12

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY,
MINES AND RESOURCES

PAPER 70-12

GEOLOGY, COLVILLE LAKE MAP-AREA AND PART OF COPPERMINE MAP-AREA NORTHWEST TERRITORIES

(Report, 2 figures and Map 12-1970)

D. G. Cook and J. D. Aitken

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ABSTRACT

The stratigraphic succession of the area extends from Proterozoic to Upper Cretaceous, and is interrupted by four or more unconformities. The sub-Cambrian and sub-Cretaceous unconformities are the most pronounced, whereas the sub-Upper Ordovician and sub-Devonian unconformities are less obvious. A fifth unconformity may be present between Lower and Upper Cretaceous shales.

The Colville Hills and northern part of the Franklin Mountains reflect compressional structures, anticlines and thrust blocks, which apparently developed above a décollement in the shale and evaporites of the Cambrian Saline River Formation.

The greatest economic potential of the area is for oil and gas. Base metal possibilities exist in the Proterozoic rocks, which include basalt flows of the Coppermine River Series, and basic dykes and sills.

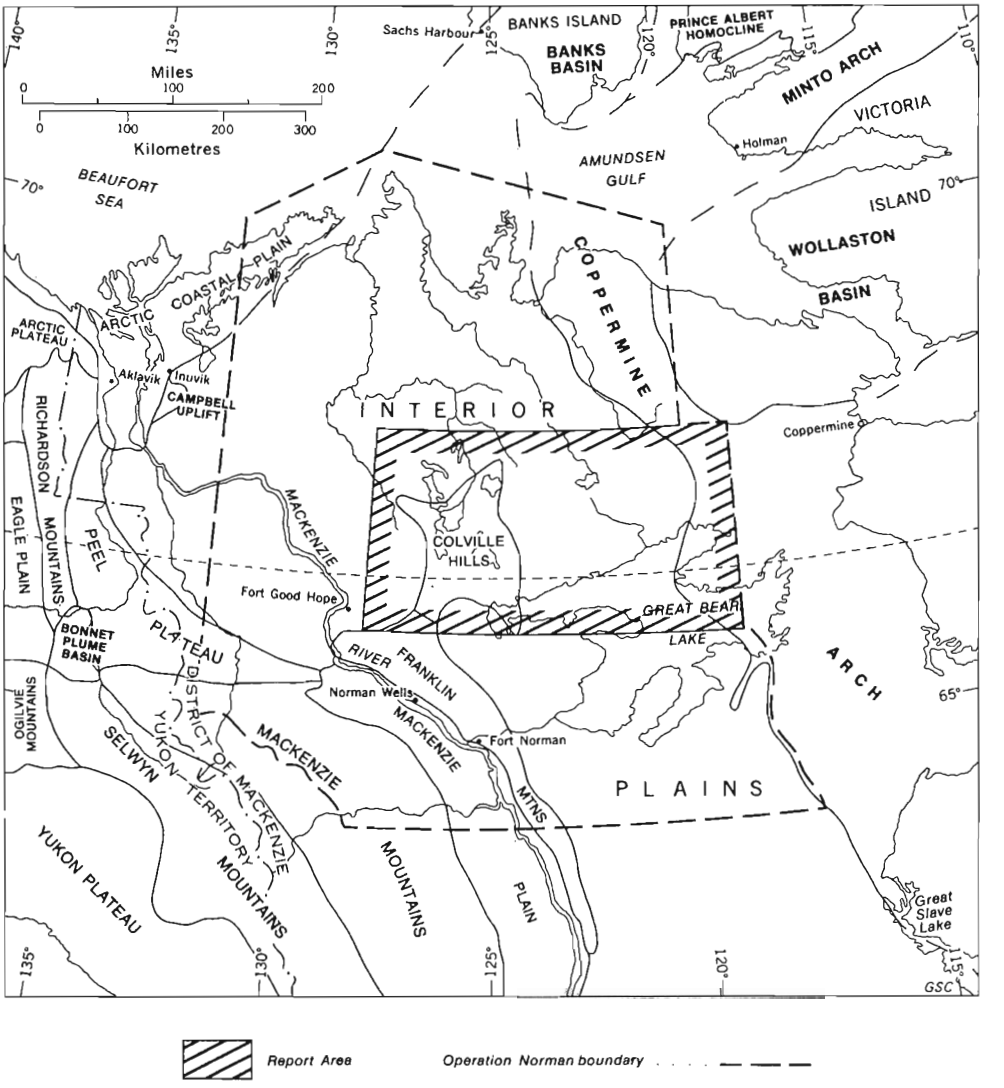

Figure 1. Index map: showing position of report area with respect to total Operation Norman area, and with respect to regional tectonic elements (Tectonic elements modified from Douglas et al., 1963).

GEOLOGY, COLVILLE LAKE MAP-AREA AND PART OF COPPERMINE MAP-AREA (96 NW and NE, PART OF 86 NW) NORTHWEST TERRITORIES

INTRODUCTION

Geological studies of the area were carried out in 1968 as part of Operation Norman, an airborne, regional, geological reconnaissance. Bedrock mapping and structural interpretation were by the authors and M.E. Ayling. Cambrian to Silurian strata within the map-area were studied stratigraphically by R.W. Macqueen, and Devonian strata by W.S. MacKenzie. A.E.H. Pedder conducted field and laboratory Devonian biostratigraphic studies. R.J. Fulton examined Quaternary deposits within the map-area. In cooperation with C.J. Yorath, D. Bardack, representing the National Museums of Canada, collected fossil fish and invertebrates from Upper Cretaceous rocks at Lac des Bois in 1969. Fossil collections submitted by Operation Norman personnel were examined by B.S. Norford (Ordovician-Silurian), A.E.H. Pedder (Devonian), J.A. Jeletzky (Cretaceous megafossils), and T.P. Chamney (Cretaceous microfossils). Reports on fossil collections from the map-area appear in appendices, and corresponding Geological Survey of Canada fossil location numbers are shown on the geological map (in pocket). Able assistance in the field was provided by C.W. Thayer, R.D. Cruikshank, C.D. Johnson, R.E. Moulton and J.F. Treacy. Precambrian rocks of the Hornby Bay Group and Coppermine River Series in the eastern part of the map-area have not been examined in detail, and distribution of these units was taken, with modifications, from Fraser (1960).

This paper is intended as a brief set of notes to amplify the geologic map. Summary papers dealing with stratigraphy of the region have been written by Macqueen (1969, 1970), MacKenzie (1969, 1970), and Fulton and Klassen (1969).

PHYSIOGRAPHY AND ACCESS

The map-area lies, to a large extent, in the Interior Plains physiographic subdivision (see Bostock, 1964) and is characterized by great expanses having low relief and containing abundant swamps, ponds, and small lakes poorly linked by sluggish streams. There are, however, notable exceptions. A number of large lakes as much as 28 miles long (e.g. Colville Lake, Lac des Bois) occur in the west-central part of the area. In the same general area as the large lakes, the low topographic relief is broken by the Colville Hills, which are long, broad, widely-separated, bedrock ridges of diverse trend, and by morainal hills commonly more than 1,000 feet high, occurring in broad areas around Horton Lake and along the north shore of Smith Arm on Great Bear Lake.

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Bedrock exposure is good in the northeastern part of the area, and fairly good in the southwestern part, but elsewhere bedrock outcrops only along ridges and in stream valleys, where it is poorly exposed. Large parts of the map-area are completely masked by thick Quaternary deposits which preclude bedrock mapping.

Access to the area is primarily by helicopter or float-equipped fixed-wing aircraft. Limited access is available by boat from Great Bear Lake, and by a winter caterpillar road to Colville Lake from Fort Good Hope on Mackenzie River.

PREVIOUS WORK

The bulk of earlier geological work within the map-area has been done by oil companies and consultants, and unpublished reports of these studies are on file with the Department of Indian Affairs and Northern Development. Apart from recent reports in connection with Operation Norman (Aitken and Cook, 1969; Macqueen, 1969, 1970; MacKenzie, 1969; Fulton & Klassen, 1969) very little published information exists pertaining directly to bedrock geology within the map-area. A geological map by Hume (1954) shows a few Silurian to Devonian exposures, mapped by Harrison (unpub. Canol Project Rpt. 17, 1944), along the Hare Indian River. Fraser's (1960) geological map of the North-Central District of Mackenzie included the northeast corner of the report area and, as noted above, contacts of Precambrian units are taken from Fraser with only slight modification. Recent geological maps by Yorath, Balkwill, and Klassen, (1969) and by Cook and Aitken (1969) adjoin the report-area along the north boundary. Another map by Cook and Aitken (1969) adjoins part of the west boundary. Douglas and MacLean (1963) compiled a small-scale map of the entire region from various sources, and Douglas et al., (1963) discussed geology and petroleum potentialities of all of northern Canada. Paleozoic stratigraphic nomenclature used in this report evolved primarily from earlier work in the region of the Mackenzie River valley and adjacent Mackenzie and Franklin Mountains. Summaries of the history of exploration in that region are presented by Hume (1954) and Tassonyi (1969). Proterozoic and basal Cambrian nomenclature, on the other hand, is derived from workers in and along the Precambrian shield to the east and southeast.

REGIONAL GEOLOGY

The position of the map-area within the total Operation Norman area and relative to regional tectonic features is shown in Figure 1. The Coppermine Arch which cuts across the eastern end of the map-area has Proterozoic sediments exposed along most of its length. Paleozoic strata unconformably flank both sides of the arch and cross the arch in the central part (see northeast corner of the geologic map - in pocket). Westward from the arch Paleozoic rocks dip very gently under the northern Interior Plains. These strata are progressively younger toward the west and on a regional scale are unconformably truncated by Cretaceous rocks.

