GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

MEMOIR 388

UPPER RAMPARTS RIVER (106 G) AND SANS SAULT RAPIDS (106 H) MAP AREAS, DISTRICT OF MACKENZIE

J.D. AITKEN
D.G. COOK
C.J. YORATH

Canada

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Available in Canada through

authorized bookstore agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Hull, Québec, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M46-388E Canada: $12.00
ISBN 0-660-10598-5 Other countries: $14.40

Price subject to change without notice

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Original manuscript submitted: 1975-11-20
Approved for publication: 1976-12-09

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Preface

Exploration for hydrocarbons in the District of Mackenzie began in 1920 with the discovery of oil at Norman Wells and resumed with renewed intensity in the mid-1950s as interest in the petroleum potential of the Interior Plains grew following the discoveries at Leduc, Alberta. Prior to the advent of helicopters capable of operating in mountainous terrain, geological knowledge of the region covered by this report was fragmentary. The success of a large-scale, helicopter-supported reconnaissance mapping project, "Operation Mackenzie" in 1957, led the Geological Survey to plan and carry out similar studies including "Operation Norman" for which field work was done in 1968 and 1969 in an area encompassing some 370 000 km^2 north of 64° N. This report presents the results of a reconnaissance study of the stratigraphy and structure of two map areas included in that project.

The region described in this report is divided, on the basis of stratigraphy, into two distinct parts, one that behaved as a stable platform from Helikian through Devonian time, the other being the Selwyn Basin, which contains a thick Hadrynian and Lower Cambrian succession and where lower Paleozoic carbonates of the platform change facies to shale. There is no record of late Paleozoic to Jurassic time but a thick, mostly marine Cretaceous succession is present northeast of the Mackenzie Mountains. The tectonic history of the region was affected most strongly by three related detachments or fault surfaces.

Some of the stratigraphic units described are known to be potential host rocks for base metal concentrations, others for hydrocarbon concentrations, and knowledge of their distribution will help focus exploration in the region. The maps that accompany this memoir are the first published for much of the area and together with the report provide a clear understanding of the geology of this part of Northern Canada.

D.J. McLaren
Director General
Geological Survey of Canada

Ottawa, March 1979

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UPPER RAMPARTS RIVER (106G) AND SANS SAULT RAPIDS (106H) MAP AREAS, DISTRICT OF MACKENZIE

Abstract

The region encompassed by Upper Ramparts River and Sans Sault Rapids map areas contains 20 647 km^2 and includes parts of Mackenzie Mountains, Peel Plateau, Peel Plain, Mackenzie Plain, and Franklin Mountains.

The cumulative stratigraphic column of the region exceeds 8840 m in thickness, although this total is not known to have accumulated at any single point. The country is subdivided into two distinct regions on the basis of stratigraphy. The first of these, and the one represented by all of Sans Sault Rapids and most of Upper Ramparts River map areas, behaved as a stable platform from Helikian through Devonian time; Hadrynian and Lower Cambrian rocks are almost entirely missing, and Paleozoic strata are mainly carbonates. The second region, occupying only the southwest corner of Upper Ramparts, is Selwyn Basin, where a thick Hadrynian and Lower Cambrian succession is present, and the lower and middle Paleozoic carbonates of the platform change facies to shale.

No sedimentary record of late Paleozoic through Jurassic time is preserved. A thick and mostly marine Cretaceous succession is present northeast of the Mackenzie Mountains. Cenozoic strata were not observed.

The obvious structures of the region, west-northwesterly trending, large-scale folds and subordinate contractional faults are, broadly, Laramide in age. The structural style is governed by the presence of kinematically related detachments at three different stratigraphic levels.

Mackenzie Mountains and the crestal regions of Franklin Mountains uplifts are judged to be devoid of hydrocarbon potential. The remainder of the two map areas is considered to have moderate potential for oil or gas production from stratigraphic traps. The Paleozoic and older sedimentary successions of Mackenzie Mountains show promise for production of zinc, lead and copper.

Résumé

Le secteur représenté par les coupures Upper Ramparts River et Sans Sault Rapids a une superficie de 20 647 km^2 et comprend certaines parties des monts Mackenzie, du plateau de Peel, de la plaine de Peel, de la plaine du Mackenzie et des monts Franklin.

La colonne stratigraphique cumulative de la région excède 8840 m d'épaisseur, même si on n'a encore trouvé aucun endroit possédant toute cette épaisseur. Le secteur se répartit en deux zones bien distinctes sur le plan stratigraphique. La première des deux zones, soit celle que représente toute la feuille Sans Sault Rapids et presque toute celle d'Upper Ramparts River, a évolué en plate-forme stable de l'Hélikien au Dévonien; les roches de l'Hadrynien et du Cambrien inférieur y sont presque totalement absentes, et les couches paléozoiques sont surtout composées de carbonates. La seconde zone qui n'occupe que l'angle sud-ouest de la feuille Upper Ramparts est celle que forme le bassin Selwyn, et dans lequel se trouve une épaisse succession de roches de l'Hadrynien et du Cambrien inférieur, et où les carbonates du Paléozoique inférieur et moyen de la plate-forme changent de faciès pour prendre la forme de schistes argileux.

Il ne subsiste aucune trace des dépôts mis en place de la fin du Paléozoique au Jurassique. Mais au nord-est des monts Mackenzie on rencontre une épaisse succession surtout marine du Crétacé. Les couches du Cénozoique n'ont cependant pas fait l'objet d'observations.

Les structures évidentes de la région, soit d'énormes plissements d'orientation ouest-nord-ouest et des failles de contraction subordonnées appartiennent généralement à la phase tectonique du Laramide. La structure procède de la présence de détachements cinématiquement reliés à trois niveaux stratigraphiques différents.

Les soulèvements des monts Franklin sont dépourvus d'hydrocarbures. Quant au reste des deux coupures, il existe peut-être un potentiel modéré d'exploitation de gaz et de pétrole des pièges stratigraphiques. Les successions sédimentaires paléozoiques et plus anciennes des monts Mackenzie laissent croire à l'existence de zinc, de plomb et de cuivre.

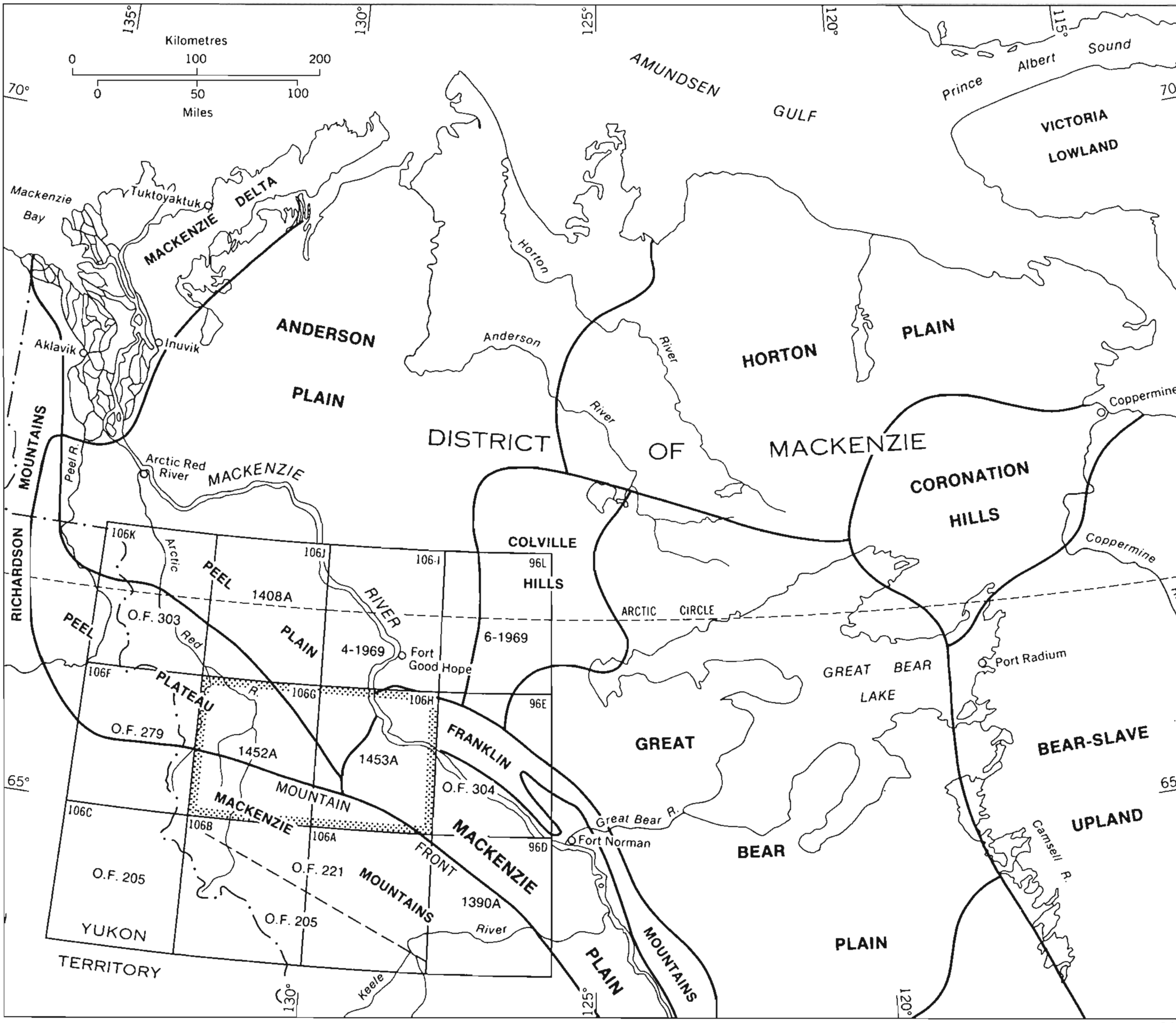

Figure 1. *Physiographic provinces (largely after Bostock, 1970) and index map for Upper Ramparts River (1452A) and Sans Sault Rapids (1453A) map areas and adjacent Geological Survey of Canada maps, as of October 1977.*

INTRODUCTION

The region comprising Upper Ramparts River and Sans Sault Rapids map areas (hereafter frequently referred to as 'Upper Ramparts' and 'Sans Sault') contains parts of five physiographic divisions, subequal in areal importance: Canyon Ranges of Mackenzie Mountains, Peel Plateau, Peel Plain, Mackenzie Plain, and northern Franklin Mountains (Bostock, 1948, 1970). It is bounded by latitudes 65° and 66° and by longitudes 128° and 132°, is 20 627 km^2 in area, and lies entirely within the District of Mackenzie (Fig. 1).

The two map areas were 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.

Personnel and acknowledgments

Geological mapping in the field was done by J.D. Aitken, M.E. Ayling, D.G. Cook, H.R. Balkwill and C.J. Yorath; subsequent compilation is by Aitken and Cook. The mapping effort was supported by stratigraphic studies by J.L. Usher (Proterozoic and Cambrian stratigraphy), R.W. Macqueen (lower Paleozoic stratigraphy), W.S. MacKenzie (Devonian stratigraphy), and C.J. Yorath (Mesozoic stratigraphy). Working visits to the party by B.S. Norford (Ordovician and Silurian paleontology) and A.E.H. Pedder (Devonian paleontology) were of great help toward an understanding of the stratigraphy. O.L. Hughes carried out studies of Quaternary geology and surficial materials, and assisted the progress of the operation in many ways. The contributions of G.K. Williams and D.C. Pugh, with regard to subsurface geology, were of great value.

