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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 70-32

BROCK RIVER MAP-AREA, DISTRICT OF MACKENZIE (97 D)

(Report, 6 figures, 2 tables and P.S. Map 13-1970)

H. R. Balkwill and C. J. Yorath

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ABSTRACT

Gently folded, unmetamorphosed Upper Proterozoic (Hadrynian or Neohelikian) sedimentary rocks, with a total exposed thickness of about 6,000 feet, underlie most of the map-area; gabbro sills and dykes locally intrude the strata. Paleozoic, marine sedimentary rocks, ranging in age from Cambrian to Middle Devonian, and having an exposed thickness of about 1,700 feet, unconformably overlie the Proterozoic rocks. Paleozoic rocks are separated by a regional hiatus from the overlying Cretaceous sequence that is about 700 feet thick and composed of quartz sandstones, siltstones, shale and coal. Thick, topographically prominent, Pleistocene glacial deposits obscure bedrock throughout wide regions.

The northwesterly trending Coppermine Arch dominates the region's geological structure. Proterozoic and Phanerozoic epeirogenesis is indicated by unconformities along and adjacent to the arch.

BROCK RIVER MAP-AREA, DISTRICT OF MACKENZIE (97D)

INTRODUCTION

Reconnaissance geological field studies of Brock River map-area were carried out in 1968 as part of Operation Norman, a regional mapping program of the lower Mackenzie River and Anderson River areas (Aitken et al., 1969 and 1970; Yorath et al., 1969). This paper is intended as a brief set of notes to amplify the geological map.

H.R. Balkwill mapped the distribution of Proterozoic and Paleozoic rocks; C.J. Yorath studied the distribution and lithostratigraphy of Cretaceous strata; R.W. Macqueen investigated exposures of Paleozoic rocks along Hornaday River; and R.W. Klassen carried out studies of Quaternary deposits and physiography. L.A. Love, A.J.M. Elliot, and D. Turner were able and resourceful assistants, and T. Samuel was a superb cook.

Brief reports of the geology of the coasts of Darnley Bay and Amundsen Gulf were made during the 1913-18 Canadian Arctic Expedition (O'Neill, 1924). Mackay (1958) studied the physiography of the region; his memoir is also an outstanding source of information about the human geography and history of exploration. Brock River map-area was included in reconnaissance studies by Fraser and others (1960) of the north-central part of the District of Mackenzie. Unpublished reports by oil companies and consultants on parts of the area are on file with the Department of Indian Affairs and Northern Development.

A Department of Transport radar station is maintained at Tysoe Point; the Eskimo community of Paulatuk is a few miles west of the map-area on the south shore of Darnley Bay.

PHYSIOGRAPHY

Brock River map-area is bounded on the north by Amundsen Gulf (Arctic Ocean), and is thus at the northern limit of the Interior Plains physiographic province (Bostock, 1970). Klassen (in Yorath, et al., 1969) modified and extended physiographic divisions in the region after Mackay (1958) and Bostock (1964). Klassen (op. cit.) recognized three physiographic divisions (Fig. 1): Brock Upland, Horton Plateau, and Anderson Plain.

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The subdivisions Brock Upland and Horton Plateau of the Horton Plain (see GSC map 1254A) have not yet been formally adopted by the Canadian Permanent Committee on Geographic Names. However, their use is considered necessary for a comprehensive description of the physiography of this region.

Brock Upland includes almost all of the region east of Hornaday River. The Upland, which is a moderately well dissected highland underlain by gently dipping Proterozoic sedimentary rocks, is the physiographic manifestation of the Coppermine Arch structural province (Fig. 2). The Melville Hills Morainic Belt, a topographically distinctive region of moraine ridges and kames, extends across Brock Upland as a convex-northward arc, thus separating the Upland into the Darnley Bay Coastlands (adjoining Amundsen Gulf) and the Hornaday Plateau (in the south-central part of the area). The Morainic Belt is a constructional feature of continental glaciation by the Amundsen Gulf and Great Bear Lake ice lobes (Fig. 1). Kames and ridges range in elevation from 500 to 2,000 feet (Fig. 3) and small lakes are abundant. Glacial drift is relatively thin over the Darnley Bay Coastlands, but the region is strongly fluted and crag and tail features are conspicuous; drift was not observed on Hornaday Plateau.

Horton Plateau is a barren, little-dissected upland south of Hornaday River and Rummy Creek. It is sculptured from gently tilted Paleozoic and Cretaceous rocks and locally is overlain by glacial drift.

Anderson Plain is west of Hornaday River and Rummy Creek, and is dominated in the map-area by the westward extension of the Melville Hills Morainic Belt.

Post-glacial marine processes apparently have had little effect on modifying the physiography of the coast. There are poorly developed marine terraces about 200 feet above sea level, near the mouths of Hornaday and Brock Rivers, but as Mackay (1958, p. 38) notes, there are ".... none of the remarkable flights of raised beaches rising to 500 or 600 feet above sea level that are such conspicuous features throughout much of the Arctic". Large, lobate deltas are presently being constructed at the mouths of Brock and Hornaday Rivers.

Bedrock is well-exposed in most parts of Brock Upland and Horton Plateau, but outcrops are rare in the Melville Hills Morainic Belt. Rock exposures are nearly continuous along Hornaday, Brock, and Roscoe Rivers, and along the shoreline from Brock Lagoon to Buchanan River. Parts of the lower courses of Hornaday and Roscoe Rivers, and especially Brock River, are characterized by narrow, spectacular canyons (Fig. 4). Mackay's (1958, p. 58) description of Brock Canyon is apt. "In places, the buff to rusty-brown canyon walls rise 350 feet above the swift-flowing river. Spired 100-foot high pinnacles with precariously balanced rocks rise like minarets along the banks. Talus deposits apron the bases of the pinnacles and often extend down to river level. The colourful Brock River gorge has the scenic attraction of some canyons in the southwestern United States." The canyons appear to be post-glacial: they are abruptly angular both in plan and cross-profile, with abundant delicate pinnacles; there are no grooves, striations, or other indications of glacial erosion (or deposition); and lineated drift maintains consistent trends on superjacent uplands, indicating original continuity across the loci of present canyons. If in fact the canyons are post-glacial, they are striking examples of the inordinate depth of erosion that has been accomplished by streams in some periglacial regions.

