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CARCAJOU CANYON MAP-AREA, DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

J. D. AITKEN
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ABSTRACT

The known stratigraphic succession of Carcajou Canyon Map-area exceeds 34,000 feet (10,400 m) in thickness and is unmetamorphosed. Of this thickness, the lower half is an apparently conformable succession of Proterozoic, mainly marine, sedimentary strata with minor gabbro dykes and sills, tentatively assigned to the Helikian. Paleozoic marine strata mainly of Cambrian, Ordovician and Devonian ages total more than 11,350 feet (3,460 m). The Mesozoic is represented only by a succession of Cretaceous marine and nonmarine, clastic strata, 3,500 feet (1,070 m) in maximum preserved thickness. Cenozoic deposits of probable Eocene age are preserved only locally; they consist of coarse-grained clastic rocks with minor volcanic intercalations.

The large-scale and obvious fold and fault structures of the map-area are broadly Laramide (*sensu lato*) in age, and are interpreted as due to "thin-skinned" deformation that does not involve the crystalline basement. Antecedent faults of Proterozoic and Paleozoic age are recognized also; some of these have been rejuvenated during Laramide deformation, and have influenced the form of the Laramide structures.

The hydrocarbon potential of the area is low, but the stratigraphic and structural conclusions developed are pertinent to the search for hydrocarbons in adjoining, more prospective map-areas. The potential of the area for metallic deposits is virtually unassessed; however, the presence of a thick Helikian(?) succession should encourage the search for sedimentary copper deposits.

RÉSUMÉ

La succession stratigraphique connue du canyon Carcajou de la région cartographiée a plus de 34,000 pieds (10,400 m) d'épaisseur et n'est pas métamorphisée. La moitié inférieure de cette épaisseur constitue une succession apparemment concordante de strates du Protérozoïque de sédiments surtout marins et quelques dykes et filons-couches gabbroïques dont l'origine serait provisoirement considérée comme hélikienne.

Les strates marines du Protérozoïque, surtout cambriennes, ordoviciennes et dévoniennes, ont en tout plus de 11,350 pieds (3,460 m). Le Mesozoïque n'est représenté que par une succession de strates de sédiments clastiques marins and non marins du Crétacé, dont l'épaisseur maximale préservée est de 3,500 pieds (1,070 m). Des dépôts cénozoïques, probablement de l'Eocène, ne se sont préservés que localement. Ils consistent en roches clastiques à gros grains présentant des intercalations de roches volcaniques peu considérables.

Des déformations importantes comme les failles et les plissements faciles à constater dans la région cartographiée sont en général du Laramine (*sensu lato*). On les attribue à une déformation superficielle qui laisse intact l'assise cristalline. On constate aussi des failles plus anciennes protérozoïques et paléozoïques. Certaines ont été rajeunies au cours de la phase du Laramide contribuant ainsi a influer sur la tectonique de type laramide.

La région a un potentiel en hydrocarbure peu élevé. Cependant, les conclusions réliées à la stratigraphie et à la structure orientent la recherche dans ce domaine vers des régions cartographiées voisines, plus prometteuses. A toutes fins utiles, les chances de trouver dans ce territoire des gîtes métallifères restent à évaluer. Cependant, la présence d'une succession hélikienne(?) épaisse est de nature a encourager la recherche de gîtes cuprifères.

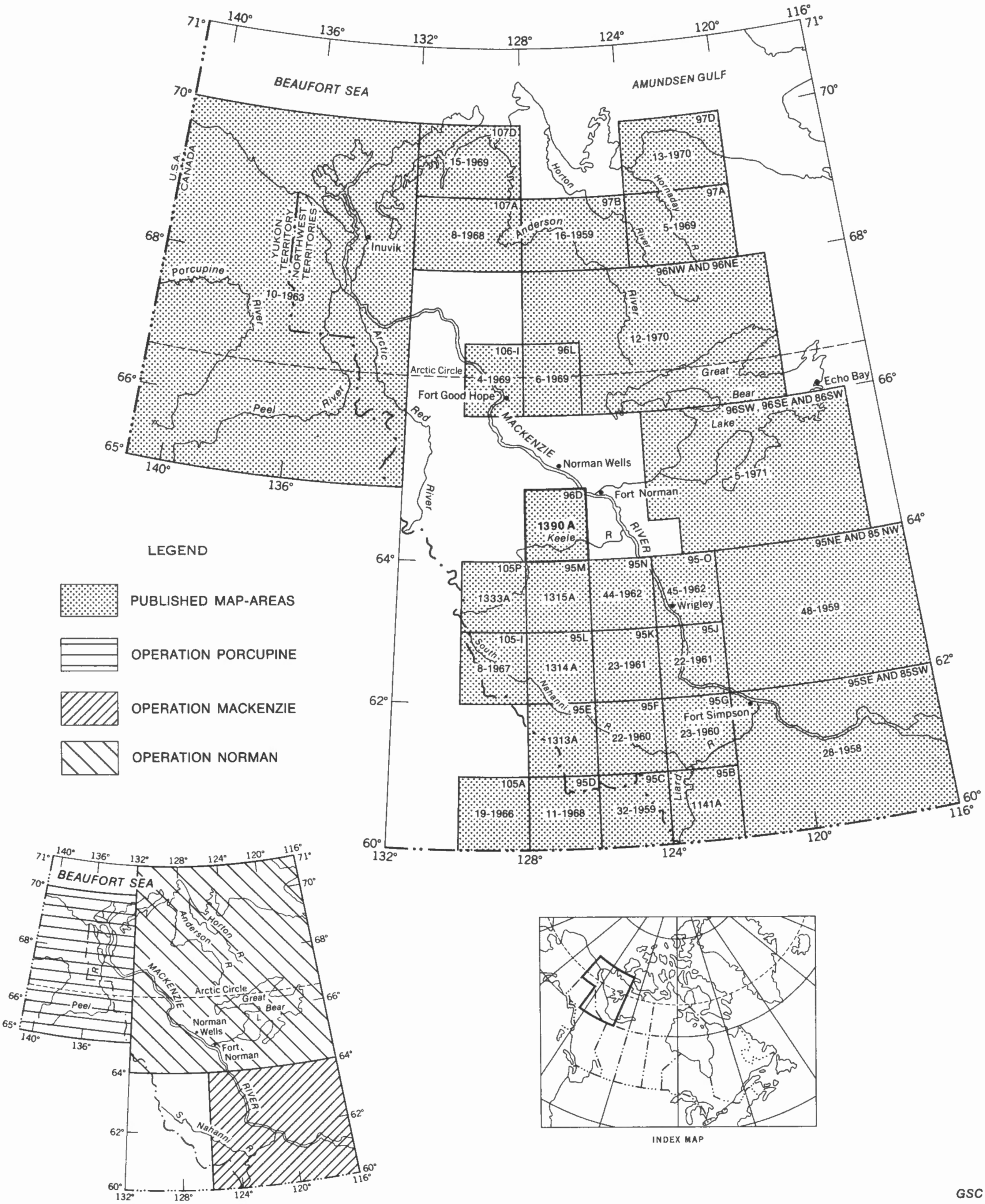

Figure 1. Index map for Carcajou Canyon (1390A) map-area and other published geological maps in the region, as of October, 1973

CARCAJOU CANYON MAP-AREA (96D), DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

INTRODUCTION

Carcajou Canyon Map-area lies mainly within the Mackenzie Mountains, but includes a part of Mackenzie Plain in its northeastern corner. It is bounded by the 64th and 65th parallels north latitude and by the 126th and 128th meridians west longitude, and lies entirely within the District of Mackenzie (Fig. 1).

The map-area was studied in the course of Operation Norman, a helicopter-supported, regional geological reconnaissance carried out in the field seasons of 1968 and 1969, with a further month's work in 1970 (Aitken, Yorath, Cook and Balkwill, 1969; Aitken, Cook and Balkwill, 1970; Cook and Aitken, 1971b). Field work on Carcajou Canyon Map-area proper was restricted to 1969, with a single day's work in 1970.

ACKNOWLEDGMENTS

The geological map is the work of the authors. This work was supported by stratigraphic studies by R. W. Macqueen (lower Paleozoic stratigraphy), W. S. MacKenzie (Devonian stratigraphy), C. J. Yorath (Cretaceous stratigraphy), and J. L. Usher (Cambrian and Proterozoic stratigraphy). Working visits to the field party by W. H. Fritz (Cambrian paleontology), B. S. Norford (Ordovician and Silurian paleontology), and A. E. H. Pedder (Devonian paleontology) were of great help toward an understanding of the stratigraphy of the region. O. L. Hughes carried out studies of surficial materials and assisted the progress of the operation in many ways.

Cheerful assistance in all phases of the work was rendered in 1969 by student assistants L. Love, C. Fipke, H. Lenstra, D. Turner, P. Graham, and G. Chitrenky, and in 1970 by K. Gladwin. Cooks T. Samuels, T. Green, and J. Cotchilly maintained the spirits and energy of the party in 1969, followed by R. Greensides in 1970.

Particular thanks are due to D. W. Gibson, who made numerous suggestions for the improvements of the report and map, and to C. J. Yorath, who wrote the sections on Mesozoic and Cenozoic stratigraphy.

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Authors' address: Institute of Sedimentary and Petroleum Geology
Geological Survey of Canada
3303 - 33 Street N.W.
Calgary, Alberta T2L 2A7

ACCESS AND TRANSPORTATION

The fragmentary state of geological knowledge of the region prior to the advent of helicopters capable of operating in mountainous terrain reflects the difficulties of surface travel in the region. The terrain is all but impossible for the practical utilization of horse transport, and the lakes suitable for use by float-equipped aircraft are few and not well located. Travel by canoe or rubber raft is possible though difficult along lower Carcajou and Little Bear Rivers; only Keele River provides access to the mountains proper by water.

Normal access to the map-area in the modern era is by helicopter, operating from a base at Norman Wells or Fort Norman. The use of light aircraft with oversize tires for landing on unprepared ground appears feasible in some limited areas, and is in fact employed by some outfitters to service their hunting camps, but was not attempted during Operation Norman.

LOGISTICS

Air support was provided in 1969 by a Bell G3b-1 and a Bell J2 helicopter contracted from Bullock Helicopters Ltd., and a Beaver aircraft contracted from Gateway Aviation, Ltd. In 1970, a Bell G3b-1 helicopter contracted from Okanagan Helicopters, Ltd. was used. A float-equipped Otter aircraft was chartered from Northward Aviation, Ltd., for camp moves. Supplies were obtained by air freight from Edmonton via Norman Wells.

PREVIOUS WORK

The early explorations of the region, commencing with those of Alexander Mackenzie in 1789, were summarized by Camsell and Malcolm (1921), and an account of exploration and settlement was given by Robinson and Robinson (1946). Hume (1954) summarized the geological investigations that had taken place between 1921 and 1954; the most important being those of Kindle, Williams, and Hume of the Geological Survey between 1921 and 1924 (a response to the discovery of oil in Norman Wells in 1920), and the intensive geological investigations conducted as part of the Canol Project (unpublished reports, all dated 1944).

Intensive exploration in the region recommenced in the middle 1950's and is continuing at an accelerated pace at this time. The reports of industry geologists are on file with the Department of Indian and Northern Affairs. Papers published by industry geologists, and by university professors and students (based, in general, on work at least partly supported by industry) include: on lower Paleozoic stratigraphy, Bell (1959); on Devonian stratigraphy and biostratigraphy, Warren and Stelck (1962 and earlier papers), Bassett (1961), Bassett and Stout (1967), Storey (1961), Crickmay (1970 and earlier papers), and Caldwell (1971 and earlier papers); on Cretaceous micropaleontology, McGill and Loranger (1961); and on regional tectonics, Martin (1959, 1961).

A new phase of investigations by government geoscientists, termed "reconnaissance" but much more detailed and complete than earlier studies, began in 1957 with Operation Mackenzie, the first of the large-scale, helicopter-supported operations of the Geological Survey of Canada to take place in the region. The most northwesterly of the map-areas covered by Operation Mackenzie, Dahadinni River (95N) (Douglas and Norris, 1963) adjoins the southeast corner of Carcajou Canyon Map-area. Operation Porcupine, in 1962, the next of the large-scale Geological Survey operations in the region, dealt with an area to the northwest (north of the 65th parallel and west of the 132nd meridian) (Norris, Price and Mountjoy, 1963). Although the Operation Porcupine area is not contiguous, the stratigraphic column and tectonics of its southeastern part have much in common with Carcajou Canyon Map-area. In 1963 and 1964, Gabrielse, Roddick and Blusson (1965, 1973) studied the geology of map-areas to the south, including Wrigley Lake Map-area which shares a common boundary with the present map-area. Operation Norman, on which the present report and those on adjoining map-areas are based, is a continuation of this modern phase of Geological Survey of Canada activities in the region.

Stratigraphers of the Geological Survey of Canada, participating in the various mapping operations, have published regional studies that bear upon the present work. These include the reports of A. W. Norris (1967, 1968) on Devonian stratigraphy and of Norford (1964) on Ordovician and Silurian stratigraphy.

Tassonyi's (1969) study of the subsurface geology of the region deals with all wells released up to March, 1961.

PHYSICAL FEATURES

Carcajou Canyon Map-area occupies part of two main physiographic subdivisions, Mackenzie Mountains and Mackenzie Plain (Bostock, 1948, 1970). Within the mountains, a further subdivision into Canyon Ranges and Backbone Ranges is recognized (ibid.).

The Canyon Ranges occupy the greater part of the map-area. The mountains of this physiographic unit mainly have flat or gently sloping, plateau-like summits, generally with elevations of less than 6,000 feet (1,830 m), although isolated, more acute summits, invariably supported by resistant Proterozoic quartzites, here and there reach to between 6,500 and 7,000 feet (1,980-2,140 m). Extensive plateau-like areas also occur at elevations below 5,500 feet (1,680 m), the most notable of these being the Plains of Abraham, and several broad, pediment-like erosional surfaces slope gently toward Mackenzie Plain.

Although sparse glacial erratics occur to elevations slightly above 5,000 feet (1,530 m), and a few poorly developed cirques occur on northern exposures of the highest summits, Canyon Ranges in general show little effect of continental glaciation. Bedrock, although intensely frost-riven, is usually well exposed above the limit of continuous vegetation which occurs at an elevation of between 3,500 and 4,000 feet (1,070-1,220 m). The paucity of lakes is one consequence of the restricted glaciation of the area.

The most pronounced effects of continental glaciation are found along the Mackenzie Mountain front, where Laurentian ice from the east flowed westward along Keele River at least as far as Nainlin Brook. The consistent northward deflections of Carcajou River and other major streams leaving the mountain front, as well as those of numerous minor streams, record diversion of the mountain drainage by the continental ice sheet. Numerous underfit valleys and abandoned spillways aligned northwesterly are further testimony to this diversion.

The topographic limits of Canyon Ranges are structurally controlled. The boundary with Mackenzie Plain [or with a narrow salient of Peel Plateau (Bostock, ibid.)] is clear and abrupt from Mirror Lake many miles northwestward. Southeast of Mirror Lake, the boundary is indistinct, partly because of the more gentle dip of the frontal homocline and partly the typical Canyon Ranges structures are abutted, not by typical gentle folds characteristic of Mackenzie Plain, but by structures of high relief similar to those characterizing northern Franklin Mountains. Canyon Ranges are bounded on the southwest by a fairly distinct change to the higher, more rugged mountains of Backbone Ranges.