Generally flat-lying strata of the Interior Plains have been buckled tectonically to form the Colville Hills in the western half of the map-area. These hills appear to be related to the Franklin Mountains lying immediately southwest of the map-area which, in turn, are probably related to the deformation that formed the Mackenzie Mountains farther southwest (Figure 1). Thus, the map-area contains features representing three regional tectonic elements; the Coppermine Arch, the Interior Plains, and the eastern foreland compressional belt of the Pacific orogen.

UPPER CRETACEOUS	Unnamed: shale	? Disconformity ?
?		
LOWER CRETACEOUS	Unnamed: sandstone	
Regional Unconformity		
UPPER AND MIDDLE DEVONIAN	RAMPARTS FORMATION	
MIDDLE DEVONIAN	HARE INDIAN FORMATION (locally includes Cretaceous shale)	
	HUME FORMATION	
	BEAR ROCK FORMATION	
Regional Unconformity		
SILURIAN UPPER ORDOVICIAN	RONNING GROUP	MOUNT KINDLE FORMATION
		Regional Unconformity
LOWER ORDOVICIAN		Unnamed: dolomite with chert
? ?		Unnamed: dolomite
UPPER CAMBRIAN		Unnamed: dolomite and shale
? ?	SALINE RIVER FORMATION	
MIDDLE CAMBRIAN	MOUNT CAP FORMATION	
	OLD FORT ISLAND FORMATION	
Regional Unconformity		
PROTEROZOIC	DIABASE DYKES	
	COPPERMINE RIVER SERIES	
	Regional Unconformity	
	DIABASE DYKES	
	HORNBY BAY GROUP	Unnamed: stromatolitic dolomite
		Unnamed: sandstone, conglomerate, quartzite

GSC

Figure 2. Table of Formations

STRATIGRAPHY

PRECAMBRIAN

Hornby Bay Group
(Kidd, 1932; Feniak, 1951; Fraser, 1960; Donaldson, 1969; Baragar and Donaldson, 1970)

Sandstones and quartzites along the eastern shore of Hornby Bay on Great Bear Lake were named the Hornby Bay Series by Kidd (1932). Essentially the same rocks were referred to as the Hornby Bay Group by Feniak (1951). Fraser (1960) included a stromatolitic dolomite unit in the Hornby Bay Group and Donaldson (1969) subdivided the group into seven units in the vicinity of Dismal Lakes about 50 miles east of the present map-area. Baragar and Donaldson (1970) restricted the name to four units beneath a previously unrecorded unconformity. The relationship between these subdivisions and the two subdivisions mapped by Fraser is not clear. Consequently, Fraser's two-part subdivision (a basal conglomerate, sandstone, and quartzite unit, and an upper stromatolitic dolomite unit) is used here.

Hornby Bay quartzite Pq

Fine-grained, pink, laminated, hard, quartzite strata are poorly exposed on the peninsula between Dease Arm and McTavish Arm of Great Bear Lake. These rocks, following Fraser (1960),have been assigned to the basal unit of the Hornby Bay Group. This unit is described by Fraser as consisting of 4,000 feet or more of conglomerate interlayered with sandstone and quartzite.

Hornby Bay dolomite Pd

Reddish brown-weathering dolomites outcropping northeast of Dease Arm on Great Bear Lake have been previously mapped (Fraser, 1960) as part of the Hornby Bay Group. Stratigraphic relationships between these rocks and the Hornby Bay quartzites are not apparent within the map-area, but they conformably overlie the quartzites south of Dismal Lakes to the east (Baragar and Donaldson, 1970). These rocks are brown to pinkish grey ferruginous dolomites, commonly stromatolitic. Local cyclic units consist of lower massive but thin-bedded strata overlain with sharp contact by stromatolitic beds two to five feet thick. Stromatolites are commonly about one foot across and are generally silicified across the top. Locally, conical stromatolites were observed. The rocks are intensely fractured and veined with hematite and quartz. Northeast of Dease Arm on Great Bear Lake, rocks of this unit are strongly deformed, and northwest trending open folds superposed on strata which dip steeply northwest, suggest more than one deformation. Because the rocks are considerably deformed no estimate of thickness could be made within the report area. Fraser (1960) estimated a thickness of about 4,000 feet of Hornby Bay dolomite south of Dismal Lakes (east of the report area), but Baragar and Donaldson (1970) recognized an unconformity within strata previously considered to belong to the Hornby Bay Group and restricted the name to strata, of undisclosed thickness, below the unconformity.

Age of the Hornby Bay Group

Hornby Bay Group sediments elsewhere in the region overlie gneissic granite which has been dated at 1,765 m.y., and are cut by the Muskox intrusion which has been dated at 1,155 m.y. The age of the Hornby Bay Group is thus bracketed by these dates (C.H. Smith in Lowdon, 1961, p. 23) and, therefore, is Helikian or late Aphebian.

The contact between the Hornby Bay dolomite and the overlying Coppermine River Series was not examined in detail, but the Coppermine River strata are flat-lying in contrast to steeply dipping Hornby Bay strata. A sharply angular unconformity is, therefore, inferred between these units. Correspondingly Baragar and Donaldson (1970, p. 121) report an unconformity separating sub-Coppermine strata from Hornby Bay strata, near Dismal Lakes, 50 miles east of the map-area.

Coppermine River Series (Pc) (Sandberg, 1913)

The Coppermine River Series was first described by Sandberg (1913), and was partly mapped by O'Neill (1924). Fraser (1960) mapped it more completely and described a lower part of 11,000 feet of brown to purplish, fine-grained or aphanitic, commonly amygdaloidal basaltic flows, and an upper part of about 15,000 feet composed of interlayered sandstone, shales, and dolomites, with minor amounts of limestone and gypsum. Basalts in the lower part of the series were examined in detail by Baragar (1967) near Dismal Lakes east of the present area. In the report-area, most of the Coppermine River Series has been removed by pre-Paleozoic erosion, and probably no more than a few thousand feet of basal basalts remain. Distribution of this map-unit is modified only slightly from that shown by Fraser. Sandstone, mudstone and dolomite beds underlying the Coppermine River Series and overlying the Hornby Bay Group were mapped by Baragar and Donaldson (1970, p. 122) to the east, but were not observed in the study-area.

Radiometric (K-Ar) ages determined for the Coppermine River basalts fall, in general, into two groups, 1,065 - 1,200 m.y. and 735 - 863 m.y., (Baragar in Wanless et al., 1968, p. 66). According to Baragar the reason for the spread of ages is not clear, but is definitely not related to stratigraphic succession. He suggests that because the Coppermine flows are probably related to the Muskox intrusion, the older (Neohelikian) ages may be more correct, and that a later, minor deformation may be responsible for up-dating some of the ages determined.

In this map-area the Coppermine River basalts are unconformably overlain by basal Paleozoic sandstone assigned to the Old Fort Island Formation.

Diabase Dykes (Pd)

Diabase dykes cut the Hornby Bay Group within the map-area whereas, east of the area (Fraser, 1960), they cut both the Hornby Bay Group and the Coppermine River Series. The dykes trend northwest or north-northeast and, therefore, appear to belong respectively to dyke swarms seven and twelve of Fahrig and Wanless (1963). Swarm seven was assigned an age of 1,315 m.y., (Paleohelikian), whereas swarm twelve apparently is younger with a radiometric age of 700 m.y. (Hadrynian), (Fahrig and Wanless, 1963).

CAMBRIAN

Old Fort Island Formation (Cof) (Norris, 1965)

The Old Fort Island Formation is a basal Paleozoic sandstone that unconformably overlies both Hornby Bay and Coppermine River strata near the eastern edge of the map-area. A minimum of 200 feet of relief on the unconformity is shown by inlying knobs of both Hornby Bay and Coppermine River rocks. Except where these knobs exist the basal sandstone forms a continuous unit, probably no more than a few hundred feet thick. It is a quartzose, silica-cemented, white or light grey, locally iron-stained, resistant, and commonly crossbedded sandstone containing minor amounts of pebble conglomerate. This sandstone usually has a scoured surface and presents a distinctive scaly appearance in air photographs. Basal Paleozoic sandstones occur along the eastern limit of Paleozoic rocks at least from Great Slave Lake (Norris, 1965) to the Arctic Ocean and are reported on Victoria and Banks Islands (Thorsteinsson and Tozer, 1962). Rocks of this stratigrapic unit in the Erly Lake map-area, northwest of the exposures examined here, have been assigned, previously, (Cook and Aitken, 1969) to the Mount Clark Formation observed in the McConnell Range of the Franklin Mountains (Williams, 1923). This assignment was made on the basis of lithology and position in the stratigraphic sequence compared with that observed in the McConnell Range. H.R. Balkwill (pers. com., 1969), however, working south of Great Bear Lake, has traced the basal Paleozoic sandstone southward into the Great Slave Lake region, and has established physical continuity with the Old Fort Island Formation mapped and defined by Norris (1965). Thus the name Old Fort Island Formation is used here, because a much more positive correlation is established with that formation to the south than with the Mount Clark Formation to the west.

No fossils other than the cylindrical burrow Scolithus have been recovered from the Old Fort Island. On Victoria Island to the north the basal Paleozoic sandstone has yielded poorly preserved fossils, for which A.W. Norris (see Thorsteinsson and Tozer, 1962, p. 40) suggests an Upper Cambrian age.

Mount Cap Formation (Ccp) (Williams, 1923)

The Mount Cap Formation, which conformably overlies the Old Fort Island Formation, outcrops only in the eastern part of the map-area, along the Coppermine Arch. The formation is known in the Franklin and Mackenzie Mountains, about 200 miles to the southwest of the exposures described here. The name was first used in the Coppermine Arch region by Cook and Aitken (1969). The degree of lithologic correspondence,as well as the stratigraphic position and sequence, was considered to justify extension of the name to the arch region.

