescalaurae: 1930, p. 42, Pl. 6, Figs. d-f; holotype and the one paratype.

Pelecypods

Archaeodon phylarchus: 1930, p. 42, Pl. 2, Figs. a-c; holotype.

Ashcroftia inversidentata: 1930, p. 43, Pl. 2, Figs. d-e; holotype and the paratype.
Astarte sonniniarum: 1930, p. 59, Pl. 6, Figs. a-c; holotype and the paratype.
Chlamys paideios: 1930, p. 54, Pl. 4, Figs. c, d; holotype (2 pieces) and the paratype (2 pieces).
Entolium balteatum: 1928, p. 62, Pl. 4, Figs. e-g; holotype and the paratype.
Entolium semilini: 1930, p. 56, Pl. 4, Fig. e; holotype.
Gervillia ashcroftensis: 1930, p. 48, Pl. 3, Figs. a-c; holotype (3 pieces).
Gilbertwhitea micromorpha: 1930, p. 46, Pl. 3, Figs. e, f; holotype.
Grammatodon semiornatus: 1930, pp. 46-47, Pl. 3, Fig. g; holotype.
Grammatodon sonninianus: 1930, p. 47, Pl. 3, Figs. h, i; holotype.
Gryphaea minutula: 1930, p. 49, Pl. 6, Figs. i-k; holotype and the paratype.
Gryphaea patera: 1930, p. 51, Pl. 4, Figs. a, b; holotype.
Homomya "jurozephriensis": 1930, p. 58, Pl. 6, Figs. g, h; holotype.
Modiolus sphenoproratus: 1930, p. 56, Pl. 7, Fig. b; holotype.
Ostrea ammonitides: 1964, pp. 157-159, Pl. 1, Figs. 5-7; two figured specimens.
Pinna amblyrhyncha: 1930, pp. 47-48, Pl. 7, Fig. a; holotype.
Pleuromya chlutosensis: 1930, p. 58, Pl. 4, Figs. f, g; holotype and the paratype.
Pleuromya rhynchophora: 1930, p. 57, Pl. 5, Figs. c-e; holotype and the paratype.
Pleuromya scutalisensis: 1930, p. 57, Pl. 4, Figs. h, i; holotype.
Scaphogonia argo: 1930, p. 52, Pl. 5, Figs. a, b; holotype.
Vaugonia mariajosephinae: 1930, p. 54, Pl. 7, Fig. g; holotype.
Vaugonia veronica: 1930, p. 53, Pl. 7, Fig. f; holotype.

Cephalopods

Arniotites begbiei: 1928, p. 61, Pl. 2, Figs. f-g; casts of holotype and the paratype.
Arniotites kwakiutlanus: 1928, p. 61, Pl. 1, Pl. 2, Figs. a-e; holotype and five paratypes.
Melanhippites harbledownensis: 1928, p. 61, Pl. 3, Pl. 4, Figs. a-d; cast of holotype, four paratypes (one represented by 2 pieces).
Paratropites spepsumensis: 1930, p. 60, Pl. 7, Figs. c-e; holotype.

CAMBRIAN, WESTERN UNITED STATES

Trilobites

Paedeumias mohavensis: 1933a, p. 74, Pl. 1, Figs. c-f; holotype, three paratypes and one topotype.

JURASSIC, WESTERN UNITED STATES

Corals

Latomeandra orthogrammica: 1933c, pp. 903-904, Pl. 23, Figs. 1-3; holotype and the paratype.

Brachiopods

Euidothyris lucerna: 1933b, pp. 882-883, Pl. 21, Figs. 1-4; holotype and the paratype.

Pelecypods

Astarte morion: 1936, p. 559, Pl. 3, Figs. 1, 2; holotype and the paratype.
Gervillia dolabrata: 1936, p. 556, Pl. 2, Fig. 6; syntypes.
Ostrea nigrimontana: 1936, p. 556, Pl. 3, Figs. 6-7; holotype and the paratype.
Parapecten praecursor: 1933c, p. 905, Pl. 25, Figs. 4-6; holotype (2 pieces) and the paratype.
Pleuromya autolycus: 1936, p. 558, Pl. 1, Figs. 1, 2, 4, Pl. 2, Figs. 1, 2, 4, 7; holotype and two paratypes.
Pleuromya hectica: 1936, p. 557, Pl. 1, Fig. 5, Pl. 3, Fig. 5; holotype.
Trichomya amphitrite: 1936, p. 558, Pl. 1, Figs. 7, 8; holotype.

Gastropods

Trochus hinchmanensis: 1933c, p. 907, Pl. 26, Fig. 3; casts of holotype.

Cephalopods

Anaplanulites hyatti: 1933c, pp. 913-914, Pl. 32, Fig. 3, Pl. 33; cast of holotype.
Cawtoniceras prionodes: 1936, pp. 559-560, Pl. 1, Fig. 3, Pl. 2, Fig. 13, Pl. 3, Fig. 3; holotype (2 pieces).
Chondroceras russelli: 1933c, p. 913, Pl. 27, Fig. 7; cast and paratype (6 pieces).
Euechioceras exoletum: 1933c, p. 909, Pl. 27, Figs. 1-5; holotype and two paratypes.
Holcophylloceras falciferum: 1933c, p. 908, Pl. 26, Fig. 4; casts of holotype.
Papilliceras blackwelderi: 1933c, p. 911, Pl. 30, Figs. 1-4; holotype (2 pieces)
Papilliceras juramontanum: 1933c, pp. 911-912, Pl. 31; holotype (2 pieces).
Papilliceras stantoni: 1933c, pp. 910-911, Pl. 29, Figs. 1-2, Pl. 32, Fig. 1; holotype.
Protothurmannia rezanoffiana: 1932, pp. 2-3, Pl. 1, Figs. 1-5, Pl. 2, Figs. 1-2; holotype (2 pieces) and 3 paratypes.
Reineckeites dilleri: 1933c, p. 914, Pl. 32, Fig. 2, Pl. 34, Figs. 1-5; holotype and three paratypes.
Stiphromorphites schucherti: 1933c, p. 909, Pl. 28, Figs. 1-3; holotype (3 pieces).

PLIOCENE, WESTERN UNITED STATES

Pelecypods

Calyptogena gibbera: 1929, p. 93, Fig. 1; holotype.

Crickmay, C.H.

The stratigraphy of Parson Bay, British Columbia; Univ. California Publs., Bull. Dept. Geol. Sci., vol. 18, pp. 51-70, (1928).

On a new pelecypod Calyptogena gibbera; Can. Field-Naturalist, vol. 43, p. 93, (1929).

The Jurassic rocks of Ashcroft, British Columbia; Univ. California Publs., Bull. Dept. Geol. Sci., vol. 19, pp. 23-74, (1930).

A new Jurassic ammonite from the Coast Ranges of California; Am. Midland Naturalist, vol. 13, pp. 1-11, (1932).

Paleontology, in Hazzard, J.C., Notes on the Cambrian rocks of the eastern Mohave Desert, California; Univ. California Publs., Bull. Dept. Geol. Sci., vol. 23, pp. 71-78, (1933a).

Attempt to zone the North American Jurassic on the basis of its brachiopods; Bull. Geol. Soc. Am., vol. 44, pp. 871-893, (1933b).

Mount Jura investigation; Bull. Geol. Soc. Am., vol. 44, pp. 895-926, (1933c).

Study in the Jurassic of Wyoming; Bull. Geol. Soc. Am., vol. 47, pp. 541-564, (1936).

Discrimination of late upper Devonian; J. Paleontol., vol. 26, pp. 585-609, (1952).

New Spiriferidae from the Devonian of Western Canada; Calgary, the author, (1953).

The older Devonian faunas of the Northwest Territories; Calgary, the author, (1960a).

Studies of the Western Canada Stringocephalinae; J. Paleontol., vol. 34, pp. 874-890, (1960b).

New Devonian fossils from western Canada; Calgary, the author, (1962).

Significant new Devonian brachiopods from Western Canada; Calgary, the author, (1963).

Ghost fossils; Bull. Can. Petrol Geol., vol. 12, pp. 153-159, (1963).

The method of indivisible aggregates in studies of the Devonian; Calgary, the author, (1967).

Discoveries in the Devonian of western Canada; Calgary, the author, (1968).

Lower Devonian and other coral species in northwestern Canada; Calgary, the author, (1968b).

57. ORDOVICIAN FAUNAS AND BIOSTRATIGRAPHY IN EASTERN AND WESTERN CANADA

Project 690006

W.T. Dean

Work has been concerned primarily with Ordovician shelly faunas and may be divided on a regional basis.

Eastern Canada. Investigations in northeastern Newfoundland resulted in the first record of Ordovician trilobites of British-Scandinavian type from the region. These are now being prepared for publication and further collecting is planned. At Random Island (eastern Newfoundland) and Long Point (western Newfoundland) collecting from Cambrian and Ordovician rocks was continued with a view to producing a detailed faunal succession. In New Brunswick collections of Ordovician shelly fossils, especially trilobites, were obtained from the area west of Bathurst in company with H. Helmstaedt. The fauna is of Middle Ordovician type and its further study is expected to give more detailed information on the age and correlation.

Western Canada. Preliminary collecting of shelly fossils from Lower Ordovician strata in the Rocky Mountains of Alberta and British Columbia was carried out accompanied by B.S. Norford. In order to obtain more information relevant to the detailed correlation of these Canadian rocks, corresponding strata in Nevada were examined in collaboration with members of the U.S. Geological Survey.

58. CAMBRIAN BIOSTRATIGRAPHY IN THE CANADIAN CORDILLERA, 1970

Project 650024

W.H. Fritz

In the Mackenzie Mountains, Yukon and District of Mackenzie, Lower Cambrian stratigraphic sections were measured. Field support was given by Operations Norman and Stewart and by R.G. Garrett. Near the headwaters of the Arctic Red River a 1,085-foot unnamed formation of dark shale and limestone is overlain by a local, but thick, unnamed quartzite formation. Lower Cambrian fossils from just below the quartzite, and in large erratic limestone blocks within the quartzite succession, give the first indication that at least the lower part of the quartzite is late Early Cambrian in age. In the Macmillan Pass area, depositional features noted in the lower portion of the Sekwi Formation indicate westward? slumping during middle Early Cambrian time.

In the Rocky Mountains south of Dawson Creek, B.C., three stratigraphic sections were measured in conjunction with Operation Smoky. On Mount Dudzic the entire Cambrian succession is approximately 5,300 feet thick. In the Dezaiko Range an anomalous dark shale unit of late Early and early Middle Cambrian age was found between the Hota-Adolphus and Tatei-Chetang Formations.

Near the Columbia Ice Fields, Alberta, fossils were collected from the Lyell, Bison Creek, and Mistaya Formations. A new Glossopleura faunule (Middle Cambrian) was collected from the north face of Mount Stephen, B.C. while working with J.D. Aitken on the Burgess Project.

59. REFERENCE SECTION IN GASPÉ FOR PALYNOLOGICAL ZONATION OF EMSIAN AND EIFELIAN ROCKS OF EASTERN CANADA

Project 600227

D. C. McGregor

A section of Early and Middle Devonian, mostly nonmarine, rocks 9,902 feet thick was measured on the south side of Gaspé Bay, Quebec. The section extends on the coast from Tar Point to one-half mile southeast of Pointe Jaune, and comprises the uppermost beds of the York River Formation, all of the Battery Point beds ("Gaspé Sandstone") measured by Logan[1], and the lower 1,085 feet of the Malbaie Formation.

Measurement of this section completes the field phase of the study of the Devonian beds of eastern Gaspé. Spores recovered from these rocks are the only biostratigraphically useful fossils present in most of the non-marine strata of the region. They allow correlation of the strata for the first time with the Emsian and Eifelian of the Orcadian Basin and the Eifel region of western Europe. The section from Tar Point to Pointe Jaune provides a standard for palynological zonation of the late Lower and early Middle Devonian rocks of eastern Canada.

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[1] Logan, W.E.: Geology of Canada; Geol. Surv., Can., Report of Progress to 1863 (1863).

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60. PERMIAN BIOSTRATIGRAPHY, NORTHERN BRITISH COLUMBIA AND NORTHERN YUKON

Project 680063

W. W. Nassichuk

As part of a project designed to examine Permian rocks and fossils in selected areas of northern British Columbia and northern Yukon, several days were spent measuring and collecting fossils from an unnamed Lower Permian formation on the extreme western flank of the Richardson Mountains. The section includes 790 feet of dark grey siltstones, silty shales and silty carbonate rocks, and is on the north bank of the Porcupine River, 11.2 miles due north of the mouth of Bell River and 5 miles east of the mouth of Berry Creek (67°26'28"N, 137°45'33"W; air photograph A14406-88). At this locality pre-Permian rocks are not exposed and Permian rocks which dip 25 degrees to the southwest are unconformably overlain by Jurassic rocks, the lower hundred feet of which are coquinoid limestones, concretionary sandstones and conglomerates. The Permian section contains few fossils and is a uniform succession of alternating resistant and recessive calcareous siltstone and silty shale beds with silty limestone and silty dolomite interbeds. Minor amounts of fine-grained sandstone and chert-pebble conglomerate are also present. Silt- and sand-size grains are mainly quartz and chert but some feldspar grains occur. Siltstone and carbonate beds range in thickness from four inches to two feet and attain cumulative thicknesses of as much as 20 feet whereas recessive shale and shaly siltstone intervals are from one foot to 20 feet thick. Although limestone and dolomite beds occur throughout the section, they are most abundant in the upper part. Approximately four feet of crinoidal limestones are present near the middle of the unit. Concretions of microcrystalline silty dolomite occur at irregular intervals throughout the section. Concretions vary in diameter from 1 inch to 10 inches and most contain finely disseminated pyrite. "Spirophyton" occurs in resistant siltstone and silty limestone beds throughout the section but is relatively more abundant in the lower half of the unit. Irregular, small lenses of silty dolomite, silty limestone and micritic limestone, containing what are possibly worm burrows, occur throughout the formation; these are parallel to bedding planes and have an average length of 4 mm and an average width of 1 mm.

Permian rocks are discontinuously exposed for at least 15 miles downstream from this section, to the general vicinity of Driftwood River. Norford[1] assigned a Permian age to some 500 feet of conglomerates that overlie Devonian rocks seven miles upstream from the mouth of Driftwood River, and 14 miles northwest of the section described here; Bassett and Stout[2] provisionally considered the conglomerates to be of Devonian age (see also Norris, ref. 3, p. 232). In any case the youngest pre-Permain rocks known between the mouths of Driftwood and Bell Rivers are Devonian.

The Porcupine River section described in this paper is similar to the upper part of the Permian succession on Peel River, near the mouth of Hart River. In the latter area thin-bedded concretionary dolomitic siltstone and shales with silty limestone and silty dolomite interbeds are unconformably overlain by Cretaceous rocks. Ammonoids from concretions in the Peel River section including Properrinites Elias have been described by Nassichuk[4] and indicate a Sakmarian age. According to E. W. Bamber (pers. comm.) the Porcupine River section also resembles a sequence of rocks in the Ogilvie Mountains designated "Middle Recessive Unit" by Nelson (ref. 5, p. 2).

Macrofossils are rare in the Porcupine River section, but moderately well-preserved plants, corals and ammonoids have been recovered. Finely striate plant leaves and stems were found in direct association with spiriferid brachiopod fragments at GSC Locality C-6593, fifty feet above the lowest exposure in the section. Poorly preserved solitary corals from 250 feet above the base, at GSC Locality C-6594, were identified by Bamber (pers. comm.) as ? Timorphyllum sp.; the genus ranges from Upper Carboniferous to Lower Permian (Artinskian) but is unknown elsewhere in the Yukon Territory. A shale sample collected 350 feet above the base at GSC Locality C-6595 was found by M. S. Barss (pers. comm.) to contain two spore assemblages. One of the assemblages (reworked) indicates a Mississippian age. The other, which is less well preserved, indicates a Permian age and includes the following forms: Limitisporites spp., Vittatina spp., Protohaploxypinus spp., Alisporites sp., Striatoabietites sp., Striatipodocarpite sp., Florinites sp., and Pityosporities cf. P. papilionis (Potonié and Klaus) Hart.

A single poorly preserved ammonoid collected by J. A. Jeletzky in 1959 was identified as Eoasianites sp. by Nassichuk, Furnish and Glenister (ref. 6, p. 11); this specimen is not Pseudogastrioceras as identified by Harker and cited by Norris (ref. 3, p. 232). Eoasianites sp. was collected at GSC Locality 38808 from a concretion in shales at high-water level.

According to Jeletzky (pers. comm., 1970) it is from a bed 300 feet above the base of the section. The author recovered 25 ammonoid specimens, assigned to three species, from silty dolomite concretions in the upper 400 feet of the section, that is, at least 400 feet above the base. No additional representatives of Eoasianites of probable Sakmarian age are in the new collection from GSC Locality C-6596. Species in the new collection are Uraloceras cf. U. burtiense (Voinova), Paragastrioceras sp. and Neoshumardites sp. All of these genera are represented in the "Assistance" Formation on Bjorne Peninsula, southern Ellesmere Island where they are considered to indicate either a late Sakmarian or early Artinskian age (ref. 6, p. 8). Paragastrioceras is confined to the Lower Permian and occurs in strata ranging from Asselian to Artinskian; the relatively wide umbilicus of P. sp. suggests a fairly advanced species. U. burtiense occurs throughout the Sakmarian and Artinskian stages in the southern Urals but is most abundant in the late Sakmarian Sterlitimakian Substage; the species occurs in the above mentioned Bjorne Peninsula fauna. Neoshumardites sp. is similar to N. sakmarae from Sakmarian strata in the Urals and to N. triceps which is known only from lower Artinskian (Aktastinian Substage) strata in the Ural Mountains and Siberia; the Yukon species can be separated from both Soviet species by subtle differences in sutural and conch form. Whereas the suture of N. sp. closely resembles that of N. triceps, conch form and ornament more closely resemble N. sakmarae; in all probability closer study will show N. sp. to be a new species. The strata bearing Uraloceras cf. U. burtiense (Voinova), Paragastrioceras sp. and Neoshumardites sp. are considered to be of late Sakmarian (Sterlitimakian) or early Artinskian (Aktastinian) age. A comparable age was provided by Nassichuk, Furnish and Glenister[6] for Metalegoceras crenatum, recovered 42 miles east-northeast of the Porcupine River locality at GSC Locality 53860. At this locality M. crenatum was recovered from 323 feet above the base of a Permian sequence of limestone, sandstone and siltstone; the Permian sequence is 568 feet thick and is separated from Devonian rocks below and Jurassic rocks above by regional unconformities (Bamber, pers. comm.). Elsewhere, M. crenatum occurs only in the "Assistance" Formation on Bjorne Peninsula, Ellesmere Island.

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[1]Norford, B. S.: Reconnaissance of the Ordovician and Silurian rocks of northern Yukon Territory; Geol. Surv. Can., Paper 63-39, (1964).

[2]Bassett, H. G. and Stout, J. G.: Devonian of Western Canada; in International Symposium on the Devonian System, vol. 1; Alberta Soc. Petrol. Geol., Calgary, Canada, pp. 712-752 (1968).

[3]Norris, D. K.: Structural and stratigraphic studies, Blow River area, Yukon Territory and western District of Mackenzie; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 230-234 (1970).

[4]Nassichuk, W. W.: Permian ammonoids and nautiloids, southeastern Eagle Plain; Yukon Territory; J. Paleontol. (in press).

[5]Nelson, S. J.: Permo-Carboniferous of the northern Yukon Territory; Alberta Soc. Petrol. Geol., vol. 9, No. 1, pp. 1-9 (1961).

[6]Nassichuk, W. W., Furnish, W. M., and Glenister, B. F.: The Permian ammonoids of Arctic Canada; Geol. Surv. Can., Bull. 131 (1965).

61. DEVONIAN BIOSTRATIGRAPHY OF NORTHERN YUKON TERRITORY AND ADJACENT DISTRICT OF MACKENZIE

Project 700034

A. W. Norris

The writer spent three months in the field, as a member of a helicopter supported party co-ordinated by D.K. Norris. Devonian and other rocks were studied to augment geological data obtained on Operation Porcupine (Project 610007) in 1962 (refs. 1, 2, and 3). Most of the work was done from three base camps located at Shingle Point on the Arctic coast, at Mile 73 on the Dempster Highway near Blackstone River, and at Margaret Lake. At the beginning of the field season several helicopter traverses were made from Inuvik to study Devonian rocks of the Campbell Lake uplift; during the move of our base from Shingle Point to Blackstone River, helicopter and other support was provided by Mr. Clay Riddell of International Nuclear Corporation Limited in order to study two Devonian sections in southern Nahoni Range.

Work from Shingle Point included traverses across the intensely folded Neroukpuk-like rocks at the headwaters of Johnson Creek and in the southern and northern Barn Mountains. Ordovician graptolites were collected from a number of dark shale horizons in the northern Barn Mountains. A section composed of Silurian and Devonian carbonate rocks in the north-eastern part of the White Mountains was measured also out of the Shingle Point base.

Work from the Blackstone River and International Nuclear Corporation base camps included eight Devonian sections measured and several helicopter traverses.

Work from Margaret Lake included two measured sections of Silurian and Devonian shale sections at the headwaters of Royal Creek, and a measured Devonian carbonate section at the headwaters of an unnamed tributary of Wind River.

Some 370 pages of field notes, covering work done from the Shingle Point and Blackstone River camps, were partly destroyed when our office tent at Margaret Lake burned to the ground on August 11, 1970. Fortunately, 87 per cent of the notes were recovered by copying the charred remains.

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[1] Norris, A. W.: Descriptions of Devonian sections in the northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 66-39, (1967).

[2] Norris, A. W.: Reconnaissance Devonian stratigraphy of northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 67-53, (1968).

[3] Norris, A. W.: Devonian of northern Yukon Territory and adjacent District of Mackenzie; in Oswald, D.H., ed., Internatl. Symposium on the Devonian System, Calgary, Alberta, Sept., 1967; Alberta Soc. Petrol. Geol., vol. 1, pp. 753-780, (1968).

62. TRIASSIC AMMONOIDS FROM BRITISH COLUMBIA

Project 670576

E. T. Tozer

Upper Triassic formations in Cape Scott (102I), Alert Bay (92L) and Alberni (92F) areas were examined. Collections of Karnian ammonoids were made from the Quatsino Limestone and of Norian Monotis from the Bonanza Group. It is anticipated that study of these collections will add to our knowledge of the position of the successive Triassic faunas of Vancouver Island.

PETROLOGY

63. NEPHELINE GNEISSES AT COPELAND MOUNTAIN, BRITISH COLUMBIA

92G/

Project 680071

K.L. Currie

Nepheline-bearing syenite gneisses occur within a highly metamorphosed metasedimentary sequence 14 miles northwest of Revelstoke. They form part of a chain of similar occurrences which partly rings the Frenchmans Cap gneiss dome. At Copeland Mountain, the nepheline-bearing rocks are intimately associated with a calcareous unit, locally rich in marble, but commonly composed mainly of calc-silicates, and a distinctive purplish biotite. So close is this association that where the calcareous unit is interbedded with quartzite nepheline is found in the calcareous interbeds and where the calcareous unit lenses out the nepheline-bearing rocks disappear also. A stratigraphic sequence is recognizable within the syenite gneiss unit. The upper part is composed of white, granular, saturated syenite, with many aplitic lenses and schliers. Molybdenite mineralization is widely disseminated in this unit, and on Copeland Mountain has formed a deposit now being mined. Below this zone a calcareous amphibolite occurs, with which many thin marble or calc-silicate layers are commonly associated. The main body of nepheline-bearing rocks lies below this amphibolite, and is surprisingly uniform in composition. At the base is a thin biotite- and hornblende-rich horizon, and a thin zone of granular saturated syenite. The calc-silicate rock below the syenite gneiss has a more brownish shade than that above, and is poorer in marble.

Two ages of folding can readily be recognized in the syenite gneiss, and a third has been recognized in regional studies[1]. The rocks appear to have behaved in a plastic manner during the first two stages of folding. Obvious normal faults are the most prominent fractures, but regional studies[1] suggest that Copeland Mountain forms part of a thrust sheet.

The remarkably precise stratigraphic control of the syenite gneiss, and the intercalations of sedimentary rocks within it strongly suggest that the syenite was a member of the stratigraphic sequence before folding began, and is thus neither a cross-cutting intrusion nor a single sill. It might have been a series of thin sills, or a sequence of phonolitic lava flows. Alternately it may be the result of metasomatism of a sedimentary rock. In view of the molybdenite mineralization associated with the syenite, the correct resolution of these alternatives is of considerable economic interest.

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[1] Fyles, J.T.: Structure of the Shuswap complex in the Jordan River area, northwest of Revelstoke, B.C.; <u>in</u> Structure of the Southern Canadian Cordillera, <u>ed</u> J.O. Wheeler; Geol. Assoc. Can., Spec. Paper 6, pp. 87-99 (1970).

64. THE PORT COLDWELL ALKALINE COMPLEX

Project 680071

K. L. Currie

The Port Coldwell complex is a roughly circular body approximately 18 miles in diameter, of which about one third is covered by the waters of Ashburton Bay, Lake Superior. Two separated phases are present, each forming an elliptical mass elongated north-south and separated by a narrow screen of fenitized country rocks. Each consists of an outer screen of alkaline gabbroic rocks commonly displaying spectacular inch-scale and graded layering, which suggest that the two lobes of the complex each forms a steep-sided funnel. The gabbro grades into monzonite which may contain both olivine and pyroxene, but consists mainly of coarsely perthitic alkali feldspar. This rock veins and alters the gabbro, converting it to complex fluidally contorted breccia. The western lobe contains crescentic masses of nepheline syenite, including coarse hydronepheline pegmatites, within the monzonites. These masses may be ring dykes, or may represent fractional crystallization products, since excellent graded layering is found locally within them. The youngest rocks of the complex form an intricate network of lamprophyre dykes, particularly well developed in the vicinity of Coubran Lake.

Fenitization is intense around the complex, to such an extent that delimitation of the edges of the igneous rocks is difficult. Although gabbro appears to be the outer phase of the complex, coarse, igneous looking syenites are found outside it gradually passing into foliated syenites, quartz syenites, and eventually country rocks.

65. A PRELIMINARY REPORT ON THE ICE RIVER ALKALINE COMPLEX, BRITISH COLUMBIA

Project 680071

K. L. Currie

The Ice River alkaline complex forms a U-shaped mass outcropping over an area of about 13 square miles in the western ranges of the Rocky Mountains. The complex consists of two parts, an earlier layered, feldspar-free, jacupirangite-ijolite-urtite-carbonatite complex, and a later layered cylindrical mass of syenitic rocks. Late syenitic and lamprophyric dykes are abundant. The feldspar-free complex consists of a cylindrical mass of jacupirangite, originally forming a vertical, or steeply dipping pipe, but now rotated some 40 degrees to the east in the saddle between Sharp and Helmet mountains, (NTS Map-sheet 82 N/M, Goodsir) to which is attached an elongate, gently plunging trough of layered ijolite-urtite rocks. These rocks show repetitive sequences of ijolite to urtite, gradually varying in composition from very basic rocks transitional to jacupirangite at the base, through nepheline-aegirine rocks in the central parts, to melanite-rich types in the upper parts. In the uppermost urtite layers wollastonite occurs, in some cases forming monomineralic layers at the top. Carbonatite layers seem to form part of the layered sequence in some places, though many of the seeming layers are in fact dykes. A large mass of carbonatite, crosscutting in detail, but conformable in general outline, forms the top of the layered complex. The thickness of the layered sequence is estimated to be roughly 3, 000 feet.

The nepheline syenite complex forms an elliptical mass slightly elongated in an east-west direction, and best exposed on the higher parts of Zinc and Manganese Mountains. In the central parts vertical layering on a scale ranging from a few inches to a few feet is prominent, but this central layered portion is surrounded by a thick, highly characteristic layer of agmatite. The range of composition is from melteigite through malignite to leucosyenite. In contrast to the highly coloured blue, green or black rocks of the ijolite-urtite sequence, the rocks are mainly dull grey in colour.

Late dykes of green nepheline syenite commonly follow the contacts of both syenite and ijolite with the country rocks, and form crescentic masses within the complex. Sodalite is sparingly present as a primary mineral in these late rocks, and abundant as an alteration product. Sodalite veins and more rarely cancrinite are also found along fractures in the other rocks, and even in limestones at a considerable distance from the intrusion. Lamprophyre dykes, some ocellar, appear to be the last phase of intrusive activity.

The contact zone of alteration of the complex with the surrounding limestone and shale is about 300 feet wide in the latter, consisting mainly of hornfels, and may be absent from the former. Fenitization is insignificant or absent, possibly because the composition of the country rocks is unfavourable. However the abundant inclusions in the contact phases of the intrusion are intensely thermally metamorphosed, and converted to hornfels or lime silicate blocks.

The intrusion appears to have exerted a profound structural effect on its surroundings, both during intrusion and during subsequent mountain building. Numerous and spectacular examples of plastic distortion of the surrounding sedimentary rocks can be seen, and it would appear that the intrusion acted as a rigid block in the midst of mobile plastic surroundings. While the present U-shape of the intrusion may be the result of deformation, it could also be the result of simple rotation of an originally umbrella-shaped intrusion.

66. PETROLOGICAL STUDIES IN THE VICINITY OF THE KISSEYNEW FRONT

Project 700065

E. Froese and J. M. Moore, Jr.

In the Flin Flon - Snow Lake region, a zone of steep metamorphic gradients and local faulting, often referred to as the Kisseynew Front, marks the boundary between a belt of volcanic and sedimentary rocks to the south and an area of metasedimentary gneisses to the north. In the Snow Lake area, the Kisseynew Front is mainly a metamorphic boundary uncomplicated by post-metamorphic faulting. Therefore, detailed mapping was begun in this area with the object of relating metamorphic isograds to stratigraphy, structure, and the distribution of intrusions. The presence of mineral deposits in the area makes it possible to study the behaviour of sulphides at different metamorphic conditions and investigate pertinent sulphide-silicate reactions.

Detailed work in the Snow Lake area is aided by available geological maps. The east half of the area (63-K-16 E1/2) was mapped by Harrison[1] and the west half (63-J-13 W1/2) by Armstrong[2]. An irregular area covering parts of 63-K-16 E1/2 and 63-J-13 W1/2 was mapped by Russell[3]. Initial work in 1970 was mainly directed towards tracing stratigraphic units, examining structural features, and collecting samples for mineralogical studies and radiometric age determinations.

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[1] Harrison, J.M.: Geology and mineral deposits of File-Tramping Lakes area, Manitoba; Geol. Surv. Can., Mem. 250 (1949).

[2] Armstrong, J.E.: Wekusko (Herb) Lake, Manitoba; Geol. Surv. Can., Map 665A (1941).

[3] Russell, G.A.: Structural studies of the Snow Lake-Herb Lake area, Manitoba; Manitoba Mines Branch, Publ. 55-3 (1957).

67.

PETROLOGY AND STRUCTURE OF DALY BAY COMPLEX, DISTRICT OF KEEWATIN

Project 700048

46 D
55 P
56 A

T.M. Gordon

The Daly Bay Complex, a complex including anorthosite, gneiss, and migmatite, was first described by Heywood[1]. The area was chosen for further study of relations between possible Archean rocks (the anorthosite) and a variety of gneisses, some of which may represent remobilized older gneisses and some younger rock groups metamorphosed, migmatized, and deformed during the Hudsonian Orogeny.

Field work commenced following break-up and was restricted to shoreline and foot traversing in that part of the area accessible by rubber boat.

Anorthositic rocks occur throughout the complex as lenticular masses and sills. The main body, in the southwestern part of the map-area, is mainly anorthosite and gabbroic anorthosite. Intense shearing, accompanied by metamorphism, has produced a marginal foliation parallel to that of the surrounding gneisses. The central zone is characterized by block structure in which areas of medium- to coarse-grained anorthosite are surrounded by, and grade into, a matrix of medium-grained crushed anorthosite. Irregular patches and lenses of fine- to medium-grained amphibolite occur throughout the body.

The dominant mineral is dark grey labradorite. Amphibole pseudomorphs after pyroxene show a subophitic relationship to plagioclase where the rocks have escaped shearing. Accessory magnetite is commonly rimmed by reddish brown garnet.

Gneisses of the complex are often garnet-bearing and usually contain over fifteen per cent biotite and/or hornblende. A preliminary subdivision based on texture and mineralogy indicates five main units between Daly Bay and Whale Point. These are:

1. a well-banded heterogeneous unit of quartz-plagioclase hornblende and/or biotite gneiss, garnet-sillimanite-biotite gneiss and schist, garnet-plagioclase gneiss, and minor impure quartzite and augen gneiss.
2. fairly homogeneous layered plagioclase-quartz-biotite gneiss and agmatite.
3. massive, foliated and locally banded K-spar-plagioclase-quartz-biotite augen gneiss.
4. interlayered garnet-plagioclase gneiss, pyroxene granulite, and augen gneiss.

5. impure quartzite, garnet-sillimanite gneiss and schist, amphibolite, and minor diopside-forsterite marble and calc-silicate rock.

The area has undergone intense deformation. Minor structures include flow, folds, rootless folds and augen and flaser fabrics. Most lithologic units are discontinuous and pinch out along the major foliation. Lineations commonly have shallow to moderate southeasterly plunges but shallow northwest plunges were occasionally observed.

No concentrations of iron-titanium oxides or chromite were observed in the anorthosite. In the gneisses minor gossans encountered on traverse were due to weathering of local concentrations of iron sulphides or biotite. Minor bornite and chalcopyrite were observed with pyrrhotite in a small gossan at 64°12'N, 89°50'W.

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

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68. EMPLACEMENT OF THE MUSKOX INTRUSION

Project 590283

T.N. Irvine

The surface geology of the Muskox intrusion and drillhole information show that the room for the intrusion was made largely by depression of its floor, rather than by elevation of its roof[1], while aeromagnetic[2] and gravity[3] data indicate that the body possibly extends as far as 100 miles on to the north beneath its roof rocks and younger cover, with its cross-sectional dimensions becoming gradually much larger. Considered together, these relations suggest that the intrusion occupies a major rift or graben structure 4, only the southern extremity of which is exposed[4]. During a general review of the field relations this past summer, in preparation for an International Geological Congress field trip in 1972, this concept was examined in more detail, particularly in the light of the last year's finding that the exposed part of the intrusion was apparently injected beneath only a very thin cover consisting mainly of Hornby Bay sandstone[5]. In this note the concept serves as the basis of a model of emplacement which attempts to explain the origin of a remarkable "contact breccia" present in the intrusion at places along its roof.

The main occurrence of the breccia is at the northeast tip of the exposed part of the intrusion, where it outcrops over an area about 5 miles long and 1/2-3/4 mile wide[1]. Throughout this area the breccia consists of subangular fragments and blocks of quartzite, a few inches to 4 feet in size, set in a relatively small proportion (generally 10-15 per cent) of granophyre matrix. An especially important feature is that the quartzite is undoubtedly derived from the Hornby Bay sandstone, whereas the country rocks adjoining the intrusion in the general area, on its roof as well as its floor side, are schists and amphibolites of the basement complex on which the sandstone was deposited. Thus the fragments and blocks must be at a level considerably below their source.

The other occurrences of breccia are only small (the most notable is about 2 miles south of the Muskox North drillhole) but xenoliths of similar

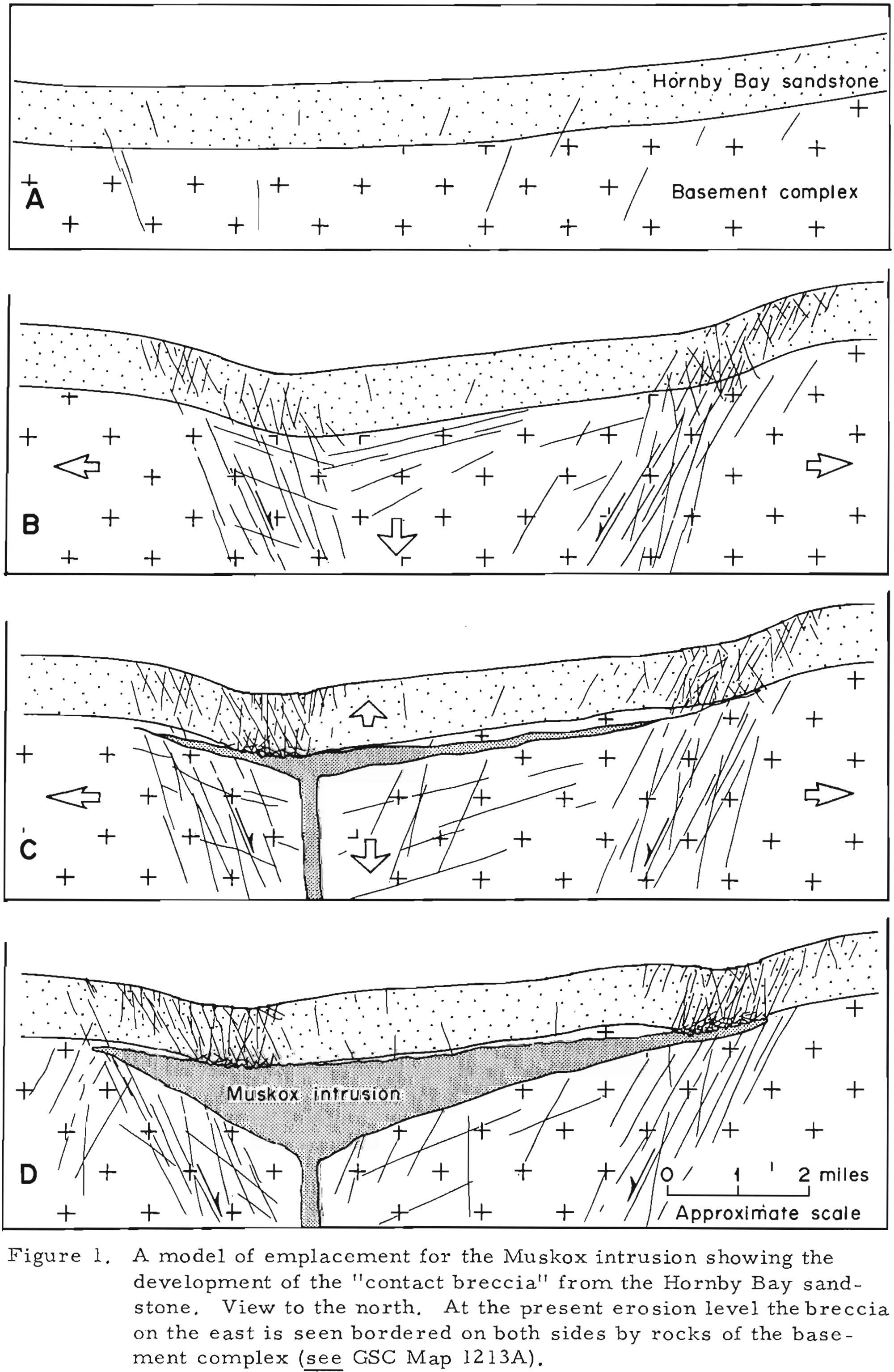

Figure 1. A model of emplacement for the Muskox intrusion showing the development of the "contact breccia" from the Hornby Bay sandstone. View to the north. At the present erosion level the breccia on the east is seen bordered on both sides by rocks of the basement complex (<u>see</u> GSC Map 1213A).

quartzite, typically rounded and embayed due to partial assimilation, are common to the granophyre in the intrusion, especially in the northern part of the large area west of the Canoe Lake fault.

In the proposed model of emplacement, shown in Figure 1, the breccia is assumed to have developed along the main zones of subsidence at the margins of the graben. Diagram A shows the Hornby Bay sandstone as it might originally have rested on the basement complex. The thickness of the sandstone is unknown but, for reasons noted last year[5], probably did not exceed 4,000 feet. There seems no evidence from the regional geology that other formations overlay the sandstone at the time.

In diagram B, the graben is at a fairly advanced stage of development, and the sandstone has become extensively fractured along its margins. In C, the magma has found its way into the structure to a level just below the unconformity where it is spreading laterally along subhorizontal fractures. It is suggested that this was a level of "compensation"[6] at which the magma could effectively "float" the remaining thin cover of low-density roof rocks, causing them to be lifted slightly while the floor beneath continued to subside due to further rifting (and, perhaps, to the removal of magma from below). Some repetition of this process of depression and then re-elevation of the roof may have furthered the brecciation of the sandstone.

In D, the magma has penetrated laterally to the margins of the graben, and the present form of the intrusion is essentially established. During the ensuing period of solidification, while ultramafic and mafic rocks formed at the base of the magma body by the settling and accumulation of mafic minerals and plagioclase[4], the sandstone immediately above the intrusion became metamorphosed to quartzite, and some of the less refractory, salic rocks along the roof contact were evidently melted. The melt is thought partly to have infiltrated the breccia zones and eventually to have resolidified as granophyre. Then came the sequence of faulting, erosion, sedimentation, diabase dyke emplacement, and basaltic volcanism outlined in last year's report, followed by those events that led to the present exposure of the intrusion.

The model is, of course, schematic in detail, and even certain basic features are conjectural. It is emphasized that none of the many faults and fractures postulated to occur along the graben can be identified with certainty. However, considering the shallow depths involved, the relatively sharp downturning of the intrusion floor must have been accomplished by displacement on fractures (rather than by "plastic deformation"). It seems likely that some of the faults are occupied by the many diabase dykes that parallel and, in places, cut the Muskox intrusion.

The evidence for the western breccia zone is also rather limited and its extent may well be exaggerated in the diagrams. However, a possible site for the breccia is beneath the drift-covered area around All Night Lake[1, 5]. A zone of deformation here would be in line with, and so may have controlled, the Canoe Lake fault to the south and the syncline in the dolomite and Coppermine basalt to the north.

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

[2] Muskox Intrusion, Coppermine River area, District of Mackenzie; Geol. Surv. Can., Geophysics Paper 1739 (1963).

[3] Hornal, R.W.: The gravity anomaly field of the Coppermine area of the Northwest Territories (Canada); Can. Dom. Observatory, Gravity Map Series, No. 45 (1968).

[4] Irvine, T.N. and Smith, C.H.: The ultramafic rocks of the Muskox Intrusion, Northwest Territories, Canada; pp. 38-49 in Wyllie, P.J., editor: Ultramafic and related rocks; J. Wiley and Sons, Inc., New York 464 p. (1969).

[5] Irvine, T.N.: Geologic age and structural relations of the Muskox intrusion in Report of Activities Part A, April to October 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 149-153 (1970).

[6] Bradley, J.: Intrusion of major delerite sills; Trans. Roy. Soc. New Zealand, vol. 3, pp. 27-55 (1965).

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69. STRUCTURAL AND PETROLOGICAL STUDY OF PINNACLE PEAKS GNEISS DOME, BRITISH COLUMBIA

Project 670278

J.E. Reesor

82 K, ✓
82 L,

The field work for this project was completed during the 1970 field season. Most of the time was occupied in extending the stratigraphic succession established in the Pinnacles culmination to Saddle Mountain, the easternmost extension of the Pinnacles dome.

Two stages of folding can be recognized, one with axial trends easterly and one with trends northwesterly. Though both folding episodes coincide with the period of maximum metamorphism, the easterly trending folds are the earlier[1]. Northwesterly folds are more sporadically developed and are important in those localities in which strata were nearly flat-lying at the end of the first episode of folding. Both sets of folding control the distribution of the map-units, though one or the other fold set is dominant in any one locality.

The north contact of the large intrusive mass to the south of Pinnacle Peaks clearly crosscuts both metamorphic isograds and earlier structures. Although contact metamorphic effects of the intrusion are difficult to recognize in the high grade Shuswap metamorphic rocks of the Pinnacles gneiss dome, a whole new set of structures has been developed in the vicinity of the granitic contact.

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[1] Reesor, J.E.: Some aspects of structural evolution and regional setting in part of the Shuswap Metamorphic Complex; Geol. Assoc. Can., Spec. Paper No. 6, pp. 73-86 (1970).

PRECAMBRIAN GEOLOGY

70. KEWEENAWAN VOLCANICS OF EASTERN LAKE SUPERIOR

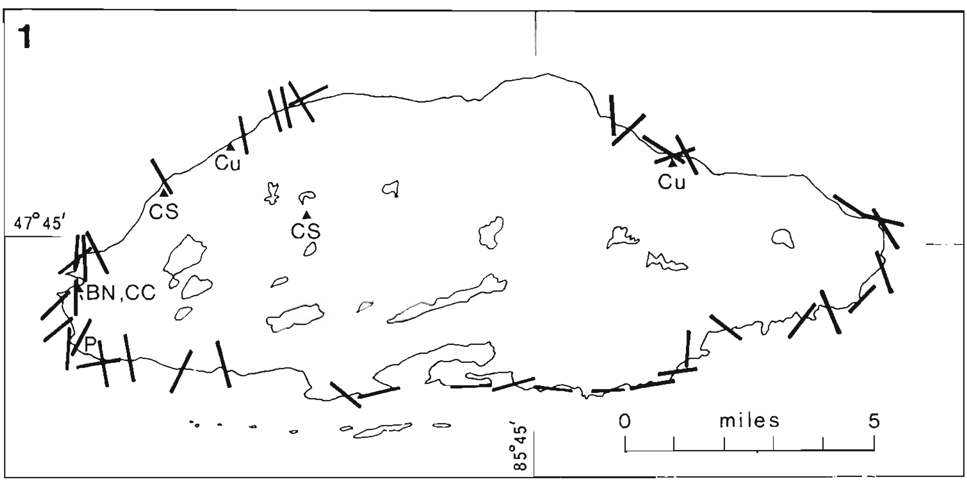
Project 680115

R.N. Annells

Michipicoten Island

During the summer the unmapped parts of Michipicoten Island were traversed; the completed geological map is in preparation for early publication and has therefore not been included in this report.

A number of previously unreported small showings of copper minerals were found in thin quartz-carbonate veins (see Fig. 1); no showings were found in viens wider than 2 inches. Quartz-carbonate veins are well exposed and relatively common on the shores of Michipicoten Island and range in thickness from less than 0.1 inch up to 5 feet, the thickest types often being part vein breccia with fragments of basalt and andesite; some of the veins bear agate and other forms of cryptocrystalline silica. The veins show some similarities to the quartz-carbonate veins and vein breccias seen in the Keweenawan flows of the Mamainse Point copper area[1,2]. Total field aeromagnetic maps of Michipicoten Island show a high positive anomaly parallel to the south shore of the island[3], an area where such veins are common.



▲ .. showings
Cu.. native copper
CC.. chalcocite
BN.. bornite
CS.. copper stain
P.. pyrite

Figure 1. Michipicoten Island; occurrences and generalized strikes of quartz-carbonate veins.

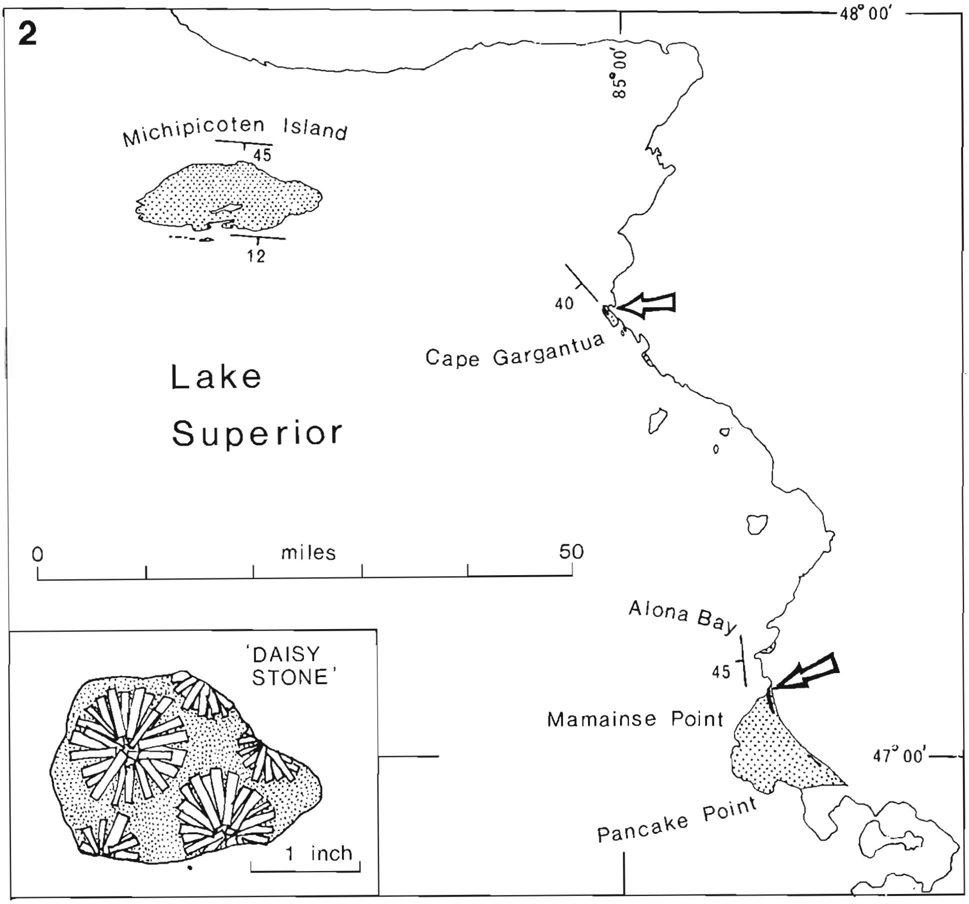


Figure 2. General map of eastern Lake Superior, showing outcrops of Keweenawan rocks (stippled) and occurrences of 'Daisy Stone' glomerophyric basalt (arrowed solid black horizon). Inset is field sketch of typical 'Daisy Stone' basalt showing large spherulitic feldspar clusters.

Mamainse Point

The entire Keweenawan lava sequence from Mica Bay to Pancake Point and also the thin Alona Bay sequence were examined and sampled in detail in order to build up a stratigraphic section controlled by distinctive petrographic features. Forty-seven samples of the lavas and related acid bodies are being chemically analyzed for the major and 16 minor elements. The thickness of the section was estimated as 14, 300 feet.

Preliminary examination of thin sections during the field season revealed that over 90 per cent of the flows traversed in the shore section are highly altered dark olivine-bearing basalts of medium-coarse grain size similar to those forming the base (unit 1) of the Michipicoten Island section[4]. If these two very similar occurrences of olivine-bearing flows were extruded during the same eruptive phase, then it seems likely that the Michipicoten Island flows above this level (units 2 to 15, ibid.) are all younger than the flows exposed at Mamainse Point.