The Backbone Ranges, represented by Tigonankweine Range in the southwest corner of the map-area, are characterized by rugged horns and arêtes locally surpassing 7,500 feet (2,290 m) in elevation. Cirques and glaciated mountain valleys, some with lakes of glacial origin, are much more prominent than in Canyon Ranges.

Within Carcajou Canyon and adjoining map-areas, the drainage pattern tends distinctly to a trellis configuration, with the major subsequent streams aligned along the non-resistant Devonian formations than occupy the major synclines. Thus, structural and topographic depressions largely coincide.

The typical development of Mackenzie Plain is seen in that part north of Little Bear River, where a featureless surface dotted with large and small shallow lakes rises gradually from elevations near 200 feet (60 m) near the Mackenzie River to maxima of about 1,000 feet (300 m) at the mountain front. Most of the plain is underlain by water-saturated, organic-rich soils with discontinuous ground ice, and covered by a sparse growth of scrubby timber, willow, and dwarf birch. Virtually the only outcrops to be found in the plain lie along the large streams traversing it. South of Little Bear River, topographic irregularities reflect the presence of faulted and folded structures similar to those of northern Franklin Mountains (Cook and Aitken, 1973), and the edge of a plateau-like accumulation of Tertiary rocks that reaches an elevation of more than 3,700 feet (1,130 m), a few miles east of the map-boundary.

STRATIGRAPHY

Although the total stratigraphic column of rocks exposed at the surface in Carcajou Canyon Map-area exceeds 34,000 feet (10,400 m) in thickness, it is notably incomplete, and important intervals of geological time are not represented in the area.

The stratigraphic column of exposed rocks begins with a thick sequence of unmetamorphosed clastic and carbonate sedimentary rocks tentatively considered to be Helikian (middle Proterozoic) in age. Strata of Hadrynian (late Proterozoic) age, prominent in the region to the southwest, are missing in the map-area. The Early Cambrian record is incomplete as compared with areas to the east and southwest; a thin Lower Cambrian clastic and carbonate sequence is confined to the vicinity of the mountain front and to the subsurface east and north of the mountain front. Similar comments apply to the Middle Cambrian carbonate and shale sequence.

Late Cambrian time appears to be well represented by mainly carbonate sedimentary rocks throughout the map-area, although documented by very few fossil discoveries. Evaporites, basal to the Upper Cambrian succession, are of somewhat restricted distribution. Lower Ordovician carbonate strata are a continuation of the sequence initiated in the Late Cambrian. Middle Ordovician time is unrepresented within the stratal record, but a richly fossiliferous sequence of Upper Ordovician and Lower Silurian carbonate rocks occurs throughout the area. Middle Silurian time is unrepresented; strata of Late Silurian age may be present, but are unfossiliferous.

The Devonian record of the region, of particular interest because of oil production from Devonian rocks at Norman Wells, is fairly complete. The basal strata are probably Lower Devonian, though unfossiliferous. The Middle Devonian succession, dominated by carbonate strata, is thick and fossiliferous, and the Upper Devonian is a thick clastic sequence.

Carboniferous, Permian, Triassic and Jurassic times have left no record in the region.

A thick, marine and nonmarine succession of late Early and Late Cretaceous age forms a clastic wedge recording the onset of tectonism that culminated in the formation of the Mackenzie Mountains. This succession is confined to Mackenzie Plain. Clastic beds of Tertiary age, questionably dated as Eocene, occur only within a limited part of Mackenzie Plain. They are notably coarse grained and record the existence, during their time of deposition, of mountainous terrain a short distance to the west, but are themselves mildly deformed.

The post-Eocene(?) record of the region is one of erosion, except for the depositional events associated with Pleistocene glaciation and 10,000 years of post-glacial time.

PRECAMBRIAN

Helikian(?)

Precambrian rocks of Carcajou Canyon Map-area form a thick succession apparently unbroken by unconformities. Aitken, Macqueen and Usher (1974) summarize the arguments, following Gabrielse (1972), that lead to a tentative assignment of this sequence to the Helikian (middle Proterozoic), but emphasize the lack of conclusive data.

Distribution of most Precambrian stratigraphic units is partly controlled by pre-Early Cambrian and pre-Late Cambrian erosion along a linear, positive element referred to as the Mackenzie Arch (*see* Aitken, Macqueen and Usher, 1974). The arch passes through Carcajou Canyon Map-area (Fig. 2).

Map-unit H1 (unnamed)

Map-unit H1, probably the oldest formation exposed in the northeastern Mackenzie Mountains, occurs at only one place in the map-area; the core of Stony Anticline at Carcajou River. The formation consists of pale grey weathering, finely crystalline[1] to microcrystalline dolomite, with minor amounts of nodular and bedded, dark grey chert. The dolomite commonly displays crinkly, algal-type laminations and algal stromatolites,

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[1] The following scale of crystallinity, suitable for field use, is applied throughout the report to sedimentary rocks of chemical origin:

Megacrystalline	- over 16 mm average crystal diameter
Very coarsely crystalline	- 4 - 16 mm average crystal diameter
Coarsely crystalline	- 1 - 4 mm average crystal diameter
Medium crystalline	- 1/4- 1 mm average crystal diameter
Finely crystalline	- 1/16-1/4 mm average crystal diameter
Very finely crystalline	- 1/64-1/16 mm average crystal diameter
Microcrystalline	- less than 1/64 mm average crystal diameter

ERA	PERIOD OR EPOCH		FORMATION AND MAXIMUM THICKNESS, in feet (metres)	LITHOLOGY
CENOZOIC	EOCENE (?)		*Unnamed 1,600 (490)*	*Gravel, conglomerate, sand, sandstone; minor beds of coal and volcanic ash or tuff; nonmarine*
Unconformity				
MESOZOIC	CRETACEOUS	U	*LITTLE BEAR AND EAST FORK FMS, undifferentiated: 1,000+ (300+)*	*Sandstone, shale, minor coal; marine and nonmarine*
		Disconformity		
MESOZOIC	CRETACEOUS	U L	*SANS SAULT AND SLATER RIVER FMS, undifferentiated: 2,500 (760)*	*Shale, sandstone, local conglomerate at base; marine*
Unconformity				
PALEOZOIC	DEVONIAN	UPPER	*IMPERIAL FORMATION 3,580 (1,100)*	*Shale, sandstone, minor limestone; marine*
			Conformable Contact	
PALEOZOIC	DEVONIAN	UPPER	*CANOL FORMATION 300 (90)*	*Shale, black, siliceous, bituminous; marine*
		Disconformity		
PALEOZOIC	DEVONIAN	MIDDLE	*HARE INDIAN FORMATION 425 (130)*	*Shale, minor siltstone and limestone; marine*
			Conformable Contact	
PALEOZOIC	DEVONIAN	MIDDLE	*HUME FORMATION 565 (170)*	*Limestone, fossiliferous; minor shale; marine*
		Disconformity		
PALEOZOIC	DEVONIAN	LOWER	*BEAR ROCK FORMATION 1,000 (300)*	*Dolomite, dolomite solution-breccia, anhydrite and gypsum, marine. Equivalent to the Camsell, Arnica and Landry Formations, jointly*
PALEOZOIC	DEVONIAN	LOWER	*LANDRY FORMATION 300± (90±)*	*Limestone, thick bedded, resistant; marine*
			Conformable Contact	
PALEOZOIC	DEVONIAN	LOWER	*ARNICA FORMATION 300(?) (90?)*	*Dolomite, brown, striped; minor solution breccia; marine*
			Conformable (?) Contact	
PALEOZOIC	DEVONIAN	LOWER	*CAMSELL FORMATION 988 (300)*	*Limestone, massive, resistant; limestone breccia; marine*
		Relationships uncertain		
PALEOZOIC	DEVONIAN / SILURIAN	L / U	*DELORME FORMATION 890 (270)*	*Dolomite, partly sandy, silty, argillaceous; marine*
		Unconformity		
PALEOZOIC	SILURIAN / ORD	L / U	*MOUNT KINDLE FM 1,025 (310)*	*Dolomite, fossiliferous, siliceous; minor chert; marine*

GSC

Table 1. Table of formations

ERA	PERIOD OR EPOCH	FORMATION AND MAXIMUM THICKNESS, in feet (metres)	LITHOLOGY
PALEOZOIC	ORDOVICIAN	Unconformity	
PALEOZOIC	ORDOVICIAN: LOWER CAMBRIAN: UPPER	*FRANKLIN MOUNTAIN FORMATION* *1,500 (460)*	*"Cherty member": dolomite, chert, drusy quartz; marine* *"Rhythmic member": alternation of very finely crystalline dolomite with finely to medium crystalline dolomite; marine* *"Cyclic member": dolomite, conglomeratic, stromatolitic, and argillaceous, shaly; marine* *"Basal red beds": sandstone, red shales, conglomerate, dolomite, chert; marine and (?) nonmarine*
PALEOZOIC	CAMBRIAN	Conformable Contact	
PALEOZOIC	CAMBRIAN: U	*SALINE RIVER FORMATION* *2,760 (?) (841 ?)*	*Red beds: shale, siltstone, sandstone, salt, gypsum, anhydrite, dolomite; marine*
PALEOZOIC	CAMBRIAN	Unconformity	
PALEOZOIC	CAMBRIAN: M L	*MOUNT CAP FORMATION 354 (108)*	*Shale, thin-bedded limestone, sandstone, siltstone; marine*
		Unconformity	
PROTEROZOIC	HELIKIAN (?)	*Gabbro dykes and sills*	*Gabbro, greenish black, medium grained*
PROTEROZOIC	HELIKIAN (?)	Intrusive Contact	
PROTEROZOIC	HELIKIAN (?)	*LITTLE DAL FORMATION* *2,300± (700±)*	*Dolomite and limestone, partly sandy, silty, and argillaceous; minor shale; marine*
PROTEROZOIC	HELIKIAN (?)	Conformable Contact	
PROTEROZOIC	HELIKIAN (?)	*Unnamed unit H5 1,050 (320)*	*Shale, partly red, nodular; limestone, dolomite; marine*
PROTEROZOIC	HELIKIAN (?)	Conformable Contact	
PROTEROZOIC	HELIKIAN (?)	KATHERINE GROUP *8,000± (2,400±)*	*Upper division: quartzite, shale, marine and (?) nonmarine* *Lower division: mainly quartzite; minor shale and dolomite; marine and (?) nonmarine*
PROTEROZOIC	HELIKIAN (?)	Conformable Contact	
PROTEROZOIC	HELIKIAN (?)	*TSEZOTENE FORMATION* *4,000+ (1,220+)*	*Shale, sandstone, dolomite, local limestone; marine and (?) nonmarine*
PROTEROZOIC	HELIKIAN (?)	Conformable (?) Contact	
PROTEROZOIC	HELIKIAN (?)	*Unnamed unit H1 (thickness unknown)*	*Dolomite, minor chert; marine*

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Table I. Continued

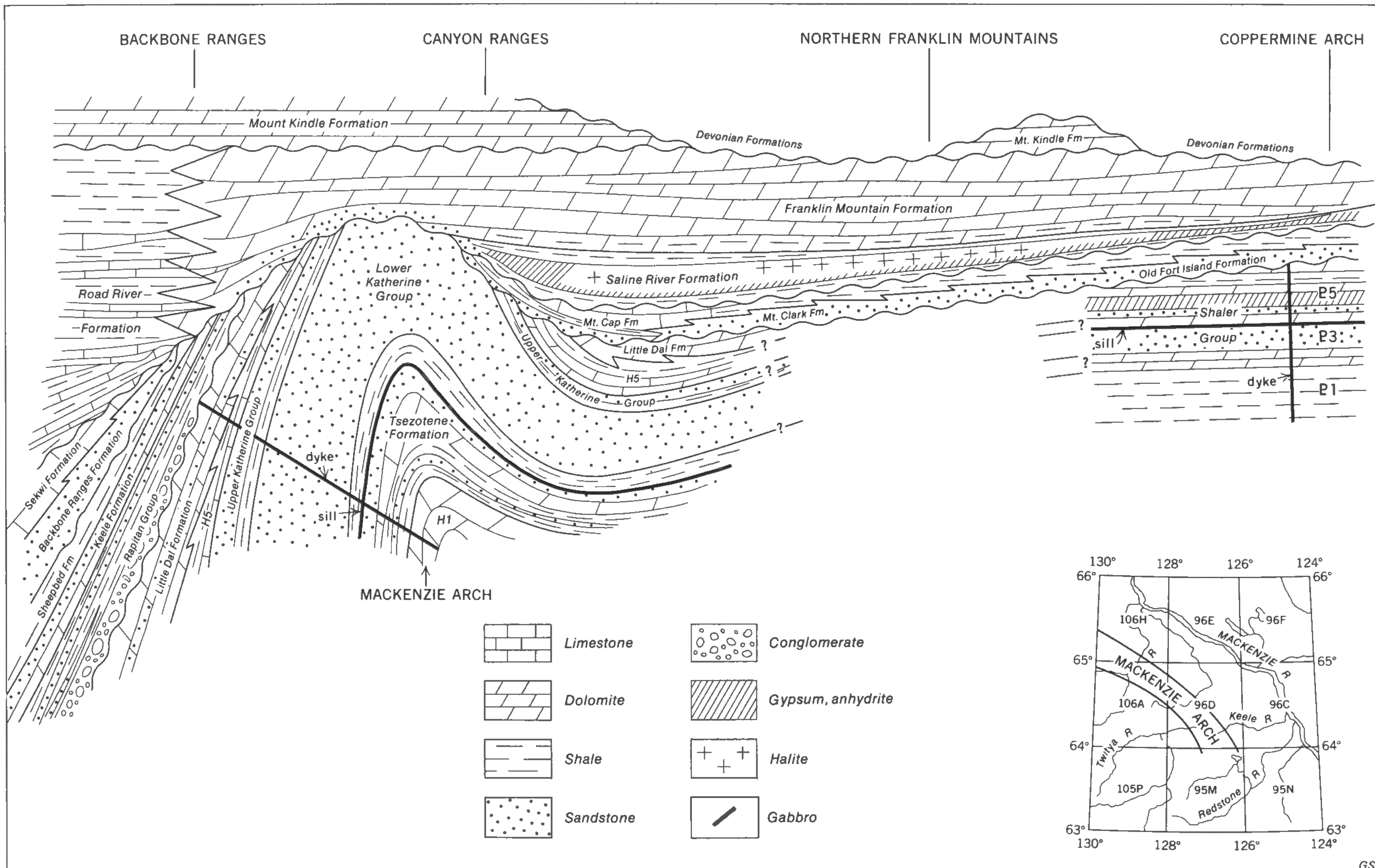

Figure 2. Diagrammatic restored stratigraphic cross-section, interior Mackenzie Mountains (Backbone Ranges) to Coppermine Arch. Reproduced from Aitken, Macqueen and Usher (in press)

and is mostly thick bedded[2], massive and resistant. The contact with the overlying Tsezotene Formation has not been observed, and the thickness of the formation is unknown.

Tsezotene Formation (Ht)

The Tsezotene Formation (Gabrielse, Blusson, and Roddick, 1973) appears to underlie the entire map-area, but is exposed only in the cores of the major anticlines. No complete section of the formation has been described in Carcajou Canyon Map-area or elsewhere, mainly because of the recessive character of the formation, and because erosion has been deep enough only locally to expose the base.

The formation consists mainly of interbedded shale (argillite), quartzite, and carbonate rocks, in various proportions. The shale is varicoloured, dark grey, greenish grey, brown, purple, green, and commonly mud-cracked. The quartzite is normally greyish green to greenish white, and generally very fine grained and well sorted, but at some localities darker, ill-sorted varieties occur. Quartzite intervals are thin bedded and flaggy; cross-lamination and ripple-marks are widespread. Dolomite characteristically occurs as isolated, medium to thick, orange-weathering beds that interrupt the clastic succession in a distinctive manner. It is grey, microcrystalline, and mainly laminated; some non-laminated beds display a relict particulate texture. Algal stromatolites occur in some beds.