The Mount Cap consists of grey, green and, locally, red shales, with interbedded burrowed glauconitic sandstone and siltstone. The base of the formation is marked, at least locally, by a few tens of feet of dark rusty brown, pyritic dolomite in sharp and apparently conformable contact with the underlying Old Fort Island Formation. The top of the Mount Cap is marked also by a few feet of dolomite that is brown-weathering and thin-bedded to laminated. The upper contact is drawn at the top of these resistant dolomites. The thickness of the formation could not be determined in the area, but is 230 feet in a section measured by R.W. Macqueen (section MQ20, see Cook and Aitken, 1969) about 25 miles to the north.

Fossils collected by J.C. Sproule and Associates from this unit on Haldane River have been identified as possibly Middle or Upper Cambrian (see Lowdon et al., 1963, p. 34; unpub. GSC paleo. report C1-62, Appendix I). Middle Cambrian fossils collected by H.R. Balkwill, and identified by W.H. Fritz, Geological Survey of Canada, were obtained south of Great Bear Lake from beds equivalent to either the Mount Cap Formation or the overlying Saline River Formation (H.R. Balkwill, pers. com., 1969). Both Lower and Middle Cambrian fossils have been collected from the Mount Cap in the Franklin and Mackenzie Mountains (Williams, 1923; Douglas and Norris, 1963; W.H. Fritz, R.W. Macqueen, and J.L. Usher, pers. com., 1969).

The Mount Cap Formation appears to correlate with only the lower part of Norris' (1965) La Martre Falls Formation in the Great Slave Lake region (H.R. Balkwill, pers. com., 1969).

Saline River Formation (Cs) (Williams, 1923)

The Saline River Formation conformably overlies the Mount Cap and outcrops only in the eastern part of the area. The name Saline River Formation was first used in the Coppermine Arch region by Cook and Aitken (1969). As with the Mount Cap, the degree of lithologic similarity as well as stratigraphic position and sequence was considered to justify extension of the name from the Franklin and Mackenzie Mountains to the Coppermine Arch region.

The thickness could not be determined within the report-area, but appears to be uniform and is 195 feet in Macqueen's section MQ20 (see Cook and Aitken, 1969). The Saline River is a recessive, poorly exposed unit of green and red shales with thin flaggy interbeds of siltstone and silty dolomite and rarely exposed intervals of white and pink gypsum. Mudcracks, ripple-marks, and salt crystal casts are common.

Fossils collected by J.L. Usher from beds tentatively assigned to the Saline River Formation in the Mackenzie Mountains about 250 miles to the southwest have been assigned a Middle Cambrian age by W.H. Fritz. The contact with the overlying Ronning Group, however, is transitional and the upper part of the formation is probably Late Cambrian.

CAMBRIAN, ORDOVICIAN AND SILURIAN

Ronning Group (COS) (Hume, 1954)

The Ronning Group comprises a thick sequence of marine strata, mainly dolomites, that conformably overlies the Cambrian Saline River Formation and that is unconformably overlain by either Devonian or Cretaceous rocks. Macqueen (1970) subdivided the group into four units including the Mount Kindle Formation at the top. In most of the map-area the four units could be mapped but, locally, two or more were combined. In the northern and central parts of the map-area, the group is incomplete owing to pre-Devonian, pre-Cretaceous, Tertiary, and Quaternary erosion.

The basal unit of the Ronning Group (€Or1) is in gradation contact with the underlying Saline River Formation. Relative to the Saline River it is a resistant unit, weathering pale yellow, and characterized by cyclic repetitions of dense, laminated, oolitic, conglomeratic and stromatolitic dolomite beds; the presence of cyclically recurring thin beds and partings of green dolomitic shale readily distinguishes this unit from the overlying unit (€Or2a). The thickness of the basal unit was not measured within the map-area, but is 145 feet at section MQ21 to the north in the Erly Lake map-area (see Cook and Aitken, 1969).

Unit (€Or2a) of the Ronning Group is cyclic also, but lacks the shale beds and partings of the basal unit, and displays a more limited range of dolomite types. It is a moderately resistant unit, weathering grey, and consisting mainly of thick beds of pale brownish grey, coarse-crystalline dolomites, commonly with vuggy porosity, alternating with greyish orange, very fine-crystalline dolomites, in part laminated. Purple mottling occurs at many localities. The unit is at least 400 feet thick, but no complete section was measured. Unit (€Or2a) is overlain by a slightly more resistant unit (€Or2b) of similar appearing dolomites, pale yellow-brown to pale grey in colour and mainly medium crystalline. This unit is characterized by an abundance of white and yellowish-grey bedded chert, stromatolites and oolites replaced by chert, and vugs lined with drusy quartz. No complete section was measured; the unit is at least 350 feet thick. The contact between these units is difficult to follow in reconnaissance mapping, and cannot be traced with confidence on air photographs. Consequently, it has been mapped only in the north-central part of the map-area where exposure is better than elsewhere. To the southwest along Maunoir ridge these units are undivided and are mapped as (€Or2).

Fossil collections by R.W. Macqueen from the lower unit (€Or2a) from widely separated localities in the Mackenzie Mountains to the west have been identified in part by W.H. Fritz and in part by B.S. Norford as of Late Cambrian age. A number of collections of gastropods from the cherty unit (€Or2b) have been collected by R.W. Macqueen in the Mackenzie and Franklin Mountains to the southwest and have been dated as Early Ordovician by B.S. Norford.

Mount Kindle Formation (Osk) (Williams, 1923)

The Mount Kindle Formation disconformably overlies older units of the Ronning Group, and is overlain unconformably by either Devonian or Cretaceous strata. It consists of brownish grey to medium grey, fine-crystalline, very thick-bedded, resistant dolomites characterized by horizons of abundant nodules of light grey or white chert and a silicified fauna of Late Ordovician and early Silurian age. Vuggy porosity occurs widely, and the vugs locally contain solid hydrocarbons. Thickness variations, from 138 feet at section MQ11 on Hare Indian River to at least 425 feet at section MQ13 at Good Hope Bay on Great Bear Lake, appear to be the result of pre-Devonian erosion. Outliers of Mount Kindle occur in a small ridge southeast of Lac Maunoir, and along Anderson River northeast of Lac Maunoir. These appear to be remnants left by pre-Devonian erosion, because the Bear Rock Formation overlies the Ronning cherty unit in Maunoir Dome. In a large area west of Smith Arm on Great Bear Lake, the Ronning Group is undivided (€OSr), because the contact between the Mount Kindle Formation and the underlying unit (€Or2, €Or2b) is difficult to recognize and trace on air photographs.

The Mount Kindle contains abundant silicified halysitid, favositid, and horn corals, and orthoconic cephalopods. Fossils collected by R.W. Macqueen and identified by B.S. Norford (Appendix II) indicate that the lower part of the Mount Kindle is Late Ordovician; the upper part, where not removed by pre-Devonian erosion is Early Silurian.

DEVONIAN

Bear Rock Formation (Db) (Hume and Link, 1945)

The Bear Rock Formation lies unconformably on the Ronning Group and is exposed only in the western third of the map-area. It consists of laminated to thick-bedded, pale brown, very fine-crystalline dolomites; thin-bedded, pale grey-weathering, pelletal limestones; and rarely exposed white gypsum. Thick units of dolomite and limestone solution breccia occur widely, and the bedded carbonates are commonly brecciated. Postglacial or postglacially rejuvenated sinkholes and subterranean drainage indicate that subsurface solution of gypsum is now in progress. Similar activity took place in Cretaceous time, as indicated by sinkholes now filled with Cretaceous sandstone. The thickness of the Bear Rock Formation could not be determined in the map-area. An incomplete section measured by W.S. MacKenzie at Sam McRae Lake, two miles south of the map-area, is about 800 feet thick, and evidence from wells drilled near Fort Good Hope to the west suggests that this figure may be an approximate maximum for the map-area. Fossils are rare, but one collection made by R.W. Macqueen near Hare Indian River and examined by A.E.H. Pedder yielded the giant ostracod Moelleritia canadensis Copeland (see Loc. No. C-1770, Appendix III). According to Pedder (pers. com., 1970), Moelleritia canadensis and a shelly fauna reported by Norris (1968, p. 22) both suggest an early Middle Devonian (Eifelian) age.

Hume Formation (Dh) (Bassett, 1961)

The Hume Formation lies with apparent conformity on the Bear Rock Formation, and occurs only in the western part of the map-area. It consists of very fossiliferous, brown, dense, thin- and medium-bedded limestone that is characteristically rubbly in outcrop. Beds and partings of brown shale, known to occur in the middle and lower part of the formation, are not exposed in the area. The formation outcrops as three or more persistent scarps which are excellent photo-geological markers. Along Carnwath River in the northwestern part of the map-area a number of anomalous small patch reefs, abundantly fossiliferous (see Loc. No. C-2521 and C-2522, Appendix III), were observed in calcareous shales at the top of the Hume Formation. No similar reef developments have been observed in the surrounding region. The thickness of the formation is estimated to be between 350 and 450 feet. In wells drilled near Fort Good Hope to the west, the Hume Formation is 340 feet thick. Abundant fossils indicate a Middle Devonian (early Givetian) age.

Hare Indian Formation (Dhi) (Kindle and Bosworth, 1921; Bassett, 1961)

The recessive Hare Indian Formation lies conformably on the Hume Formation. It occurs only near the western boundary of the map-area, and outcrops rarely. The persistent basal member consisting of dark brown, fissile, bituminous shale characterized by abundant Tentaculites and thin beds of fibrous limestone, and including a bed of limestone with abundant brachiopods (Leiorhyncus castanea Meek) was observed west of Lac à Jacques in the southwest corner of the area. Higher beds in the region south and west of the map-area consist of greenish grey, grey, and pale brown shales, with minor thin beds of calcareous siltstone and, locally, beds of fossiliferous limestone. West of Lac à Jacques, however, one or more thick beds of very fine-grained, calcareous, quartzose sandstone are present in the upper part of the Hare Indian Formation and form a low but distinct scarp. The Hare Indian, as mapped near the northern part of the western boundary of the report-area includes Cretaceous shales that are readily differentiated from overlying Cretaceous sandstone, but which could not be subdivided from shales of the Hare Indian Formation. It was not possible to obtain a precise thickness within the map-area, but the formation appears to be about 250 feet thick west of Lac à Jacques. Twenty miles west of the map-area in a well at the Ramparts on Mackenzie River the Hare Indian is about 700 feet thick.