Few of the Mamainse Point flows have field characters sufficiently distinctive to make them useful stratigraphic marker horizons. However, a 1,450-foot sequence dominated by basalt flows bearing pseudomorphs after large olivine phenocrysts (up to 0.2 inch) was discovered near the base of the section and this can be followed for about 4 miles southwards along strike. At the base of this particular sequence is a remarkable glomerophyric basalt flow mapped by Giblin[2] which is crowded with large plagioclase laths grouped into spherulitic clusters up to an inch in diameter; this flow can be traced at intervals for about 7 miles southwards along strike and is known as the 'Daisy Stone' by local residents[5] (Fig. 2).

A number of acid bodies associated with the basalts were also examined; one thin acid intrusive sheet cutting the basalts at a high angle near mile 62 on Highway 17 north was found to have a 2-foot basal selvage of fine-grained basaltic material indicating more or less simultaneous availability of basic and acid material during the Middle Keweenawan.

Cape Gargantua

The thin sequence of Keweenawan basalt flows at Cape Gargantua was examined and sampled, and a flow of glomerophyric basalt mapped by Ayres[6] from near the base of this sequence was found to be exactly similar in field characters to the Mamainse Point 'Daisy Stone' flow already mentioned. The occurrence at a similar stratigraphic level of two such similar and distinctive flows is felt to indicate that the flows proceeded from the same magma source and were extruded simultaneously either as separate flows or as parts of the same laterally continuous group of flows. The Gargantua and Mamainse Point 'Daisy Stone' outcrops are about 38 miles apart along the strike direction of the east shore Keweenawan flows; the greenstone basalt flow of the Michigan Keweenawan has been traced for 55 miles along strike and, by analogy, it seems possible that the Mamainse Point-Gargantua rock might have had a similarly large original extent (Fig. 2).

The remaining flows at Cape Gargantua are dominantly rather altered olivine-bearing basalt types similar to those in the Mamainse Point sequence and unit 1 of the Michipicoten Island sequence.

Continuing laboratory work on this project will include further electron microprobe and X-ray analyses of primary and secondary minerals from the samples collected, together with the determination of some physical properties of the different rock types. Paleomagnetic studies of the Mamainse Point and Cape Gargantua flows initiated this summer in collaboration with Dr. W. A. Robertson of the Geomagnetic Observatory will augment previous work[7] and provide a further control on areal stratigraphic correlation within the Keweenawan of eastern Lake Superior.

[1] Thomson, J. E., Geology of the Mamainse Point copper area; Ontario Dept. of Mines 62nd Ann. Rept., Pt. 4, 1-25 (1953).

[2] Giblin, P. E.: Ontario Dept. of Mines, Prelim. Geol. Maps, pp. 553, 554 and 555 (1969).

[3] Geological Survey of Canada; Aeromagnetic Map 2164G (1963).

[4] Annells, R. N.: Volcanic studies on Michipicoten Island, Ontario, (41N); in Report of Activities, Part A: April to October, 1969; Geological Survey of Canada, Paper 70-1, Pt. A, pp. 115-117 (1970).

[5] Jones, Hugh: Personal communication (1970).

[6] Ayres, L. D.: Geology of Townships 31 and 30, Ranges 20 and 19; Ontario Dept. Mines Geol. Rept. 69, 38 (1969).

[7] Palmer, H. C.: Personal communication (1970).

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71. GEOLOGY OF THE CANADIAN SHIELD OF THE RIVIÈRE GATINEAU MAP-AREA, QUEBEC

Project 680030

A. J. Baer

The writer and an assistant undertook a survey of the Grenville Province in Quebec between 72°W and 76°W and south of 48°N. This work included reconnaissance mapping of geologically unknown areas and control of existing maps against field observations. Traverses were made along roads, and stations were established at one-mile intervals where practicable. This summer's operation was the third and last stage of the project preliminary towards compilation of a geological map of NTS 31 at the scale of 1:1 million.

The first part of the season was spent in Mont Laurier and Kempt Lake map-areas (NTS 31 J and 31 O). As this region has been mapped recently at a scale of 1 inch equals 4 miles[1] it will not be dealt with in this report. During the second part of the season, work was mainly confined to Trois-Rivières and La Tuque (NTS 31 I and 31 P) map-areas.

According to predominant lithologies, the Trois-Rivières-La Tuque area may be divided into three unequal parts. The southwestern corner is occupied by rocks of the Morin anorthositic suite and by mangerites and quartz monzonites associated with them. The region east of the St. Maurice River is characterized by several large bodies of diorite, gabbro and minor anorthosite, whereas west of the St. Maurice River, green pyroxene gneiss (granulite) is found in abundance. Hornblende gneiss, hornblende-biotite gneiss and biotite gneiss are ubiquitous. Rocks attributed to the Grenville Group are nowhere abundant. Preliminary results suggest that lithologies of the Grenville Group vary systematically from west to east or from northwest to southeast between Lake Baskatong (longitude 76°W) and longitude 72°W, east of Shawinigan. The relative abundance of marble and quartzite decreases to the southeast, whereas that of biotite-garnet-sillimanite gneiss and rusty, graphite-bearing gneiss increases. East of the St. Maurice River, biotite-garnet-sillimanite gneiss and rusty gneiss are associated with amphibolite that may represent metavolcanics. Much more work is needed before such relationships can be interpreted as a transition from shallow water to deep water in the original sedimentation basin.

Foliation planes are relatively steep in the southwestern corner of the Trois-Rivières area, where rocks appear to be wrapped around the Morin anorthosite body, but elsewhere the dips rarely exceed 30 degrees. Irregular domes and basins appear to be the dominant structural elements but because of a lack of key-horizons they are hard to recognize.

Major northeasterly trending normal faults are common in the southern part of the area where, in many places, they mark the contact of Precambrian and Paleozoic rocks. Another fault system extends from La Tuque to the south and southeast, along the valley followed by the CN railway line to Hervey Junction.

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[1] Wynne-Edwards, H. R. et al. : Mont Laurier and Kempt Lake map-areas, Quebec; Geol. Surv. Can., Paper 66-32 (1966).

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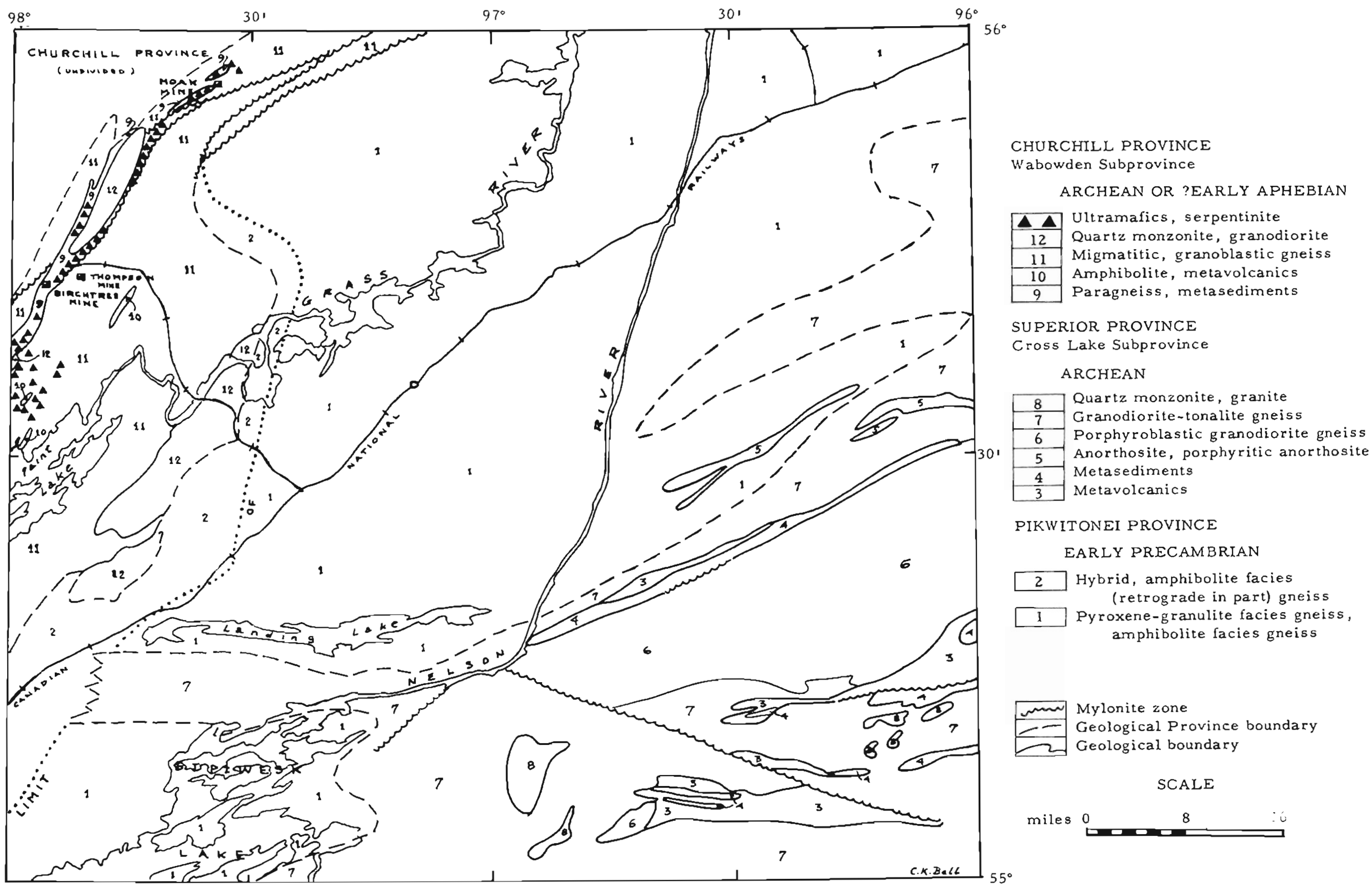
72. GEOLOGICAL INVESTIGATIONS ACROSS THE BOUNDARY BETWEEN THE CHURCHILL AND SUPERIOR TECTONIC PROVINCES

Project 630025

63 P

C.K. Bell

Mapping, at a scale of 1 inch equals 4 miles, was resumed in Sipiwesk (63P) after a lapse of 5 years. Geology in the southwestern corner of the map-area is adapted from Milligan[1] and Allen[2, 3]. The geology of the northeast quarter of the map-area is largely derived from Patterson[4], and Quirke et al[5]. A summary of the regional geology, and a 1:100, 000 scale map of the Wabowden Subprovince accompanies the latter publication.



Sketch map of geology of Sipiwesk map-area, Manitoba

Regional investigations by helicopter (70 hours in June) have helped to confirm that the pyroxene-granulite facies gneisses that have been included in the Pikwitonei Province are basement rocks upon which the 'type' Archean rocks of the Superior Province (Cross Lake Subprovince) have been deposited. Accordingly, the boundary between unit 1 and unit 7 is a metamorphosed unconformity. It is approximately defined by the limit of hypersthene. The boundary between the Pikwitonei and Churchill Provinces is a northeast-trending mylonite zone east of Moak Mine. A southern extension of this shear zone probably marks this entire boundary but its existence has still to be proven. Patterson's[4] western limit of hypersthene-bearing rocks was confirmed. Aside from active exploration and mine development in Wabowden Subprovince by the International Nickel Company of Canada, Limited, little work is being done elsewhere in the map-area by mining companies. Nothing of economic importance was recognized by the writer during mapping in the Pikwitonei and Superior Province portions of Sipiwesk map-area.

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73.

2 M
3 D
12 I, P
13 A ✓

PRECAMBRIAN GEOLOGY, STRAIT OF BELLE ISLE, NEWFOUNDLAND

Project 680130

H.H. Bostock

Geological mapping of Precambrian crystalline rocks at the northern end of the Long Range Mountains, Newfoundland, begun in the summer of 1969, was extended to the Precambrian-Paleozoic contact. Upper Precambrian and Lower Cambrian basic volcanic and sedimentary rocks, which overlie or are in fault contact with the crystalline rocks, were also mapped.

The crystalline rocks consist mostly of medium- to fine-grained, granitic to dioritic gneisses that commonly show a mineral lineation. Pelitic schists containing coarse sillimanite, though widespread, are rare and typically in bands less than 100 feet wide. Some 30 feet or more of calc-silicate gneiss was observed in a restricted area about 7 miles north of Torrent River. Porphyritic and massive granitic rocks that are locally schistose have intruded the gneisses. Amphibolite lenses up to 1 1/2 miles long and several hundred feet thick are widely scattered throughout the area, and some of these contain talc schist and remnant banding.

Arkose, subgreywacke, dark siltstone, and some conglomerate, of the Precambrian (?) and Lower Cambrian Bradore Formation overlie and are in fault-contact with crystalline rocks along the margins of the area mapped. In the hills north of Otter Cove some 25 feet or more of similar sediments underlie basic volcanic rocks, and lie on fine-grained granitic gneiss. Farther north in Cloud River canyon, the basal beds of the Bradore Formation are interbedded with basic volcanic rocks; and near the north margin of the area mapped the Bradore sediments apparently lie entirely on top of the basic volcanic rocks.

Iron sulphide gossans, though rare, are commonly associated with the pelitic schists, the most extensive of such gossans being located at: - 50° 50' 10"N, 56° 33' 30"W; and 50° 40' 15"N, 56° 50' 29"W. Scattered pebbles of magnetite-rich iron-formation were observed in conglomerate within the Bradore Formation at Wild Cove. Minor purple fluorite is present locally in fine-grained granitic gneiss near the Precambrian-Paleozoic contact not far from Northwest Brook.

74. SEDIMENTOLOGIC AND STRATIGRAPHIC STUDY OF THE HORNBY BAY AND COPPERMINE RIVER GROUPS, DISTRICT OF MACKENZIE

Project 680057

J. A. Donaldson

Hornby Bay dolostones previously mapped in Dismal Lakes area[1] were traced westward into Bebensee Lake area (86 miles), and sedimentary structures in these rocks (stromatolites, oncolites, vermiform structures, crossbeds, ripple-marks, etc.) were studied in detail to gain information

Figure 1. Looking northeast at section through chaotically deformed zone in Hornby Bay dolomite. Bebensee Lake area, 67° 06'N; 118° 42'W. GSC photo 201538.

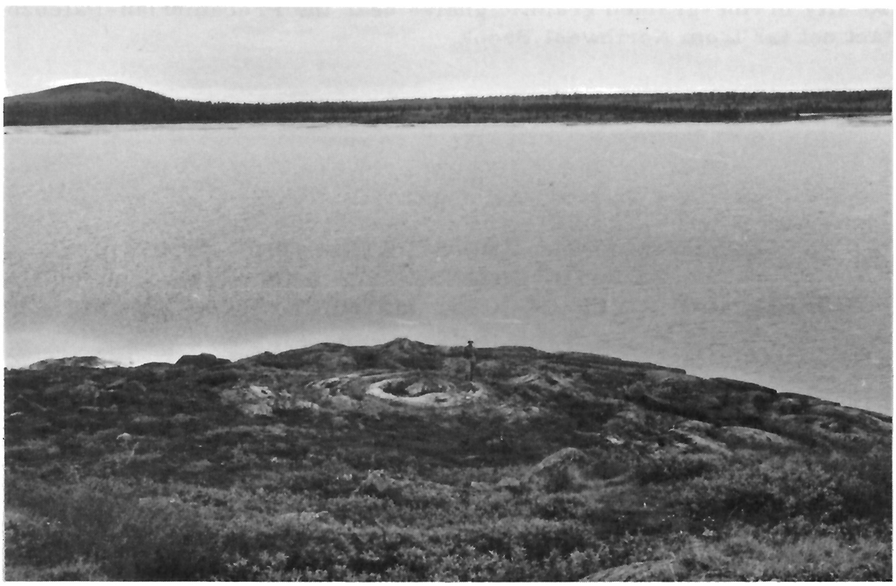

Figure 2. Domical stromatolites up to 10 metres in diameter. East shore of island one mile west of Prospect Island, Dease Arm of Great Bear Lake. GSC photo 201539.

on paleoenvironments and stratigraphy. The carbonate succession thickens southwestward, and facies changes occur, but the prominent central unit of massive dolostone characterized by conical stromatolites[2] can be followed almost without interruption to Dease Arm of Great Bear Lake, 70 miles southwest of Dismal Lakes. Beds containing oolites and 'molar-tooth' structures form distinctive markers, and a pisolitic zone, possibly relict caliche, locally occurs immediately beneath basalts of the overlying Coppermine River Group.

The unconformity recognized within the Hornby Bay Group during the previous field season cannot be traced with certainty south of Bebensee Lake, where outcrops are sparse and stratigraphic relationships are obscured by faults. Repetition of strata suggests that some strike faults, increasingly abundant toward Great Bear Lake, are thrusts. Intensely deformed strata overlain and underlain by undeformed beds occur in several localities, but appear to be restricted stratigraphically. The style of folding suggests soft-sediment deformation (Fig. 1), and the zone may therefore mark a significant décollement due to gravity sliding. Red mudstones containing casts of halite and gypsum are involved, and possibly the deformation is related to solution of evaporites. Less likely is the possibility that the zone of deformation represents a low-angle overthrust; cleavage is lacking, and although the contained folds commonly are overturned, their axes do not define a consistent trend.

Sedimentary rocks of the Coppermine River Group were studied in detail along the Richardson, Rae, Coppermine, and Asiak Rivers, and along the north shore of Richardson Bay, in an attempt to assemble a composite section of these poorly exposed rocks. Bedded gypsum was encountered north of the Rae River, further substantiating correlation with strata of the Hornaday River Basin to the northwest[3]. Sparse paleocurrent data suggest the depositional basin deepened to the north. Configuration of the basin holds implications for economic potential of the sedimentary rocks, particularly the red beds and interbedded shales, siltstones, and argillites that overlie the Coppermine River basalts. Copper mineralization, including chalcocite and native copper, occur in these rocks, particularly the argillaceous strata (in part glauconitic). If the interpretation of basin deepening to the north is correct, the possibility of stratiform copper deposits beneath the gently dipping overlying strata remains yet to be adequately evaluated.

A new occurrence of conical stromatolites was found in carbonates of the Coppermine River Group. These are gradational with normal domical-columnar stromatolites, i.e., convex laminations gradually give way to conical laminations along the growth axes of the columns. A few basal exposures of conical stromatolites in the Hornby Bay Group show gradual coalescence of gentle undulations upward from planar bedding. In yet another locality (Dease Arm), giant domal stromatolites form spectacular biohermal masses (Fig. 2).

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75. EDEHON LAKE AND NUELTIN LAKE MAP-AREAS, DISTRICT OF KEEWATIN

65A
65B

Project 680085

K. E. Eade

The investigation of the stratigraphy and structure of the Aphebian sedimentary rocks was continued[1,2,3] in Nueltin Lake east half (65B E1/2) and Edehon Lake west half (65A W 1/2) map-areas in conjunction with reconnaissance mapping (for publication on a scale of 1:250,000), using a combination of helicopter and ground traverses. The region has been mapped previously on a scale of 1 inch to 8 miles[4,5].

The Aphebian Hurwitz Group rocks in the northeast corner of the Nueltin Lake map-area are contiguous with the type rocks of this group in Kognak River map-area[6,7] to the north, but only the stratigraphically lower part of the group is present, i.e. conglomeratic greywacke and greywacke, orthoquartzite, slate with gabbro sills, argillite and phyllite, and minor dolomite and limestone. To the south and east of these Hurwitz Group rocks, isolated bands and small areas of similar rocks or their metamorphic equivalents are present. The lithology and stratigraphy indicate they are correlatives of the Hurwitz Group. The grade of metamorphism is higher in these rocks than it is in those of the type Hurwitz Group. As primary sedimentary structures are rare or absent in all the sedimentary rocks direction of sedimentary transport cannot be determined.

Basic volcanic rocks with some rhyolite bands, greywacke conglomerate, and greywacke with minor quartz-magnetite iron-formation bands, granodioritic gneisses and granodiorite, all probably of Archean age, underlie the Aphebian sedimentary rocks. In the northern and central part of the region these rocks are in the almandine-amphibolite facies of regional metamorphism but in the southern part the granulite facies is prevalent. Igneous plutons of granite, quartz monzonite, or granodiorite composition intrude all the previously mentioned rocks and were probably emplaced during the Hudsonian Orogeny. Coarse-grained, porphyritic, fluorite-bearing granite occurs in the western part of the region but elsewhere the igneous rocks are, for the most part, medium grained and equigranular.

Regional structural trends are mostly northeast but in the extreme south and southeast of the region the trends are east to slightly north of east. Folds in the Hurwitz Group rocks in the northeast corner of the Nueltin Lake map-area trend either northeast or east, with reverse faults associated with the east-trending folds. This deformation pattern is the same as that in equivalent rocks in the Kognak River map-area. Many major faults are present in the region and mark the contacts of the Aphebian rocks with underlying rocks in many places.

Scintillometer readings (Rank type ND148 scintillometer) were made on the Aphebian orthoquartzite, greywacke and conglomeratic greywacke in a number of places but observed values were background (5 to 8 μ R/hour) or only slightly above. Readings on the younger intrusive granite, quartz monzonite, and granodiorite were commonly 15 to 20 μ R/hour and in some places up to 35 μ R/hour. At the northeast corner of Tatinnai Lake (60° 59' N, 97° 34'W) and at 60° 35'N, 98° 34' 30"W, small occurrences of quartz-magnetite iron-formation contain some beds rich in pyrite that result in extensive rusty weathering zone. In a metamorphosed greywacke containing abundant sillimanite, minor specks of chalcopyrite are present (60° 34' 45"N, 96° 52' 30"W). Minor molybdenite mineralization is present in the quartz monzonite to granite near 60° 29'N, 96° 51'W.

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[2] Ennadai Lake and Nueltin Lake map-areas, District of Keewatin; in Report of Activities, Part A: April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 137-139 (1970).

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76. HARP LAKE ANORTHOSITE, LABRADOR

Project 670003

R.F. Emslie

Reconnaissance work was continued on the large Harp Lake anorthositic intrusion in central Labrador. The body is approximately centred at 62°W and 55°N. Work included examination of contact relations between the central layered rocks and the younger adamellite group along the northeast margin of the intrusion. This contact is partly a fault and partly intrusive. The eastern portion of the intrusion contains much well-developed igneous layering with consistent easterly dips near 25 degrees. Typically the layers are formed by alternating olivine-bearing and plagioclase-rich rocks. In the western part of the intrusion several rounded cobbles and boulders of massive magnetic oxide float were found and pebbles of oxide washed out of the glacial drift are common. No significant concentration of these oxides was discovered in place. A number of sites within the intrusion were drilled for paleomagnetic studies.

A brief visit was paid to the Michikamau intrusion, approximately 50 miles to the southwest. On the west shore of Lake Michikamau para-gneisses of the contact aureole were systematically sampled. Detailed examination of a mass of olivine gabbro previously believed to be a large inclusion is now known to be an intrusion into the upper part of the main pluton.

77. BASIN ANALYSIS OF THE ATHABASCA SEDIMENTARY BASIN

Project 680135

74

W.F. Fahrig

Approximately 25,000 feet of diamond-drill core from the Athabasca sedimentary basin were megascopically examined. This examination included core from the 4,776 feet of Athabasca Formation and 340 feet of underlying basement intersected by the Rumpel Lake stratigraphic test hole which was drilled as a joint project by Gulf Minerals Company, Saskatchewan Department of Mineral Resources, and Geological Survey of Canada. A report on this hole[1] has indicated that the Athabasca at this locality is divisible into two members, a lower 3,000 feet + unit with characteristics suggesting deposition in a braided fluviatile environment, and a thinner upper unit with characteristics suggesting deposition in a beach, barrier, lagoon and nearshore marine environment. The two-fold division indicated by Lerand has been observed in cores from as far west as the Carswell Lake area indicating that these members are present throughout the central and western parts of the Athabasca basin.

[1] Lerand, M.M.: Athabasca Formation Rumpel Lake stratigraphic text lithologic description. Private report to Gulf Minerals Company, Jan. 22, 1970.

78. HURONIAN ROCKS NORTH OF LAKE HURON

Project 610030

41 J J
41 K

M.J. Frarey

About three weeks were spent in the Echo Lake, Wakwekobi Lake, and Bruce Mines map-areas, previously mapped by the writer[1, 2, 3]. Problem localities were revisited, particularly where there has been new information arising from more recent investigations. The following notes include information obtained from assessment files of the Ontario Department of Mines and Northern Affairs, and other data kindly provided by Texas Gulf Sulphur Company; included also are a few previously unpublished observations and revisions made prior to 1970, chiefly in the Sault Ste. Marie map-area.

Bruce Mines Map-area

1. Birch and Calf Islands, lying just east of Cedar Island in the North Channel of Lake Huron at the southern boundary of this map-area, were previously unmapped. These are underlain by feldspathic quartzite beds, probably of the Mississagi Formation. A drillhole near the south tip of Birch Island intersected a thickness of about 2,100 feet of these beds; from this, together with the thickness exposed northward on the island, it is apparent that the Mississagi Formation has a minimum thickness of at least 3,000 feet in this part of the North Channel. Similar beds are exposed on Thessalon, Serpent, and Sulphur Islands outside the map-area to the south.
2. Conglomerate and paraconglomerate occurring from Larry Island to Pallideau Island, North Channel, and shown on existing maps[3,4] as Espanola Formation, have been reclassified as Gowganda Sandstone underlying the southwestern half of Larry Island is reclassified to Serpent. Slump features are well displayed in the Gowganda of Larry Island.

Echo Lake and Sault Ste. Marie Map-areas

1. Along the southeast shore of Echo Lake and eastward through an area of poor outcrop, a broad band of Serpent Formation is shown on current maps[1,4]. Further work has shown that much of this is underlain by Gowganda Formation, as indicated on Figure 1. Attempts to trace the Espanola and Bruce Formations through the gap between Echo Lake and Two Horse Lake some four miles to the southeast were unsuccessful.
2. West of Echo Lake, detailed mapping resulted in numerous changes, also shown in Figure 1. Discovery of additional outcrops of Bruce and Espanola Formations has led to the reclassification of tracts previously mapped as Serpent Formation either to Mississagi Formation or Gowganda Formation. It appears that sandstone, mostly thick-bedded protoquartzite, is a more extensive and thicker component of the Gowganda in this area than to the southeast of Echo Lake. The Mississagi beds southwest of the Garden River Fault consist mainly of grey, medium-grained feldspathic quartzite similar to that of the formation elsewhere in the Huronian Belt. Thus, it is in sharp contrast with the coarse-grained conglomeratic strata of the Aweres Formation some five miles to the northwest, which have been tentatively correlated with the Mississagi following Roscoe, rather than with the Serpent as suggested by Hay.
3. Localities in the southeast corner of Echo Lake map-area were also revisited. Correlation problems there have been discussed previously[6]; they involve the identification of sizable areas of quartzite stratigraphically between the basement and Gowganda beds, and of smaller occurrences of siliceous paraconglomerate, in Morin, Otter, Galbraith and Haughton Townships (Fig. 2). The quartzite contains a few beds of quartz-pebble conglomerate, some of which are radioactive, and has been most recently

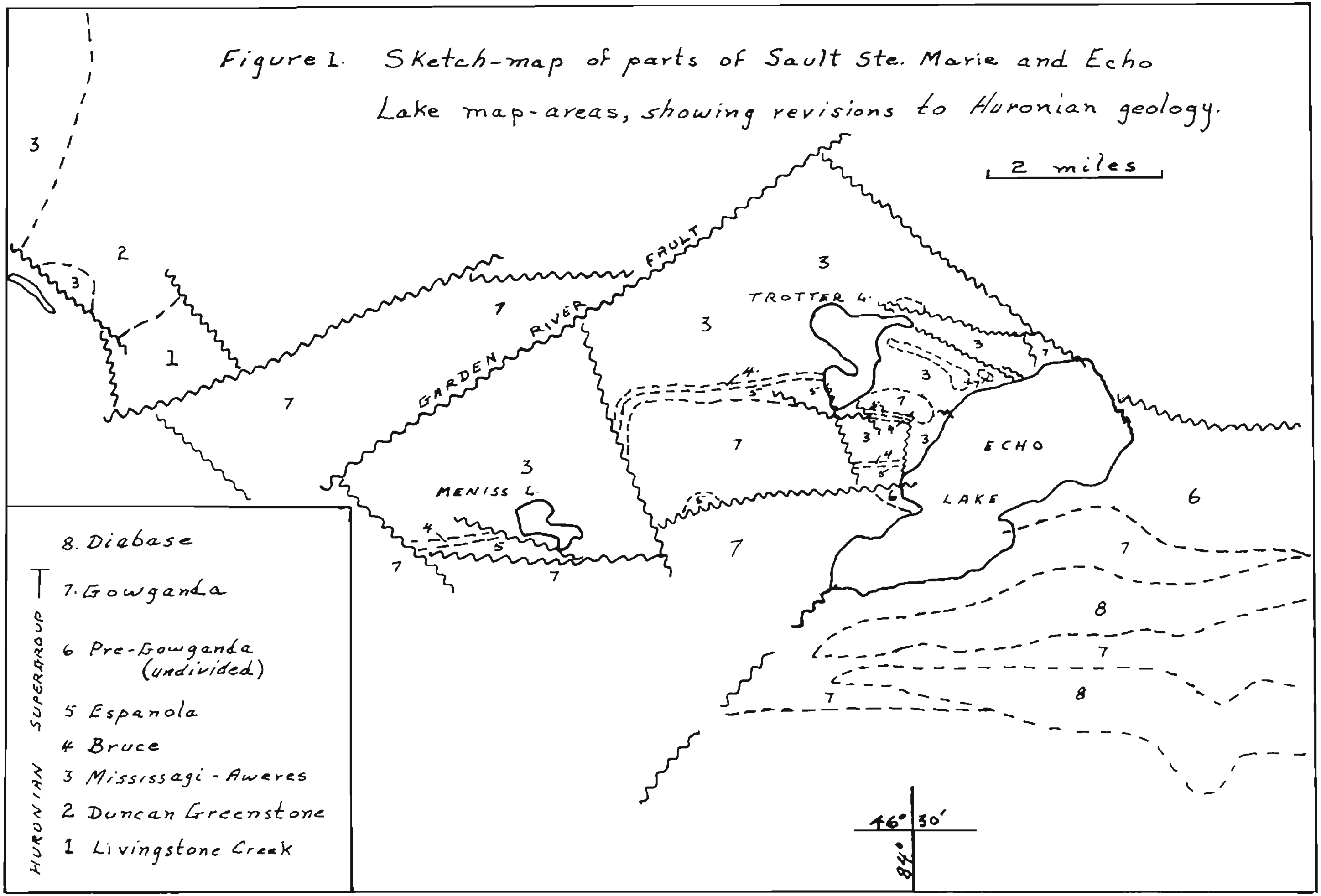

Figure 1. Sketch-map of parts of Sault Ste. Marie and Echo Lake map-areas, showing revisions to Huronian geology.

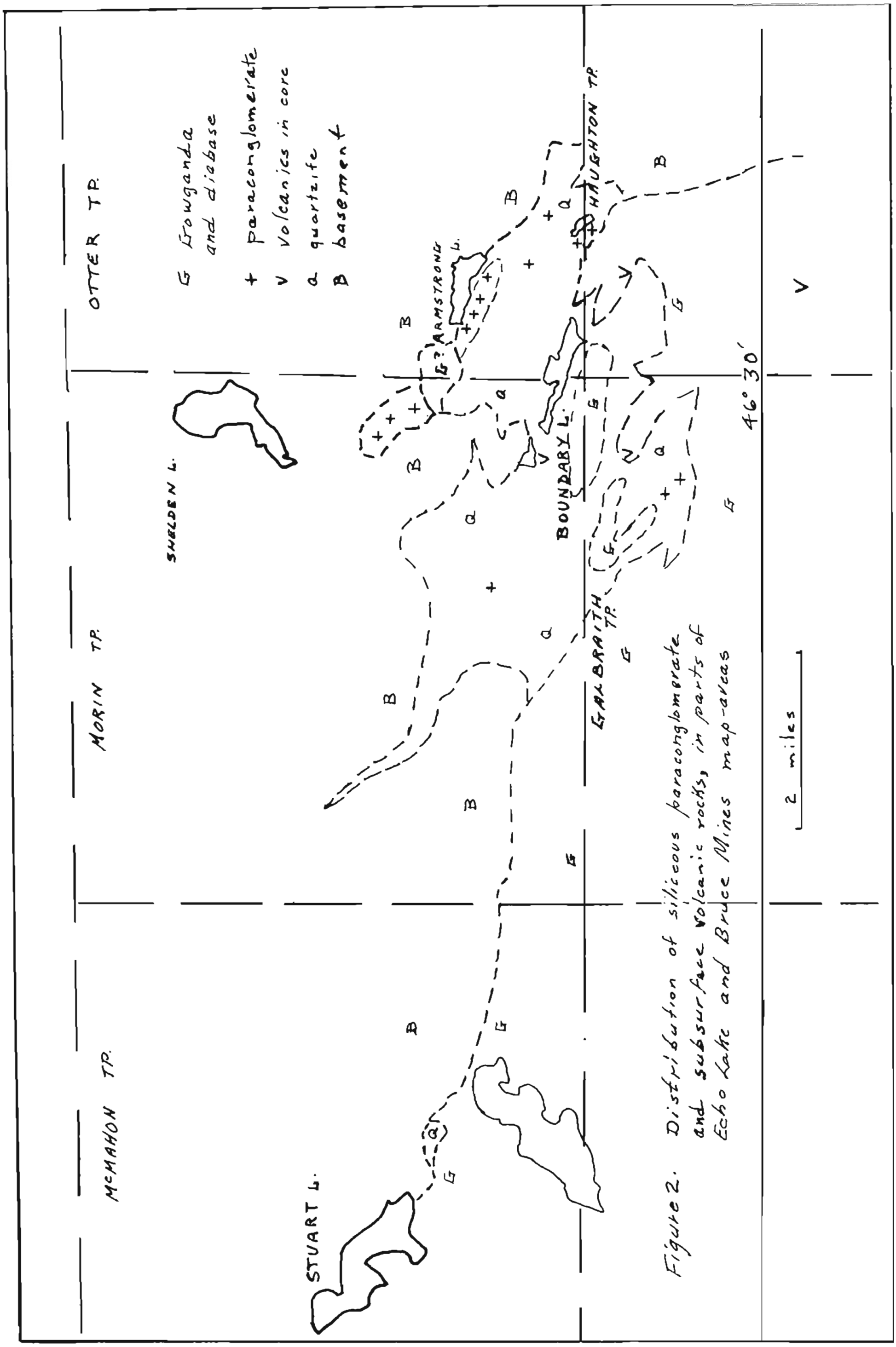

Figure 2. Distribution of siliceous paraconglomerate and subsurface volcanic rocks, in parts of Echo Lake and Bruce Mines map-areas

considered as either Mississagi or Matinenda (Upper of Lower Mississagi of former usage). Areas of the paraconglomerate south of Sheldon Lake in Morin Township were considered by Collins[7] to represent a facies of the Gowganda and in the writer's first mapping this was extended to smaller patches of similar character. Detailed work has shown however that some of these occurrences are practically adjacent to dissimilar Gowganda paraconglomerate, and in all likelihood are not part of that formation. Lithologically they resemble the Bruce or Ramsay Lake paraconglomerates in that grey granitic clasts are predominant, but the nearest exposures of Bruce conglomerate are 8 to 10 miles to the southwest and known occurrences of Ramsay Lake are even farther removed. The problem area is within or close to the regional distribution limit of both conglomerates[6], but reliable specific correlation from surface evidence is further inhibited by the absence of recognizable strata of the Espanola or Pecors Formations overlying the paraconglomerate beds. The latter everywhere rest conformably on quartzite and have erosional upper surfaces, with the exception of one or two places where the conglomerate is also overlain by quartzite. Information from recent drilling is of interest to these problems. Intersections obtained just west of Boundary Lake, and others south of that lake include thin beds of similar conglomerate in sections that contain basic volcanic intercalations. In some holes such conglomerate occurs both above and below the volcanic intervals. The association with the volcanics may be significant, if Huronian volcanics are restricted to the Elliot Lake Group (i. e., pre-Ramsay Lake) as has been the suggestion to date[6, 8]. Correlation of the paraconglomerate outcrops in question (and that in the drill cores) with the Bruce would then be unlikely, paraconglomerate stratigraphically above the volcanics would correlate with the Ramsay Lake, and quartzite below such conglomerate would belong to the Matinenda Formation. Paraconglomerate below the volcanics might be local or might possibly represent an equivalent of conglomerate in the Stinson member of the Matinenda near Elliot Lake[9].

4. Figure 2 also shows, near the southeast end of Stuart Lake, McMahon Township, a small area of quartzite that is not indicated on existing maps. The quartzite is mostly fine-grained and massive-looking; quartz-pebble conglomerate, evidently non-pyritic, occurs near the lower limit of the exposure area. These strata lie between the basement rocks and the Gowganda Formation, and present correlation difficulties similar to those discussed above.

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[5] Hay, R. E.: Sault Ste. Marie-Ile Parisienne, Ontario; Geol. Surv. Can., Map 1181A (1964).

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[8]Robertson, J. A., Frarey, M. J., and Card, K. D.: The Federal-Provincial Committee on Huronian Stratigraphy progress report; Can. J. Earth Sci., vol. 6, pp. 335-336.

[9]Pienaar, P. J.: Stratigraphy, petrology and genesis of the Elliot Group, Blind River, Ontario, including the uraniferous conglomerate; Geol. Surv. Can., Bull. 83 (1963).

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79. YELLOWKNIFE AND HEARNE LAKE MAP-AREAS, DISTRICT OF MACKENZIE

85I
85J

Project 700015

J. B. Henderson and A. J. M. Elliot*

In the Yellowknife map-area field work was initiated which will ultimately result in a 1:250, 000 map of the area, known for the most part only through early reconnaissance mapping[1]. Most of the area is of Archean age. The eastern quarter of the map-area has been previously mapped on a one mile to the inch scale or better by Jolliffe[2]. The southwestern part of the area, where not covered by the north arm of Great Slave Lake, is underlain by limestones, dolomites, sandstones and shales of Ordovician and Devonian age previously mapped by Douglas and Norris[3].

Field work during the past season was concentrated along the road between the city of Yellowknife and the east and the village of Rae just west of the map boundary, and in the areas of Russell, Stagg and Awry Lakes along the northern boundary of the area. Bedrock exposure throughout the area underlain by Precambrian rocks is excellent.

The Precambrian area conists of a large central granitic area bordered on the east and northwest by sediments and volcanics of the Yellowknife Supergroup.

The granitic area is locally variable in composition and texture, ranging from massive to gneissic granites to granodiorites. The granitic rocks in the eastern half of the area mapped tend to be somewhat more uniform and more intermediate in composition than the generally more highly variable granitic rocks in the western part. The pink to grey, medium- to medium-coarse-grained, equigranular to locally porphyritic granitic rocks are weakly foliated. In contrast, the granitic rocks to the west are more massive and are medium grained to coarsely porphyritic. Dykes, sills and and irregular bodies of light pink, biotite-poor to aplitic intrusions and pegmatites are more abundant in the east. Narrow zones of angular amphibolitic inclusions are also more abundant in the eastern part. A common feature found in the pink, biotite-poor, granitic rocks between Stagg Lake and Great Slave Lake is the occurrence of widely scattered, small, bright yellow stains of uranophane in both the granite and associated pegmatitic phases. No primary uranium minerals were noted. The granitic rocks everywhere exhibited an intrusive relationship with the Yellowknife volcanics and sediments.

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*Seasonal field assistant.

The Yellowknife volcanics and sediments north of Yellowknife Bay have been previously described[2]. Volcanics and sediments of the Yellowknife Supergroup also occur around Russell and Stagg Lakes. A major unit of predominantly silicic to intermediate tuffs, agglomerates and pillowed flows occurs east of Russell Lake. Sediments in the area are predominantly thick to thin bedded, typically graded, laterally continuous greywacke and interbedded mudstone with internal structures typical of turbidites. Despite the relatively high regional metamorphic grade (porphyroblasts of cordierite and andalusite) there is commonly perfect preservation of primary sedimentary structures. On a few islands in the lake associated with the normal sediments are thin zones of thin-bedded silicate-sulphide iron-formation. On the west shore of the southern part of the lake, beds of primary carbonate are associated with the iron-formation. The carbonate in places is extensively mineralized with pyrite. East of Russell Lake at Stagg Lake, the sediments are much more deformed and more highly metamorphosed. Only rarely are primary sedimentary structures preserved.

Throughout the area mapped there is a regional northeasterly grain to the country as shown by the foliation in the granitic rocks and the attitudes of the supracrustal rocks in the northwestern part of the area. The area is broken by a series of left-lateral north-northwesterly trending faults parallel to the West Bay Fault at Yellowknife. Northeasterly, northwesterly and, to a lesser extent, northerly trending diabase dykes are common in the area.

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[1] Jolliffe, F. (A. W.): Yellowknife River area, Northwest Territories; Geol. Surv. Can., Paper 36-5 (1936).

[2] Jolliffe, A. W.: Quyta Lake and parts of Fishing Lake and Prosperous Lake Areas, Northwest Territories; Geol. Surv. Can., Papers 39-6, 40-14 (1940).

Jolliffe, A. W.: Yellowknife Bay map-area; Geol. Surv. Can., Map 709A (1942).

Jolliffe, A. W.: Prosperous Lake map-area; Geol. Surv. Can., Map 868A (1946).

[3] Douglas, R. J. W., and Norris, A. W.: Horn River map-area, Northwest Territories; Geol. Surv. Can., Paper 59-11 (1959).

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80. WALRUS, COATS AND BENCUS ISLANDS, DISTRICT OF KEEWATIN

15 N ½

Project 700080

W. W. Heywood

The reconnaissance geological mapping of Coats, Walrus and Bencus Islands at the entrance to Hudson Bay was completed in seven days with the CCGS "Labrador" as a mobile base and using the ship's helicopter for traversing. Walrus and Bencus are smaller islands lying north of Coats. Mansel Island, which is underlain by Paleozoic rocks (Sanford, pers. comm.) was not visited by the writer. B. V. Sanford was responsible for the Paleozoic geology and a summary of his field work will be found elsewhere in this publication.

The Precambrian rocks of Coats and Bencus Islands consist almost entirely of foliated to massive granitoid rocks and gneiss. Amphibolite layers and quartz-rich layers are present but not widespread. These rocks are similar to those on Southampton Island and are possibly also of Aphebian age.

At 80° 18'W, 62° 27'N, on Coats Island, a small anorthosite knob is exposed in an area of drift about 5 miles south of the main Precambrian-Paleozoic contact.

Structural trends are northeast and three prominent lineament directions are present. These are northeast parallel to foliation, east-west, and northwest.

Walrus Island, between Coats and Southampton Islands is about a mile long and a half a mile wide. The maximum elevation is 165 feet above sea level, and the limited bathimetry available indicates that it stands about 500 feet above a more or less uniform sea floor. The island is wholly underlain by layered gabbroic anorthosite. Layers range from a few inches to 10 feet or more thick and have fairly consistent attitudes, dipping northeastward at roughly 30 degrees. Some layers are characterized by abundant pyroxene crystals and aggregates of crystals as much as 6 inches across.

No minerals of economic interest were noted in these areas.

81. STRATIGRAPHY AND STRUCTURE OF THE EPWORTH FOLD BELT, DISTRICT OF MACKENZIE (86 O, P)

Project 690024

86 O
86 P ✓

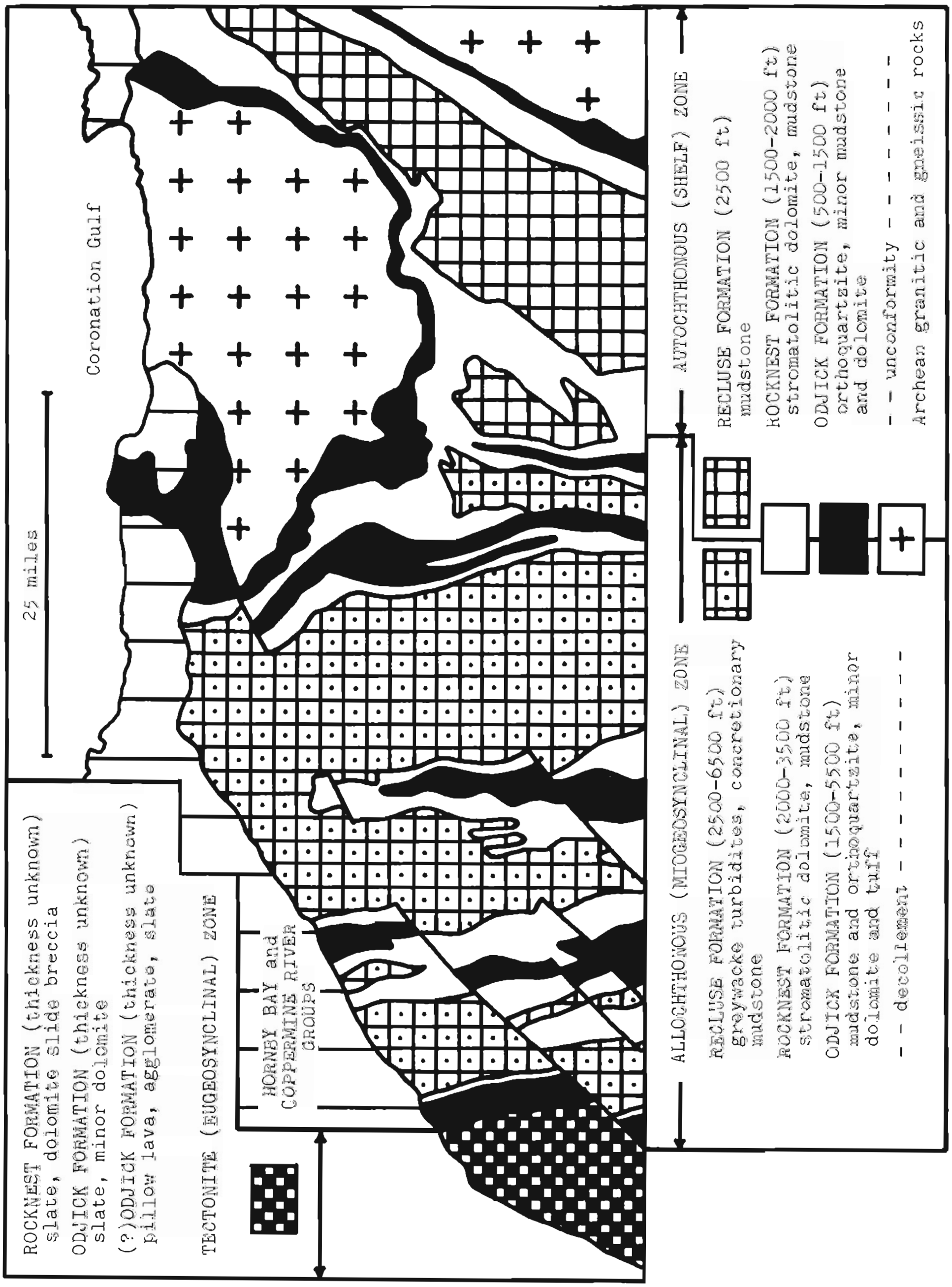
P.F. Hoffman, P.A. Geiser* and L.K. Gerahian*

The Epworth fold belt constitutes the type area of the Coronation Geosyncline[1]. Its stratigraphy and depositional history have been outlined[1,2,3]. The objectives of mapping during the 1970 field season were to revise the reconnaissance map[4] in accordance with the current stratigraphic nomenclature (Fig. 1) and to obtain structural data over a cross-section of the north end of the fold belt.

The fold belt is subdivided into three sectors: an eastern "autochthonous (shelf) zone", a central "allochthonous (miogeosynclinal) zone" and a western "tectonite (eugeosynclinal) zone". In the autochthonous zone, the Aphebian supracrustal strata (Epworth Group) are less than 5,000 feet thick. They are gently folded into broad basins and arches except near the margins of large anticlinal uplifts of Archean basement, where they are locally overturned. The basement uplifts postdate Recluse deposition and resemble the Laramide basement anticlines that form the mountain ranges of Wyoming. Marginal to the uplifts, the Aphebian cover is unmetamorphosed but folded about sinuous to en echelon, northeast-trending axes, genetically related to southeastward overturning of the uplifts. Complex folds are produced at the intersection of divergent flexural-slip fold systems, i.e. local northeasterly folds related to the uplifts and regional northerly folds resulting from eastward translation and consequent compression in the allochthonous zone.

In the allochthonous zone, the Epworth strata thicken westward to 15,000 feet. The eastern boundary of the zone marks the isopach hingeline,

*Seasonal field assistant.



Coronation Gulf
25 miles
HORNBY BAY and COPPERMINE RIVER GROUPS
AUTOCHTHONOUS (SHELF) ZONE
RECLUSE FORMATION (2500 ft)
mudstone
ROCKNEST FORMATION (1500-2000 ft)
stromatolitic dolomite, mudstone
ODJICK FORMATION (500-1500 ft)
orthoquartzite, minor mudstone and dolomite
- - unconformity - - - - - - -
Archean granitic and gneissic rocks
ALLOCHTHONOUS (MIOGEOSYNCLINAL) ZONE
RECLUSE FORMATION (2500-6500 ft)
greywacke turbidites, concretionary mudstone
ROCKNEST FORMATION (2000-3500 ft)
stromatolitic dolomite, mudstone
ODJICK FORMATION (1500-5500 ft)
mudstone and orthoquartzite, minor dolomite and tuff
- - decollement - - - - - - - -
ROCKNEST FORMATION (thickness unknown)
slate, dolomite slide breccia
ODJICK FORMATION (thickness unknown)
slate, minor dolomite
(?)ODJICK FORMATION (thickness unknown)
pillow lava, agglomerate, slate
TECTONITE (EUGEOSYNCLINAL) ZONE

the feather-edge of the westerly derived greywacke turbidites in the Recluse Formation and the eastern limit of known décollement. Broad structural basins, in which relatively gently folded Recluse strata are exposed, are separated by four, complex, tightly compressed, box-like anticlinoria, in which the Rocknest and Odjick Formations are exposed. The anticlinoria are, in places, overturned to the east and contain bedding-plane thrust faults, in some cases folded, resulting in the repetition of up to 5, 000 feet of strata. Compression in the cores of the anitclinoria is manifested in the carbonate rocks by chaotic mega-breccias and abundant "bedding slip wedges"[5], and in the argillaceous rocks by local passive-slip folding. The soles of the thrust slices indicate that the primary décollement surface is in the black mudstone at the base of the Odjick Formation, with a secondary décollement in a mudstone unit within the Rocknest Formation. In general, the style of the allochthonous zone is believed to resemble the Alpine fore-land structures of the Jura Mountains. The folds and thrusts are displaced, particularly in the west, by many northeast faults with dextral, near-horizontal movement.