In Tigonankweine Anticline at Keele River, a distinctive carbonate member, about 200 feet (60 m) thick and peculiar to that vicinity, occurs at an estimated 1,000 feet (300 m) below the top of the formation. The lower three-quarters of this member consists of flaggy, laminated, recrystallized grey limestone, with a three-foot (1 m) bed at the top consisting of club-shaped algal stromatolites. The upper quarter is yellowish weathering dolomite.

Although gabbro dykes have been observed to cut all Helikian(?) formations of the region, gabbro sills appear to be restricted to the Tsezotene; three or more sills are present at some localities. Of particular interest is what appears to be a single gabbro sill of regional extent and 60 to 100 feet (20 to 30 m) thick that lies within the uppermost 500 feet (150 m) of the formation wherever that interval has been observed.

The thickness of the Tsezotene is not known with any accuracy. In Stony Anticline at Carcajou River, its minimum thickness is 1,500 feet (460 m); in Tigonankweine Anticline at Keele River, the thickness as mapped definitely exceeds 4,000 feet (1,220 m), with the base concealed. The basal contact has not been observed. The contact with the overlying Katherine Group is gradational and conformable, and is drawn at the base of the thick, almost uninterrupted quartzite strata of the latter. The position of the contact is readily approximated on aerial photographs.

Katherine Group (Hkl and Hku)

A thick sequence of well-bedded, resistant quartzite with minor amounts of shale and dolomite is one of the most widespread rock-units of the Canyon and outer Backbone Ranges. It was designated "Katherine Group" or "Mount Katherine Series" by workers of the Canol Project, who indicated a Cambrian and/or earlier age (*see* Hume, 1954; name originally used by Link, 1921). The type locality is Katherine Creek, or Mount Katherine (unidentified), on the northern border of the present map-area. There, the top of the group was placed at the base of a succession of dusky red nodular shales [here a part of unnamed Helikian(?) unit H5], although the contact on that basis does not correspond to the top of the quartzite-dominated succession, chosen in this report as the logical and readily mappable top of the Katherine Group. Mapping has established that the Katherine Group is equivalent to and continuous with the Tigonankweine Formation of Gabrielse *et al.* (1973).

The Katherine Group is divided into upper and lower units (Aitken, Macqueen and Usher, 1974). The lower unit (Hkl) consists of orthoquartzite, well bedded and resistant, with minor intervals of recessive red and green shale, and dolomite that is commonly stromatolitic. The quartzite is white, pale grey, pale yellow, and pink in colour, mainly very fine and fine grained and well sorted, flaggy to massive, and conspicuously crossbedded. The lower unit is about 2,100 to 2,200 feet (630 to 670 m) thick in a section measured on the east flank of Stony Anticline on Imperial River, just off the northwestern corner of the map-area. It thickens notably toward the southwest; along Keele River it is about 3,500 feet (1,050 m) thick in Tawu Anticline and about 6,000 feet (1,800 m) thick in the west limb of Tigonankweine Anticline.

The upper part of the Katherine Group (Hku) consists of two sub-units that are widespread and distinctive airphoto map-units. The lower, recessive sub-unit consists of dark grey to black shale, with minor interbeds of quartzite and of dolomite that is commonly stromatolitic and orange weathering. The upper sub-unit consists of white to grey and purplish quartzite and brick red sandstone, well bedded and resistant. The upper Katherine along the mountain front ranges in thickness from 250 feet (76 m) to about 520 feet (158 m) and, like the lower Katherine, thickens westward to more than 2,200 feet (670 m) at a section 14 miles west of the west boundary of the map-area at Latitude 64°15'N.

The upper part of the Katherine Group occurs in two areas separated by the Mackenzie Arch (Fig. 2); one is in the southwest corner of the map-area, the other in a northwest-trending belt through the central part of the map-area. Along most of the intervening area, the upper unit has been removed by Precambrian or pre-Late Cambrian erosion, so that Cambrian formations lie directly on the lower

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[2] The terminology of Ingram (1954) is used throughout the report to designate bedding thickness.

Katherine Group. The upper unit does persist across the Arch in a small area near Carcajou River.

Map-unit H5 (unnamed)

Conformably overlying the Katherine Group is a lithologically diverse, slightly resistant unit of group rank that is characterized by orange-weathering, partly stromatolitic dolomite; flaggy microcrystalline dolomite and probably equivalent black, flaggy micritic limestone; and maroon, red, green, grey and black shale. The unit represents about the lower one-third (i.e. the Precambrian part) of the type Macdougal Group (obsolete) (Nauss, 1944; Hume, 1954; Aitken, Macqueen and Usher, 1974), together with some underlying carbonate and shale strata that were not described by Nauss. Although the lithology of unit H5 changes in detail from place to place, the following sequence developed in the Dodo Creek-Rouge Mountain (north-central) area can be regarded as characteristic. A basal member consists of a lower shale part and an upper carbonate part. The recessive shale, notably black, but including red, green and grey varieties, contains interbeds of quartzite, dolomite and limestones, including stromatolitic and flat-pebble conglomerate types derived from these limestones. The more resistant upper part is composed of dark grey to black micritic limestone, uniformly thin bedded and flaggy except for some nodular intervals and intervals with algal stromatolites. The limestone is altered in certain intervals and at some localities to dark grey, flaggy, cryptocrystalline, yellow-weathering dolomite and orange-weathering stromatolitic dolomite. Beds of dolomite with relict particulate and flatstone and roundstone conglomerate textures are common. The carbonates are interrupted by a few intervals of grey to black, commonly calcareous shale.

The second member of the unnamed unit H5 is the distinctive and widespread "Dead End Shale" of Nauss (1944). It is characterized and dominated by brick red to deep brownish red, calcareous, thin-bedded shale with abundant ellipsoidal nodules of red to pinkish grey, cryptocrystalline limestone. Thin green intervals interrupt the generally reddish colouration. The "Dead End Shale" sub-unit is 150 to 250 feet (45 to 75 m) thick along the mountain front, and thickens to as much as 370 feet (112 m) in the Backbone Ranges.

At some localities, a variable thickness of only moderately resistant, thin-bedded, dark grey micritic limestone or derived dolomite, with interbeds of dark grey shale, intervenes between the "Dead End Shale" and the overlying Little Dal Formation, and is mapped with unit H5.

The unnamed unit H5 is 475 feet (144 m) thick at the type section of the "Macdougal Group", at Dodo Canyon, and 638 feet (194 m) thick eight miles southeast of Rouge Mountain. In the Backbone Ranges, its thickness locally exceeds 1,000 feet (300 m).

Unit H5 is overlain gradationally and conformably by the massive, resistant carbonates of the Little Dal Formation. Variation of the thickness of the thin-bedded, non-resistant carbonates with interbedded shales that intervene between unit H5 and the Little Dal, and the presence of tongues of massive, resistant carbonate in unit H5 in Mount Eduni (106A) Map-area to the west, suggest that that lower part of the Little Dal is a facies equivalent of the upper part of unit H5.

Unit H5 is missing along Mackenzie Arch and, because of erosional truncation of the Little Dal Formation, is overlain locally by the Cambrian Mount Cap, Saline River and Franklin Mountain Formations (Fig. 2).

Little Dal Formation (Hld)

The uppermost Helikian formation of the map-area is a thick-bedded, resistant unit of lithologically varied dolomites and limestones that is characterized at many localities by eye-catching yellow, pink and orange weathering colours, commonly in exposures continuous along strike with the more normal pale grey weathering strata. The continuity of this unit with the Little Dal Formation of Gabrielse *et al.* (1973), as mapped in the Wrigley Lake Map-area, is established.

The Little Dal occurs in two widely separate outcrop areas within Carcajou Canyon Map-area. Its absence from most of the map-area appears to be due mainly to erosion along the Mackenzie Arch (Fig. 2) at subsequent unconformities, but also may be due in part to a change of facies to less resistant carbonates and shales of unnamed unit H5. The occurrence in the southwestern part of the map-area, to the southwest of Bolstead Syncline, is thin but lithologically similar to the typical development of the formation in the mountains to the south and west. It consists of mainly pale grey weathering, largely thick-bedded carbonates: micritic limestone with mud-cracks, flat-pebble conglomerate, oolitic limestone and limestone with a variety of algal stromatolites and algal oncolites, and dolomites derived from these; sandy, silty and argillaceous limestone and dolomite, and dolomite beds with "molar tooth" structure (O'Conner, 1972). No stratigraphic section has been measured in the field; graphic measurement indicates a maximum thickness of 2,300 feet (700 m).

The occurrence of the Little Dal Formation east of Canyon Fault, between Keele and Carcajou Rivers on the northwest flank of Mackenzie Arch (Fig. 2), is distinctly different. It consists almost entirely of dolomite weathering deep orange to brick-red, with minor remnants of grey-weathering limestone. Two lithologies are predominant and alternate with one another. The first is dolomite composed of algal stromatolites of a variety of forms, among which columnar types are prominent and very large - up to 20 feet (6 m) high. The second is dolomite derived from micritic, laminated limestone interbedded with shaly dolomite. At the one section studied in detail within the eastern area of occurrence on Little Bear River southeast of Rouge Mountain (Sec. U-13; Aitken, Macqueen and Usher, 1974), the formation is 414 feet (126 m) thick. The transition facies between the brick-red "eastern" facies and the "normal" facies to the west has been removed by Precambrian or pre-Late Cambrian erosion along Mackenzie Arch.

Basic intrusions (Hg)

In the Canyon Ranges of Mackenzie Mountains, all formations considered here to be of Helikian age are cut by diabase dykes trending N10°W-N20°W. The dykes do not cut younger formations, including the Hadrynian(?) units that are well developed to the south and west but missing from Carcajou Canyon Map-area. So far as is presently known, the dykes are lithologically similar to the sills in the Tsezotene Formation, and are considered to be related to them. Field evidence, therefore, suggests that the diabase intrusions are Helikian in age. The importance of obtaining absolute radiometric ages for these intrusions cannot be over-emphasized, but the attempts made to date, notably those of D. K. Norris (pers. com., 1972), have failed because of the lack of an unaltered potassium-rich mineral, the low bulk potassium content of the rocks, and their general low-grade alteration. Norris also has measured the remanent magnetization of the intrusive rocks, but the scatter of calculated paleopole positions is too great to permit firm conclusions to be drawn as to their age (D. K. Norris, pers. com., 1972).

No dykes of mappable thickness and extent have been examined in Carcajou Canyon Map-area. J. L. Usher examined a set of at least three dykes, 10 to 40 feet (3 to 12 m) thick, that cut the Little Dal Formation about 8 miles (12.9 km) southeast of Rouge Mountain (Sec. U-13; Aitken, Macqueen and Usher, 1974). None of these cuts the immediately overlying basal sandstone of the Mount Cap Formation.

PALEOZOIC

Lower and Middle Cambrian

Mount Cap Formation (Єc)

The Lower and Middle Cambrian strata of the map-area form a single mappable unit, identified as the Mount Cap Formation (Williams, 1922). In Carcajou Canyon Map-area, the Mount Cap occurs only within the area northeast of the Katherine and Canyon Faults, and constitutes the middle part of the type Macdougal Group (obsolete) of Nauss (1944).

The Mount Cap has been studied in a complete section (Secs. U-12, MQ-6; Aitken, Macqueen and Usher, 1974) at Dodo Canyon, and in a faulted, incomplete section (Sec. U-13; ibid.) southeast of Rouge Mountain. At Dodo Canyon, the formation is 329 to 354 feet (100 to 108 m) thick, and consists of thin-bedded, impure micritic limestone that is notably pyritic, dark grey to black shale, and subordinate well-burrowed, partly glauconitic sandstone and siltstone. Locally, as at the head of Katherine Creek and in the outcrop belt from Inlin Brook to Pyramid Mountain, a resistant basal unit composed of sandstone and quartzite, as much as 50 feet (15 m) thick, forms a useful marker bed.

At Dodo Canyo, trilobites belonging to the Lower Cambrian *Bonnia-Olenellus* Zone, and the Middle Cambrian *Albertella* and *Glossopleura* Zones have been collected from the Mount Cap Formation (W. H. Fritz, GSC internal reports C10-1968 WHF, C14-1969 WHF). Fritz suggests that the basal Middle Cambrian *Plagiura-Poliella* Zone and the lower part of the *Albertella* Zone may be missing at a disconformity within the Mount Cap. A single collection (GSC loc. C-4185, GSC internal report C24-1969 WHF), questionably assigned to the *Plagiura-Poliella* Zone that is missing at Dodo Canyon, was collected from the Mount Cap Formation on Little Bear River.

In the Mackenzie Mountains, erosion along the Mackenzie Arch has resulted in truncation of all Precambrian formations down to the lower unit of the Katherine Group by the base of the Mount Cap Formation (Fig. 2). The unconformity locally displays visible angularity. The arch was reactivated as a positive element following deposition of the Mount Cap, because the Mount Cap is, in turn, truncated at the unconformity beneath the Saline River and Franklin Mountain Formations. An example of this relationship is seen at Imperial River, where the Mount Cap [here only 83 feet (25 m) thick] is overlain by the Saline River at a clearly erosional contact.

The Mount Cap Formation is missing from the southwestern part of the map-area. It can be inferred to underlie Mackenzie Plain in the northwest because it occurs widely in wells in the plains and Franklin Mountains (e.g. Shell Keele River L-4 well; Imperial Vermilion Ridge No. 1 well).

Upper(?) Cambrian

Saline River Formation (Єs)

A recessive unit characterized by red beds and gypsum that underlies the Franklin Mountain Formation is recognized as the Saline River Formation (Williams, 1923). It was included in the type Macdougal Group (obsolete) as the "Sanguine gypsum" by Nauss (1944).

The Saline River consists of red and green gypsiferous shale, mudstone and subordinate siltstone, and pink, white, and grey gypsum, with thin, intercalated beds of yellowish brown dolomite, locally brecciated and stromatolitic. Mud-cracks and salt-crystal casts are common. In the east limb of Foran Anticline south of Keele River (Sec. MQ-33; Aitken, Macqueen and Usher, 1974), fine- to coarse-grained, pale grey gypsiferous quartz sandstone, friable in part, dominates the formation and is interbedded with dusky red to greyish green, sandy mudstone and shale; ripple-marks and salt-crystal casts are common.

Within Carcajou Canyon Map-area, the Saline River Formation occurs only in the country northeast of Foran Syncline. The westerly pinchout seen within the map-area can be traced also along the mountain front (northeast limb of Stony Anticline) beyond the map-boundary. The formation is present continuously only east of Mountain River. Farther west, it may be present discontinuously for about another 25 miles (40 km). Rapid variations in thickness are characteristic of the formation; it is 318 feet (97 m) thick in the east limb of Stony Anticline at Imperial River; 421 feet (128 m) at Dodo Canyon (Sec. MQ-6; ibid.), and 590 feet (180 m) south of Keele River (Sec. MQ-33; ibid.). At Imperial Vermilion Ridge No. 1 exploratory well, nine miles (14.5 km) north of the northeast corner of the map-area, the drilled thickness is 2,782 feet (848 m). Two members are recognized in the Vermilion Ridge well: an upper shale unit 562 feet (171 m) thick, and a lower salt and anhydrite unit about 2,200 feet (670 m) thick (Tassonyi, 1969). Some tectonic thickening may have occurred, but the depositional thickness of the salt is undoubtedly great. It is recognized, also, that the thicknesses determined in outcrop are subject to large errors, due to the characteristically poor exposure and contortion of the formation and, also, to leaching of evaporites in the weathering zone.