The fauna of the Hare Indian Formation indicates a Middle Devonian (Givetian) age.

Ramparts Formation (Dr) (Kindle and Bosworth, 1921; Caldwell, 1964)

The Ramparts Formation occurs only in a small area in the southwest corner of the map-area. The formation is poorly exposed, but the assignment to Ramparts Formation is confirmed by four fossil collections made and examined by A.E.H. Pedder (C-1850-52 and C-4253, Appendix III). The eastern limit of the Ramparts Formation in the map-area is an ancient mesa with at least 200 feet of relief. This mesa, which is partly buried by basal Cretaceous sandstone, may mark the approximate depositional limit of the Ramparts.

The name Ramparts Formation was used by Kindle and Bosworth (1921) for limestone beds overlying Hare Indian shales at the Ramparts on Mackenzie River west of Fort Good Hope. Hume and Link (1945) applied the name Ramparts Formation to the entire sequence of Hume, Hare Indian and Ramparts Formations as used here. Bassett (1961) correlated the upper limestones (Ramparts Formation) of the sequence with limestones exposed at Kee Scarp east of Norman Wells, and rejected the name Ramparts because he believed that the name was preoccupied by Mississippian strata in Yukon and Alaska. He suggested the alternative name, Kee Scarp Formation. Caldwell (1964) maintained that even if Bassett's correlation were correct, re-naming of the unit to Kee Scarp was not justified, and he suggested a return to Ramparts Formation as originally used by Kindle and Bosworth (1921). This paper follows Caldwell's recommendation, and Ramparts Formation is used for all limestone strata overlying Hare Indian shales and overlain by one or the other of Devonian Canol Formation, Devonian Imperial Formation, or Cretaceous sediments. Tassonyi (1969) also has used the name Ramparts Formation for these strata.

Only about 150 to 200 feet of limestone of the lower part of the Ramparts Formation occur within the map-area. In the region to the west and southwest it can be subdivided into two and locally three units with a total thickness up to 800 feet. The lower part, zero to 300 feet thick, consists mainly of medium-bedded, brown, partly argillaceous limestones characterized by or largely formed of transported fragments of branching tabulate corals. About 50 miles west of the map-area this unit grades by facies change into the Hare Indian Formation along the Mackenzie River downstream from Fort Good Hope. By contrast, the overlying part of the formation, zero to 500 feet thick, is thick-bedded and massive, consisting of pale brown limestone, commonly with large globular stromatoporoids. This massive unit is the uppermost unit in most places, but is locally overlain by dark platy argillaceous and bituminous limestone and calcareous shale up to 50 feet thick. These are the unnamed beds of Braun (1966). In the Operation Norman area these beds have been mapped as part of the Ramparts Formation following Caldwell (1964).

The lower beds of the Ramparts Formation bear Stringocephalus and are Middle Devonian (Givetian) in age. From the middle of the higher massive beds Braun (1966, p. 252) reports a Givetian ostracod fauna. The uppermost beds of calcareous shale and argillaceous and bituminous limestone at the top of the Ramparts Formation at Carcajou Ridge, have yielded goniatites of Late Devonian (early Frasnian) age (House and Pedder, 1963, pp. 516-517).

Canol and Imperial Formations

The Upper Devonian Canol and Imperial formations have been removed from the western part of the map-area by pre-Cretaceous erosion; farther east, their absence may be due to non-deposition.

CRETACEOUS

Cretaceous strata occur in the western part of the map-area and north and south of Smith Arm on Great Bear Lake. These strata overlie a profound regional unconformity that truncates progressively older underlying rocks from west to east. Lower Cretaceous rocks form the base of the sequence in most of the map-area, but are absent locally beneath Upper Cretaceous strata.

Cretaceous lower shale (mapped with Dhi)

Near the northern part of the western boundary of the map-area, grey Cretaceous shale beds occur beneath a sandstone unit. These shale beds are anomalous in that over much of the area the sandstone is basal to the Cretaceous sequence. Specific shale samples have been dated by T.P. Chamney (see Loc. No. C-2573, Appendix IV) as early Cretaceous (Albian). In the field, however, these shales and underlying Hare Indian shales could not be differentiated and consequently the Cretaceous beds have been mapped with the Hare Indian Formation.

Cretaceous sandstone (Kss)

Cretaceous sandstone occurs primarily in a broad area west of Lac Belot, and is poorly exposed in a small area south of Lac des Bois. This sandstone is the basal Cretaceous unit over most of its area of occurrence although it is locally underlain by shale, mentioned above, and seems to be absent at Lac des Bois where Upper Cretaceous shales apparently overlie Paleozoic strata. The sandstone is quartzose and white except where oil-stained. Grain size varies abruptly from fine to coarse even between adjacent laminae. Layers of quartz and chert pebbles occur locally. Calcite cement causes local lustre-mottling. Where not calcareous, the sandstone is friable and porous, and many exposures consist of unconsolidated white sand. Crossbedding is ubiquitous. The Cretaceous sandstone, whose thickness is not known to exceed 100 feet, was in part deposited on a surface with at least 200 feet of relief. East of Lac à Jacques, a Cretaceous mesa supported by resistant Ramparts Formation strata is partly buried by the sandstone. The sandstone appears to be continuous with the Sans Sault Formation of the Mackenzie River valley to the southwest, and with the lower division of the "Silty zone" of the Anderson River region (Yorath et al., 1969). On the basis of contained spores, W.S. Hopkins assigned an Early Cretaceous age to a basal sandstone occurring south of Lac des Bois (see Loc. No. C-4314, Appendix IV).

Cretaceous shale (Ksh)

Cretaceous shales overlying the basal sandstone have been mapped in the northwest part of the map-area, and in a small area south of Lac des Bois. These rocks are rarely exposed; their distribution has been mapped primarily on the basis of topographic expression. They are soft, brownish grey shales with local ironstone concretions. In greyish brown fissile shales on the west shore of Lac des Bois there occur large oblate laminated siltstone concretions as much as five feet in diameter, containing fish and invertebrate fossils. Shale deposits along the western margin of the map-area are of Early Cretaceous age (T.P. Chamney, see Loc. No. C-2575, Appendix IV), whereas the fish and invertebrates at Lac des Bois are Late Cretaceous (Waldman, 1969; J.A. Jeletzky, see Loc. No. 84342, Appendix IV). The Lac de Bois exposures appear to be basal at that point; thus Upper Cretaceous strata overstep to the east. In the Arctic coastal plains region to the north (Yorath et al., 1969) an unconformity has been recognized within the Cretaceous succession. Unpublished micropaleontological data (T.P. Chamney, pers. com., 1970) shows this to be an unconformity between Upper Cretaceous (Coniacian) and Lower Cretaceous (Middle Albian). Probably the same unconformity occurs within the Cretaceous shale map-unit discussed above.

Cretaceous Rocks Undivided (K)

In some areas such as north and south of Smith Arm on Great Bear Lake bedrock exposure is too poor to permit subdivision of the Cretaceous rocks. Exposed rocks are shales or sandstones with some thin coal beds. Microfossils from eighteen shale samples from that area have all been identified by T.P. Chamney as Late Cretaceous (see Loc. Nos. C-2569-2571 and C-4291-4300, Appendix IV). Most are more closely dated as probably Santonian. According to Chamney, these correlate with the Cretaceous "Bituminous zone" (Yorath et al., 1969) of the Arctic coastal plains. Craig (1960, p. 7) reported Lower Cretaceous shales exposed in the core of a pingo

6 miles east of Horton Lake. The Early Cretaceous age, based on palynology, was assigned by D.C. McGregor in 1960 (see Loc. No. 5535, Appendix IV). This isolated occurrence of Cretaceous rocks suggests that much of the unmapped central part of the map-area may be underlain by Cretaceous strata.

On the west flanks of Maunoir Ridge, hematite-cemented conglomerate has been deposited against a scarp, at least 100 feet high, of Ronning Group dolomite. Since the scarp was made by erosion of the anticline which forms Maunoir Ridge the conglomerate post-dates the deformation which formed the anticline. On the basis of the spore genus Gleicheniidites from the conglomerate, W.S. Hopkins (see Loc. No. C-4318, Appendix IV), suggests a Jurassic or Cretaceous age. Early Cretaceous sandstones are tilted along the anticlinal Belot and Colville Ridges and, therefore, pre-date those folds. If the anticline in Maunoir Ridge formed contemporaneously with those in Belot and Colville ridge, then the conglomerate, which post-dates deformation, also post-dates the Early Cretaceous sandstone, and is probably Late Cretaceous in age.

STRUCTURAL GEOLOGY

EPEIROGENESIS

Four and possibly five Phanerozoic periods of regional uplift and erosion are evident in the geological record of this area. Regional unconformities occur at the base of the Cambrian, Upper Ordovician, Devonian, Cretaceous, and probably Upper Cretaceous successions. The sub-Cambrian, sub-Devonian, and most notably the sub-Cretaceous unconformities all involved some degree of regional tilting demonstrated by overstepping of younger units. This overstepping is apparent in each case from the distribution of map-units on the accompanying geologic map. The unconformity at the base of the Upper Ordovician Mount Kindle Formation is apparent from observed local erosional relief and from regional stratigraphic and paleontologic considerations. An unconformity is suspected between Lower and Upper Cretaceous rocks because one at that level has been documented in the Arctic coastal Plains to the north (Yorath et al., ibid.). Its presence cannot be confirmed in this area.