The western boundary of the allochthonous zone is a "tectonite front" less than a mile wide, west of which the Epworth strata are penetratively deformed in passive-slip folds withregional, west-dipping cleavage and have greenschist facies metamorphism. The tectonite front coincides with important facies changes - the feather-edge of the easterly derived ortho-quartzite tongues in the Odjick Formation, the probable depositional edge of the exogeosynclinal Recluse Formation and the abrupt westward dissappearance of the shallow marine stromatolitic Rocknest carbonates into a thin "starved" section of deep marine shales with beds of carbonate submarine slide breccia. Thus, the tectonite zone contains a metamorphosed, dominantly argillaceous succession correlative with the Odjick and Rocknest Formations to the east. Uplift in the tectonite zone provided the probable source for the greywacke turbidites of the Recluse Formation to the east. Basic pillow lavas and agglomerates in the tectonite zone, previously assigned[6] to the Archean Yellowknife Group, may be correlative with basic lapilli tuff beds found near the base of the Odjick Formation throughout the allochthonous zone. Poor exposure, more than deformation or metamorphism, inhibits stratigraphy within the tectonite zone.

The metamorphism and intense deformation of the Epworth strata are consistent with their position adjacent to the orogenic belt (Bear Province) of the Coronation Geosyncline. Correlative successions of similar thickness and lithologies in the Great Slave Supergroup[1] in the East Arm of Great Slave Lake are, however, unmetamorphosed and relatively little deformed. The gross tectonic setting of the latter is now interpreted as an "aulacogen"[7] (i. e. a graben-like downwarp within the foreland, merging with, but perpendicular to, the flanking orthogeosyncline).

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82.

16 KLM
26
27 AB
36 IP
37 AB

OPERATION PENNY HIGHLANDS SOUTH-CENTRAL BAFFIN ISLAND

Project 690061

G. D. Jackson

This project completed the reconnaissance bedrock geological mapping of Baffin Island between 66° and 69° north latitude and of Cumberland Peninsula, an area of about 54,000 square miles. This also completes the helicopter reconnaissance mapping of Baffin Island. Two Bell helicopters, one 47G4 and one 47G4A, were used for geological traversing. Support was provided by a De Havilland Otter equipped with oversize wheels. Field observations were placed on prepared forms to enable the data to be fed into computers. The writer was assisted in advance preparations by W.C. Morgan, W.L. Davison and I.F. Ermanovics. Assistance in the field was provided by W.L. Davison, D.G. Benson and I.F. Ermanovics of the Geological Survey; and by W.J. Crawford of Tacoma Community College.

Nearly all of the rocks in the map-area are of Aphebian or Archean age. About half of the map-area is underlain by a charnockite-granulite complex[1,2] that is composed mainly of a fine- to coarse-grained, massive to locally faintly foliated porphyritic (feldspar) charnockite of quartz monzonite composition. Assorted granulite facies gneisses and metasediments occur as "relicts" within the charnockite and in relatively thin lenses and zones adjacent to it. Fine- to medium-grained rocks underlie several areas between Cumberland Sound and Nettilling Lake. They may be either metamorphosed grits or sheared granitic rocks.

Migmatites, layered gneisses and associated massive to foliated granitoid rocks outcrop mainly in belts adjacent to the charnockite-granulite complex. The migmatites and gneisses contain metamorphosed gabbro sills and dykes and include at least two ages of migmatites: those derived from or involving Aphebian metasediments, and older, probably Archean migmatites.

A group of highly folded metamorphosed Aphebian strata, "Piling Group", outcrops mainly in an eastward-trending belt up to 80 miles wide that extends from Longstaff Bluff on the west, to Horne Bay on the east. These rocks are probably an extension of the Penrhyn Group[3, 4] on Melville Peninsula, and may be correlative with similar rocks in the southern part of this map-area, in southern Baffin Island, and in northeastern Labrador-Ungava[6]. Within the map-area this group is mainly composed of a thick monotonous flysch-like sequence of metamorphosed pelites, siltstones, sandstones and greywackes. Along the southern side of the belt the lower part of the group includes a relatively thin ophiolite-like sequence of metamorphosed basic volcanics and associated basic and ultrabasic sills and dykes and rusty graphite- and pyrrhotite-bearing strata that may include some sulphide facies iron-formation. Metamorphosed chert, orthoquartzite and arkose are also present. Unlike the northern side of the belt[3], no ophicalcite was observed. Pegmatites and lit-par-lit migmatites are abundant along the southern edge of the belt and adjacent to "gneiss domes". Similar relationships occur along the north side of the belt[3].

A thick sequence of metamorphosed strata, similar to those of the Mary River and Piling Groups[3, 7] outcrops throughout the southern half of Cumberland Peninsula, and is tentatively called the "Hoare Bay" Group. Like the Mary River Group[3, 7] it contains a larger proportion of metamorphosed pelites and greywackes, and a thicker, more extensively developed ophiolite-like sequence than does the Piling Group. Ultrabasic plugs are present as well as sills and dykes. Ophicalcite and metamorphosed oxide-, silicate- and possibly sulphide-facies iron-formation were observed in a few places. The strata of the "Hoare Bay" Group are intensely veined by a network of criss-crossing pegmatites and granitic dykes in several areas.

Most of the strata of the Piling and Hoare Bay Groups are in the amphibolite facies; although the Hoare Bay Group is in general somewhat higher grade and contains more "granitic" material than the Piling Group. Some of the strata, however, such as those in the centre of the area underlain by the Piling Group may be in the upper greenschist facies.

Fresh unaltered and undeformed diabase dykes outcrop throughout the map-area and are most abundant in the metasedimentary belts. They trend northwesterly and most are probably related to the swarm of Hadrynian dykes to the northwest that were mapped during operation Bylot[3, 7].

Patches of fresh flat-lying basalts outcrop for about 55 miles along the eastern coast of Cumberland Peninsula between Cape Dyer and Cape Searle[8, 9]. According to Wilson and Clarke[8], the flows are up to 1,400 feet thick and rest on or are interbedded with up to 500 feet of sedimentary rocks containing plant fossils of Upper Cretaceous-Eocene age[8].

Rusty, pyrite-pyrrhotite bearing zones are associated mainly with the basic metavolcanics in the Piling and Hoare Bay Groups. Some chalcopyrite mineralization is present mainly in the Hoare Bay Group. These zones occur both in the basic igneous rocks and in the associated sediments and are useful as horizon markers. Lean iron-formation was observed in a few places, mainly in the Hoare Bay Group. A few veinlets, up to one half inch thick, of a fairly good grade of cross-fibre asbestos occur at one locality in marble of the Hoare Bay Group.

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83. STRATIGRAPHY, SEDIMENTOLOGY, AND CORRELATION OF THE NONACHO GROUP DISTRICT OF MACKENZIE

Project 650008

J. C. McGlynn

The field work for the study of the Nonacho Group of sediments was completed; this year's work was concentrated along the northwest and northeast arms of Nonacho Lake, along the Talston River and south of Tronka Chua Lake. The objectives of the study are: to study the stratigraphy, structure and sedimentary petrology of Nonacho strata; to correlate these rocks with 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, lithic sandstones, polymictic conglomerates, conglomeratic arkoses and shales. In the northwest arm of Nonacho Lake the succession is composed of fining-upward cycles of conglomeratic arkose and shales. Most of the clasts in the conglomerate are derived from nearby basement rocks. In the northeast arm of Nonacho Lake the strata comprise thickly bedded lithic sandstones and minor shales and thinly bedded sandstone and shales. Conglomerate lenses occur along the contact of the Nonacho strata and basement and are essentially sedimentary breccias composed of angular clasts of basement rocks in an arkose matrix. In the Tronka Chua region, the bulk of the sedimentary rocks are thick-bedded lithic sandstones or arkoses with thin shale beds or shale chip conglomerates at the top of each bed. Fining-upward cycles of conglomerate, arkose, and shale occur along the western margin of the basin above the basement plutonic complex. Along the Talston River, conglomerate occurs as lenses along the contacts with basement rocks. Clasts are derived from the basement rocks. Higher in the succession polymictic conglomerate occurs with clasts of basement rocks but also of volcanic rocks, quartzite and other sedimentary rocks that do not outcrop in the basement. All of the strata along the Talston River are maroon coloured. All Nonacho strata are essentially unmetamorphosed.

Evidence from contact areas on both sides of the basin indicate that all plutonic rocks in the contact with Nonacho strata are older and therefore part of the basement in which the sediments were deposited. Commonly along the western margins of the basin evidence of unconformity has been destroyed or obscured by faulting.

Preliminary analysis of about 1, 500 crossbed orientations collected from 54 sites indicates a complex pattern. Taken together they display no dominant trend of current direction. In the northeast arm of Nonacho Lake, the dominant trend of transport is south along the west margin of the basin and east to southeast in the remaining part of the basin. In the northwest arm of Nonacho Lake, transport directions are south to southwest on west side and south to southeast on the east side of the basin. In the Tronka Chua region the paleocurrent trend is southwest where as along the Talston River the dominant trend is northeast. Near the margin of the basin the paleocurrent directions tend to parallel the strike of the basin but in central part of the basin the pattern is more variable.

The oldest rocks in the area in the basement of the Nonacho strata comprise mafic-rich gneisses, granitic gneiss, porphyroblastic gneiss or flaser gneiss with bands, lenses and irregularly shaped masses of very acidic massive and locally pegmatic granodiorite or granite. Bands of amphibolite and metagabbro occur within the granitoid rocks. Mafic minerals are commonly altered to chlorite near the margins of the basin.

The youngest rocks in the area are northerly trending diabase dykes. They occur in scattered small swarms of very narrow dykes both in granitoid gneisses and Nonacho strata along the margin of the basin.

The Nonacho strata are thrown into broad folds about axes that strike northeast in the western part of the basin and east-northeast in the eastern part. Fold axes dip steeply and the folds plunge gently both to the northeast and southwest. Where shale is abundant in the section the folds are compressed tightly, and intense cleavage destroys original sedimentary structures. In arkose, cleavage is developed along axial zones of folds and in massive arkose sequences movement occurs along faults that occur in axial zones parallel to fold axes. Faulting is concentrated along the margins of the basin particularly along the eastern margin. In the basement, broad northeast-trending zones of mylonite are common as are zones of intense brecciation and shearing. Boulders of mylonite and crushed plutonic rock in Nonacho conglomerates indicate that some of the movement along these faults was pre-sedimentation. These faults probably are boundary faults that formed the original basin and movement continued during sedimentation and, at a higher level, after sedimentation both during and after the folding of Nonacho strata.

A number of uranium showings and copper prospects have been discovered in the region. Most occur in the basement near contacts with Nonacho rocks in shear, mylonite or breccia zones. Attention of prospectors is therefore directed to the contact zones of Nonacho strata and basement rocks particularly where faulting is intense. Consideration should also be given to searching for sedimentary or fossil placer deposits within Nonacho sediments especially around MacInnis Lake where such deposits are known. During the past summer copper mineralization was discovered by the author at one locality on the eastern shore of the northwest arm of Nonacho Lake at 62°04'40" latitude, 109°17'42" longitude. Here chalcopyrite was disseminated in fractures in granitic gneiss. The mineralized section could be traced along the shore of the lake for about 100 feet.

84. VOLCANIC STRATIGRAPHY AND METALLOGENY OF THE KAMINAK GROUP

Project 700052

R.H. Ridler

Introduction

Stratigraphic and metallogenetic study of the Archean Kaminak Group was initiated in the Kaminak Lake area of the District of Keewatin about 250 miles north-northwest of Churchill, Manitoba. The area was selected on the basis of abundant outcrop, ease of access, excellent four-mile geological data and the known wide variety of Archean lithofacies[1]. Standard examination and sampling was performed on a twenty-two mile line of section traversing the entire group (Fig. 1). One hundred chip samples were taken of the volcanic rocks for major oxide analysis. Many showings were examined and specimens of the mineralization taken.

General Geology

The Kaminak Group in the Kaminak Lake area is provisionally divided into three sequential mafic to felsic to sedimentary volcano-sedimentary cycles. One complex sedimentary formation, three mafic volcanic and three felsic volcanic formations are recognized. On Figure 1 these formations are numbered from oldest (1) to youngest (6).

Thickness of individual formations varies considerably along and across strike. The presence of well defined endogenous domes within the middle felsic formation (4) creates the most conspicuous variations of this kind. Other changes in thickness may be accounted for by facies variation

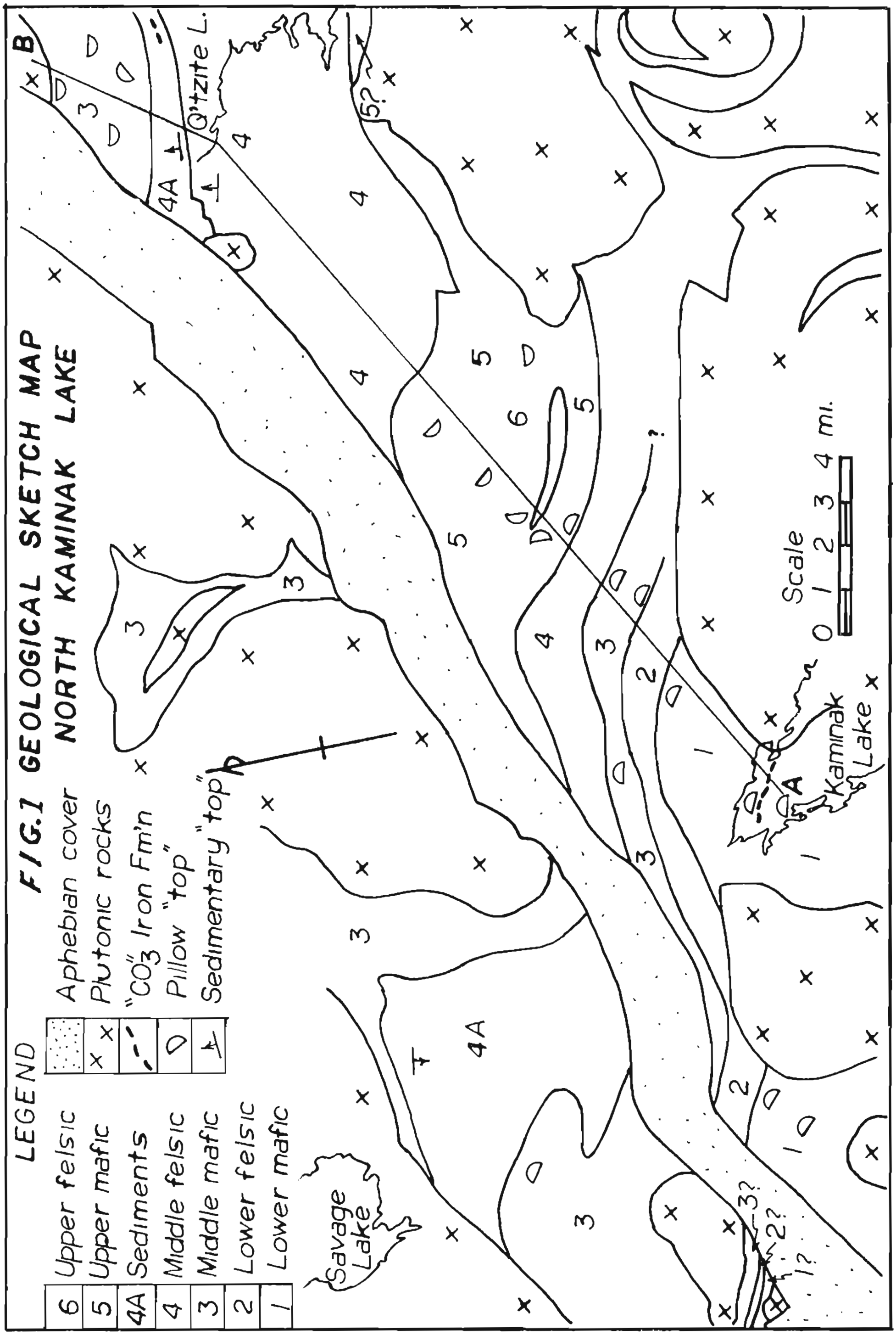
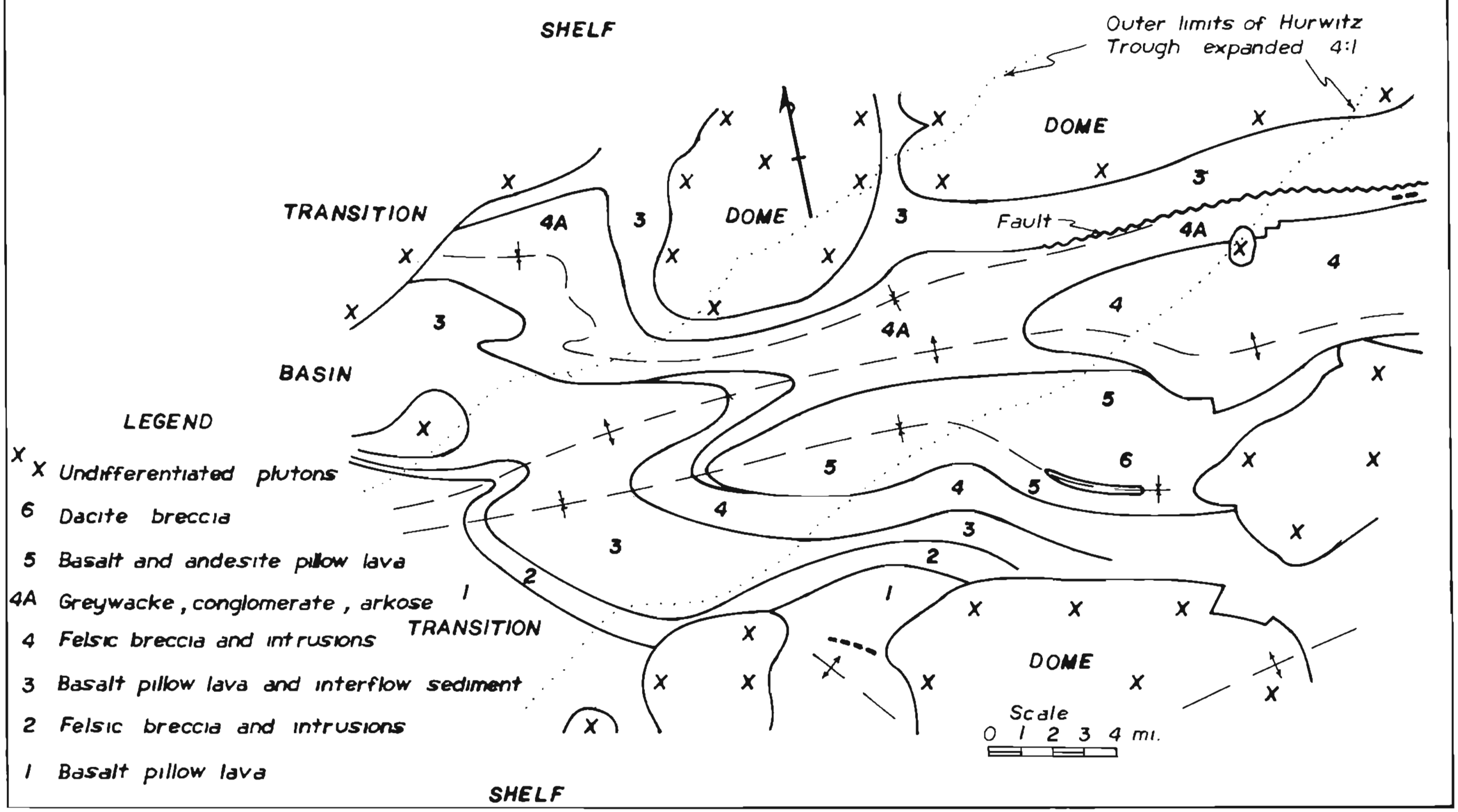


FIG.1 GEOLOGICAL SKETCH MAP
NORTH KAMINAK LAKE
LEGEND
6 Upper felsic
5 Upper mafic
4A Sediments
4 Middle felsic
3 Middle mafic
2 Lower felsic
1 Lower mafic
Aphebian cover
Plutonic rocks
"CO3" Iron Fm'n
Pillow "top"
Sedimentary "top"
Savage Lake
Kaminak Lake
Q'tzite L.
Scale 0 1 2 3 4 mi.
A
B

FIG. 2

PALINSPASTIC RECONSTRUCTION of the PRE-HUDSONIAN GEOLOGY of the NORTH KAMINAK LAKE AREA



such as the entire replacement of the middle felsic formation (4) by its sedimentary equivalent (4A) towards the west.

Each of the mafic formations is characterized by abundant basalt pillow lava with subordinate massive phases. Interflow cherts, tuffs, and black shales are common. Towards the top of the youngest mafic formation (5) andesite flows may be present. The thickest individual flows encountered measured five hundred feet in thickness. Amygdular texture is ubiquitous, variolitic texture usually absent. The maximum thickness of mafic lava is 17, 000 feet.

Each of the felsic formations appears to be composed of a coalescing series of endogenous domes cored by porphyry and mantled and overlain by breccias and tuffs. The felsic volcanics range in composition from dacite to ultra-siliceous rhyolite. Plagioclase, quartz-plagioclase, and quartz porphyries are common, both as massive and pyroclastic varieties. Fragments up to 66 feet in diameter were observed but the common range is from 6 inches down. Compositional uniformity varies from extreme to polymict, angularity from extreme to spherical. Matrix varies from effectively zero to greater than 50 per cent and may contrast in composition to a marked degree with the fragment population. Many of these variations appear to be rationally related to proximity to an endogenous dome probably representative of a vent. The maximum thickness of felsic volcanics is 16, 000 feet.

The main sedimentary zone of the group displays a great variety of facies ranging from unbedded polymict conglomerate to crudely bedded arkose and subgreywacke to varved and laminated argillites and siltstones to iron-formation. The banded sediments show grain gradation, soft-sediment deformation, crossbedding, and piercement structures, Iron-formation in the area examined is predominantly of carbonate and/or sulphide facies, well banded and may be up to 100 feet thick. The maximum thickness of sediments appears to be about 10, 000 feet.

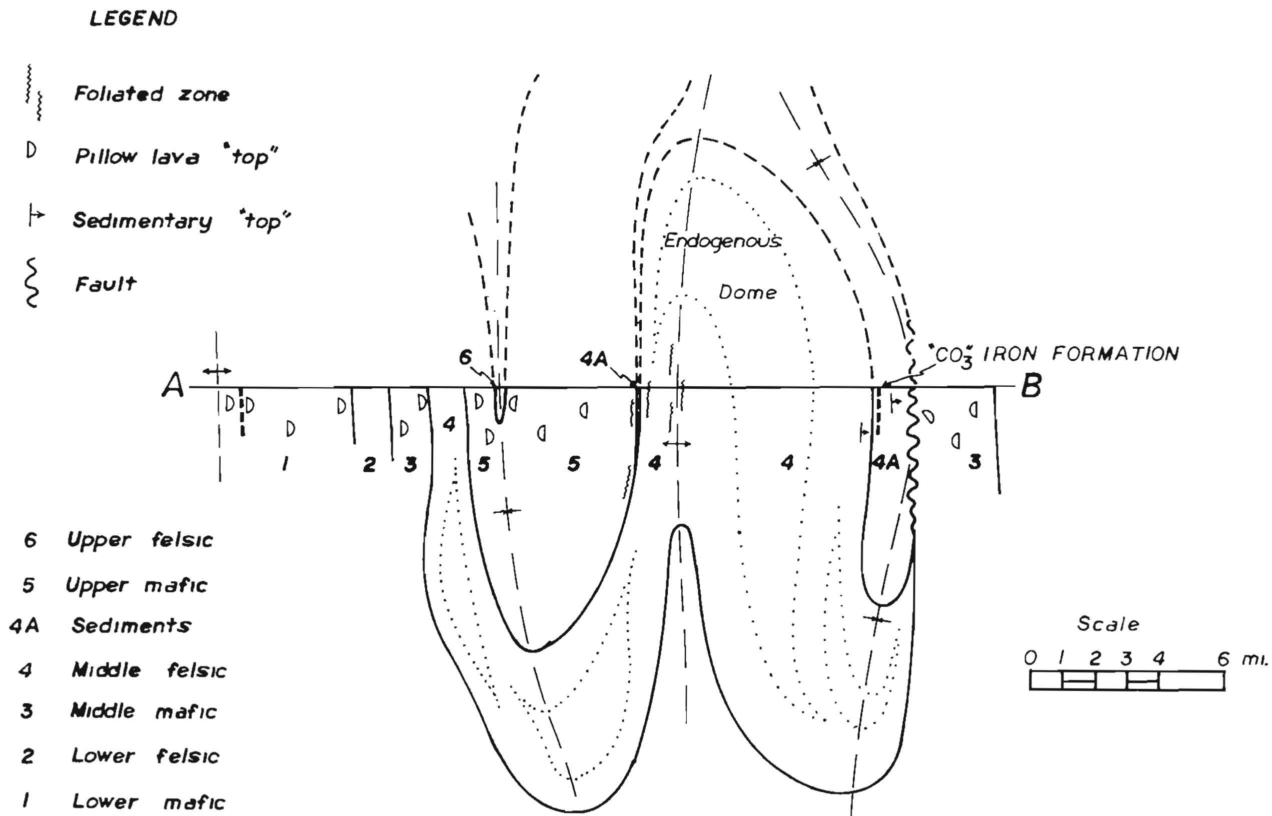
Stratigraphy

The stratigraphy of the Kaminak Group in the Kaminak Lake area is entirely analogous to the polycyclic volcanism and sedimentation patterns displayed in Archean supracrustal rocks of the Superior Province. An older mafic to felsic complex without significant clastic sediments is succeeded by a mafic to felsic sequence capped and mantled by its erosional residue and exhalative products. This in turn is overlain by a younger mafic to felsic volcanic cycle. Areal distribution of iron-formation facies, clastic sedimentary facies and the various ages of volcanism are consistent with an older shelf to younger basin configuration (Fig. 2).

The base of the Archean section has not yet been satisfactorily established. Unlike the typical case (3) in the Superior Province, the lowermost known unit (1) does not rest peneconformably on granitic gneiss domes in the area examined.

FIG. 3

IDEALIZED CROSS-SECTION of the KAMINAK SYNCLINORIUM



Structure

Isoclinal folding of the Archean supracrustal rocks about doubly plunging west-northwest axes dominates the structural pattern. The folding of the overlying Aphebian rocks has been superimposed on the older Archean patterns. Thus the Archean fold axes are gently folded about axes trending at 55 degrees east of north. Clearly tectonic fabrics support the above two-phase deformation. Examples are intersecting foliations and transposition of bedding. A particularly convincing example of the latter is the transportation of the long axes of pillows adjacent to the "Hurwitz Trough". The undoubted shortening of the crust indicated by this feature has been accounted for in the palinspastic reconstruction in Figure 2 by extending the area covered by the trough four to one. The probable fold style and correlation of units are diagrammatically indicated, assuming no significant strike-slip displacement along the trough.

Asymmetry of fold limbs, axial "crush" zones and zones of accommodation marginal to competent lithological units are present (Fig. 3).

Block faulting is important locally but large displacements are unknown.

Metallogeny

Sulphide, carbonate and oxide facies iron-formation are well developed regionally in a pattern consistent with a shelf to basin to shelf analysis from north to south as in Figure 2. Abundant occurrences of chalcopyrite as disseminations, laminae and discordant veins in the interflow sediments of the mafic platform (3) under the rhyolitic accumulation (4) suggest that the carbonate/sulphide facies which overlies unit 4 and is overlain by the andesites of unit 5 should contain base-metal-rich portions as do analogously young stratigraphic zones in the Superior Province. The presence of abundant fragments of massive pyrite in the polymict felsic breccias on the south limb of the central anticline (Fig. 2) is taken as compelling evidence for proximity to a sulphide iron-formation.

Pyrrhotite-rich portions of flows in the oldest mafic unit (1) and the presence of nickel showings elsewhere in probably correlative stratigraphic units suggest an early Archean nickel-rich mafic interval similar to analogous stratigraphic zones in the Superior Province and West Australia.

Chemical and clastic sedimentary, felsic volcanic and hypabysal intrusive lithologies, very favourable for the occurrence of precious metal mineralization (4), are abundant. Units 4, 4A and their stratigraphic equivalents are particularly suitable.

Most of the youngest felsic phase, unit 6, appears to be structurally above the erosion surface in the Kaminak Lake area (Fig. 3). Nevertheless it contains several thin zones of sulphide facies iron-formation which, considered in the context of its stratigraphic youthfulness and disposition under Kaminak Lake, make it an attractive, albeit difficult, exploration target.

With the admittedly limited data on hand then, it appears that similar to other Archean assemblages, the Kaminak Group possesses an older nickeliferous mafic assemblage succeeded by younger felsic and sedimentary assemblages with associated base and precious metal indications.

The presence of thick, well bedded pyritic carbonate facies iron-formation well down towards the base of unit 1 (Fig. 1) constitutes an unresolved stratigraphic problem at the present time. The iron-formation closely resembles some known gold-rich carbonate facies iron-formation in the Superior Province.

The undoubted presence in this area of two distinct periods of deformation separated by perhaps one billion years, and experience gained through exploration and mining in the structurally and perhaps stratigraphically analogous Flin Flon belt strongly suggest that originally strata-bound or stratiform sulphide and precious metal mineralization will now occupy structurally favourable sites of unusual shapes which may be highly discordant with bedding orientation.

Conclusions

The Archean stratigraphy and tectonics of the Kaminak Group in the Kaminak Lake area of the District of Keewatin are highly analogous to that displayed in differentiated volcano-sedimentary complexes of the Superior Province. The great thickness, wide variety and extreme differentiation of lavas, the abundant presence of thick facies-differentiated iron-formation and its regional distribution, the many showings of base and precious metals and the complex structure inescapably lead to the conclusion that major ore fields, similar to those found in the Superior Province, should be present.

Future field and laboratory studies will undoubtedly outline other volcano-sedimentary complexes within the belt and help to extend or modify the present preliminary tectono-stratigraphic model.

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QUATERNARY GEOLOGY: ENVIRONMENTAL AND ENGINEERING GEOLOGY STUDIES

85. SALINE GROUNDWATER, CENTRAL RESEARCH FOREST, RAMSAYVILLE, ONTARIO

Project 680098

M. J. J. Bik, R. Herr*, and J. Salm**

During the 1968 field season a detailed survey of the Central Research Forest was initiated by the Division of Quaternary Research and Geomorphology at the request of the Forest Management Institute, Department of Fisheries and Forestry[1]. The discovery of the existence of artesian conditions in confined aquifers in the valleys of Black Creek and Borthwick Creek was one of several unexpected results of this survey. The aquifers are horizons of fractured, sensitive marine clay, that occur between 60 and 150 cm below the surface of the terrain and are from 5-30 cm thick. The overlying impermeable horizon consists of non-sensitive, stiff, isotropic, conchoidally fracturing marine clay. Heads of water of up to 90 cm above the base of the impermeable horizon were observed to exist in these aquifers, and locally water has been noted to rise to 10 cm below the surface of the terrain.

During the 1969 field season the Inland Waters Branch of the Department of Energy, Mines and Resources initiated a study of groundwater flow patterns below the Central Research Forest. The study was requested by the Forest Management Institute as the results of the survey of surficial deposits indicated that detailed knowledge of these patterns was required to develop a sound water and forest management program.

An investigation into the erratic behaviour of electric water level sensing devices used during the groundwater studies revealed a range of variability of conductivity in the order of 100-5,000 micromhos/cm in the valley environments. Information obtained from 7 piezometer nests indicates that salinity in an aquifer occurring at 40-60 m below the surface of the terrain may attain levels of 10,000 ppm, and that, if a measure of vertical permeability does exist in the clay that overlies this aquifer, portions of the Central Research Forest are subjected to a slow upward movement of rather saline groundwater.

The parts of this Forest that are located in the valleys of Black Creek and Borthwick Creek were planned to support over 100 different tree species in small forest stands. A cover of at least 175,000 trees, mainly hardwoods of 76 different species, was projected for the valley of Black Creek. Many species are rather exacting in their demands for depth of rooting zone above the groundwater table as well as for nutrient supply in the soil. The detection of salinity in the groundwater during the past summer may delay the progress of the plantation establishment until more pertinent information is available. Reliable estimates of the possible effect of saline groundwater flow on vegetation 15-20 years from now are an essential prerequisite for the commitment of substantial investment in a park of large size.

*Inland Waters Branch, Department of Energy, Mines and Resources.
** Forest Management Institute, Department of Fisheries and Forestry.

The Central Research Forest straddles a valley in bedrock (Fig. 1) that is masked by Pleistocene depositional and Holocene depositional and erosional morphology. The thalweg of the valley in bedrock has an elevation of 20-24 m a.s.l. This thalweg has a gravel train that is up to 3 m thick; the

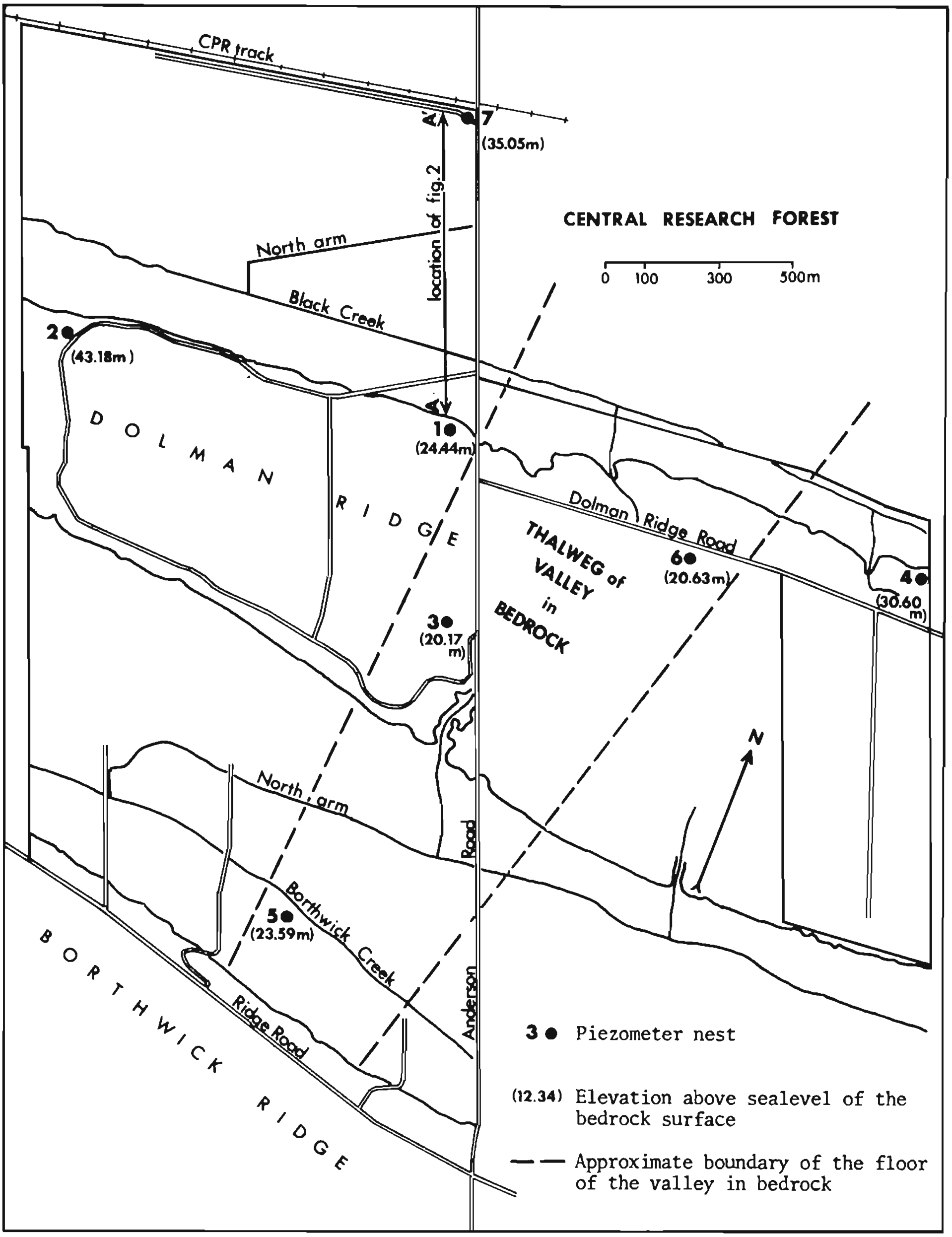

Figure 1. Location of features mentioned in text.

gravel train is covered by marine clay which locally attains a thickness of 60 m. The valleys of Borthwick Creek and Black Creek are incisions into the marine clay and attain depths of up to 15 m below the surface of the marine clay on Dolman Ridge and Borthwick Ridge. Peat and nonmarine, nonorganic deposits, usually less than 1 m thick, cover the marine clay in both valleys. Up to 5 m of mainly fine sand covers the marine clay on Dolman Ridge and Borthwick Ridge.

The water levels measured in the 7 piezometer nests and the water table found to exist on September 8, 1970, along a section from Dolman Ridge in the south, to the CPR track in the north, and approximately 70 m to the west of Anderson Road, indicate a near vertical direction of infiltration below Dolman Ridge, except for the 100 m of terrain that adjoins the escarpments. Near vertical ascent of groundwater occurs below Black Creek and an area extending approximately 250 m to the north of it, and below the area between both arms of Borthwick Creek. It would appear that all terrain below 66.75 m may be subject to upward groundwater flow. The area of Black Creek between the CPR track and the (canalized) north arm of Black Creek is subject to horizontal flow in a southerly direction. Slow northerly flow appears to occur in the gravel train that rests on the thalweg of the valley in bedrock. Pumping tests in the piezometers showed a rapid rate of recovery in those that extend to just above the bedrock level or that have their screens in the gravel train. Much lower recovery rates occur in piezometers that extend into the marine clay.

The distribution of groundwater salinity in that part of the surficial deposits where tree roots would be expected to develop, was measured along a line of auger holes made in 1968. If the groundwater contains salt to a higher degree than the tolerance level of the concerned tree species, rooting depth in the topsoil may be confined to the area above the highest seasonal water level. Commonly, however, the rooting depth extends to the lowest seasonal groundwater level and beyond. Root zone depths may therefore be so restricted as to be insufficient to support mature trees of big size. Furthermore, there is a difference between mere survival of a species at certain critical levels of salinity and the normal healthy development of this species; a struggle for existence may render a tree incapable of coping with infestations with various pathogens.

The auger holes were developed as groundwater observation wells during July 1970 by inserting 5.10 m of 7.5 cm OD PVC pipe, in each of which 2 holes of 4 mm diameter were drilled at 20 cm intervals; 30 cm of pipe was left protruding from the ground *. Conductivity of the groundwater was measured with a Solu-Bridge #RB-349, which was calibrated in the laboratory prior to field use. The results of observations on September 8 and 14, 1970, are recorded in Figure 2. The holes were pumped out on September 14th and salinity was measured in terms of the Hach Kit NaCl test in samples obtained from various depths. Initial recovery rates were established from observations during the period September 14-21, and a conductivity profile was again measured in each hole on September 21st.

The elevation of the groundwater table on September 8, 1970, would suggest the existence of three areas that are separate as regards groundwater

*Budget restraints did not permit the installation of piezometer nests. Consequently, no quantitative assessment can be made of salt transport as related to near-surface groundwater flow.

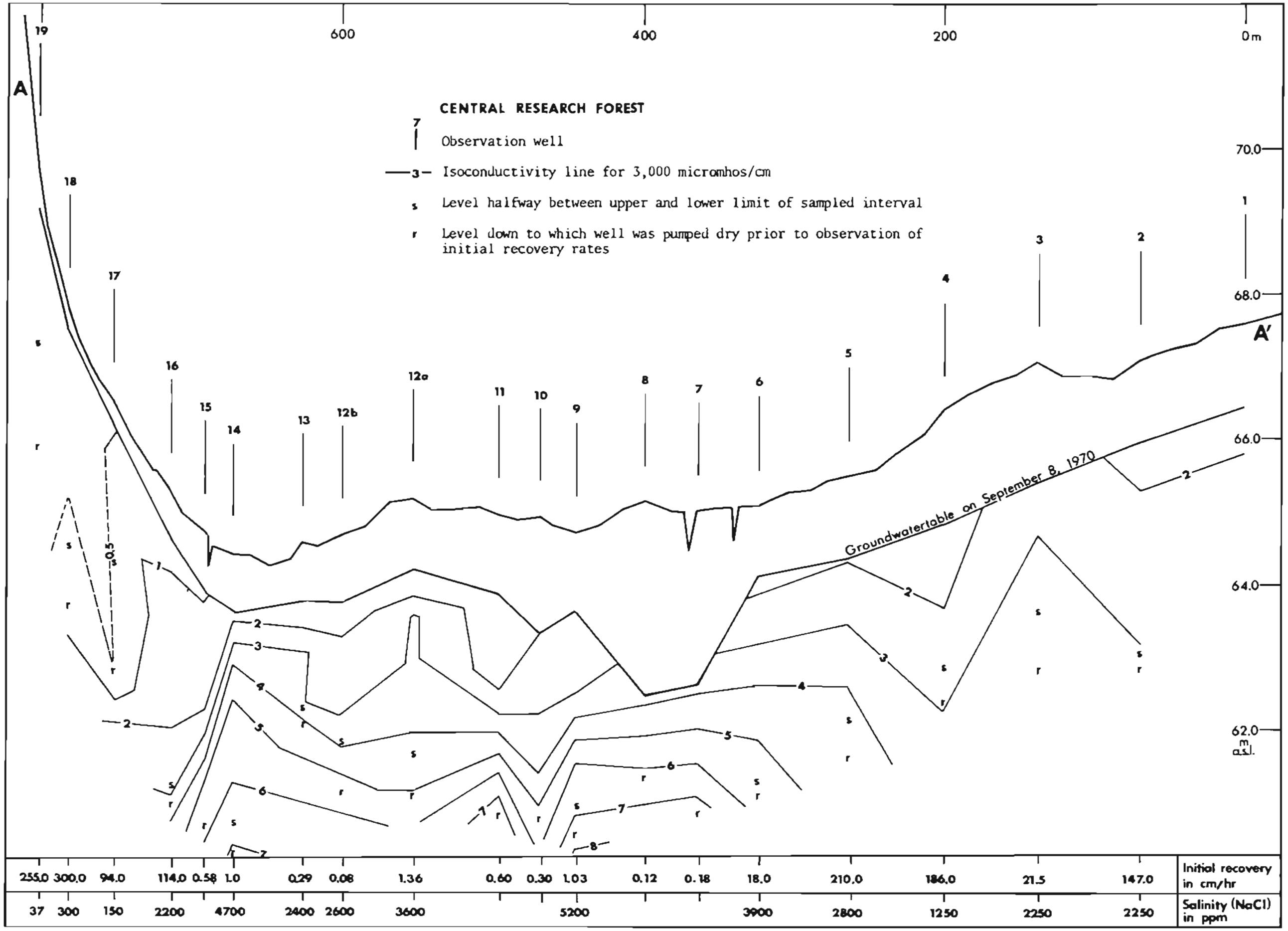

Figure 2. Vertical distribution of groundwater conductivity, salinity, and initial recovery rates in observation wells of section A-A.

table behaviour and permeability near the groundwater table; the areas spanned by holes 1-6 (subsection1), 7-15 (subsection 2), and 16-19 (subsection 3) as indicated on Figure 2.

The water levels in the holes of subsection 1 did not respond to changes in meteorological conditions and did not descend in response to evapotranspiration during the period September 8-14. A minor drop in the water table was observed on September 21st in holes 4 and 6, presumably in response to evapotranspiration. The conductivity of the water that collected in these holes immediately after pumping was approximately the same as the conductivity measured 15-20 hours later, when water levels prior to pumping had been re-established. The conductivity measured 10 cm below the groundwater table prior to pumping differed less than 100 micromhos/cm from the values obtained after recovery was completed on September 15th. This limited range of variation of conductivity after complete recovery suggests that the water that collected in the holes of subsection 1 was derived from a near surface horizon. The relatively rapid recovery suggests that the fractured, sensitive clay supplied the water for recovery. Conductivity of the water in this aquifer ranges from 1,900-2,800 micromhos/cm; the salinity ranges from 1,000-2,000 ppm (NaCl equivalent). On September 21st the conductivity profile in holes 2 and 3 did not differ more than 100 micromhos/cm from the values measured prior to pumping on September 14th; in holes 4, 5 and 6 the profile had been re-established down to a depth of 3 m below the surface; below this level, however, the values measured one week after pumping were up to 1,000 micromhos/cm lower than those measured at corresponding levels prior to pumping. It would appear that the gradual re-establishment of the conductivity profiles prior to pumping reflects diffusion of salt from the caly that surrounds the observation wells.

The second subsection is characterized by low initial recovery rates. Though the conductivity and salinity close to the water table on September 8th are comparable to the values measured in the first subsection, the conductivity measured 10 cm below the surface of the water that collected in these holes after pumping closely approximates the conductivity measured at the corresponding levels prior to pumping. The low initial recovery rates indicate the low measure of permeability that exists in the clay when unfractured. A fractured horizon occurs in the clay; between holes 10 and 15, however, it is not covered by an impermeable horizon. In holes 11-15, the groundwater table was located just below or in this fractured horizon on September 8th.

Conductivity measurements in the range of 4,600-7,300 micromhos/cm in the water that collected after pumping and salinity levels of 2,400-5,200 prior to pumping probably reflect the salinity of the groundwater in the clay, if not the salinity of the clay itself. The groundwater table in the area of holes 7 and 8 gradually descended to a level of 2.5 m below the surface in response to evapotranspiration during the summer. Vegetation in this area clearly has to be capable of permitting salinity levels in the order of 2,500-3,000 ppm. Similar or higher levels of salinity occur within 2.5 m below the surface in the area between holes 8-15; tree roots are expected to reach into this zone during exceptionally dry summers.

Finally, low conductivities were measured in subsection 3. The conductivity of the water collecting in these holes after pumping corresponded to the conductivity measured at a depth of approximately 2.5 m below the surface prior to pumping. The conductivity measured 15 hours after pumping at 10 cm below the water table, which had recovered completely in each hole of this subsection, was also slightly higher than that measured at a corresponding level prior to pumping. The comparatively high initial recovery rates may reflect flow through a thin mantle of sandy colluvial deposits on the northern slope of Dolman Ridge, in which the water table on September 8th was located. The increase in near surface conductivity may also reflect a substantial measure of flow through the horizon of fragmented clay, which in this subsection, is again covered by an impermeable horizon.

Though groundwater salinity in the third subsection does not impose limitations on the selection of species for planting, and minor restrictions would appear to apply to the first subsection, the distribution of salinity in the second subsection implies substantial restrictions in the choice of planting material. According to the literature, inasmuch as it refers to species that were chosen, the range of survival levels of the majority of species selected for planting in the Central Research Forest is 2,000-6,000 micromhos/cm in terms of chloride content; the minority of selected species tolerate 6,000-12,000 micromhos/cm.

The low recovery rates in piezometers that extend into the marine clay only, as well as the low recovery rates in subsection 2, suggests that the rate of upward flow of saline water through the marine clay is low indeed. Yet, in approximately 250 acres of the Central Research Forest the net movement of groundwater is upward and this results in accumulation of salt in the subsoil in areas where the drainage of atmospheric water through the upper soil horizons is insufficient to remove this salt. The efficiency of the drainage of this atmospheric water in this respect is not known.

Finally, as the net result of upward groundwater flow in part of the valley environment of the Central Research Forest appears to lead to a slow rate of increase in the salt content of the pore water of the subsoil, it would appear that the upper 20 m of the marine clay were deposited in a Champlain Sea that had probably lost a substantial measure of its initial salinity, presumably as a result of dilution by meltwater flow from farther west.

[1]Bik, M.J.J.: Surficial deposits and geomorphology, Central Research Forest, Ontario; in Report of Activities, Part A: April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 187-188 (1969).

86. ENGINEERING GEOLOGY AND MAPPING, WELLAND CANAL

30 L
30 M

Project 620052

E.B. Owen

Field work was concentrated on NTS sheets 30 L/14g (Welland Junction) and 30 M/3b (Allanburg) 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 ends where the new canal will join the existing Welland Canal almost all of the By-Pass has been excavated. Excavations for, and construction of, two tunnels which will pass beneath the By-Pass are presently underway. The excavation for the Welland River diversion has been stopped until construction of a temporary bridge across the excavation by the CNR has been completed.

Reports and geological sections describing the various soils encountered in five completed excavation contracts along the By-Pass have been prepared for use by The St. Lawrence Seaway Authority. Geological mapping has revealed differences between quantities of the various materials encountered in the excavations and those previously inferred from test borings and the occurrence of low shear strength materials at higher elevations in the excavations than the contractors had expected. The latter increased the cost of excavating to the contractors as it was necessary for them to change their method of excavation from scrapers to a more expensive drag line operation sooner than they had calculated.

Four bridges at Townline Tunnel are to be founded on bedrock by means of caissons. Bedrock cores from 26 caisson sites were examined and reported upon. Geological bedrock sections were prepared for each bridge site. In general, bedrock consisted of thin-bedded, argillaceous dolomite containing, in places, considerable gypsum. Zones of broken rock and those containing large quantities of gypsum were identified.

Surface mapping of surficial deposits was completed for map-sheet 30 L/14g and 30 L/14b (Lorraine). The latter consisted of about 5 square miles along the Lake Erie shoreline east of Port Colborne. As well, a geological section has been prepared for most of the By-Pass project which occurs in map-sheet 30 L/14g.

87. ENVIRONMENTAL GEOLOGY PROTOTYPE STUDY - OTTAWA-HULL REGION

31G/ Project 700049

J.S. Scott

The increasing expansion of Canadian cities in response to both population increases and the accelerated trend toward urbanization has focused attention on the requirement for land-use planning as a basis for the orderly and efficient development of urban-centred regions. Geological and related earth science data are significant components of the information required by planners, developers and administrators concerned with the multiple aspects of land-use in the expanding urban environment. Accordingly, geological activities concerned with the integration and synthesis of earth science data for the use of planners and administrators in the management of land resources, water resources and subsurface fluids, waste disposal, and usable rock and mineral materials have been designated by Frye as "environmental geology"[1].

The region centred about the cities of Ottawa and Hull, which was selected for a prototype environmental geology study, comprises an area of about 3,000 square miles (7,770 km^2) bounded by 45°00' - 45°38'N and 75°15' - 76°15' W. Most of the Ottawa-Carleton region and the National Capital area of Ontario and Quebec are contained within the boundaries of the study area.

The principal objectives of the project are to develop methods of compiling, evaluating and presenting geological information to meet the needs of planners, administrators and engineers. Emphasis is being placed on the distribution, thickness, spatial arrangement and physical properties of surficial and bedrock materials and on the development of a comprehensive information system to permit these data to be updated and displayed as required.

Field activities relating to the project during the 1970 field season were directed toward collection of borehole data and processing of these data for computer storage and manipulation, surficial geological mapping of the Kemptville (31 G/4) and Winchester (31 G/3, W 1/2) map-areas, engineering geological evaluation of bedrock materials and overburden thickness and seismic velocity evaluation of geological materials by the hammer seismic method.