As noted above, the contact with the underlying Mount Cap Formation is erosional. The base of the Saline River can be seen to overstep the Mount Cap Formation and each of the underlying Helikian units, to lie on the lower Katherine along the northeast flank of the Mackenzie Arch (GSC Map 1390A, this report); furthermore, the Saline River is unaffected by the Katherine Fault, which displaces the Mount Cap and older formations. These observations record a period of significant deformation and erosion along Mackenzie Arch that intervened between the deposition of the Mount Cap and Saline River Formations. The variable thickness of the Saline River is considered to reflect its accumulation in topographic and/or structural depressions during the Late Cambrian transgression. The Saline River onlaps the Mackenzie Arch but is overlapped by the Franklin Mountain Formation along the axis of the arch. The arch, therefore, apparently was a positive element during deposition of the Saline River. Positive relief on the arch would account in part for the restriction of marine circulation required to bring about hypersaline conditions. The evaporitic basin in which the Saline River and equivalent formations were deposited extends eastward beneath the Interior Plains to the Canadian Shield and Coppermine Arch. The nature of the restrictive barriers bounding the basin to the north and/or south is not known.

The Saline River Formation is virtually unfossiliferous. No fossils were recovered from it in the course of Operation Norman, but Williams (1923) collected *Lingulella* sp. and *Micromitra* sp. in talus from the upper part of the formation. The Saline River is in conformable, gradational contact with the overlying Franklin Mountain Formation which has yielded fossils no older than Dresbachian. The unconformity beneath the Saline River is regarded, therefore, as the regional "sub-Upper Cambrian" unconformity (cf. the "sub-Franconian" unconformity of Gabrielse *et al.*, 1973).

The age of the formation is considered, therefore, to be early Late Cambrian, although available evidence does not exclude its extending into latest Middle Cambrian.

Upper Cambrian and Lower Ordovician

Franklin Mountain Formation (ЄOf)

A thick, poorly fossiliferous sequence of carbonate strata that occurs between the underlying brilliantly coloured shales and evaporites of the Saline River Formation and the overlying richly fossiliferous, dark-weathering carbonates of the Mount Kindle Formation, was named the Franklin Mountain Formation by Williams (1922, 1923). The section considered by Norford and Macqueen (in prep.) to be the type section is that on the east-facing slopes of Mount Kindle, twelve miles (19 km) northeast of Wrigley airport. It underlies the section considered by them (ibid.) to represent the type Mount Kindle Formation.

The Canol geologists did not adopt the terms Franklin Mountain Formation and Mount Kindle Formation, but instead dealt with the two formations as a single unit, the Ronning Group. Studies carried out under Operation Norman (Macqueen, 1970; Norford and Macqueen, in prep.) have shown that the Franklin Mountain and Mount Kindle Formations are easily separated, and that the Franklin Mountain Formation is recognizable throughout the Franklin Mountains, the Canyon Ranges of the Mackenzie Mountains north of the 64th parallel, and in outcrops within the Interior Plains northeastward to the west flank of the Coppermine Arch (*see* Cook and Aitken, 1969, 1971a) as a sub-Mount Kindle unit of the Ronning Group.

Four informal members of the Franklin Mountain Formation are widely recognized, although nowhere do all four occur in a single stratigraphic section and, in some areas, none are recognizable.

The "cyclic" member (ЄOf2), 150 to 400 feet (45 to 120 m) thick (Macqueen, 1969, 1970), is the basal member almost everywhere that the Franklin Mountain Formation overlies the Saline River Formation. It forms a slightly recessive, pale yellowish orange weathering zone beneath the more resistant, grey- or yellowish grey weathering dolomite that overlies it. In the Norman Range of the Franklin Mountains (96E), the member consists of 20 or more lithic cycles, the most common upward sequence being as follows: (a) olive-grey, argillaceous, shaly dolomite; (b) pale yellowish orange, very finely crystalline dolomite; (c) conglomeratic dolomite composed of rounded and wafer-like, elongate flat pebbles; (d) dolomite with algal stromatolites of domal, columnar, or digitate form. In Carcajou Canyon Map-area, the unit is difficult to recognize, in part owing to the paucity of flat-pebble conglomerate and stromatolitic dolomite in exposures along the frontal Mackenzies and consequently has been differentiated only in the southeastern part of the map-area. Near the depositional limits of the Saline River Formation along Mackenzie Arch, the Saline River becomes more sandy and less argillaceous, and the cyclic member disappears; it is not known to be present anywhere that the Franklin Mountain overlies pre-Saline River formations. The cyclic unit has conformable and gradational contacts with the Saline River beneath and with the rhythmic unit above.

In the southwestern part of Carcajou Canyon Map-area, a unit (€Ofl) occurs that has been named informally the "basal red beds". Its lithology consists mainly of sandstone that is brownish purple, medium to very fine grained, thin and medium bedded; it weathers dull purplish red. Numerous beds of conglomerate also occur; these consist mainly of shale pebbles, but include pebbles of dolomite, quartz, and quartzite. Deep red shale is subordinate in amount, as are beds of yellow-weathering, microcrystalline dolomite and thin beds or lenses of grey chert. Salt-crystal impressions have been noted locally. At several localities, the corrugated grazing-track *Arthrophycus* is developed prominently on bedding planes.

The basal Franklin Mountain red beds are characteristically about 100 feet (30 m) thick where measured at localities to the northwest. Although no measurement has been made in Carcajou Canyon Map-area, the unit as mapped is significantly thicker there.

The base of the basal red-beds unit is an unconformity displaying obvious topographic relief, and an angular relationship is visible at a number of localities. The red beds are in conformable and gradational contact with the overlying Franklin Mountain rhythmic unit, or with Franklin Mountain Formation, undifferentiated.

At many localities at which the cyclic member is missing, and especially where the underlying rocks are sandstones or quartzites, thick beds of sandstone, dolomitic sandstone and sandy dolomite are incorporated in the base of the Franklin Mountain Formation. These beds are generally pale grey or yellowish grey; only locally are they pale red. For this reason, their weathered colour is similar to that of the overlying and interbedded dolomites, and their limits cannot be seen from any distance. The basal sandstones and sandy beds, therefore, have not been mapped separately, although their position and lithology obviously suggest correlation with the basal red-beds member.

Overlying either the cyclic unit, the marginal facies of the Saline River Formation, or the basal red beds and sandstone is the "rhythmic" member (€Of3) (Macqueen, 1969, 1970), which is about 800 to 1,100 feet (290 to 330 m) thick. This resistant unit is characterized by well-bedded, grey- and yellowish grey weathering outcrops generally lacking significant amounts of chert, with a rhythmic striping that reflects the alternation of the two major lithologies. The sedimentary rhythm consists of an alternation of dolomite that is very finely crystalline, silty, and pale brownish grey to greyish orange, with dolomite that is finely to medium crystalline, and brownish grey. Along the mountain front and less commonly to the southwest, many of the brownish grey beds contain oolites and algal stromatolites. Westward within the map-area, the rhythmic unit becomes less distinctly separable from the overlying "cherty" member, for two reasons: firstly, the diminution of chert in overlying beds and, secondly, a deterioration of its markedly rhythmic character.

Overlying the rhythmic unit in much of the map-area is the "cherty" member (€Of4) (Macqueen, 1969, 1970), a unit of thick-bedded, finely to medium crystalline dolomite. In Franklin Mountains and particularly in the Interior Plains, this unit is characterized by an abundance of silica occurring as drusy quartz, and novaculitic, mostly white chert that has commonly preserved algal stromatolites and oolites. Along the frontal Mackenzies, this character is less strongly developed, and it deteriorates westward until the cherty member no longer can be distinguished from underlying dolomites. The basal contact of the cherty member appears conformable in the field, but Norford and Macqueen (in prep.) infer an unconformity on sedimentological grounds, because the number of rhythmic repetitions within the underlying rhythmic member changes from place to place, whereas the average thickness in the individual rhythms does not appear to change significantly. The thickness of the cherty member appears to be governed mainly by erosion at the base of the underlying Mount Kindle Formation, and ranges within the map-area between 135 and 560 feet (41 to 170 m) at measured sections. Farther north, it reaches thicknesses well in excess of 1,000 feet (300 m) (Norford and Macqueen, ibid.).

The threefold (cyclic-rhythmic-cherty) or twofold (rhythmic-cherty) subdivision of the Franklin Mountain is recognizable only in the eastern half, more or less, of the map-area. The subdivision has been mapped only south of Keele River and east of Foran Anticline; to the north along strike, the members are distinguishable, though not with ease, and subdivision of the 1,000- to 1,500-foot (300-460 m) thick Franklin Mountain Formation has not proved to be practicable in the course of reconnaissance mapping. As noted above, the basal red beds are mapped only in the southwest.

The Franklin Mountain Formation as a whole lies gradationally and conformably on the Saline River Formation where the latter is present, and with strong regional unconformity, locally visibly angular, on pre-Saline River formations down to and including the lower division of the Katherine Group.

The Franklin Mountain is everywhere overlain by the subtle but major unconformity at the base of the Mount Kindle Formation, except in those areas where the Mount Kindle is missing through pre-Devonian erosion. At such localities, Devonian rocks overlie the Franklin Mountain.

The sparse fossil evidence bearing on the age of the Franklin Mountain Formation is summarized by Norford and Macqueen (ibid.). The cyclic and rhythmic units are mainly Late Cambrian in age whereas the cherty unit is mainly Early Ordovician based on the following evidence. Trilobites from the base of the rhythmic unit at section MQ-32, in the east flank of Foran Anticline south of Keele River, belong to the *Cedaria-Crepicephalus* Zone (Upper Cambrian, Dresbachian). Collections from the lower part of the rhythmic unit near the mountain front on Arctic Red River, forty miles (65 km) northwest of the map-area, yield a distinctive Late Cambrian, Franconian echinoderm ossicle. At six localities, one of them the mountain front at Imperial River, immediately north of the map-area, the cherty unit has yielded silicified gastropods indicative of an Early Ordovician age. No fossils of post-Early Ordovician age have been recovered anywhere; the formation is thus Upper Cambrian and Lower Ordovician with the Cambrian-Ordovician boundary occurring near the top of the rhythmic unit or near the base of the cherty unit. The possibility of upper Middle Cambrian beds at the base of the Franklin Mountain is not ruled out by the fossil evidence, but is not consistent with the view that the Saline River-Franklin Mountain cycle overlies the regional "sub-Upper Cambrian" unconformity ("sub-Franconian" unconformity of Gabrielse, Blusson and Roddick, 1973).

Ordovician and Silurian

Mount Kindle Formation

The Mount Kindle Formation (Williams, 1922, 1923; revised by Norford and Macqueen, in prep.), is a lithologically and faunally distinctive, unconformity-bounded formation of resistant dolomite, and is one of the most extensive in northwestern Canada. The type section is at Mount Kindle, northeast of Wrigley. It corresponds to the upper part of the "Ronning Group" of the Canol geologists (Hume, 1954), has priority over that term, and can be differentiated readily from the underlying Franklin Mountain Formation. In map-areas to the south [Dahadinni, Wrigley, Camsell Bend, Root River (Douglas and D. K. Norris, 1961, 1963); Flat River, Glacier Lake, Wrigley Lake (Gabrielse *et al.*, 1973)], the Mount Kindle was mapped as such only in Franklin Mountains. In the Mackenzies to the west, an equivalent but generally thicker unit was mapped as the Whittaker Formation.

The Mount Kindle displays little lithologic variation. It consists mainly of medium to dark brownish grey, very finely to medium crystalline, mostly thick-bedded dolomite. Minor intervals of pale grey, very finely to microcrystalline dolomite also occur. An abundant fauna dominated by corals and orthocone cephalopods, generally silicified, can be found at most exposures. Intervals of chert nodules are common. Fair to good vuggy porosity is developed in a few beds. The Mount Kindle can be recognized at a distance by its predominantly dark brown weathering aspect, interrupted by a minor number of grey-weathering beds, and by its tendency to form outcrops that are more resistant, massive, and blocky than overlying and underlying formations.

In Carcajou Canyon Map-area, the Mount Kindle Formation is paraconformable on the Franklin Mountain Formation, although at least all of Middle Ordovician time is missing at the contact. Locally, as in the vicinity of measured section MQ-33, near Nainlin Brook, the contact is demonstrably angular.

In map-areas to the south, the Whittaker Formation (synonymous with Mount Kindle) is more obviously unconformable because it rests locally on strata as old as late Proterozoic (Gabrielse *et al.*, 1973).

The Mount Kindle-Delorme contact also is generally paraconformable but, 20 miles (32 km) west of Carcajou Canyon Map-area, the Mount Kindle is cut out by pre-Delorme(?) erosion (*see* footnote, p. 13). The Bear Rock Formation is clearly unconformable on the Mount Kindle, and sub-Bear Rock erosion accounts for most of the thickness variation of the latter. Whether this erosion is either in part or largely of pre-Delorme age has not been established.

The large fauna of the Mount Kindle Formation, characterized by halysitid, favositid, and horn corals and orthocone cephalopods, and indicative of a Late Ordovician and Early Silurian age, is summarized by Gabrielse *et al.* (1973), and Norford and Macqueen (in prep.). In the Operation Norman area, there are relatively few occurrences of the Silurian faunas because of erosion of the upper parts of the Mount Kindle.

The thickness of Mount Kindle beds surviving pre-Delorme/Bear Rock erosion in Carcajou Canyon Map-area varies from zero to a measured maxima of 1,025 feet (310 m) at section MQ-23, in the east limb of Foran Anticline.

Upper Silurian(?) and Lower Devonian

"Delorme Formation"

An easily mapped rock unit basal to the Devonian succession of much of the region is treated here, with some reservations, as the Delorme Formation. On the one hand, no fossils whatsoever have been recovered from this unit, and several of the lithologic attributes that distinguish the Delorme in map-areas to the south are lacking or weakly developed. On the other hand, physical continuity with the Delorme Formation as mapped by Gabrielse, Blusson and Roddick (1973) in Wrigley Lake Map-area (95M), has been established along the common boundary with Carcajou Canyon Map-area. Furthermore, Gabrielse *et al.* (ibid.) comment that the rocks mapped by them as Delorme are "essentially continuous" with those of the type locality at the headwaters of Pastel Creek in Delorme Range, Root River Map-area, as established by Douglas and D. K. Norris (1961).

The Delorme Formation has been recognized only in the southern part of Carcajou Canyon Map-area; even along the south boundary it is missing in the extreme east and extreme west. Nowhere does its thickness approach the values - up to 3,800 feet (1,150 m) - reported from map-areas to the south (Douglas and D. K. Norris, 1961, 1963; Gabrielse *et al.*, 1973), and it is in fact not known to reach one-quarter of that figure. In areas near the pinchout of the formation, for example, the hanging wall of Gambill Fault, where the formation is recognized but is too thin to be mapped separately, the Delorme has been included in the base of the Bear Rock Formation.