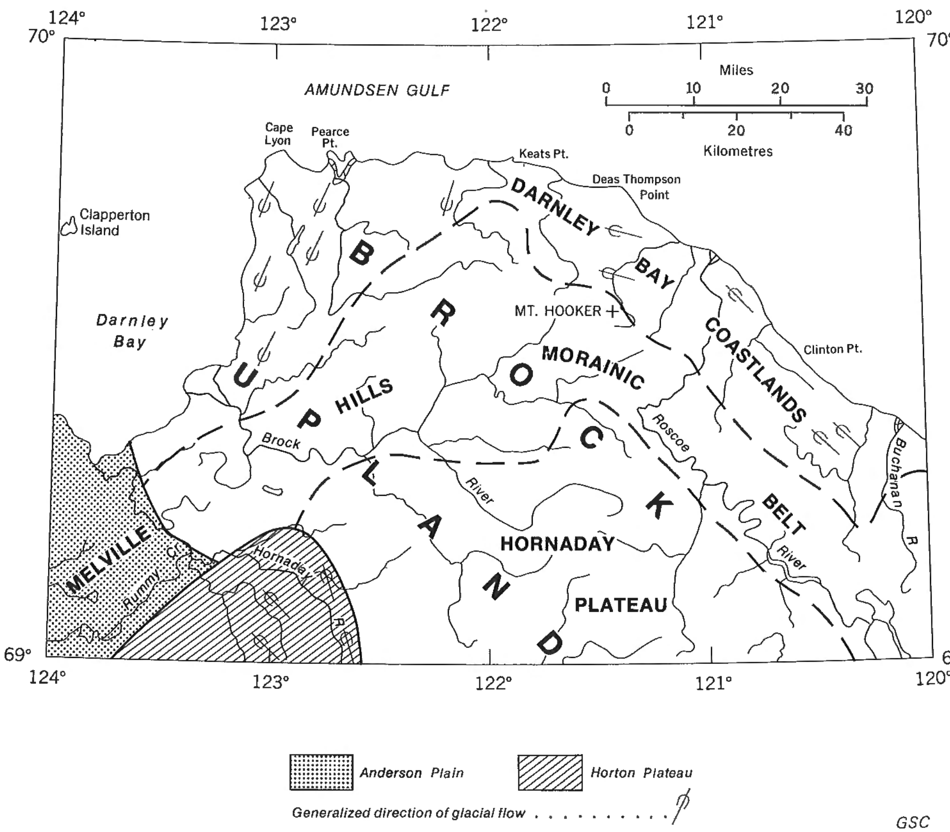

Figure 1. Physiographic divisions, Brock River Map-area (After Klassen, <u>in</u> Yorath et al., 1969)

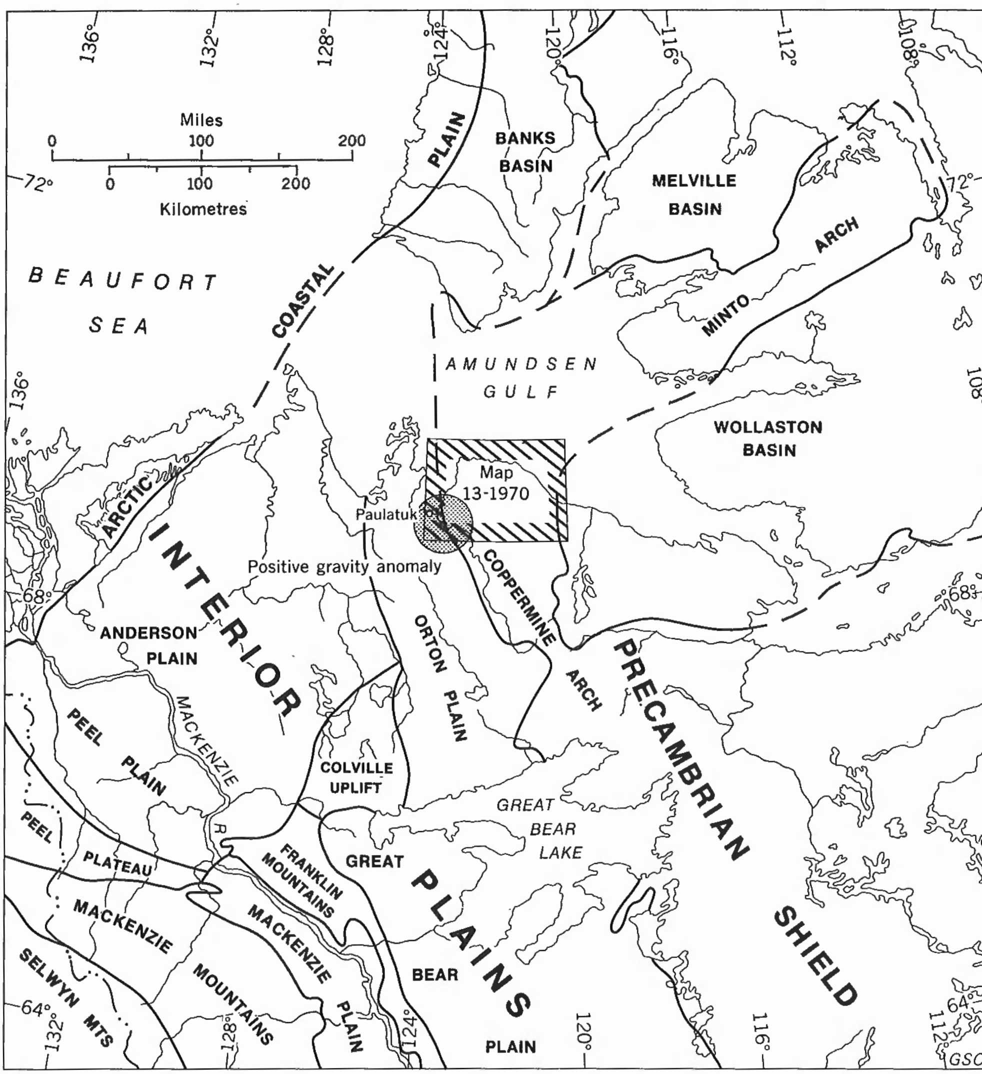

Figure 2. Structural provinces of the northern Interior Plains and environs (Slightly modified from Douglas et al., 1963)

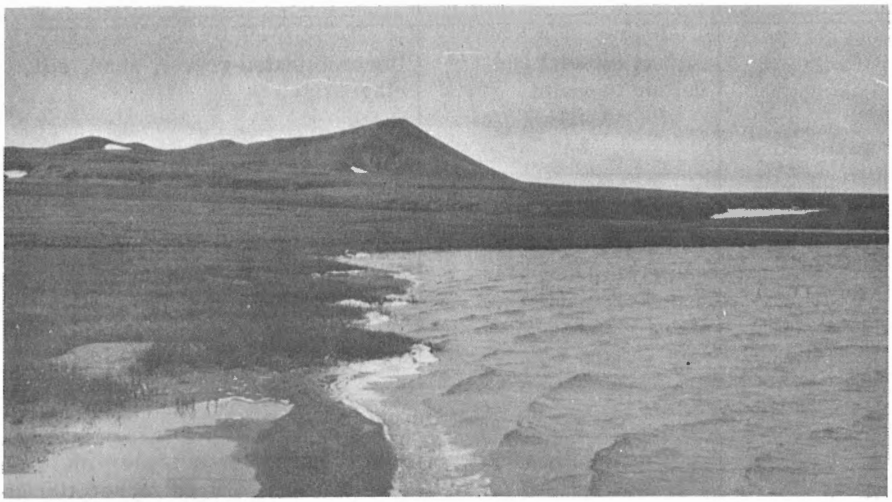

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Figure 3.

Westward view of Mount Hooker (elev. 1,500 feet), a prominent kame in the Melville Hills Morainic Belt.