OROGENESIS

Precambrian and Mesozoic orogenies are recorded in the deformed strata within the map-area.

Steeply folded or tilted dolomites of the Hornby Bay Group trend northeastward from Dease Arm on Great Bear Lake and dip northwestward. Superposed on this northeast trend are broad, open folds plunging northwestward. These have not been examined in detail and, in large part, are interpreted from air photographs. Two periods of deformation can be inferred, the first a northwest-southeast compression, and the second a northeast-southwest compression.

Phanerozoic rocks from the Ronning Group to at least the basal Cretaceous sandstone inclusive, were compressed to form the structures of the Franklin Mountains, represented in the map-area by Jacques Range in the southwest corner of the map-area, and the Colville Hills occurring in the western half of the area.

Most of Jacques Range within the area is formed by a homoclinal north-dipping plate here interpreted as a thrust plate. This plate plunges out abruptly to the east but is replaced by another plate slightly en echelon to the first and trending more southeasterly. This second homocline dips southwesterly and is underlain by south-westerly-dipping thrusts which are, therefore, opposed in sense of transport to the thrust inferred beneath the plate to the east. The Franklin Mountains to the south are characterized by such reversals of the sense of transport within a given range, and by variable structural trends.

The Colville Hills are formed by a number of low-relief, generally anticlinal ridges which, as a group, also display a variety of trends and opposing asymmetries. Tunago Ridge, a homocline of Ronning Group strata, merges with Jacques Range south of the area, and trends to the north-northeast past the west end of Tunago Lake. Overturned beds occur locally along the east flank and, consequently, a high angle fault along the east side is interpreted as a reverse fault.

Belot Ridge occurs en echelon to the west of Tunago Ridge and extends along the west side of Belot Lake. The southern third of the ridge is flanked on the east by a high angle fault also interpreted as a reverse fault. The rest of the ridge is a steep-limbed anticline whose crest is characterized by chaotic structure and trench-like lineaments which may be tectonic features or may be due to joint enlargement and collapse attendant upon solution of underlying gypsum in the Devonian Bear Rock Formation. Just past the north end of Belot Lake the ridge bifurcates into a north-trending spur which plunges out within 6 miles and another branch which extends about 28 miles to the northeast before plunging out.

Colville Ridge, between Colville and Aubry Lakes, trends east-northeast away from Belot Ridge and toward Maunoir Ridge. It is about 36 miles long, with bedrock very poorly exposed along it. It is here interpreted as an anticline because Belot Ridge to the west and Maunoir Ridge to the east are anticlines, but the possibility of an underlying reverse fault, as with Tunago Ridge and the south part of Belot Ridge, can not be excluded.

Colville Ridge merges with Maunoir Ridge west of Lac Maunoir. Maunoir Ridge is a broad poorly exposed anticline which along its southern part is distinctly asymmetric,with the western limb steeper than the eastern. This part of the ridge trends to the north-northwest, but where Colville Ridge merges with it, it swings to the northeast along the northwest shore of Lac Maunoir and extends about 30 miles in that direction before plunging out. Maunoir Dome occurs about mid-way along this part of the ridge and is unique in this region. It is subcircular with Ronning Group strata in its core flanked by beds of the Bear Rock Formation. It forms a conspicuous bulge in the otherwise rectilinear Maunoir Ridge and stands about 900 feet higher than the rest of the ridge. The dome presumably has Saline River Formation evaporites structurally thickened in its core. Its origin must be related to that of the ridge, but the reason for its localization is obscure.

Two small, unnamed anticlinal ridges occur. One trends slightly east of north and occurs a few miles southeast of Lac Maunoir. The other trends parallel to the south part of Maunoir Ridge and occurs en echelon with it to the east.

Southeast of Lac des Bois, Good Hope Ridge is formed by another anticline more or less on strike with Maunoir Ridge but displaying the opposite asymmetry, its eastern limb being steeper than its western.

Finally, a small unnamed anticlinal structure occurs on the south side of Smith Arm of Great Bear Lake. It appears to be slightly en echelon to, rather than the southward extension of Good Hope Ridge.

The origin of structures in the Colville Hills, as with the Franklin Mountains, are not completely understood. The inconsistent asymmetry and variety of structural trends suggest a common origin with the Franklin Mountains. This suggestion is strengthened by the physical merging of Tunago Ridge (Colville Hills) with Jacques Range (Franklin Mountains) just south of the map-area. Deformation in both structural provinces probably extended down to and included the Saline River Formation, whose evaporite and shale beds provide a zone of low strength or high ductility suitable for décollement. Flow of the evaporites in conjunction with deformation would result in accumulation of abnormal Saline River Formation thicknesses in the cores of the anticlinal structures. Localization of individual structures may have been controlled by variations in stratigraphic thickness above the Saline River Formation, or conversely may reflect discontinuities or thickness variations in the Saline River itself.

ECONOMIC GEOLOGY

No metallic minerals of economic significance were noted in the map-area. The Coppermine River Series flows, and Hornby Bay Group sediments intruded by basic dykes, appear to constitute the only rocks with potential for base metal exploration.

The greatest economic potential of the area is for oil and gas. Oil saturated sands at Lac des Bois and on the west flank of Belot Ridge attest to the presence of hydrocarbons in the area. Unfortunately all formations down to and including the Ronning Group are widely exposed, and hence this and younger formations exist as potential petroleum reservoirs in only a small part of the total map-area. In the south central part of the map-area petroleum potential may exist in Ordovician/Silurian carbonate rocks capped by Cretaceous shales. The Old Fort Island sandstone may have hydrocarbon potential. Its distribution in the subsurface may be discontinuous, as is the case south of Great Bear Lake (H.R. Balkwill, pers. com., 1970). Formations older than the Saline River Formation are probably not involved in the folding that produced Colville Hills; if this is the case, the anticlinal ridges are not significant structures from the point of view of possible deeper reservoir formations.

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APPENDICES

I - Report on Cambrian fossils

II - Reports on Ordovician-Silurian fossils

III - Reports on Devonian fossils

IV - Reports on Cretaceous fossils

Appendix I

REPORT ON CAMBRIAN FOSSILS

Report No. €1-62, by B.S. Norford on fossils collected by J.C. Sproule and Associates from an area north of Great Bear Lake.

Samples

RM 185	Bloody River Area 67° 06' N., 120° 44' W
RM 187	Haldane River Area 67° 06' N., 120° 41' W
RM 190	Haldane River Area 67° 14' N., 120° 41' W

Comments

Inarticulate brachiopods from the three localities are probably of Middle and/or Late Cambrian age.

Appendix II

REPORT ON ORDOVICIAN-SILURIAN FOSSILS

Report by B.S. Norford on fossils from northwest District of Mackenzie, collected by R.W. Macqueen, Operation Norman, 1968 (NTS 96L).

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Mount Kindle Fm., 470-490 feet above base of Section MQ5	65° 03" N., 127° 18' W. echinoderm debris stromatoporoid (?) indeterminate solitary coral Bighornia sp. Catenipora sp. Sarcinula sp. age: Late Ordovician	C-1753

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Mount Kindle Fm., talus from above 500 feet	As for C-1753 echinoderm debris indeterminate solitary coral Lobocorallium sp. favositid coral age: Late Ordovician	C-1754
Mount Kindle Fm., 546-555 feet above base of Section MQ5	As for C-1753 indeterminate tabulate coral Catenipora sp. Favosites sp. Palaeophyllum sp. Sarcinula sp. age: probably Late Ordovician	C-1755
Mount Kindle Fm., 562 feet above base of Section MQ5	As for C-1753 Catenipora sp. ?Catenipora sp. age: late Middle Ordovician to Late Silurian	C-1765
Mount Kindle Fm., 632 feet above base of Section MQ5	As for C-1753 ?Catenipora sp. age: late Middle Ordovician to Late Silurian	C-1757
Mount Kindle Fm., 645-651 feet above base of Section MQ5	As for C-1753 echinoderm debris indeterminate solitary coral Bighornia sp. ?Palaeofavosites sp. ?Thaerodonta sp. age: Late Ordovician	C-1758
Mount Kindle Fm., 656 feet above base of Section MQ5	As for C-1753 indeterminate halysitid coral age: late Middle Ordovician to Late Silurian	C-1759
Mount Kindle Fm., 681 feet above base of Section MQ5	As for C-1753 echinoderm debris bryozoan indeterminate solitary coral ?Calapoecia sp. age: probable Middle or Late Ordovician	C-1760

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Mount Kindle Fm., 703-715 feet above base of Section MQ5	As for C-1753 strophomenid brachiopod Bighornia sp. indeterminate tabulate coral age: Late Ordovician	C-1761
Mount Kindle Fm., near top of exposure	66° 07' N., 126° 15' W. Hare Indian River echinoderm debris indeterminate solitary coral Calapoecia sp. Catenipora sp. ?Palaeofavosites sp. age: Late Ordovician	C-1768
Mount Kindle Fm., near top of exposure	66° 17' N., 126° 25' W Hare Indian River indeterminate solitary coral Palaeofavosites sp. ?Palaeofavosites sp. age: Late Ordovician to Late Silurian	C-1769
Mount Kindle Fm., 5 feet above base of Section MQ13	66° 15' N., 126° 15' W indeterminate solitary coral Parafavosites sp. age: Late Ordovician to Late Silurian	C-1771
Mount Kindle Fm., 85 feet above base of Section MQ13	As for C-1771 echinoderm debris indeterminate solitary and tabulate corals Palaeophyllum sp. Catenipora sp. sowerbyellid brachiopod ?Diceromyonia sp. ?Rhynchotrema sp. age: Late Ordovician	C-1772
Mount Kindle Fm., 95-115 feet above base of Section MQ13	As for C-1771 Bighornia sp. Streptelasma sp. Palaeophyllum sp. indeterminate tabulate coral Catenipora aff. C. rubra Sinclair and Bolton Catenipora sp. Sarcinula sp. age: Late Ordovician	C-1773

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Mount Kindle Fm., 75-80 feet above base of Section MQ13	As for C-1771 indeterminate solitary coral ?Palaeophyllum sp. ?Palaeofavosites sp. age: probably Late Ordovician	C-1774
Mount Kindle Fm., 373-400 feet above base of Section MQ13	As for C-1771 straight cephalopod (?) indeterminate solitary coral ?Cystiphyllum sp. (fasciculate form) Catenipora sp. favositid coral age: Silurian	C-1775
Mount Kindle Fm., 0-12 feet above base of Section MQ14	66° 17' N., 126° 25' W. Bighornia sp. Deiracorallium sp. Streptelasma sp. indeterminate tabulate coral ?Calapoecia sp. Favosites sp. Palaeofavosites sp. Plaesiomys sp. age: Late Ordovician	C-1776
Mount Kindle Fm., 18 feet above base of Section MQ14	As for C-1776 Bighornia sp. Lobocorallium sp. rhynchonellid brachiopod age: Late Ordovician	C-1777

Comments

The material is poorly preserved but silicification, though coarse, allows the solitary corals and brachiopods to be etched free.