The Delorme Formation of the map-area is recognized as a moderately resistant unit of well-bedded dolomite that weathers pale grey, pale yellow, or dull orange-grey and shows up as a conspicuously pale-coloured unit on aerial photographs. Characteristic of the formation is pale grey dolomite that is microcrystalline and commonly laminated, although in medium and thick beds. Irregular, crinkly lamination of stromatolitic type is seen at some localities. Also common is finely and very finely crystalline dolomite in thin beds and weathering yellow-brown to brownish grey. Beds of sandy and silty dolomite, locally grading to dolomitic sandstone and siltstone, are considered especially important in confirming the Delorme Formation; in Mount Eduni Map-area (106A) immediately to the west, such beds characterize the top and base of the formation, but such a tripartite subdivision was not apparent in Carcajou Canyon Map-area. Cyclic repetition of dolomite of different types was noted near Gambill Fault and lower Nainlin Brook. Intervals of varicoloured shales, characteristic of the formation in areas to the south and west, do not occur within the map-area, although locally, as at Nainlin Brook, beds of argillaceous, in part pink-mottled, dolomite occur near the base of the formation. Limestones, which also are important elements of the Delorme in map-areas to the south, have not been recorded from the present map-area.

The Delorme Formation appears concordant with the underlying Mount Kindle Formation in most of the region and within Carcajou Canyon in particular, although a significant gap between the ages of the oldest described Delorme fossils and the youngest fossils of the Mount Kindle implies an unconformity. The unconformity is confirmed in a part of Mount Eduni Map-area, 20 miles (32 km) west of the present map-area, where the base of the Delorme cuts downward across underlying formations to lie locally on Hadrynian formations[1]

The Delorme Formation has been measured at only two localities within the map-area. At section MN-3, at the south boundary of the map-area, it is 890 feet (270 m) thick. At section MQ-35, in Gambill Range, it is only 120 feet (36 m) thick, and for this reason has not been mapped separately from the Bear Rock Formation.

The Delorme is overlain by the Bear Rock Formation, or by the Camsell Formation where subdivision of the Bear Rock equivalents is feasible. The northward thinning and disappearance of the Delorme may be a pinchout beneath the overlapping but conformable Bear Rock or, alternatively, may represent truncation of the Delorme (and Camsell?) at a sub-Bear Rock/Arnica unconformity; the evidence presently available is consistent with either interpretation. The former interpretation would appear to be favoured by Gabrielse *et al.* (1973), while the latter is favoured by Douglas and D. K. Norris (1963, p. 13, 14), who refer to erosion beneath the Arnica/Bear Rock.

No fossils have been recovered from the Delorme Formation during the present investigation. Documentation of Delorme faunas is contained in the memoir by Gabrielse *et al.* (1973), where a Late Silurian and Early Devonian age is assigned.

Lower Devonian

Bear Rock Formation and equivalents

In most of Carcajou Canyon Map-area, only one Devonian formation is recognized beneath the Middle Devonian Hume Formation; it is the lithologically distinctive but practically unfossiliferous Bear Rock Formation. In map-areas to the south, west, and northwest, and along the southern boundary of the present map-area, three formations, jointly homotaxial with the Bear Rock, are mappable; these are, in upward sequence, the Camsell, Arnica, and Landry Formations. Like the Bear Rock, these three formations are lithologically distinctive and virtually barren of significant fossils. The following

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[1] In reviewing the manuscript of this paper, H. Gabrielse and S. L. Blusson urged that our con-conclusions in regard to a sub-Delorme unconformity be dealt with cautiously. They point out that, in the map-areas with which they have dealt, the Delorme is everywhere concordant with the underlying Whittaker (Mount Kindle) Formation and, further, that no fossils have been reported from basal Delorme strata, so that our remarks in regard to the gap in age between the youngest Mount Kindle and oldest Delorme fossils need not be taken at face value.

On the other hand, the evidence from Mount Eduni Map-area, supported by our completed manuscript map, is straightforward: within an area of some 200 square miles, an unfossiliferous carbonate formation that underlies the Bear Rock Formation progressively truncates the Mount Kindle and older formations. We have tentatively identified this formation as the Delorme, an identification difficult to avoid given its stratigraphic position.

Clearly, our colleaques are justified in urging caution in dealing with the implications of these relationships, and we have queried the sub-Delorme contact in Figure 3 to acknowledge the uncertainties. Further work on this important question is required.

discussion is based on the assumption, not proven but consistent with all observations to date, that the sequence Camsell-Arnica-Landry is at least largely equivalent to the Bear Rock Formation, and that this sequence lies conformably or unconformably on the Delorme Formation, and unconformably on pre-Delorme formations (Fig. 3).

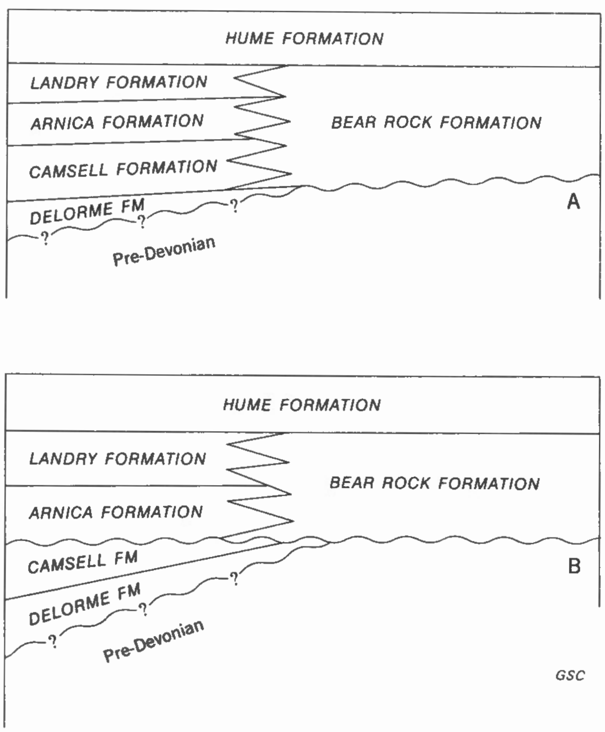

Figure 3. Two interpretations of Lower and Middle Devonian stratigraphy of the map-area: A - conformable sequence; B - sub-Arnica/Bear Rock unconformity

The Camsell, Arnica and Landry Formations can be recognized to the west of Carcajou Canyon Map-area, and have been traced by the writers northwestward to the Mackenzie Mountain front near Arctic Red River. On the basis of sequence and lithological similarity, these three formations appear to correlate with the lower, middle, and upper units of the Gossage Formation described by Tassonyi (1969) in the subsurface beneath Peel Plateau and Peel Plain. Thus, this tripartite sequence occurs over an extensive area which bounds the platform of Bear Rock deposition on the south, west, and northwest.

Locally, as in Foran Syncline at the southern boundary of the map-area, the circumstances of structure, exposure, and limited time have prevented the delimitation of the Camsell, Arnica and Landry Formations separately, although all three can be recognized in outcrop. In such circumstances the three formations are mapped jointly as Bear Rock Formation.

Bear Rock Formation

The Bear Rock Formation ("Bear Mountain Formation" of Kindle and Bosworth, 1921; redefined by Hume, 1954) is a widespread and easily identified lithologic unit in the map-area. The type section is at Bear Rock, on the east shore of Mackenzie River near the mouth of Great Bear River. Because outcrop sections of the formation tend to be misleading (*see* below), Tassonyi's (1969) establishment of a reference well for the study of the formation in the subsurface (Imperial Vermilion Ridge No. 1; 65°07'51"N, 126°05'00"W) was a useful step.

Description of Bear Rock lithologies is best commenced with Tassonyi's (1969) study of the subsurface occurrences, where circulating groundwater has had the least effect on the character of the formation. Tassonyi recognized two informal members, a lower, evaporitic member and an upper, brecciated member. The evaporitic member, up to 1,015 feet (319 m) thick, "...consists predominantly of dense anhydrite with interbedded, brown, buff, grey, microcrystalline to very finely crystalline, or microgranular dense and aphanitic, in places anhydritic, dolomites" (Tassonyi, 1969, p. 43). The evaporitic member is overlain gradationally by the brecciated member, up to 440 feet (135 m) thick, that "...consists of brown and grey, microcrystalline to finely crystalline, or microgranular dolomites which, under the microscope, may show a microbrecciated pattern. Interbedded aphanitic dolomite or limestone beds are rare. The common presence of a chalky, microcrystalline, variably calcareous matrix causes strong effervescence in hydrochloric acid and, in the field, the rocks may be classed erroneously as limestones .....Minor amounts of anhydrite, in the form of interstitial filling are normally associated with this member" (Tassonyi, 1969, p. 44).

Outcrops of the Bear Rock Formation have been affected profoundly by solution, and give a false impression of the true nature of the formation. The evaporitic member is represented by a chaotic, calcareous and gypsiferous breccia of angular to slightly rounded dolomite fragments. Anhydrite is never seen and its hydrated descendant, white to grey gypsum, outcrops only rarely, but the widespread presence of sinkholes along the trace of the Bear Rock testifies to the presence of evaporites undergoing Recent solution beneath the surface. At many localities, the breccias support a topography of spectacular "hoodoos". The brecciated member at the surface resembles its subsurface counterpart rather more closely. It appears as moderately resistant, bedded but partly brecciated dolomites, as described by Tassonyi. The dolomites are virtually everywhere fetid or petroliferous.

Except where "hoodoo" topography is developed, the Bear Rock Formation tends as a whole to be recessive in relation to overlying and underlying formations, poorly exposed, and poorly vegetated. It commonly appears on aerial photographs as a band of pale-coloured, chaotic topography.

Because of solution and collapse at and near the surface, measurement of outcrop sections of the Bear Rock Formation can give erroneous results. Representative thicknesses are best taken from well penetrations, where the range is from a maximum of 1,010 feet (307 m) at the Imperial Loon Creek No. 2 well (65°11'06"N, 126°54'23"W), to 645 feet (196 m) at Imperial Whirlpool No. 1 (65°32'25"N, 129°13'17" W). The latter figure includes 205 feet (62 m) of the pellet limestone member of the Gossage Formation, which is a facies equivalent to part of the upper Bear Rock Formation (Tassonyi, 1969).

Where the Delorme Formation is missing, or so thin as to be included with the Bear Rock Formation, the Bear Rock generally lies with abrupt disconformable contact on the Mount Kindle Formation; erosion at this contact is believed to account for most of the variation in thickness of the Mount Kindle. In Summit Anticline, near the east boundary of the map-area, a thin remnant of the Mount Kindle is preserved only locally; elsewhere, the Bear Rock overlies the cherty unit of the Franklin Mountain Formation. Ten miles (16 km) farther east, in McKay Range, the Bear Rock lies on the Franklin Mountain rhythmic member. Fifteen miles (24 km) west of Carcajou Canyon Map-area, on Twitya River, the Bear Rock overlies the Helikian Little Dal Formation.

The question of the Delorme-Bear Rock contact is more difficult. The observed relationships are consistent either with erosional truncation of the Delorme beneath the Bear Rock, or with conformable overlap of the Delorme by the Bear Rock and its equivalents (Fig. 3). More detailed work is required to resolve this problem.

Camsell Formation

Douglas and D. K. Norris (1961) introduced the name Camsell Formation for a unit of ridge-forming limestone and limestone breccia. No type section was designated, but the original definition mentions the occurrence of the formation in Whittaker and Delorme Ranges of Root River Map-area (95K).

In the type area, the Camsell is overlain by the Sombre Formation but, along the southern boundary of the present map-area, where continuity has been established with the Camsell as mapped by Gabrielse *et al.* (1973) in Wrigley Lake Map-area, it is overlain by the Arnica Formation, which may contain Sombre equivalents.

The Camsell Formation in Carcajou Canyon Map-area is characterized by resistant, very thick bedded or non-bedded micritic limestone weathering pale grey and by thick, non-bedded intervals of limestone breccia, doubtless solution breccia, that weathers pale grey with splashes of yellow and orange. The brightly coloured basal beds described by Douglas and Norris (ibid.) are not present, as appears to be the case also in Flat River, Glacier Lake, and Wrigley Lake Map-areas (Gabrielse *et al.*, 1973). The Camsell is considered by the writers to correspond with the lower limestone member of Tassonyi's (1969) Gossage Formation.

The Camsell rests with fairly abrupt but apparently conformable contact on the Delorme. In map-areas to the south, the contact is described as indefinite, and the Camsell and Delorme Formations are believed to be partly equivalent (Gabrielse *et al.*, 1973). The Camsell is overlain by the apparently conformable Arnica Formation.

At the only measured section within the map-area (Sec. MN-3), the Camsell is 988 feet (300 m) thick, half the thickness [up to 2,000 ft. (610 m)] reported from map-areas to the south.

Arnica Formation

The Arnica Formation, with type section at First Canyon on South Nahanni River (Douglas and D. K. Norris, 1961), constitutes an easily recognized lithologic unit occurring along the southern boundary of Carcajou Canyon Map-area. Physical continuity is established there with the unit mapped as Arnica Formation by Gabrielse *et al.* (1973) in Wrigley Lake Map-area (95M).

The formation appears in outcrop and on aerial photographs as a moderately resistant unit characterized by alternating stripes of dark- and pale-weathering beds. The dark-weathering beds are dolomite, grey-brown to dark brown, very finely crystalline and fetid, strongly reminiscent of Bear Rock dolomites. The pale-weathering beds are dolomite, pale grey, microcrystalline, partly laminated and barren of fossils. A minor number of solution-breccia beds are similar to breccias in the Bear Rock Formation. The formation as a whole is regularly thick bedded.

The Arnica Formation normally overlies the Camsell with apparent conformity, and is conformably overlain by the Landry Formation. At some localities west of Carcajou Canyon Map-area, however, the Camsell is not recognizable as a clear-cut unit, and the Arnica is mapped as lying directly on the Delorme Formation. Douglas and D. K. Norris (1961, p. 14; 1963, p. 14) suggest an unconformity at the base of the Arnica, but observations in the Operation Norman map-areas favour the interpretation that the Arnica-Camsell contact is conformable.

No section of the Arnica Formation was studied in detail nor measured within Carcajou Canyon Map-area. In the course of mapping, its thickness was observed to be characteristically a little thinner than that of the Hume. At a section 18 miles (29 km) west of the map-area (Sec. MN-8; 64°33'N, 128°36'W), the Arnica is 302 feet (92 m) thick. The thinning from the 1,500 feet (460 m), that is normal for Glacier Lake Map-area (95L) to the south, represents condensation of the section as the shallow platform of Bear Rock sedimentation is approached.

As noted by Douglas and D. K. Norris (1961) and by Gabrielse, Blusson, and Roddick (1973), the Arnica Formation passes laterally into part of the Bear Rock

Formation. It corresponds in stratigraphic position and lithology to the middle dolomite member of the Gossage Formation (Tassonyi, 1969).

Landry Formation

The Landry Formation is the uppermost of the lithologic units that pass laterally into the Bear Rock Formation. It was named by Douglas and D. K. Norris (1961), who cited Delorme Range and Whittaker Range, in Root River Map-area (95K), as areas typical of two different aspects of the formation. In Carcajou Canyon Map-area, the formation is present only along the southern boundary where continuity with the formation as mapped by Gabrielse *et al.* (1973) is established.

The Landry consists of resistant, very pale grey weathering, thick-bedded limestones that are easily recognized at a distance and on aerial photographs, because of their contrast with the dark-weathering and less resistant Arnica below and the recessive Hume above. In detail, the limestones are monotonous micritic and pelletoid limestones, barren of fossils. The Landry Formation corresponds in stratigraphic position and lithology with the informal pellet limestone member of the Gossage Formation (Tassonyi, 1969).

The Landry Formation is in conformable and gradational contact with the Arnica Formation below, and in abrupt or gradational, apparently conformable contact with the Hume Formation above. Bassett (1961), however, presented evidence for disconformity at the base of the Hume.