Cheerful assistance in all phases of the work was rendered in 1968 by student assistants C. Thayer, D. Moulton, C. Johnson, J. Tracy and D. Cruikshank; in 1969 by student assistants L. Love, C. Fipke, H. Lenstra, D. Turner and P. Graham; and in 1970 by K. Gladwyn. Excellent food prepared by F. O'Connor, T. Green and J. Cotchilly in 1968; T. Samuels, J. Cotchilly and T. Green in 1969; and R. Greensides in 1970, maintained the energy and spirits of the party.

Residents of Norman Wells and Fort Good Hope, too numerous to mention, expedited the work by performing many favours; courtesy demands that John and Jessie Williams of Norman Wells (later of Whitehorse) be especially acknowledged for their help.

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 unsuitable for the practical utilization of horse transport because of the water-saturated soils encountered everywhere except on mountainsides and on the beaches and bars of the larger streams. Lakes suitable for use by float-equipped aircraft are few. Carcajou, Mountain, and Arctic Red rivers are navigable by canoe or rubber raft to the boundaries of the two map areas, as are the lower reaches of Hume and Ramparts rivers. The streams and the climate are unforgiving, and a moment's carelessness or bad luck can carry a severe penalty.

Normal access to the map area in the modern era is by helicopter, operating from Norman Wells as supply base. It is possible, in some limited areas, to land light, fixed-wing aircraft equipped with oversize tires on unprepared ground, and such aircraft are in fact employed by some outfitters and exploration companies.

Previous work

The early explorations of the region by Europeans, 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 in 1921 - 24 (a response to the discovery of oil at Norman Wells in 1920), and the intensive geological investigations conducted as part of the Canol Project (unpublished reports, all dated 1944).

Intensive exploration for hydrocarbons in the region recommenced in the middle 1950s and is continuing at a reduced pace at the date of writing. Reports by geologists employed by industry are on file with the Department of Indian Affairs and Northern Development. Papers published by industry geologists and by academics (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) and Bassett and Stout (1967), Braun (1966), Storey (1961), Crickmay (1970 and earlier papers), and Caldwell (1971 and earlier papers); on Cretaceous micropaleontology, McGill and Loranger (1961); on regional tectonics, Martin (1959, 1961); and on regional and petroleum geology, Gilbert (1973) and Kunst (1973).

A new phase of investigations by government geoscientists, termed 'reconnaissance', but more detailed and complete than earlier studies, began in 1957 with Operation Mackenzie, one of the first of the large-scale, helicopter-supported operations of the Geological Survey to take place in the Cordillera. The northern limit of mapping under Operation Mackenzie (64°) forms the southern boundary of the Operation Norman region. The next major operation, Operation Porcupine (1962), had the 132nd meridian as its eastern limit, which is the western boundary both of Operation Norman and the region dealt with in this report. In the period 1963 - 66, the Flat River, Glacier Lake and Wrigley Lake map areas to the south of the Operation Norman region (Gabrielse, Blusson and Roddick, 1973) were mapped, largely in connection with Operation Nahanni. Sekwi Mountain map area (Blusson, 1971), also to the south, was mapped in 1966 and 1967 in conjunction with Operation Sekwi.

Operation Norman was a continuation of the modern phase of Geological Survey of Canada activities in the region. Geological mapping has reached the stage at which the geology of Upper Ramparts River and Sans Sault Rapids map areas is tied to published or manuscript maps on all sides (Fig. 1). It is tied southward to that of Wrigley Lake (Gabrielse et al, ibid.) and Sekwi Mountain (Blusson, 1971) map areas via geological maps of Carcajou Canyon, Mount Eduni, and Bonnet Plume Lake map areas (Aitken and Cook, 1974a,c).

Stratigraphers and paleontologists of the Geological Survey of Canada, operating with logistical support from the various mapping operations, have published regional stratigraphic studies of particular importance to the present work. These include: the reports of Aitken, Macqueen and Usher (1973) on Precambrian and Cambrian strata; Norford (1964) and Norford and Macqueen (1975) on Cambrian to Silurian stratigraphy; A.W. Norris (1967, 1968) on Devonian stratigraphy; and Mountjoy (1967) and Mountjoy and Chamney (1969) on Cretaceous stratigraphy. Tassonyi's (1969) study of the subsurface geology of the region deals with all wells released to March 1961.

A reconnaissance gravity map that includes most of the two subject map areas is available (Hornal et al., 1970).

Comments on the geological maps

Much of the subject region is admirably suited to rapid mapping from helicopters. Many of the stratigraphic units are expressed distinctly in the topography and on aerial photographs, and ground control from widely separated landings is sufficient for the drawing of a geological map that is 'correct' at a scale of 1:250 000. This is not the case everywhere. Even in areas that provide a good deal of bedrock outcrop, discontinuous drift cover can mask the airphoto 'signature' of map units; the outcrop expression of good airphoto marker units may become indistinct where deformation is intense and structure complex; and units that are recognized easily in one part of the region may become indistinct or unrecognizable elsewhere because of facies changes. The rapid pace of the work allowed little time for traversing on foot and, for this reason, details of many of the more complex structures are not yet fully understood.

Early in the compilation stage, a decision was made to draw maps that would, as far as possible, present an interpretation of the bedrock geology of the entire report area, even in extensive areas lacking outcrop. Where such areas are involved, the level of confidence obviously ranges from 'projection' through 'interpretation' to 'speculation'.

An effort has been made to convey the level of confidence with which the maps may be read by the choice of symbols. Geological contacts indicated by solid lines ('observed' contacts) either have been observed from the ground or from the air at close range, or are traceable with confidence on the air photographs from points at which they have been observed. A solid-line contact does not mean necessarily that the contact is exposed.

Contacts indicated by broken lines (long dashes; 'approximate' contacts) are uncertain as to position only. The presence of the unit is not in doubt. Such contacts are drawn, for example, where two adjoining formations have been observed from the ground, but the contact between them lies within a covered interval of a width that is significant at the scale of the map. They are used also in areas in which, for a variety of reasons (steep mountain faces, intense deformation, partial cover), the contact is not visible on air photographs. At a lower level of confidence, broken-line contacts are used to delineate formations that are largely or wholly concealed. This is done only in simple homoclinal sequences where one or more contacts are well exposed and other contacts in the sequence can be placed by extrapolation, assuming constant dip and thickness.

The 'assumed' contact (short dashes) may represent boundaries of a formation that, based on all evidence, is present, but whose position is poorly controlled. At a lower level of certainty, the 'assumed' contact may be used in extensive areas of cover to suggest a simple, reasonable configuration for formations not observed but almost certainly present. At the lowest level of certainty, the 'assumed' contact is used to interpret the distribution of formations that possibly are not present at all as, for example, at and near stratigraphic pinch-outs in covered areas. Speculation obviously is involved, and made necessary by our decision to present a complete map of the bedrock. The rule has been to avoid introducing faults or folds that are not extensions of observed structures.

Fault traces and fold hinges have not been mapped indiscriminately. Solid-line symbols are used to delineate observed structures whose positions are well documented. The lines are broken where: (a) the structure is observed but not well delineated or, (b) the structure per se has not been observed, but its nature and approximate position are strongly implied by observed geological relationships.

The thoughtful reader will not be misled. By careful attention to the types of symbols used, observational fact can be distinguished from various degrees of approximation and speculation.

Topographic names

Few geographical features in the region have been named officially. Discussion of unnamed features is difficult and leads to excessive verbiage, and few readers welcome geological descriptions largely related to geographic coordinates. Accordingly, the writers have proposed names for the outstanding geographic features of the region that are presently unnamed, and for a few less prominent features that are associated with geological phenomena of particular interest. These proposals have been submitted to the Canadian Permanent Committee on Geographic Names, but have not yet been approved. These unofficial geographic names are identified in the text and on the maps by the use of quotation marks.

PHYSICAL FEATURES

Upper Ramparts River and Sans Sault Rapids map areas jointly occupy parts of five distinct physiographic provinces: Mackenzie Mountains, Peel Plateau, Peel Plain, Mackenzie Plain and northern Franklin Mountains (Fig. 1).

Mackenzie Mountains

Only the Canyon Ranges subdivision of Mackenzie Mountains is represented within the subject map areas. The mountains are mostly subdued in outline; extensive, flat or gently sloping areas are common on the ridges and uplands, but steep slopes and cliffs descend from them to the major valleys, which are straight and characterized by broad, flat bottoms. Summit heights, and ruggedness reflecting mild alpine glaciation, increase southward from the mountain front. In general, the higher summits are between 1830 and 1980 m in elevation; only a few peaks along the southern boundaries of the maps surpass 2140 m. The topography is adjusted closely to bedrock structure, but the pronounced trellis pattern of drainage that characterizes Canyon Ranges to the east-southeast is developed only fragmentarily.

According to the interpretation of O.L. Hughes (pers. com., 1974), the Canyon Ranges of the region were covered first (except for promontories along the mountain front and nunataks) by north-flowing montane ice during a glaciation considered to be pre-Wisconsin. The Wisconsin advance of Laurentide ice from the southeast reached to levels only slightly above 1070 m along the mountain front (that is, not as high as the preceding, montane glaciation). Laurentide ice penetrated the mountains along the major valleys, but probably did not reach the 'Grand Forks' of Arctic Red River. A subsequent, late-Wisconsin advance of montane glaciers reached almost to the 'Grand Forks', to leave a record there of terminal moraines behind an apron of pitted outwash.

Only the higher peaks along the southern border of the two map areas have been extensively sculptured by alpine glaciation.

Peel Plateau

Peel Plateau and Peel Plain are structurally a single, slightly deformed unit. The plateau is an erosional remnant, capped and protected by resistant Upper Cretaceous sandstones. Generally, the higher parts of the gently rolling upland surfaces are outlined by the 760 m contour. Only at 'Lichen Ridge' does the surface exceed 910 m in elevation. On the south, the plateau is limited by the *en echelon* mountain-front flexures, in which the Cretaceous sandstones are upturned and truncated. On the north, a subdued erosional escarpment nearly 300 m high descends to Mackenzie Plain. The eastern limit, between 'Shortcut Creek' and Gayna River, is topographically indistinct, but may be taken as the limit of Upper Cretaceous, feature-forming sandstones.

According to the interpretation of O.L. Hughes (pers. com., 1974), the part of Peel Plateau within the map areas presently considered was glaciated by a piedmont expansion of montane ice in pre-Wisconsin time, and subsequently was covered by southeasterly derived Laurentide ice. The record of Laurentide glaciation includes extensive areas of subdued hummocky moraine, outwash deposits of sand and gravel, and northwest-trending meltwater channels, but the major features of topography and drainage are of preglacial origin.