Almost all of the collections are Upper Ordovician. Some are dated by their faunal content, others by their stratigraphic position within the measured sections. The Upper Ordovician collections can be correlated with the basal part of the Mount Kindle Formation of the type section at Mount Kindle, with the lower part of the resistant portion of the Beaverfoot Formation (Bighornia-Thaerodonta Fauna, Norford, 1969, pp. 38-40), and with Unit 12 of the Canyon Ranges Section at the northwest end of the Mackenzie Mountains (Norford, 1964, pp. 21-22, 123).

Collection C-1775 is the only collection that is Silurian; as yet its age cannot be further refined.

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Report by B.S. Norford on fossils from northern District of Mackenzie, submitted by D.G. Cook, 1970, (NTS 96N)

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Mount Kindle	67° 39' N., 124° 14' W., east bank of Anderson River straight cephalopod Maclurites sp. ?Bighornia sp. ?Catenipora sp. age: probably Late Ordovician	C-5456
Mount Kindle	67° 47' N., 124° 40' W., east bank of Anderson River straight cephalopod streptelasmid coral Catenipora sp. age: probably Late Ordovician	C-5457
Mount Kindle	67° 40' 27" N., 124° 23' 45" W., east bank of Anderson River colonial coral? not diagnostic	C-5458

Appendix III

REPORTS ON DEVONIAN FOSSILS

Report by A.E.H. Pedder on Devonian fossils collected from the District of Mackenzie by W.S. MacKenzie, R.W. Macqueen and A.E.H. Pedder on Operation Norman, 1968 (NTS 96L, M)

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Bear Rock Fm., 0-62 feet above base of Fm., MQ11	Hare Indian River; 66° 23' N., 126° 18' W.; 96L atrypid brachiopod, fragmentary fragment of a small orthoconic nautiloid Moelleritia canadensis Copeland age: Eifelian	C-1770
Bear Rock Fm., about 40 feet above base of a 120 foot section MN10	West side of Lac Belot; 66° 48' N., 126° 27' W.; 96L ostracods, not studied age: unknown	C-1812
Bear Rock Fm., about 45 feet above base of a 120 foot section MN10	West side of Lac Belot; 66° 48' N., 126° 27' W.; 96L gastropods, indeterminate fragments age: unknown	C-1811
Bear Rock Fm., about 50 feet below top of a 123 foot section MN11	West side of Lac Belot; 66° 47 1/2' N., 126° 26' W.; 96L gastropods, indeterminate fragments age: unknown	C-1813
Bear Rock Fm., about 30 feet below top of a 123 foot section MN11	West side of Lac Belot; 66° 47 1/2' N., 126° 26' W.; 96L ostracods, not studied age: unknown	C-1814
Hume Fm., isolated outcrop of approx. 6 feet stratigraphic thickness. Very roughly 50 feet above base and 150 feet below top of Fm. PT23	Hare Indian River, north of Echo Bend; 66° 20' N., 127° 16 1/2' W.; 96L Alveolites sp. undet. Schuchertella adoceta Crickmay age: Eifelian, adoceta Zone	C-2539

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Hume Fm., isolated outcrop of approx. 40 feet stratigraphic thickness PT5	Carnwath River, right bank; 67° 23' N., 127° 44' W.; 96M stromatoporoids, not studied Favosites sp. undet. Thamnopora sp. undet. Alveolites sp. undet. Syringopora sp. undet. Aulopora Disphyllum sp. undet. Billingsastraea verrilli (Meek) Utaratuia praeclara (Crickmay) Taimyrophyllum stirps (Crickmay) Aphroidophyllum howelli Lenz Aphroidophyllum meeki Pedder Dohmophyllum sp. nov., as in C-2538 Redstonea sp. undet. Sociophyllum glomerulatum (Crickmay) Stringophyllum sp. undet. Mesophyllum sp. undet. Plasmophyllum sp. undet. "Microplasma" sp. cf. M. fongi sensu Lenz 1961 Mackenziephyllum insolitum Pedder Douvillina sp. undet. Carinatina dysmorphostrota (Crickmay) Desquamatia aperanta (Crickmay) Desquamatia arctica (Warren) Spinatrypa andersonensis (Warren) Undispirifer compactus (Meek) orthoconic nautiloid trilobite, under study by A.R. Ormiston age: Late Eifelian or early Givetian, dysmorphostrota Zone.	C-2521
Hume Fm., isolated outcrop of approx. 45 feet stratigraphic thickness PT6	Carnwath River, right bank; 67° 32' N., 127° 56 1/2' W.; 96M Sphaerospongia tessellata auct. stromatoporoid, not studied Favosites sp. undet. Thamnopora sp. undet. Alveolites sp. undet. Syringopora sp. undet. Hexagonaria sp. cf. H. gemmifera Crickmay Billingsastraea verrilli (Meek) Utaratuia praeclara (Crickmay) Taimyrophyllum stirps (Crickmay) Aphroidophyllum howelli Lenz Aphroidophyllum meeki Pedder Redstonea graciliseptata (Pedder) Stringophyllum sp. undet. Sociophyllum glomerulatum (Crickmay)	C-2522

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
	Mesophyllum sp. Plasmophyllum sp. "Microplasma" sp. cf. M. fongi sensu Lenz 1961 Fistulipora sp. undet. trepostomatous bryozoan, study pending stropheodontid, indet. "Spinulicosta" stainbrooki Crickmay Carinatina dysmorphostrota (Crickmay) Desquamatia aperanta (Crickmay) Desquamatia arctica (Warren) Spinatrypa andersonensis (Warren) Spinatrypa coriacea Crickmay Spinatrypa (?) borealis (Warren) Emanuella sp. undet. Undispirifer compactus (Meek) Tentaculites sp. undet. orthoconic nautiloid trilobite fragments, same species as in C-2521 age: Late Eifelian or early Givetian, dysmorphostrota Zone	
Hume Fm., 12 foot cliff at or very close to the top of the Fm. PT22	Scarp north of Echo Bend on Hare Indian River; 66° 20 1/2' N., 127° 17 1/2' W.; 96L Sphaerospongia tessellata auct. Favosites sp. undet. Alveolites sp. undet. Billingsastraea verrilli (Meek) Dohmophyllum sp. nov., as in C-2521 Mesophyllum sp. undet. Schizophoria sp. undet. "Spinulicosta" stainbrooki (Crickmay) Carinatina dysmorphostrota (Crickmay) Desquamatia aperanta (Crickmay) Desquamatia arctica (Warren) Spinatrypa andersonensis (Warren) Spinatrypa (?) borealis (Warren) Undispirifer compactus (Meek) age: Late Eifelian or early Givetian, dysmorphostrota Zone.	C-2538

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Hume Fm., 37 feet above base of a 97 foot exposure. MN19	Near mouth of an unnamed south-flowing tributary of Hare Indian River, 20 miles northwest of Lac à Jacques; 66° 29' N., 127° 52' W.; 96L Favosites sp. undet. Billingsastraea verrilli (Meek) Taimyrophyllum stirps (Crickmay) Sociophyllum glomerulatum (Crickmay) Mesophyllum rectum (Meek) Douvillina sp. undet. "Spinulicosta" stainbrooki Crickmay Desquamatia arctica (Warren) Spinatrypa (?) borealis (Warren) age: Late Eifelian or early Givetian, dysmorphostrota Zone.	C-4254
Hume Fm., 82-97 feet above base of a 97 foot exposure. MN19	Near mouth of an unnamed south-flowing tributary of Hare Indian River, 20 miles northwest of Lac à Jacques; 66° 29' N., 127° 52' W; 96L Favosites sp. undet. Alveolites sp. undet. Billingsastraea verrilli (Meek) Mesophyllum sp. undet. Desquamatia arctica (Warren) Spinatrypa (?) borealis (Warren) trilobite pygidium, indet. age: Late Eifelian or early Givetian, dysmorphostrota Zone	C-3236
Ramparts Fm., upper 5 feet of a 40 foot exposure. MN18	16 1/2 miles west of the north end of Lac à Jacques; 66° 16 1/2' N., 127° 59' W.; 96L Thamnopora sp. undet. Syringopora sp. undet. Disphyllum sp. cf. D. goldfussi (Geinitz) Hexagonaria sp. cf. H. arctica (Meek) halliid coral, undescribed Grypophyllum sp. nov. Hypothyridina florens Crickmay?, fragmentary specimen "Atrypa" sp. ex. gr. "A". hormophora Crickmay "Atrypa" sp. cf. A. pechiensis sensu Warren & Stelck 1956 Cyrtina sp. undet. Paracyclas sp. undet. Straparollus (Euomphalus) sp. undet. age: Late Givetian	C-1852