No section of the Landry Formation was studied in detail nor measured in Carcajou Canyon Map-area. Characteristically, its thickness as observed in the course of mapping is a little less than that of the overlying Hume Formation. Like the Arnica, the Landry is much thinner in the present map-area than in areas to the southeast, south, and southwest, where its thickness ranges from 400 to 1,600 feet (120 to 490 m) (Douglas and D. K. Norris, 1963; Gabrielse *et al.*, 1973).

Age of the Bear Rock, Camsell, Arnica and Landry Formations

Devonian formations beneath the Hume Formation have not yielded diagnostic fossils within the present map-area. Nevertheless, while it is acknowledged that lithologic units are commonly time-transgressive, the age of these formations can be fairly closely established.

In the first place, conodonts from the upper part of the Bear Rock Formation at Powell Creek, northwest of Carcajou Canyon Map-area, indicate an Early Devonian late Emsian age (T. T. Uyeno, pers. com., 1973). In the second place, the Bear Rock Formation, and the Camsell-Arnica-Landry sequence, are sandwiched between the Hume Formation above and the Delorme Formation below. The former is abundantly fossiliferous and closely dated as Middle Devonian (Eifelian), whereas the latter, though less fossiliferous, is adequately dated as Late Silurian and Early Devonian. Even if the Delorme has been traced incorrectly from its type area to the present map-area, the formation here labelled "Delorme", occurring high on the platform relative to more southerly, basinal occurrences, could only be younger, not older, than the true Delorme. Thus the Bear Rock and its equivalents can be dated as Early Devonian. Gabrielse *et al.* (1973) noted the paucity of fossils in the Camsell-Arnica-Landry sequence in the eastern and northern parts of Wrigley Lake Map-area but recorded numerous fossils from the region southwest of Redstone Plateau, where limestone, rather than dolomite, dominates the succession.

Middle Devonian

Hume Formation

The Hume Formation (Bassett, 1961) is a widespread and extremely fossiliferous formation dominated by limestone, whose type section is at the front of the Mackenzie Mountains on the east branch of Hume River. Two members can be recognized: a lower member more or less equivalent to the Headless Formation (Douglas and D. K. Norris, 1961; Gabrielse *et al.*, 1973), and an upper member more or less equivalent to the Nahanni Formation (Hage, 1945; Douglas and D. K. Norris, 1960; Gabrielse *et al.*, 1973). For mapping at a scale of 1:250,000, it is impractical to attempt a finer resolution of stratigraphy than that achieved by tracing the upper and lower contacts of the Hume but, in detailed work, the delineation of Headless and Nahanni "members" would be straightforward.

The lower member of the Hume, generally compromising one-half to three-quarters of the formation in Carcajou Canyon Map-area, consists of extremely fossiliferous skeletal micritic limestone in nodules, nodular thin beds, and irregular thin and medium beds, with partings and thin intervals of brown and grey shale. The fauna is dominated by solitary corals, small colonial corals, brachiopods and stromatoporoids. The lower member is recessive and commonly covered or poorly exposed.

The upper member consists of massive, pale grey weathering limestone in indistinct thin to thick beds, with an abundant fauna of large colonial corals and stromatoporoids. It is resistant, forming low cliffs and narrow ridges and, together with the recessive lower member, constitutes an excellent aerial photograph marker unit.

The basal contact of the Hume Formation generally appears conformable, and indeed is located with difficulty at some localities although Bassett (1961) gave evidence for at least local disconformity. The contact is placed at the lowest skeletal limestone or the lowest shale parting. At any rate, in view of the closeness in age of the Hume and Bear Rock Formations, no great hiatus can be present. The contact with the overlying shale of the Hare Indian Formation is abrupt and conformable.

Relative to other formations in the map-area, the Hume Formation varies little in thickness, ranging between 565 feet (171 m) at section MN-5 in Grotto Syncline at Little Bear River, and about

460 feet (140 m) in a section near the lake at the head of Carcajou River, 11 miles (18 km) west of the map-area (Sec. MN-9, 64°34'N, 128°22'W).

The Hume Formation is abundantly fossiliferous and well dated. A. W. Norris (1967) assigned it to the Eifelian and Givetian. To quote the most recently published conclusion, "With the exception of a few feet of Givetian *Leiorhynchus castanea*-bearing beds at the top, the formation is Eifelian on the basis of conodonts" (Lenz and Pedder, 1972, p. 7). That is to say, the formation is early to mid-Middle Devonian in age.

Hare Indian Formation

The Hare Indian Formation (Kindle and Bosworth, 1921; reviewed by Bassett, 1961) is a widespread unit of marine shale with a few thin limestone beds that overlies the Hume Formation. The type section is represented by the shale underlying the type Ramparts limestone at the Ramparts on Mackenzie River, where the base of the Hare Indian is not exposed. A completely exposed reference section, designated the type section by Hume and Link (1945, p. 20), occurs in Imperial Anticline on Mountain River.

In the region north of Carcajou Canyon Map-area, the Hare Indian Formation comprises two members. The basal "spore-bearing member" (Tassonyi, 1969), composed of dark brownish grey to black, bituminous, fissile shale, is generally from 30 to 50 feet (9-15 m) thick, and characteristically carries abundant, well-preserved spore cases about 1/4 mm in diameter, as well as abundant *Styliolina* sp., *Tentaculites* sp., and brachiopod spines. The upper member is composed of greenish grey shale with minor amounts of thin limestone beds. The upper member changes southward to the black bituminous shale facies so that, in Carcajou Canyon Map-area, the entire Hare Indian Formation is black shale (W. S. MacKenzie, pers. com., 1973). For this reason, and because it is poorly exposed, the Hare Indian had to be combined with the overlying Canol and the basal shales of the Imperial Formation for mapping purposes.

The Hare Indian Formation is in abrupt but conformable contact with the underlying Hume Formation, and is overlain disconformably by the more resistant, black, siliceous, blocky-fracturing Canol shales.

At the single measured section of the Hare Indian Formation within the map-area, section MN-5, on Little Bear River, the formation is 130 feet (40 m) thick. The thickness of 425 feet (130 m) (W. S. MacKenzie, pers. com., 1973) encountered in the Mobil *et al.* Slater River A-37 well (64°55'05" N, 126°05'42"W) may be taken as a maximum for the map-area. In the Mackenzie Mountains, the Hare Indian is thin and locally missing, probably because of pre-Canol erosion.

The fauna of the Hare Indian Formation is dominated by brachiopods. The formation is entirely Givetian (mid- to late Middle Devonian) in age (A. W. Norris, 1967; Caldwell, 1971).

Ramparts (Kee Scarp) Formation

Geologists participating in Operation Norman have followed the practice of retaining the term Ramparts Formation for the limestone overlying the Hare Indian Formation and having its type section at "The Ramparts" on Mackenzie River above Fort Good Hope (Kindle and Bosworth, 1921). It is agreed that the Ramparts Formation is the same formation for which Bassett (1961) proposed the name Kee Scarp Formation.

The Ramparts Formation is of particular interest in the region because it is the reservoir for oil at Norman Wells. It does not outcrop within the map-area, nor has it been encountered by the one well drilled within the map-area (Mobil *et al.* Slater River A-37; 64°56'05"N, 126°05'42"W) nor by any of the wells outside but adjacent to the map-area. Nevertheless, the possibility that a constructional bank or mound, or an erosional outlier of Ramparts limestone may be present in the subsurface of Mackenzie Plain north of 64°30' cannot be ruled out. Petroleum exploration in the Mackenzie Plain during and since the Canol Project has been dominated by the search for such masses of Ramparts Formation isolated from the main body of the formation, which lies west and north of the map-area (Tassonyi, 1969, Fig. 4).

Upper Devonian

Canol Formation

The Canol Formation (Bassett, 1961) is recognized as a unit of distinctive, black siliceous shale that occurs throughout the map-area. The type section is at Powell Creek at the Mackenzie Mountain front. For reasons given above, it has been included with the underlying Hare Indian Formation and the overlying, basal Imperial shale into a single unit, although in more detailed mapping there would be little difficulty, other than that of poor exposures, in mapping the upper and lower contacts of the Canol.

The distinctive siliceous shale that characterizes the Canol and generally makes up the bulk of the formation is black, hard, bituminous, siliceous, regularly thin bedded, and blocky fracturing. Other shales that are present to a greater or lesser extent are dark grey to black, fissile, more or less bituminous, and in part calcareous. At numerous localities, discoid calcareous concretions up to three feet (1 m) in diameter occur sparsely. Well-weathered cliffs of the formation are partly rusty and partly coated with a yellow bloom. Although not forming conspicuous features, the Canol is more resistant to weathering than the overlying and underlying shales, and in valley-wall exposures tends to form near-vertical cliffs. Many Canol outcrops are burned or oxidized to a brick-red colour.

Tassonyi (1969) effected a subdivision of the subsurface Canol into three members; this was not attempted in outcrop. He further commented (ibid., p. 90) on the high resistivity and high radioactivity that characterize the formation in the subsurface.

The base of the Canol Formation is abrupt, disconformable, and remarkably planar in outcrop. The top is gradational over five to twenty feet (1.5-6 m) into the basal shales of the Imperial Formation.

Thicknesses of the Canol Formation vary between 270 feet (82 m) at section MN-5 at Little Bear River, and 300 feet (90 m) at section MN-9 (Lat. 64°34'N, Long. 128°22'W).

Tassonyi (1969) summarized the sparse paleontological evidence that indicates a Late Devonian, Frasnian age for the Canol. This assignment is confirmed further by the conodont assemblages of the formation (Lenz and Pedder, 1972, p. 37).

Imperial Formation

The Imperial Formation (Hume and Link, 1945; modified by Bassett, 1961) is recognized as a thick sequence of marine shale, siltstone, and sandstone with local thin limestone beds that overlies the Canol Formation and comprises the youngest Devonian strata of the region. The type section is on Imperial River at the Mackenzie Mountain front. Although the writers agree with Bassett's inclusion of an interval of grey shale in the base of the Imperial, this basal member has been included, for reasons given above, with the underlying Canol and Hare Indian Formations for mapping purposes in Carcajou Canyon Map-area. Thus, the base of the Imperial Formation as mapped corresponds to the base of the lowest ridge-forming interval of sandstone or siltstone.

The formation is dominated by shale that is grey or greenish grey, partly silty, and weakly fissile. Zones with calcareous concretions occur here and there. Also important is siltstone that is greenish grey, micaceous, calcareous, generally thin bedded and laminated. A subordinate part of the formation is formed by sandstone that is pale brown to brownish grey, very fine grained, argillaceous, carbonaceous, and generally calcareous. Many sandstone beds, and some of the siltstone beds, carry prominent sole markings of both organic and inorganic origin. Because of the resistance and tendency of the sandstone-bearing intervals to form prominent topographic features, of which there are commonly only two or three, there is a tendency to acquire an exaggerated impression of the proportion of sandstone in the Imperial Formation. Fossils are not common within the formation as a whole, but where fossils (including brachiopods, corals, ammonoids and gastropods) do occur, typically in sandstone, they are usually abundant within a zone a few inches thick. Locally, these concentrations of fossils may constitute a limestone bed of coquina type.

A limestone lentil within the Imperial Formation, the Jungle Ridge limestone lentil (Tassonyi, 1969), does not outcrop within the map-area, but probably is present in the subsurface of the northeastern corner of the map-area, as it occurs at a depth of 1,618 feet in the Imperial Canol Bluefish No. 1-A well (Lat. 64°56'01"N, Long. 125°50'54"W). The reader is referred to Tassonyi's report for a description and discussion of this lentil.

In the mountainous part of the map-area, the Imperial is the youngest formation preserved and, accordingly, no complete section has been studied. The maximum measured thickness, 3,580 feet (1,090 m), occurs at section MN-8 (Lat. 64°33'N, Long. 128° 36'W). In Mackenzie Plain, the Imperial is overlain everywhere by Cretaceous strata and the sub-Cretaceous unconformity cuts downward to pre-Imperial formations a few miles northeast of Mackenzie River in NTS 96E to the north, and a few miles west of McKay Range in NTS 96C to the east. Maximum preserved thicknesses of up to 2,680 feet (815 m) are found along the Mackenzie Mountain front.

The faunas of the Imperial Formation indicate a Late Devonian (Frasnian and Famennian) age (House and Pedder, 1963, as "Carcajou Mountain Formation"; A. W. Norris, 1967; Caldwell, 1971).

MESOZOIC
(C. J. Yorath)

As far as is presently known, Mesozoic strata within Carcajou Canyon and immediately adjoining map-areas are entirely of Cretaceous age. Exposures are poor and widely separated.

Cretaceous

The Cretaceous succession consists of marine and nonmarine clastic sedimentary rocks of the Sans Sault, Slater River, Little Bear and East Fork Formations of conventional usage (Tassonyi, 1969). The entire succession is characterized by rapid lateral changes in lithofacies; time correlations, therefore, are dependent almost entirely upon biostratigraphy, and upon micropaleontology in particular. Pending the completion of paleontological studies, the Cretaceous succession is treated in terms of two gross lithostratigraphic units: the Sans Sault and Slater River Formations, undivided, and the Little Bear and East Fork Formations, undivided.

Sans Sault and Slater River Formations, undivided

The lowest part of the Lower Cretaceous succession adjacent to the Mackenzie Mountains front in map-areas north and east of Carcajou Canyon is composed of a basal sandstone, 50 to 160 feet (15-50 m) thick, that is regarded as the most southwesterly expression of the arenaceous Sans Sault Formation. It is overlain by a sequence of black, plastic, concretionary shale grading upward to a sequence of interbedded shale and thin, calcareous, argillaceous sandstone beds. Presumably equivalent rocks on Imperial River, a short distance north of the present map-area, are about 3,000 feet (920 m) thick. The predominantly shaly sequence is regarded as the Slater River Formation.

In Carcajou Canyon Map-area, the basal sandstone appears to be missing, except near the northern boundary where a thin basal sandstone is mapped by southward extrapolation from isolated outcrops near the southern boundary of the adjoining map-area (Norman Wells, 96E).

An incomplete succession of black, plastic shale with thin bentonite seams exposed within the narrow valley of Slater River in the northeastern corner of the map-area was designated the type section of the Slater River Formation by Stewart (cited by Tassonyi, 1969, p. 107-108). Samples from this exposure yield fish teeth, fish bones, a few megaspores and a few specimens of *Saccamina* sp. (GSC internal report 5-TPC-1971, by T. P. Chamney), indicating an age near the Early Cretaceous-Late Cretaceous boundary.

A macrofauna collected in 1972 from shale on Grotto Creek identified as Slater River Formation by a field party of V. Zay Smith and Associates was dated as early Turonian by B. D. E. Chatterton (J. F. Conrad, pers. com., 1973).

The Mobil *et al.* A-37 exploratory well in the northeastern corner of the map-area penetrated about 530 feet (162 m) of medium grey, slightly calcareous shale with common fish scales, spores, and minor amounts of bentonite, overlying 540 feet (165 m) of pale grey, argillaceous, slightly calcareous and locally glauconitic siltstone. This succession, identified as Slater River Formation, overlies the Upper Devonian Imperial Formation.

Little Bear and East Fork Formations, undivided

Exposures of the Little Bear and East Fork Formations, including the type sections of the two formations, occur in stream valleys in the eastern and northeastern parts of the map-area.