J.M. Morin and J.R. Belanger (graduate students, University of Ottawa) collected a total of 3, 100 borehole logs from 14 agencies (federal and provincial government agencies and consulting engineers) in Ontario and Quebec. These data have been coded in a form acceptable to a computer-based Symap (synagraphic + mapping) program. Bedrock topography of the Blackburn (31 G/5L, 1:25, 000) map-area based on 237 data points derived from borehole and seismic data has been successfully produced in a trial with the Symap program. Additional capabilities of the Symap program to produce maps of other geological parameters are being investigated.

Determinations of depth to bedrock and velocities of overburden and bedrock materials were provided the project by the Exploration Geophysics Division (see Project 680037). A total of 2, 158 seismic data points were obtained throughout the project area south of the Gatineau Hills. These data will be incorporated with the borehole information for the determination of bedrock topography, drift thickness and correlation of physical properties of the materials encountered.

Surficial geological mapping at a scale of 1:50, 000 of the Kemptville (31 G/4) and Winchester (31 G/3, W 1/2) map-areas, which contain approximately 30 per cent of the southern part of the Ottawa-Hull region was completed by S.H. Richard. Surficial deposits within these areas comprise grey, calcareous, sandy till overlain by fossiliferous marine clays, sands and beach deposits of the Champlain Sea. In general, these deposits are thickest within the valley of the Rideau River, which occupies the central portion of the area. Both to the east and west of the Rideau Valley the flat-lying to gently dipping limestones and dolomites of Paleozoic age are either exposed or thinly covered by surficial deposits. A particularly well developed marine beach extends for approximately 19 miles north from South Gower (45°00'N, 75°33'W). Further detailed studies of this and other north-south trending beaches may provide useful information on the magnitude of postglacial uplift within the area.

Engineering geological characteristics of bedrock material within the Ottawa-Hull region were examined by J.A. Code. This work emphasized the textural and structural properties and weathering characteristics of the rock masses in situ. Assessment of the physical and mechanical properties of rock specimens for further qualification of the engineering geological classification of the bedrock materials will be made from NX core specimens to be obtained during a forthcoming drilling program. Data obtained from the engineering geological studies is being directed toward the assessment of: (a) the influence of bedrock topography on future land-use, (b) the effect of structural discontinuities in rock mass properties and utilization of rock as a construction or foundation material, and (3) the excavation characteristics of various rock types.

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[1] Frye, J.C.: Geological information for managing the environment; Illinois State Geol. Surv., Environmental Geol. Notes No. 18 (1967).

QUATERNARY GEOLOGY: INVENTORY MAPPING AND STRATIGRAPHIC STUDIES

88. GLACIAL GEOLOGY AND GEOMORPHOLOGY, SOUTHERN ELLESMERE ISLAND, COBURG AND DEVON ISLANDS, DISTRICT OF FRANKLIN

Project 670031 and 700028

W. Blake, Jr.

Field work in 1970 was a continuation of studies carried out in 1967 and 1968 on the glacial geology and geomorphology of southern Ellesmere, Coburg, and Devon Islands [1,2]. Base camp was at Cape Storm in southwestern Ellesmere Island. Local travel was by means of a Piper Super Cub equipped with low-pressure tires, and support was provided by Otter aircraft of the Polar Continental Shelf Project. Part of the field season was devoted to detailed sampling at several sites visited briefly earlier; new areas studied were Graham Island and various localities in western Devon Island - Radstock Bay, Thomas Lee Inlet, and Viks Fiord. At the end of August, through the courtesy of the Arctic Institute of North America and in connection with the "North Water" Project being sponsored by that organization, a Twin Otter flight was made to easternmost Ellesmere and Devon Islands, to Coburg Island, and to the Carey Islands, Greenland. Unfortunately, it was not possible to attempt a landing at the Carey Islands because of heavy fog.

As in 1967 and 1968, special attention was paid to collecting samples for radiocarbon dating, to studying the distribution , elevation, and stratigraphy of marine deposits, and to recording fluctuations in the marginal positions of glaciers by means of aerial photography. A particular effort was made to locate and sample driftwood, whale bones, and shells from the Cape Storm area, as, due to the abundance of organic remains from sea level to nearly 400 feet, this locality is ideally suited for studying the pattern of postglacial emergence. S.B. McCann, McMaster University, spent a week in the Cape Storm area and initiated a study of processes occurring at the modern shore to complement his investigations at Radstock Bay.

Five days were spent examining a section in southeastern Coburg Island where strata containing a well preserved and varied marine fauna alternate with beds that are nearly devoid of macrofossils. The latter beds are probably related to glacier advances. The highest beaches in this part of Coburg Island are over 70 feet a.s.l.

The highest postglacial shells found upvalley from the northwesternmost arm of Thomas Lee Inlet, Devon Island, were in deltaic deposits at approximately 235 feet a.s.l., whereas the highest occurrence south of the westernmost arm of Viks Fiord was at approximately 290 feet. These elevations are considerably lower than those at which the highest postglacial features occur farther north on Devon Island and along the coast of southwestern Ellesmere Island, where values close to 400 feet a.s.l. are not uncommon.

As noted in previous reports on field work [1,2], many glaciers are now at, or have recently retreated from, their maximum extent since general deglaciation over 8,000 years ago. Recession of the snout by calving is especially noticeable in the case of the largest tidal glacier at the head of

South Cape Fiord, as the position of the glacier was sketched by Glenister in 1953[3] and was photographed from the air in 1959, 1967, 1968, and 1970.

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[1]Blake, W., Jr.: Glacial geology and geomorphology, southeastern Ellesmere and northwestern Devon Islands, District of Franklin; in Report of Activities, Part A May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, pp. 154-155 (1968).

[2]Blake, W., Jr.: Glacial geology and geomorphology, southeastern Ellesmere Island and Coburg Island, District of Franklin; in Report of Activities, Part A April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, pp. 188-189 (1969).

[3]Glenister, B. F.: Sydkap Fiord; in Fortier; Y. O. et al.: Geology of the north-central part of the Arctic Archipelago, Northwest Territories (Operation Franklin); Geol. Surv. Can., Mem. 320, pp. 284-292 (1963).

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89. SURFICIAL DEPOSITS, HERSCHEL ISLAND, YUKON TERRITORY

Project 690047

M. Bouchard

The surficial sediments consist principally of glacially deformed marine deposits which comprise gravels, sands, silts, silty clays, and sand-silt laminae. Pockets of gravel are found throughout the island and interbedded sand and gravel occur in conspicuous exposures in cliffs at Collinson Head at the eastern margin of the island. Deformation in the marine sediments includes tilting, folding, and shearing of the beds. Shear planes are particularly well developed in the fine-grained deposits.

Till is exposed only in the southwestern part of the island and is characterized by fine matrix and local abundance of boulders. Glacially transported boulders are scattered on the surface throughout the island.

The deformed marine beds are almost everywhere covered by an unfossiliferous mantle of silt 5 cm to 1 m thick. Locally pebbles are scattered over the silt, some of which were derived from the Rapitan Formation of the Mackenzie Mountains.

The occurrence of permafrost throughout the area is demonstrated by the presence of polygonal patterns, soil circles, ice wedges, etc. The moisture content of the frozen sediments was systematically surveyed. Changes in the thickness of the active layer were measured at three observation stations, from July 19th to August 24th, at 2-day intervals.

90. WISCONSIN STRATIGRAPHY, NORTH SHORE OF LAKE ERIE, ONTARIO

Project 690052

40 I

A. Dreimanis

Most of the field season of 1970 was spent measuring and correlating sections along the Lake Erie cliffs, up to 140 feet high, between Port Stanley and Port Bruce, and along Kettle and Catfish Creeks. The correlation was aided by a continuous sequence of colour photos taken from a boat along the lake cliffs between New Glasgow and Port Burwell. These photos will also help to interpret the various types of cliff erosion and slumping.

Most of the deposits investigated were of Late Wisconsin age. Mid-Wisconsin interstadial lacustrine sediments containing fine-grained plant detritus were found only in the Catfish Creek valley west of Jaffa. Pine and spruce dominate among the pollen of this interstadial deposit, according to the preliminary pollen analysis by A.A. Berti.

In the area under study in 1970, the oldest of the Late Wisconsin drift units, the Catfish Creek Drift, is exposed only in the valleys of Catfish Creek, its tributaries, and the Kettle Creek valley, particularly in the former. There, in some sections (in a buried moraine?), the Catfish Creek Drift is at least 100 feet thick, and consists of two major subunits. The lower, containing ice-thrust deformational structures, was deposited by the glacier coming from north and northwest (the Huron lobe?). The following later glacial advances which deposited the upper layers of the Catfish Creek Till, were from northeast and southeast.

The Catfish Creek Drift is in a few places separated from the overlying Port Stanley Drift by deltaic, littoral, and lacustrine deposits which are assigned to the Erie Interstade. In addition to an already known interstadial section in the Catfish Creek valley, 1.8 miles northeast of Sparta (erroneously interpreted as possibly of Lake Arkona age by Dreimanis and Packer[1], re-interpreted by Dreimanis[2], when Port Stanley Till was found on top of the gravels), a new section was found in the Nineteen Creek valley 1.5 miles south-southeast of New Sarum.

The next younger, the Port Stanley Drift, consists of at least three major till sheets and several minor till layers, interbedded with varved lacustrine sediments of Lake Maumee. They are exposed most clearly along the Lake Erie Cliffs in a shingle-like arrangement, very gently dipping up-glacier (southeast). The earliest glacial advance was from the east or east-southeast, and the subsequent ones were from the southeast. The minor till sheets, one of them traceable for several miles along the lake cliffs, appear to be annual deposits of short-distance re-advances of the Erie lobe which was partly afloat, like an ice shelf, in Lake Maumee. Direct continuation of annual till layers into the winter laminae of thick varves was noted in several places. Detailed studies of the inter-relationship of deposition of till and varved sediments were done at several sections, and N.-A. Mörner undertook geochronologic investigations of the varved sediments. His studies were supported by the National Research Council of Canada grant A-4215 to the author of this report.

About two hundred samples of glacial and related meltwater deposits were collected for laboratory investigations. The quantitative lithologic analysis of nearly all pebbles collected, and some of the granulometric and carbonate analyses of the fine fractions have already been done, but their results have not yet been evaluated.

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[1]Dreimanis, A., and Packer, R. W.: Field trip guide, friends of Pleistocene geology eastern section 22nd reunion, May 16 and 17, 1959, London, Ontario, pp. 1-23 (1959).

[2]Dreimanis, A.: Pre-Maumee lake stages of Wisconsin ice age in Lake Erie basin; Abstracts, Tenth Conf. Great Lakes Research, p. 33, (1967).

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91. QUATERNARY GEOLOGY, WINNIPEG (EAST-HALF)

62 H E½ √

Project 700053

M. M. Fenton

Field work consisted of (i) examination of the surface deposits and the drilling of about 300 hand auger holes (3 ft. deep), and (ii) the drilling of 25 power auger holes 10 to 100 feet deep. Though the work is not sufficiently advanced to make definite interpretations four general units are distinguishable within the map-area, (i) lacustrine clay in the west, (ii) till in the west-centre, (iii) lacustrine sand in the east-centre, and (iv) outwash in the east. The lacustrine clay forms a level plain, part of the Red River basin of glacial Lake Agassiz. The till is silty and calcareous and forms a low west-facing scarp at the boundary of the lacustrine clay. Subsurface data indicate the till lies above stratified deposits and below the lacustrine sand. The outwash, comprising sand, with some gravel at a depth of 70 feet, is some 50 to 200 feet higher than the lacustrine sand.

One section yielded plant remains and indicated there may be more than one till in the area.

92. QUATERNARY GEOLOGY INVENTORY, SOUTHERN LABRADOR

3D
12P √
13

Project 690043

R. J. Fulton, D. A. Hodgson, Gretchen V. Minning

The second season of inventory mapping of the Quaternary geology of Labrador south of the 56th parallel was successfully completed. Field mapping covered sheets 13 A, B, D, G, I, J, and K and parts of 3 D, 12 P, 13 C, 13 E, 13 L, 13 N, and 13 O. Deposit landform maps are being compiled on uncontrolled photo mosaics at a scale of 1:50, 000 for open file distribution. This work was requested by the Newfoundland Department of Mines, Agriculture and Resources which is currently undertaking a forest inventory-land capability study of the area.

A helicopter was used and field work was conducted in a manner similar to that sucessfully used by the Geological Survey in mapping bedrock.

A map adequate for immediate land classification needs can be produced in this way but it is felt that modifications to this approach, taking into account some of the peculiarities of Quaternary mapping units, would benefit future projects.

Little detailed information pertaining to Quaternary history was found. Major belts of ice-marginal deposits were located in several areas but their significance and age are unknown.

93. SURFICIAL GEOLOGY, SOUTHWEST CAPE BRETON ISLAND, NOVA SCOTIA

Project 700056 11F J

D.R. Grant

This study of the surficial geological environment is the first large-scale, systematic, detailed-reconnaissance survey of its kind in Nova Scotia. Cape Breton Island, particularly its southern or lowland part, was chosen because no surficial mapping had been done, and because of an immediate need for knowledge of the nature, distribution, thickness, and origin of surface forms and materials to aid the current search for base metals non-metallic minerals, groundwater, and construction materials. Mapping commenced from the designated industrial growth area centred on Strait of Canso, with reconnaissance of adjoining areas, and is planned to progress eastward around Bras D'Or Lake to Sydney.

Surface materials comprise mainly glacial debris, with restricted but significant waterlaid deposits. Till is thin and discontinuous on the crystalline uplands, but averages several tens of feet over the intervening lowlands underlain by softer clastic and evaporitic rocks. Typically the till is a reddish brown pebbly clay, apparently derived from large areas of reddish brown siltstones and sandstones. However, essentially the same till is widely spread over equally large areas that are underlain by rocks that are not reddish brown and are coarser, with relatively minor changes in colour, stone content and lithology. This homogeneity is regarded as a result of the varied transport history.

Large deposits of sand and gravel occur widely on the west slopes of Creignish Hills, particularly between Craigmore and Creignish, served by road, rail and sea transport, and convenient to the chief demand area at Strait of Canso. Additional deposits along River Inhabitants include an esker near its mouth, and broad expanses of outwash and modern floodplain gravels in the upper reaches. Similar alluvial deposits occur along River Denys together with large proglacial (?) gravel fans where its tributaries debouch from Creignish Hills. Numerous smaller glaciofluvial bodies are scattered over the neighbouring lowland. In view of the abundant alternate sources, the present practice of exploiting modern beach and river deposits appears quite unnecessary, and indeed constitutes a serious if not irreversible disturbance of hydrology and ecology.

Abundant evidence was gathered relating to the sequence and direction of ice movements to which the surface deposits owe their origin, composition and form. Striations are common because of the generally hard rocks and the number of fresh exposures created by shoreline erosion and recent road improvement. Still, a deliberate effort was made to excavate and expose additional glaciated surfaces wherever practicable. It is usually possible to determine the absolute direction of ice flow because, together with the usual stoss-and-lee asymmetry and differential plucking, most exposures were of clastic rocks such as conglomerate, agglomerate and tuff that commonly show minature crag-and-tail. Several distinct patterns of ice flow are evident. Their relative ages are commonly indicated by crossed striations, and many large definitive outcrops which, because of the stoss-and-lee principle, preserve up to three separate stossed facets that in turn often show crag-and-tail markings.

A west to east flow, evidenced mainly in the southern area, was apparently the earliest, and may represent the initial advance. On Isle Madame, where an irregular surface of hard rock with east-west structure has favoured preservation of indicators of this movement, the eastward-pointing scoured surfaces are commonly overlain by brick-red or salmon-red till probably derived from red beds offshore.

The second and main phase was a strong flow to the north and north-west. This is believed to represent the last glacial maximum because more than three-quarters of all ice flow direction measurements gave this indication, and because the trend is found over the entire area, over the highest hills (ca 1,000 feet) from Atlantic Ocean to Gulf of St. Lawrence. Shell fragments, presumably from marine sediment incorporated as the ice moved landward from Scotian Shelf, are widespread (though present in minute quantities) in the tills of Isle Madame and lower River Inhabitants valley. A concentration of such fragments in the River Inhabitants esker at Grantville gave an apparently finite radiocarbon age of 32,100 ± 900 years (GSC-1408). Whether the age is finite as measured, or much greater, it is nonetheless consistent with the hypothesis of ice moving northward onto Cape Breton Island bringing rock types from offshore, as well as material deposited during the previous nonglacial period. The lateral extent of the movement is considerable. Thirty northward indicators were mapped on the mainland as far west as Antigonish and no limit was found. To the east, twenty northward indicators were previously mapped by the writer. These were interpreted by Prest and Grant[1] as northward deployment of the early eastward flow. Goldthwait (ref. 2, p. 87) also suspected a centre on the shelf, but rejected the idea simply because other centres had apparently not formed on highlands. Whatever the source of the ice, and the reasons for its localization, there is now overwhelming evidence of northward flow over all of southern Cape Breton.

The third and probably final phase included a variety of movements seemingly related to thinning and recession. South of a line through West Bay, the last flow was southeasterly. The movement was generally less intense, but locally it removed earlier deposited tills of foreign derivation and generated a till of more local provenance. This late, local reversal of flow has been attributed by Prest and Grant[2] to late-glacial rise of sea level that calved into the ice cap along shelf basins (here the Chedabucto basin), effectively reversing flow in the southern portion of the ice cap by drawdown, and shifting the ice shed inland. North and west of Creignish Hills, latest flow became easterly and the ice margin retreated downslope to the west judging by the trend of corrugated moraine, by numerous kame terrace and belts of ice contact gravel with northward current structures, across three divides. East and south of Creignish Hills, over River Denys lowland and

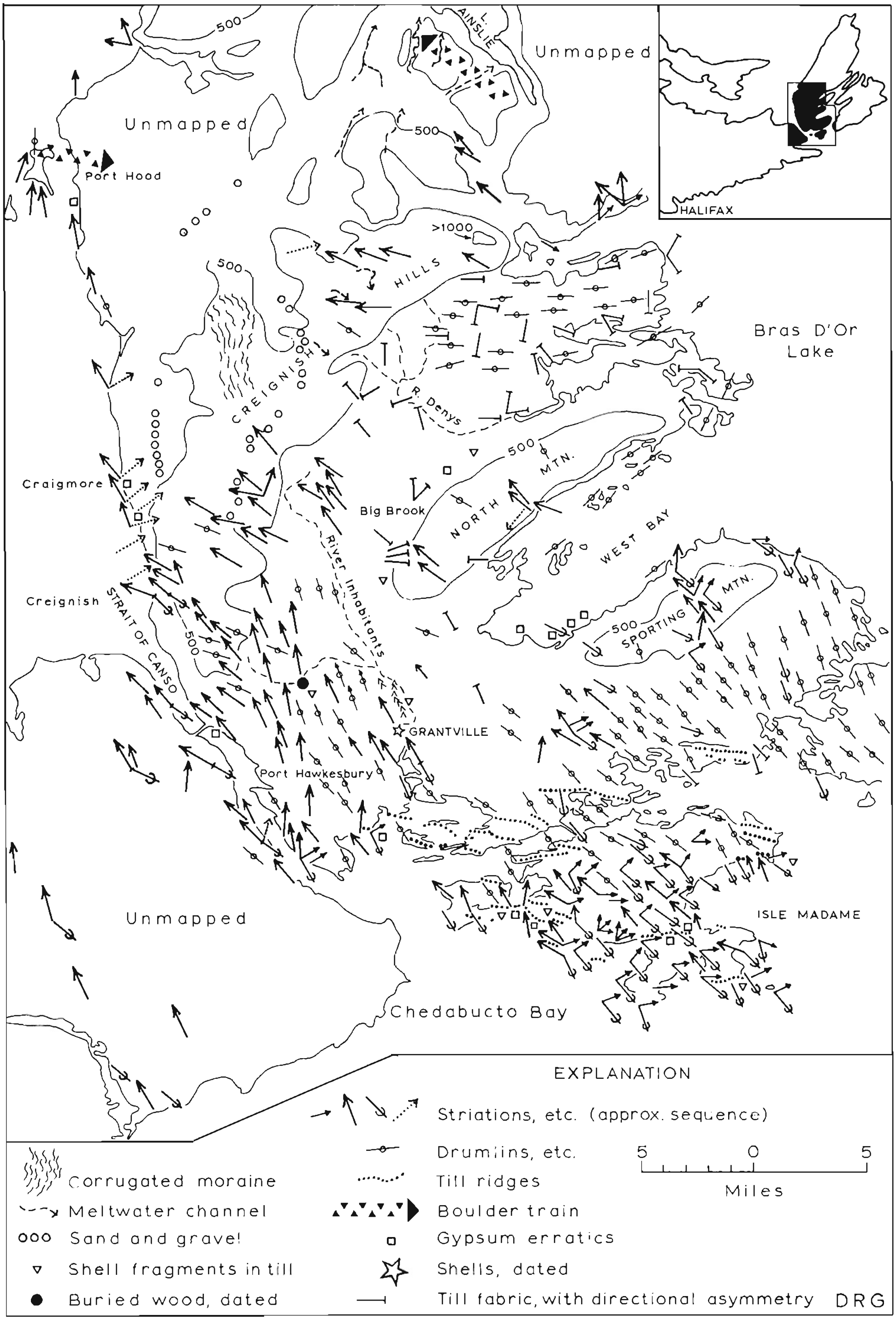

Figure 1. Glacial features, southwest Cape Breton Island, Nova Scotia

western Bras D'Or Lake margins, evidence of final retreat is less consistent. Striations point southwest and the till surface bears east-west streamlining, but till fabrics, specifically the stossing and imbrication of till boulders, is east-pointing.

The divergent glacial transport accounts for the homogeneity of tills in the area, in contrast to the similarity of tills to bedrock lithology elsewhere in Nova Scotia. Figured are two boulder trains cited by Norman[3]. No such localized dispersions were noted in the map-area, except for the wholesale northward transport of crystalline rocks from Creignish Hills onto the red bed terrain, and scattered occurrences of gypsum float around West Bay, Isle Madame and River Inhabitants.

Abundant glacial debris, disruptive topography, and shifting ice flow were thought to favour the burial of preglacial valleys and their alluvium, thus providing groundwater aquifers for the current community water supply program. However, hammer seismic profiles across major stream alignments on the west coast showed disappointingly thin cover over bedrock. Similarly the two- to three-mile wide floor of upper River Inhabitants valley has less than 100 feet of overburden.

One buried depression containing preglacial deposits has been discovered that is of major, if academic, interest. A western branch of River Inhabitants exposes 30 feet of till (with shell fragments) overlying at least 15 feet of organic sand with interbedded peat and wood, enclosed by bedrock walls. The wood is more than 39,000 years old (GSC-1406). This is the same occurrence discovered by Sir William Dawson (ref. 4, pp. 50-51), that has eluded searchers for 120 years.

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[1]Prest, V. K., and Grant, D. R.: Retreat of the last ice-sheet from the Maritime Provinces-Gulf of St. Lawrence region; Geol. Surv. Can., Paper 69-33, 15 pp. (1969).

[2]Goldthwait, J. W.: Physiography of Nova Scotia; Geol. Surv. Can., Mem. 140, 179 pp. (1924).

[3]Norman, G. W. H.: Lake Ainslie map-area; Geol. Surv. Can., Mem. 177, 103 pp. (1935).

[4]Dawson, Sir J. W.: Acadian geology (first edition), Edinburgh, 388 pp. (1855).

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94. QUATERNARY GEOLOGY, TASEKO LAKES MAP-AREA, BRITISH COLUMBIA

92O J

Project 680129

J. A. Heginbottom

This project was initiated in 1968 to provide general areal information on the Quaternary deposits and landforms, particularly for forest land inventory and ARDA classification. During that year the northeast quarter of the area was mapped[1]. In 1969 the mapping was extended to cover the southeast quarter[2], and during the past field season the western half of the map-area was completed. The mapping has been done primarily by the interpretation of aerial photographs, with the field component of the project being devoted largely to ground checking and the collection of samples for laboratory examination. Field work in the mountainous southwestern part of the map-area was restricted to a single helicopter traverse southwest from Williams Lake into the head of the Tchaikazan Valley.

The Taseko Lakes map-area lies astride the boundary between the Interior Plateau of British Columbia and the Coast Mountains. The northern part of the map-area consists largely of the rolling to level upland of the Fraser Plateau, marked by isolated hill masses rising above the general plateau level, and dissected by the deeply incised valleys of the Fraser and Chilcotin Rivers. On the southeast, the plateau gives way to the Camelsfoot Range of the Interior System Mountains and on the southwest to the Chilcotin Ranges of the Coast Mountains[3].

Bedrock is exposed in the hill and mountain masses and in the upper sides of the deep valleys, but much of the area is covered by a varying thickness of unconsolidated material. The bedrock of the area was studied by Tipper[4], Jeletzky and Tipper[5], and Trettin[6].

The bedrock valleys of the Fraser and Chilcotin Rivers apparently were eroded in preglacial time. They were filled with up to 1,800 feet of sediment comprising alternating layers of very hard grey till, diamictite and stratified silts. The fill is most extensive at about 51°35'N, where the bedrock valley is over four miles wide. To the north the bedrock valley is much narrower, about one mile wide at 52°N, and the fill is consequently less voluminous. The valley also decreases in width to the south, particularly south of Crows Bar, where the river flows in a deepening gorge between the Camelsfoot and Marble Mountains.

The extensive cover of ground moraine varies from less than one foot to at least 15 feet thick. It is formed of a greyish brown, stony, sandy to sandy-loam till, with a low to very low clay content. This till is normally firm and compact but not hard. On working, it becomes quite friable when dry. The upper layers of the till are frequently paler in colour, a feature associated with a lime concentration. In many areas the till surface is marked by spreads of boulders, which are up to five or six feet long, are commonly subangular to subrounded and vary from almost completely buried to entirely exposed. The surface form of the ground moraine varies considerably.

Within the valleys of the mountains and upland areas small till and glaciofluvial deposits have been mapped as one unit. Esker systems within the map-area are all associated with meltwater channels. Numerous extensive systems of meltwater channels throughout the area include true marginal or submarginal channels, and superglacial or englacial channels superimposed from the downwasting ice. Deposits of glaciofluvial sand and gravel are also associated with these meltwater channels. In and beside the valley of the Chilcotin River, upstream from Hanceville a complex area of meltwater channels, eskers, crevasse fillings, pits, mounds and kames is interpreted as the site of a remnant mass of stagnant ice situated in the Chilcotin Valley. Meltwater drained along the margins, through and under this ice mass, which gradually shrank down into the valley.

Lake deposits occur locally in a few, east bank tributary valleys of the Fraser Valley, where they apparently formed behind dams of morainic material. No evidence of a system of proglacial lakes was found.

A number of corries occur within the Camelsfoot and Chilcotin Ranges. They commonly face north to northeast, and several are associated with deposits of recent alpine glaciers. A number of glaciers exist in the extreme southwest of the area and appear to have retreated in recent years.

Following the melting of the Fraser ice sheet, the main rivers cut down into the valley fill, with apparently few still-stands. During such periods, extensive alluvial fans were initiated, and in many areas have coalesced to form bahadas. As river incision has been resumed, these fans are now being dissected. Many fans are being eroded at the bottom while continuing to build up at the head.

Modern stream deposits are not widespread. The major rivers exhibit no flood plain development except for three recent meander cut-offs on Chilcotin River, and a broad open alluvial plain in the Chilcotin Valley upstream of the Stoney Indian Reserve - the site of the stagnant ice mass described above.

Swamp and bog deposits are also restricted. The best development is in upland valleys and some of the shallower valleys cut in the plateau. In many cases, swamps owe their initiation to beaver activity.

A shallow and patchy layer of fine, brown, windblown material, generally about 12 inches thick, but ranging from a few inches to three feet, covers much of the plateau area, the valley fill and the alluvial fans. This material is too widespread, patchy and variable in thickness to form a mappable unit. No active sand dunes are known within the area. However, narrow lines of fossil lip dunes were found along the edges of several benches of Fraser Valley. They are too degraded to indicate paleo-wind directions.

Landslides, slumps, earthflows and their associated deposits are widespread. The deposits are of mixed materials ranging in age from early Tertiary, and possibly older, to Recent. The landslides themselves are also of various ages. Some may have occurred as the ice melted and ceased to support certain slopes. Most others are apparently the results of stream incision and undercutting. These processes and the consequent slope failures are continuing still. The risk of landsliding is an important factor which must be fully considered in the design of any engineering or construction activities in this area, particularly activities in the Fraser Valley.

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[1] Heginbottom, J.A.: Quaternary geology of the Taseko Lakes map-area, British Columbia; in Report of Activities, Pt. A, April to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 201 (1969).

[2] Heginbottom, J.A.: Quaternary geology of the Taseko Lakes map-area, British Columbia; in Report of Activities, Pt. A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 176 (1970).

[3] Holland, S.S.: Landforms of British Columbia: a physiographic outline; B.C. Dept. Mines Petrol. Resources, Bull. 48, 138 pp. (1964).

[4] Tipper, H.W.: Preliminary map, Taseko Lakes area, British Columbia; Geol. Surv. Can., Map 29-1963 (1963).

[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, 218 pp. (1968).

[6] Trettin, H.P.: Geology of the Fraser River Valley between Lillooet and Big Bar Creek; B.C. Dept. Mines Petrol. Resources, Bull. 44, 109 pp. (1961).

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95. QUATERNARY GEOLOGY, KINGSTON, ONTARIO

Project 680062

31C N½ ✓

E.P. Henderson

Striae and other associated ice-flow features indicate ice movement about 15 degrees west of south over the region north from Marmora to Coe Hill. This direction is almost perpendicular to the extensive Dummer moraine[1] which runs along the southern boundary of the area, and is in good agreement with previously recorded ice movements to the east, in the Madoc-Bancroft region[2].

Glacial deposits are the most widespread unconsolidated materials in the area and characteristically are thin and discontinuous. Locally, however, the till is more than 10 feet thick, particularly on the flanks of hills or in morainic areas. Several irregular areas near the southern border of the district north of Marmora are underlain by Paleozoic limestones rather than the mixed Precambrian rocks present over the rest of the region. Stony knobs and ridges of Dummer terminal moraine, which lies largely to the south of the mapped area, are present in the two larger of the limestone areas, one in the heavily-wooded southwest corner and the other extending for two miles northwest from Deloro. In areas of well developed morainic topography, local relief may exceed 40 feet with till accumulations that must exceed 50 feet in thickness. Several atypical isolated drumlins, the largest of which is 150 feet high and 2 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 one place have formed tabular outwash deposits of considerable extent. These form a series of large sand-gravel flats along a major north-south spillway system extending from a few miles northwest of Coe Hill into the Crowe River drainage east and southeast of Chandos Lake. They are best developed along the southern parts of the spillway where sands and gravels also underlie extensive coterminous tracts of swamp. Although esker and kame deposits to date have been more extensively exploited for sand and gravel than have the flat-lying outwash, a larger reserve of commercial materials should be found in the latter type of deposits.

Although glacial Lake Iroquois extended across most of eastern Ontario as the Wisconsin ice-sheet retreated to the north and northeast, evidence of subaerial erosion and lack of lacustrine deposits north of Crowe Lake near the southern boundary of the map-area, at elevations below the maximum recorded farther south for Lake Iroquois, indicates that lake levels in the Ontario basin had fallen below those elevations when the damming ice still stood south of the Marmora-Madoc region, probably at the position of the Dummer moraine.

Small areas of lacustrine deposits that do exist north of Crowe Lake are apparently some 100 to 150 feet below level of the Lake Iroquois water-plane. This suggests that meltwater from a low-level spillway channel to the north entered a lower level lake which formed soon after the Lake Iroquois stage. This water body may have been Lake Frontenac, considered by Mirynech[3] as the shortest-lived post-Iroquois stage in the Ontario Basin, or perhaps an even lower post-Frontenac stage.

Rotted coarse-grained granitic bedrock, present intermittently over several square miles 5 to 10 miles north of the village of Oak Lake, was exposed to depths as great as nine feet in roadcuts and numerous small borrow pits formed by removal of the rotted bedrock for road maintenance. The short time available for the formation of such a deep weathering profile in these rocks suggests the rotted bedrock may represent part of a deep regolith, developed during a previous interglacial, or even earlier, time, which has escaped erosion during the subsequent glaciation of the area.

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[1] Chapman, L.J., and Putnam, D.F.: The physiography of southern Ontario; Univ. Toronto Press (1951).

[2] Henderson, E.P.: Quaternary geology, Kingston (north half), Ontario; in Report of Activities, Pt. A April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 176-178 (1970).

[3] Mirynech, Edward: Pleistocene geology of the Trenton-Campbellford map-area, Ontario; unpubl. Ph.D. thesis, Univ. Toronto, 176 pp. (1962).

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96. QUATERNARY STRATIGRAPHY, OLD CROW BASIN AND PORCUPINE RIVER VALLEY

Project 680031

O. L. Hughes

A single section on the south bank of Porcupine River was sampled in detail to supplement samples collected in 1968. Samples are to be distributed to Dr. S. Federovich for pollen analysis, to Dr. D.E. Delorme (Inland Waters Branch) for identification of ostracods and to Dr. L.V. Hills (University of Calgary) for identification of spruce cones.

97. QUATERNARY RECONNAISSANCE, NORTHWEST DISTRICT OF MACKENZIE

General ✓

Project 690046

O.L. Hughes

Helicopter-supported ground and air observations were made during a 2-week period to supplement work done in 1969 (in conjunction with Operation Norman 2)[1]. Dr. M. Kuc co-operated in the examination of selected organic terrain sites in an effort to improve interpretation from high level airphotos of such terrain.

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[1] Hughes, O.L.: Quaternary reconnaissance, northwest District of Mackenzie; in Report of Activities, Pt. A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 178-179 (1970).

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98. QUATERNARY STRATIGRAPHY, SOUTH SASKATCHEWAN RIVER, SASKATCHEWAN

72K ✓
72N

Project 700058

P.F. Karrow

Some of P.P. David's sections were visited, including the reference section for the Prelate Ferry soil[1], and additional till samples were collected for analysis. A new sample of the paleosol was also collected for radiocarbon dating. Joint field excursions were carried out with A.M. Stalker, C.S. Churcher, and E.A. Christiansen to the outstanding vertebrate fossil localities near Medicine Hat and Swift Current as well as to the exposures of multiple till sequences between Saskatoon and Swift Current.

Additional sections were described along South Saskatchewan River between Estuary and the former Pennant Ferry. The most revealing sections were found between Prelate Ferry and Lancer Ferry. Although exposures were searched, no new vertebrate localities were discovered except for a few possibly old fragments of bone found in late glacial river terraces between Empress, Alberta and Leader, Saskatchewan. Correlation between Saskatchewan sequences farther north and the sequence near Medicine Hat will therefore have to depend on till sheet stratigraphy. Field criteria appear inadequate for correlation and laboratory analyses of till samples appear to hold the only hope.

At least four till sheets are exposed along South Saskatchewan River, often being separated by only a few feet of stratified material. Much thicker stratified beds occur near Prelate Ferry. Earlier drilling by the Saskatchewan Research Council has indicated the presence of more till layers below river level (Christiansen, pers. comm.). A deep bedrock valley underlies the river downstream as far as Lancer Ferry so that bedrock is not generally exposed. Bedrock is commonly exposed, however, near the former Cabri and Pennant Ferries. Increased shore erosion around the head of Lake Diefenbaker may expose older Quaternary deposits. The deposits to the west along the river (between Leader and Lancer Ferries) are probably of Late Quaternary age.

[1] David, P.P.: The Late Wisconsin Prelate Ferry paleosol of Saskatchewan; Can. J. Earth Sci., vol. 3, No. 5, pp. 685-696 (1966).

99. QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF THE ASSINIBOINE RIVER VALLEY AND ITS TRIBUTARIES, MANITOBA

Project 660033

R.W. Klassen

Field work entailed some stratigraphic drilling, detailed sampling of Quaternary sections along the Assiniboine River Valley and its tributaries and the preparation of a route log for part of the 1972 I.G.C. (C22) field excursion.

Five boreholes drilled within the anomalously broad segment of Assiniboine River Valley northwest of Alexander, Manitoba indicate this part of the valley is younger than the narrower upstream and downstream parts. Some 60 feet of valley fill here overlies shale bedrock whereas the narrower segments contain some 160 feet of fill overlying bedrock at a lower elevation. The diversion of Assiniboine River Valley in this locality appears to be the result of a local east to west readvance of a late Wisconsin ice lobe in the Agassiz basin. Wood collected at a depth of 30 feet in one borehole may provide a minimal radiocarbon age for the time of diversion.

100. SUBMERSIBLE TRIALS AND LAKE ONTARIO STUDIES

Project 680055

C.F.M. Lewis

Field work on the Quaternary geology of the Great Lakes was limited this year to a few short activities.

During May the writer, with B.V. Sanford (Crustal Geology Division), participated in the trials in the Great Lakes, of Pisces III, the Department of National Defence's submersible. The trials, supported by personnel and vessels from the Canada Centre for Inland Waters were conducted at the entrance to Georgian Bay and in central and western Lake Erie. Dr. P.G. Sly of the Limnogeology Section, Canada Centre for Inland Waters, co-ordinated the dives, which were made by a number of workers from the Great Lakes scientific community. Pisces III's single sphere carried two observers in addition to a Royal Canadian Navy pilot. Facilities included two mechanical manipulators (one fully articulated), high intensity illumination, underwater television with video tape recorder, an instrument-boom-equipped pH/Eh, DO, temperature sensors, and current meter.

In the clear, deep waters of Georgian Bay it was found possible to observe, photograph and even sample the lake bed in extreme detail. Local mapping would be feasible although the slow, horizontal speed of the submersible precludes its effective use as a long-distance traversing vehicle.

Thin- and thick-bedded Silurian dolomites were recognized from their weathering characteristics on the lake bed near Flowerpot Island. These strata, the Eramosa and Guelph beds, respectively, were correlated with their known occurrences onshore in the adjacent Bruce Peninsula.

The shallow turbid waters of Lake Erie provided a greater challange to submersible users. Poor visibility often made direct port-hole viewing of the lake bed impossible. Useful detail could be resolved, however, and photographic and sampling operations directed by using a television camera mounted on one of the external manipulators. Pisces III, essentially a deep water submersible (3, 600 feet depth capability), had great difficulty maintaining its trim and stability in shallow depths less than 100 feet.

It was felt that the trials were particularly successful in demonstrating the submersible's great potential for geological and other studies in inland seas. Among many possible applications, the submersible is invaluable for (1) the in situ study of lake bed features having horizontal dimensions of tens of centimetres to tens or one hundreds of metres; (2) studies of the relation of the lake environment to local sediment distribution, including the provision of ground truth for acoustic sediment surveys; (3) the provision of stratigraphic control at submerged outcrops for the extension of bedrock geology under the Great Lakes.

A reflection seismic profiling survey of the Toronto Waterfront between Mimico and Scarborough in Lake Ontario was undertaken jointly in October by the Limnogeology Section of Canada Centre for Inland Waters (Dr. P. G. Sly), the Exploration Geophysics Division of the Geological Survey of Canada (G. D. Hobson, Project 660054) and the writer. This survey will provide reconnaissance information on bedrock topography, sediment type and thickness, etc. to assist with the evaluation of anticipated design and construction problems which might be encountered during future development of this fast-growing area. Thirteen lines, spaced approximately one mile apart, were run perpendicular to the shoreline trend up to four miles offshore using a boomer source and hydrophone eel receiver towed 40 feet astern of the survey vessel. Signals of 20 to 1, 000 hertz frequency were recorded in analog form on both paper records and magnetic tape.

Four piston cores were collected from two areas of Lake Ontario in support of limnogeology programs of the Canada Centre for Inland Waters and the writer's ongoing stratigraphic studies. An 11 m glacial sediment sequence of laminated clay over till over bedrock was penetrated in the Charity Shoal region of the Kingston basin. Close to the deepest part of Lake Ontario, in 224 m of water and about 63 km northeast of Rochester, a complete Holocene mud section (about 6 m) was collected with the upper 11 m of the underlying glaciolacustrine laminated clay section.

Dr. J.H. MacAndrews of the Royal Ontario Museum continued palynological studies of Lake Ontario and Lake Erie sediments with financial assistance from the Geological Survey. The distribution and relative abundance of pollen species in the surface sediments of Lake Ontario have been mapped. Indications of varying forest composition within the present drainage basin are evident, although the magnitude of these variations, due to dispersal and source processes, is not intense enough to obscure variations in the stratigraphic column due to Quaternary climatic fluctuations. Several pollen zones within the Pleistocene and Holocene muds of Lake Ontario and Lake Erie have been recognized and correlated with pollen diagrams from small lakes in adjacent Ontario, New York, and Ohio. The depth of the ragweed pollen zone associated with agricultural settlement around the Ontario basin between 100 and 200 years ago is being mapped in Lake Ontario sediments to provide estimates of recent sedimentation rates.

101. UPLIFT STUDIES OF THE LAKE HURON BASIN

Project 650037

C. F. M. Lewis and L. A. Jaskula

Data on the deformation of the Nipissing and related beaches, radiocarbon dates on organic materials related to sequences of emergence features, and similar geological evidence are being assembled to provide quantitative estimates of warping (differential uplift) of the Huron Basin during the past 6 millenia. The estimates will extend those based on direct observations within historic time, such as trends in water-level gauge records and differences in elevation revealed by repeated precise levelling surveys. Studies of emergence phenomena have shown, to date, that for the last 6,000 years the northern Lake Huron area at Little Current on Manitoulin Island has been rising about 2.7 mm per year relative to the lake outlet area at Sarnia[1].

In 1970, precise profiling of Nipissing and lower shorelines in the "thumb" area of Michigan confirmed the southern Lake Huron region as one of stability for the last 5,000 years, although lake levels have fallen approximately 7 m during the same period. Cores of organic sediment were raised from five small lakes and marshes at various altitudes above Lake Huron in Michigan between Port Huron and Tawas City on Saginaw Bay. This data should provide a radiocarbon chronology of "eustatic" fall in lake level due to erosion of the outlet.

Throughout the period of this project, studies of the deformation of a single, previously-level datum - the Nipissing water-plane - were undertaken. Detailed surveys and sample collection were completed in 1970 on Manitoulin Island where the Nipissing shoreline could be easily recognized. At each of 50 sites, approximately five profiles were levelled across the shorebluff and surficial materials were described and/or collected along each profile. The regional trend of isobases will be established and relations sought between uplift of the shoreline, nature of parent material, coastal paleodynamics (probable fetch, offshore gradient, wave incidence, etc.), depth to bedrock, and the underlying geology.

A reconnaissance of the Lake Ontario shoreline adjacent to Niagara Peninsula revealed two reaches similar in form to the Nipissing beach on Manitoulin Island. Limited observations of seasonal variations in morphology and coastal processes will be undertaken to supplement the Manitoulin study.

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[1] Lewis, C. F. M.: Recent uplift of Manitoulin Island, Ontario; Can. J. Earth Sci., vol. 7, No. 2, Pt. 2, pp. 665-675 (1970).

102. QUATERNARY GEOLOGY, ARNPRIOR MAP-AREA, ONTARIO AND QUEBEC

31 F J

Project 690055

Gretchen V. Minning

Mapping of Quaternary geology in the Arnprior map-area begun in 1969 was completed at a scale of 1:50, 000. In addition to providing information on the distribution of surficial materials and Pleistocene chronology, the map will in part provide information for an environmental geology project covering the Ottawa-Carleton region.

Surface exposures of bedrock include Precambrian igneous and metamorphic rocks and lower Paleozoic limestones and dolomites. Varying thicknesses of unconsolidated Pleistocene glacial and nonglacial deposits mantle the bedrock. Pleistocene deposits consist of (1) glacial sediments - till, outwash, and ice contact stratified drift; (2) primary and reworked marine sediments - clay, sand, and gravel; and (3) recent sediments - fluvial clay, sand, and gravel, aeolian sand, and organic material[1].

Hammer seismic data and water well records assembled during the summer will provide information on the thickness of the unconsolidated material. Samples of Pleistocene sediments were collected for laboratory analysis which will augment field observations in the definition of significant characteristics of the units mapped. Organic material for radiocarbon dating was collected from Champlain sea beach deposits and also from fluvial gravel.

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[1] Minning, Gretchen V.: Quaternary geology, Arnprior map-area, Ontario and Quebec; in Report of Activities, Pt. A, April to October 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 180-181 (1970).

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103. QUATERNARY GEOLOGY, MACKENZIE DELTA AND ARCTIC COASTAL PLAIN, DISTRICT OF MACKENZIE

97 F 107 E
107 C
107 D

Project 690047

V.N. Rampton

Most of the 1970 field season was spent mapping Quaternary deposits and landforms of the Malloch Hill (97 F), Mackenzie Delta (107 C), Stanton (107 D), and Cape Dalhousie (107 E) map-sheets. A preliminary evaluation of the data collected during this season and previously [1,2,3], suggests that the region can be divided into 13 areas, each having a unique arrangement of surficial deposits and near-surface unconsolidated sediments. In many cases these areas closely coincide with the physiographic regions of the Mackenzie Delta area as described by Mackay[4].

In area 1 (see Fig. 1), sand and gravel deposited by proglacial streams flowing west from Franklin Bay toward the old channel of the Horton River, and by the ancestral Horton River, generally cap the Cretaceous shales. The lower terraces of the old channel of the Horton River are

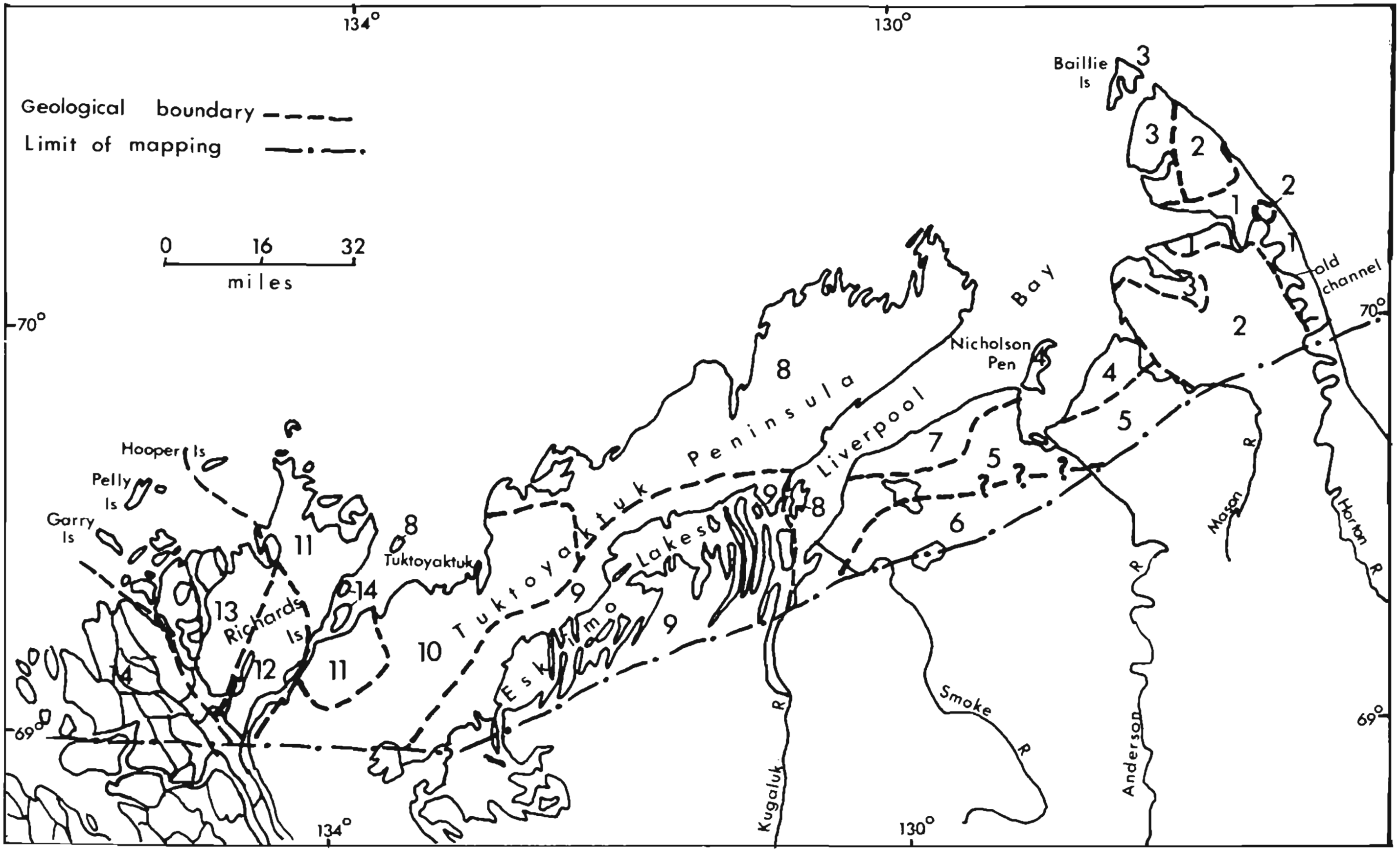

Figure 1: Sketch map showing Quaternary geology, MacKenzie Delta and Arctic coastal plain.

composed of finer-grained material than the higher terraces. Forty feet (±) of ice-rich till overlies glaciofluvial deposits at some localities in the southeast part of the area.

Unconsolidated deposits of peat and organic silt only in area 2 are quite thin but thicken to 15 feet on poorly drained sites and in depressions. Twenty-five feet of gravel, which seem to be the equivalent of Tertiary gravels described by Yorath et al.[5] to the south, were found at the top of a 200-foot cliff northeast of Mackenzie Lake. Clasts identical to those dominant in this unit were found scattered over the weathered shale surface throughout area 2.

Exposures in area 3 indicate that 5 to 35 feet of fine-grained brownish sand, often very ice-rich, 10 to 30 feet of very thinly interbedded sand and silt, and here and there gravel overlie shale and ice-rich marine clay. The sand, silt, and gravel can be found up to more than 100 feet above sea level. Their exact thickness and relation to underlying beds at these higher levels were not completely investigated.

The stratigraphic sequence in area 4 is similar to that of area 3, except that gravel is generally absent and a clayey diamicton, often icy, generally caps the sequence. The northwestern third of Nicholson Peninsula is composed of sediments that have been by thrust from their original position in Liverpool Bay to the west by an advancing glacier[6], and is apparently a north-northwest trending anticline with associated minor structural features (drag folds, minor faults, etc.). Sections along the northwest side of the peninsula suggest the following sequence of sediments from top to bottom; (1) a thin layer of bouldery till, (2) 1 foot to 6 feet of fine-grained brown sand, (3) 35 to 45 feet of very thinly bedded clay, silt, and silty clay, (4) 60 to 120 feet of medium-grained grey sand, (5) 100 (±) feet of interbedded dark grey clay, silt, and fine-grained grey sand that is frequently stained orange.