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Ramparts Fm., 20 feet above base of a 36 foot exposure MN17	10 1/2 miles west-southwest of the north end of Lac à Jacques; 66° 14' N., 127° 46' W.; 96L Schizophoria sp. undet. Rhyssochonetes sp. undet. Productella sp. undet. Hadrorhynchia? sp. undet. Emanuella sp. undet. age: Late Givetian	C-1851
Ramparts Fm., 30 feet above base of a 36 foot exposure MN17	10 1/2 miles west-southwest of the north end of Lac à Jacques; 66° 14' N., 127° 46' W.; 96L Schizophoria sp. undet. Productella sp. undet. Hadrorhynchia? sp. undet. "Atrypa" sp. ex gr. "A." hormophora Crickmay Warrenella franklini (Meek)? Cyrtina sp. undet. Stringocephalus sp. indet., juvenile specimen age: Late Givetian	C-4253
Ramparts Fm., upper 5 feet of a 36 foot exposure. MN17	10 1/2 miles west-southwest of the north end of Lac à Jacques; 66° 14' N., 127° 46' W; 96L Schizophoria sp. undet. Rhyssochonetes sp. undet. Productella gulosi Crickmay Hadrorhynchia? sp. undet. Leiorhynchus sp. cf. L. hippocastanea Crickmay "Atrypa" sp. ex gr. "A." hormophora Crickmay Emanuella sp. undet. Cyrtina sp. undet. age: Late Givetian	C-1850

Comments

The giant ostracod Moelleritia canadensis is widely distributed in the Gossage/Bear Rock Formation. It is endemic, but related species in the Urals and Germany, and associated faunas in Yukon and Victoria Island suggest that it is probably of Eifelian age (Copeland 1962, GSC Bull. 91, pp. 1, 2).

Two megafaunal zones can now be recognized in the Hume Formation. The lower, indexed by Schuchertella adoceta, is represented in these collections by C-2539. The other Hume collections all contain forms diagnostic of the upper, or Carinatina dysmorphostrota Zone.

As the zonation of the Ramparts Formation is currently under review collections from this formation are not assigned to zones. Nevertheless it is likely that all come from the upper part (post Rensselandia laevis bearing beds) of the platform member of the limestone.

Report by T.P. Chamney on Middle Devonian microfossils from shale samples taken by J.D. Aitken, on Operation Norman, 1968 (NTS 96 L & M)

Stratigraphy	Locality, Fauna & Age	GSC Loc. No.
Hare Indian Fm. outcrop	24 mi. southwest of Tadek Lake 66° 42' N., 127° 53' W. (96L) Tentaculites spp. Styliolina sp. megaspores 2 spp. ostracod sp. age: Middle Devonian (Givetian)	C-2590
Hare Indian Fm. outcrop	Northwest corner of 96 M 67° 53' N., 127° 41' W. megaspores 2 spp. age: Middle Devonian (Givetian)	C-2574

Comments

GSC sample location C-2590 with the criconarids (Tentaculites spp. and Styliolina sp.) confirm an age assignment of Givetian as a biostratigraphic equivalent of the Hare Indian Formation. The associated smooth trilete plant megaspores are also present in GSC sample location 2574 and as such are similarily assigned to the Givetian.

Appendix IV

REPORTS ON CRETACEOUS FOSSILS

Report by T.P. Chamney on Early Cretaceous microfossils from shale samples collected by J.D. Aitken, on Operation Norman, 1968 (NTS 96 L & M)

Locality, Fauna & Age	GSC Loc. No.
Carnwath River 67° 21' N., 127° 41' W. (96 M) Urigerinammina (Bimonolena) sp. Miliammina ex. gr. M. sproulei ?Ammodiscus sp. Haplophragmoides sp. Ammobaculites sp. megaspores: ?derived from Paleozoic age: Early Cretaceous (Early to Middle Albian)	C-2573
Tchaneta River 67° 15' N., 127° 29' W. (96L) Siphotextularia spp. Saccamina lathrami Haplophragmoides spp. ?Verneuilinoides sp. ?Trochamminoides sp. megaspore sp. age: Early Cretaceous (Early to Middle Albian)	C-2575

Comments

Siphotextularia spp. including Siphotextularia rayi Tappan are the index markers for the silty zone of the Anderson Plains area. The age assignment is from Aptian to Early Albian of the Early Cretaceous.

Report by T.P. Chamney on Late Cretaceous microfossils from shale samples collected by J.D. Aitken on Operation Norman, Great Bear Lake area, District of Mackenzie in 1968 (NTS 96 J).

Locality, Microfossils & Age	GSC Loc. No.

South Scented Grass Hills, Smith Arm, 66° 02' N., 122° 01' W.

?Radiolaria: 2 spp. C-2569
plant cuticle (orange colour)

age: poorly preserved microfauna but the presence of radiolaria would indicate similarity to previous samples of the Upper Cretaceous

South Scented Grass Hills, Smith Arm, 66° 09' N., 123° 15' W. C-2570A, B, & C are from one location, but are from successively higher stratigraphic positions

Foraminifera: C-2570A

Haplophragmoides cf. H. spiritense Stelck & Wall
H. cf. H. rugosa Gouger
H. cf. H. bonanzaense Stelck & Wall
H. minute sp.
Gaudryina tailleuri Tappan
?Verneuilinoides cf. V. fischeri (dwarf) Tappan
?Textularia cf. T. gravenori Stelck & Wall
Miliammina cf. M. bisobscura Stelck & Wall
Ammodiscus sp.
Ammobaculites n. sp.
?Arenobulimina cf. A. torula

age: Elements of the Haplophragmoides spp. of this microfaunal assemblage have been previously recovered from the upper part of the Bentonitic Shale Zone of the Anderson Plains. But the combination with M. cf. M. bisobscura and G. tailleuri have only been recorded to date from the Tuluvak and Ayiyak Members of the basal Schrader Bluff Formation (Coniacian) in Alaska. Since this is the first occurrence of this very abundant foraminiferal assemblage in Arctic Canada the age can only be tentatively established as near the Upper/Lower Cretaceous boundary; the age relationship for the boundary in this area may be Coniacian/Albian.

Locality, Microfossils & Age — GSC Loc. No.

Same location as C-2570A

?Radiolaria sp. — C-2570B
Vertebrate:
Fish scales
bone
age: The poorly preserved radiolaria associated with the vertebrate remains is a similar assemblage as C-2565 (not reported here) which was assigned to the Upper Cretaceous of probable Santonian stage, and is correlated with C-4297.

Same location as C-2570A

?Radiolaria sp. — C-2570C
Vertebrate:
fish scales sp.
bone
Megaspore:
fragments of 1 sp.
plant "cuticle"
age: The radiolarian species are ankerite casts and also much mica (phlogopite and muscovite) is associated with the ?reworked organic remains. The rock unit could thus be a possible reworked deposit of ?Pleistocene age.

Mackintosh Bay, Smith Arm, 66° 06'N., 123° 21' W. C-2571A, B, C, & D are from one location but are from successively higher stratigraphic positions

Foraminifera: — C-2571A
Hippocrepina (Hyperamminoides) 2 spp.
Saccammina sp.
?chambered, coiled trochammina-like sp.
Megaspore: sp.
age: The closest area for comparison of a Saccammina-Hippocrepina assemblage is from the surface samples of Coalmine Lake, District of Mackenzie, on the extreme northwestern flank of the Mackenzie River Delta. An Upper Cretaceous age assignment for this latter area has been given but, as in the case of C-2570A, this foraminiferal assemblage as such has not been encountered in the immediate area in any known sequentially collected control section.

Locality, Microfossils & Age	GSC Loc. No.
Same location as C-2571A	
?radiolarian spine ?Radiolaria sp. age: From the very poor micro-organic recovery the radiolarian elements in the assemblage indicate correlation with the control section C-4291 to 4300 and are questionably assigned to the Upper Cretaceous.	C-2751B
Same location as C-2571A	
Megaspore: 2 spp. age: The megaspore assemblage is similar to C-4291 to C-4298 which were assigned to the Upper Cretaceous of probable Santonian stage.	C-2571C
Same location as C-2571A	
Radiolaria: 3 spp. Megaspore: 3 spp. age: Upper Cretaceous of probable Santonian stage similar to the control section C-4291 to 4300	C-2571D

Comments

Radiolaria is a subclass of the phylum Protozoa included in the kingdom Protista. There are only a few workers sufficiently versed in this class of micro-organisms to place these fossil forms in their proper suprageneric divisions. In order to expedite biostratigraphic application of the abundant specimens of Radiolaria recovered from the Upper Cretaceous of Arctic Canada, a regional reference collection of species number system has been maintained for several years and is used for this report. It is known that some of the subspherical, spined forms may belong to the subclass Heliozoa but have been curated in the Protista regional reference collections with the Radiolaria.

The radiolarian assemblages recovered from preparation and picking of these samples for this report are correlative with the Anderson Plains of the Arctic Coast, Operation Norman I. They occur in the Bituminous Shale Zone collected by the author in 1963 from the following sections and locations:

Anderson River, 68 CR 4A and 4B, 69° 16' N., 128° 13' W.

Anderson River, 68 CR 5A (basal part), 69° 15' N., 128° 12' W.

Horton River, 68 CR 16A, 69° 27' 30" N., 126° 58' W.

Report by T.P. Chamney on microfossils from shale samples from a section measured by R.W. Macqueen north of Smith Arm, Great Bear Lake, and northeast of Kilekale Lake, 66° 28' N., 123° 40' W (NTS 96 J).