STRATIGRAPHY

Gently tilted, unmetamorphosed, Upper Proterozoic (Hadrynian or Neohelikian) sedimentary rocks, locally intruded by gabbroic sills and dykes, underlie most of Brock Upland. The sequence has a total exposed thickness of about 6,000 feet (Table 1).

Cambrian quartz sandstones unconformably overlie the Proterozoic strata and are succeeded, in turn, by about 1,500 feet of Lower and Middle Paleozoic clastic and carbonate rocks. A regional hiatus separates the Paleozoic rocks from Lower Cretaceous quartz sandstones, siltstones, shale, and coal. The sequence of Cretaceous strata has an approximate thickness of 700 feet.

Unconsolidated Quaternary deposits and Recent alluvium form a widespread mantle on the older rocks.

System or Series	Map-unit and estimated maximum thickness (feet)	Lithology
Quaternary	Recent alluvial and deltaic deposits (Qal) ?	Unconsolidated gravel, sand, silt, and clay
	Unconformity	
	Moraines, glaciofluvial, and glaciolacustrine deposits (Qm) 500	Unconsolidated gravel, sand, silt, and clay; locally bedded; till
	Unconformity	
Lower Cretaceous	"Bentonitic zone" (Kb) 300	Black, soft, plastic shale with fossiliferous, orange, concretionary limestone
	"Silty zone" (Ks) 400	Light to dark grey shale and mudstone; light grey, friable sandstone; local coal; local limestone concretions
	Unconformity	
(?) Lower and Middle Devonian	Bear Rock Formation (Db) 260	Dolomite: light brown-grey and light green-grey; fine crystalline; calcareous; interbeds of pale green, pink, and maroon shale near base; local dolomite-pebble conglomerate at base
	Unconformity	
Upper Cambrian and Lower Ordovician	"Ronning Group": 'Cherty unit' (€Or$_{2b}$) 400	Dolomite: pale yellow-brown to pale grey; mainly medium crystalline; abundant white and yellowish grey, stromatolitic and locally oolitic chert; abundant drusy quartz
	"Ronning Group": 'Rhythmic unit' (€Or$_{2a}$) 500	Dolomite: pale brownish grey; fine- to coarse-crystalline; interbedded with greyish orange dolomite; partly laminated

Table 1. Table of Map-units

System or Series	Group	Map-unit and estimated maximum thickness (feet)	Lithology
Upper Cambrian and Lower Ordovician	"Ronning Group"	'Cyclic unit' (€Orl) 63	Dolomite and rare limestone; cyclic repetitions of laminated beds, oolitic beds, conglomeratic beds, stromatolitic beds, and thin beds of dolomitic shale
Cambrian		Saline River Formation (€s) 120	Red and green shales; gypsum; halite; siltstone; flaggy dolomite with salt-crystal casts
		Mount Cap Formation (€cp) 200	Green, grey, and minor red shales; glauconitic sandstone and siltstone
		Old Fort Island Formation (€o) 200	Sandstone: white, grey, locally red and green; quartzose; fine to very coarse grained and conglomeratic; crossbedded; locally friable
Unconformity			
Neohelikian or Hadrynian		Unit Ᵽ$_6$	Gabbro sills and dykes
	Intrusive contact		
	Shaler Group	Unit Ᵽ$_5$ 500	Maroon and green dolomite, siltstone, and orthoquartzite; local gypsum
		Possible unconformity	
		Unit Ᵽ$_4$ 500	Pink and buff dolomite; green shale; dark grey limestone; large domal stromatolites
		Unit Ᵽ$_3$ 1,500	Pink, grey, buff, and maroon ortho-quartzite; minor shale near top
		Unit Ᵽ$_2$ 800	Buff, pink, and grey dolomite; fine- to coarse-crystalline; partly cherty
		Unconformity	
		Unit Ᵽ$_1$ 3,000 (base not exposed)	Dark grey-green shale, argillite, and siltstone

Table 1 continued

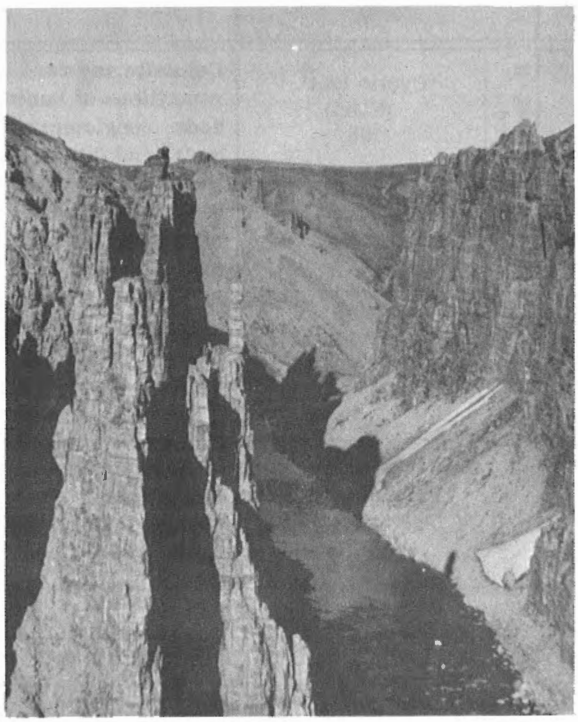

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Figure 4.

Brock Canyon, view looking east; here the canyon is about 350 feet deep. Delicate pinnacles are sculptured from Proterozoic dolomite (map-unit P_2) chiefly by rockfall along systematic joints.

PROTEROZOIC

Shaler Group (Thorsteinsson and Tozer, 1962; Cook and Aitken, 1969)

Most of Brock Upland is underlain by a thick sequence of unmetamorphosed, largely or entirely marine clastic and carbonate strata that are intruded by diabasic dykes and sills. These rocks are tentatively correlated with the Proterozoic Shaler Group of Banks and Victoria Islands (Thorsteinsson and Tozer, 1962). Five informal

Terms to describe stratification		Terms to describe cross-stratification		Thickness	Terms to describe splitting property
Very thick-bedded	Beds	Very thickly cross-bedded	Cross-beds	Greater than 120 cm	Massive
Thick-bedded	Beds	Thickly cross-bedded	Cross-beds	120 cm (about 4 ft.) to	Blocky
Thin-bedded	Beds	Thinly cross-bedded	Cross-beds	60 cm (about 2 ft.) to	Slabby
Very thin-bedded	Beds	Very thinly cross-bedded	Cross-beds	5 cm (about 2 in.) to	Flaggy
Laminated	Laminae	Cross-laminated	Cross-laminae	1 cm (about 1/2 in.) to	Shaly (claystone, siltstone) Platy (sandstone, limestone)
Thinly laminated	Laminae	Thinly cross-laminated	Cross-laminae	2 mm (about .08 in.) or less	Papery

Table 2. Classification of bed thickness (after McKee and Weir, 1953, p. 383)

stratigraphic units, with an exposed thickness of about 6,000 feet, were mapped within the Shaler Group, as were the sills and dykes that locally intrude them. Stratigraphic sections were not measured in the Proterozoic rocks, nor were the rocks examined in detail; estimates of unit thicknesses are based on regional structure.