Over 30 feet of ice-rich till is exposed at the top of many sections in area 5. Deep thermokarst depressions in this area suggest that icy till and other ice-rich Quaternary sediments may be much thicker, even though Cretaceous shales are commonly present near the surface. In many places up to 30 feet of mud-flow deposits and pond silts overlie the tills.

In area 6, sections along the lower reaches of Smoke River indicate that only a thin layer of till overlies the Cretaceous shales.

Colluvium, lacustrine sediments, ground ice, clayey till, and channel deposits of grey sand and gravel up to 40 feet thick cap 50 to 100 feet or more of fine-grained brown deltaic sands in coastal exposures in area 7. In the western part of the area, grey sands can also be found underlying the brown sands[3,4].

Area 8 appears to be a proglacial outwash plain, composed predominantly of grey sand. Dune-sand blankets much of the surface[4] as the upper part of the sands have been reworked by wind. In the southern part of area 8, gravel beds become more common and the sand coarser. Although neither Mackay[4] nor the writer have noted any exposed ground ice bodies in this area, most depressions are probably thermokarst.

Exposures around Eskimo Lakes indicate that the following sequence underlies the eastern part of area 9; from top to bottom (1) 10 (±) feet of till and till-like deposits, (2) 20 to 80 feet of grey sand and gravel, (3) 20 to 50 feet of fine-grained brown sand, (4) an unknown thickness of grey sand. In the western part of area 9, mounds and ridges of sand and gravel are common at the surface, and only grey sand is exposed under the thin cover[4].

In the southeastern part of the area, the till may thicken, but few good exposures are available to verify this. Adjacent to Eskimo Lakes in many places are benches that are composed of lacustrine sediments; the texture of these sediments closely reflects their position relative to former shorelines, i.e. gravel and sand are found close to former shorelines, and clay and silty sand away from former shorelines. Thick ground ice is common along the southeastern side of Eskimo Lakes in the western part of area 9.

Area 10 consists of north-south trending belts of (a) fluvial grey sands (occasionally containing some gravel) and (b) hills capped with till or till-like material, but generally cored with ground ice. Thermokarst activity has made it difficult to delineate the boundaries between the two units, but an involuted pattern, which has been previously described by Mackay[4], often marks the till-capped ice-cored hills. Coastal exposures and excavations at Tuktoyaktuk reveal that both the till-like materials and fluvial deposits contain large masses of ground ice. At Peninsula Point 4 1/2 miles southwest of Tuktoyaktuk the following sequence is exposed from top to bottom; (1) 0 to 2 feet of dune sand, (2) 1 foot to 4 feet of peat and organic silt, (3) 5 to 10 feet of black pebbly clay, (4) 45 feet of medium-grained grey sand with rare pebbles, (5) 12 feet of fine-grained brown sand, (6) more than 5 feet of medium-grained grey sand with occasional pebbly layers. This sequence is probably representative of the stratigraphy throughout area 10 except for the absence of ground ice in the section. In addition, units 2 and 3 are generally absent or thinner in the areas of fluvial sands and thicker in the area of till-capped hills.

In area 11, fine-grained brown sand correlative to the fine-grained brown sands in areas 7, 9, and 10 are 15 feet to more than 60 feet thick. In the southern part of the area they are capped by a thin boulder lag, whereas in the northern part of the area they are capped by till and till-like material up to 15 feet thick. Near the top of many cliffs dune sand up to 10 feet thick is present. In some exposures medium-grained grey sand is exposed under the finer grained brown sand. Grey sand and gravel are also present in channels cut into the brown sand.

Glacier thrusting has elevated sediments above their normal level at some localities in area 11. The sedimentary sequences exposed at two of these sites are thought to be indicative of the regional stratigraphy. A section at the southern edge of a large island northeast of Richards Island (69°32.5'N, 133°54'W) exposes from top to bottom; (1) 8 feet of greyish dune sand, (2) a gravel lag, (3) 15 feet of fine-grained brown sand, (4) 35 feet of grey sand containing coarse wood detritus, (5) more than 40 feet of thinly bedded silty clay (marine). A series of sections on the northern edge of Hooper Island (69°42'N, 135°54'W) expose from top to bottom; (1) 2 feet of pebbly sand, (2) 35 feet of fine-grained brown sand, sometimes ice-rich, (3) 12 feet of medium-grained grey sand containing beds of woody detritus, (4) 10 to 30 feet of dark grey clay, (5) 5 feet of light brownish grey sand and clay with black mottles, (6) 4 feet of very dark grey sand, (7) more than 5 feet of black clay. Ground ice is common in the lower 3 units.

In area 12, glaciofluvial gravel and sand, often pebbly, cover much of the area. In the northern part of the area, these deposits are at least 10 feet and probably more than 30 feet thick; ground ice is occasionally present within them. In the southern part of the area, the fluvial sediments do not form such a continuous cover; sands capped by a thin till are often present.

Area 13 is a complex of (a) rolling hills that are composed of clayey till to at least a depth of 10 feet, (b) a gravel and sand terrace, and (c) the modern Mackenzie Delta surface. Exposures at Kendall and Pelly Islands suggest the stratigraphic sequence underlying the till is similar to the sequence at Hooper Island. The thinly bedded clay, silt, and fine-grained sand exposed along the south edge of Garry Island were probably deposited in an ancestral Mackenzie Bay and thrust to that position by glacial action.

Area 14 is the modern Mackenzie Delta whose surface is predominately clay, silt, and fine-grained sand.

Common to most areas are depressions filled with pond deposits and beds of peat 5 feet to 20 feet thick. The peats are generally marked by high-centre tundra polygons or small thermokarst pools.

Gravity profiles were undertaken at four sites where stratigraphic studies at nearby localities and the local topography indicated the presence of large ground ice bodies. Preliminary results on one profile over a large pingo suggests that gravity can be successfully used to detect the presence and estimate the thickness of subsurface ground ice.

M. Bouchard, University of Montreal, completed detailed geomorphic mapping of Herschel Island.

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[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] Rampton, V.N.: Quaternary geology, Mackenzie Delta and Arctic coastal plain, District of Mackenzie; in Report of Activities, Part A, May October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 181-182 (1970).

[4] Mackay, J.R.: The Mackenzie Delta area, N.W.T.; Geograph. Br., Mem. 8, (1963).

[5] Yorath, C.J., et al.: Preliminary account of the geology of the eastern part of the northern interior and Arctic coastal plains, Northwest Territories; Geol. Surv. Can., Paper 68-27 (1969).

[6] Mackay, J.R.: Deformation by glacier-ice at Nicholson Peninsula, N.W.T.; Arctic, vol. 9, pp. 218-228 (1956).

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104. QUATERNARY GEOLOGY, DAWSON CREEK, BRITISH COLUMBIA

Project 690049 93 P ✓

T. Reimchen

Three and one half months were spent in the study and mapping (1/250,000) of glacial deposits and geomorphology in the Dawson Creek map-area (93P), British Columbia. Preliminary mapping was completed for the north half of the area.

Widespread glacial lacustrine sediments and till characterize the surficial deposits. In the northwest part of the area, two Cordilleran advances are evidenced by two successive till units whereas toward the east Laurentide drift representative of one advance is found. During final glacial recession, thick lacustrine sediments were deposited as a result of glacier damming to the east.

Well developed postglacial river terraces are present in the valleys of the major river systems.

Further study and mapping is necessary before detailed stratigraphy and chronology can be provided.

105. QUATERNARY GEOLOGY, PINE PASS-JASPER AREA, BRITISH COLUMBIA AND ALBERTA

93H 94B 93O 94C J 94F

Project 690049

N.W. Rutter

Approximately four weeks were spent in the field. The objective was to correlate the glacial stratigraphy and Quaternary events from previously completed field work in the Peace River Reservoir area (660031)[1, 2, 3] with that of the Fort St. John area to the east studied by W.H. Mathews[4]; the south part has been completed by the writer under this project[5] and the southeast part was begun by T. Reimchen (reported elsewhere in this publication). The results of this investigation will be included in the final report of the Peace River Reservoir area (660031).

Important results include:

(1) The discovery of Cordilleran till with underlying alluvial fan deposits within the Peace River gap indicating that the gap was formed before the last glacial advance.

(2) The discovery of beach deposits in the upper part of the recessional moraine located between Portage and Bullhead Mountains that correspond with the higher shorelines described by Mathews in the Fort St. John area (2,625 feet or $\pm$ 2,750-foot shorelines). These indicate that a lake was present well up the Peace River Valley to at least the area of Carbon Creek after about 11,600 years B.P. (radiocarbon date from mammoth tusk found in the moraine) when ice to the east still dammed the valley.

(3) The presence of a north-south trending escarpment between Hudson Hope and Portage Mountain which may represent a shoreline correlative with Mathews' 2,260-foot shoreline in the Fort St. John region.

(4) The presence of Cordilleran till between thick lake deposits near Maurice Creek about 2 miles southeast of Hudson Hope. These units correlate closely in time to Mathews' Laurentide till between two lacustrine units exposed further east. Their relationship will help solve ice front positions during late glacial time.

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[1] Rutter, N.W.: Surficial geology of the Peace River dam and reservoir area, British Columbia; in Report of Activities, Part A, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, p. 87 (1967).

[2] Rutter, N.W.: Surficial geology of the Peace River dam and reservoir area, British Columbia; in Report of Activities, Pt. A, May to October, 1967; Geol. Surv. Can., Paper 68-1, Pt. A, p. 182 (1968).

[3] Rutter, N.W.: Surficial geology of the Peace River dam and reservoir area, British Columbia; in Report of Activities, Pt. A, May to October, 1968; Geol. Surv. Can., Paper 69-1, Pt. A, p. 217 (1969).

[4] Mathews, W.H.: Quaternary stratigraphy and geomorphology of the Fort St. John Area, northeastern British Columbia, B.C., Dept. Mines and Petrol. Res., 22 pp. (1963).

[5] Rutter, N.W.: Quaternary geology, Pine Pass, British Columbia-Jasper, Alberta (Parts of 83, 93); in Report of Activities, Pt. A, May to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 183 (1970).

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106. GLACIAL-INTERGLACIAL STRATIGRAPHY, MOOSE RIVER BASIN, ONTARIO

Project 690045

R.G. Skinner

This study, initiated in 1969[1], was completed in 1970. All major rivers in the Moose River Basin north of the Precambrian outcrop limit were traversed. The objectives were to investigate the Quaternary deposits and associated organic remains in order to (a) determine the age, nature, and stratigraphic relationships of the interglacial and glacial deposits, and the sequence of environments and events they record, and (b) provide areal geologic information applicable to land-resource management. A generalized stratigraphic column is presented below.

Tyrrell Sea sediment.
Glaciolacustrine sediments, discontinuous occurrence.
Till, silty, typically brownish, not very compact.
Glaciolacustrine sediments.
Till, grey to greenish grey, clay-silt, compact, locally with marine shell fragments.
Missinaibi beds.
Till, sandy.
Glaciolacustrine sediments.
Till, sandy, very compact.

The Missinaibi beds[2] record several depositional environments including marine, fluvial, lacustrine, palustrine, and glaciolacustrine. Several interglacial fossiliferous fluvial and lacustrine beds were sampled for studies of faunal and pollen content. The bulk of the Missinaibi beds consists of proglacial lacustrine sediments. Commonly they overlie a layer of moss, twigs, logs, and stumps which rest on weathered fluvial, marine, or glacial deposits. The basal proglacial beds are very rich in organic matter and grade upward into organic silt and green clay rythmites, or into inorganic rhthmites or massive green clay with lenses of calcareous silt.

The upper brownish till occurs at least as far north as Kwataboahegan River. A similar brown silty till caps the Pinard (Fraserdale) delta moraine and probably is equivalent to the Cochrane till to the south.

Two marine shell collections obtained close to the marine limit should provide critical dates on the time of marine invasion south of James Bay.

Waterworn sticks collected in deltaic sands beneath till near the mouth of the Montreal River[1] have a radiocarbon age of more than 42,000 years B.P. (GSC-1299). Rounded gyttja clasts found with the wood were analyzed for pollen content and contained more than 30 per cent Quercus and 6 per cent Tilia.

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[1] Skinner, R.G.: Quaternary stratigraphy, Moose River Basin; in Report of Activities, Pt. A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 186 (1970).

[2] Terasmae, J., and Hughes, O.L.: A palynological and geological study of Pleistocene deposits in the James Bay Lowlands, Ontario; Geol. Surv. Can., Bull. 62, 15 pp. (1960).

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107. QUATERNARY STUDIES IN THE SOUTHWESTERN PRAIRIES

Project 650027

General ✓

A. MacS. Stalker

During the summer of 1970, 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 southwestern part of the Great Plains. As in previous years, the excavation and archeological work was undertaken by a party from the Department of Archaeology, University of Calgary, this year directed by Mr. Colin Poole with supervision by Dr. B. Reeves.

The collection of bones from the "basal gravel and sand" and the "lower sands" of Kansan and Yarmouthian ages was considerably increased during low water stage of South Saskatchewan River. Most of those bones come from about ten miles downstream from Medicine Hat. Apart from that, work in the Medicine Hat region was directed towards recovery of bones from intertill beds of assumed mid-Wisconsin age. Excavation was carried on at the Reservoir Gully Site near the west edge of Medicine Hat (NE 1/4 sec. 27, tp. 12, rge. 6 W 4th mer.), and at the Galt Island Site one mile west of Redcliff (NW 1/4 sec. 7, tp. 13, rge. 6, W 4th mer.). Both sites were prolific, but many of the bones from Reservoir Gully were fractured and poorly preserved, a condition caused by post-depositional faulting and action of groundwater. Wood for radiocarbon dating, invertebrate fossils, seeds, and pollen-bearing material were conspicuously lacking at both sites.

Study at gravel pits near Empress, Alberta, confirmed the presence there of two distinctive faunas. Pits on a terrace of Red Deer River just north of town (in NE 1/4 sec. 13, tp. 23, rge. 1, W 4th mer.) furnished a cold weather fauna that included Mammuthus primigenius (Siberian mammoth), Equus conversidens (Mexican ass), Rangifer (caribou), Camelops sp.? (extinct camel), and Bison cf. occidentalis (extinct western bison). Those animals evidently lived shortly after the maximum of Classical Wisconsin glaciation. The other, apparently a warmer climate fauna, was found in pits directly south of Empress (in SE 1/4 sec. 13, tp. 23, rge. 1, W 4th mer.) and is probably older. These two faunas seem to be different in age from any found near Medicine Hat.

Ten days spent on the farm of Mr. G.H. Wellsch of Stewart Valley, Saskatchewan, significantly increased the bone collection, and particularly that of small mammals, from the Early Pleistocene (Kansan) deposits there (SE 1/4 sec. 4, tp. 20, rge. 14, W 3rd mer.). Animals identified from the site until the end of 1969 included:

Megalonychidae ? Megalonyx sp. (ground sloth)
Canidae indet. (medium size dog-like carnivore)
Lynx cf. L. rufus (medium size bobcat-like carnivore)
Mammuthus cf. haroldcooki (Cook's mammoth)
Equus pacificus (extinct Pacific horse)
Equus complicatus (extinct eastern horse)
Platygonus sp. (extinct peccary)
Camelops sp. (extinct camel)
Antilocapridae indet. (extinct prongbuck)

The fauna indicates that the deposits were laid down shortly after the end of the Pliocene Epoch, and they are estimated to be about 1,400,000 years old. Stones from the Canadian Shield are found in the fossiliferous beds. As those stones could only have been brought to the area by a Laurentide ice-sheet, there was at least one continental glaciation in southern Saskatchewan before 1,400,000 years ago. The fauna is of a warm climate type, and the deposits are probably interglacial.

Dr. J.A. Westgate, of the Department of Geology, University of Alberta, kindly studied volcanic ash found by the writer on the Wellsch farm near the top of the fossiliferous beds. It occurs in a bed up to eight inches thick, and its final deposition was by water. The ash, which does not resemble any other known deposit, analyzed as follows (in percentages):

SiO_2	=	73.42	TiO_2	=	0.35	Al_2O_3	=	14.71
FeO	=	1.69	MgO	=	0.48	CaO	=	1.50
Na_2O	=	4.62	K_2O	=	2.93	Cl	=	0.1
F	=	0.0	P_2O_5	=	0.15	MnO	=	0.06

QUATERNARY GEOCHRONOLOGY AND PALEONTOLOGY

108. PUMICE ON RAISED BEACHES, EASTERN ARCTIC CANADA

Project 680065

W. Blake, Jr.

Work on this project during the 1970 field season was carried out in conjunction with projects 670031 and 700028. A great deal of pumice (more than 100 pieces) was collected near base camp at Cape Storm, Ellesmere Island, and several driftwood logs from the pumice level were collected for dating. Additional pumice finds were made at two other sites visited previously - South Cape Fiord, Ellesmere Island, and Boat Point, Devon Island - and a single piece of pumice was found near Cape Vera, Devon Island. There, as elsewhere, it occurred with driftwood on a morphologically well-defined beach. It was at approximately 84 feet above sea level, slightly above the level at which it occurs near Cape Hawes, six miles to the north[1].

Pumice was not found at several beach areas investigated around Thomas Lee Inlet, Sandhook Bay, and Viks Fiord, Devon Island, nor was it found near the south end of North Kent Island. A further search was also carried out on Coburg Island, but only a cobble of gray insulating material, which resembles pumice and which occurs widely on modern beaches in the eastern Arctic, was found.

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[1] Blake, W., Jr.: Studies of glacial history in Arctic Canada. I. Pumice, radiocarbon dates, and differential postglacial uplift in the eastern Queen Elizabeth Islands; Can. J. Earth Sci., vol. 7, pp. 634-664 (1970).

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109. PALYNOLOGICAL STUDIES IN CENTRAL SASKATCHEWAN

Project 650030

R. J. Mott

Lake bottom sediments were collected from two lakes in central Saskatchewan to augment a sampling program begun in 1965[1] in order to provide material for radiocarbon dating and palynological studies. The sites selected are 55 miles and 80 miles northeast of the most northerly of the lakes sampled previously. Basal organic sediments from both sites should provide minimum dates for deglaciation. As the second site is only 5 miles north of the Cree Lake moraine the date obtained will provide a minimum date for the time of ice retreat from the moraine.

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[1] Mott, R. J.: Palynological studies in central Saskatchewan; in Report of Activities, Part A, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 122-123 (1967).

General

110. QUATERNARY PALYNOLOGY

Project 690064

R. J. Mott

A reconnaissance survey of the Cypress Hills area of Alberta and Saskatchewan was conducted to evaluate sampling sites for future palynology and geochronology studies. Suitable sites for coring with the hand-operated devices presently in use could not be found. Heavier, powered equipment for sampling through the ice in winter or in dry depressions is required.

One lake east of Lake Timiskaming in the Province of Quebec was cored for radiocarbon dating and palynological studies to support work previously carried out in the North Bay area of Ontario. Basal organic material from this core should provide a minimum date for deglaciation of the area.

QUATERNARY GEOPHYSICS

111. BOREHOLE LOGGING: NEW BRUNSWICK AND PRINCE EDWARD ISLAND

General ✓

Project 680036

J. E. Wyder and J. G. Bisson

Two months of borehole logging services were supplied on a co-operative basis to Dr. M. L. Parsons, Inland Waters Branch, at various sites near Cap-Pelé, Shippegan and Chatham, New Brunswick and Summerside and Cornwall, Prince Edward Island.

In three drillholes (2 near Summerside, P. E. I. and 1 near Cap-Pelé, N. B.) natural gamma counts significantly above background level were recorded.

A well at Georgetown, P. E. I., was logged for the Prince Edward Island Water Authority.

Two weeks were spent in unsuccessful attempts to locate and log deep holes previously drilled by the Geological Survey but not geophysically logged at that time.

The sidewall sampler was supplied on a co-operative basis for a three-week period to E. C. Halstead, Inland Waters Branch, at Aldergrove, B. C.

The sidewall sampler was supplied on a co-operative basis to the British Columbia Waters Investigations Branch for use in the Okanagan Valley "Groundwater Resource Exploration Program".

QUATERNARY SEDIMENTOLOGY AND GEOMORPHOLOGY

112. EROSION IN A PERMAFROST ENVIRONMENT, DISTRICT OF MACKENZIE

107 B, C

Project 690054

J. A. Heginbottom

This project was initiated in 1969[1], following the fire at Inuvik in August 1968. The experiments begun in 1969 were inspected. The experiment to measure movement of surface material on a hillslope was abandoned because of insufficient control for surveying. New measurements were made of ground height and active-layer thickness at the same sites used in 1969. Summary results are presented in Table I.

Table I

Thickness of active layer (cm)

Date of observations:		May 30 to June 8, 1969	September 16 to 17, 1969	July 4 to 5, 1970	August 27, 1970
Terrain type					
Unburned	Min.	0.0	0.0	6.0	
	Medium	10.0	43.0	28.5	
	Max.	23.0	75+	64.5	75+
Burned	Min.	0.0	18.0	10.0	
	Medium	7.0	42.0	37.5	
	Max.	20.0	75+	75+	75+
Scarified (Firebreak)	Min.	0.0	38.0	30.5	
	Medium	10.5	65.0	60.0	
	Max.	21.5	75+	75+	

Most of the field time was devoted to installing three sites for an experiment in controlled disturbance of the ground surface. The sites selected are outside the area of the 1968 fire, and are described briefly in Table II.

Table II

Site	Slope	Aspect	Material	Morphology	Vegetation
MS 1	3.5°	S	Clay	Hummocky	Open spruce - lichen
MS 2	3.5°	N	Clay	Hummocky	Open spruce - lichen
MS 3	6°	NW	Clay	Hummocky	Spruce - willow - heath

At each site, six plots were marked out and four bench marks were installed. Disturbance of the plots is planned for the spring of 1971.

A brief visit was paid to Norman Wells to inspect erosion in the form of earth-flows resulting from fires in the Norman Wells Forest in 1968 and 1969, similar to those seen at the sites of other fires in the Inuvik forest. In all cases the earth-flows occur on steep slopes - usually the bluffs of a river valley, and they appear to be restricted to south- and east-facing slopes.

[1] Heginbottom, J. A.: Erosion in a permafrost environment, District of Mackenzie; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 196-197.

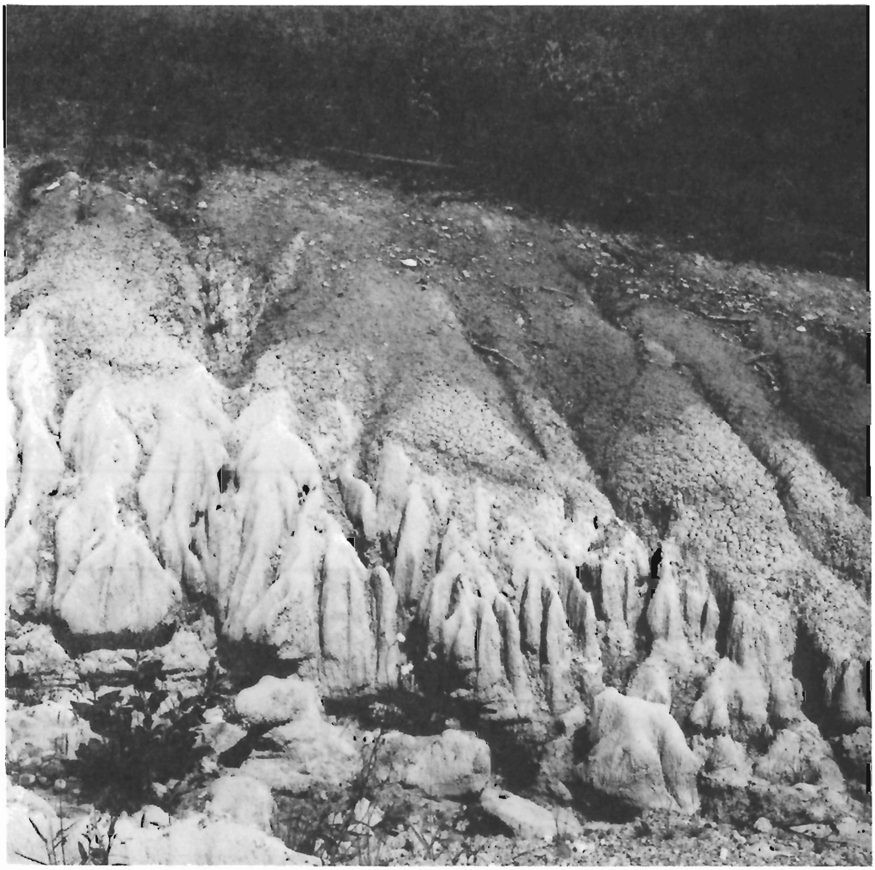

Figure 1. L'influence de la nature du matériel est évident lorsque l'on compare la couche argileuse du haut avec les grès pâles du bas, qui présentent des formes en draperies, par opposition aux croupes arrondies de l'argile. (GSC photo 201540)

Figure 2. (opposite) Une section aplanie au bulldozer à l'entrée du village de Swan Hills présentait des ravins de profondeur variant entre 5 et 42 cm, 3 semaines après l'exécution des travaux. Le matériel est du grès tendre. (GSC photo 201541)

113. ETUDE SUR LE RAVINEMENT DANS LES COLLINES SWAN

Projet 700035

83 J, 0

Jean Lengellé

L'objet de ce projet est l'étude des phénomènes d'érosion et des processus qui les engendrent. Ces travaux permettront de suggérer des mesures correctives au ravinement catastrophique résultant du déboisement et, surtout, de proposer des mesures préventives pour l'avenir.

La région à l'étude couvre le champ de pétrole Swan Hills, qui comprend environ un millier de puits, répartis sur 750 km^2. Une forêt mixte trouée de lacs et de marécages recouvrent les collines Swan. Depuis 1957, année du début de l'exploration du pétrole, les compagnies pétrolières ont construit des centaines de kilomètres de route, et ont ainsi déboisé des étendues inpressionantes. La législation de l'Alberta requiert autour de chaque puit une superficie dégagé de 3. 2 acres. On peut estimer le déboisement à environ 5 à 8%, suivant les endroits. L'implantation des puits s'est faite sans tenir compte de la lithologie, ou de la topographie et, dans cette région particulièrement sujette aux précipitations (41. 5 cm. de pluie pour mai, juin, juillet et août 1968), le ravinement prend des proportions inquiétantes et les glissements de terrain emportent les routes.

Au cours des mois de juillet et août 1970, des zones types ont été repérées en fonction de plusieurs variables dont la plus importante est la nature du matériel. La cartographie détaillée des zones présentant des potentiels érosifs a été entreprise. Des traverses par hélicoptère et en radeau pneumatique ont permis de régionaliser les observations.

Les données recueillies au cours de l'été 1970, bien que préliminaires et partielles, semblent mettre en évidence le rôle prépondérant de la lithologie, tant sur les formes (Fig. 1), que sur la vitesse du ravinement (Fig. 2). Par ailleurs, la présence de strates horizontales de nature

différente (argile, grès, sable, till, etc.) complique sérieusement la mise au point de mesures correctives, car ces couches réagissent différemment (Fig. 3). De plus, même en milieu homogène, les méthodes classiques de lutte contre l'érosion par la construction de terrasses remblayées suivant les courbes de niveau, semblent vouées à l'échec.

Des travaux détaillés sur des bassins élémentaires sont en cours, et vont permettre une meilleure appréciation du taux de progression des processus. Six parcelles expérimentales ont été installées pour permettre des comparaisons de la vitesse d'érosion, en fonction de reconditionnement de la surface après le déboisement.

Figure 3. Succession de couches de nature différentes (de bas en haut: grès, argile, veine de charbon, argile, grès, till). Les formes varient selon la nature du matériel. (GSC photo 201542)

Il convient d'ajouter que les sédiments emportés par le ravinement ont deux exutoires principaux: d'une part, ils ensablent la forêt dont les arbres meurent à plus ou moins brève échéance et, d'autre part, ils gorgent la rivière Swan dont la charge solide atteint plusieurs milliers de tonnes par jour après de fortes précipitations.

Nous tenons à remercier l'Alberta Department of Lands and Forests qui a généreusement mis à notre disposition de nombreuse données recueillies au cours des quatre dernières années.

114. GEOMORPHIC PROCESSES, MACKENZIE VALLEY, ARCTIC COAST, DISTRICT OF MACKENZIE

Project 680047

107 A, B, C, D, E

J. Ross Mackay

Permafrost

Resistivity, seismic reflection, and temperature data were combined to test the effectiveness of resistivity and seismic reflection in picking up the bottom of permafrost in deltaic deposits where depths were known to be less than 300 feet. In the low distal islands of the Mackenzie Delta, results were obtained with an agreement at the test sites of about $\pm$ 10 per cent. Resistivity and seismic reflection were used to locate the bottom of aggrading permafrost in recently drained lakes. The depth of permafrost (Z in feet) which has grown in three recently drained lakes in sands and sandy silts can be approximated by:

$$Z = (20 \pm 5 \text{ feet}) \sqrt{t}$$

where t is time measured in years.

Pingos (107 C, 107 D)

In 1969, bench marks were installed on 6 pingos in order to study the rate of pingo growth. At two of the sites, where young pingos occur, growth in the past year amounted to some 4 and 8 inches, respectively. An actively growing pingo can probably be recognized by tension cracks, resembling ice-wedges, which cross the pingo and continue onto the exposed lake bottom. Some of the tension cracks remain partially "open" all year. One crack was probed in March and July to a depth of 50 feet.

Ground Ice (107 A, B, C, D)

A ground ice map is under preparation. The principal source of data is from shot hole drill logs provided by oil companies. In the Tuktoyaktuk Peninsula and Richards Island areas, ground ice as much as 110 feet in thickness has been penetrated during seismic drilling operations.

Coastal Retreat (107 C, 107 D, 107 E, 117 D)

A field and airphoto mapping program is being undertaken to map coastal retreat. A comparison of early and recent air photographs shows that local coastal recession amounting to more than 1,000 feet has occurred in some areas since 1935.

Mackenzie River

Ground ice, some 20 feet thick, and lying beneath 5 to 15 feet of peat and lake silts, was found about 20 miles downstream from Fort Simpson. Many slumps in sands and silty sands, along the river, have probably occurred as a result of permafrost thaw in the bare, vegetation free banks. The slumps resemble rotational slumps but with sliding along the permafrost surface. The forest fires of the 1968 and 1969 summer seasons have caused extensive slumping of the active layer from Mile 610 to Mile 900 along Mackenzie River. Locally, there is badland topography.

Mixing studies of the Liard-Mackenzie Rivers and the Great Bear-Mackenzie Rivers was continued[1]. Slight underrunning by Liard River occurred at Fort Simpson and by Great Bear River at Fort Norman. Great Bear River water can be traced well over 100 miles downstream from Fort Norman on the basis of temperature and turbidity. Infrared photography (National Aeronautical Establishment, National Research Council, Ottawa) likewise shows a clear thread of Great Bear River water extending downstream, along the right Mackenzie River bank, for about 100 miles. Temperature profiles across Mackenzie River between Fort Simpson and Arctic Red River, at about 15 mile intervals, show that the shallow waters on both right and left banks, and along islands, warms up in the day and cools down at night. Thus, warm/cold water extends along both banks and downstream from islands. (Study initiated under the former Geographical Branch and continued partly with equipment purchased from a Water Resources Research Grant, Department of Energy, Mines and Resources.)

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[1] Mackay, J.R.: Lateral mixing of the Liard and Mackenzie Rivers downstream from their confluence; Can. J. Earth Sci., vol. 7, No. 1, pp. 111-124 (1970).

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115. SEDIMENTOLOGY AND PEBBLE TRANSPORT IN THE WINDSOR ESKER, QUEBEC

Project 660030

Barrie C. McDonald

Detailed study was completed of stratigraphic, sedimentologic, and pebble transport features of the Windsor esker[1]. Emphasis was given primarily to interrelationships between facies, to the use of variance of paleocurrent data as an environmental index, and to interpretation of pebble frequency data.

Additional details and samples were obtained concerning:

1. Recognition of current crescents in vertical section, and their application to paleocurrent studies;
2. The interrelationship between the attitude of parallel lamination and fall velocity of the sand particles, and its significance for reconstruction of the paleohydraulic environment; and
3. Sedimentologically meaningful parameters of gravel.

Investigation was made of variations in abundance of trachyte, peridotite, and black slate pebbles, each of 2-5 cm intermediate diameter. Determination of within-site variation was given special consideration. In one gravel pit, six subsamples of 100 pebbles each were collected from within a vertical face 25 metres long and 15 metres high. Using the 600 pebbles as indicative of the "true" abundance at that location, the $\pm$ variation of the individual 100 pebble samples equalled about one-half of the frequency indicated by that sample. It follows that no fewer than 100 pebbles should be counted at each site, the effect of counting more being to decrease the variance. With sample sizes of only 100 pebbles, frequencies less than about 3 per cent are unreliable.

Also indicated from the frequency data are the following:

1. Compositional variation with any one exposed face, although limited, occurs unpredictably both vertically and laterally;
2. Factors that contribute to unpredictable within-site variation are thought to be (a) random counting error; (b) the sorting effect of selective transportation which results from variation in pebble shape and rock density; and (c) selective comminution of less resistant pebbles;
3. Comparison of subsamples collected from the same bed indicate that considerable variation is possible within the same bed over as little as two metres laterally;
4. To minimize the effect of unpredictable variation at any site, it is desirable to use a composite sample composed of subsamples from different facies and separated spatially by at least a few metres; and
5. Because of unpredictable variation in frequencies, a conservative smooth "working" curve that diminishes the amplitude of anomalies should be drawn through the actual frequency data.

A minimum of 100 pebbles per sample and a maximum spacing of one kilometre between samples are recommended for a reconnaissance sampling program where the objective is a better knowledge of underlying bedrock types and their distribution. This should be followed up by larger, more closely spaced samples for more detailed information at more promising localities. Where the objective is the discovery of rare particular pebbles, the sample size should be several hundred pebbles at each site.

Factors that result in reproducible anomalies along the esker trend include bedrock variation, the esker stream locally having eroded subjacent till or crossed lithologic trains in the till, and incorporation into the main esker of sediment from a tributary esker carrying a compositionally different load.

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[1] McDonald, B.C., and Banerjee, I.: Sedimentology of eskers near Peterborough, Ontario and Windsor, Quebec; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 198-199 (1970).

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116. TRACE ELEMENT AND MINERAL INDICATOR TRACING - KAMINAK LAKE, DISTRICT OF KEEWATIN

55 E, F, K, L ✓

Project 700014

W.W. Shilts

An esker and till sampling program was initiated in the Kaminak Lake-Quartzite Lake-Carr Lake region of eastern Keewatin, Northwest Territories. Samples of glacial till, marine sediments, and esker sediments were collected on predetermined grids and will be analyzed to determine the dispersal patterns caused by glacier transport of mineral and rock fragments and trace elements from their source areas.

Most sampling was accomplished by helicopter (Bell 47G2) traverses from a fixed base camp. The traversing technique employed allowed up to 45 samples from 50 cm to 75 cm deep pits to be taken per day.

Till sampling was complicated by the presence of two distinct till units which are present in section but are not always recognizable in sample pits. The older till unit is sandy, compact, and grey; the younger is very clayey and maroon to red-orange. In section, the two facies can be seen to be intersheared with 0.5 m to 1.0 m thick thrust plates of grey till alternating with similar thicknesses of red till. In sample pits in frost boils (the till sampling medium) distinct, disoriented fragments of either facies occur embedded in a matrix of the other facies. Where possible, samples of both facies were taken from a single sample point.

Sand samples from depths below 40 cm were collected at 0.32 km intervals along a 30 km segment of the Copperneedle River esker and at similar depths at 0.15 km intervals along a 25 km segment of the Kaminak Lake esker. The mineralogical and trace element composition of heavy minerals from these samples will be studied in detail.

STRATIGRAPHY

117. LOWER CARBONIFEROUS AND PERMIAN STRATIGRAPHY, MONKMAN PASS AREA, NORTHEASTERN BRITISH COLUMBIA

Project 680084

93 I

E.W. Bamber and R.W. Macqueen

Lower Carboniferous

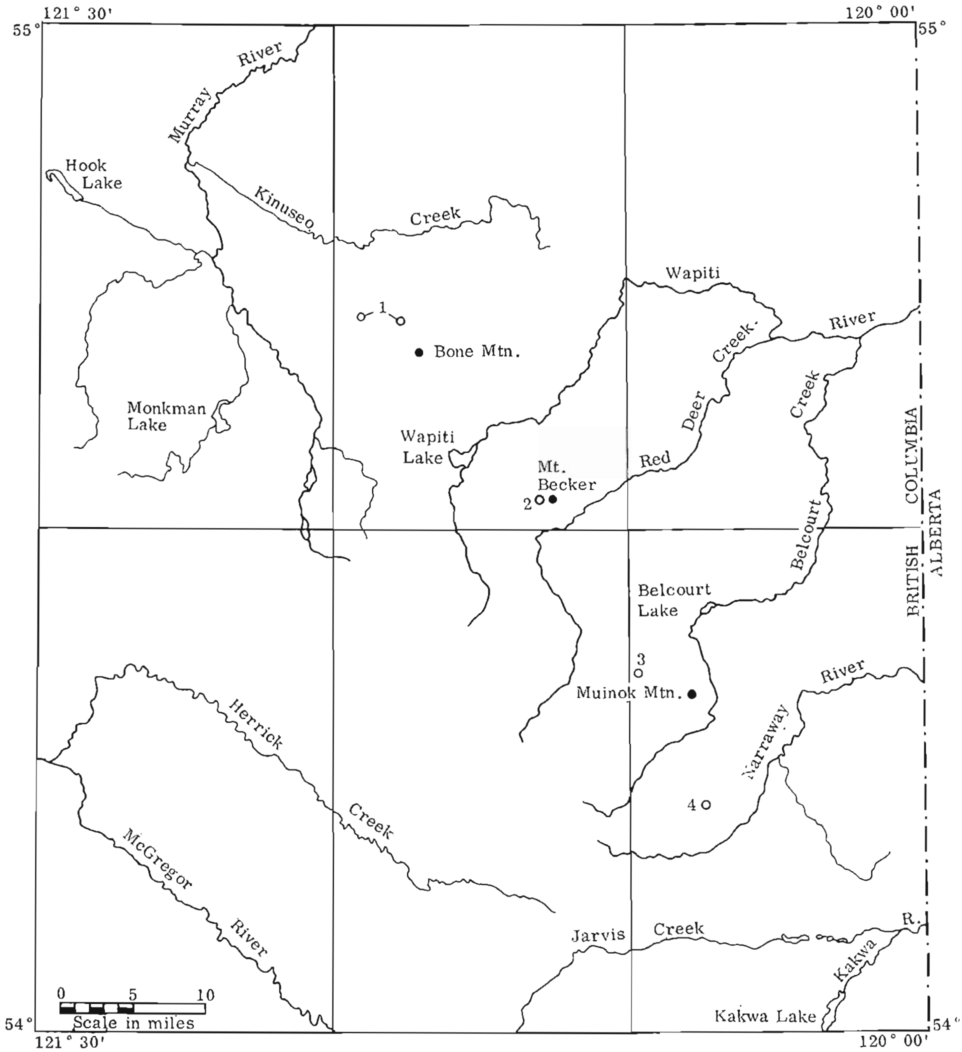
In the Monkman Pass area (NTS 93 I), the Lower Carboniferous contains a lower recessive sequence, about 400 feet thick, of micritic to skeletal-micritic limestone, shale and siltstone, assigned to the Banff and ? Exshaw Formations (Early to Middle Tournaisian). This is overlain by approximately 1,200 to 1,500 feet of more resistant carbonates assigned to the Rundle Group (Middle Tournaisian to Middle Viséan). The Banff Formation has a uniform lithologic character throughout the region, whereas the Rundle Group displays marked facies changes from northwest to southeast.

Three subdivisions are present within the Rundle of the Hook Lake - Wapiti Lake area (Fig. 1): a lower, light grey-weathering, resistant unit (100-200 feet) of medium- to very coarse grained, locally dolomitized skeletal limestone and minor micritic limestone; a middle, brownish grey-weathering, recessive, argillaceous unit (400-500 feet) of micritic-skeletal limestone, fine- to medium-crystalline dolomite, and minor fine- to very coarse grained, skeletal limestone or its dolomitized equivalent; and an upper, light grey- and brown-weathering, resistant unit (550-650 feet) of fine- to coarse-crystalline dolomite with minor skeletal limestone. North of Wapiti Lake the middle part of the upper unit consists of recessive, argillaceous, micritic limestone or its dolomitized equivalent (approximately 100 feet thick). At Mount Becker (section 2), the middle unit contains a larger proportion of fine-crystalline dolomite than is found to the north.

The lower and middle units of the Rundle, described above, were included in the "Dessa Dawn Formation" at Wapiti Lake by Laudon et al.[1]. The overlying light grey-weathering carbonates, including 95 feet of Permian carbonates belonging to the Belcourt Formation of McGugan and Rapson[2], were assigned to the Rundle (restricted) by Laudon et al.[1].

A very significant facies change takes place within the Rundle between Mount Becker (section 2) and Belcourt Creek (section 3) to the south, where the three-fold subdivision can no longer be recognized. The Rundle in section 3 is dominated by fine- to coarse-crystalline, porous dolomite, medium- to coarse-grained skeletal limestone with sparry calcite cement, and lesser amounts of skeletal-micritic limestone. The skeletal limestone of the lower part of the section (215 feet) is similar to that of the lower subdivision to the north, and is overlain by 342 feet of micritic-skeletal limestone with pelletoid grains, and interbeds of finely crystalline, partly argillaceous dolomite. The overlying 470 feet consists of medium- to coarse-crystalline dolomite which has replaced medium- to coarse-grained, thick-bedded, locally crossbedded, echinoderm limestone. This dolomite shows well-developed intercrystalline porosity and minor vuggy porosity throughout. The uppermost 451 feet of the Rundle also is mostly dolomite, but is mainly fine-crystalline and less porous. Interbeds of skeletal and skeletal-micritic limestone are also present.

Preliminary observations to the south (section 4) indicate that the Rundle Group of the Narraway River area is lithologically similar to that of the Jasper Park-Nordegg area[3, 4, 5, 6], and can be divided from base to top into three formations: the Pekisko (echinoderm limestone); the Shunda (dominantly micritic, pelletoid-grain and birdseye limestone, and fine-crystalline dolomite); and the Turner Valley (fine- to medium-crystalline dolomite which contains skeletal fragments and is crossbedded locally). The micritic limestone of the middle and upper Shunda at section 4 is equivalent in stratigraphic position to part of the porous, medium- to coarse-crystalline dolomite of the Belcourt Creek Section.



1. Fellers Creek Section
2. Mount Becker Section
3. Belcourt Creek Section
4. Narraway River Section

Figure 1. Index Map.

The Rundle of the Hook Lake-Wapiti Lake area, which passes northward into the Besa River and Prophet Formations[7,8] is interpreted to be of open marine origin. In contrast, the micritic, pelletoid-grain, and birdseye limestones of the Shunda Formation in the Narraway River area probably represent deposition under semirestricted marine conditions. The thick succession of coarse-crystalline dolomite (section 3) is believed to have been derived from shallow-water echinoderm shoals which formed a barrier separating the semirestricted Shunda from the northern open marine succession of the Hook Lake-Wapiti Lake area. The lateral extent and trend of the barrier facies is not known. It may extend into the adjacent subsurface to the east, thus separating the evaporitic Shunda Formation of the Southern Alberta Plains from the shallow basinal sequence of shale and argillaceous limestone assigned to the Shunda in the subsurface of northern Alberta and northeastern British Columbia[7,9,10].

Permian

Lower Permian rocks rest disconformably on the Lower Carboniferous Rundle Group throughout the area. Between Wapiti Lake and Kakwa River (Fig. 1) the following Permian formations, described by McGugan and Rapson[2], are well developed (base to top): the Belcourt Formation (25 to 160 feet of light brown- and grey-weathering, very fine- to fine-crystalline, cherty dolomite containing fusulinid foraminifers and colonial corals, and separated from the Rundle by chert-pebble conglomerate); the Ranger Canyon Formation (2 to 20 feet of chert, silicified carbonate, and sandstone, with basal phosphatic, chert-pebble conglomerate); and the Mowitch Formation (10 to 71 feet of light brown, calcareous, glauconitic sandstone separated from the Triassic by a thin, phosphate-pebble conglomerate).

North of Wapiti Lake, only the Belcourt Formation is present. At section 1, it consists of 167 feet of cherty, dolomitic, micritic-skeletal and micritic limestone, with some coarse-grained, skeletal limestone containing abundant fusulinid foraminifers. The lower 19 feet is conglomeratic limestone containing numerous chert pebbles and rare beds of conglomerate. A thin, irregular unit of cherty sandstone with phosphate pebbles separates the Belcourt from the overlying Triassic. Near Hook Lake (Fig. 1), only the basal conglomerate and conglomeratic limestone of the Belcourt is present. There, it ranges in thickness from 1 foot to 11 feet and is separated from the Triassic by a thin unit of sandstone with phosphatic pebbles similar to that at the top of section 1.

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118. OPERATION PEEL SOUND–PRINCE OF WALES ISLAND REGION

68 ✓

Project 700029

R.L. Christie, J. Wm. Kerr, and R. Thorsteinsson

An airborne geological study of the Prince of Wales Island region was carried out during June, July, and August of 1970. In the course of the work approximately 570 landings were made by a Piper Super Cub and a Bell 4764 helicopter. Numerous ground traverses were completed, and sections measured.

The recent field work has confirmed earlier geological description with, of course, refinement in the mapping of units and knowledge of stratigraphy. A preliminary report, with maps on a scale of 1:125,000, is now in preparation, and will be placed on open file while undergoing publication.

New geological information is as follows: (a) Light-weathering, medium-bedded dolomite of the Allen Bay Formation (Ordovician, Silurian) is exposed on the westernmost peninsula of Prince of Wales Island; to the east are scattered limestone exposures of the overlying Read Bay Formation (Silurian), that are identified by the contained shelly fauna. The distribution of rock units indicates that the principal structural feature of the island west of the Boothia Uplift is a broad, shallow syncline that extends northwestward from about the southern tip of the island and plunges gently northwest; (b) The western, unnamed carbonate facies (equivalent) of the Peel Sound Formation is overlain, in scattered areas of northwestern Prince of Wales Island, by light-coloured, medium- to thick-bedded, and massive, commonly porous dolomite. This unit, probably about 700 feet thick, may rest disconformably upon underlying strata. A Devonian age is indicated from fossil collections. The unnamed dolomite formation is similar lithologically to the Disappointment Bay Formation (Emsian and Eifelian) of Bathurst and Cornwallis Islands. Positive identification, however, must await fossil identifications; (c) The dolomite described above is overlain, apparently with gradational contact, by an unnamed quartzose sandstone formation near the northwestern extremity of Prince of Wales Island. This unit is mainly light coloured, thin- to thick-bedded, and fine- to medium-grained sandstone. The minimum thickness of beds preserved is about 500 feet. This youngest bedrock formation of the island has not yielded fossils, but is probably of Devonian age.

119. OPERATION NORMAN, DISTRICT OF MACKENZIE

Project 670068

106 A,B G H ✓

D.G. Cook and J.D. Aitken

Operation Norman, a regional geologic study in the lower Mackenzie River area (Fig. 1), combines reconnaissance bedrock mapping, stratigraphic studies, and investigation of Quaternary surficial deposits. The bedrock program is being carried out by the Institute of Sedimentary and Petroleum

Geology, Calgary; Quaternary studies are by the Division of Quaternary Research and Geomorphology. The Operation Norman area (Fig. 1) is about 145,000 square miles.

The field program begun in 1968 was completed in 1970. Figure 1 indicates the total area examined, shows geological maps released and in press to date, and outlines the part examined in 1970. This report summarizes the results of the 1970 field season only.

The 1970 field program was confined to the Mackenzie Mountains in the southwesternmost part of the operation area. Reconnaissance mapping

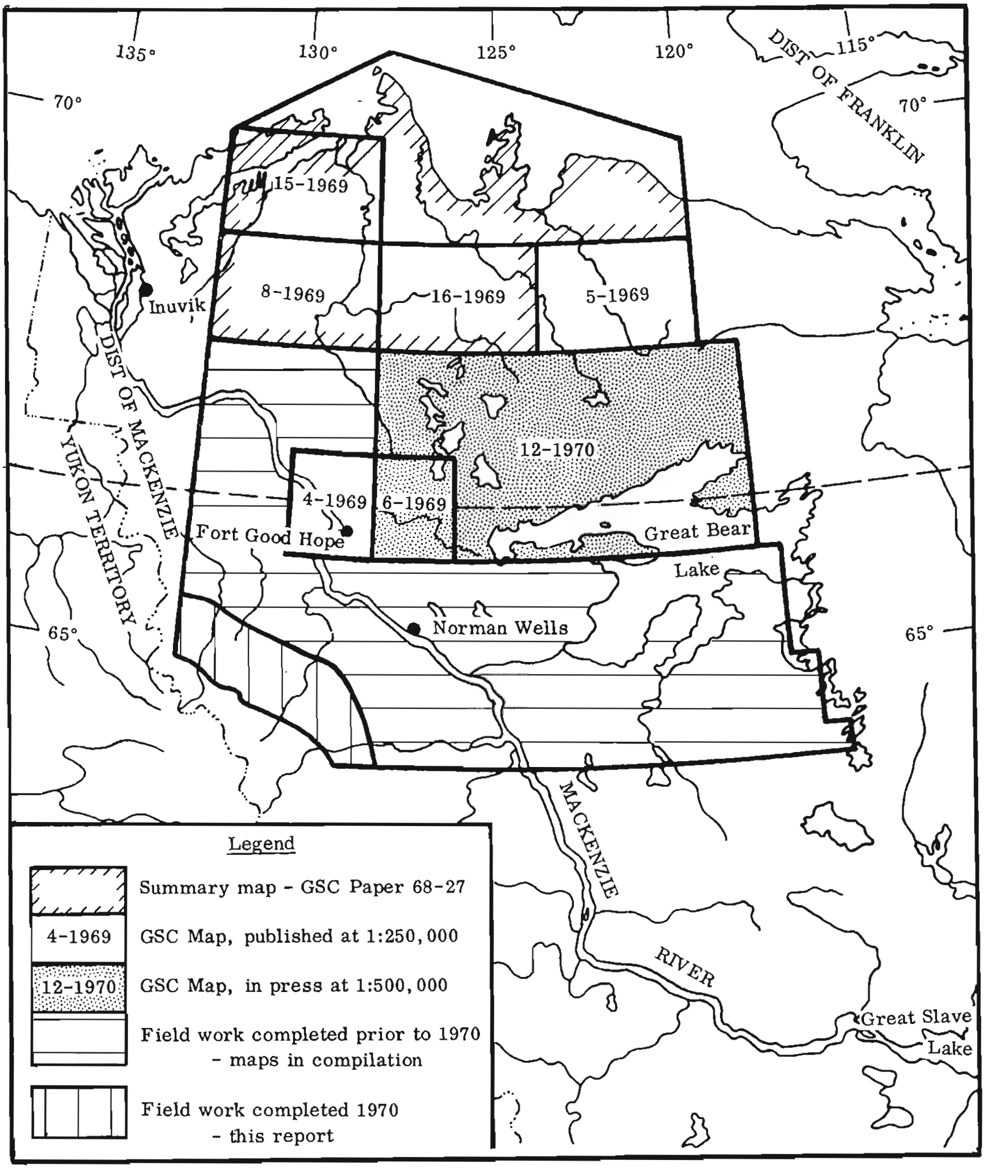

Figure 1. Stages of mapping - Operation Norman.

and regional structural investigation were done by J.D. Aitken and D.G. Cook. J.L. Usher, Queen's University, continued a study of Proterozoic strata begun in 1969. W.S. MacKenzie spent a few days obtaining additional data on Devonian stratigraphy. Quaternary surficial deposits were examined by O.L. Hughes (see report elsewhere in this publication). Discussion of the broad geological findings are presented below.