Peel Plain

Peel Plain is a monotonous expanse of nearly level ground at an elevation of about 150 m, largely covered with glacial drift, bogs, swamps and small lakes that mask bedrock almost completely. It lies across the projected trends of Mackenzie Plain Synclinorium and the northwestern Franklin Mountains, and owes its flatness to the absence of the structural uplifts that characterize the other two provinces. The major streams are incised slightly, and their valleys provide the few outcrops that exist.

Mackenzie Plain

Structurally, Mackenzie Plain is a part of the northern Franklin Mountains subregion, differing from the Franklins by the presence of broad expanses of nearly flat topography at low elevations. Bevelled, weakly resistant Cretaceous strata form these flat, low surfaces.

Mackenzie Plain differs from Peel Plain by being interrupted by local uplifts of Franklin Mountains structural type, and by offering somewhat better bedrock exposures along its incised streams.

Franklin Mountains

The northern Franklin Mountains are separated from Mackenzie Mountains by Mackenzie Plain (structurally, Mackenzie Plain Synclinorium). They are linear to arcuate bedrock ridges, rather widely separated by broad, generally flat-bottomed valleys with few outcrops. Relief is not great; most of the ridges in Sans Sault Rapids map area barely exceed 300 m in elevation, and only Gibson Peak exceeds 760 m. At the termination of the Franklin Mountains in the northeastern corner of Sans Sault Rapids map area, a strong east - west structural and topographic trend is evident, but this is not representative of the northern Franklins as a whole, where westerly, northerly and northwesterly trends are developed about equally.

The Franklins were covered entirely by Laurentide ice during the Wisconsin glaciation. Nevertheless, as shown by glacial flutings, crag-and-tail features and retreatal moraines, they affected the local directions of ice flow profoundly.

STRATIGRAPHY

The trace of Plateau Fault, in the southwestern corner of Upper Ramparts map area (Fig. 23), divides the region covered by this report into two areas that have had markedly different depositional histories. The greater part of the region, that lying northeast of Plateau Fault, behaved essentially as a stable platform from Helikian through Middle Devonian time; the total exposed stratigraphic column is relatively thin and punctuated by major hiatuses. The area southwest of Plateau Fault differs from the stable platform in the following ways: (a) the exposed stratigraphic column is much thicker; (b) it contains a number of formations missing from the stable platform; (c) a number of intervals represented by carbonate strata on the stable platform are represented mainly by shaly sequences (Fig. 2). The tendency of this southwestern area throughout the Hadrynian to Early Devonian interval at least was clearly more strongly and persistently negative; it is the Selwyn Basin (Gabrielse, 1967).

The post-Devonian record in the two map areas presently considered is too fragmentary to permit any generalization about post-Devonian differentiation between the earlier platformal and basinal regions. By Cretaceous time, the region had undergone a major diastrophic reorganization, and thick marine deposits accumulated in the (Cretaceous) Mackenzie Trough, a feature superimposed upon the earlier stable platform region.

Stable platform region

The oldest rocks exposed within the stable platform region comprise a thick, apparently conformable succession of clastic and carbonate sedimentary rocks with minor amounts of evaporites, intruded by gabbros. Although confirmation by absolute dating methods is lacking, this succession is probably Helikian in age, and certainly Precambrian.

In most of the platform region, the Helikian(?) succession is overlain unconformably by a mainly carbonate succession of Late Cambrian and Early Ordovician age. Locally, these two successions are separated by Upper Cambrian evaporites; more locally still, the evaporites overlie the erosional feather edge of a Lower and Middle Cambrian clastic and carbonate succession. The relationships of Upper Cambrian strata to all older formations (Fig. 2) define an ancient linear 'high', the Mackenzie Arch.

The Cambro-Ordovician carbonates are overlain paraconformably by a regional carbonate blanket dated Late Ordovician and Early Silurian. Paraconformably above this, in turn, is a map unit of pure and impure carbonate rocks of probable Late Silurian and Early Devonian ages. Overlying the Siluro-Devonian strata is a widespread, thick and varied succession of Lower and Middle Devonian rocks, composed mainly of carbonates with a variable content of evaporites. The Middle Devonian record ends with widespread deposition of shale and, in the eastern half of Sans Sault Rapids map area, late Middle Devonian limestone banks.

Late Devonian sedimentation commenced with black marine shale, succeeded by a thick, flysch-like succession of shale and sandstone.

Selwyn Basin

The upper Proterozoic to Lower Devonian succession of the Plateau Thrust Sheet appears to have been deposited in Selwyn Basin, to the southwest of a persistent hinge line or hinge zone, because of the presence there of several formations that are missing from the stable platform region (Fig. 2). The uppermost Helikian(?) formations of the platform persist beneath the basinal deposits, suggesting that the hinge is a post-Helikian feature, possibly dating from the Racklan (pre-Hadrynian) orogeny (Gabrielse, 1967).

The Helikian(?) succession is overlain unconformably by three thick, mainly clastic formations assigned to the Hadrynian. These are overlain, in turn, conformably or disconformably, by two thick and widespread Lower Cambrian formations, sandstones and overlying carbonates respectively, that record a period of relative stability.

An abrupt reversion to basinal behaviour is recorded at the disconformable contact between Lower Cambrian strata and the Road River Formation (s.l.). The latter formation ranges from Middle Cambrian to Early Devonian and, thus, is equivalent to much of the Paleozoic succession of the stable platform. A great interval of time is recorded by mainly argillaceous rocks; such carbonate strata as do occur have deep-water characteristics, or have clearly undergone mass movement from shallower into deeper water.

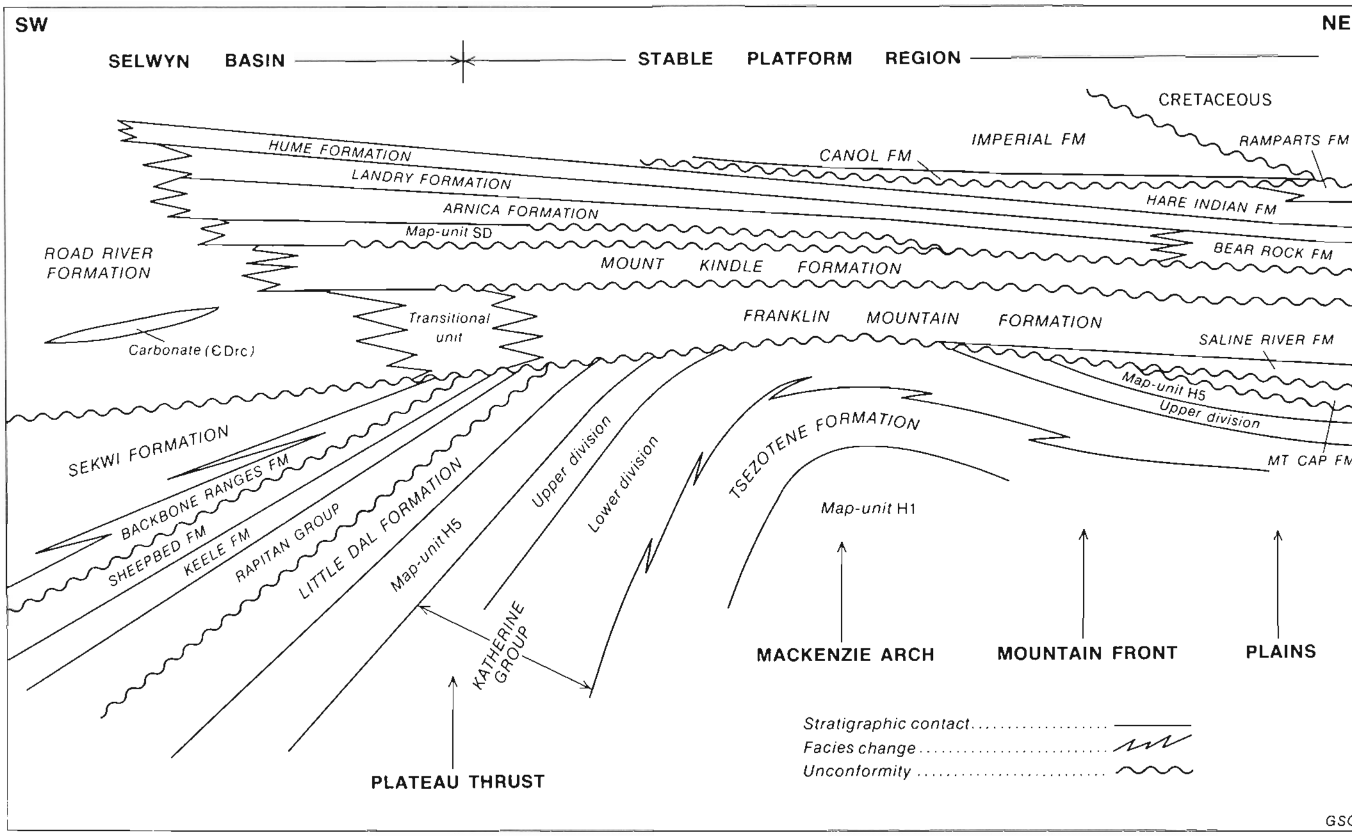

Figure 2. *Stratigraphic relationships in Upper Ramparts River and Sans Sault Rapids map areas.*

Some Lower Devonian and lower Middle Devonian carbonate formations persist from the stable platform for some distance into the northwestern part of Selwyn Basin as seen, for instance, in Mount Eduni (Aitken and Cook, 1974a) and Sekwi (Blusson, 1971) map areas. These southwesterly carbonate incursions into the basin, although thicker than their platform equivalents, maintain about the same lithology, and record at least a temporary stabilization of the northeastern edge of Selwyn Basin.

Post-Devonian strata

No geological record for most of post-Devonian time is preserved in Upper Ramparts River and Sans Sault Rapids map areas. In Peel Plateau and Mackenzie Plain, a Lower Cretaceous succession of marine shale with deep-water characteristics is succeeded by a Lower and Upper Cretaceous succession that is increasingly sandy and coarser grained upward, recording the rise of source mountains to the south. These thick deposits accumulated in the (Cretaceous) Mackenzie Trough, a feature superimposed upon the earlier stable platform.

No post-Turonian, pre-Quaternary strata are known to occur within the two subject map areas. Quaternary glaciation has affected the region profoundly through both erosional and depositional processes; the record of these events is dealt with elsewhere (see Hughes et al., 1973, and sources cited therein).

Sources of stratigraphic nomenclature

Most of the stratigraphic units considered in this report have been dealt with in regional summaries of recent date; therefore, it is unnecessary here to discuss the origins of nomenclature and the locations of type sections. In general, only recent sources are cited and the interested reader must turn to these to determine the origins and authorship of stratigraphic nomenclature.

Pre-Mesozoic stratigraphy of the stable platform

Precambrian

No absolute ages have been obtained for any of the rocks here tentatively designated as Helikian and Hadrynian. In these tentative age assignments, the reasonable arguments of Gabrielse (1972) are followed (see also Aitken, Macqueen and Usher, 1973, p. 21, 22) with the understanding that direct proof of age is lacking.