The oldest Proterozoic strata (map-unit P_1) consist of dark grey-green, calcareous shale and flaggy to slabby, laminated siltstone (see Table 2 for quantitative classification of bed thicknesses used herein). The shale is micromicaceous on parting surfaces and some beds contain finely disseminated pyrite. Unit P_1 forms low sea cliffs along the eastern shore of Darnley Bay, and locally crops out along Brock River at the approximate axis of the Coppermine Arch. The base of the unit is not exposed, and the uppermost beds are abruptly and unconformably overlain by dolomite assigned to unit P_2. Map-unit P_1 is estimated to be at least 3,000 feet thick, based on exposures near Cape Lyon.

The lowermost rocks assigned to unit P_2 are composed of thin-bedded, maroon and buff[1], finely crystalline[2], nonporous dolomite. These strata are overlain by thin- to very thick-bedded, resistant dolomite that forms headlands at Pearce Point, but which is best exposed in the narrow gorge of Brock River (Fig. 4). Dolomite in the upper part of the unit is light buff, light pink, and light grey; it is very finely crystalline, and there are abundant reticulate masses of tan-weathering chert, as well as some beds with laminations of chert. The upper part of the sequence has poor porosity locally in the form of disconnected small vugs. Map-unit P_2 is estimated to be about 800 feet thick at Brock River, and may be thicker than this at Pearce Point. The unit is overlain conformably by orthoquartzite assigned to unit P_3.

Light pink, maroon, light grey, and light buff orthoquartzites (P_3) are widely exposed on Hornaday Plateau and in the Darnley Bay Coastlands near Keats Point. These rocks are fine to coarse grained, very well cemented by silica, thick bedded and resistant. A few recessive intervals of maroon and dark green shale, up to 50 feet thick, occur in the upper part of the sequence. Map-unit P_3 is estimated to be about 1,500 feet thick, and is conformably overlain by strata assigned to unit P_4.

The lowermost beds assigned to unit P_4 consist of light pinkish buff, buff- to orange-weathering, finely crystalline dolomite with small reticulate masses of chert. These nonporous, thin- to medium-bedded rocks are exposed along the Arctic Coast at Keats Point, at Hornaday River, and southwest of Roscoe River (where they are overlain by about 100 feet of medium to dark green and maroon shale, and thin-bedded, medium green siltstone). The remainder of unit P_4 is buff and pinkish buff, nonporous, finely crystalline dolomite, with beds of large domal stromatolites and, near Deas Thompson Point, a sequence, about 100 feet thick, of dark grey, aphanocrystalline, thin-bedded limestone. Complete sections of unit P_4 are not exposed, but the sequence is estimated to be about 500 feet thick.

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1 In this report buff is used for colours in the range - yellowish grey to very pale orange, 5Y7/2 to 10YR8/2 in the Rock Colour Chart (Goddard et al., 1963). Tan is used for colours in the range - light brown to moderate brown, 5YR6/4 to 5YR4/4.

2 Folk's (1962) grade scale is used herein for carbonate rocks; Wentworth's (1922) grade scale is used for non-carbonate rocks.

The uppermost Proterozoic sedimentary rocks in the area (unit P_5), consisting of maroon and light green dolomite, siltstone, orthoquartzite, and thin beds of gypsum, are poorly exposed eastward from Clinton Point and along the unnamed river immediately west of Buchanan River. Dolomite in this sequence is very finely crystalline and thin bedded. Orthoquartzites are thin bedded and cross laminated. The lower contact of unit P_5 was not observed; near Buchanan River the unit is overlain unconformably by Cretaceous sandstones. Cook and Aitken (1969) report that a possible unconformity occurs at the base of the unit in the Erly Lake map-area (97A), and, also, that the sequence is overlain there unconformably by Cambrian sandstones. Unit P_5 is about 500 feet thick near Buchanan River and is absent in the western part of the Coppermine Arch, as a result of pre-Paleozoic erosion.

Diabase sills and dykes (P_6)

Proterozoic sedimentary rocks are intruded by sills and dykes of dark green to dark grey, diabasic gabbro. Dykes range in width from a few tens of feet to about 400 feet; the longest, near Deas Thompson Point, is exposed for about 5 miles. All observed dykes are nearly vertical and trend northwesterly, parallel to the regional trend of the Coppermine Arch.

Sills are developed most conspicuously in map-units P_1, P_2, and P_4; except for a thin sill near the southern border of the map-area, the very thick sequence of orthoquartzites designated as unit P_3 appears to be free of sills. Some sills are nearly 100 feet thick and are continuously exposed over wide areas, particularly between Hornaday and Roscoe Rivers.

Argillaceous rocks adjacent to the dykes, and above and below sills, are altered to pelitic hornfels, whereas carbonate rocks are bleached and recrystallized. The zones of alteration are, at most, a few tens of feet wide.

Age and Correlation of Proterozoic Rocks

The name Shaler Group was proposed by Thorsteinsson and Tozer (1962) for a thick succession of clastic, carbonate and minor evaporitic rocks, intruded by gabbro sills and dykes, that are exposed in the Shaler Mountains of Victoria Island (almost coincident with the Minto Arch, Fig. 2). At the type locality the Shaler Group unconformably overlies gneissic basement rocks that probably crystallized (or recrystallized) during the Kenoran (2,400 m.y.) orogeny. Gabbro sills and dykes that intrude the Shaler Group yielded radiometric ages of 635 m.y. and 640 m.y. (Christie, 1964, p. 10).

Precambrian rocks in the Brock River map-area were correlated previously with the Coppermine River Series (O'Neill, 1924; Fraser, 1960; Yorath et al., 1969), which is a widespread succession of sedimentary and mafic extrusive rocks in the southern part of the Coppermine Arch (Fig. 2). Tentative assignment to the Shaler Group is preferred for the following reasons: (1) the Coppermine River Group is characterized by extensive, intercalated basalt flows and is lithologically unlike the sequence in Brock River map-area; moreover, at its type locality the Coppermine River Group is overlain along a pronounced angular unconformity by a succession of Upper Proterozoic rocks (Barager, 1967; Barager and Donaldson, 1970) that are lithologically similar to the sequence in Brock River map-area; (2) Proterozoic strata in the map-area lie on trend with the Shaler Group at its type locality and are similar to that group in lithology and stratigraphic position; (3) Proterozoic units in the map-area are in mappable continuity with units mapped as the Shaler Group in adjoining Erly Lake map-area (Cook and Aitken, 1969).

The Shaler Group in the Brock River map-area is likely Hadrynian or Neohelikian. Gabbro dykes in the immediate area yielded radiometric ages of 705 m.y. and 770 m.y., based on whole-rock, K-Ar determinations (Wanless et al., 1965, p. 48). The strata are overlain along a regional angular unconformity by Cambrian quartz sandstones (Cook and Aitken, 1969).