Two exposures on Little Bear River constitute the type section of Little Bear Formation. A lower interval of 445 feet (135 m) is exposed at Latitude 64°37.7', and an upper interval of 305 feet (93 m) at Latitude 64°38.5'. The two exposures are estimated to be in approximate stratigraphic continuity, without significant overlap or gap. The contact with the presumably underlying Slater River Formation is not exposed. The total section is divisible into a lower sandstone unit, a middle mudstone unit and an upper sandstone unit.

The lower unit, 445 feet (135 m) thick, consists of basal medium grey and mottled, rusty weathering mudstone, locally with clay ironstone concretions, that grades rapidly upward to argillaceous siltstone and fine-grained sandstone containing poorly preserved plant remains. Medium- and thin-bedded sandstone becomes dominant upward, and exhibits small flame structures, oscillation ripple-marks, and raindrop imprints. A three-inch seam of carbonized wood and low-grade coal occurs 115 feet (35 m) above the base. The unit is capped by 130 feet (40 m) of fine-grained, well sorted, medium-bedded to massive sandstone, with local low-angle foreset bedding, load casts, and thin, discontinuous dark chert pebble beds.

The middle mudstone unit, 245 feet (75 m) thick, consists of poorly exposed, rusty brown and maroon-weathering mudstone that becomes increasingly silty and sandy upsection. The uppermost 50-foot (15 m) interval of the unit contains thin beds of sandstone that is medium grey and grey-brown, fine grained and argillaceous. The contact with the overlying unit appears to be erosional, with visible relief of about one foot (0.3 m).

The disconformably(?) overlying upper sandstone unit, 60 feet (18 m) thick, is composed of sandstone that is fine grained, well sorted, massive, blocky, pale to medium grey weathering. It contains a one-foot bed of coal and carbonized wood, and mudstone that is medium grey and rusty brown and orange-weathering, blocky and nodular. Hume (1924) reported coal beds "up to 18 feet thick" (p. 5b) or "18 inches" (map) near the junction of East Little Bear and Little Bear Rivers. Coal exceeding one foot (0.3 m) in thickness was not seen by the writers.

Sandstone of the Little Bear Formation is best distinguished from that of the Sans Sault by the presence in the former of abundant grains of tripolitic chert, seen as minute white flakes in hand specimens.

The age of the type Little Bear Formation is Santonian to Campanian, on the basis of contained palynomorphs. Rocks equivalent to the middle mudstone unit on the East Fork of Little Bear River yield early or middle Campanian palynomorphs, and it is assumed, therefore, that the thin upper sandstone unit is not older than middle Campanian (GSC internal reports K-3WWB-1971, K-5WWB-1973, by W. W. Brideaux).

The possibility that Turonian(?) beds occur within the Little Bear Formation was pointed out by Jeletzky (1971, p. 54), who refers to "the discovery of a large *Inoceramus* of early Late Cretaceous affinities in the Little Bear Formation on Little Bear River (Hume, 1924, p. 4B, Pl. 1A)". However, the specimen referred to was merely photographed and not collected for identification, and its significance remains in doubt.

Jeletzky (op. cit., p. 58) also referred to "a 2-foot long Santonian *Inoceramus* ex gr. *cardissoides-pinniformis*" which was "found on Redstone River and ......presumed to have been collected from the East Fork shale because of its clay ironstone matrix". The uncertainty as to the precise stratigraphic position of the fossil permits correlation of the Redstone River locality with the concretionary basal mudstone (Santonian) of the Little Bear Formation, rather than with the East Fork Formation. The East Fork shale at localities examined by the writer contains no ironstone. C. R. Stelck (pers. com., April 24, 1973), who identified and dated the Redstone River collection, agrees that, on the basis of a Santonian palynological age for the lower beds of the Little Bear Formation type section, the collection from the Redstone River was probably from the Little Bear Formation or its equivalent.

The type section of the East Fork Formation is on East Little Bear River near its junction with the Little Bear proper (Lat. 64°47'N; Long. 126°02'W). The section is poorly exposed in a minor tributary valley, above interbedded sandstone and mudstone of the Little Bear Formation. It consists of a laterally discontinuous, rusty brown weathering, six- to fifteen-foot thick (2-4.5 m) conglomerate made up of pebbles of black chert, quartzite, and carbonate rocks, overlain by a monotonous succession of black, plastic, blocky-weathering shale. Only the basal 100 feet (30 m) were examined; it is estimated that at the type section the thickness is about 250 feet (75 m).

Overlying the type section of the Little Bear Formation is an exposure of about 20 feet (6 m) of black plastic shale of the East Fork Formation. The contact appears to be erosional, and is underlain by a ferruginous, yellow-weathering band that, according to X-ray analysis, contains about ten per cent kaolinite (A. E. Foscolos, analyst). This layer may represent a fossil soil horizon.

The age of the East Fork Formation, on the basis of contained palynomorphs, is Campanian to possibly early Maastrichtian (GSC internal reports K-3WWB-1971, K-5WWB-1973, by W. W. Brideaux). In view of the dating of the upper units of the Little Bear Formation on East Little Bear River (not older than middle Campanian, *see* above), the East Fork is considered here to be middle to late Campanian and possibly early Maastrichtian.

Exposures of burned and burning shales (*bocannes*) occur in the East Fork Formation in the footwall of Gambill Fault. It is noteworthy that the East Fork Formation is only slightly younger than the burning shales of the Smoking Hills Formation ('Bituminous zone') of late Coniacian to early Campanian age (Yorath and Balkwill, in prep.) at the Smoking Hills on the Arctic coast.

Present information (as reflected on the accompanying geological Map 1390A) indicates that east of Gambill Fault the Little Bear-East Fork lies directly on Devonian strata. If this relationship, based on sparse sampli n g, is indeed factual, it records overstep of the Sans Sault-Slater River by the Little Bear-East Fork, and suggests an unconformable relationship between the two gross units. The lack of any record of Coniacian dates from the succession supports this idea. Cook and Aitken (1971, p. 11, 12) record similar relationships between upper Lower Cretaceous and Upper Cretaceous strata in Colville Lake and eastern Coppermine Map-areas.

CENOZOIC
(C. J. Yorath)

Tertiary

Strata of probable Tertiary age are of limited distribution in the region, and are thickest [exposed: 1,000' (305 m); estimated total thickness: 1,600' (490 m)] in an area between Tertiary and Summit Creeks, in Fort Norman Map-area (96C) immediately east of the present map-area. These rocks occupy a small area along the eastern boundary of Carcajou Canyon Map-area.

The Tertiary strata consist of poorly consolidated to unconsolidated sand, gravel, and conglomerate, low-grade lignite, and porous, friable pale-coloured tuff. They are considered mainly to represent alluvial fans deposited in response to the "Laramide" rise and consequent erosion of the frontal Mackenzie Mountains. The Tertiary strata are themselves deformed, with dips as high as 20 degrees in the vicinity of McKay Range in Fort Norman Map-area (96C) to the east.

Presumably correlative rocks near Fort Norman have been dated by W. A. Bell (*in* Hume, 1922, p. 76) as Eocene. Poorly preserved plant remains were collected at the Tertiary Creek section, but these have not been identified.

Quaternary

Presentation of observations on the Quaternary history and deposits of the map-area in this report would be inappropriate, in view of the existence of reports dealing specifically with these topics. The reader is referred to Geological Survey of Canada Open File 155, compiled by P. T. Hanley (1973) for information of the surficial geology of the region.

STRUCTURE

The structural history of Carcajou Canyon Map-area is best discussed in terms of antecedent (pre-Laramide) structures and Laramide structures. The term Laramide, as used here, includes all compressive deformation referred to an orogenic event of uncertain duration that probably began during, if not prior to, the Early Cretaceous and is known to have continued into the early Tertiary.

ANTECEDENT STRUCTURES

Pre-Laramide events are represented by unconformities at the bases of the Hadrynian(?) (in map-areas to the west and south), the Cambrian, Upper Cambrian, Upper Ordovician, Upper Silurian(?), Lower Devonian, Upper Devonian, and Cretaceous. Although these events were mainly epeirogenic with related tilting and erosional bevelling, there is a clear record of block faulting or taphrogeny which preceded several of these unconformities. Such taphrogenic events are antecedent to Laramide structures.

A significant positive tectonic element, the Mackenzie Arch (Fig. 2) crosses Carcajou Canyon Map-area. On the basis of evidence from map-areas to the west and south, it originated as a landmass as early as the late Proterozoic (Aitken, Macqueen and Usher, 1974). Within the present map-area, its existence as a landmass is recorded at the sub-Cambrian and sub-Upper Cambrian unconformities.

Pre-Rapitan structures

Angular unconformity at the base of the Hadrynian (upper Proterozoic) Rapitan Group in northern Selwyn Mountains records intense pre-Rapitan folding (Douglas, 1970, p. 373) whereas, in Mackenzie Mountains west of Carcajou Canyon Map-area and in the areas described by Gabrielse *et al.* (1973), the record appears to be one of pre-Rapitan block faulting. Steeply dipping faults of north-northeasterly to north-northwesterly strike that cut the Helikian units commonly can be demonstrated to pre-date Franklin Mountain strata [for example, a cluster of faults along the southwest limb of Foran Syncline, 3 to 7 miles (5 to 11 km) north of Keele River]. Locally, faults of similar trend appear to pre-date the Mount Cap Formation as in the basin of Katherine Creek. In the absence of uppermost Proterozoic, Lower Cambrian and Middle Cambrian beds, these faults may be, and probably are, much older than the rocks that overlie them. Such faults are not known to offset the easily mapped Little Dal-Rapitan contact in map-areas to the west, and several of them are clearly truncated at that contact; they are, therefore, in part at least of pre-Rapitan age. The northerly strike of Helikian dykes also suggests a Proterozoic age for these northerly-trending faults. In several instances, north-northeasterly to north-northwesterly trending faults offset Paleozoic strata as well as Proterozoic. These are suspected of being reactivated pre-Rapitan structures.

Pre-Mount Cap faults

Steeply dipping, northerly striking faults in the basin of Katherine Creek appear to have displacements that both precede and follow deposition of the Mount Cap Formation. These may be reactivated pre-Rapitan faults.

Pre-Saline River fault

At the head of the south fork of Katherine Creek, the Katherine Fault, a gently dipping thrust fault with minimum stratigraphic displacement of 2,500 feet (760 m), superposes quartzites of the lower Katherine Group on sandstones of the Mount Cap, yet displaces neither the Saline River Formation nor the base of the Franklin Mountain Formation. The nature of this post-Early Cambrian, pre-Late Cambrian structure reveals that the movements recorded by the sub-Upper Cambrian unconformity, which were clearly of tangential or orogenic nature in Selwyn Mountains (Gabrielse *et al.*, 1973) had some degree of similar expression in the Canyon Ranges, despite the widely paraconformable nature of the sub-Upper Cambrian contact.

Suspected pre-Delorme faults

In Mount Eduni Map-area (106A) immediately west of the present map-area, a situation occurs repeatedly in which the stratigraphic position of the base of the Delorme Formation relative to underlying beds differs by many hundreds of feet on either side of a reverse fault. Although these relationships can be explained by tectonic juxtaposition of different parts of an erosionally bevelled succession overlain by the Delorme Formation, the possibility remains that they record pre-Delorme faulting. If such faults exist, their trend must be more or less parallel to the Laramide faults or, alternatively, the Laramide faults may be, in part, reactivated pre-Delorme faults. This possibility should be kept in mind during any analysis of Laramide structure.

Mackenzie Arch

The general name, Mackenzie Arch, was applied by Douglas (1970) apparently to encompass a number of Proterozoic and Paleozoic positive features more or less aligned on an arcuate trend from the southern Mackenzie Mountains to the Ogilvie Mountains. This regional feature is a composite arch along which uplift and erosion occurred at different places at different times, as the axis of maximum uplift (or minimum subsidence) shifted laterally. The Mackenzie Arch thus comprises a number of successive arches; for example, the Redstone Arch in southern Mackenzie Mountains and the Ogilvie Arch in the Ogilvie Mountains (Gabrielse, 1966).

One such component arch extends north-northwestward across Carcajou Canyon Map-area, where it lies *en echelon* east of Redstone Arch. Its extent southward from Carcajou Canyon Map-area is not known; to the northwest it has been traced to the mountain front near Arctic Red River, where it probably plunges beneath Peel Plateau. This arch became inactive by the Late Cambrian, whereas Redstone Arch to the south continued to affect sedimentation into the Devonian.

The pre-Rapitan, pre-Mount Cap, and pre-Saline River faults described above all may date from various periods of uplift of the arch that crosses the map-area. The pre-Delorme faults, on the other hand, occur to the southwest and are probably the northernmost expression of movements on the Redstone Arch.

Existence of the Mackenzie Arch is indicated most obviously by the more or less symmetrical truncation of Helikian and Lower and Middle Cambrian strata at the sub-Upper Cambrian unconformity. Its earlier existence is shown by the fact that the Lower and Middle Cambrian Mount Cap Formation also truncates Helikian formations. It is not known whether the Mount Cap and equivalents extended across the arch, or whether, alternatively, the arch was emergent during the Early and Middle Cambrian. Aitken, Macqueen and Usher (1974) suggest the possibility that the Arch existed even earlier, because it appears to control the distribution of the Hadrynian Rapitan Group.

To summarize, the Mackenzie Arch, or more strictly, the component arch crossing Carcajou Canyon Map-area, first developed in pre-Early Cambrian, possibly Hadrynian time, and may have been partly or entirely emergent until the early Late Cambrian, when it formed the restriction necessary for the development of evaporitic conditions during deposition of the Saline River Formation to the east. The arch became submerged during the Late Cambrian, and widespread marine platform conditions returned to the region, as recorded by the Franklin Mountain Formation.

LARAMIDE STRUCTURE

The Laramide structural geology of Carcajou Canyon Map-area is of particular interest because the map-area is one of those that occupy a position along the Mackenzie Arch intermediate between the belt of structures to the south, of north-south trend, and the belt of structures to the northwest having an east-west trend. Examination of the geological map of this report and those of adjoining map-areas shows that the change in Laramide trend is continuous; no kinks in trend, and no truncation of structures of one trend by those of another, have been observed.

The Laramide deformation resulted mainly in broad folding; however, high-angle and, less commonly, low-angle thrust faults, rejuvenated antecedent faults, and a few strike-slip faults also developed.

Two major structural provinces are represented in Carcajou Canyon Map-area, the Mackenzie Mountains represented by the Canyon and Backbone Ranges, and Mackenzie Plain.

Canyon and Backbone Ranges

Canyon and Backbone Ranges are essentially similar in structure, except that the average structural level is slightly higher in the latter.

The structural style is dominated by folds of unusual character, consisting of broad, flat-topped anticlines separated by narrow synclines that are essentially v-shaped but may be complex. The anticlines cannot be represented on the geological map by the trace of a single hinge-plane, and instead have been located by the traces of two monoclinal bends of opposed sense. Locally, the two monoclinal hinges converge to produce anticlines of normal aspect. In some places, the anticlines are flanked by synclinal, monoclinal bends that outline areas of flat or gently dipping strata, plateau-like in aspect but of essentially synclinal character. The remarkable Plains of Abraham, as much as 14 miles (22 km) wide as measured across the tectonic trend, is the most notable of these areas.

The folds are mostly symmetrical. However, a tendency to asymmetry, with southwesterly dipping axial planes, is noticeable in the vicinity of the mountain front.

The major folds are extremely persistent along strike. For example, Stony Anticline and Syncline persist to the west-northwest beyond the present map-area across the entire width of Sans Sault Rapids Map-area (106H), a total distance of more than 105 miles (168 km). Also, Tigonankweine Anticline extends 45 miles (72 km) to the southeast, in Wrigley Lake Map-area (95 m) (Gabrielse *et al.*, 1973) and more than 75 miles (120 km) to the northwest, crossing the entire width of Mount Eduni Map-area (106A), while swinging to a nearly east-west trend. The fold has thus been mapped for more than 140 miles (220 km). Wavelength of the major folds ranges from 8 to 24 miles (13-38 km).