The history of nomenclature of Precambrian units and the locations of type sections, where these have been designated, may be found in the regional summary by Aitken et al. (ibid.).

Helikian(?)

Map unit H1. Map unit H1, a resistant unit of pale grey weathering dolomite with minor amounts of chert (Fig. 3), is exposed (within the report area) only in the core of Tawu Anticline. It probably is the oldest formation exposed in the Mackenzie Fold Belt. Upper Ramparts River map area provides the most complete sections of the unit known to the writers; it is expected that one of these will be chosen as the type section when the unit is named.

TABLE OF FORMATIONS

A. Stable platform region

Era	Period or Epoch	Formation and maximum thickness (metres)	Lithology
Cenozoic	Quaternary	Glacial, fluvioglacial and lacustrine deposits; alluvium (Qa)	Till, gravel, sand, silt clay; unconsolidated
		Unconformity	
Mesozoic	Lower and Upper Cretaceous	Trevor Formation (K) 1153	Sandstone, mudstone nonmarine and marine
		Contact, conformable, intertongued	
	Lower Cretaceous	Arctic Red Formation (K) 1220	Mudstone, shale, siltstone, sandstone; basal sandstone and conglomerate; marine
		Sans Sault Formation (K) 442 (Equivalent to Arctic Red Formation)	Sandstone, mudstone; marine
		Unconformity	
Paleozoic	Upper Devonian	Imperial Formation (Di) 850	Shale, sandstone; marine
		Conformable contact	
		Canol Formation (Dc) 92+	Shale, black, siliceous, bituminous; marine
		Disconformity	
	Middle Devonian	Ramparts Formation (Dr) 261	Limestone; marine
		Conformable Contact	
		Hare Indian Formation (Dhi) 198+	Shale, minor siltstone and limestone; marine
		Conformable contact	
		Hume Formation (Dh) 105	Limestone, fossiliferous; minor shale; marine
		Conformable contact	
	Lower Devonian	Bear Rock Formation (Db) 260 (Equivalent to Landry and Arnica formations)	Dolomite, typically pale brown or striped, bituminous; gypsum, solution breccia; marine
		Landry Formation (Dl) 385	Limestone, thick-bedded, resistant; marine
		Conformable contact	
		Arnica Formation (Da)	Dolomite, brown, striped; minor gypsum and solution breccia; marine
		Relationships uncertain	
	Upper Silurian(?) and Lower Devonian(?)	Unit SD 275	Dolomite, partly sandy, silty, argillaceous, partly orange-weathering; marine. Locally (especially sub-surface), limestone with shale partings
		Unconformity	
	Upper Ordovician and Lower Silurian	Mount Kindle Formation (OSk) 245+	Dolomite, siliceous, fossiliferous; minor chert; marine
		Unconformity	

A. Stable platform region *(cont'd)*

Era	Period or Epoch	Formation and maximum thickness (metres)	Lithology
	Cambrian and Ordovician	Transitional unit (from Franklin Mountain to Road River) (€Ot) 550	Dolomite and limestone; shale interbeds; marine
	Upper Cambrian and Lower Ordovician	Franklin Mountain Formation (€Of) 739	'Cherty' member: dolomite, white chert, drusy quartz; marine
			'Rhythmic' member: dolomite, minor grey chert; sandy beds at base where 'rhythmic' member is basal; marine
			'Cyclic' member: dolomite, orange-weathering, recessive; interbeds of argillaceous dolomite
		'Basal redbeds' (€Ofb) 87	Sandstone, partly red, red mudstone, dolomite; marine
		Conformable contact	
	Upper Cambrian	Saline River Formation (€s) 848	Redbeds: shale, siltstone, sandstone; salt, gypsum, anhydrite, dolomite; marine
		Unconformity	
	Lower and Middle Cambrian	Mount Cap Formation (€c) 25	Shale, thin-bedded limestone, glauconitic sandstone, siltstone; marine
		Unconformity	
Proterozoic	Helikian(?)	Basic intrusions (Hg)	Dykes and sills of gabbro, greenish-black, medium grained
		Intrusive contact	
		Little Dal Formation (Hld)[1] 120(?)	Dolomite, polygenic, partly sandy, silty and argillaceous, algal stromatolites abundant; minor shale; marine
		Conformable contact	
		Unnamed Unit H5[1] 1340	Upper division (H5u): shale, dolomite, quartzite; thick gypsum; marine
			Lower division (H5l): limestone, commonly nodular; shale, dark grey, red; dolomite, polygenic; siltstone, quartzite, H5r - reefs of stromatolitic limestone and dolomite.
		Conformable contact	
		Katherine Group 712+	Upper division (Hku): quartzite, dolomite, shale; marine and(?) nonmarine
			Lower division (Hkl): mainly quartzite; minor shale and dolomite; marine and(?) nonmarine
		Contact conformable, intertongued	
		Tsezotene Formation (Ht) 748+	Shale, sandstone, dolomite; marine and(?) nonmarine
		Conformable(?) contact	
		Unnamed Unit Hl Thickness unknown; 370 minimum	Dolomite, minor chert; marine

[1] See footnote p. 12

B. Selwyn Basin

Era	Period or Epoch	Formation and maximum thickness (metres)	Lithology
Paleozoic	Middle Devonian	Hume Formation (Dh) 105	Limestone, fossiliferous; minor shale; marine
		Conformable contact	
	Lower and Middle Devonian	Landry Formation (Dl) 385	Limestone, thick-bedded, resistant; marine
		Conformable contact	
	Lower Devonian	Arnica Formation (Da) 190	Dolomite, brown, striped; minor gypsum and solution breccia; marine
		Relationships uncertain	
	Upper Silurian(?) and Lower Devonian(?)	Unit SD 275	Dolomite, partly sandy, silty, argillaceous, partly orange-weathering; marine
		Relationships uncertain	
	Cambrian to Devonian	Road River Formation (D:CDr) 1500(?)	Shale, limestone, dolomite, chert; carbonate conglomerate; marine
	Upper Ordovician and Lower Silurian	Mount Kindle Formation (OSk) 245^+	Dolomite, siliceous, fossiliferous minor chert; marine
		Unconformity	
	Cambrian and Ordovician	Transitional unit (between Franklin Mountain and Road River) (COt) 550	Dolomite and limestone; shale interbeds; marine
	Upper Cambrian and Lower Ordovician	Franklin Mountain Formation (COf) 739	Monotonous dolomite; secondary chert; redbeds locally at base; marine
		Unconformity	
	Lower Cambrian	Sekwi Formation (Csk) 910	Limestone, dolomite, minor shale and quartzite; marine
		Contact conformable, intertongued	
		Backbone Ranges Formation (Cb) 610(?)	Sandstone, quartzite, dolomite, varicoloured shale; marine and(?) nonmarine
		Unconformity(?)	
Precambrian	Hadrynian	Sheepbed Formation (Hs) 275	Shale, dark grey to black; marine
		Conformable contact	
		Keele Formation (Hk) 150	Limestone, dolomite, quartzite, shale, conglomerate; marine
		Conformable contact	
		Rapitan Group (mainly or entirely upper division) (Hr) 520	Shale, siltstone, sandstone, pebbly grit; marine
		Unconformity	
	Helikian(?)	Little Dal Formation (Hld) 120(?)	Dolomite, polygenic, partly silty, sandy and argillaceous;algal stromatolites abundant; minor shale; marine
		Conformable contact	
		Unnamed Unit H5 300(?) Base faulted	Upper division (H5u): shale, dolomite, quartzite; thick gypsum; marine

Figure 3. *Characteristic pale grey weathering outcrops of map unit H1, Tawu Anticline east of Arctic Red River. Ht – Tsezotene Formation; Hg – gabbro; Hkl – Katherine Group (lower division); €Of-Franklin Mountain Formation. GSC 163576*

The formation consists mainly of pale grey weathering, medium to dark grey, microcrystalline to fine-crystalline[1] dolomite, that is mostly thick bedded[2] and massive. Crinkly cryptalgal-type lamination is common, whereas low-domal algal stromatolites are relatively rare. 'Birdseye' (fenestral) dolomite, and dolomite derived from pellet grainstone and flat-pebble conglomerate limestone form a minor part of the formation; primary fabrics are well preserved only where silicified. Accessory quartz sand and silt occur in some beds. Thin, discontinuous beds of black chert are characteristic of much of map unit H1. Fluorite was observed in two beds of the unit in a canyon on the south flank of Tawu Anticline, 21 km east of Arctic Red River. An upper bed contains only traces of the mineral, but a lower bed, of dolomitic sandstone 61 cm thick, is estimated to contain about 5 per cent fluorite-filled vugs. Blebs of a solid hydrocarbon are present in one specimen of the unit.

The base of map unit H1 is not exposed. At a measured section near the fluorite locality mentioned above, the formation is at least 370 m thick. The upper contact, concordant with the overlying Tsezotene Formation, generally is covered and has not been studied in detail. The contrast in lithology and resistance at the H1-Tsezotene contact facilitates mapping; locally, the contact is occupied by a gabbro sill.

Tsezotene Formation. A thick and widely exposed, lithologically heterogeneous formation intervenes between the dolomite of unit H1 and the thick quartzite of the Katherine Group. It is characterized by well-bedded exposures of sombre colour, interrupted by bright orange-weathering dolomite beds (Fig. 4). Outcrops in Upper Ramparts and Sans Sault map areas are in mapped continuity, via Mount Eduni and Carcajou Canyon map areas, with the type Tsezotene Formation of Wrigley Lake map area (Gabrielse et al., 1973).

The formation is a thick succession of mudrocks (shale, mudstone, argillite) with intervals comprising sandstone or quartzite, siltstone, and the orange-weathering dolomite that lends an unmistakable character to any extensive exposures of the formation.

The mudrocks vary from fissile clay shale to nonfissile mudstone. Colours are predominantly grey, greenish grey or brown, but in places are purplish red and black.

The characteristic sandstone of the Tsezotene is predominantly very fine grained, grading to siltstone. These

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[1] Crystallinity of nonclastic sedimentary rocks is indicated according to the following classification.

Modal crystal size	(mm)
Coarse crystalline:	greater than 1.0
Medium crystalline:	0.25 - 1.0
Fine crystalline:	0.06 - 0.25
Very fine crystalline:	0.03 - 0.06
Microcrystalline:	less than 0.03

[2] The bedding thickness classification of Ingram (1954) is used throughout this report.