Data from other parts of the Coppermine Arch (Wanless et al., 1968, p. 66) corroborate a probable Late Proterozoic age for the Shaler Group. As previously noted, the Coppermine River Group is overlain unconformably by rocks probably equivalent to some part of the Shaler Group. Basaltic flows within the Coppermine strata yield a spread of radiometric ages, but a group within the range 1,0C5-1,200 m.y. is considered to be the most reliable, and may provide a maximum age for the overlying Shaler Group. A probable minimum age is supplied by a diabase sill having a radiometric age of 605 m.y. that intrudes the post-Coppermine River strata.

PALEOZOIC

Paleozoic marine sedimentary rocks, ranging from Cambrian to Middle Devonian, flank the eastern and western limbs of the Coppermine Arch and unconformably overlie Proterozoic sedimentary and intrusive rocks. The cumulative thickness of Paleozoic strata is estimated to be about 1,700 feet.

The Paleozoic succession is homotaxial with the sequence of units elsewhere in the eastern part of the northern Interior Plains (see Aitken et al., 1969, 1970). Because identifiable fossils are uncommon, assignments of geological age to the Paleozoic rocks are based principally on lithological correlation with paleontologically dated strata elsewhere in the lower Mackenzie and Anderson River areas, and consequently are tentative. Stratigraphic nomenclature and assignments of geological age (Table 1) are partly amended from an earlier publication (Yorath et al., 1969) for reasons that follow.

Old Fort Island Formation: Єo (Norris, 1965)

A sequence of light grey, light buff, and light pink, medium- to coarse-grained quartz sandstones, about 200 feet thick, overlies Proterozoic dolomite (unit B_4) along a slight angular discordance in Hornaday Canyon. The sandstones are mineralogically supermature, with poorly to moderately well-sorted, well-rounded quartz grains in a siliceous cement. Cementation is incomplete and as a result, the rocks are distinctively friable, porous, and recessive in outcrop. Granule lenses (granules to 3 mm) are common.

The thin- to thick-bedded sandstones are conspicuously cross bedded (both trough and planar types); light pink iron-staining commonly marks the base of sets of cross-strata.

Near the base of the succession there are a few sets of beds, as much as 4 feet thick, of light green and maroon, argillaceous, sandy siltstone. Indistinct trails and burrows were noted on some bedding surfaces in the lower part of the formation.

Norris (1965) mapped the distribution of basal Paleozoic quartz sandstones along the margin of the Canadian Shield from Great Slave Lake to latitude 64 degrees north. He proposed that the name Old Fort Island Formation be used for these porous, friable, and conspicuously cross-bedded rocks that are exposed along the North Arm of Great Slave Lake. Rocks similar in lithology and stratigraphic position to the Old Fort Island Formation were mapped near Great Bear Lake by Balkwill in 1969 and can be traced to the Brock River map-area (Fraser, 1960; Cook and Aitken, 1969). Cook and Aitken (1969) tentatively correlated these rocks with the Mount Clark Formation of the Franklin Mountains (Fig. 2), but there is much uncertainty regarding the age and stratigraphic relationships of the Mount Clark Formation at the type locality (see Hume, 1954, pp. 9-13) and assignment to the Old Fort Island Formation is preferred.

The formation is unfossiliferous except for trails and burrows. However, its age in Hornaday Canyon is indicated by the following criteria: it rests unconformably on rocks that were slightly deformed as recently as 605 m.y.; and it is overlain conformably by rocks tentatively assigned to the Mount Cap Formation, from which Early and Middle Cambrian fossils have been collected in the Mackenzie and Franklin Mountains (Cook and Aitken, in press). Accordingly, the Old Fort Island Formation is tentatively considered Lower Cambrian in the map-area, but as a disconnected, transgressive, basal clastic deposit, its age likely differs from place to place along the margin of the Canadian Shield.

Mount Cap Formation: Ꞓcp (Williams, 1923)

The Old Fort Island Formation is overlain conformably by a succession of glauconitic sandstones with subordinate amounts of interbedded maroon and green shale and orange-weathering dolomite. These rocks are correlated tentatively with the Mount Cap Formation.

Sandstones in the Mount Cap Formation are light grey-green with some purple bands, and consist of slightly argillaceous, micaceous and silty, well-cemented (silica), fine- to medium-grained quartz sand with macroscopically visible glauconite in many beds. The strata are thick to very thick bedded (Fig. 5) and cross-stratification is uncommon, in contrast to the Old Fort Island Formation. Burrows and trails are common on some bedding surfaces.

Recessive sets of red and green, fissile shale beds, from 6 inches to 2 feet thick, are fairly abundant in the lower part of the formation. Very finely crystalline, very thin-bedded, yellowish-orange and light green dolomite is interbedded with shale in the recessive intervals.

The Mount Cap Formation is about 200 feet thick at La Ronciere Falls (Macqueen, pers. com., 1969) where the thick sandstone beds form the lip of the falls (Fig. 5). Cook and Aitken (1969) reported that the unit is about 230 feet thick in the southeastern part of Erly Lake map-area (97A).

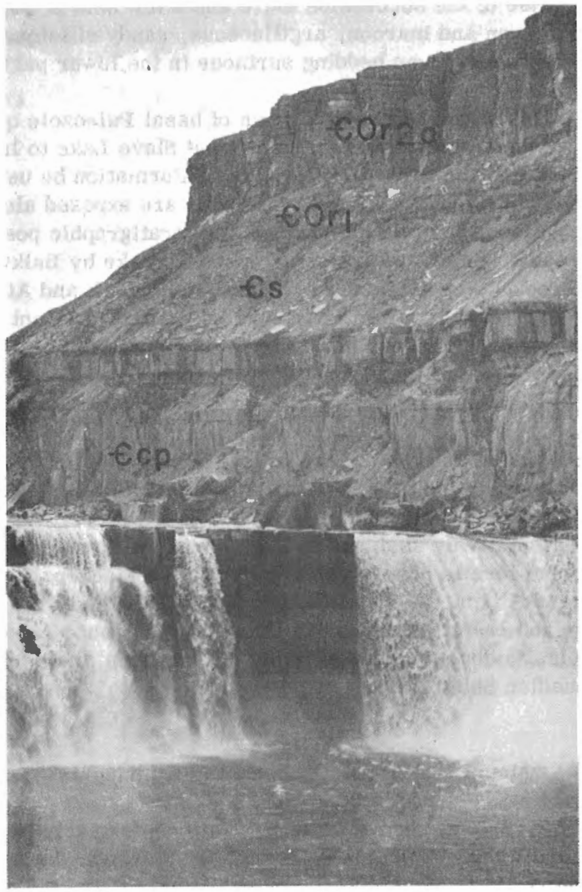

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Figure 5.

La Ronciere Falls, Hornaday River; height of the falls is about 70 feet. Resistant beds in the Mount Cap Formation (€cp) form the lip of the falls and lower walls of the canyon; Saline River Formation (€s) and the 'cyclic unit' (€Orl) of the 'Ronning Group' are poorly exposed in the recessive slope; the 'rhythmic unit' (€Or_{2a}) of the 'Ronning Group' forms the upper cliff.

Fossils were not collected from the Mount Cap Formation in Brock River map-area. Middle Cambrian taxa were reported (Hume, 1954, pp. 10-11) at the type locality (Mount Cap Formation in the Franklin Mountains) and recent collections from Mount Clark, also in the Franklin Mountains, are late Early Cambrian (W.H. Fritz, GSC Paleontology Section Report C-19-1969-WHF).