Distance from base of section	Microfossils & Age	GSC Loc. No.
0 to 4 feet	Radiolaria: Dictyometra sp. ?Nasselaria sp. 5 other spp. Megaspores: 3 spp. Vertebrates: bone sp. (fish) age: Upper Cretaceous, probably Santonian but could be slightly older (?Coniacian). It is correlatable with the Hesperornis sp. zone (Russell, 1966).	C-4291
20 feet	?Trochammina cf. T. kiskatinawensis Stelck & Wall Radiolaria: Nasselaria sp. 3 other spp. Megaspores: 2 spp. Vertebrate: bone sp. age: Upper Cretaceous, probably Santonian	C-4292
35 feet	?Pseudouvigerina sp. Radiolaria: 5 spp. age: Upper Cretaceous, probably Santonian	C-4293
55 feet	Radiolaria: spp. Vertebrate: bones (fish) scales sp. age: Upper Cretaceous, probably Santonian	C-4294
70 feet	Radiolaria: 3 spp., very abundant forming "White Speckled Shale" 2 other spp. Vertebrate: bone sp. (?bird bone fragments) age: Upper Cretaceous, probably Santonian; the ?bird bones with selenite crystals again indicate correlation with the upper part of the Bituminous Shale Zone of the Anderson Plains.	C-4295

Distance from base of section	Microfossils & Age	GSC Loc. No.
85 feet	Radiolaria: 4 spp. Vertebrate: bone (?bird) age: Upper Cretaceous, probably Santonian	C-4296
95 feet	Radiolaria: Dictyometra sp. 6 other spp. Megaspores: 1 sp. Vertebrate: bone (?otolith) age: Upper Cretaceous, probably Santonian	C-4297
115 feet	Radiolaria: Nasselaria sp. 2 other spp. Megaspores: sp. Vertebrate: bone (dk. red-amber) age: Upper Cretaceous, probably Santonian; the megaspores are similar to those recoved from the Vermillion River Formation of Manitoba.	C-4298
130 feet	Radiolaria: Nasselaria sp. Dictyometra sp. 5 other spp. Vertebrate: bone sp. megaspore: sp. age: Upper Cretaceous, probably Santonian	C-4299
140 feet	Radiolaria: 2 spp.. Vertebrate: bone sp. age: Upper Cretaceous, probably Santonian	C-4300

Comments

The very abundant occurrence of radiolaria in this section, associated with common vertebrate remains, selenite and jarosite indicates equivalence with the Bituminous Shale Zone of the Anderson Plains along the Arctic Coast to the north.

The Anderson Plains sections of the Bituminous Shale Zone are represented by sections CR 4A, 4B on the Anderson River and CR 16A on the Horton River. In this geologic province peaks of radiolaria development occur in the lower and the upper parts of the Bituminous Shale Zone, and are separated by a middle interval of poor microfossil recovery consisting mainly of plant megaspores of the "spear" form.

References

Russell, D.
1967: Cretaceous Vertebrates from the Anderson River N.W.T.; Can. J. Earth Sci., vol. 4.

Palynology report by W.S. Hopkins, Jr. on two outcrop samples from the Northwest Territories, collected by D.G. Cook, 1969.

Lithology	Locality, Flora & Age	GSC Loc. No.
Poorly consolidated sand with carbonaceous layers	S.W. of Lac des Bois, NWT, 66° 24' N., 124° 52 1/2' W. (NTS 96K) Laevigatosporites sp. Osmundacidites wellmanii Couper Rouseisporites cf. R. Triangularis Pocock Gleicheniidites senonicus Ross Cicatricosisporites australiensis (Cookson) Potonie Cicatricosisporites cf. C. perforatus (Baranov, Nemkova, Kondratiev) Singh Cicatricosisporites sp. Trilobosporites apiverrucatus Couper Trilobosporites cf. T. canadensis Pocock Murospora florida (Balme) Pocock Deltoidospora sp. Sphagnum antiquasporites Wilson and Webster Lycopodiumsporites austroelavatidites (Cookson) Pocock Baculatisporites sp. Cyathidites australis Couper Verrucosisporites sp. ?Cedrus sp. Pinus sp. Haploxylon-type ?Keteleeria sp. Tsugaepollenites mesozoicus Couper Taxodiaceae ?Araucariacites sp. Podocarpus sp. Classopollis classoides (Pflug) Pocock and Jansonius Monosulcites sp. Ephedra sp. ?Quercus-type age: Aptian but see "Comments"	C-4314

Lithology	Locality, Flora & Age	GSC Loc. No.
CW 58 Hematite cemented conglomerate	Maunoir Ridge, 67° 08' N., 125° 06' W. (NTS 96K) Gleicheniidites cf. G. senonicus Ross Pinus sp. haploxylon-type age: Probably Mesozoic	C-4318

Comments

Sample C-4318 was essentially barren, but contained several spores of the form genus Gleicheniidites. Assuming these are indigenous to the rock, it would suggest an age of Jurassic or Cretaceous for the samples.

Sample C-4314 is most interesting in that it contains a relatively large flora, and for the most part the palynomorphs are well preserved. The most abundant elements of the flora appear to be the coniferales, suggesting a widespread conifer forest in the area at the time of deposition. Most elements of the florule would be compatible with a Jurassic or Cretaceous age, but several more sharply delimit the age interpretation. Rouseisporites has been found in rocks ranging in age from Barremian to Lower Aptian of Canada; Cicatricosisporites perforatus from Aptian to Turonian of Canada and the USSR; and Murospora florida has been recorded from Neocomian to Aptian of both Australia and Canada.

The highly doubtful Quercus-type grain, if it is truly tricolpate, would suggest at least an Albian age. However, the identification is questionable at best, and consequently is disregarded in drawing age conclusions.

Consideration of the overall flora, plus those which appear to have a more restricted stratigraphic range, leads me to consider this sample to be most probably Aptian in age.

Palynology report by D.C. McGregor on samples submitted by B.G. Craig from the Northwest Territories 1959, for study of spore content.

Locality and Flora	GSC Loc. No.
From a pingo, 8 mi. east of Horton Lake, north of Smith Arm of Great Bear Lake, N.W.T. Field No. CD87a and CD87c Spores: cf. Aneimia dorsostriata Bolkh. Cicatricosisporites dorogensis Pot. & Gel. Cyathidites sp. Gleicheniidites senonicus Ross Leiotriletes sp. Lophotriletes sp. (cf. Lygodium) Lygodioisporites sp. cf. Lycopodium subrotundatum Kara-Mursa cf. Osmunda. Trilobosporites apiverrucatus Couper	5535

Locality and Flora	GSC Loc. No.
Pollen: Abietineaepollenites sp. Cycadopites sp. Ephedripites sp. Pinuspollenites sp. (Pityosporites) cf. Podocarpidites biformis Rouse	

Comments

The identifications given above are based on sample CD87a, and all remarks here apply to that sample only. Sample CD87c yielded very few recognizable microfossils, those that were seen suggest, however, that it is the same or nearly the same age as CD87a.

The age of the assemblage is Lower Cretaceous. The abundance of Schizaeceous types (Cicatricosisporites, Lygodioisporites, cf. Aneimia) indicates that the assemblage is post-Jurassic, and the absence of angiosperm pollen indicates that it is pre-Albian. Trilobosporites apiverrucatus is regarded by Couper (1958), Palaeontographica 103B (4/6) as a key form for the Wealden.

The microfossils in CD87a are well preserved. There is no evidence whatever of mixing with older or younger forms than Lower Cretaceous ones. The possibility of secondary deposition of the microfossils appears to be eliminated.

Report by J.A. Jeletzky on Upper Cretaceous fossils collected by D. Bardack, Department of Biological Sciences, University of Illinois, Chicago, U.S.A. at Lac des Bois (96K), District of Mackenzie, N.W.T. in 1969 and submitted for identification on October 1, 1969.

Identifications	GSC Loc. No.
From: "Cretaceous. Lac des Bois, on the W side of the lake, on a peninsula which projects into the lake; approx. 66° 52' N., 125° 22' W; in concretions which have weathered out of a cliff which reaches 35' in height. Most concretions came from the lower levels of this cliff."	
Scaphites delicatulus Warren	84342
Inoceramus labiatus Schlotheim	
Otoscaphites cf. seabeensis Cobban and Gryc	
Borissiakoceras cf. ashurkoffae Cobban and Gryc	
Inoceramus ex aff. lamarcki Parkinson	
a generically indeterminate (new genus?) kelaenid squid (order Teuthida Naef, 1916, family Kelaenidae Jeletzky, 1966 nov. nomen.)	
indeterminate pelecypods	

Age and correlation: The well preserved and diagnostic fossils of the lot GSC loc. 84342 permit its unreserved early Turonian (Watinoceras and Inoceramus labiatus zone; see Jeletzky, GSC Paper 67-72, p. 27-28) dating. The lot GSC 84342 can furthermore be placed in the upper part (subzone) of the interregional Watinoceras and Inoceramus labiatus zone characterized by Watinoceras reesidei and Scaphites delicatulus (Jeletzky, loc. cit., p. 28; W.A. Cobban and G. Gryc, 1961, Journ. Pal. vol. 35 (1), p. 178). This subzone is known to occur in the middle part of the Slater River Formation (about 1,100 feet above base according to Dr. C.R. Stelck, personal communication) of the Mackenzie River valley (Hume, 1954, GSC Mem. 273, p. 47, 51; Warren, 1947, Journ. Pal. vol. 21 (2), p. 118, 119). The lot GSC loc. 84342 is, therefore, undoubtedly correlative with this part of the Slater River Formation.

The recognition of the early Turonian age of the "basal Cretaceous sandstone" exposed at Lac des Bois is extremely important paleogeographically and stratigraphically. It indicates either non-deposition or subsequent erosion of Sans Sault Formation in this area and the extensive eastward transgression of the early Turonian (Second White Specks) sea on Mackenzie Plains. The lower part of the Slater River Formation may be absent also, unless it is of the early Turonian age in its entirety.