Bed thickness	(cm)
Very thick bedded:	greater than 100
Thick bedded:	30 - 100
Medium bedded:	10 - 30
Thin bedded:	3 - 10
Very thin bedded:	1 - 3
Laminated:	0.3 - 1
Thinly laminated:	less than 0.3

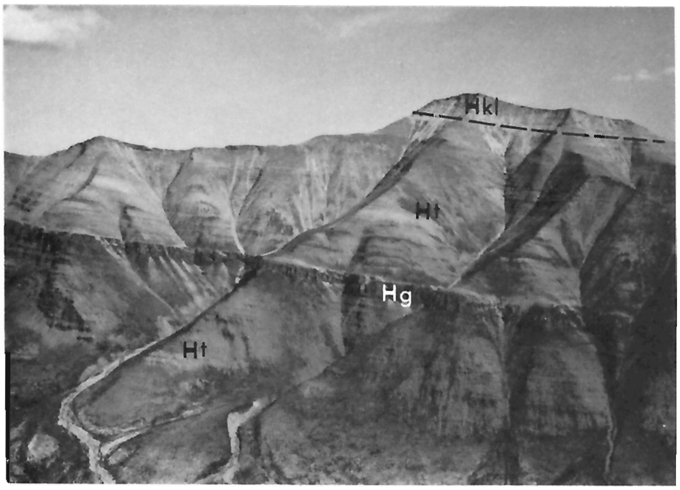

Figure 4. *Tsezotene Formation overlain by basal Katherine Group quartzites, south limb of Tawu Anticline, east of Arctic Red River. Ht – Tsezotene Formation; Hg – gabbro; Hkl – Katherine Group (lower division). GSC 202866*

strata are largely argillaceous and immature, grey, greenish grey or dark grey and, commonly, of 'pepper and salt' aspect. Beds of mature, orthoquartzitic sandstone also are present at intervals in the formation. They are very fine and fine grained and pale grey to white or very pale green. Both types of sandstone are thin to medium bedded, with planar lamination and crosslamination. Both are hard and well cemented, and usually are described as quartzite in the field. Mud cracks and ripple marks are widespread.

The dolomite beds are grey, microcrystalline to fine-crystalline, and commonly silty or sandy. Beds with cryptalgal lamination and simple domal algal stromatolites are fairly common. Some beds have a relict calcarenitic or conglomeratic texture. Virtually all dolomite in the Tsezotene weathers bright orange or yellowish orange.

Although gabbro dykes cut all of the Helikian(?) formations, gabbro sills are confined to the Tsezotene Formation (Figs. 4, 5). Three sills are present within the core of Tawu Anticline near Arctic Red River. The lowest, occupying the H1-Tsezotene contact, has not been measured, but is estimated to approach 30 m in thickness. The second sill, 35 m thick at Section U-3 (65°14'N, 131°01'W), is 192 m below the top of the formation. The third, 18 m thick at Section U-3, is 50 m below the top.

Although the Tsezotene has not been subdivided in the course of mapping, it appears likely that a practicable four-fold subdivision could be effected within the region under consideration. A basal recessive unit consists mainly of brown to pale yellow-brown weathering mudrocks with rather widely spaced intercalated beds of silty dolomite and siltstone. This incompetent unit is characteristically deformed into attenuated folds and is poorly exposed. Accordingly, its thickness was not measured. Usher's estimate (Aitken, Macqueen and Usher, 1973, p. 62) of 300 to 610 m may be excessive because of tectonic thickening.

The succeeding unit, 185 m thick at Section U-3, typically occurs as brown-weathering cliffs; it is the most resistant unit of the formation. It is dominated by mainly immature but partly mature sandstone and quartzite grading to siltstone, but contains subordinate units of varicoloured mudrocks among which some red and purple-red varieties generally are present.

The third unit, 220 m thick at Section U-3, is moderately resistant. It consists of mudrocks that are mainly

Figure 5. *Upper contact of a gabbro sill, 18.2 m thick, in the Tsezotene Formation near crest of Tawu Anticline, east of Arctic Red River. Note the sharp contact and lack of scoria at the top of the sill, and the overlying zone of bleached, hornfelsed argillite, about 1.5 m thick. GSC 163597*

grey to black, with dolomite-dominated intervals up to 90 m thick. The dolomite is largely silty and sandy and, locally, contains chert. Thin beds of quartzite occur here and there throughout the member.

An upper recessive unit, only 37 m thick at Section U-3, but several tens of metres thick west of Arctic Red River, consists of varicoloured mudrocks interbedded with thin beds of mature and immature sandstone and quartzite, siltstone, and a few beds of dolomite.

No complete section of the Tsezotene Formation has been measured. At Section U-3, the formation is at least 745 m thick (partly estimated). Distinct southward thickening is apparent from mapping, but has not been confirmed by actual measurement and, in any event, the base of the formation is not exposed south of Tawu Anticline.

The basal contact of the Tsezotene Formation has not been studied in detail. The upper contact is gradational (Fig. 4) and, at some localities, somewhat arbitrary because of the presence of substantial thickness of mature quartzite (Katherine-like lithology) in the top of the Tsezotene. In the course of compiling the map, it became almost certain that the contact between the Tsezotene and the overlying Katherine Group is intertongued and diachronous; an observed 'base of Katherine' contact can be traced with confidence in several places to localities at which another tongue of resistant, mature quartzite, clearly 'basal Katherine' appears at a slightly lower level. At one place in Tawu Range, this had to be resolved by resorting to an arbitrary cutoff at which the contact was shifted from one stratigraphic level to another. The direction in which Katherine orthoquartzite changes to Tsezotene mudrock and immature sandstone is not established.

Katherine Group. The Katherine Group (Aitken, Macqueen and Usher, 1973) comprises a thick, quartzite-dominated succession that is one of the most widespread and easily recognized stratigraphic units in the Canyon and exterior Backbone Ranges. It corresponds to the thick quartzite formation mapped as Tigonankweine in map areas to the southeast (Gabrielse et al., 1973).

The Katherine is divided into upper and lower divisions. The lower Katherine consists mainly of quartzose sandstone and quartzite whose flaggy, lichen-covered rubble usually obscures the recessive, nonsandstone intervals. Katherine arenites are similar to those of the Tsezotene; however, the mature, orthoquartzitic sandstone units predominate over the immature, 'dirty' sandstone units. The predominant grade is very fine grained. Colours range over the scale through brown and brownish grey to white; red and pale greenish colours also occur. Carbonate-cemented beds are fairly common. Bedding scale ranges from thin bedded and flaggy (more characteristic of the darker, less mature sandstone) to very thick bedded and massive (the white orthoquartzites). Crossbedding (Fig. 6) and crosslamination are ubiquitous, mud cracks and ripple marks common. Recessive intervals, generally of subordinate thickness, alternate with the resistant sandstone intervals. These consist mainly of varicoloured mudrocks similar to Tsezotene mudrocks, with minor thin beds of sandstone and siltstone. A few dolomite beds, similar to those in the Tsezotene Formation, occur within the recessive intervals. A conspicuous purple shale unit, 68 m thick at Section U-4 (65°09'15"N, 131°17'30"W), is an excellent marker along the southern limb of Tawu Anticline and, possibly, more regionally.

Figure 6. *Typical stacked sets of low-angle crossbeds in quartzites of the basal Katherine Group, near crest of Tawu Anticline, east of Arctic Red River. The flaggy parting along cross-laminations is characteristic. GSC 163595*

The upper division of the Katherine consists of a lower, relatively recessive part and an upper, resistant part. The lower part consists of mudrocks (dark grey to black, with some greenish grey) interbedded with orange- and grey-weathering dolomites that commonly are stromatolitic, the dolomites becoming rather more prominent downward. A few beds of sandstone and siltstone also are present. The upper part consists of thin- to thick-bedded, varicoloured, partly reddish orthoquartzite that is very fine to medium grained and rarely coarse grained.

The lower Katherine is 424 m thick at Section U-3 (65°14'N, 131°01'W) and the upper Katherine is 288 m thick at Section U-4 (65°09'15"N, 131°17'30"W), for a total thickness of 712 m. Pronounced thickening of both lower and upper Katherine toward the more interior ranges of the Mackenzies is established (Aitken, Macqueen and Usher, 1973; Aitken and Cook, 1974c), but many more measurements are required to establish isopach trends.

The top of the resistant, quartzite-dominated Katherine Group is mapped easily, whether it is the conformable contact with map unit H5 or, as in much of Stony and Tawu Anticlines, the unconformity beneath Paleozoic rocks, which along Mackenzie Arch has cut low enough to remove the upper Katherine (Aitken, Macqueen and Usher, 1973).

Map unit H5[1]. Map unit H5 is a thick, widespread, lithologically heterogeneous and easily recognized stratigraphic unit that intervenes between the quartzite-dominated Katherine Group and the feature-forming carbonate strata of the Little Dal Formation. Because the unit was poorly understood, a field study specifically aimed at its clarification was undertaken by Aitken in 1976 (when the manuscript of this memoir was already completed). This recent study clarified, and indeed simplified, the stratigraphy and sedimentology of the unit, and showed that certain assumptions previously held were invalid. For these reasons, this section of the manuscript has been rewritten to incorporate the new data.

[1]Since completion of this memoir in 1975, it has been established that map unit H5 corresponds to the lower two thirds, more or less, of the type Little Dal Formation. Subdivisions of map unit H5 will in future be treated as formations of the Little Dal Group. (See J.D. Aitken, D.G.F. Long, and M.A. Semikhatov, "Progress in Helikian stratigraphy, Mackenzie Mountains" in Current Research, Part A, Geological Survey of Canada, Paper 78-1A, p. 481 - 484, and J.D. Aitken, "Stratigraphy and Sedimentology of the Upper Proterozoic Little Dal Group, Mackenzie Mountains, N.W.T.", in Proterozoic Basins in Canada, F.H.A. Campbell, ed., Geological Survey of Canada, Paper 81-10)

Map unit H5 is a stratigraphic unit of group rank on the order of 1340 m thick, and readily divisible into five conformable, mappable subunits of formation rank. In stratigraphic sequence, the temporarily and informally named subunits are: the mud-cracked subunit, the basinal sequence (further divisible into mappable, lithologic entities), the grainstone subunit, the gypsum subunit, and the rusty shale subunit. Although there is an intricate facies pattern within the basinal sequence, each of the subunits was deposited as a regional, 'blanket' formation, and the facies changes previously assumed to take place within the unit and its assumed relationship to the overlying Little Dal Formation (e.g., Aitken, Macqueen and Usher, 1973) do not exist.

No complete section of map unit H5 occurs within the report area. Regionally, with few exceptions, the upper two subunits and the Little Dal Formation are limited to the Plateau Thrust Sheet, which nowhere contains any part of the lower three subunits. A composite section, however, can be viewed within Upper Ramparts River map area. The mud-cracked subunit, the basinal sequence and the grainstone subunit can be examined at Section U-2, and the gypsum (incomplete) and rusty shale subunits can be observed in thrust-slices at 65°01'30"N, 131°10'00"W. Investigators particularly concerned with unit H5 are advised to visit the extreme headwaters of Gayna River, in Bonnet Plume Lake map area. There, an excellent section extending from the base of the map unit to nearly the top of the grainstone subunit can be examined at 64°58'20"N, 130°30'37"W. The gypsum and rusty shale subunits and their relationship to the underlying grainstone subunit and to the overlying Little Dal and Franklin Mountains formations can be examined in the vicinity of 64°57'30"N, 130°46'00"W. The two sections occur on opposite limbs of the Shattered Range Anticline, and the relationship between them is easily traced. Representative thicknesses given here for each of the subunits are based on a group of well-studied sections in Mount Eduni map area (Aitken, 1977), but undoubtedly indicate the correct order of thicknesses in the report areas.