Saline River Formation: Єs (Williams, 1923)

The Saline River Formation is a recessive sequence that conformably overlies the Mount Cap Formation in exposures along the upstream part of Hornaday Canyon (Fig. 5). At La Ronciere Falls the formation is about 120 feet thick (Macqueen, pers. com., 1969) and consists of maroon, green, and buff, generally non-calcareous papery shale that is interbedded with light grey-green and greenish-buff, very finely crystalline, platy dolomite. Dolomite beds are partly gypsiferous (light pink, buff and white gypsum); dessication polygons, salt casts and ripple-marks are common on many bedding surfaces.

Fossils collected near the type locality in the Franklin Mountains were assigned to the Middle Cambrian (Hume, 1954, p. 11). Collections from Saline River strata in the Mackenzie Mountains were tentatively assigned to the Glossopleura Zone of the Middle Cambrian, as were collections from rocks tentatively correlated with the Saline River Formation near Great Bear Lake (W. H. Fritz, GSC Paleontology Section Reports C-19-1969-WHF and C-9-1969-WHF).

'Ronning Group' (Hume and Link, 1945; Bell, 1959; Macqueen, 1970)

Macqueen (1970) used the term 'Ronning Group' in a reconnaissance sense to include four, widespread, Lower Paleozoic shelf carbonate units in the plains east of the lower Mackenzie River. From the base upward these are the informally named 'cyclic', 'rhythmic', and 'cherty units', and the overlying Mount Kindle Formation. Strata were assigned to the 'cyclic', 'rhythmic', and 'cherty units' in the map-area, although the 'cyclic unit' is very thin. The Mount Kindle Formation is absent[1], perhaps because of non-deposition, but more likely as a result of erosion associated with a sub-Devonian unconformity as is the case in other parts of the Operation Norman area (Macqueen, op. cit., p. 226; Cook and Aitken, 1969).

The 'cyclic unit' ($ЄOr_1$) of the 'Ronning Group' is in gradational contact with the underlying Saline River Formation along Hornaday Canyon. The base of the 'cyclic unit' is marked by the appearance of distinctive pale yellow-orange-weathering, aphanocrystalline dolomite, with alternations of dolomite strata having the following textures: finely laminated (argillaceous and silty laminations), aphanocrystalline beds; oolitic beds; flat-pebble conglomerate (intraclast) beds; stromatolitic beds; and thin beds of light green, dolomitic shale. According to Macqueen (pers. com., 1969) this succession is 63 feet thick at La Ronciere Falls.

A sequence of pale brownish grey, fine- to medium-crystalline dolomite, interbedded with pale greyish-orange, fine-crystalline dolomite, gradationally overlies the 'cyclic unit' and is assigned to Macqueen's informally named 'rhythmic unit' ($ЄOr_{2a}$) of the 'Ronning Group'. A subtle banded appearance is imparted locally by the alternating colours of the beds. The base of the 'rhythmic unit' is marked by the absence of shale beds and partings that are characteristic of the underlying sequence, with a resultant contrast in weathering profile; the 'rhythmic unit' forms substantial cliffs above the recessive 'cyclic unit' beds (Fig. 5). Unit $ЄOr_{2a}$ has moderate to poor pin-point vuggy and intercrystalline porosity. At Hornaday Canyon the unit is about 500 feet thick.

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[1] See addendum for additional information obtained since this paper was written.

About 400 feet of light- to medium-grey, and buff, thin- to thick-bedded, fine- to predominantly medium- and coarse-crystalline dolomite (ϵOr_{2b}) conformably overlies the 'rhythmic unit'. This succession is distinguished by drusy quartz that lines vugs, by beds of light grey and white chert, and by abundant stromatolites replaced by grey and white chert. It was given the informal name 'cherty unit' by Macqueen (1970). Some sets of beds have poor to moderate vuggy porosity and some have poor to fair intercrystalline porosity. Unit ϵOr_{2b} underlies much of Horton Plateau, where it locally forms small, abrupt escarpments ranging from a few feet to a few tens of feet high; also, it is exposed locally in the extensively drift-covered region in the southeastern part of the map-area. The cherty rocks also crop out on Clapperton Island in the western part of Darnley Bay.

Paleontological data are sparse from 'Ronning Group' rocks in the Operation Norman area. The lower part of the 'rhythmic unit' at the Mackenzie Mountain front contains brachiopods and echinoderm ossicles dated by B. S. Norford (Geological Survey of Canada) as Late Cambrian (possibly Franconian). Silicified gastropods collected from the 'cherty unit' are thought by Norford to be Early Ordovician. With this control the following possibilities exist: the Middle Cambrian - Upper Cambrian boundary is near the top of the Saline River Formation, in the 'cyclic unit', or near the base of the 'rhythmic unit'; the Cambrian - Ordovician boundary is in the upper part of the 'rhythmic unit' or in the lower part of the 'cherty unit'.

Bear Rock Formation: (Hume and Link, 1945; Bassett, 1961; Tassonyi, 1969)

Clastic and carbonate strata that are assigned to the Bear Rock Formation disconformably overlie thick-bedded 'Ronning' dolomites near the mouth of Hornaday Canyon. Local relief on the disconformity is as great as 150 feet (Fig. 6). Thin-bedded, aphanocrystalline dolomite and limestone, and light green and maroon, calcareous shale, with some grey chert pebbles at the base, occupy depressions in the discontinuity and are draped over knobs of nearly horizontal 'Ronning' strata. The effect of this draping is to develop random folds in the Bear Rock Formation that are not expressed in the underlying rocks. Local relief on the disconformity decreases westward; along Horton River in the adjacent Simpson Lake map-area, it is generally less than 50 feet (Balkwill and Yorath, 1970).

The upper part of the Bear Rock sequence in Hornaday Canyon is buff and grey, calcareous and slightly gypsiferous, fine-crystalline, thin-bedded dolomite. In contrast to parts of the formation in neighbouring regions (Balkwill and Yorath, op. cit.; Cook and Aitken, 1969) it is not brecciated, apparently because of the local scarcity of readily soluble evaporites in the sequence. The rocks have poor to fair intercrystalline porosity but lack the cavernous porosity that is characteristic of much of the Bear Rock Formation in other parts of the lower Mackenzie River region.

Fraser (1960) collected Middle Devonian fossils from the Bear Rock Formation in Hornaday Canyon. This is consistent with age determinations of the upper part of the formation in other areas (Norris, 1968, p. 22; Cook and Aitken, in press). The age of the basal beds is uncertain; in the Mackenzie Valley the Bear Rock Formation is partly Lower Devonian and may be locally as old as Upper Silurian (Tassonyi, 1969).