Twenty-three stratigraphic units (Table I), some of which are lateral facies of others, were mapped. Seven regional unconformities occur (see Table I). The most important of these is the sub-Ronning Group unconformity, because it cuts upward stratigraphically from northeast to southwest with resultant successive appearances of younger and younger units as one proceeds deeper into the Mackenzie Mountains. Because of this rapid appearance of additional stratigraphic units the sequence differs radically from that mapped in 1968 and 1969 to the north and east[1]. Proterozoic and Lower Cambrian stratigraphic units described by Gabrielse, Blusson and Roddick[2] to the south were recognized, and identifications were verified by field collaboration with S.L. Blusson. Their nomenclature has been adopted and is used here (Table I). A pre-Devonian and Devonian upland, presumably the northern extension of the Redstone Arch[3] occurs in the south and central parts of the 1970 field area. Greater uplift in this area in pre-Devonian time is marked by deeper erosion on the sub-Devonian unconformity. Over most of the region Devonian rocks rest on the Mount Kindle Formation, but in the region of the pre-Devonian uplift they rest on rocks as old as Little Dal Formation. In the southern part of the area Bear Rock Formation strata overlie Little Dal rocks, and Devonian rocks older than Bear Rock are absent, probably because of nondeposition. This would indicate that an upland persisted locally through much of Lower and Middle Devonian time.

Significant facies changes occur at three stratigraphic levels. The most noteworthy of these is from microcrystalline dolomites of the Ronning and Mount Kindle Formations, through a transition zone of argillaceous limestone, to black shales of the Road River Formation. The change is exposed best in the western part of the 1970 field area. There the progressive facies change can be observed southward from one thrust plate to another and, also, as a change along the strike within specific thrust plates. The transition from Ronning to Road River occurs farther to the north than that from Mount Kindle to Road River, and is exposed better. A Devonian facies change from Bear Rock Formation to a number of units apparently equivalent to the Camsell, Arnica, and Landry Formations mapped by Gabrielse et al.[2], has been noted previously[1]. The Proterozoic Little Dal Formation in part overlies, and is in part a lateral facies of, thin bedded limestones with shale. Gypsum beds occur locally beneath the Little Dal and are a lateral facies of the lower part of the above mentioned limestones and shales.

A wide folded belt with broad anticlines and tight complex synclines characterizes the frontal Mackenzie Mountains[1]. To the southwest this fold belt gives way abruptly to a complex belt of imbrication dominated by thrusts, many of which die out to the west in west-plunging anticlines commonly overturned to the north. The abrupt change in structural style coincides closely with the abrupt appearance of younger Proterozoic units (and a resultant thicker sequence) beneath the sub-Ronning unconformity.

The fold and thrust belts are differentiated sharply, but the differences in structure appear to be due to differing stratigraphy. Both styles record horizontal translation and indicate a period of compressive deformation which,

TABLE I

TABLE OF STRATIGRAPHIC UNITS

<table>
<tr><td>MIDDLE AND UPPER DEVONIAN</td><td colspan="2">Hare Indian, Canol, and Imperial Formations undivided</td><td>3,000</td></tr>
<tr><td colspan="4">Disconformity ?</td></tr>
<tr><td>MIDDLE DEVONIAN</td><td colspan="2">Hume Formation</td><td>400</td></tr>
<tr><td>LOWER AND MIDDLE DEVONIAN</td><td colspan="2">Unnamed: Limestone (Landry Formation Equiv. ?)
Unnamed: Dolomite (Arnica Formation Equiv. ?)
Unnamed: Limestone and limestone breccia (Camsell Formation Equiv. ?)</td><td>0- 600
0- 600
0- 500</td></tr>
<tr><td>SILURIAN AND LOWER DEVONIAN</td><td colspan="2">Unnamed: Dolomite and sandy dolomite (Delorme - Sombre Formations Equiv. ?)</td><td>0- 450</td></tr>
<tr><td colspan="4">Regional Unconformity</td></tr>
<tr><td>UPPER ORDOVICIAN AND SILURIAN</td><td rowspan="3">Road River Formation southwestern part of area only
(Middle Cambrian strata not separately mapped)</td><td>Mount Kindle Formation</td><td>0- 600</td></tr>
<tr><td></td><td colspan="2">Regional Unconformity</td></tr>
<tr><td>MIDDLE CAMBRIAN TO UPPER ORDOVICIAN</td><td>Ronning Group including basal quartzite</td><td>0-1,400</td></tr>
<tr><td colspan="4">Regional Unconformity</td></tr>
<tr><td>LOWER CAMBRIAN</td><td colspan="2">Sekwi Formation
Backbone Ranges Formation</td><td>0-1,300
0-1,000</td></tr>
<tr><td colspan="4">Regional Unconformity</td></tr>
<tr><td rowspan="7">PROTEROZOIC</td><td colspan="2">Sheepbed Formation
Keele Formation
Upper Rapitan Formation</td><td>0-1,000
0-1,200
0-3,500</td></tr>
<tr><td colspan="3">Regional Unconformity</td></tr>
<tr><td colspan="2">Middle Rapitan Formation</td><td>0-1,000</td></tr>
<tr><td colspan="3">Regional Unconformity</td></tr>
<tr><td colspan="2">Lower Rapitan Formation</td><td>0-1,300</td></tr>
<tr><td colspan="3">Regional Unconformity</td></tr>
<tr><td colspan="2">Diabase Dykes
Little Dal Formation
Unnamed: shale, sandstone, gypsum, limestone, dolomite
Unnamed: upper quartzite; lower shale and dolomite
Tigonankweine Formation
Tsezotene Formation (including diabase sills)
Unnamed: grey dolomite and chert</td><td>
0-1,500
0- 700
0-2,000
3,000
1,200
1,200</td></tr>
</table>

in the mountains, cannot be placed more accurately than post-Devonian. Both Cretaceous rocks flanking the mountain front to the northeast, and Tertiary strata near the McKay Range to the southeast were deposited probably as a result of uplift and deformation to the southwest and west; yet both have been deformed subsequently. Orogeny appears to have begun at least as early as Lower Cretaceous and to have continued at least till Tertiary time.

Epeirogenic uplifts are marked by three Proterozoic unconformities and by four Paleozoic unconformities (see Table I). Uplift preceding Ronning deposition was accompanied by block or wrench faulting and some thrusting[1], because some faults affecting Proterozoic strata are truncated by the sub-Ronning unconformity. West of Arctic Red River a number of north-trending diabase dykes are truncated by the same unconformity. All observed pre-Ronning structures occur in areas where Lower Cambrian strata are missing, and the youngest rocks observed to be affected are in the Sheepbed Formation. Consequently, some or all of these structures could pre-date the Lower Cambrian Backbone Ranges Formation.

The geology of the area examined in 1970 is pertinent to oil exploration in the facies changes, and the effect of unconformities in Paleozoic rocks in the mountains, must be understood for a full understanding of the plains areas to the northeast where exploration for hydrocarbons is in progress. Because of the thick and well exposed Proterozoic sequence, however, the area has more direct potential for economic or industrial minerals. Copper minerals, malachite and azurite, were observed in brecciated dolomite assigned to the Little Dal Formation near Godlin River (southeast part of the 1970 area). Fluorite occurs in irregular calcite-fluorite veins in the cherty dolomite stratigraphic unit (oldest unit, Table I), near the headwaters of Ramparts River. Bedded gypsum occurs in deposits up to 800 feet thick at a number of localities.

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120. TRIASSIC STRATIGRAPHY, HOOK LAKE-SMOKY RIVER AREA, NORTHEASTERN BRITISH COLUMBIA AND NORTHWESTERN ALBERTA

Project 680084

D.W. Gibson

Field work in 1970 consisted of examining and sampling in detail several Triassic sections in the Rocky Mountain Foothills and Front Ranges, between Hook Lake in northeastern British Columbia and Smoky River in northwestern Alberta. This investigation, part of Operation Smoky (see G.C. Taylor, this publication), extends and concludes earlier work begun in 1968 between the Sikanni Chief River and Pine Pass area of northeastern British Columbia[2,3].

Triassic rocks in the Hook Lake-Smoky River area are divided into two main and contrasting lithofacies, the Whitehorse and Sulphur Mountain Formations. These formations are equivalent to those previously recognized and described between the Athabasca and Smoky Rivers of Alberta[1].

Whitehorse Formation

Complete sections of the Whitehorse Formation in the Hook Lake-Smoky River area are scarce, and were observed only in the vicinity of Smoky and Kakwa Rivers. The formation, comprising a variable sequence of buff- to light grey-weathering limestones, dolostones, sandstones, and minor siltstones, intraformational breccias, and gypsum, is divided into 3 members which in descending order are: (1) the Winnifred Member, (2) the Brewster Limestone Member, and (3) the Starlight Evaporite Member. The formation ranges in measured thickness from a minimum of 430 feet in the east to over 1,300 feet in the west. All members of the Whitehorse Formation are lithologically similar and equivalent to those described between the Smoky and Athabasca River area to the south, and correlate with the Charlie Lake and Baldonnel Formations of the Sikanni Chief River-Pine Pass area to the north.

Sulphur Mountain Formation

The Sulphur Mountain Formation, consisting of a variable sequence of dark grey- to brown-weathering dolomitic to calcareous siltstones, silty shales, silty limestones, and minor dolostones, and very fine grained sandstones, ranges in thickness from an estimated minimum of 800 feet near Stoney Lake in the east, to a maximum measured thickness of 1,700 feet near Wapiti Lake to the west. The formation is tentatively divided into 4 members which in ascending order are: (1) the Phroso Siltstone Member, (2) the Vega Siltstone Member, (3) the Whistler Member, and (4) the Llama Member. The lithology of these 4 units is similar to that of the equivalent members south of Smoky River; however, some facies variation between the two areas is apparent. One such change occurs between the lower two members of the Sulphur Mountain Formation. South of Smoky River these two lithofacies are readily separated into distinct units, whereas in the Hook Lake-Smoky River area the strata and contact relations of the two member are such that division into separate members is very difficult and may necessitate the grouping of the two facies into a single unit. Another facies variation between the two areas is shown by the Llama Member. In the Hook Lake - Smoky River region this member consists mainly of very calcareous siltstone, and very fine grained sandstone, with interbeds of silty and commonly fossiliferous limestone. South of Smoky River the Llama Member consists mainly of very dolomitic siltstone with no limestone interbeds. The lithology of the Whistler Member between the two areas is similar, differing only in the proportions of calcite and dolomite. The Sulphur Mountain Formation correlates with the Grayling, Toad, and Liard Formations in the Sikanni Chief River - Pine Pass area to the north.

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[1]Gibson, D. W.: Triassic stratigraphy between the Athabasca and Smoky Rivers of Alberta; Geol. Surv. Can., Paper 67-65 (1968).

[2]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).

[3]Gibson, D. W.: Triassic stratigraphy, Pine Pass region, northeastern British Columbia; in Report of Activities, Part A: April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, p. 208 (1970).

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121. STRATIGRAPHY, FACIES AND PALEOGEOGRAPHY OF MESOZOIC ROCKS OF NORTHERN AND WEST-CENTRAL YUKON

Project 550004

J. A. Jeletzky

The months of June and July, 1970 were spent in the stratigraphical-paleontological study of Jurassic and Cretaceous rocks of northern and west-central Yukon, and in the support of field work of D.K. Norris and F.G. Young in these and adjacent areas. Atlantic Richfield Canada Ltd. kindly provided helicopter transportation to several relatively inaccessible sections.

The approximate boundaries of the surveyed Mesozoic areas are indicated in Figure 1 where they are numbered from 1 to 6. These areas are numbered and discussed in the same order in the text for convenience of the reader.

1. Headwaters of Cache Creek

In the section NC 479 of D.K. Norris at about 68°16'46" N and 136°31'40"W on the divide between headwaters of Cache Creek and Fish River, the Bug Creek sandstone is reduced to about 70 feet (est.) and is overlain by an about 1,000-foot-thick (est.) poorly exposed recessive interval apparently

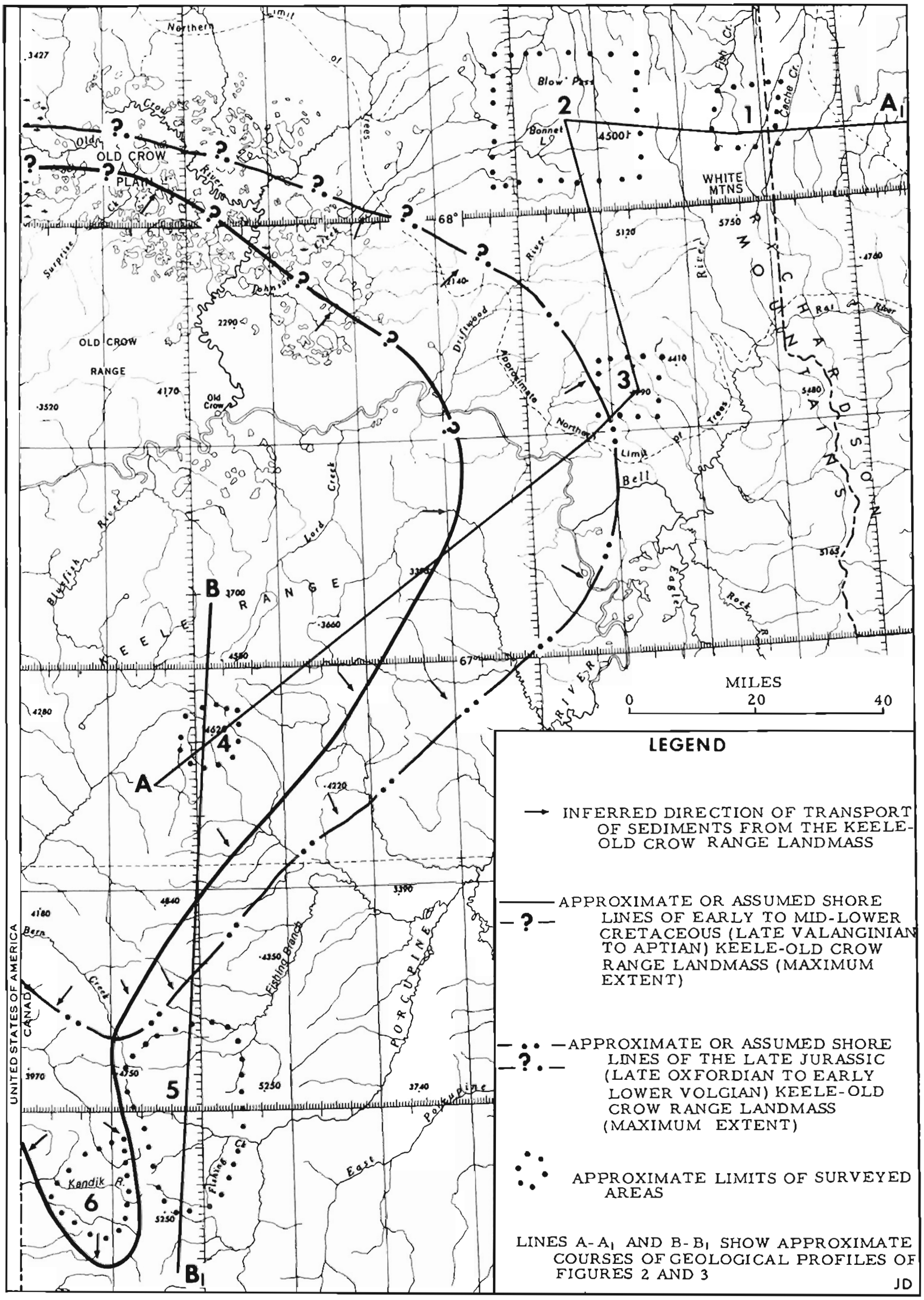

Figure 1. Index map showing locations of surveyed areas, that of cross-sections of Figures 2 and 3 and that of the shorelines of Upper Jurassic and early to mid-Lower Cretaceous landmasses.

underlain exclusively by dark grey shale and/or siltstone. This shaly unit is overlain conformably by at least 150 feet (top covered) of buff to orange coloured thin slabby to laminated, ripple-marked, fine-grained quartzose sandstone containing Buchia concentrica (Sowerby) s. lato. This sandstone appears to represent a thin marine wedge of the thick, largely nonmarine. Upper Jurassic sandstone (Ref. 1, p. 80, Fig. 6) which is widespread in the Keele Range-Porcupine River canyon-Waters River area and the eastern pinchout zone of this sandstone derived from Keele-Old Crow Range landmass (Figs. 1-2). This marine, thin wedge of the formation, appears to be entirely absent in the Husky Formation of northeastern Richardson Mountains. It may, however, be represented by a 65-foot-thick sandstone-rich interval in unit 1 of the upper Bell River section described by Jeletzky (Ref. 2, p. 31).

The Cache Creek section appears to be situated in the northwestern pinchout zone of Bug Creek sandstone which thickens to at least 500-600 feet southward and eastward (see Ref. 3, p. 161 and unpublished).

2. Bonnet (=Bonny) Lake-Blow Pass area

Early Carboniferous coal-bearing unit. Some Sigillaria-like plant remains have been found by Atlantic Richfield Canada Ltd. geologists, D.K. Norris and the writer in the previously unfossiliferous, coal-bearing clastics (Ref. 1, pp. 77-79) widespread in the area and south of Bonnet Lake in the headwaters of Johnson Creek. This indicates the early Carboniferous (early Mississippian) age of this unit which is equivalent to the lithologically similar Kek-Kek-Tuk Formation of northern Alaska according to H. Raasveldt of Atlantic Richfield Canada Ltd. The apparently gradational contact of these early Carboniferous coal-bearing clastics with the overlying marine early Lower Jurassic rocks (see Ref. 1, p. 78) is therefore paraconformable only. A regional overlap of the marine Jurassic over nonmarine Carboniferous rocks is suggested by the facies and age difference of the basal Jurassic beds from one part of the area to another (Fig. 2).

Kingak equivalent. In Blow Pass the basal Jurassic beds are represented by the late Sinemurian sandstones (Ref. 1, p. 78) while farther south in headwaters of Johnson Creek (approx. 68°09'45"N, 137°58'W) they are represented by siliceous siltstones with different ammonites possibly belonging to Psiloceras s. lato of a Hettangian age (Dr. H. Frebold, pers. comm., Oct. 1, 1970). These at least 200-foot-thick, basal Jurassic clastics appear to grade upward into Pliensbachian shales.

No pebble conglomerates were observed in the overlying ? 2,000 - foot-thick Pliensbachian to early Oxfordian siltstone-shale unit corresponding to and continuous with the Kingak shale of northern Alaska (see Ref. 4, p. 119; Ref. 5, p. 191, Fig. 29). All conglomeratic interbeds observed within the outcrop areas of this unit by Gabrielse (Ref. 6, geol. map) and Jeletzky (Ref. 1, p. 79, Fig. 6) appear to be fault slices of the late Aptian Chert conglomerate unit (see below). No tongues of the Bug Creek sandstone were observed either. This may, however, be due to the lack of exposures as no continuous, well exposed sections of the unit were observed.

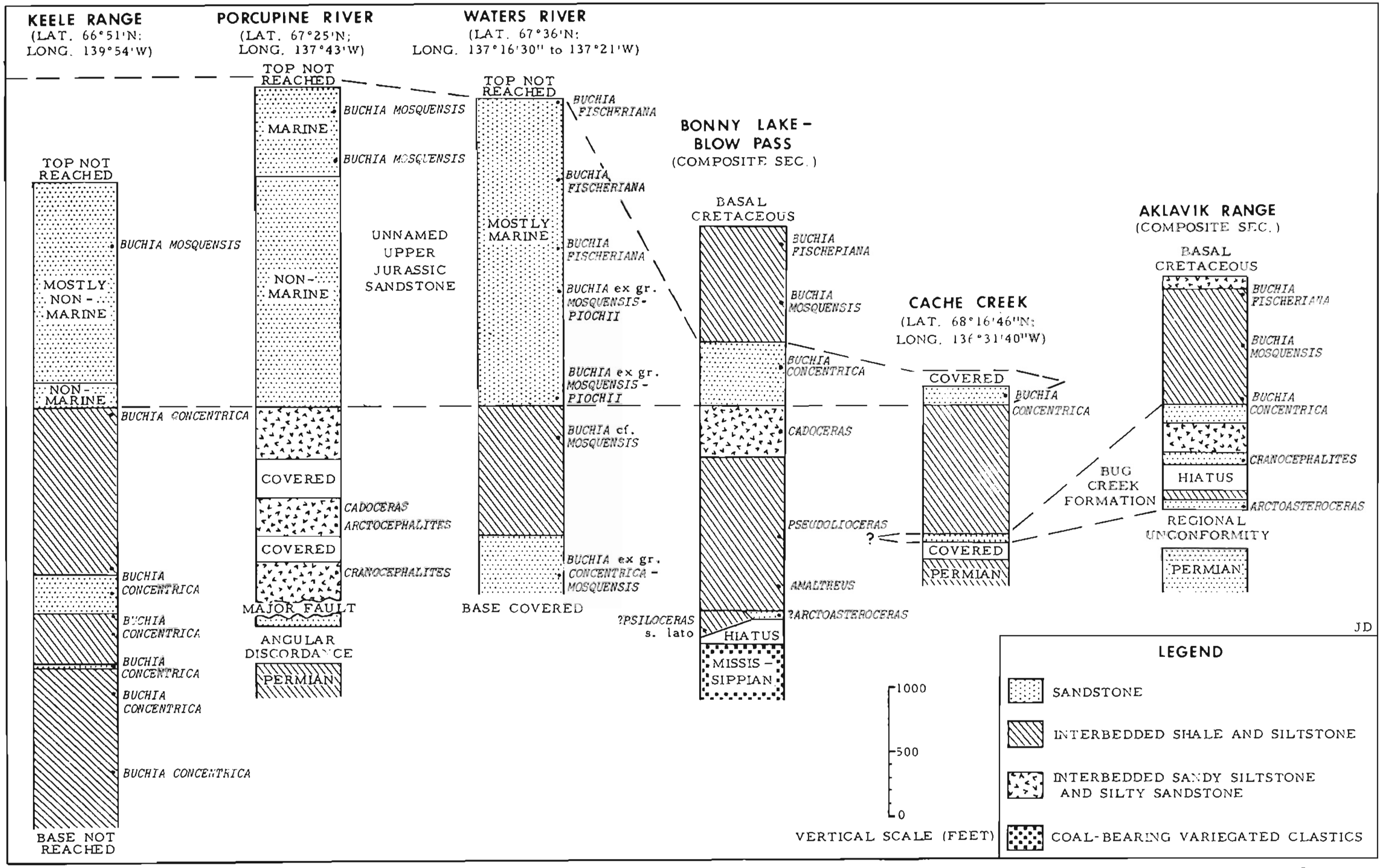

Figure 2. Age and facies relationships of Jurassic rocks of southeastern Keele Range, Porcupine Plains and Northern Richardson Mountains. The approximate geographic position of this cross-section is shown by line A-A, on Figure 1.

Unnamed Upper Jurassic Sandstone. An at least 350-foot-thick unit of buff to orange, fine to very fine grained, mostly fairly quartzose sandstone overlies the Pliensbachian-early Oxfordian shale-siltstone unit on the western slopes of 4,500'+ high nameless north-trending ridge flanking Blow Pass from the east.

This sandstone contains late Oxfordian to Kimmeridgian B. ex gr. concentrica-mosquensis. Like B. concentrica-bearing sandstone of the Cache Creek area it appears to be a northward pinching out marine tongue of the Upper Jurassic sandstone of the Keele Range, Waters River and Porcupine River areas (Fig. 2).

Husky Formation. On the eastern side of Blow Pass in the area 8 to 11 miles northeast of Bonnet Lake, Husky Formation (Ref. 8, p. 26) is at least 2,600 (possibly up to 3,000) feet thick. It is largely represented by extremely monotonous black to dark grey shale locally rich in variously shaped clay ironstone concretions and lithologically similar to that of the Upper shale-siltstone division. Only in the basal 1,000 feet (est.), and at the level 700 to 900 feet below its top, does this offshore facies of Husky Formation include considerable lenses, interbeds and members of sandy to very sandy siltstone and silty to pure quartzose, mostly quartzite-like and fine-grained sandstone.

Buchia faunas ranging from the early B. mosquensis (mid- to late Kimmeridgian) to Buchia keyserlingi-inflata fauna (mid-Valanginian) found in this facies of the Husky Formation indicate that it replaces laterally the restricted Lower sandstone and Bluish-grey shale divisions of more southerly and westerly parts of Bonnet Lake area (Ref. 2, pp. 10-14, 37-42, Fig. 1, correlation chart). The northern facies of the restricted Lower sandstone division (i.e. Buff sandstone member equivalents) outcropping immediately west and south of Bonnet Lake (Jeletzky, ibid.) appears to be replaced in particular by series of up to 1/2-mile-long and ?200-foot-thick lenses of mostly quartzite-like, quartzose sandstone 1,100 to 900 feet below top of the Husky Formation. These facies relationships suggest a northward and ?eastward shaling out of the lower part of Lower sandstone division within Bonnet Lake-Blow Pass area.

The White quartzite division is about 1,000 feet thick in its only measured section but appears to be of similar thickness elsewhere in the area. It appears to grade into overlying and underlying rocks. This division is lithologically similar to its equivalent in the Bell River area (Ref. 2, pp. 14-16, 26), except for the occurrence of considerable interbeds of less quartzose to greywacke- or arkose-like, locally carbonaceous sandstones and of numerous interbeds of intensively crossbedded and ripple-marked sandstones. These lithological characters suggest its estuarine to beach nature. However, no marine fossils have been found in the division.

The Coaly quartzite division is about 800 feet thick in its only measured section. Like its equivalent in Bell River area (Ref. 2, pp. 16-18, 23-26), it is represented by an irregular alternation of hard, weathering-resistant, sandstones with medium hard to soft sandstones and siltstones and forms similar outcrops. However, it includes a much lower ratio of carbonaceous rocks and only a few or no interbeds of pronouncedly coaly rocks. It includes, furthermore, considerable interbeds of intensively crossbedded and/or ripple-marked sandstones lithologically similar to those of the underlying White quartzite division. Numerous but poorly preserved Inoceramus-like marine pelecypods occur locally in these partly or ? entirely marine interbeds. The facies of the Coaly quartzite division of Bonnet Lake-Blow Pass area resembles that of the Coal-bearing division of northeastern Richardson Mountains (Ref. 7, pp. 7-10) but appears to be less palustral and more estuarine to littoral in origin than the latter. It differs considerably from the Bell River facies of the division (Ref. 2, pp. 16-18, 23-26) which appears to be largely or entirely of an alluvial to palustral origin and was presumably deposited much farther inland.

The weathering-resistant White quartzite and Coaly quartzite divisions (see Ref. 2, pp. 14-18, Fig. 1, correlation table) cap almost continuously the unnamed 4,500'+ north-trending range situated about 10 miles east of Bonnet Lake for 10 to 11 miles northward.

The Upper shale-siltstone division was only observed east of the above mentioned 4,500'+ nameless range. No well exposed, measurable sections were found and the division is only tentatively estimated to be at least 2,000 feet thick. Only a few nondiagnostic marine pelecypods were found in it. The lithology of the Bonnet Lake-Blow Pass outcrops of the division is generally similar to that of its Aklavik Range outcrops (Ref. 8, pp. 10, 54-65). However, the dark to light grey, pure to silty shale of the middle part of the division contains less clay ironstone bands and concretions and does not weather as intensively rust or orange coloured as its equivalents in Aklavik Range. It is, furthermore, commonly interbedded with considerable amounts of pure to sandy siltstone in thin beds and 20-to 50-foot-thick members and contains some thin interbeds of commonly crossbedded and ripple-marked, fine-grained silty sandstone. The lithology of Upper shale-siltstone division of our area is thus transitional to that of the presumably equivalent Dark grey siltstone division of the upper Bell River area (Ref. 2, pp. 19-20, 23). It may be interpreted as an offshore facies of the latter unit.

Equivalent of the Upper sandstone division outcrops extensively in the axial part of a major syncline at the head of Rapid Creek 13 to 15 miles east of Bonnet Lake and in that creek's valley for 6 to 7 miles north therefrom. These rocks consist of a 200-foot-thick ridge-forming mostly quartzite-like to true quartzite Lower sandstone member gradationally overlying the sandy siltstones of the Upper shale-siltstone division. Only the basal 40 to 50 feet of the member are built largely or entirely of this sandstone. Higher up the hard, weathering-resistant sandstone includes considerable interbeds of sandy siltstone with clay ironstone inclusions and bands. The ratio of this siltstone gradually increases upward until the sandstone disappears and the member grades into a 600- to 650-foot (est.) unit of apparently unfossiliferous dark to dull grey, friable, more or less sandy siltstone comprising the middle part of the division. This recessive, invariably poorly exposed siltstone unit is overlain with an apparently sharp, erosional contact and a thin pebble conglomerate at the base, by the Upper sandstone member. This inferred erosional disconformity may correspond to the erosional interval observed within the Upper sandstone division in Vittrekwa River basin (Ref. 7, p. 14). The Upper sandstone member consists of dull brown to brownish grey, moderately hard to friable, fairly to strongly porous, fine to very fine grained greywacke that weathers light tan to rust-coloured. The lithology of this member allies it with the overlying Upper Aptian and lower Albian clastics. One ? or more interbeds of gritty and fine pebbly coquina rich in Astarte ex aff. A. cantabrigiensis Woods, other pelecypods and gastropods specifically identical with those of the Upper sandstone division of eastern Richardson Mountains (Ref. 7, p. 16) but devoid of Aucellina and cephalopods, occur in this 70 (est.) to ?100-foot-thick member. Judging by distant observations, the Upper sandstone member is immediately and conformably overlain by the Upper Aptian Lower shale-siltstone unit. The contact is, however, not exposed in any of the sections studied.

Upper Aptian to lower Albian flysch. An at least 6,000-foot-thick sequence of predominantly pelitic to arenaceous rocks overlying the Upper sandstone division equivalent is restricted to two north-trending grabens situated east and west of Bonnet Lake. These "dumped" clastics have a characteristic flysch-like lithology and differ strongly from the underlying Lower Cretaceous and Jurassic rocks in the apparently complete replacement of the previously prevalent quartzose sandstone by the quartz-poor, mostly chert-enriched greywackes. They are turbidites, in part at least, judging by the common presence of various sole markings, convolute bedding and graded bedding in some parts of the succession.

This drastic change of sedimentological regime apparently was caused by strong uplifts in the southern and ?western parts of the Richardson Mountain-Porcupine Plain basin by the strong Aptian tectonic movements (Ref. 9, p. 543; Ref. 10, pp. 88-89). These uplifts were apparently accompanied by a considerable narrowing and deepening of the residual depositional basins.

The upper Aptian to lower Albian clastics of the area can be subdivided into (downward sequence):

1. Upper shale-siltstone unit characterized by a more or less cyclical alternation of 50- to 600-foot members consisting entirely or largely of pure to silty, friable, recessively weathering black to dull grey shale and similar mostly pure siltstone with 40- to 250-foot variegated members. The latter members are characterized by a cyclical, thin interbedding and/or interlamination of the above shale and siltstone with smaller to about equal amounts of mostly fine grained, dull green to dull brown, hard to very hard and quartzite-like greywacke and hard, more or less sandy siltstone. These coarser grained rocks may locally become prevalent or even replace completely the friable shales and sandstones. Coarse-grained greywacke and conglomeratic interbeds are extremely rare and do not exceed 4 feet in thickness. These predominantly dark grey to dark brown weathering, extremely monotonous rocks are generally poor in the orange- to rust-weathering clay ironstone bands and concretions. Instead their recessive shale-siltstone members may be locally rich in whitish yellow to buff-weathering concretions and bands of hard, commonly calcareous shale or siltstone. Many bedding planes of hard and sandy siltstone and greywacke are replete with comminuted plant fragments and coaly specks occur locally.

The maximum measured thickness of the Upper shale-siltstone unit is about 2,200 feet; its top is invariably cut off by major north-trending faults and no younger Cretaceous rocks were seen within the area. The unit appears to grade downward into Chert conglomerate unit through a 130-foot-thick greywacke member.

Very rare fragments of Sonneratia (s. lato) sp. indet. found in the uppermost 350 feet of the unit indicate the correlation of these beds with the Sonneratia (s. lato)? sp. A zone of the lower Albian (see Ref. 11, p. 74, pl. XXIII, correlation chart). This basal zone of the Canadian Albian faunal succession is younger than the early lower Albian Leymeriella tardefurcata zone of the international standard. This permits the tentative correlation of the so far unfossiliferous middle and lower parts of the unit with this basal Albian zone. The lower part of the unit could, however, be already of the latest Aptian age.

2. Chert conglomerate unit underlying the Upper shale-siltstone unit and consisting predominantly of mottled dark to light grey or brown, pebble conglomerate. Fairly to poorly rounded chert pebbles comprise 75 to 90 per cent of the total, the remainder being represented by a variety of other sedimentary and metamorphic rock types. The matrix varies from fine- to coarse-grained, locally gritty greywacke to black sandy siltstone or shale. The pebbles are mostly very fine (1/8- to 1/4-inch) to fine (1/4- to 1-inch). Minor interbeds, lenses and pods of medium (2- to 4-inch) pebble conglomerate are, however, present in the unit. Hard, tightly packed and matrix-poor siliceous conglomerate alternates haphazardly with friable to almost unconsolidated, ferruginous conglomerate rich in matrix and locally grading into pebbly shale. One inch- to 130-foot-thick, lenticular beds, lenses and pods of coarse- to fine-grained, commonly gritty and fine pebbly greywacke, sandy to very sandy and locally pebbly dark grey to black siltstone and black shale are interspersed with the conglomerate. Bedding is mostly absent or poorly developed.

The Chert conglomerate unit is at least 900 feet thick in the westernmost known exposures 8 to 10 miles northwest of Bonnet Lake. It is, however, 600 to 700 feet thick in the sections situated 9 to 10 miles farther east on the eastern side of Blow Pass.

Only comminuted plant remains and coaly specks were found in the Chert conglomerate unit. It is believed, however, to be a late (?latest) Aptian deposit because of:

a) Stratigraphic position some 1,800 feet below the Sonneratia-bearing early lower Albian beds;

b) Inferred late Aptian age of the next older uppermost beds of the Lower shale-siltstone unit; and

c) Probable connection with the strong Aptian tectonic movements which have affected several adjacent areas (Ref. 9, p. 543; Ref. 10, pp. 88-89).

3. Lower shale-siltstone unit closely resembles the Upper shale-siltstone unit in its lithology. The unit includes, however, several 100- to 400-foot-thick members of brown to rust-weathering shale and/or siltstone rich in concretions and bands of clay ironstone. It includes, furthermore, a greater ratio of laminae, layers and thin to thick beds of fine- to medium-grained greywacke. A 300- to 400-foot-thick member of this greywacke occurs at the top of the unit and another similarly thick member occurs in its lower part. This unit appears to grade upward into the Chert conglomerate unit.

The Lower shale-siltstone unit is at least 3,100 feet thick judging by the combination of several partial sections measured on the eastern side of Blow Pass.

The presence of Inoceramus cf. neocomiensis d'Orbigny 350 to 450 feet below the top of the Lower shale-siltstone unit is strongly suggestive of its general Aptian age, even though the time ranges of Inoceramus ex gr. neocomiensis are not yet worked out in detail in Canada. The presence of an early upper Aptian fauna (Ref. 7, p. 16) in the upper part of the Upper sandstone division of adjacent areas indicates that the Upper shale-siltstone unit is not older than the late upper Aptian.

3. Headwaters of Waters River

Unnamed Upper Jurassic sandstone. The eastern side of a 3,500+ nameless mountain west of Waters River (67°36'N; 137°16'30" to 137°21'W) exposes an about 3,800-foot-thick section consisting largely of buff to rust-coloured, friable and porous, fine-grained, quartzose sandstones.

An about 400-foot-thick (base covered) Lower sandstone member contains Buchia ex gr. concentrica-mosquensis fauna. It is overlain by an about 1,000-foot-thick siltstone-shale member containing Buchia cf. mosquensis fauna followed in turn by an about 2,400-foot-thick (top not reached in the syncline axis) Upper sandstone member containing Buchia ex gr. mosquensis-piochii in the lower 1,100 feet and Buchia fischeriana in the upper 1,300 feet.

Reconnaissance of a few other adjacent sections, distant observations, and airphoto interpretation indicate that this sandstone unit outcrops extensively in the headwaters of Waters River and is continuous with the equally thick or thicker Upper Jurassic sandstone units of the Porcupine River-southeastern Keele Range area (Fig. 2).

The Waters River facies of the Upper Jurassic sandstone unit differs from that of the Porcupine River-southeastern Keele Range area in the prevalence of littoral to estuarine, intensively crossbedded and ripple-marked sandstones commonly rich in marine to brackish water fossils and in the presence of considerable interbeds of the Husky-like marine siltstone and shale. Carbonaceous to coaly, plant-bearing nonmarine sandstone characteristic of the Porcupine River-Keele Range facies of the unit occur but rarely.

Bug Creek equivalent. The base of the Upper Jurassic sandstone unit was observed only in one briefly visited and poorly exposed section in eastern headwaters of Berry Creek (67°37'30"N: 137°30'W) shown to the writer by H. Raasveldt of Atlantic Richfield Canada Ltd. There the ?1,000-foot-thick Lower sandstone member is underlain apparently conformably by an about 450-foot-thick shale-siltstone member followed by an about 100-foot-thick sandstone member containing Bathonian to Callovian ammonites and belemnites. This light brown, friable to medium hard, porous, quartzose sandstone is correlative with the Sandstone-siltstone member of Bug Creek Formation of the eastern Richardson Mountains (Ref. 3, p. 17). Gentle, poorly exposed slopes below this sandstone are underlain by at least two more unfossilferous, respectively ?100 (upper) and ?300 to 400 (lower)-foot-thick older Jurassic sandstone members separated from each other by several 100-foot-thick members of recessively weathering shale and siltstone. Permian rocks underlie the basal Jurassic sandstone. Though correlative with the Bug Creek Formation, these three sandstone units seem better interpreted as derived from the same western source area as the overlying Upper Jurassic sandstone

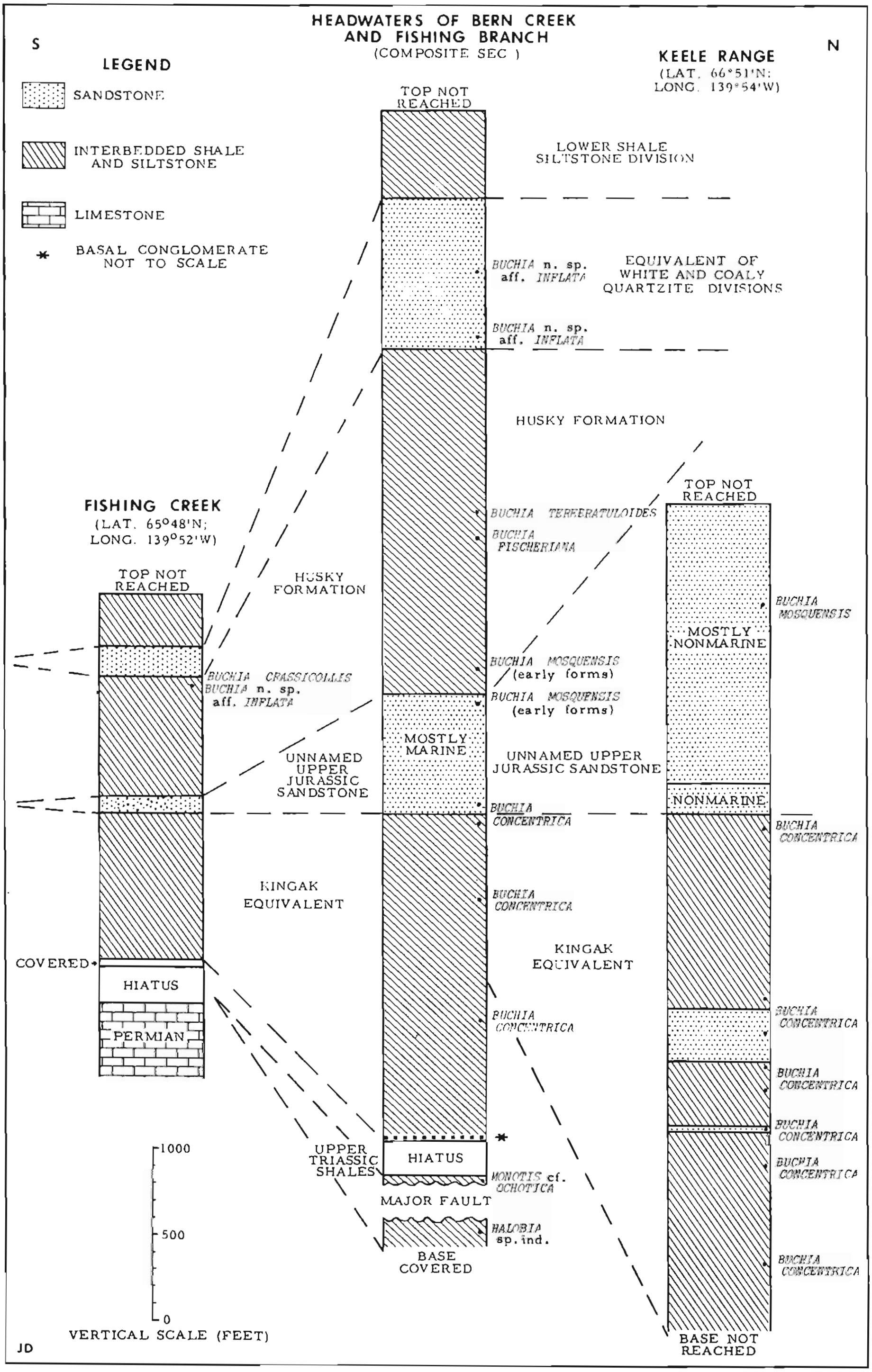

Figure 3. Age and facies relationships of the Mesozoic rocks of northern and west-central Yukon. The approximate geographical position of this cross-section is shown by line B-B, on Figure 1.

unit. So far as known (Ref. 2, p. 9; Ref. 3, p. 24), these sandstones are largely ?or entirely replaced laterally by dark grey, marine shales and siltstones of Kingak equivalent beneath central Richardson Mountains.

4. Southeastern Keele Range

Unnamed Upper Jurassic sandstone. Buchia mosquensis (Buch) s. str. was found in place some 540 feet below the visible top of the up to 1, 800-foot-thick (top not reached in the syncline axis) "orthoquartzite formation" at the locality where Mountjoy (see Ref. 12, pp. 5, 7) measured his second section 235MJ (66° 51'N; 139° 54'W). Numerous, well-preserved B. concentrica (Sowerby) s. lato occur throughout the thickness of the underlying, about 4, 000-foot-thick, dark grey shale-siltstone unit (Fig. 3). Buchia cf. inflata (Toula) reportedly collected closely beneath the "orthoquartzite formation" in this section (fossil lot 235MJ-11a or GSC loc. 52669; see Mountjoy, loc. cit., p. 8) is therefore either derived from a small fault slice in the section or more likely is a mislabelled sample collected elsewhere.

The predominantly carbonaceous to coaly, mostly hard, dense and nonporous, largely nonmarine sandstone of the "orthoquartzite formation" is therefore an indurated facies of the plant-bearing, nonmarine sandstones and overlying Buchia mosquensis-bearing marine sandstone of the Porcupine River area (Ref. 1, p. 80, Fig. 6; previous sections of this report and Figs. 1-2). The same is evidently true of the correlative "orthoquartzite formation" in the not visited main sections 230 MJ and 232MJ of Mountjoy (loc. cit., p. 7).

Like the comparably thick Waters River section, the Keele Range sections of "orthoquartzite formation" may possibly include some late to latest Jurassic rocks (Buchia piochii and Buchia fischeriana zones) in their so far unfossiliferous uppermost beds. There is, however, no reason to assume their upward extension into the early Lower Cretaceous. The previously proposed correlation of the "orthoquartzite formation" of Keele Range with the Lower sandstone division of Richardson Mountains and the "Keno Hill Quartzite" of the Tombstone area (Mountjoy, loc. cit., p. 5, Table 1) is therefore an error caused by the lack of fossil control.

Neither pre-upper Oxfordian Jurassic rocks nor the Lower Cretaceous rocks was observed in the investigated part of Keele Range.

5. Northwestern Ogilvie Mountains

A large outcrop-area of Mesozoic rocks occurs in the area confined between the headwaters of Bern Creek and Fishing Branch of Porcupine River in the north and those of Fishing Creek in the south.

Upper Triassic rocks equivalent to those of the Monster syncline area (Ref. 13, pp. 16-17) are the oldest Mesozoic unit observed within the area. They begin with an at least 150-foot-thick unit (both contacts covered and probably faulted) of black fissile siltstone and shale with several 1 to 3-foot interbeds of limestone. The fauna includes Upper Triassic Halobia sp. indet. (E.T. Tozer; pers. comm., October 16, 1970).

An about 60-foot-thick unit of black fissile shale devoid of limestone interbeds disconformably and probably regionally unconformably underlies the

Jurassic rocks. Its lower contact is invariably covered. An abundant fauna of the upper Norian Monotis cf. ochotica (Keyserling) and Monotis sp. occurring throughout the thickness of this shale unit dates it as younger than the Halobia-bearing rocks (E. T. Tozer, pers. comm., October 16, 1970).

Kingak equivalent. In headwaters of Bern Creek and Fishing Branch of Porcupine River (66°05' to 66°12'N; 140°15' to 140°30'W) the Jurassic rocks begin with a mottled grey 3- to 3 1/2-foot-thick basal conglomerate consisting largely of 1/8- to 1/4-inch poorly rounded to angular chert and black shale pebbles. Pebbles are included in an abundant shaly to sandy matrix locally rich in indeterminate marine shell fragments. The conglomerate locally grades into fine pebbly shale. It overlies the orange-weathered, deeply eroded surface of the Monotis-bearing shale and its upper contact appears to be abrupt and uneven also.

The basal Jurassic conglomerate is overlain by a 175- to 200-foot-thick unit of mottled dark to light grey, friable to very hard, commonly siliceous and sandy siltstone lithologically similar to the basal Jurassic (?Hettangian) siltstone of Bonnet Lake-Blow Pass area. This unit locally contains some 5- to 12-foot-thick interbeds of fine-grained sandstone and an at least 20-foot-thick interbed of dark brown, intensively rust-weathering oolitic rock (?iron or phosphate oolite). Poorly preserved, marine pelecypods of general Jurassic affinities were found in the middle part of the unit.

An at least 500-foot-thick (all sections are faulted) unit of dark grey to bluish grey, friable, pure to silty shale gradationally overlies the basal Jurassic siltstone unit. The shale is locally rich in bands and concretions of dark brown to rust-weathering, very hard shale. Poorly preserved true belemnites found at the 390-foot level suggest a Toarcian or later Jurassic age for the upper part of the unit (Ref. 3, p. 12). The shale grades into a 1,100- to 1,200-foot-thick unit of dark to light grey, pure to sandy, mostly friable siltstone with bands and concretions of hard, rust-weathering, ferruginous siltstone. The siltstone becomes progressively more sandy and lighter grey in colour upward in the section. Interbeds and pods (1 inch to 10 feet thick) of hard, very sandy, intensively crossbedded and ripple-marked, ferruginous siltstone and fine-grained sandstone lithologically similar to those of the overlying Upper Jurassic sandstone unit, appear in the upper half of the unit and become increasingly frequent toward its top. A rich fauna of littoral pelecypods and gastropods apparently devoid of any cephalopods occur in these sandy interbeds. Buchia concentrica Sowerby s. lato ranges throughout the unit indicating its equivalence with the much thicker B. concentrica-bearing shale-siltstone unit of southeastern Keele Range (Fig. 3).

The Kingak equivalent shales out and simultaneously strongly thins out toward south-southeast (Fig. 3). It is only 850 to 880 feet (approx.) thick and appears to be represented mostly by black to dark bluish grey shale with one about 270-foot unit of pure siltstone in the middle in the headwaters of Fishing Creek (65°48'N; 139°52'W). Only one 15-foot interbed of very fine grained silty sandstone was observed in the upper part of Kingak equivalent in these sections which obviously represent its mid-basin facies.

Unnamed Upper Jurassic sandstone is only 650 to 700 feet thick in the headwaters of Bern Creek (approx. 66°06'N; 140°25'30" W) and thins out to a 90- to 150-foot-thick tongue five miles farther east in the headwaters of Fishing Branch (approx. 66°10'N; 140°15'W). Throughout this area the fine to very fine, commonly silty, predominantly quartzose to polymictic (subgreywacke) sandstone of the unit is strongly crossbedded and ripple-marked and interbedded with variable amounts of hard, sandy to very sandy siltstone as in the underlying siltstone unit. An abundant littoral to ? brackish water fauna of pelecypods and gastropods occurs at many levels. Carbonaceous, plant-bearing sandstone is rare or absent and the sandstone appears to be a largely littoral to estuarine deposit.

The sandstone also thins out to an about 100-foot-thick tongue 27 miles south-southeast in the headwaters of Fishing Creek (approx. 65°48'N; 139°52'W). In these sections the unit includes almost 50 per cent of hard, sandy to very sandy siltstone, is devoid of any coquina interbeds, and is clearly transitional to the Husky Formation in its lithology (Fig. 3).

The thicker sections in the headwaters of Bern Creek have yielded Buchia concentrica (Sowerby) s. lato in the lower part and the early forms of B. mosquensis (Buch) in the upper part. Only B. concentrica (Sowerby) s. lato was found in the attenuated sections in the headwaters of Fishing Branch. No diagnostic fossils were found in the Fishing Creek sections of the unit.