The mud-cracked subunit, 40 to 60 m thick, is less resistant than the uppermost Katherine Group on which it lies, but more resistant than most of the overlying basinal sequence. It consists primarily of sandstone and mudrocks in a coarsening-upward, shallowing-upward cycle on which are imposed numerous ill-defined, coarsening-upward cycles of smaller scale. The shales and mudstones are mainly dark grey, shedding black talus; grey and olive shades occur also. Dolomitic siltstone commonly occurs in minor amounts within the mudrock units, in thin ripple-marked beds or disconnected 'starved' ripples. The sandstone beds are mainly pale grey, very fine and fine grained; rip-up breccias of shale chips are prominent at their bases. Mega-ripples with the appropriate crosslamination are common. A few medium and thick beds of brown-weathering, dolomitized grainstone occur in most sections. The unit is distinguished by, and informally named for its abundance of mud cracks, which increase in abundance and coarseness upward. At Section U-5 (Aitken, Macqueen and Usher, 1973), the mud-cracked unit comprises units 1 through 7 (map unit H5), totalling 49 m.

The basinal sequence conformably overlying the mud-cracked subunit is typically about 250 to 400 m thick and comprises several different lithologies, each of which may replace the other laterally. The presence of limestone nodules, and nodular beds clearly of concretionary origin, is characteristic. The most striking expression of this character is in the 'Dead End Shale' of Nauss (1944; cited in Hume, 1954), described at the type section of the Macdougal Group (obsolete) at Macdougal Canyon. It is characterized and dominated there by brick-red to deep brownish red, calcareous, laminated shale with abundant ellipsoidal nodules and nodular thin beds of red to pinkish grey, microcrystalline limestone. Subordinate greenish stratigraphic intervals normally occur. The 'Dead End Shale' is not a useful stratigraphic unit, however, because the red colouration appears and disappears along strike; in places brown-weathering limestone nodules occur in dark grey shale that appears black at a distance.

Medium and thick nodular 'beds' of microcrystalline limestone, usually somewhat silty and displaying ripple crosslamination, and locally dolomitized, also occur in the basinal sequence, notably in its lower quarter. Molar-tooth structure (Bauerman, 1885; Rezak, 1957) is present locally. Intervals containing grey, calcareous, finely laminated siltstone occur at all levels.

Resistant deep-water 'rhythmites', several hundred metres thick, interrupt the nodular facies in many places and, locally, form tongues passing into nodular facies. The rhythmites consist of thin, lenticular beds of silty microcrystalline limestone separated by thinner beds of grey to dark grey, carbonaceous, calcareous silty shale or shaly siltstone. The two alternating lithologies form a simple ABABAB rhythm, remarkable in the constancy of bed thickness and the monotony of the lithology. The diagenetic or concretionary character of the limestone beds is indicated by the widespread occurrence of long-wavelength current ripples within them, outlined by grains of quartz silt. Thin units of gravity-slumped and penecontemporaneously folded beds occur in places within both the nodular facies and the rhythmites.

The most striking and obvious lithologic units within the basinal sequence are the stromatolitic reefs, distinguished on the accompanying maps as H5r. These reach their maximum development in the Shattered Range Anticline, southeast of the report area, although several good examples are preserved in the south limb of Tawu Anticline, east and west of Section U-5. Intense diagenesis, both recrystallization and dolomitization, has obscured the original nature of much of the reef-forming carbonate but, at favoured localities, the texture of the primary sediment is well preserved, either as microcrystalline limestone or very fine crystalline dolomite. The core material consists mainly of stromatolite bioherms built one upon the other. Small-scale branching-columnar stromatolites predominate, column diameters being mainly 1 cm or less. The lateral and upper surfaces of the individual columnar-branching bioherms commonly are overgrown with cryptalgal laminites that display surprisingly steep, even locally overturned initial dips. The reef core proper generally is thickly mantled with coarse, blocky reef talus; metre-scale blocks are common. The reef taluses wedge rapidly into deep-water rhythmites, proving that the reefs stood with relief not less than tens of metres above the basin floor.

The level of reef-growth initiation is fairly consistent. The bases of most of the reefs examined are low in the basinal sequence, but the reef at Section U-5 has its base within the upper part of the mud-cracked subunit. Precise determination of the height of the reefs is difficult. Some of the more spectacular examples south and southeast of the report area approach 300 m in height. Usher estimated the reef of Section U-5 to be about 120 m high, but its depositional top may not be preserved.

The grainstone subunit forms an easily recognized double cliff above the less resistant basinal sequence. Its base is drawn where rocks of clearly shallow-water origin appear gradationally above the basinal sequence. It is characterized and dominated by medium and thick beds of various lime grainstones, generally completely dolomitized and weathering grey-brown. Depositional texture is indistinct or destroyed by dolomitization but, within scattered nodules of grey to white chert, preservation is total. Within these nodules, ooid, pellet, intraclast and oncolite grainstones are represented, the first of these being the most prominent. Next in abundance to the grainstones are beds of very fine crystalline grey dolomite, weathering yellow-grey, which are interpreted as ex-calcisilites. These contain abundant quartz silt in places and intergrade with dolomitic siltstones. Ripple forms and ripple crosslamination are widespread. Biostromes of columnar and simple domal stromatolites occur at most localities. Grey shale and lime mudstone occur but are subordinate within the unit; their lack of resistance to weathering causes the shelf between upper and lower cliffs. Molar-tooth structure is well developed at several levels.

Above the grainstones, but included within the grainstone subunit, is a useful marker composed of grey, microcrystalline, yellow-weathering, platy and flaggy dolomite characterized by prominent, usually sand-filled mud cracks. Some grey, yellow-weathering dolomitic shale generally is present, with lesser amounts of stromatolitic dolomite (simple, low domes) and thin sandstone beds. Salt-crystal casts are preserved at the top of the marker unit.

At Section U-2, the grainstone subunit is anomalously thick (344 m) and may be thickened tectonically. It comprises units 2 to 10 inclusive, that were assigned mistakenly to the Little Dal Formation by Aitken, Macqueen and Usher (1973, p. 57, 58). Of this thickness, the uppermost 72 m belongs to the platy yellow dolomite marker. Regionally, thickness of the grainstone subunit is on the order of 240 to 290 m.

The gypsum subunit succeeds the platy dolomites at the top of the grainstone subunit abruptly but gradationally. Markedly less resistant and commonly covered, it consists of pure near-white to argillaceous dark grey gypsum with, in places, some red colouration, and a small content of thin beds of grey, gypsiferous shale. The basal beds are notably argillaceous and dark. Laminated, nodular ('chicken wire') and enterolithic structures alternate throughout the gypsum column. Indicators of shallow-water deposition such as mud cracks, small-scale ripple marks, and beds of sandstone or siltstone are notably missing except at the top of the subunit. The gypsum unit is faulted and incomplete within the report area. At the locality at the head of Gayna River, cited above, the subunit is thick and complete, but structural complications so far have prevented its measurement. The gypsum is 530 m thick in a section at 64°47'N, 219°42'W but, there, is erosionally truncated by the base of the Franklin Mountain Formation.

The fifth and highest subunit of map unit H5 is the rusty shale subunit that succeeds the gypsum with abrupt gradation. It is intermediate in resistance between the underlying gypsum and the overlying, commonly near-vertical cliffs of the Little Dal Formation. The subunit consists largely of slightly to extremely fissile shale that is grey, greenish grey, and black, with one or more purple intervals. Next in abundance is dolomite or, less commonly, relict limestone, of several habits. Cryptalgal laminites preserved as grey, microcrystalline, yellow-weathering dolomite are prominent, especially near the base, where they form part of a succession of clearing-upward cycles with dark shales (shale diminishing upward). A few beds of intraclast grainstone or wackestone, and mat-chip breccias, commonly siliceous, normally are associated with the laminites. Higher in the subunit, one or two stromatolite biostromes or horizons of bioherms occur; these are characterized by branching, strongly expanding columnar stromatolites. Minor in amount, but rather prominent, are beds of red and white, very fine grained sandstone with very well developed ripple marks and distinctive, crescentic mud cracks. These, with some planar-laminated siltstone beds, occur at about the middle of the subunit. Analytical data are not available, but this subunit appears to be notably rich in iron. Pyrite is prominent in all rocks, the stromatolitic dolomites weather to a deep rusty shade, and nearly all of the shales display pronounced rusty weathering.

The upper and lower contacts of the rusty shale subunit are gradational. The top is drawn at the top of the highest shale interval, beneath thick, massive dolomite or limestone of the basal Little Dal. Thus, several thick intervals of dolomite, similar to the Little Dal dolomites and generally with particulate textures, are incorporated into the top of the rusty shale subunit. In Mount Eduni map area, the subunit is 102 to 215 m thick and, although no section has been measured within the report area, its thickness there appears to fall within that range.

In view of the facts that the Little Dal Formation is everywhere underlain by the rusty shale and gypsum subunits of map unit H5, and that those subunits have the characteristic of 'blanket' deposits that everywhere overlie the lower three subunits of H5, previous speculations (Aitken, Macqueen and Usher, 1973; p. 17) about a facies relationship between the lower part of the Little Dal and the upper part of map unit H5 are invalid.

For purposes of reconnaissance mapping, map unit H5 has been divided into upper and lower divisions. The lower division comprises the mud-cracked subunit, the basinal sequence, and the grainstone subunit; the upper division comprises the gypsum and rusty shale subunits.

Little Dal Formation[1]. The Little Dal Formation (Gabrielse et al., 1973) is a thick, feature-forming carbonate unit that succeeds the generally less resistant and more lithologically varied strata of map unit H5. Continuity with the Little Dal in Wrigley Lake and Sekwi Mountain map areas (Gabrielse et al., 1973; Blusson, 1971) is established by the geological maps of Mount Eduni and Bonnet Plume Lake map areas (Aitken and Cook, 1974a).

The Little Dal is dominated by carbonate rocks that, in the report area, are almost entirely dolomite. Among these, rocks of cryptalgal origin are the most important. These include much poorly- to well-preserved cryptalgal laminite (as grey, mainly very fine crystalline dolomite that weathers yellow or yellow-grey) in which bedding is readily visible. Much more diagnostic of the formation, however, are thick, extremely resistant, nonbedded intervals comprising similar dolomite, that in favourable exposures are seen to be bioherms of columnar-branching stromatolites.

Molar-tooth dolomite (Bauerman, 1885; Rezak, 1957) is prominent mainly in the lower quarter of the formation. Ooid grainstones, as grey limestone or grey, grey-weathering, fine-crystalline dolomite form a widely recognizable basal member; the ooids commonly have sand-grain nuclei. Lime mudstones and calcisiltites or, more commonly, their dolomitized equivalents form a relatively minor part of the formation as do intervals that defy interpretation and are recorded simply as 'crystalline dolomite'.

Along strike to the southeast, a distinct member above the unbroken, mainly grey-weathering basal carbonates of the formation contains many beds of grey, black, green, yellow, and purple shale, arranged in clearing-upward cycles with yellow-weathering peritidal dolomites. This member is thin or missing in the report area, presumably because of erosion at the sub-Rapitan unconformity.