The folds are of concentric type, and their development was not accompanied by the development of cleavage; such folds must die out at depth at a surface of structural detachment, or décollement (Dahlstrom, 1970). In the mountains, the décollement must lie deeper than the oldest formation exposed (Map-unit H1), nevertheless it is here regarded as a feature that is not only real, but one dominating the structure of the region. Along the mountain front, the regional décollement is believed to rise abruptly to a position within the evaporites of the Saline River Formation (Fig. 4), and to maintain that position as far as the northern Franklin Mountains to the northeast (*see* below).

Contractional faulting, although widespread, is subordinate to folding in the region. Although the faults have dips mainly greater than 40 degrees, their common parallelism to bedding suggests that they are genetically related to thrust faults; this is proved to be the case with the Canyon Fault, which over 30 miles (48 km) of its trace is a reverse fault like any other in the map-area, but flattens near its northern termination into a classical, near-horizontal thrust fault. Other faults in adjoining map-areas display similar behaviour. The contractional faulting clearly appears to be related to the folding, especially in the case of the common "out-of-the-syncline" thrusts. Thrust faults of back-limb and fore-limb position also occur. Dahlstrom's (1970) analysis suggests that the typical, folding-related thrust fault should migrate from a back-limb position in the older beds to a fore-limb position in younger beds. The distribution of mapped contractional faults is not as predicted; indeed, fore-limb thrusts appear more common in older rocks and back-limb or "out-of-the-syncline" faults in younger.

The minor thrust faults in back-limb or "out-of-the-syncline" positions readily can be explained as a response to the greater shortening experienced by beds involved in the strongly folded synclines (Dahlstrom, 1970), and accordingly are drawn in the cross-sections as dying out in the synclines at no great depth. The major thrusts, on the other hand, affect the entire exposed sedimentary section, and are considered to be rooted in the regional décollement.

Thrust faults of southwesterly dip predominate throughout most of the map-area; only near the southern border do the northeasterly- and easterly-dipping thrusts appear that are so prominent in Wrigley Lake Map-area to the south (Gabrielse, *et al.*, 1973). The symmetry of the thrust-fault system in the southeastern corner of the map is reminiscent of the structural style in the northern Franklin Mountains, where opposition of thrust-fault dips and of the asymmetry of folds is widespread (Cook and Aitken, 1973).

Gambill Thrust Fault differs from the above-described contractional faults in three ways: it underlies a rather gently deformed plate, its trace is closely associated with the trace of the Saline River Formation, and it appears, for a distance of twenty miles (32 km), to mark the front of the Mackenzie Mountains. Gambill Fault appears to be most easily understood if it is considered to be related to the décollement postulated (Cook and Aitken, 1973) to underlie the northern Franklin Mountains and Mackenzie Plain at the level of the Saline River evaporites. The structural "step" from the Canyon Ranges to the Mackenzie Plain is postulated to mark the line along which displacement is transferred from the deep décollement level postulated for the Mackenzies to the relatively

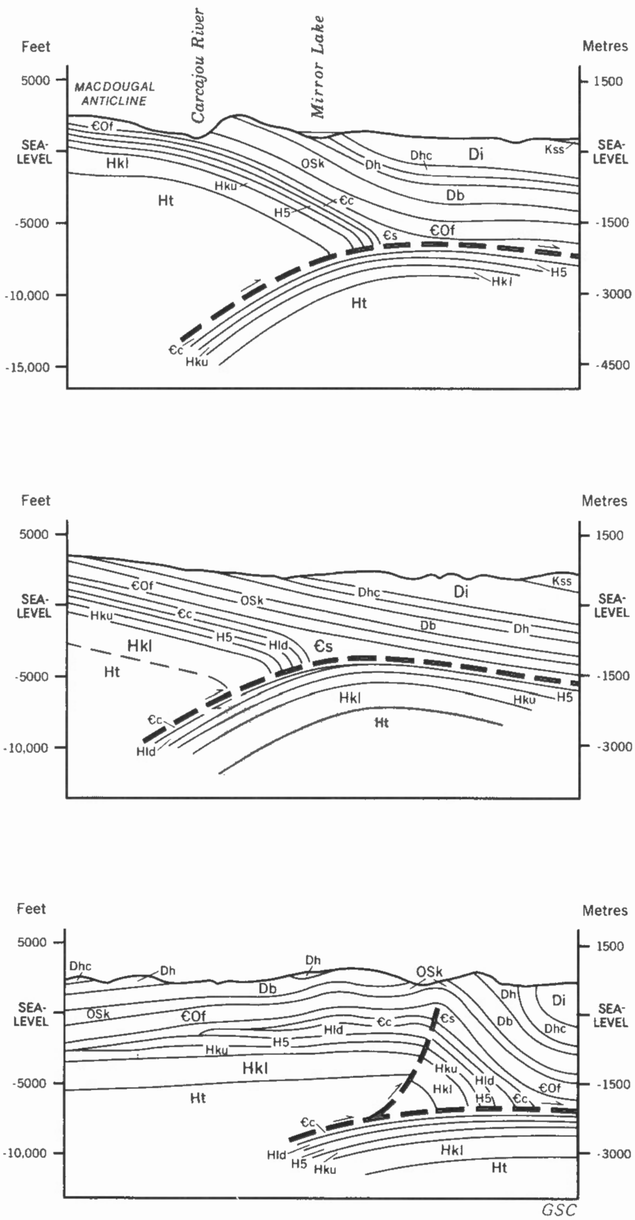

Figure 4. Interpretation of deep mountain-front structure along lines of section A-B (top), C-D, and E-F (bottom). See Map 1390A for lines of section.

shallow décollement level postulated for Mackenzie Plain and the northern Franklins. Gambill Fault along the southern half of its trace corresponds in position to the structural "step", and appears to be a splay from the shallow (Saline River) décollement. The manner in which it dies out in stratigraphically higher beds is consistent with this interpretation.

Faults of extensional or apparently extensional character are numerous, but mostly of limited strike length and small displacement. Faults of north-northeasterly to north-northwesterly strike are distinctly concentrated in areas of Proterozoic exposures; as mentioned above, some of these are clearly pre-Late Cambrian in age, and all are suspected of being Precambrian. Reactivation of some of these faults during Laramide deformation has caused their extension into Paleozoic rocks, and their orientation has favoured dextral strike-slip displacement during their Laramide history.

Many of the normal faults displacing Paleozoic rocks are strictly parallel to Laramide folding and, in several instances, follow local deviations in fold trend. These faults appear to be extensional movements following relaxation of Laramide compression.

A scattering of small normal faults of varied trend also affect Paleozoic strata. A north-south set and an east-west set are fairly prominent, but no other distinct clustering of strikes is apparent.

In the southwestern quarter of the map-area there occur three faults of modest strike length with moderate strike-slip or oblique-slip displacements, that are oriented transversely to the fold axes. These faults appear to have behaved as tear faults permitting independent development of thrusts or folds in adjacent blocks during Laramide deformation.

In the southern part of the map-area, a few faults display inconsistency in the sense of stratigraphic offset across the fault, which suggests that they are strike-slip faults. One of these, the Conundrum Fault, cuts the southern boundary of the map-area at Longitude 127°30'W. In addition to the variable sense of stratigraphic offset, the Conundrum Fault truncates well-defined fold axes. If the axis of a syncline with a core of Little Dal Formation is correlated across the fault as a marker for the determination of displacement, a dextral displacement of about seven miles (11 km) is indicated. This is comparable to the 9 to 12 miles (14-19 km) of dextral strike-slip displacement calculated for the similar Hayhook Fault in Glacier Lake and Wrigley Lake Map-areas (Gabrielse *et al.*, 1973).

Mackenzie Plain and inlying structures

Mackenzie Plain is a gently folded synclinorium interrupted by abrupt anticlinal uplifts such as: Summit Anticline; McKay Range, eight miles (13 km) east of the present map-area; and Imperial Anticline (Hume, 1954, map). Gambill Fault is a structure which marks the boundary between plain and mountains in its southern extent, but becomes a Mackenzie

Plain structure to the north. All of these structures record horizontal compression of the accessible part of the stratigraphic column, rather than vertical movements involving a crystalline basement.

As stated earlier, a décollement zone at the level of the Saline River Formation is postulated to underlie Mackenzie Plain. If this view is correct, the pronounced anticlinal structures that interrupt the Plain (for example, Summit Anticline) would not be expected to be present beneath the décollement.

ECONOMIC GEOLOGY

PETROLEUM AND NATURAL GAS

The potential of the region for hydrocarbon production has been well summarized by Tassonyi (1969). The following is a brief summary of that potential, with particular focus on Carcajou Canyon Map-area.

Source rocks

Potential source rocks for hydrocarbons are well distributed throughout the stratigraphic column of the region.

It is more or less conventional to consider only rocks of Phanerozoic age as potential source rocks for hydrocarbons, nevertheless, in view of the existence of major fields of natural gas in Proterozoic strata of the Soviet Union (Vassoyevich *et al.*, 1971), and the occurrence of oil in Proterozoic rocks in Australia (Murray, 1965), it might be worthwhile to consider the numerous intervals of black shale in the Helikian succession as potentially productive of natural gas.

Dark-coloured marine shales that are potential source beds are fairly abundant within the Phanerozoic succession, commencing at the base with such beds in the Mount Cap Formation. Although it occurs only to the west of the present map-area, the Middle Cambrian to Lower Devonian Road River Formation, rich in dark marine shale is, or once was, in lateral stratigraphic continuity with carbonate rocks of Carcajou Canyon Map-area extending from Franklin Mountain Formation to Bear Rock Formation. Pre-Laramide migration on the scale of scores of miles of course would be required to bring Road River hydrocarbons to any potential traps in the present map-area.

The Devonian succession contains dark marine shale in the Hare Indian, Canol, and Imperial Formations; the existence of Norman Wells oil field proves that the succession has generated petroleum. The heavy oil that saturates basal Cretaceous sandstones in the region of Fort Good Hope also may be of Devonian source.

The Bear Rock Formation, although it has not yielded significant amounts of oil or gas to any of the many drill holes that have penetrated it, is so consistently petroliferous on a regional scale as to suggest that the petroleum is indigenous to the formation.

The Cretaceous succession consists in large part of shale that is marine and dark in colour. In the opinion of the writers, the heavy oil encountered in the Candel DECKMG *et al.* East MacKay B-45 exploratory well, although pooled in lower Paleozoic rocks, is probably of Cretaceous source.

Reservoir rocks

Significant porosity other than fracture porosity was not observed in Proterozoic rocks.

Although no significant porosity was observed in sandstones of the Mount Cap Formation, these sandstones must thicken to the southeast toward the type section of the partly equivalent Mount Clark Formation, which contains porous, semi-friable intervals (Aitken, Macqueen and Usher, 1974). Sandstones that are probably equivalent and which outcrop at the eastern edge of the Interior Plains also are in part porous and friable (Cook and Aitken, 1969).

Most of the dolomites of the Franklin Mountain have tightly knit, mosaic fabrics, and show little promise of possessing porosity other than fracture porosity. Parts of the cherty unit, however, are both vuggy and intensely fractured, and merit serious consideration as potential reservoirs. The Mount Kindle Formation also consists largely of non-porous dolomites, but does contain intervals of macroscopic vuggy porosity at some localities, and also contains siliceous intervals which tend to be intensely fractured.

The Bear Rock Formation is so extremely porous and permeable that it has been the cause of lost-circulation problems in many of the wells that have penetrated it. The porosity must be cavernous, judging by the size of material (tin cans, small spruce trees) that can disappear out of the well bore into the formation. It appears likely that solution openings are involved. Nevertheless, the formation has yet to produce a significant show of hydrocarbons (a small flow of gas is common) on drillstem test.

The Camsell and Landry Formations display little porosity. The Arnica is somewhat similar to the Bear Rock and is in part porous. The Hume Formation is not promising as a reservoir, although it has yielded a "bleeding core" from one well (Tassonyi, 1969, p. 145).

As discussed above under the heading "Stratigraphy", the Ramparts Formation, reservoir for the Norman Wells oil field, is not known to be present within the map-area, but the possibility cannot be excluded that an outlying mass may be present in the subsurface of Mackenzie Plain.

The brittle, siliceous shales of the Canol Formation are characteristically intensely fractured in outcrop. If these fractures are open in the subsurface, the Canol has potential as a reservoir formation. According to Boggs (cited *in* Tassonyi, 1969), oil occurred in the Canol in the vicinity of the Norman Wells field, and was produced from the Canol in one well.

Sandstone units of the Imperial Formation are characteristically very fine grained and somewhat argillaceous. They appear to be poor prospects for oil reservoirs, but might have some gas potential.

Sandstone units in the Cretaceous succession are generally clean and porous, and their lenticularity enhances their trapping potential. The problem is to find them in situations where they are under a sufficient overburden and not breached by erosion nearby and updip.

Potential traps

Only that part of Carcajou Canyon Map-area occupied by Mackenzie Plain can be considered seriously to hold any potential for containing hydrocarbon traps. In the mountains, erosion has breached all formations down to those deep in the Proterozoic succession and the synclines occupied by Devonian strata are narrow and breached by erosion on each steeply dipping limb.

In considering the potential for accumulations of Devonian oil in Mackenzie Plain, one must consider the extremely long time span between Devonian deposition and the formation of Laramide structures. Primary migration of Devonian hydrocarbons must have been completed during this long period, therefore, the only chance for accumulations of Devonian hydrocarbons would appear to be in stratigraphic traps of Paleozoic age, whether these primary accumulations were later modified by Laramide structure or not. The apparent uniformity of the Devonian succession from the southwest to the northeast flank of Mackenzie Plain, and the absence of pronounced unconformities in the Devonian succession, would appear to limit the possibilities to the chance of an isolated mass of Ramparts limestone, or pinchout of a sandstone of the Imperial Formation.

The Cretaceous succession of Mackenzie Plain appears to be more prospective than the Devonian succession. Sandstone units within the Sans Sault-Slater River interval are lenticular, and offer good possibilities for stratigraphic traps. The basal sandstone in particular has good reservoir characteristics and is known to pinch out against the sub-Cretaceous unconformity. The Little Bear-East Fork interval is generally too thin and too widely breached by erosion to be prospective in itself; nevertheless, the apparent unconformable overstep of the Sans Sault-Slater River succession by the Little Bear-East Fork may afford possibilities for unconformity-related traps in porous intervals of the older succession.

COAL

Seams of coal and lignite, generally thin or of poor quality, or both, occur in the Cretaceous and Tertiary successions of the area. Investigations carried out under Operation Norman have not advanced knowledge of these occurrences beyond the level of Tassonyi's (1969, p. 139, 140) summary of the literature. There is no reason to suspect the presence of commercial accumulations of coal.

METALLIC MINERALS

No significant occurrences of metallic minerals were noted in the course of mapping but, in view of the sparse distribution of ground observations, this should not be taken to condemn the potential of the area.

The greatest potential for a commercial concentration of metals appears to lie in the Helikian sedimentary rocks, which are cupriferous on a continental scale (Harrison, 1972; Gabrielse *et al.*, 1973; Aitken, Macqueen and Foscolos, 1973), and are the hosts of a copper deposit at Little Dal Lake in Glacier Lake Map-area (95L) to the south of Carcajou Canyon Map-area.

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