The above described relationships suggest a pronounced but gradual thinning out and simultaneous shaling out of the unnamed Upper Jurassic sandstone of southeastern Keele Range toward the south and southeast within the about 55-mile-wide interval separating section 235MJ from the headwaters of Bern Creek and Fishing Branch. These relationships, and the even more pronounced south-southeastward and eastward attenuation of the Upper Jurassic sandstone away from its Bern Creek sections, indicates that the central part of the Upper Jurassic basin of west-central Yukon was situated beneath Porcupine Plains and within the present Ogilvie Mountains south of headwaters of Fishing Creek. The apparently complete absence of Jurassic marine rocks between the latter area and the Tombstone area is obviously due to their subsequent erosion as already suggested by Frebold, Mountjoy and Tempelman-Kluit (Ref. 12, pp. 24-25).

The distribution of Buchia zones within the investigated sections (Figs. 2-3) indicates that the upper part of the unnamed Upper Jurassic sandstone becomes progressively replaced laterally by shales and siltstones of the Husky Formation while its lower boundary remains approximately isochronous.

Husky Formation of the Bern Creek-Fishing Branch area does not seem to differ materially from that of Bonnet Lake-Blow Pass area in its thickness, lithology and age limits. No complete, well exposed sections of the formation were seen, however, in this area. The basal beds of the Husky Formation contain early forms of Buchia mosquensis Buch while its topmost beds contain Buchia keyserlingi (Lahusen) and possibly include some part of Buchia n. sp. aff. inflata zone in the Fishing Creek sections (see below). Thus, the formation replaces laterally the restricted Lower sandstone and Bluish grey shale divisions of Upper Bell River area just as it does in the Bonnet Lake-Blow Pass area. It is uncertain whether or not any sandstone interbeds and lenses, similar to those of the Bonnet Lake-Blow Pass area, occur in the upper part of the Husky Formation of our area.

Like all older Jurassic units, Husky Formation thins out drastically south-southeastward (i.e. basinward) becoming 700 feet (? or less) thick in the headwaters of Fishing Creek (Fig. 3). Its source area must have been situated in the northwestern part of Keele Range (Fig. 1).

Equivalent of White and Coaly Quartzite divisions. The stratigraphic order of coaly and white quartzite facies of early Lower Cretaceous time is reversed in the area as compared with that characteristic of the Richardson Mountains (Refs. 2, 7 and in the Bonnet Lake-Blow Pass section of this report).

Throughout the area dark grey to black, more or less sandy siltstones of upper Husky Formation grade upward into a 100- to 550-foot-thick unit of dark grey to black, more or less coaly sandstones with considerable interbeds of similarly coloured, sandy siltstones commonly rich in specks, small pods, laminae and thin layers of impure coal and carbonized plant remains. Some light grey to buff, feebly carbonaceous to noncarbonaceous sandstones occur in the upper part of the unit.

Unlike the predominantly quartzose sandstones of the equivalent White quartzite division of the Richardson Mountains, the coaly sandstones of our area are commonly polymictic and silty; their composition may approach that of a true greywacke. Hard to very hard, fine to very fine grained sandstones with little or no interstitial porosity predominate. The sandstones are commonly intensively crossbedded and ripple-marked. They contain marine fossils at many levels which commonly occur in carbonaceous to coaly beds in association with plant remains. This indicates a littoral to estuarine origin for most or all of the Coaly sandstone unit.

The equivalence of the Coaly sandstone unit with the White quartzite division and the White sandstone member of the Richardson Mountains is indicated by the presence of numerous and well preserved mid- to late Valanginian Buchia n. sp. aff. inflata (Toula) throughout its thickness.

The Coaly sandstone unit grades upward into a 175- to at least 330-foot-thick unit of whitish grey to dirty white or buff coloured, moderately hard to friable, fairly to strongly porous, quartzose sandstone to orthoquartzite. Fine-grained sandstone predominates but the unit may include considerable interbeds of medium-grained sandstone in its thickest, northwesternmost studied sections. The sandstones are commonly slightly to moderately carbonaceous and may contain some comminuted, carbonized plant remains. No marine fossils were seen and the unit appears to be of an alluvial origin.

The White sandstone unit of the area is lithologically indistinguishable from White sandstone member of Lower sandstone division of eastern Richardson Mountains[7, 8] and of the White quartzite division of the western Richardson Mountains[2]. It is younger, however, than either of these units and correlative with the early to mid-Hauterivian Coal-bearing and Coaly quartzite divisions of these areas because of its gradational superposition on the mid- to late Valanginian Coaly sandstone unit.

The White and Coaly quartzite division equivalent is at least 880 feet thick in its northwesternmost studied sections in the headwaters of Bern Creek. It is, however, only 400 to 450 feet thick (est.) five miles east therefrom in the headwaters of Fishing Branch. The unit thins out even more markedly toward the south-southeast where its section 630NC (approx. 65°50'N; 139°55'W to 139°51'W) measured by D.K. Norris in the headwaters of Fishing Creek is only 250 feet thick (approx.). It consists largely of the 175-foot-thick white to buff-weathering quartzose sandstones (Fig. 3). The underlying Coaly sandstone member is only about 75 feet thick, its lower part being replaced by the at least 100-foot-thick (base covered) friable, dark grey, silty shale apparently representing the uppermost Husky Formation. This shale contains Buchia crassicollis (Keyserling) s. str., B. n. sp. aff. inflata (Toula), and Homolsomites quatsinoensis (Whiteaves).

The above facies changes indicate an early Lower Cretaceous (late Valanginian to mid-Hauterivian) paleogeographical pattern similar to that of the Upper Jurassic sandstone time (Fig. 1). The White and Coaly quartzite division equivalent of our area must have been derived from a large, temporarily expanded and uplifted (mid- to late Valanginian orogenic phase; Ref. 9, pp. 357-359) northern source area centred in the Keele and Old Crow Ranges. The central part of the mid-Valanginian to mid-Hauterivian marine basin of west-central Yukon must have been situated well to the east of the headwaters of Fishing Branch and to the south of those of Fishing Creek. There is every reason to assume that this marine basin extended into the Tombstone area where the "Keno Hill Quartzite" (Ref. 12, pp. 3-4, Table 1) represents its southern littoral facies.

Upper shale-siltstone division was only studied in several incomplete or structurally complex sections. Judging by the longest but severely faulted and partly contorted section measured on the divide between Bern Creek and Fishing Branch (approx. 66°11'N; 140°25'W) this division is at least 5,000 feet thick. Except for the 200- to 300-foot-thick transitional zones at the top and at the base consisting of the interbedding of sandy siltstones and fine-grained, slabby sandstones, the division consists of extremely monotonous sequence of pure to silty shale. The shales are mostly jet black to dark grey in the fresh and weathered state but include considerable interbeds of laminated multicoloured (alternation of rust, light grey and dark brown-weathering lamellae) shale and siltstone in the lower part. The upper 1,200 to 1,500 feet of the unit tend to be replete in variously shaped, large (up to 15 feet long) and small (1-3 inches in diameter) concretions and 3- to 18-inch bands of orange-weathering hard clay ironstone, hard black siltstone, and whitish yellow weathering limy shale and the same is true of its basal 800 feet. In contrast, the middle part of the unit tends to be devoid of or poor in these bands and concretions. This deep water facies of the Upper shale-siltstone division is almost unfossiliferous except in the basal silty and sandy beds which have yielded some long-ranging marine pelecypods and gastropods. No facies or thickness changes of the division were noted within the area but it appears to be completely replaced laterally by nonmarine rocks some 20 miles to southeast of the headwaters of Bern Creek (see in Kandik River section).

Equivalents of the Upper sandstone division appear to be widespread in the headwaters of Bern Creek and Fishing Branch of Porcupine River, judging by distant observations and airphoto interpretation. Only one partial section of the unit was measured, however, on the divide between these creeks (approx. 66°11'N; 140°28'W). The upper part of this section is represented by 200 to 300 feet of dark bluish grey, friable, recessively weathering shale overthrust by the sandstones of the equivalent of White and Coaly quartzite divisions. This shale seems to grade downward into a 400- to 450-foot-thick sandstone unit apparently corresponding to the Lower sandstone member of the Bonnet Lake-Blow Pass area. The upper 115 feet of this unit consists of dull to light grey, hard to medium hard, mostly dense but not quartzite-like, thinlybedded to laminated, quartzose to polymictic (subgreywacke) fine to very fine grained sandstone. This sandstone is mostly intensively crossbedded and ripple-marked and is mostly or entirely marine. The fauna includes I. neocomiensis like inocerami, Pecten (Entolium) cf. orbicularis d'Orbigny and other marine pelecypods and gastropods of Aptian affinities. The remaining 300- to 350-

foot-thick part of the unit consists largely of dark grey to black, massive-looking to indistinctly and heavily bedded, carbonaceous to coaly, fine grained sandstone closely similar to that of the older Coaly sandstone unit. This apparently nonmarine, locally plant-bearing sandstone appears to be quartzose to fairly quartzose and contains minor pods and lenses of lighter coloured sandstone with marine pelecypods. Some interbeds of dark grey to black, carbonaceous to coaly, sandy siltstone occur in the lower 50 to 100 feet of the unit immediately overlying transition beds with the underlying Upper shale-siltstone division.

Younger parts of the Upper sandstone division equivalent or any younger Cretaceous rocks were not seen within the area.

6. Headwaters of Kandik River

Jurassic and basal Cretaceous shale-siltstone unit. The extremely thin shale-siltstone unit confined between the Permian Jungle Creek Formation and equivalent of White and Coaly quartzite divisions was studied in two sections situated respectively approximately at 65°49'30"N and 140°20'W and 65°43'N and 140°24'W and observed in several other sections from the distance. The unit appears to represent the extremely attenuated mid-basin facies of the Kingak equivalent, Upper Jurassic sandstone and Husky Formation of other surveyed areas.

There are no indications of any breaks in sedimentation within this unit in these apparently unfaulted sections and such faunal zones as are present in it are correspondingly attenuated.

Only 467 feet of the Jurassic and basal Cretaceous black to dark grey shale and siltstone were measured in the better exposed more southerly section. The unit is, however, estimated to be 800 to 850 feet thick in the less satisfactorily exposed more northerly section. This suggests a northerly source area situated somewhat farther away from the Kandik River sections concerned than from the similarly thin but somewhat more sandy sections in the headwaters of Fishing Creek (Fig.).

Equivalent of White and Coaly quartzite divisions. In both of the above mentioned sections the Jurassic and basal Cretaceous shale-siltstone unit is conformably and apparently gradationally overlain by a strongly attenuated sandstone unit lithologically similar to and correlative with the Equivalent of White and Coaly quartzite divisions of northwestern Ogilvie Mountains (e.g. in the headwaters of Fishing Creek).

The Kandik River sections permit the recognition of a 28- to 75-foot-thick Coaly sandstone unit below and an 18- to 35-foot-thick White sandstone unit above. However, only a few poor marine fossils, including one *Buchia* resembling *B*. n. sp. aff. *inflata* (Toula), were found in the basal few feet of the Coaly sandstone unit in the more southerly section. The rest of the unit is strongly coaly, plant-bearing, and apparently nonmarine throughout. The White sandstone unit is likewise more carbonaceous than its Ogilvie Mountains equivalent and contains lamellae and up to 3-inch-thick interbeds of coaly shale. As in northwestern Ogilvie Mountains, the thickness of the equivalent of White and Coaly quartzite divisions and that of its component units decrease markedly toward the south.

Mid-Lower Cretaceous coaly clastics. The equivalent of White and Coaly quartzite divisions is conformably and apparently gradationally overlain by an about 3,000-foot-thick (est.) predominantly nonmarine unit lithologically similar to the Coal-bearing division of eastern Richardson Mountains (Ref. 7, pp. 7-9). This unit consists of an irregular alternation of 6-inch to 100-foot-thick beds and members of light to dark grey, hard and dense (often quartzite-like to true quartzite), mostly fine to very fine grained sandstones with similarly thick beds and members of black to dark grey, mostly more or less sandy, carbonaceous to coaly siltstone and similarly coloured coaly shale. The sandstones are predominantly quartzose in spite of their silty and coaly lithology. Small pods and 1- to ?12-inch-thick interbeds (?lenticular) of impure coal are scattered throughout the succession.

One or two 20- to 60-foot-thick interbeds of dirty white to buff-weathering, fine- to medium-grained, intensively crossbedded and ripple-marked quartz sandstone containing marine pelecypods and belemnites occur 500 to 1,000 feet above the base of the unit. One of these marine interbeds yielded Acroteuthis ex gr. panderiana (Sintsov) suggestive of their Barremian age (Ref. 8, p. 13). This circumstance and the apparently gradational contact of the unit with the overlying Upper Aptian to lower Albian flysch suggest its time equivalence to the Upper shale-siltstone and Upper sandstone divisions of more easterly areas of west-central and northern Yukon. The essentially nonmarine (apparently palustral to estuarine) mid-Lower Cretaceous coaly clastics apparently were deposited within the southern part of the previously mentioned Keele-Old Crow Range early to mid-Lower Cretaceous landmass erected by the mid- to late Valanginian tectonic movements. Unlike the adjacent parts of northwestern Ogilvie Mountains, however, this promontory was apparently not flooded by the late Hauterivian to Aptian seas, except for brief and apparently marginal incursions in the Barremian.

The rapid thinning out of the equivalent of White and Coaly quartzite divisions toward the south and the apparent thickening of marine interbeds of the mid-Lower Cretaceous coaly clastic unit in the same direction suggest that the early to mid-Lower Cretaceous landmass concerned did not extend more than a few miles south of Kandik River basin (Fig. 1).

The presence of only feebly to moderately carbonaceous, at least partly marine sections of the mid-Lower Cretaceous coaly clastic unit (?equivalent of Upper sandstone division) west of its above described sections (at approx. 65°49'30"N and 140°50'W) suggests that in the west this landmass did not extend beyond the Yukon-Alaska boundary. This hypothesis agrees well with the old record (Ref. 14, p. 106) of "Buchia crassicollis" just south of 66°N in marine rocks evidently representing some part of the underlying equivalent of White and Coaly quartzite divisions and with the predominantly marine nature of the equivalent argillaceous to arenaceous rocks in the adjacent areas of Alaska (Ref. 15, pp. 113-121).

These data suggest that the nonmarine early to mid-Lower Cretaceous rocks of the headwaters of Kandik River were deposited within a narrow, north-south-directed, lowlying (?lower course and delta of a large south-flowing river) promontory of the Keele-Old Crow Range landmass (Fig. 1).

Upper Aptian to lower Albian flysch. At about 140°27'30"W the mid-Lower Cretaceous coaly clastics plunge beneath a thick (possibly up to 5,000 feet) poorly exposed and structurally complex succession of rhythmically and thinly bedded to laminated shales, pure to very sandy siltstones and mostly fine-grained greywackes closely resembling the Upper Aptian and lower Albian flysch of Bonnet Lake-Blow Pass area (see there). Considerable interbeds of poorly rounded to angular, fine to very fine pebble conglomerate, consisting predominantly of chert pebbles occur in the upper part of the unit. The top of the unit is not reached in the central part of a large, north-trending synclinal structure underlain by these rocks. The north-trending western limit of the outcrop area of the Upper Aptian and lower Albian flysch appears to be situated at or near 140°45'W.

The Upper Aptian to lower Albian flysch of the Kandik River area appears to be unfossiliferous and was correlated with the equivalent flysch clastics of Bonnet Lake-Blow Pass area because of their close lithological similarity and the apparently conformable superposition of the Kandik River area flysch on the mid-Lower Cretaceous coaly clastics.

The Jurassic and Lower Cretaceous rocks of Kandik River area have been assigned an Upper Cretaceous age by the workers of Operation Porcupine (see Geol. Surv. Can. Map 10-1963) because of their predominantly coaly lithology and inferred nonmarine mode of deposition. However, Mountjoy (Ref. 16, p. 3) has later suggested their being Lower Cretaceous in age.

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122. CRETACEOUS AND JURASSIC STRATIGRAPHY OF SOME AREAS OF SOUTHWESTERN BRITISH COLUMBIA

Project 670064

J.A. Jeletzky

About two and a half weeks in August, 1970 were spent in studying the Cretaceous and Jurassic sections of Manning Park in preparation for my duties as one of the co-leaders of AO3 and CO3 I.G.C. field trips and in gathering the necessary data for the chapter of AO3 and CO3 guide book dealing with the Mesozoic rocks of the Manning Park area. The results will be published in the AO3 and CO3 guide book now in preparation (see also Ref. 1).

About 9 days in August were spent supporting mapping project 630016 of J.A. Roddick and W.W. Hutchinson in Pemberton map-area (92J).

The following downward sequence of Cretaceous rocks was observed in the previously unexplored, basically synclinal but intensively faulted structure of Camelsfoot Range in northeastern corner of Pemberton map-area:

1. Sedimentary facies of ? Kingsvale Group

This is represented mostly by an irregular interfingering of heavy beds and members (2 to 50 feet) of mostly coarse- to medium-grained, gritty and pebbly, friable to moderately hard arkose and greywacke with less common and thinner beds of fine to coarse grit and fine pebble conglomerate. These clastics weather characteristically whitish grey to light or dark brown.

Minor (6-inch to 3-foot) interbeds of brown to olive green more or less sandy siltstone and silty shale occur at more or less regular, 20- to 50-foot wide intervals. Convolute bedding with tight, often overturned folds and brecciation caused by the penecontemporaneous slumping are prevalent in these fine-grained interbeds and are not uncommon in some of the adjacent arenaceous rocks. The prevalent southwestward overturning of slump fold axes indicates the southwestern direction of paleoslope and a northeastern source area for the ? Kingsvale sediments.

The apparent absence of marine fossils, the often carbonaceous to coaly character of rocks, and the common presence of carbonized plant fragments on bedding planes suggest a nonmarine origin of most or all of ? Kingsvale sediments.

The ? Kingsvale sediments occupy the axial part of Camelsfoot synclinal structure and are more than 1,500 feet thick. Top of the unit was not reached in any of the sections studied. The contact with the underlying Jackass Mountain Group is poorly exposed and complicated by faulting but appears to be conformable (? and gradational).

The ? Kingsvale sediments are assigned a latest Albian and/or Cenomanian age following a similar dating of the lithologically and stratigraphically comparable Division A of the Kingsvale Group in the Taseko Lakes map-area (Tipper, in Ref. 2, p. 61). This tentative dating agrees well with the apparently conformable superposition of ? Kingsvale sediments on the Albian Massive greywacke division of the Jackass Mountain Group.

2. Jackass Mountain Group

The Jackass Mountain Group of Camelsfoot Range is subdivisible in the following four lithological divisions (descending order) which do not match either the divisions used by Jeletzky and Tipper (Ref. 2, pp. 44-46) in the adjacent part of Taseko Lakes map-area or those proposed by Duffell and McTaggart (Ref. 3, pp. 39-42) for the adjacent Ashcroft map-area:

2A. Massive greywacke division consisting mostly of green-grey to dull brown, coarse- to medium-grained, massive to heavily and indistinctly bedded, often conchoidally to spheroidally weathering, hard and weathering-resistant, mostly gritty and pebbly, probably tuffaceous, greywacke. Considerable interbeds of similarly coloured, hard, massive, fine- to medium-grained greywacke, grit and fine pebble conglomerate interfinger with the coarse- to medium-grained greywacke at some levels. These interbeds are particularly common in the basal and uppermost parts of the division where they may form 50- to 125-foot-thick members. Friable, fine to very fine greywacke and mudstone occur only rarely as thin beds or laminae.

All grains and clasts are poorly to extremely poorly rounded and sorted according to size. Grains of a dark mineral and feldspar strongly predominate and quartz grains are notably scarce. The volcanic clasts appear to be more common than any other types but various sedimentary, metamorphic and intrusive (mainly granitoid) clasts are not uncommon.

The massive greywacke and associated rocks occur mostly in 150- to 1, 100-foot-thick ridge-forming units separated from each other by 30- to 70-foot-thick, recessive-weathering units consisting of a thin cyclical interbedding or interlamination of fine to very fine grained greywacke, and pure to sandy mudstone. Light coloured arkoses are very rare or absent, except in the topmost beds ?transitional to ?Kingsvale Group.

About 4, 750 feet of the unit was measured in its longest, apparently continuous section across Birch Mountain. The complete thickness of the unit may exceed this as both its contacts are faulted in this section.

No plant or animal remains were seen in the Massive greywacke division, except for the lowermost exposed conglomeratic unit of the Birch Mountain section. The latter unit has yielded a fragment of an unusually evolute Tetragonites? n. sp. ex aff. kitchini Krenkel suggestive of the general Albian age of these basal beds at least. These basal beds cannot be older than the late lower Albian Brewericeras (Brewericeras) hulenense zone, however, because of the occurrence of the early lower Albian fauna in the underlying Grey siltstone-shale division (see below). The middle and upper parts of the division are believed to span most or all of the middle and upper Albian time because of the inferred latest Albian and/or Cenomanian age of the overlying ?Kingsvale sediments (see there).

The Massive greywacke division seems to be a rapidly deposited ("dumped") partly(?) or entirely, marine unit because of the apparent total absence of plant remains or coaly particles and very rare presence of marine fossils. The common presence of directional sole markings, graded bedding and penecontemporaneous slumping in the more finely grained, thinly bedded greywacke and mudstone interbeds suggest turbiditic origin for some of its rocks at least. No lateral facies changes have been noted in the division within the investigated area.

The Massive greywacke division is lithologically similar to and appears to grade laterally into the Division C of Jackass Mountain Group of the adjacent parts of Ashcroft and Taseko Lakes map-areas (compare Duffell and McTaggart, Ref. 3, p. 41 and Tipper in Jeletzky and Tipper, Ref. 2, p. 46). It appears to be equivalent of the greater upper part of the Taylor Group of the western parts of Taseko Lakes map-area.

2B. Grey siltstone-shale division consisting of thin interbedding (usually 1/4 to 6 inches) or interlamination of dark to light grey, friable to hard and flinty, pure to very sandy siltstone with similarly coloured pure to silty shale. A considerable ratio (up to 30-35 per cent) of small pods, 1 to 5 feet long and 1 to 4 inches thick lenses and similarly thick, persistent interbeds of very fine, light grey, hard, siliceous greywacke may be intercalated with darker grey shale and siltstone beds giving the unit a strikingly banded to laminated appearance. The local occurrence of graded bedding and sole markings suggest a turbiditic origin of part or all of these flysch-like rocks. The unit includes several 50- to 450-foot-thick members of pure, friable shale with concretions and bands of dark to dull grey, cryptocrystalline limestone weathering dirty white or tan.

In northwestern sections centred around Birch Mountain in Ore Creek basin the mostly argillaceous rocks of the middle part of the division contain numerous 1- to 7-foot-thick interbeds, lenses and pods of coarse- to fine-grained greywacke and pebble to cobble conglomerate rich in various intrusive pebbles ranging from alaskite to diorite. The shales and siltstones themselves are commonly arenaceous, gritty and pebbly in this interval. These rocks appear to be all turbidites as the coarse-grained greywacke interbeds usually are gritty and pebbly, exhibit well developed graded bedding, and have well developed sole markings at the base. The same is true of the conglomerate interbeds which tend to become finer and finer upward and then to grade into pebbly shales. The division is at least 1,713 feet thick and may possibly be over 2,000 feet thick.

The division appears to become more shaly southeastward as an apparently complete section situated about 10 miles southeast of Birch Mountain in the headwaters of Applespring Creek does not seem to contain any significant arenaceous and conglomeratic interbeds.

The presence of well preserved early lower Albian Brewericeras (Leconteites) lecontei fauna in turbiditic pebbly siltstones 1,001 to 1,013 feet stratigraphically below the top of the division indicates its correlation with the lower part of flysch-like Albian and (?)Aptian clastics of Mount Waddington map-area (Ref. 4, p. 104), dark grey siltstone unit of the Jackass Mountain Group of Manning Park area (Ref. 1, pp. 218, 222, Fig. 1) and presumably with the so far unfossiliferous shales of the pre-Brewericeras (Brewericeras) hulenense-bearing part of shaly facies of Taylor Creek Group of Taseko Lakes map-area (Jeletzky in: Jeletzky and Tipper, Ref. 2, pp. 55, 56, Table 2). No unit lithologically similar to the Grey siltstone-shale division was recorded in the Jackass Mountain Group of the Ashcroft map-area (Ref. 3, pp. 39-43) and it is interpreted tentatively as an offshore facies of the lower part of the Division C of that area.

2C. Variegated clastic division underlying the Grey siltstone-shale division conformably and consisting of a generally cyclical alternation of thick units built predominantly of siltstone and shale with those built largely or entirely of arenaceous rocks. Most of these shaly and sandy units contain minor interbeds of coarser clastics at more or less regular intervals. This results in sedimentary cycles of the second and third order.

The siltstones and shales of the division are lithologically similar to those of the Grey siltstone-shale division. They form several 100- to 1,600-foot-thick recessively weathering, poorly exposed units. These predominant, mostly banded to laminated fine-grained clastics are frequently intercalated with rare to common 6-inch to 5-foot interbeds of fine- to coarse-grained greywacke, grit and pebble conglomerate recurring at intervals ranging from several feet to several scores of feet.

Local presence of various sole markings, graded bedding and convolute bedding suggest a turbiditic origin for some ?or most of these rocks. The unfossiliferous Section 18 previously assigned tentatively an early Lower Cretaceous age (Jeletzky in: Jeletzky and Tipper, Ref. 2, pp. 195-196) is now believed to represent one of these units.

The intervening 60- to 1,300-foot-thick predominantly arenaceous units consist of grey-blue, brown or rust-coloured, fine- to coarse-grained, often gritty and pebbly greywacke with subordinated interbeds of buff to light grey arkose. Partings, laminae and 1-inch to 5-foot interbeds of siltstone and shale as in the intervening fine-grained units are common locally. In most units the sandstones are interfingered with rare to numerous but more or less regularly (i.e. cyclically) recurring 6-inch to 20-foot-thick beds, lenses and pods of fine to coarse grit and fine to coarse, generally well rounded pebble conglomerate consisting predominantly of granitoid intrusive clasts but including many other sedimentary and volcanic rock types. These grit and conglomerate interbeds are concentrated predominantly in the middle part of the division where they may rarely be up to 100 feet thick. As a rule, they comprise 5 to 20 per cent of the thickness of the arenaceous units containing them.

About 6,135 feet of Variegated clastic division was measured in the poorly exposed but apparently continuous section in the headwaters of northern confluents of Ore Creek. About 6,410 feet of the division was estimated to outcrop in another apparently continuous section in northwestern headwaters of Applespring Creek. The contact with the underlying Coaly clastic division was not observed in either of these sections and may be faulted.

An apparently Aptian marine fauna including Inoceramus n. sp. aff. neocomiensis (d'Orbigny), and Eotetragonites sp. indet., occurs in the uppermost 200 feet of the division. Another apparently Barremian marine fauna including Quoieccia ex gr. aliciae Crickmay and Acroteuthis (Boreioteuthis) ex gr. impressa(Gabb) occurs about 1,100 feet below its top in the Applespring Creek section. The third apparently Barremian fauna including trigoniids Q. ex gr. aliciae Crickmay and Yaadia cf. lewisagassizi Crickmay was found about 300 feet farther down in the same section. The middle and lower parts of the division contain some marine fossils but did not yield any diagnostic forms.

The largely ?or entirely marine, at least partly turbiditic Variegated clastic division appears to be, in part, an offshore facies of the predominantly conglomeratic, apparently nonmarine Division B (or French Bar Formation) of Ashcroft and Taseko Lakes map-areas (Ref. 3, pp. 40-41; Tipper in: Jeletzky and Tipper, Ref. 2, pp. 44-46). The division includes, however, some beds equivalent to the marine upper part of the Division A of Jackass Mountain Group of the Ashcroft map-area, judging by the presence of Barremian fossils in this part of the latter division (Ref. 3, p. 48).

The Variegated clastic division appears to be correlative with the basal conglomerate of Taylor Creek Group and the Barremian variegated clastic rocks of the Relay Mountain Group of the western part of Taseko Lakes map-area (Ref. 2, pp. 41-43, 52, 54).

2D. Coaly clastic division consisting of mostly carbonaceous to coaly siltstone and shale interbedded with up to 35 per cent of carbonaceous to coaly sandstones. Grit and pebble conglomerate are absent or extremely rare in all better known section of the division.

Dark grey to black, weathering grey, dark brown or rust-coloured, carbonaceous to coaly siltstone and shale predominate in the Coaly clastic division. They are interbedded, however, with considerable siltstone and shale lithologically indistinguishable from those of the Variegated clastic and Grey siltstone-shale divisions.

These siltstones and shales form 20- to 500-foot-thick units intercalated with 5- to 100-foot-thick beds and members of brown-grey to dark grey, fine- to coarse-grained, polymictic sandstone (subgreywacke) and greywacke. These arenites are commonly carbonaceous to coaly and rich in plant fragments including fossil wood. Fine- to medium-grained, well sorted and rounded, fairly quartzose sandstone (subgreywacke) strongly predominate but the coarse-grained, gritty and fine pebbly greywackes resembling those occurring in the overlying rocks are also present. The arenaceous interbeds are common in Ore Creek sections but rare to absent in those measured north of Junction Creek.

About 1,250 feet of Coaly clastic division were measured in its longest, well exposed and uninterrupted section in the lower course of Ore Creek. In this section both contacts of the division are faults and its complete thickness is unknown. Up to 2,000 feet of the almost exclusively shaly rocks of the division are estimated to outcrop in the cursorily surveyed sections on the mountainous eastern banks of Yalakom River in the interval 2 2/5 to 3 1/2 miles northwest of the mouth of Junction Creek. In these sections the division appears to underlie conformably and possibly gradationally the Variegated clastic division but its base is covered and probably faulted.

No marine fossils were seen in the Coaly clastic division. Therefore, and because of the abundance of coaly particles, fossil wood and other plant remains throughout its exposed thickness, the division is believed to be a largely or entirely nonmarine (presumably palustral to alluvial) deposit. No diagnostic fossils of any kind have so far been found in the division.

The lowermost exposed beds of the Coaly clastic division are invariably faulted either against Buchia-bearing Upper Jurassic to early Lower Cretaceous siltstones and shales (Ref. 4, p. 67) or against older rocks. However, the division appears to be younger than the Buchia-bearing beds because of the apparently conformable contact with the overlying Variegated clastic division and the general structural setting. This suggests the general Hauterivian age of the division and its equivalence with the lithologically similar, presumably nonmarine lower part of the Division A of Jackass Mountain Group of the Ashcroft map-area (Ref. 3, p. 39).

The Coaly clastic division appears to be a largely or entirely nonmarine equivalent of the early to late Hauterivian part of Relay Mountain Group of Taseko Lakes map-area (Jeletzky in: Jeletzky and Tipper, Ref. 2, pp. 32-40).

At the end of August about 5 days were spent collecting fossils from the outliers of Cretaceous sedimentary rocks in Quatsino Sound and at the Christensen Point. A new, presumably Turonian Inoceramus spp. fauna was collected from the uppermost siltstone unit of the Cristensen Point outlier (Ref. 5, p. 211).

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123. MOUNT ROBSON MAP-AREA, ALBERTA AND BRITISH COLUMBIA

Project 650023

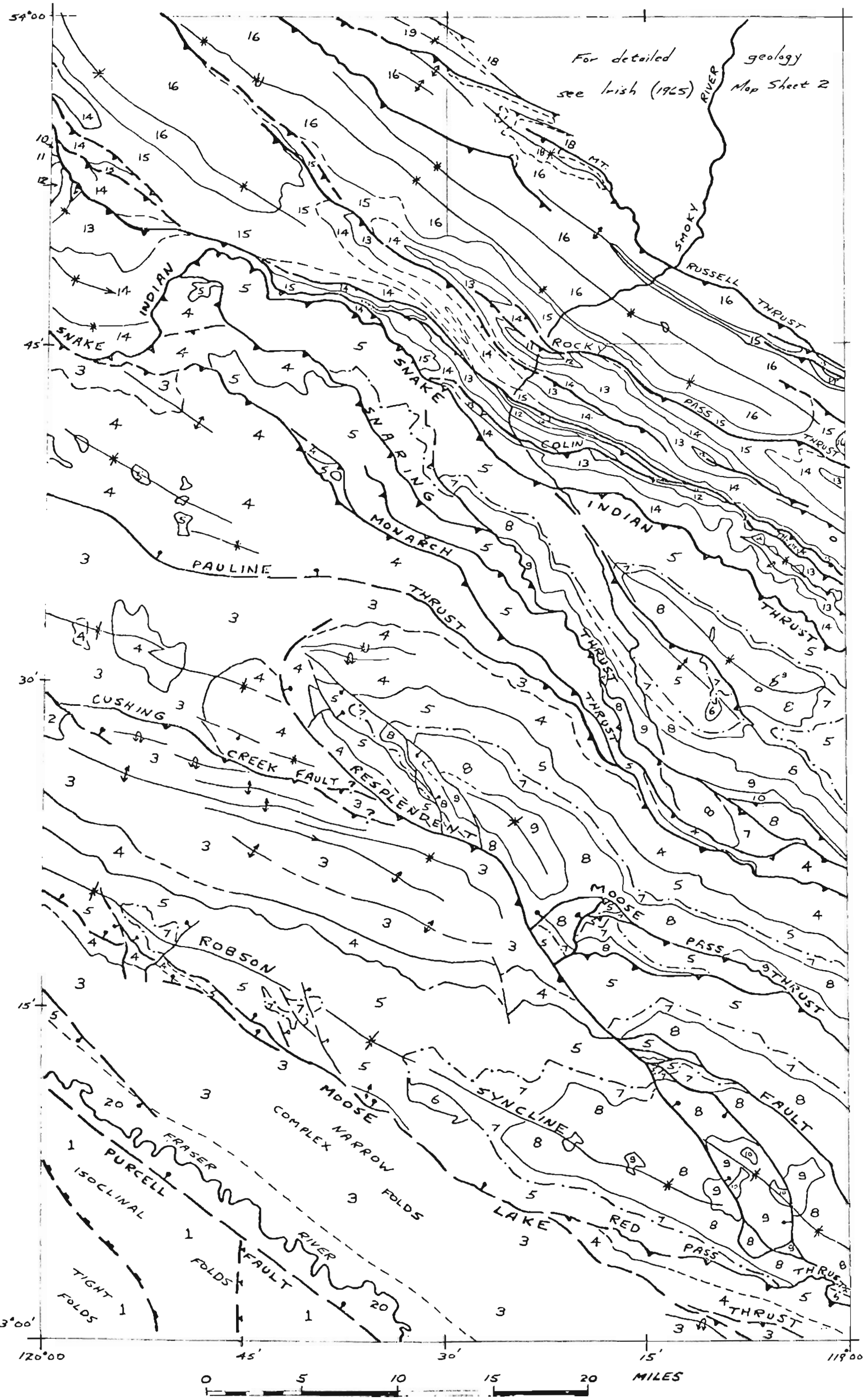
E.W. Mountjoy

Field work in this area was carried out in the summers of 1967 and 1968 in conjunction with geological investigations of McBride map-area and Operation Bow-Athabasca, and also in 1962[1,2] when mapping of the area to the east included part of Mount Robson proper. R.B. Campbell mapped that part of this area southwest of the Rocky Mountain Trench. Geological summaries of adjacent areas are available[1,2,3,4,5,6,7].

The stratigraphy of the map-area is similar to that of the Mount Robson E 1/2 where the diagnostic features of the stratigraphic units have been outlined[1,3,8]. The main differences occur in the Proterozoic Miette Group and Ordovician units. The informal units in the Miette Group thicken westward and near the west boundary of the map-area nearly 10,000 feet of middle Miette strata occur. Lower Miette[6] black shales and argillaceous limestones form a distinct unit at the base on the west boundary of the map-area. Eastward the upper Miette contains progressively more thick and poorly sorted sandstone and grit beds making it more difficult to distinguish easily between the middle and upper Miette. In the northwest corner of the map-area younger Ordovician units, the Monkman and Skoki Formations, appear above the Chushina Formation beneath the sub-Devonian unconformity[7,8].

This is an important area for linking structures of the regions to the southeast and northwest. Previous geological sketch maps[8,9] of this region lacked details concerning fault relationships. The structure of adjacent areas along strike to the southeast has been outlined in detail[1,2,3]. Important structural summaries of the region to the south in relation to structures of this map-area have been published recently[5,10].

The two most prominent structures in the area are the Snake Indian Thrust and the Mount Robson Syncline. Northeast of the Snake Indian Thrust a narrow Front Range gradually plunges northwest, and near Sheep Creek becomes part of a broad Foothills belt. At this latitude the Snake Indian Thrust forms a convenient structural boundary between the Front Ranges or Foothills and the Main Ranges. This thrust is one of the most important in the region, beginning as a series of imbricate thrust faults within the Chetamon thrust sheet north of Jasper and continuing across the Mount Robson,


54°00'
45'
30'
15'
53°00'
120°00
45'
30'
15'
119°00
For detailed geology see Irish (1965) Map Sheet 2
SMOKY RIVER
RUSSELL THRUST
ROCKY PASS THRUST
MT. COLIN
INDIAN THRUST
INDIAN SNAKE
SNAKE SNARING
MONARCH THRUST
PAULINE
THRUST
CUSHING CREEK FAULT ?
RESPLENDENT
MOOSE PASS THRUST
ROBSON
MOOSE SYNCLINE
COMPLEX NARROW FOLDS
FAULT
MOOSE LAKE
RED PASS THRUST
FRASER RIVER
PURCELL FAULT
ISOCLINAL FOLDS
TIGHT FOLDS
0 5 10 15 20 MILES

LEGEND

Recent and Pleistocene

20

Lower Cretaceous

19 Fort St. John Group

17 Cadomin Formation

16 Nikanassin Formation

Jurassic

15 Fernie Group

Triassic

14 Whitehorse and Sulphur Mountain Formations

Permian And Carboniferous

13 Ishbel and Rundle Groups Banff Formation

Devonian

12 Palliser Formation

11 Fairholme Group

Ordovician

10 Undivided

Upper Cambrian

9 Lynx Group

Middle Cambrian

8 Undivided

Lower Cambrian

7 Mahto Formation

6 Mural Formation

Lower Cambrian and Earlier

5 McNaughton Formation

Precambrian

Windermere

4 Upper Miette Group

3 middle Miette Group

2 lower Miette Group

1 Kaza Group

Garnet isograd approximate

Staurolite-kyanite isograd approximate

McBride and Monkman Pass areas, possibly as far as Pine Pass[8]. An abrupt westward turn in the surface trace of this fault south of Sheep Creek and southeast of Intersection Mountain definitely indicates that the eastern part of this thrust is relatively flat and that the Snaring and Monarch thrusts merge with the Snake Indian Thrust at depth to form a common décollement beneath the eastern Main Ranges. Southeastward the Snaring and Monarch thrusts join the important and extensive Pipestone Pass (Pyramid) Thrust[5]. An upper fault, named Pauline Thrust, splays from Monarch Thrust near Short Creek and marks a fault boundary between middle Miette and upper Miette strata. The Pauline Thrust exhibits definite thrust relationships south of Jackpine River and presumably continues northwest to the head of Morkill River in McBride map-area. These thrust sheets, together with the Moose Pass Thrust, form the distinctive eastern Main Ranges in which mainly Middle and Lower Cambrian strata are involved in a series of west-dipping homoclinal thrust sheet structures.

The Resplendent Fault exhibits unusual structural relationships which are different from those of the faults in the Main Ranges to the south. It begins south of the map-area at the Moose Lake Thrust, and both transects and offsets the Robson synclinal axis for about two miles[2, 10]; the Moose Pass Thrust apparently terminates against it at Bess Pass; and it appears to turn northeastward and end abruptly in the Jackpine River valley north of Draco Peak, where it separates different structures on either side of the valley. South of the map-area it is a right lateral transcurrent fault which becomes a high angle thrust fault (possibly with transcurrent displacement) from Coleman Glacier to Draco Peak. At Jackpine Pass the Resplendent Fault dips west at between 70 and 80 degrees and has a stratigraphic throw of about 12,000 feet. Several normal faults of small displacement and more northerly trends (similar to normal faults in the Field-Howse Pass region) cut across the Robson syncline and join the Resplendent Fault at Carcajou Pass. The complex relationships along this fault are difficult to unravel. Some of the normal faults might be later than the thrusting, similar to relationships observed in the region to the south, but there is no positive evidence to date them. Later transcurrent motion along portions of normal faults and a thrust fault could explain the complex relationships observed. The Moose Pass Thrust may continue northwest as the Cushing Creek Fault, being slightly offset by a normal fault between Resthaven Mountain and Mount Philips that utilizes the Moose Pass Thrust for over half this distance. The large stratigraphic throw at Jackpine Pass indicates that the fault is largely one with thrust displacement.

The Robson Syncline is the most prominent feature of the map-area with more than 9,000 feet of resistant lower Paleozoic carbonates. It is asymmetric with a steep and in places overturned southwest limb and a gentle northeast limb with dips of 20 to 40 degrees. It is broken by a few normal faults of small displacement, with northerly trends and rarely northeast trends. The southwest limb is broken by the steep-dipping Red Pass Thrust which places strata low in the McNaughton Formation over the Middle Cambrian Titkana Formation on Mount Kain. The Mount Robson Syncline is underlain by the Moose Pass and Resplendent Thrusts which presumably underlie this structure to the northwest in the McBride area, and at depth extend to the Rocky Mountain Trench and beyond.

The Robson Syncline is bordered on the southwest by the Moose Lake Fault, which places strata of the middle Miette against middle Gog Group across most of the map-area, and hence has a stratigraphic displacement of about 10,000 feet. Along much of its length this fault is near vertical, but near Nevin Creek it appears to dip steeply to the northeast. An area of complexly folded and faulted middle Miette occurs between the Moose Lake Fault and the Rocky Mountain Trench. Rocks near the trench have been metamorphosed to chlorite grade. Though mapped as middle Miette some upper Miette strata may occur within this area of complex structure.

The Rocky Mountain Trench is a flat valley two to four miles wide, filled with Recent and Pleistocene alluvium and glacial deposits. On the southwest side of the trench Kaza Group (stratigraphically equivalent to the middle Miette) staurolite-kyanite-quartz-mica schists have been mapped by R.B. Campbell. On the basis of the geology of the areas southeast of the map-area[4, 5, 11, 12] the west side of the trench is bounded by a fault which may be the extension of the Purcell Thrust. On the west boundary near the mouth of Nevin Creek, and in the adjoining McBride map-area, the McNaughton Formation has been downfaulted along a normal fault against Middle Miette strata. This normal fault continues northwest to north of McBride.

The Kaza Group southwest of the trench forms the east flank of a geanticline and is isoclinally folded. It changes in metamorphic grade from biotite on the west boundary to kyanite-staurolite grade at the trench. The garnet and kyanite-staurolite isograds end against the Purcell (?) Fault and must be offset by this fault. For relationships of this area to adjoining areas see various reports by R.B. Campbell[4, 6, 11, 12].

No economic deposits were observed except for gypsum and anhydrite which occur near the base of the Whitehorse Formation immediately north of Forgetmenot Pass at latitude 54°46'[13]. Some outcrops of the McNaughton Formation near Red Pass or Holmes River might be of sufficient purity to warrant use as a source of silica.

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124. JURASSIC AND CRETACEOUS STRATIGRAPHIC STUDIES BETWEEN SUKUNKA AND KAKWA RIVERS, NORTHEASTERN BRITISH COLUMBIA

83 L
93 I

Project 680084

D.F. Stott

As part of Operation Smoky (see G.C. Taylor, this publication), Jurassic and Cretaceous rocks were examined in the Foothills and Plains, most of the investigations being centered in Monkman Pass (93I) and Wapiti (83L) map-sheets. Owing to the necessity of completing 1:250,000 maps and because previous stratigraphic studies had been made in the region[1, 2], much of the work consisted of revision of and addition to existing maps.

The Jurassic Fernie Formation is probably in the order of 1,500 feet or more thick at Murray River northwest of Turning Mountain. It is more than 1,700 feet at Mount Minnes and, probably, is even thicker to the west near Mount Hannington. It decreases in thickness eastward, being about 900 feet near Stinking Springs, 12 miles east of Mount Minnes. Subdivisions similar to those found north of Peace River[3] can be recognized but commonly are not well defined because of poor exposures. Most of the increased thickness appears to occur in the upper part of the formation above the glauconitic marker bed.

The outcrop belt of the Minnes Group[4] is narrow between Sukunka and Narraway Rivers and sections are poorly exposed. As a result, detailed facies relationships are not readily determined. Two major subdivisions are recognized. The lower part, about 1,800 feet thick at Mount Minnes and 600 feet thick near Stinking Springs, consists dominantly of very fine to fine-grained, well bedded sandstone containing intercalated shale and marine fossils. Those beds apparently are largely equivalent to the Monteith Formation of Pine River region. The upper part, some 3,600 feet thick at Mount Minnes, contains innumerable cycles of carbonaceous coal, mudstone, siltstone, and fine-grained, platy sandstone. The succession represents the continental facies equivalent to the marine Beattie Peaks and Monach Formations and the overlying upper Minnes unit of the Carbon Creek region. Thick coal seams are unknown in the Minnes Group, the main coal development being in the overlying succession.

The Bullhead and Fort St. John Groups[1] and Smoky Group[2] were examined at many new localities. At Bullmoose Mountain, the Cadomin Formation is 276 feet thick and the Gething is about 1,275 feet thick, confirming the general regional trend of increasing thickness from south to north in the Foothills, as previously outlined. In a continuous section east of Kinuseo Creek, the thickness of the Cadomin Formation is 306 feet; of the Gething, 346 feet; of the Moosebar, 373 feet; and of the Commotion Formation, 1,404 feet. The measurements and lithology can be equated satisfactorily with the Wapiti, Quintette, and North Wolverine sections previously published, thereby further confirming the postulated relationships. Well-developed coal seams, some as much as 15 feet thick and a few probably thicker, occur throughout this region. One of the more persistent seams occurs at the top of the Cadomin conglomerate but thick seams occur above other conglomerates and in other stratigraphic positions within both the Gething and Commotion Formations.

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125. DEVONIAN AND EARLIER STRATIGRAPHY, AND STRUCTURE OF MONKMAN PASS AND WAPITI MAP-AREAS, BRITISH COLUMBIA AND ALBERTA

Project 680084

83 L

G. C. Taylor

Reconnaissance mapping of Monkman Pass and Wapiti map-areas was completed during the summer's operations by staff geologists G. C. Taylor, D.F. Stott, D.W. Gibson, E.W. Bamber, R.W. Macqueen, L. Jansa, and W.H. Fritz (see elsewhere this publication for separate reports).

Forty-nine stratigraphic units were recognized and mapped within the two map-areas. This report deals mainly with the Devonian and older stratigraphy and regional structure. The oldest stratigraphic unit observed has been assigned to the Miette Group of Proterozoic (Helikian?) age and consists of about 1,000 feet of limestones and dolomites that have largely been recrystallized. These are overlain by an estimated 10,000 feet of quartzose conglomerates of the middle Miette. Locally these conglomerates occur as conglomeratic mudstones with large though sparse boulders in a mudstone matrix. The boulders consist predominantly of orthoquartzites; however, one granite pebble was observed. Generally, less than 2,000 feet of upper Miette black argillites overlie the conglomerates. Capping the Miette Group is the Byng Dolomite which occurs as thick, lenticular bodies of carbonate about 1,000 feet thick immediately beneath Early Cambrian Gog quartzites. The dolomite is commonly medium to coarse crystalline and light tan in colour. Locally a very dark grey, dense, fine-crystalline limestone occurs at the base of the Byng. Free floating quartz sand and thin orthoquartzite beds are present in eastern exposures. Near the northern boundary of Monkman Pass map-area the Miette Group has been moderately metamorphosed and carries the name Misinchinka Group.

The Gog Group, 2,000-6,000 feet thick, exhibits a pronounced facies change from the clean orthoquartzites of the eastern succession to a sequence containing abundant shales, especially in the MacNaughton Formation in the western Ranges. There is also a striking thinning of the group to the northwest. In the western Ranges the Mural Formation contains a 15-foot interval rich in hematite and magnetite at its base. Both the Mural and the Mahto Formations are thicker in the western Monkman Pass map-area than in McBride map-area to the south. Within the Dezakio and Misinchinka Ranges latest Early Cambrian clastics are present; these correlate with similar rocks of the Dome Creek area west of the Rocky Mountain Trench. The Middle Cambrian Tekai-Chetang, Titkana, and Arctomys Formations occur in a predominantly carbonate facies that also thickens westward. Within the Dezakio Range the Tetai-Chetang interval exhibits a facies change to Chancellor type rocks. The Late Cambrian Lynx Formation (1,400-2,000 feet thick) also passes westward into a clastic rich facies.

Ordovician rocks are widespread and thick (± 5,000 feet) throughout the map-areas; Chushina, Monkman, Skoki, and Beaverfoot Formations are recognized. A regional unconformity separates the latter two formations.

In the extreme southwest corner of the Monkman Pass map-area, but lying to the east of the Rocky Mountain Trench, there occurs a thick sequence of predominantly volcanic sediments (agglomerates?) with thin basic flows, that is interbedded in its upper part with limestones. No fossils have been found in the carbonates, but similar carbonates along strike to the south in the McBride map-area have yielded Ordovician and Silurian fossils. The McBride locality is structurally complex. Basic sills are also known from the Halfway map-area to the north within late Ordovician rocks. On this tenuous evidence the volcanic complex is tentatively considered to be of Ordovician age.

Silurian strata are known only from the Dezakio Range, where 1,400 feet of carbonates of a similar facies to the Nonda Formation unconformably overlie the Beaverfoot Formation. These strata probably onlap the Peace River - Alberta Arch system of highs to the east and record the maximum westward development of the archs.

Devonian strata also record onlap from the west and northwest onto the Peace River - Alberta Arch system. Beds assigned to the early Middle Devonian Stone Formation can be traced around the west flank of the arch and southward as far as Monkman Lake. The late Middle Devonian Pine Point Formation onlapped even farther to the southeast and east with 1,800 feet of these strata (without a stratigraphic top) recorded within ten miles of the southern boundary of the Monkman Pass map-area. The southern exposures of this sequence reveal the rapid development of a westward thickening, basal, clear quartz sandstone approximately 700 feet thick in the Hart Ranges north of Jarvis Creek.

The stratigraphic relationships of the Upper Devonian strata to the Middle Devonian rocks can only be inferred, as they were observed in structural continuity at only one location, and there, the critical interval was not exposed. Approximately 1,000 feet of black shale assigned to the Perdrix Formation overlies the Middle Devonian. Long tongues of fossiliferous Mount Hawk carbonates extend northward from the Monkman Pass map-area as far as the Pine Pass. These are overlain by 470 feet of dense fossiliferous limestone assigned to the Southesk Formation. About 110 feet of dolomitic and arenaceous limestone overlies the Southesk, and is tentatively assigned to the Sassenach Formation which is overlain by 800 feet of nodular limestones of the Palliser Formation. These Upper Devonian carbonate units pass northwestward into shales of the Besa River Formation with the lower units extending farther to the northwest.