No section of the Little Dal has been measured within the report area. The strata mistakenly assigned to the Little Dal at Section U-2 (Aitken, Macqueen and Usher, 1973; p. 57, 58) belong, in fact, to map unit H5. The thickness of the Little Dal at 65°03'30"N, 131°26'30"W is estimated, by graphic construction, to be 460 m.

Basic intrusions. Sills up to 35 m thick of diabasic gabbro intrude the Tsezotene Formation and, locally, the H1-Tsezotene contact (see discussion under Tsezotene Formation above). Dykes of similar gabbro, up to 60 m wide, most commonly intrude the Katherine and Tsezotene formations and map unit H1 but, so far as known, cut all pre-Rapitan

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[1]See footnote, p. 12.

formations. The strike of the dykes is N10° - 20°W, parallel to the pre-Rapitan faults of the region (Aitken and Cook, 1974b). Only the thicker sills and dykes are mapped and, in mapping, the sills are not assumed to be continuous beneath covered areas (although in most places, they probably are).

D.K. Norris (pers. com., 1972) has provided the following description of the diabasic gabbro:

> The diabase is dark greenish grey and is characteristically medium crystalline, except near its chilled margins. In thin section it is commonly observed to comprise approximately 70 per cent mildly sericitized plagioclase (An50-60), with 15 to 20 per cent highly altered clinopyroxene (augite), 10 per cent altered amphiboles (hornblende and tremolite-actinolite) and minor amounts of disseminated magnetite and chloritized biotite.

Columnar jointing is well developed in the sills. Where the contacts of sills have been studied, both the overlying and underlying beds are thermally altered (Fig. 5). No indication of concordant gabbro bodies having originated as lava flows has been observed.

Paleozoic

The existence of recent papers that summarize the stratigraphy of various Paleozoic systems encountered in the Mackenzie Mountains, Franklin Mountains, Mackenzie Plain and Peel Plateau makes it unnecessary to present details of the history of nomenclature, locations of type sections, and other information pertaining to each formation described here. Accordingly, in the context of each formation considered, reference normally is made here to only one or two works of recent date and broad scope, from which the interested reader may pursue the entire literature concerning a particular formation or succession.

Lower and Middle Cambrian

Mount Cap Formation. The Mount Cap Formation (Aitken, Macqueen and Usher, 1973) of the frontal Mackenzie Mountains is recognized as an interval of sandstone (usually glauconitic and thoroughly burrowed), impure limestone, and varicoloured shale. Contained fossils are of late Early and early Middle Cambrian age. It has not been studied within the two map areas presently considered, but is assumed to be present in the north limb of Stony Anticline near the east boundary of Sans Sault Rapids map area as an erosionally bevelled feather edge, as suggested by its presence at Loretta Canyon, 3.2 km to the east. The feather edge of the Mount Cap lies in a recessive, poorly exposed interval that comprises the lower, recessive part of the Upper Katherine Group, the Mount Cap, the westerly thinning Saline River Formation (all of which have some lithological features in common), and the recessive, basal Franklin Mountain. Consequently, detailed study would be required to pinpoint the pinchout of each of the three distinct units involved. The Mount Cap is 25 m thick at Loretta Canyon (65°06'N, 127°57'W; Section U-11, Aitken, Macqueen and Usher, 1973); this is a maximum thickness for the unit at surface exposures in Sans Sault Rapids map area.

Positive features of Paleozoic age limit the southerly and westerly extent of the Mount Cap Formation. On the south, in the mountains, the Mount Cap is removed by erosion on the north flank of the west-northwest-trending Mackenzie Arch (ibid.). On the west, in the subsurface of Peel Plateau and Plain, it is overstepped by the Saline River Formation along a very ill defined line trending about north-northwest from its surface termination as mapped here (W.S. MacKenzie, pers. com., 1974). Mount Cap thicknesses of at least 120 m (Tassonyi, 1969), and possibly as much as 215 m (Aitken, Macqueen and Usher, 1973) may be encountered in the subsurface northeast of the zero isopach.

Upper Cambrian

Saline River Formation. The Saline River Formation (Aitken, Macqueen and Usher, 1973) is a recessive unit of bedded evaporites and redbeds that underlies the Franklin Mountain Formation. Within the report area it outcrops only in the north limb of Stony Anticline from about Powell Creek eastward, but is widespread in the subsurface of Mackenzie Plain and northern Franklin Mountains, where it is believed to affect profoundly the tectonic style.

In Mackenzie Mountains, the Saline River is composed of red mudstone (commonly silty and sandy), red and green shales and siltstones, pale pink to grey gypsum (anhydrite in the subsurface), and grey, microcrystalline dolomite. The thick intervals containing halite encountered in the subsurface do not outcrop; the abundant layers of calcareous, gypsiferous breccia of redbed fragments seen in outcrop may be a record of salt beds removed by solution. Red and grey sandstones are relatively unimportant in the thicker sections of the Saline River, but become increasingly prominent in the thinner sections near the pinchout of the formation. This indicates that the zero edge of the Saline River is depositional. Salt-crystal casts are present in most rocks; mud cracks and ripple marks are widespread.

Very little of the Saline River Formation is exposed in Sans Sault Rapids map area. At Loretta Canyon, just off the eastern edge of the map, it is 97 m thick (Section U-11; 65°06'N, 127°57'W; in Aitken, Macqueen and Usher, 1973). From there it thins west-northwestward to at least as far as Powell Creek, where a good exposure reveals dark red mudstone and sandstone, gypsiferous breccia, gypsiferous sandstones and abundant salt-crystal casts. This exposure is the most westerly seen; the pinchout mapped west of Powell Creek is poorly controlled by ground observations. Saline River thicknesses of up to 848 m have been penetrated in the subsurface northeast of Mackenzie Mountains (Tassonyi, 1969).

The unconformity at the base of the formation (Aitken, Macqueen and Usher, 1973) is confirmed in Sans Sault Rapids map area. In the north limb of Stony Anticline, the Saline River Formation oversteps the Mount Cap Formation, the lower Little Dal, and the upper Katherine, to rest on lower Katherine quartzites at Powell Creek. The contact with the overlying Franklin Mountain Formation is conformable and gradational.

Upper Cambrian and Lower Ordovician

Franklin Mountain Formation. The Franklin Mountain (Norford and Macqueen, 1975) is a thick formation of well-bedded dolomite that displays mainly pale colours when weathered (Figs. 7, 8, 25 - 29, 31). It overlies formations ranging in age from Helikian? to Late Cambrian, and is overlain unconformably by sombre-weathering, more massive and resistant dolomites of the Mount Kindle Formation or, in their absence, by breccia and evaporitic dolomite of the Bear Rock Formation.

In the northern Franklin Mountains and the frontal Mackenzie Mountains east of Gayna River, the Franklin Mountain Formation is divisible with reasonable ease into two and, more locally, three informal lithologic units or members (Norford and Macqueen, 1975). Within most of the report area, however, these units are mappable only under favourable circumstances and, in any event, their boundaries generally are not traceable on aerial photographs between points of ground observation. As the Franklin Mountain Formation is traced westward or southward from the region in which it is easily subdivided, two changes are observed: the basal, 'cyclic' unit is approximately coextensive with the underlying Saline River Formation, and the 'rhythmic' and 'cherty' units become much less clearly differentiated. Accordingly, although the 'cyclic' unit, where present, and the 'rhythmic' and 'cherty' units can be differentiated by careful examination of continuous sections, the Franklin Mountain above the 'basal redbeds' is treated as a single map unit. The 'basal redbeds' unit is present discontinuously, but is mapped only where it constitutes a prominent unit.

Despite all of the foregoing, the established informal lithological units provide a useful framework for the discussion of Franklin Mountain lithologies.

The 'basal redbeds' unit, which occurs only where the 'cyclic' unit is absent, is discontinuous and variable in thickness. At Section U-2 (65°11'30"N, 131°34'30"W), 8 km west of the 'Grand Forks' of Arctic Red River, it is 87 m thick. The unit consists mainly of alternating dolomite and dolomitic mudstone. The dolomite is grey to pink, microcrystalline and commonly argillaceous, weathering partly red, partly yellow or orange. The mudstone is dark red and grades into argillaceous dolomite. A thick unit of quartzite and dolomitic sandstone is present at the top. Chert occurs as both beds and fragments near the base. Some bedding planes display feeding burrows. Sixteen km to the east-southeast along strike, the 'basal redbeds' unit is only 12 m thick (estimated) and consists of quartzite and dolomitic sandstone, fine and very fine grained and well sorted, with minor sandy dolomite. Trace fossils attributable to trilobites are present.

The 'cyclic' unit overlies the Saline River Formation conformably and gradationally. It is characterized by its recessive outcrop and pale yellowish orange weathering, and by the presence of intercalated beds of olive-grey argillaceous dolomite (commonly taken as dolomitic shale) among the beds of nonargillaceous, microcrystalline to very fine crystalline dolomite. Its thickness in the area probably does not exceed 30 m.

Throughout most of the two map areas, the rhythmic character that is typical of the 'rhythmic' unit in the region to the east (Norford and Macqueen, 1975) is poorly displayed. Destruction of depositional texture by dolomitization generally is nearly complete; the unit is lithologically monotonous and difficult to interpret. The bulk of the 'rhythmic' unit consists of dolomite that is pale grey to pale grey-brown and predominantly fine crystalline; very fine crystalline and microcrystalline beds are less common. Medium to thick bedding predominates; a few thin-bedded and laminated beds occur at intervals in a weak expression of rhythmic character. Particulate and oolitic depositional textures are rare, or rarely recognized. Algal stromatolites are rare. Sandy dolomite beds occur only in the lower part of the unit; silty laminae are conspicuous only in its upper part. Secondary silicification is common in parts of the unit as nonselective tracery, or selective replacement of primary grains. Secondary grey chert, rare in the more typical developments of the 'rhythmic' unit to the east, occurs more or less throughout the unit, though in small quantity, as nodules and thin beds. Millimetre- to decimetre-scale vugs occur at intervals throughout the unit; some of these are lined with drusy quartz, a characteristic developed elsewhere only in the overlying, 'cherty' unit. A measured thickness of 492 m of the rhythmic unit at Section MQ-41 near 'Rumbly Creek' (65°22'N, 131°25'W) may be close to a maximum for the two map areas.

Where the 'cyclic' unit is missing (notably across the crest of Mackenzie Arch), the basal few metres of the 'rhythmic' unit normally contain at least a few beds of sandstone and sandy dolomite interbedded with dolomites similar to those higher in the unit; beds of quartzite-pebble conglomerate occur at some localities. The sandstone beds are red at many, but not all, localities; the red colouration fading out upward to grey. The sandy zone (which corresponds to the 'basal redbeds' unit) is especially thick and prominent at and near localities at which the Franklin Mountain overlies older sandstone and quartzite.