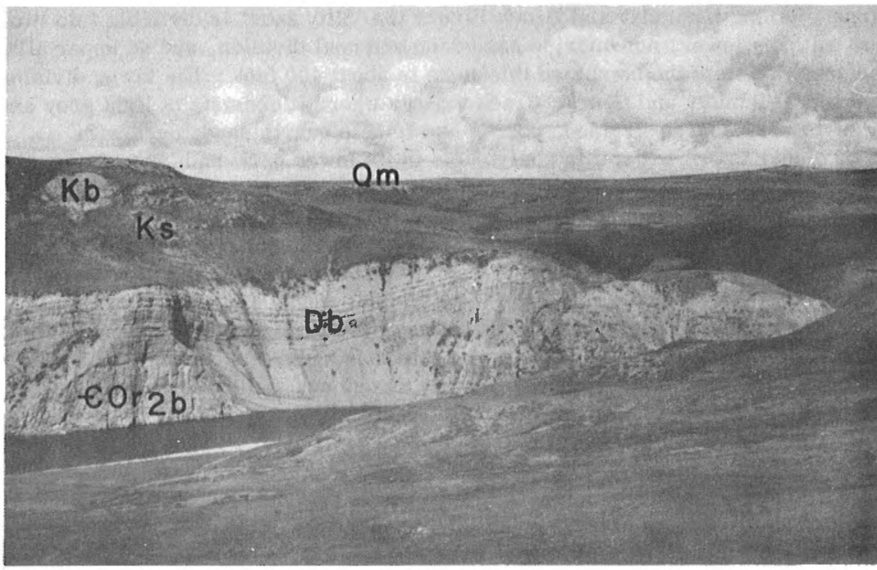

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Figure 6.

Mouth of Hornaday Canyon, view looking east: knobs of 'Ronning' cherty unit (€Or_{2b}) disconformably overlain by Bear Rock Formation (Db); note depositional draping of latter. Cretaceous 'Silty zone' (Ks) and 'Bentonitic zone' (Kb) poorly exposed in recessive slope; upland surface overlain by glacial drift (Qm).

CRETACEOUS

Exposures of Cretaceous rocks in Brock River map-area are scattered along the downstream parts of Hornaday and Brock Rivers, along the western part of the Darnley Bay Coastlands, and along the unnamed stream immediately west of Buchanan River. Cretaceous strata are believed to extend westward toward Anderson Plain but exposures are few and poor because of the extensive cover of glacial drift.

Four informally named Cretaceous lithostratigraphic units have been mapped in the northernmost parts of the northern Interior Plains (Yorath et al., 1969). The 'Silty zone' and 'Bentonitic zone', which are the lowermost of these units, were mapped in the Brock River area.

'Silty zone'

Proterozoic and Paleozoic rocks are overlain with pronounced unconformity by poorly to moderately well-indurated clastic rocks assigned to the Lower Cretaceous 'Silty zone'. Along Hornaday and Brock Rivers the 'Silty zone' is divisible into two informal units: a lower, non-marine sandstone and coal division, and an upper siltstone and mudstone division; the combined thickness is about 400 feet. The lower division is best exposed in Rummy and George Creek valleys where it consists of light grey and buff, fine- to very coarse-grained, porous and friable quartz sandstones with prominent planar cross-beds; thin coal seams in its lower part; and large (one to three feet in diameter) orange-weathering, calcareous concretions. Along Hornaday River, about four miles from the junction with George Creek, the low-grade lignites and sandstones form recessive slopes above resistant Paleozoic carbonates (Fig. 6). Here the lignite beds are red because of partial combustion.

Along the downstream parts of Hornaday and Brock Rivers the lower sandstone and coal division grades upward to the upper siltstone and mudstone division. The latter is composed of dark grey, concretionary mudstones and interbedded grey-brown siltstones. Coquinas containing very poorly preserved pelecypods and gastropods occur in the lower 80 feet of the unit on Brock River.

Two isolated occurrences of the lower sandstone and coal division are preserved in small grabens along Hornaday River near the southern boundary of the area. There are few exposures north of Brock River, but all of the Cretaceous rocks in this area belong to the lower sandstone and coal division.

Rocks with lithologies typical of the lower division of the 'Silty zone' occur in the vicinity of Buchanan River where the sequence is about 200 feet thick and unconformably overlies Proterozoic dolomites (unit P_5).

'Bentonitic zone'

A thin veneer of strata assigned to the 'Bentonitic zone' conformably overlies the 'Silty zone' along Hornaday River and its tributaries First and Second Creeks. In adjacent map-areas (97B and 97C; see Yorath et al., 1969) the 'Bentonitic zone' consists of a basal cone-in-cone bed overlain by uniform black, plastic and concretionary shales. In the Brock River area only the lowermost few feet are exposed and these include the well defined cone-in-cone layer. A maximum thickness of about 300 feet is estimated for this unit in the map-area.

Age and Correlation of Cretaceous Rocks

Age assignments of Cretaceous strata are tentative, pending completion of micropaleontological studies. The units are tentatively correlated with formations of similar lithology and stratigraphic position on Banks Island (Yorath et al., 1969). The lower sandstone and coal division of the 'Silty zone' appears to be the lithologic equivalent of the Isachsen Formation (Lower Cretaceous: pre-Albian) as described by Thorsteinsson and Tozer (1962). The upper siltstone and mudstone division is probably correlative with the lower member of the Christopher Formation, which has yielded diagnostic early to middle Albian faunas. The upper member of the Christopher

Formation has been dated as middle to late Albian (Thorsteinsson and Tozer, op. cit.) and is lithologically similar to the 'Bentonitic zone'. T.P. Chamney (pers. com., 1969) has identified middle Albian glomospirellid foraminifers from the upper beds of the 'Bentonitic zone' in the Anderson River area (107A). A few immature and fragmental ammonites were collected from the 'Bentonitic zone' on Horton River, west of the map-area. Jeletzky (GSC Paleontology Section Report Km-3-1969) tentatively suggested that they represent the late lower or early middle Albian Arcthoplites or Beudanticeras affine zone, but was unable to provide positive identifications due to the paucity, immaturity and fragmental nature of the specimens collected.

QUATERNARY

Thick, topographically prominent moraines and related glacial deposits (Qm) occur mainly within the Melville Hills Morainic Belt (Fig. 1). The deposits are mostly coarse- to very coarse-grained, light grey to buff quartz sand, which appears to have been largely derived from the poorly indurated quartz sandstones of the lower sandstone and coal division of the Cretaceous 'Silty zone'. The thickness of the moraines ranges from a thin veneer to several hundred feet.

Recent alluvium (Qal), consisting of unconsolidated gravel, sand, and silt, locally mantles the narrow floodplains of major streams. Large, lobate fan deltas of silt and fine-grained sand are presently being constructed at the mouths of Brock and Hornaday Rivers.

STRUCTURAL GEOLOGY

Structural provinces (Fig. 2) in the map-area are Coppermine Arch, Horton Plain, and Wollaston Structural Basin. These structural divisions are widespread regional features that lack abruptly defined boundaries or markedly contrasting structural styles; rather, the broad-limbed folds and steeply-dipping faults of all three provinces are elements of subtle tectonism on a cratonic region that has been relatively stable through Late Proterozoic and Phanerozoic time.