The structural style of the map-areas is transitional between Northern and Southern Rocky Mountain structural types. Thrust faulting is the predominant mode of deformation within the mountain areas, though no great amount of transport need be inferred. Indeed many of the thrusts can be traced into asymmetric folds in both directions along strike so that the amount of translation is rigidly limited. The thrust sheets themselves are thick packets of strata within which there is a considerable amount of folding. Leading edges of the thrust sheets are characteristically imbricated. The Foothills region is predominantly a fold belt, although it contains more numerous high angle reverse faults than comparable areas to the north. The mode of deformation is consistent with the model of décollement mechanics that is generally advocated for this region.

126. STRATIGRAPHY AND SEDIMENTOLOGY OF LOWER PALEOZOIC CLASTIC UNITS, TANQUARY AND CAÑON FIORD REGIONS, ELLESMERE ISLAND

Project 690002

H. P. Trettin

Field work was done between June 6 and August 14, (1) near the head of Tanquary Fiord (Fig. 1a, locs. 1, 2); (2) east of Cañon Fiord at Caledonian Bay (Fig. 1a, loc. 3 and Fig. 2); and (3) south of Cañon Fiord (Fig. 1a, loc. 4 and Fig. 1b). The three general areas were reached by airplane. Fly camps were established by back-packing and ski-doo at Tanquary Fiord, and by back-packing south of Cañon Fiord.

The writer is indebted to G. Hattersley-Smith (Defence Research Board) and to student assistants B. Petri and B. Ward for hospitality and ski-doo support at Tanquary Camp. K.G. Alexander and F.G. Fox made available a Panarctic Otter for camp moves in the Cañon Fiord region at a time when charter aircraft could not be obtained. Assistance from D. Crane (Pacific Petroleums) and the personnel of the Weather Station Eureka is also gratefully acknowledged. R. Thorsteinsson has made preliminary identifications of several graptolite collections.

Tanquary Fiord

The work at Tanquary Fiord was intended to clarify problems resulting from Operation Grant Land (1965-67). Photogeological structural interpretations were checked northwest of Tanquary Fiord (Fig. 1a, loc. 1), and the transition from the Grant Land to the Hazen Formation, two newly proposed units[1], was studied east of the head of the fiord (Fig. 1a, loc. 2). There, clastic limestones representative of a submarine slope environment occur stratigraphically between red and green shelf-type slates, and dark grey, bedded, radiolarian (?) cherts of basin-type. Characteristics of the slope environment are: (1) thin- to very thin bedded, medium dark grey, finely microcrystalline limestones alternating with medium dark grey slate (see ref. 2); and (2) thin-bedded dolomitic calcarenites showing graded bedding. The stratigraphic sequence represents a regional subsidence that occurred in Early Ordovician or Late Cambrian time.

Caledonian Bay

Three major lower Paleozoic successions had previously [3,4,5] been distinguished at Caledonian Bay (Fig. 1, loc. 3 and Fig. 2): (1) shelf-type carbonates assigned to the undivided Allen Bay and Read Bay Formations; (2) graptolitic shales and limestones assigned to the Cape Phillips Formation; (3) thick, almost unfossiliferous clastic sediments assigned first to the Eids Formation[3] and later to the Cape Rawson Group[4]. The three units occur in vertical succession at individual sections, but together ascend in age in a southeasterly direction so that they are facies equivalents on a regional scale, with the Cape Rawson-clastics grading southeastward to the Cape Phillips shales and limestones, which, in turn, grade southeastward to the Allen Bay and Read Bay carbonates. The main objective of the present

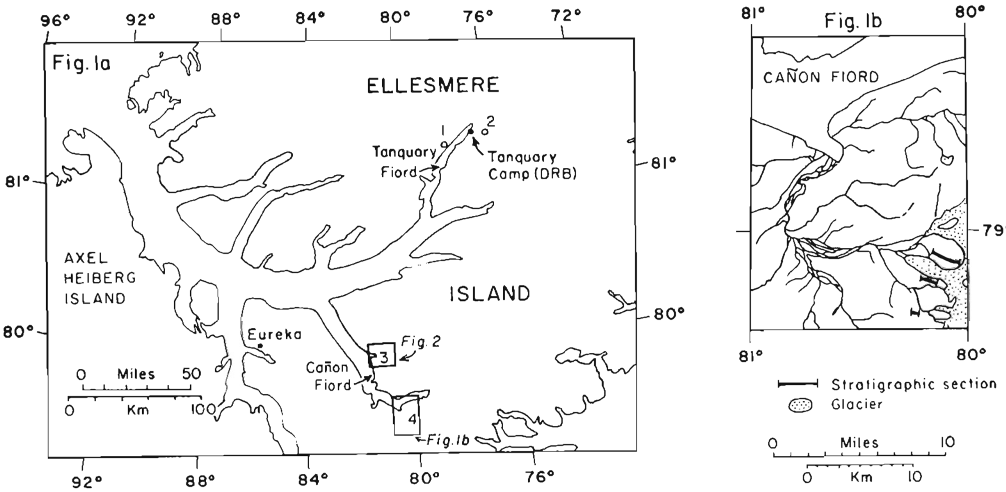

Fig. 1. Index maps

work was to elucidate the stratigraphy and sedimentology of the Cape Rawson-type rocks, and their relationship with the Cape Phillips Formation.

Stratigraphy

The Cape Phillips Formation consists of about 200 feet of dark grey, calcareous, slaty shale and siltstone at section II (Figs. 2b, 2c) and of 750 feet of similar shale and siltstone with interbedded limestone at section IV. Soft-sediment slump-structures, and a boulder of shelf-type carbonate rock observed at this section are features not previously reported from the formation. Preliminary, incomplete fossil identifications indicate that the formation is mainly Wenlockian and Ludlovian (Middle and Upper Silurian) in age at sections III and IV.

The Cape Rawson Group (a reconnaissance term to be abandoned[1]) is subdivided as follows: the lower and middle part is assigned to the Imina, a formation widely exposed in northern Ellesmere Island[6, 7, 1], and the upper part to an unnamed unit, here referred to as map-unit 4 (of Fig. 2b).

The Imina Formation consists of alternating, very fine grained calcareous sandstone, slaty calcareous siltstone, and slaty calcareous shale with minor amounts of conglomerate and breccia. The sandstones and siltstones show flysch-type primary structures such as graded and massive bedding, parallel and convolute lamination, ripple-marks and sole marks (flute casts, groove marks, etc.). Conglomerate and breccia about 400 feet above the base of section II contain limestone clasts with a shelf-type fauna. Crinoidal granule conglomerate with lenses of sandstone and siltstone is shown as map-unit 3a (Figs. 2b, 2c). The thickness of the formation decreases from possibly more than 10,000 feet at the fault-bounded section I (section 9)[4] to 2,030 feet at section II, and 495 feet at section III. The formation wedges out between sections III and IV, and probably was not deposited anywhere southeast of Caledonian Bay.

The full age range of the Imina Formation at Caledonian Bay is uncertain because the identification of the fossil collections has not yet been completed. Monograptus bohemicus of early Ludlovian age, however, is now known to occur about 6, 000 feet below the top of the unit (at loc. (b) of Fig. 1). This shows that the formation is younger in central Ellesmere Island than in northern Ellesmere Island (see refs. 1, 6, 7) and thus confirms the conclusion[8] that the depositional basin of the unit migrated southeast during the Silurian.

Map-unit 4 is composed mainly of laminated calcareous mudstones with a pronounced slaty cleavage. Sandstones and siltstones, similar to those in the Imina Formation, form less than 10 per cent of unit. A fossiliferous breccia near locality (d) contains shelf-type benthos. The thickness of the unit, difficult to establish because of minor folds and faults, probably exceeds 1, 000 feet.

The fossils from locality (d) have not yet been identified. Air reconnaissance suggests that map-unit 4 includes all strata south of Caledonian Bay and east of Cañon Fiord previously to the Cape Rawson Group or Eids Formation[3, 4]. Those rocks were considered to range in age from latest Silurian to Early Devonian[4].

Sedimentology

A model of physiography and sedimentation during the Late Silurian is shown in Figure 2d. Three major depositional environments are recognized: a (miogeosynclinal) shelf, and an adjacent slope and basin, the latter referred to as the axial trough of the Franklinian geosyncline[8].

Northwestward flowing turbidity currents of low density and low velocity (a) probably deposited shelf-derived mud and lime mud on the slope and proceeded into the adjacent basin. Submarine slides originating in carbonates at the edge of the shelf traversed the slope (b), and came to rest in the adjacent basin (c). It has been shown previously that the Imina Formation is comparable to modern submarine fan and trough-deposits and that it was derived mainly from the northwestern margin of the trough[1, 8]. In northwestern Ellesmere Island, turbid flows (turbidity currents s. s. and other types of flows), carrying terrigenous silicate particles and shelf-derived carbonate particles, descended into the trough in southeastward directions and were deflected to the southwest at the bottom. Southwestward axial transport (e) also prevailed at Caledonian Bay, southeastward transverse transport (f) was subordinate, and northeastward axial transport (d), perhaps due to local eddies, was uncommon.

Conditions probably were similar during the time interval represented by map-unit 4, except that turbid flows depositing sand were less frequent.

Structure

The Read Bay-Allen Bay carbonates, the Cape Phillips Formation and the Imina Formation form a major, simple syncline that is bounded by a normal fault on the northwest. Northwest of that fault the structure is complex, and the stratigraphic succession below section I is upside down. The slates of map-unit 4 exposed in the centre of the major succession exhibit complex minor folds and faults; only a few folds are shown on the map.

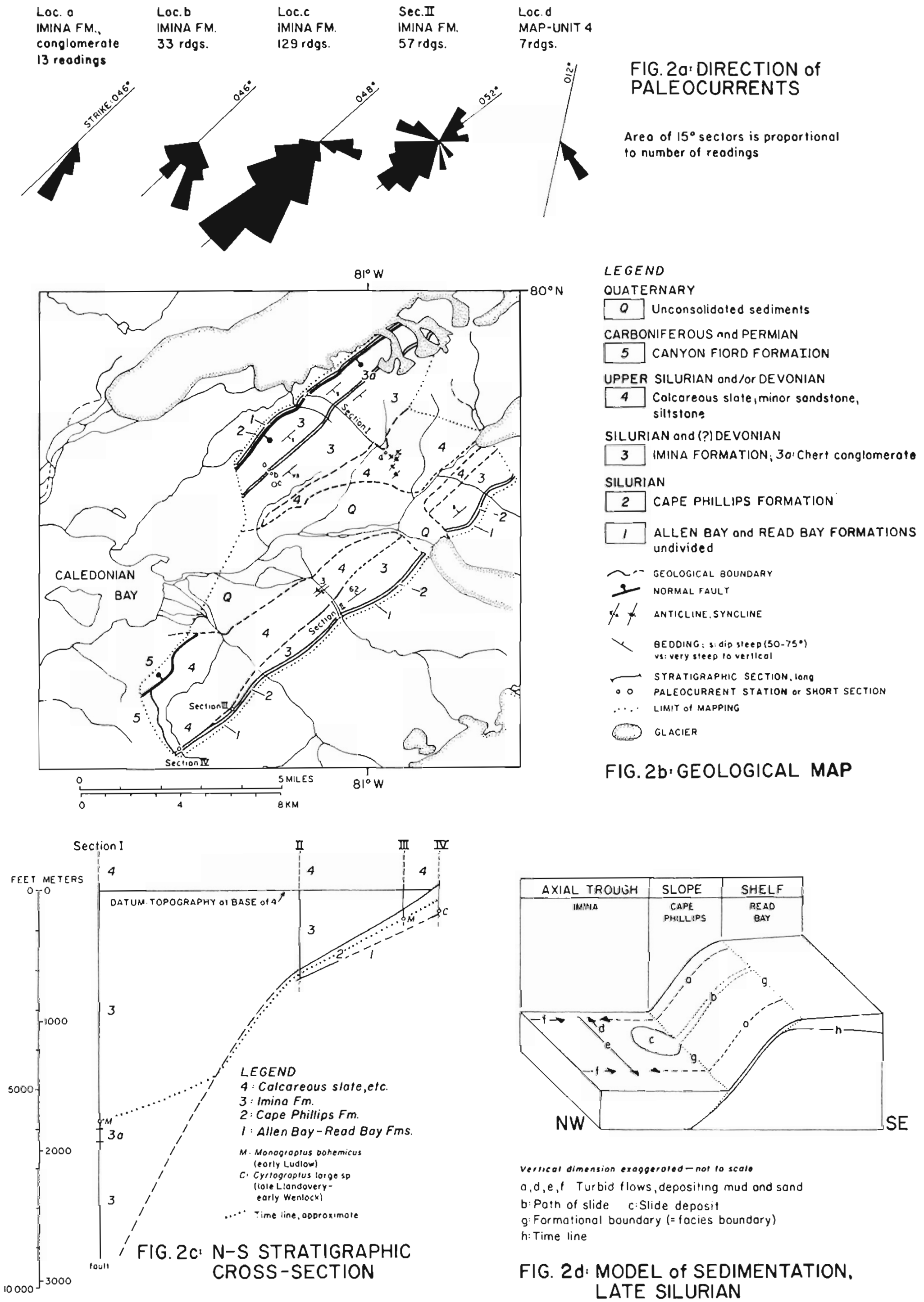

Figure 2. Geological features of the Caledonian Bay area.

Figure 3. Soft-sediment slump structures in red beds underlying the Vendom Fiord Formation.

South of Cañon Fiord

A predominantly clastic Devonian succession south of Cañon Fiord (Fig. 1b; see section 14)[4] was measured and sampled in detail in order to determine the depositional environment and provenance of the sediments. The section is divisible as follows: (1) red beds, previously assigned to the Cape Rawson Group, age uncertain but presumed to be Early Devonian - 1,100 feet; angular unconformity at top; (2) Vendom Fiord Formation, probably late Early and/or early Middle Devonian - 1,230 feet; (3) transition beds - 130 feet; (4) Blue Fiord Formation, early Middle Devonian - 350 feet; (5) Okse Bay Formation, late Middle and Late Devonian - 1,710 feet; angular unconformity at top; (6) Eureka Sound Formation, Cretaceous and Tertiary - not measured.

Special attention was given to two problems briefly discussed below.

Provenance and tectonic significance of the "Cape Rawson" beds

The "Cape Rawson" beds are laminated and crosslaminated dolomitic siltstones and silty dolomites that weather mainly pale red with some olive green. Trace amounts of gypsum and stromatolites occur in the lower part of the section. Soft-sediment slump structures were observed about 400 feet below the top (Fig. 3). The clastic/carbonate ratio increases at this level.

These strata were probably not derived from the orogenic belt to the northwest as most other parts of the Cape Rawson Group were, but from the craton to the southeast as was the Vendom Fiord Formation. This conclusion is based on the shallow marine to supratidal depositional environment of these red beds and on their similarity to the siltstones of the Vendom Fiord Formation. The slump structures probably mark the beginning of the Caledonian earth movements that subsequently produced the angular unconformity at the top of the red beds, and the overlying Vendom Fiord conglomerate[9].

Provenance of the Okse Bay Formation

Preliminary petrographic studies combined with regional tectonic investigations[1] suggest that lower Paleozoic sedimentary formations such as the Imina, Hazen, and Grant Land, removed from a structural high in the southern Grant Land Mountains, may have been the principal source of the Okse Bay strata south of Canon Fiord.

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[4] Kerr, J. W.: Devonian of the Franklinian miogeosyncline and adjacent stable region, Arctic Canada; in International Symposium on the Devonian System, D.H. Oswald, ed., vol. 1, pp. 677-692; Alberta Soc. Petrol. Geol., Calgary, Alberta (1968).

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[7] Trettin, H. P.: Geology of Ordovician to Pennsylvanian rocks, M'Clintock Inlet, north coast of Ellesmere Island, Canadian Arctic Archipelago; Geol. Surv. Can., Bull. 183 (1970).

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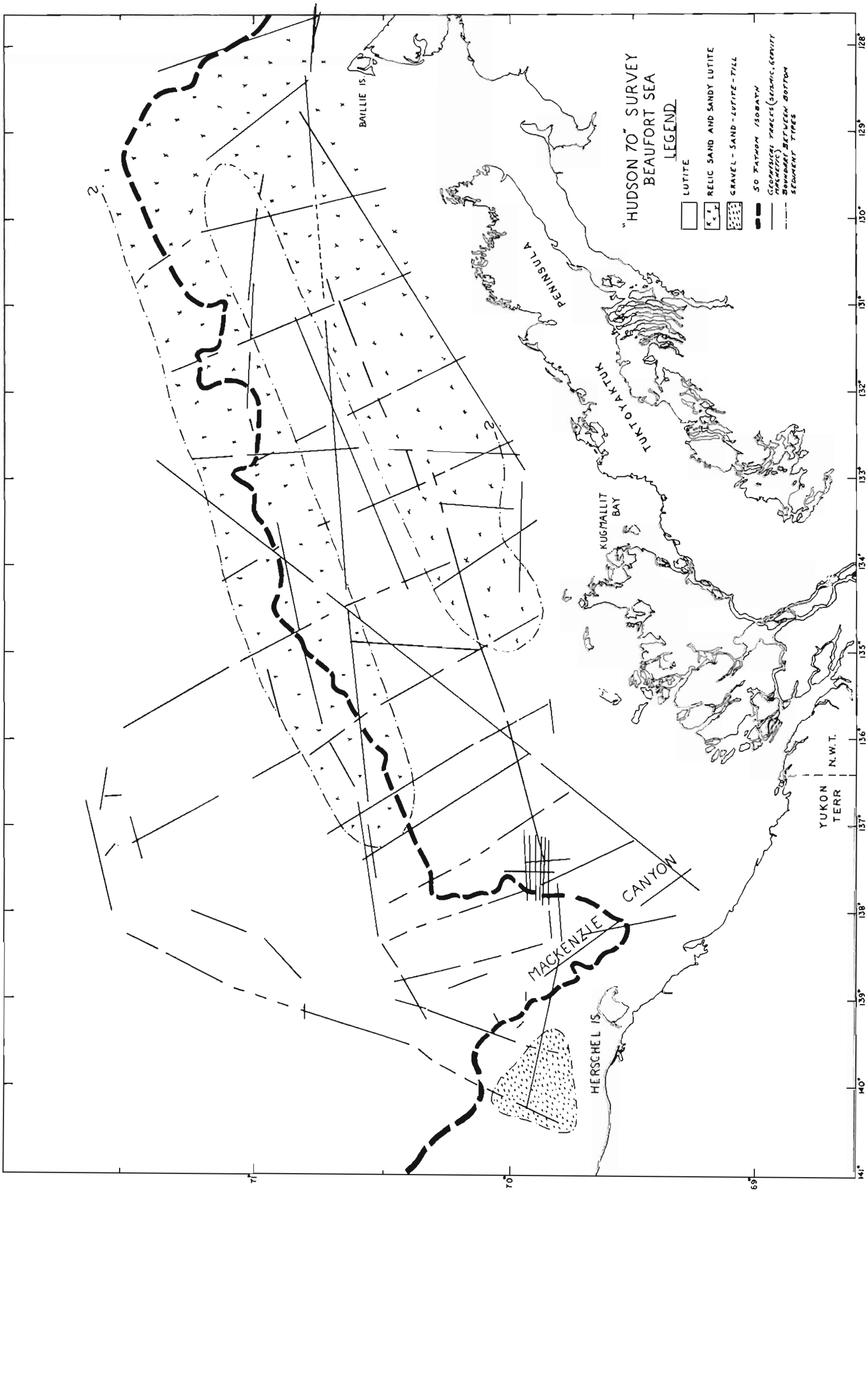
[9] Kerr, J. W.: Vendom Fiord Formation — a new red-bed unit of probably early Middle Devonian (Eifelian) age, Ellesmere Island, Arctic Canada; Geol. Surv. Can., Paper 67-43 (1967).


"HUDSON 70" SURVEY
BEAUFORT SEA
LEGEND
LUTITE
RELIC SAND AND SANDY LUTITE
GRAVEL - SAND - LUTITE - TILL
50 FATHOM ISOBATH
GEOPHYSICAL TRACKS (SEISMIC, GRAVITY MAGNETIC)
BOUNDARY BETWEEN BOTTOM SEDIMENT TYPES
BAILLIE IS.
PENINSULA
TUKTOYAKTUK
KUGMALLIT BAY
N.W.T.
YUKON TERR
MACKENZIE CANYON
HERSCHEL IS.

127. SEISMIC AND SEDIMENT STUDIES IN THE BEAUFORT SEA

Project 690020

C. J. Yorath, J. Shearer and C. J. Havard

This report summarizes preliminary sediment studies carried out by C. J. Havard and C. J. Yorath of the Institute of Sedimentary and Petroleum Geology, who in collaboration with the Bedford Institute, participated in Phase 8 of the Hudson 70 cruise between August 26 and September 22, 1970. The latter part of this report summarizes the results of the shallow reflection seismic profiling carried out by J. Shearer of the Quaternary Research and Geomorphology Division and C. J. Yorath.

The ship used was the Canadian Hydrographic Services vessel, C. S. S. Hudson, and the project was designated as "Hudson 70". Phase 8 of this cruise, under the scientific direction of B. R. Pelletier of the Bedford Institute entailed reconnaissance studies of the Beaufort Shelf and continental slope. A number of programs were carried out including seismic, gravity, magnetic, side-scan-sonar and echogram profiling, bottom coring, grab-sampling and dredging, vertical and surface macro- and microbiological tows, oceanography, and bottom photography and television. The survey tracks were located on the basis of satellite navigation, decca, and dead reckoning. A Bell 206 helicopter was used for logistics support, ice surveys and related coast-line geological studies.

The area of the survey is located between 69° and 72° N and 128° and 141° W, and lies entirely within the Beaufort Sea. Ninety-four van-veen grab samples and 47 gravity piston cores were taken along 13 lines which extended from near shore to beyond the continental shelf break. Grab samples were collected at all stations occupied and cores were taken on every second line. Bottom sampling and coring (in addition to other types of station work) were done during the daylight hours following the completion of night-time seismic profiling. The ship's tracks covered the three principal bathymetric subdivisions of the region: the Beaufort Shelf, Mackenzie Canyon, and the shelf break and continental slope.

Bottom Sediments and Cores

The general ocean bottom sediment types on the Beaufort Shelf, as determined from grab samples, are shown on Figure 1. The finest grained sediments, or lutites, are restricted to four areas: the Mackenzie Canyon, the continental shelf break and slope, the central shelf, and the southern shelf north of Kugmallit Bay. Most of the modern Mackenzie River sediment is fine grained and is principally delivered to the Canada Basin via Mackenzie Canyon; however some of this material is apparently swept northeastwards and is deposited as a linear belt over the central shelf region. Sandy lutites occur on the shelf as two broad east-west trending belts. The arenites of these deposits possibly represent relict material deposited during periods of lower sea level and thus may be older than the central shelf and Mackenzie Canyon lutites. A semielliptical region of sandy gravels, sands and hard pebbly lutites occurs northwest of Herschel Island. These have been tentatively interpreted as relict glacial deposits and ice-pressed tills.

Core recovery in the region was variable with maximum recoveries obtained in the Mackenzie Canyon and just beyond the shelf break. The principal stratigraphic units within the cores are: carbonaceous laminated lutite, clay laminated lutite, homogeneous unlaminated lutite and sand.

Within Mackenzie Canyon the cores consist of carbonaceous laminated lutite which thins seaward down the axis of the canyon. Beyond the 200 fathom isobath, the carbonaceous lutite is underlain by the clay laminated lutites which are, in turn, underlain by homogeneous unlaminated lutites. Eastward from the Mackenzie Canyon along the shelf break and continental slope, this three-fold subdivision is present but is less systematic. Individual units vary greatly in thickness.

On the eastern shelf core recoveries are low and lithologies are principally fine- to medium-grained poorly consolidated sand. The sands are well sorted, grain supported, have a minor lutite matrix and are rich in heavy minerals.

Successful coring of a mud-squeeze structure, defined on the basis of seismic profiling, yielded a recovery of fine-grained, unconsolidated sand. The recovery from another conical feature, believed to be a pingo, was dark grey carbonaceous lutite with a well developed vesicular structure due probably to escaping gas. At one station on the eastern shelf, just west of Baillie Island and beneath about 20 fathoms of water, a core yielded fresh water ice lenses overlain by dense lutites.

Seismic Profiling

Approximately 1,200 miles of shallow seismic profiling were completed. Equipment used consisted of a Huntec sparker unit and a Bolt one cubic inch and 10 cubic inch air gun and hydrophone array. These two systems were run simultaneously over most of the Beaufort Shelf area. Beyond the shelf break, only the air gun system was used. Filtered air gun data was displayed upon an Alpine recorder and unfiltered data was recorded upon magnetic tape.

Over the shelf area where water depths are very shallow, signal recording was limited by the interference of the first multiple. The sparker and air gun records show a flat but dissected surface lying between 300 and 400 feet below present datum. Below this surface the sediments dip gently seawards. In a few places, clear definition of infilling sediments above the dissected surface was obtained. As deeper waters were encountered towards the shelf break, record quality improved and displayed a seaward dipping progradational sequence of sands and muds which have suffered downslope creep and/or slumping. Seismic (sparker) records over the above described pingo-like structure show flat-lying strata below a conical dome with a relief of about 80 feet. This would indicate a near surface mechanism for its formation, and the presence of ice in one of the shelf cores would suggest a similar mechanism to the formation of pingos on nearby Tuktoyaktuk Peninsula.

128. MESOZOIC STRATIGRAPHIC STUDIES, NORTHERN YUKON TERRITORY AND NORTHWESTERN DISTRICT OF MACKENZIE

Project 700068

117A/9

F. G. Young

Field work in 1970 included familiarization with Jurassic and Cretaceous rock units, and descriptions of new sections in rocks mainly of late Lower Cretaceous (Albian) and Upper Cretaceous ages. The guidance of Drs. D.K. Norris and J.A. Jeletzky in the field is gratefully acknowledged. New stratigraphic information was obtained in the Arctic coastal plain, northern Richardson Mountains, western Ogilvie Mountains, Eagle Plain, and northwestern Mackenzie Mountains of Yukon Territory. Type sections of the Moose Channel Formation[1] (Upper Cretaceous) exposed near the northwestern edge of Mackenzie Delta (Fig. 1), and the Trevor Formation[2] (late Lower Cretaceous) exposed south of the junction of Peel and Snake Rivers, were measured for the first time.

Field studies were made on a little known, thick sequence of dark shales, coarse sandstones and conglomerates which outcrop in the Arctic coastal plain west of Mackenzie Delta. These rocks are assigned tentatively a late Lower Cretaceous (Albian) age on the basis of a few ammonites identified in the field by J.A. Jeletzky. At present, the sequence is poorly established due to structural complications, few exposures, and a lack of marker beds and fossils. Future micropaleontological research should help determine thicknesses and internal stratigraphic relationships. The sequence consists of several thousand feet of shale, in which there are sandstone beds characterized by flute- and groove-casts typical of turbidites. Some members in the sequence are rich in chert- and quartzite-pebble conglomerates and lithic sandstones. Carbonaceous plant fragments are the only obvious fossils in the rudaceous members. Rare ammonites occur in the thick shale members.

Resting unconformably above the deformed Albian strata are relatively undeformed clastic rocks of Upper Cretaceous age[1, 3] in the coastal plain area. A nearly complete section in this series was studied along the canyon walls of Cache Creek-Fish River (Fig. 1).

At the base of this sequence is an unnamed soft mudstone formation in excess of 1,100 feet (335 m) thick. This unit exhibits unusual graded tilloids or pebbly mudstones that possibly represent subaqueous mudflow deposits, in its basal 200 feet. The mudstones are carbonaceous in the uppermost 300 feet, and include lentils of burrowed sandstone.

The Moose Channel Formation conformably overlies the mudstone unit, and consists of a lower sandstone member (1,920 ft. or 585 m) and an upper coaly mudstone member (950 ft. or 290 m). The sandstones of the lower member are, for the most part, poorly to moderately sorted, fine- to coarse-grained, compacted chert litharenites containing coalified plant remains. Thin layers of conglomerate and shale are interbedded with the sandstone; gravel-filled channels, abundant current-formed structures, coarse plant fragments and the lack of marine fossils suggest these sediments are fluviatile. Initial analysis of paleocurrent measurements indicates a general flow direction toward the east-northeast. Hence, potential hydrocarbon traps associated with delta-margin deposits equivalent to the Moose Channel sandstones lie in the subsurface beneath the lower Mackenzie Delta.

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[1] Mountjoy, E.W.: Upper Cretaceous and Tertiary stratigraphy, northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 66-16 (1967).

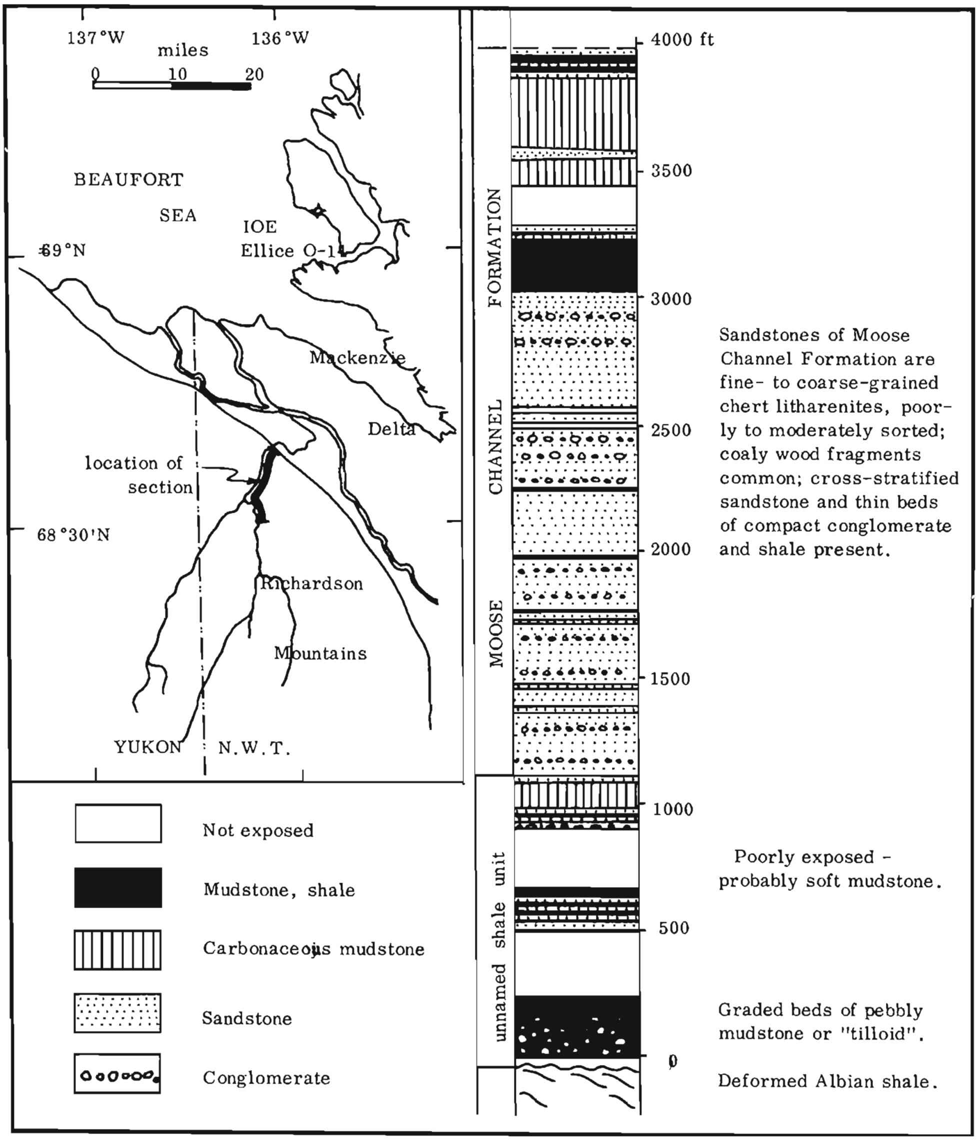

Figure 1. Generalized Stratigraphic Section of Upper Cretaceous Rocks West of Mackenzie Delta.

[2] 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).

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GENERAL

129. THE NATIONAL MINERAL COLLECTION

Project 550101

H.R. Steacy

H.R. Steacy visited many of the classical mineral-collecting localities in the Grenville of Ontario and Quebec in connection with planning a field excursion to such localities for the 1972 International Geological Congress. With the assistance of the Mines Branch C.H.R. Gauthier collected 13 rock specimens weighing 1 to 3 tons each for use in the development of a Court of Geology near the Geological Survey of Canada headquarters building in Ottawa. The experience so gained will be available to communities contemplating similar projects.

1[illegible] MINERAL-COLLECTING LOCALITIES IN NORTHERN MANITOBA AND SASKATCHEWAN

Project 640048

Ann P. Sabina

Mineral-collecting localities in the Precambrian of northern Manitoba and Saskatchewan, between La Ronge, Saskatchewan and Thompson, Manitoba, were visited. Almost 100 localities, including a few operating mines were investigated with the intention of providing collecting sites for tourists and collectors. For the casual visitor, access to most operating mines is prohibited. Most of the occurrences are accessible by automobile; a few are reached by boat or by air. This poses little problem for the average tourist who uses boat and air transportation for fishing in the area. Although collecting localities are not numerous, there are sufficient occurrences to provide a diversion for tourists whose prime interest in the area is for fishing.

In the La Ronge area, there are former uranium and gold prospects, and operating copper and copper-nickel mines. Minor occurrences of beryl, tourmaline, andalusite, and garnet are found between La Ronge and Flin Flon.

Mines which were formerly operated in the Flin Flon area yield specimens of chalcopyrite, pyrrhotite, arsenopyrite (crystals), pyrite (crystals), sphalerite, garnet, and secondary copper minerals. For the collector, the Snow Lake area provides the most interest. Fine specimens of kyanite, staurolite, garnet, and pyrite can be found in the mine dumps. An attractive marble and fossils, are also found in this area. The operating nickel mines in Thompson, are not accessible to collectors.

ADDENDUM
(received 6 November, 1970)

131. STRUCTURE OF THE CONTINENTAL SLOPE WEST OF VANCOUVER ISLAND * BETWEEN 48°N AND 49°10'N

92 B.C

Project 680138

Sandra M. Barr and R.L. Chase
Department of Geology
University of British Columbia

A geological and geophysical study of the continental slope west of Vancouver Island between 48°N and 49°10'N has been undertaken to determine the boundary effects between the Juan de Fuca and North American lithospheric plates (Fig.1). This is in conjunction with an investigation of the ocean floor in the vicinity of the northern end of Juan de Fuca Ridge, postulated to be an active centre of sea-floor spreading[1, 2].

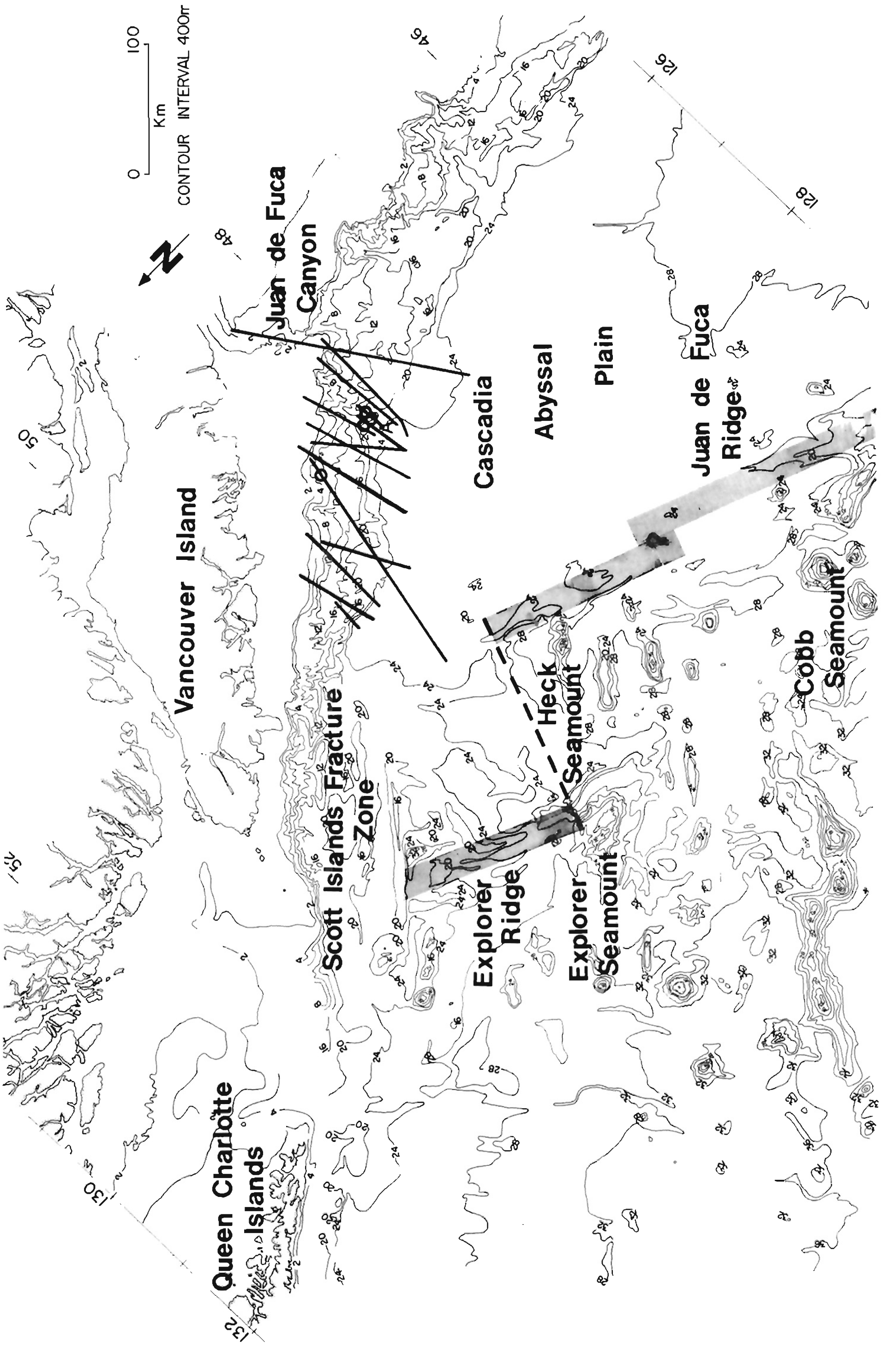
The study was initiated in 1969 when 9 continuous seismic reflection profiles across the continental slope were obtained on two cruises by geologists of the Institute of Oceanography, University of British Columbia, on the C.S.S. "Parizeau". Three dredge hauls on the slope yielded small samples of grey mudstone, as well as unconsolidated sediments. In 1970, three cruises on the C.N.A.V. "Endeavour" contributed 4 seismic profiles across the slope, and 3 dredge hauls, in one of which mudstone bedrock was obtained. The locations of seismic profiles and dredge stations are shown in Figure 1. Echo-sounder and magnetic records were obtained coincident with the seismic profiles.

The average width of the continental slope in the study area is 50 km. The uppermost slope below the shelf break tends to be relatively steep (up to 15°) and obvious slumped blocks are common. Four major canyons, in addition to Juan de Fuca Canyon which marks the southern boundary of the study area, cross the slope, and other smaller channels are common on the seismic profiles. Sediment infilling of these features is minor, suggesting that they functioned as sites of transport of sediment by currents during the Pleistocene and possibly more recently. Sedimentary reflectors underlying the slope are often truncated on the steeper channel walls.

The uppermost unit of the slope is sedimentary, shows well-layered reflecting horizons, and thins to the west. On some seismic profiles this unit appears to be continuous with gently folded Late Tertiary strata designated Layer A on the continental shelf[3]. On the slope this layered unit drapes over what appears to be a sedimentary but poorly-stratified "basement" whose surface is undulatory but generally west-dipping. Attempts to obtain dredge samples of this unit have not yet been successful.

The base of the continental slope rises abruptly from the generally horizontal strata (probably turbidites) of the Cascadia Abyssal Plain. In profile A (Fig. 1) there is evidence that the rise at the base of the slope is composed of deformed and uplifted abyssal plain deposits. Seismic profiles obtained during the present study do not penetrate to oceanic basement at the

* This investigation was also supported in part by the Defence Research Board of Canada (Grant Number 9511-95).


0 Km 100
CONTOUR INTERVAL 400m
Vancouver Island
Queen Charlotte Islands
Scott Islands Fracture Zone
Juan de Fuca Canyon
Cascadia Abyssal Plain
Juan de Fuca Ridge
Explorer Ridge
Explorer Seamount
Heck Seamount
Cobb Seamount

base of the slope, but show at least 1.5 seconds (approximately 1.5 km) of layered strata to be present. The gentle folding of sedimentary reflectors at the base of the slope in Profile A is compatible with horizontal compression accompanying underthrusting of oceanic crust under the continental margin in this area. The absence of seismic activity beneath the continental slope since recording of earthquakes commenced seems to indicate that underthrusting has ceased, at least temporarily, and that at present the Juan de Fuca plate is part of the American plate. We do not as yet have enough information on age of deformed and undeformed units on the continental slope to ascertain when the latest deformation occurred.

Further dredging and collection of magnetic data is planned for 1971.

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2 Morgan, W.J.: Rises, trenches, great faults, and crustal blocks; J. Geophys. Research, Vol. 73, pp. 1959-1982 (1968).

3 Barr, Sandra M., and Murray, J.W.: Structure of the continental margin west of Vancouver Island, British Columbia; in Report of Activities, Part A: April to October, 1969; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 21-25 (1970).

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132. CONTINENTAL SHELF AND SLOPE STUDIES, NORTHWESTERN VANCOUVER ISLAND, BRITISH COLUMBIA

92L
102I

Project 680103

*J.W. Murray, *R.D. Macdonald and **D.L. Tiffin

The program of geological and geophysical studies on the continental shelf and slope west of Vancouver Island was continued in the late summer of 1970. This project, initiated by the University of British Columbia in 1967, is under the sponsorship of the Geological Survey of Canada.

The purpose of the 1970 program was to study in greater detail the northern Tofino Basin (ref. 1, pp. 14-17; ref. 2, pp. 20-25) previously outlined. The northern extension of this basin near the Scott Islands had in previous years received limited attention. However, it is of particular importance in view of the presence of large scale faults.

Continuous seismic profiles using sparker and boomer transducers were obtained over a total of 260 kilometres (Fig. 1). The higher frequency boomer provided increased resolution of shallow sub-bottom features on the continental shelf. The sparker was used in studies of the deeper portions of the basin. Record study and correlation, show that the continental shelf southwest of the Scott Island is underlain by either very thin or no younger Tertiary strata whereas Miocene and Pliocene strata (B.E.B. Cameron, oral communication, 1970) underlie much of the continental shelf to the south.

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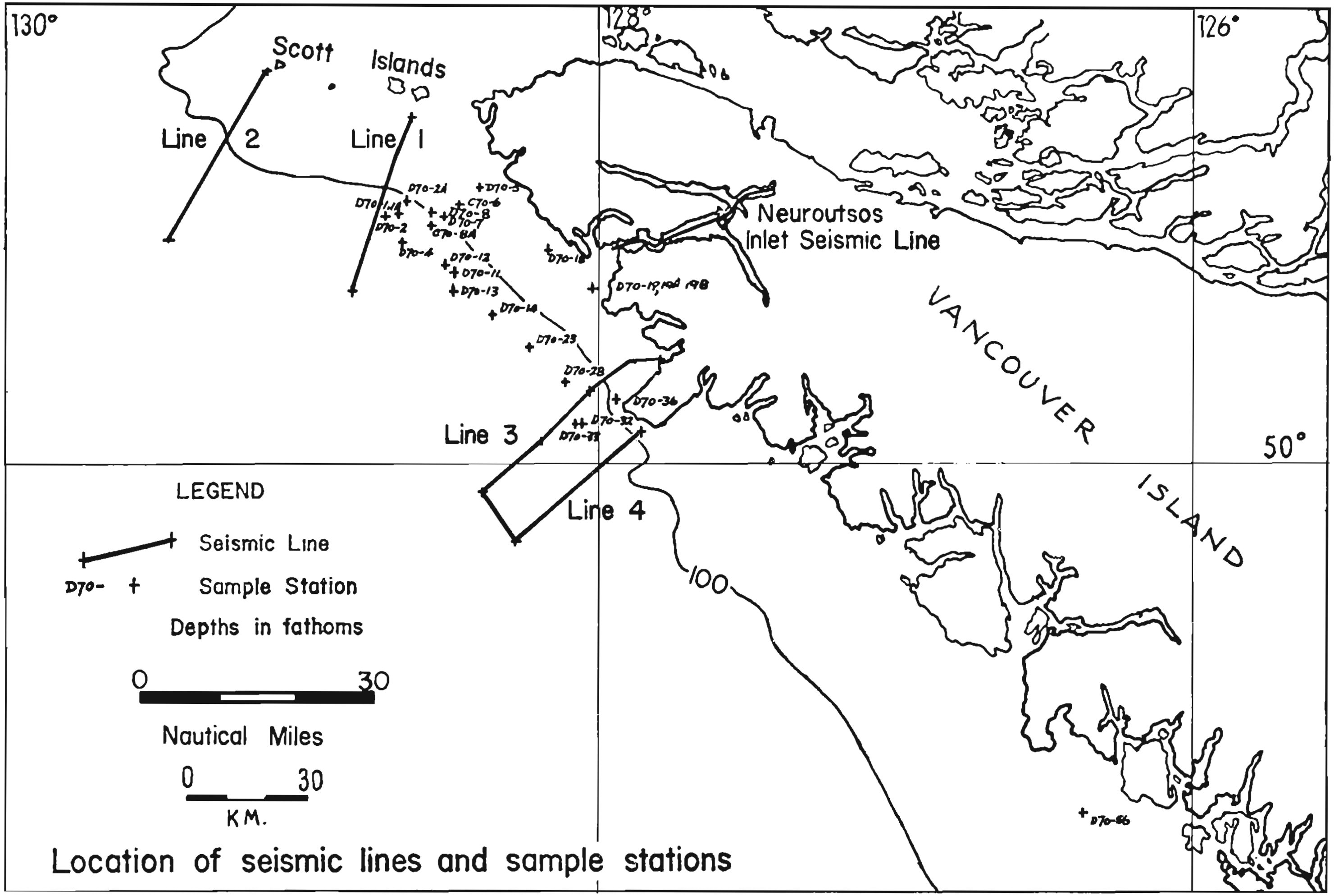

Location of seismic lines and sample stations

TABLE I. SUMMARY OF RESULTS OF SAMPLING PROGRAM (NORTH TO SOUTH)

Station	Latitude	Longitude	Depth(fms)	Type of Sampler	Results	Material
D70-1	50°33.8'	128°42.0'	530	Dredge (24")		dk. green indurated sst.; semiconsolidated lt. grey mud
D70-1A	50°33.6'	128°42.8'	520	Dredge (24")		shelly, carbonaceous mudstone; brown, silty mudstone
D70-2	50°33.5'	128°44.6'	320-380	Dredge (24")		Pleist. blue clay; blue-grey to grey-brown mudstone; sandy mudstone
D70-2A	50°35.6'	128°40.2'	260-160	Dredge (24")		blue-grey and green mudstone; fissile, brown, silty mudstone; blue clay
D70-4	50°41.4'	128°30.0'	52-48	Dredge (24")		Pleistocene gravel
D70-5	50°36.7'	128°26.2'	51-48	Dredge (24")		hard, muddy sandstone
D70-8	50°33.1'	128°35.6'	105	Dredge (12")		blue-grey mudstone, light brown mudstone
D70-19	50°24'	128°02.1'	55-48	Japanese rock dredge	No sample	
D70-19A	50°24'	128°02.6'		Dredge (12")	No sample	
D70-19B	50°24.1'	128°02.5'	55	Dredge (12")		volcanic, metamorphic rock frags.; muddy sand
D70-18	50°28.8'	128°11.8'	25	Dredge (12")	No sample	
C70-6	50°34.4'	128°30.4'	100	Corer	No sample	
C70-8A	50°32'	128°35.5'	140-108	Dredge (12")		light brown mudstone; blue clay
D70-7	50°33.1'	128°33'	100-98	Dredge (12")		blue, stony clay; blue-grey mudstone
D70-12	50°27'	128°32.6'	395-150	Dredge (12")		blue-grey and green mudstone
D70-11	50°26.2'	128°31.0'	198	Dredge (12")	No sample	
D70-13	50°23.6'	128°33'	570-320	Dredge (12")		olive-brown, Recent mud; brown mudstone
D70-14	50°20.4'	128°22.6'	360	Dredge (12")		blue clay; brown and green mudstone
D70-27	50°11'	128°07.8'	287	Dredge (12")		brown and green mudstone.
D70-28	50°11'	128°07.9'	190-130	Dredge (12")	No sample	
D70-31B	50°12'	128°04.4'	68	Dredge (12")		conglomerate - grit rock
D70-32	50°05.6'	128°04.4'	580	Dredge (12")		mudstone; blue clay
D70-33	50°05.8'	128°05.6'	260-195	Dredge (12")	No sample	
D70-36	50°08.9'	127°57.9'	32-38	Dredge (12")		quartzite; quartzitic, grey sandstone
D70-23	50°15.8'	128°15.8'	460	Dredge (12")	No sample	
D70-56	49°13.7'	126°22.8'	34-28	Dredge (12")		greywacke; shaly, grey sandstone

Study of the structure of the shelf and slope in this area is enhanced by the presence of numerous bedrock outcrops of probably Cretaceous, Miocene and Pliocene age. Much of the cruise time, therefore, was allocated to an extensive sampling program. All samples were obtained by dredging. The nature of the surficial Pleistocene sediments and the bedrock did not allow successful coring. A summary of the sampling results is presented in Table 1. These samples have been submitted to B.E.B. Cameron, Cordilleran Section, Geological Survey of Canada, for micropaleontologic and biostratigraphic studies.

A more comprehensive report of this area will appear as soon as the various analyses of samples and interpretations of seismic lines are completed. A paper entitled "Tectonics and Depositional History of the Continental Margin off Vancouver Island, British Columbia" is currently being submitted to the Journal of Geophysical Research.

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[1] Murray, J.W., and Tiffin, D.L: Structure of the Continental Margins 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).

[2] Barr, S.M., and Murray, J.W.: Structure of Continental Margin west of Vancouver Island, British Columbia, in Report of Activities, Part A: April to October, 1969, Geol. Surv. Can., Paper 70-1, Pt. A, pp. 20-25.

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