Coppermine Arch

Coppermine Arch, which dominates the structure of the map-area, is a northwesterly trending cratonic salient of Proterozoic sedimentary rocks (with minor intrusions), unconformably flanked on the east and west by easterly and westerly dipping homoclines of Paleozoic and Cretaceous strata. The arch is slightly asymmetrical, with a somewhat steeper southwestern limb; the approximate axis is marked by outcrops of unit P_1 of the Shaler Group near the upstream portal of Brock Canyon. Southwestward asymmetry of structures within the arch (including folds and reverse faults) was noted in adjacent Erly Lake map-area (Cook and Aitken, 1969).

Several diastrophic events in the Coppermine Arch and environs are indicated by the following stratigraphic - structural relationships: (1) intra-Proterozoic unconformities between units P_1 and P_2 and between units P_4 and P_5; (2) widespread Late Proterozoic intrusion of diabasic dykes and sills for which radiometric determinations yield an age of about 700 m.y.; (3) a regional sub-Paleozoic angular unconformity

(Wanless et al., 1968, p. 66, suggest mild deformation of parts of the Coppermine Arch at about 605 m.y., based on radiometric age determinations); (4) pre-Bear Rock Formation channelling of 'Ronning Group' carbonate rocks; (5) a regional unconformity beneath Lower Cretaceous rocks; and (6) faulted Lower Cretaceous rocks and a hiatus between these strata and Pleistocene glacial deposits.

Where the stratigraphic record permits observation, these and additional indicators of mild tectonism are widespread in the lower Mackenzie River region. Thus, the importance of the Coppermine Arch as a singularly active feature in the tectonic history of the area is not readily apparent. There are, however, local considerations which suggest that there were two phases when the arch acted as a discretely positive structure. First, local erosional relief in sub-Bear rock carbonates ('Ronning Group') is much more pronounced on the western flank of the arch than it is westward in the Horton Plain. Also, Cook and Aitken (1969) mapped post-Bear Rock Middle Devonian strata (Hume Formation) on the eastern flank of the arch in close stratigraphic proximity to the 'Ronning Group', a condition which suggests that the Bear Rock Formation is absent or very thin. Together these lines of evidence indicate probable Early Paleozoic (Caledonian) uplift of the 'proto' Coppermine Arch and suggest that it may have acted as a partial barrier for Bear Rock deposition. Secondly, clasts in basal Cretaceous sandstones and conglomerates ('Silty zone') in the adjacent Simpson Lake map-area (97B; Balkwill and Yorath, 1970) markedly increase in size toward the Coppermine Arch, suggesting that they were derived from uplift and erosion of the arch during the Early Cretaceous.

The relationships between the Coppermine Arch and structures involving similar Proterozoic rocks on Banks and Victoria Islands (Thorsteinsson and Tozer, 1962) are not readily apparent; 90-mile wide Amundsen Gulf separates the regions.

Dykes and significant faults consistently strike northwesterly, parallel to the approximate axis of the arch. This is parallel to the dominant trend of these features in other parts of the structure (Cook and Aitken, 1969). Most of the faults appear to be high-angle normal faults and were probably generated in response to broad crustal arching, although interpretation is difficult sometimes because of extensive drift cover, widespread felsenmeer, and low local relief.

Horton Plain and Wollaston Structural Basin

Coppermine Arch is flanked on the west by Horton Plain structural province (Yorath et al., 1969) and on the east by Wollaston Structural Basin. Horton Plain is a westward-dipping homocline where Paleozoic clastic and carbonate rocks, and poorly indurated Cretaceous strata are little deformed. Random small folds in the Bear Rock Formation, with amplitudes of a few tens of feet, are at least partly the result of depositional draping over irregularities in the underlying 'Ronning' paleo-surface.

The westernmost part of Wollaston Structural Basin is contiguous with the eastern flank of the Coppermine Arch; at the boundary, the Paleozoic rocks dip eastward as a gently undulatory homocline.

A subsurface structure of great significance is indicated by a spectacular gravity high that rises about 130 mgal above the regional field near the mouth of Hornaday River (Fig. 2). According to Hornal and others (1970, p. 10): "A good fit to the anomaly was obtained from a model shaped like an inverted cone of gabbroic composition ($\rho = 3.0$ g/cm^3) which intruded Precambrian rocks of density 2.7 g/cm^3 and which approached within 3 miles of the surface". The feature does not demonstrably affect Paleozoic or Cretaceous rocks; gabbroic sills and dykes in the Shaler Group may be a manifestation but the relationship is not presently clear. Possibly the structure is comparable in genesis and age to layered ultrabasic intrusions, such as the Muskox Complex (Smith, 1962), which are known in Proterozoic rocks in parts of the northwestern District of Mackenzie (Hornal, 1969).

Structural Control of Topography

Coppermine Arch is a distinct topographic prominence as well as being a structural high. The backbone of the arch is provided by resistant Proterozoic orthoquartzites (unit P_3) that form Brock Upland. From the crest of the upland the slope of the terrain conforms in a general way to the regional dip of the Proterozoic rocks, particularly along the western flank where there is a fairly smooth southwestward gradient.

Nearly vertical systematic joints are very well developed in brittle rocks throughout the Coppermine Arch, Horton Plain and westernmost part of Wollaston Structural Basin. Predominant joints strike northwesterly and northeasterly; preferential erosion along the trends of master joints has imparted an abrupt angularity to drainage patterns (excluding areas overlain by drift) and to parts of the coastline, as at Halcro Point. Rockfall, facilitated by joints, has developed spectacular gorges along some rivers (Figs. 4 and 5).

ECONOMIC GEOLOGY

No metallic sulphides, other than pyrite or marcasite, were found in the rocks, but the Proterozoic rocks were not investigated in detail and the possibilities of mineralization, particularly along faults and intrusive contacts, should not be discounted.

Prospects for significant accumulations of hydrocarbons appear to be poor. Some of the Phanerozoic rock units have sufficient porosity and permeability to serve as potential hydrocarbon reservoirs, if permeability barriers or structural anomalies are present. Cretaceous 'Silty zone' strata crop out at or near the surface and the unit can be disregarded as a possible reservoir in the map-area. Paleozoic rocks (including porous zones in the Bear Rock Formation, 'Ronning Group', and Old Fort Island Formation) dip westward in an apparently unbroken homocline that may have permitted up-dip migration and escape of hydrocarbons. Depositional draping in the lower part of the Bear Rock Formation may provide local, small structural traps.

The thin coal seams of the lower sandstone and coal division of the 'Silty zone' have been used as a source of fuel by trappers and at the Paulatuk mission, but the deposits are not extensive.

ADDENDUM

Rocks corresponding to the Upper Ordovician - Lower Silurian Mount Kindle Formation (see Macqueen, 1970) were not observed in Brock River map-area. However, the possibility that isolated, thin patches of these rocks occur in Horton Plateau should not be discounted: fossils collected by Shell Canada, Limited, and identified by B. S. Norford (Geological Survey of Canada) indicate the local presence of strata equivalent to the lower part of the Mount Kindle Formation along Horton River in nearby Simpson Lake map-area within localities previously mapped as older rocks ('Ronning Group' unit $\text{€}Or_{2b}$; see Balkwill and Yorath, 1970).

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