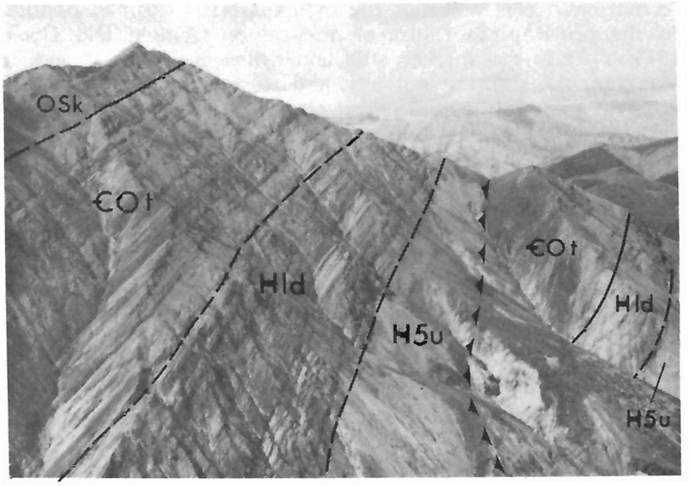

Figure 7. *Unconformable contact between Franklin Mountain Formation (transitional facies, €Ot) and Little Dal Formation (Hld), showing low-angle truncation of the latter. H5u – map unit H5, upper division; OSk – Mount Kindle Formation. Note repetition of the sequence due to thrusting. GSC 163592*

The 'cherty' unit does not differ greatly from the 'rhythmic' unit except that it includes more intervals that are extremely silicified, and contains abundant nodules of chert or drusy-quartz-lined vugs. The chert is white, instead of grey as in the underlying 'rhythmic' unit. Stromatolites replaced by white chert, typical of the 'cherty' unit farther east, are rare. The dolomite is predominantly pale grey, fine crystalline, and thin to thick bedded. A zone with oncolites is present at Section MQ-41. Thickness of the 'cherty' unit is variable because of erosion at the sub-Mount Kindle unconformity (Norford and Macqueen, 1975). The thickness of 245 m at Section MQ-41 may be fairly representative for the two map areas.

In many views of the Franklin Mountain Formation, a gross division into two parts is visible. The lower part is less resistant than the higher, and is relatively pale weathering or pale and dark striped. The higher part is brownish grey weathering, distinctly darker and less varied than the lower and, thus, might be mistaken for the Mount Kindle Formation (see below). The boundary between these two Franklin Mountain units presumably corresponds to the 'rhythmic'-'cherty' boundary, but it is difficult to pinpoint the change in weathering aspect on rocks underfoot. A subdivision of the Franklin Mountain based on weathering characteristics may be mappable; a test of this awaits more deliberate studies.

Fossils are rare in the Franklin Mountain; however, several collections of brachiopods and echinoderm fragments establish a Late Cambrian, Franconian age for at least part of the 'rhythmic unit' within Upper Ramparts map area (Norford and Macqueen, 1975). To the southwest, in the frontal Mackenzies at Keele River, strata at the base of the 'rhythmic' unit have yielded Late Cambrian, Dresbachian trilobites (ibid.). Early Ordovician gastropods have been collected from the 'cherty' unit at three localities, one of them the mountain front at Imperial River (ibid.).

The Franklin Mountain lies with pronounced unconformity, locally visibly angular, on various older formations down to and including the lower part of the Katherine Group (Fig. 2). It is overlain unconformably, almost everywhere within the present map areas, by the Mount Kindle Formation.

Cambrian and Ordovician

Transitional unit. A belt of Cambro-Ordovician strata intermediate in character between Franklin Mountain Formation and Road River Formation crosses the southwestern corner of Upper Ramparts River map area, separating the area in which the Cambro-Ordovician succession consists essentially of dolomite from that in which it consists essentially of shale (Fig. 2). The trend of this belt is more northerly than that of the principal thrust faults and, as a result, the change from Franklin Mountain Formation to the transitional facies occurs within continuous thrust sheets.

The transitional unit has received only the most cursory study at two landing sites; no stratigraphic section has been measured, and it exists essentially as a map unit recognizable in close aerial observation and traceable on air photographs. Its characteristics include a significant increase in limestone beds at the expense of dolomite (relative to the Franklin Mountain), and the appearance of intercalated beds of dark-coloured shale. At a locality immediately west of the western boundary of Upper Ramparts map area, coarse debris-flow breccia indicates that at least a part of the unit consists of slope deposits. A ribbed appearance is characteristic of most mountain-sides supported by the unit.

The transitional unit of the report area has been mapped only where the Mount Kindle Formation is recognizable above it; thus, it occupies the position of the Franklin Mountain and must be at least partly time equivalent. It is not known whether or not Middle Cambrian strata are included in the basal part (see Aitken, Macqueen and Usher, 1973, p. 33, 34 for discussion). Although detailed study of the Franklin Mountain - Road River transition remains to be carried out, it is apparent that, in the region presently considered, the lower part of the Franklin Mountain begins to change to argillaceous equivalents along a line lying northeast of the corresponding change in the upper Franklin Mountain.

The transitional unit rests unconformably on the Little Dal Formation at the southwestern edge of the stable platform area. In Selwyn Basin, it rests on various post-Little Dal Formations up to the Sekwi Formation.

By a rough graphical determination, the thickness of the transitional unit is 520 to 550 m, in the most northerly panel between 'Orthogonal River' and Arctic Red River.

Upper Ordovician and Lower Silurian

Mount Kindle Formation. The Mount Kindle Formation (Norford and Macqueen, 1975) is recognized as a regionally persistent unit of carbonates, mainly dolomite, whose dark weathering colour, resistance to weathering, and generally fossiliferous character distinguish it from the Franklin Mountain Formation below and from Silurian and Devonian carbonate formations above (Figs. 8, 25 - 27, 31).

The characteristic Mount Kindle dolomite is medium to dark greyish brown or brownish grey in colour, and very fine crystalline, with a distinctive steely lustre; it weathers sombre brownish grey. Beds of pale grey, more coarsely crystalline dolomite also occur. Although the scale of bedding ranges from thin to very thick, the overall aspect is of a thick-bedded, massive, blocky-fracturing unit. Intervals of vuggy porosity are common. The Mount Kindle dolomites

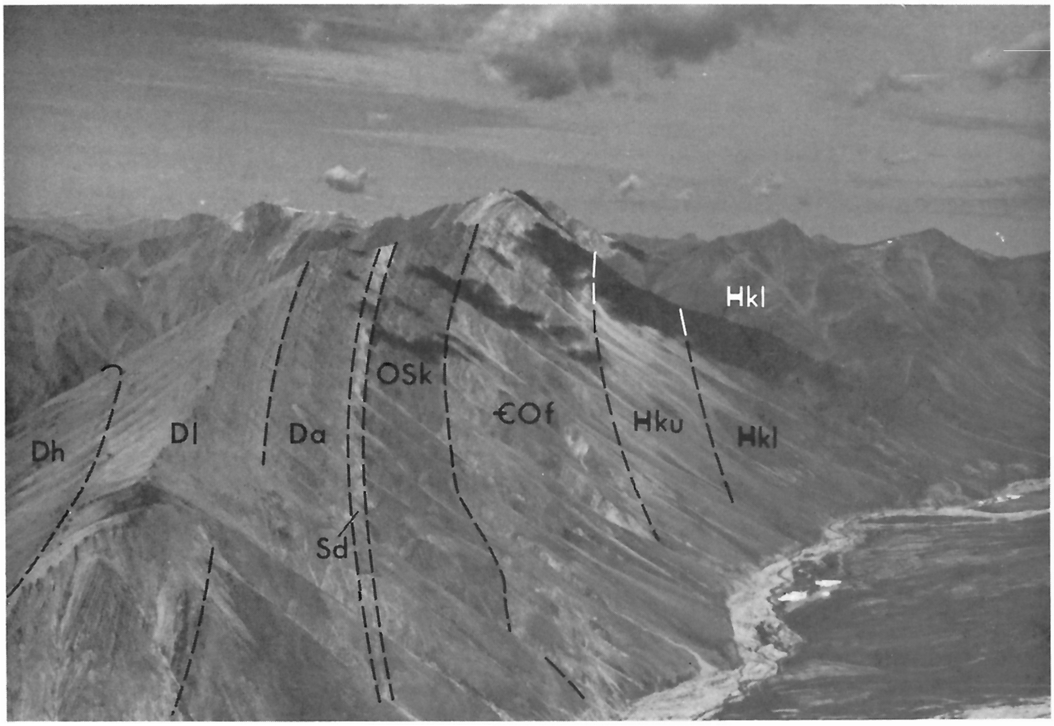

Figure 8. *Helikian to Middle Devonian section, south limb of Tawu Anticline at the southern boundary of Upper Ramparts River map area. Hku and Hkl – upper and lower divisions of Katherine Group; €Of – Franklin Mountain Formation; OSk – Mount Kindle Formation; SD – unnamed Silurian and Devonian unit; Da – Arnica Formation; Dl – Landry Formation; Dh – Hume Formation. GSC 163553*

appear mainly to be derived from micritic limestones (lime mudstones) with a variable content of whole and comminuted skeletal material. Pale grey weathering limestone occurs in the Mount Kindle in the vicinity of the facies change to shale of the Road River Formation (Fig. 2), but has not been examined in the report area.

Nodules of white and grey chert occur throughout the formation. The fossil content provides an important lithological criterion for distinguishing the Mount Kindle from other carbonate formations of the region. Most extensive exposures yield fossils, although these are obvious only where silicified. The characteristic fossils are silicified orthocone cephalopods, stromatoporoids, and corals, especially the easily recognized 'chain corals', *Halysites* and *Catenipora.*

Regionally, the Mount Kindle Formation lies unconformably on the Franklin Mountain and the Cambro-Ordovician transitional unit, but it is concordant (paraconformable) throughout Upper Ramparts and Sans Sault map areas. Its upper contact with the undifferentiated Siluro-Devonian unit (which may include equivalents of the Delorme Formation) probably is disconformable (Aitken and Cook, 1974c); that with the Bear Rock Formation is unconformable.

The Mount Kindle has been measured at a single locality, Section MQ-41, near 'Rumbly Creek' (65°22'N, 131°25'W). The thickness determined there, 245 m, probably is fairly representative for the report area, although thicknesses of nearly twice that value are known to be present at Keele River to the southeast (Macqueen, 1970).

On the basis of its fossil faunas, the Mount Kindle Formation is Late Ordovician and Early Silurian in age (Norford and Macqueen, 1975).

Upper Silurian and Lower Devonian[1]

Map unit SD. A sequence of carbonate rocks that is recessive relative to the underlying Mount Kindle and pale in colour relative to overlying and underlying strata (Figs. 8, 11, 25) marks the base of the Devonian carbonate succession over much of Upper Ramparts River and Sans Sault Rapids map areas. It is homotaxial with the formation identified, with considerable reservation, as the Delorme Formation in Mount Eduni (Aitken and Cook, 1974a) and Carcajou Canyon (Aitken and Cook, 1974c) map areas. Although the writers are confident that the unit identified as 'SD' on the accompanying maps includes the equivalent of the unit identified as Delorme in Carcajou map area, it was decided not to extend farther the use of the term 'Delorme' for two reasons:

(1) As discussed by Aitken and Cook (1974c), the term 'Delorme' has been extended to rocks far from the type section, different in lithology from the Delorme of the type area, and largely unfossiliferous.
(2) The Camsell formation has not been recognized in the region presently considered; its equivalent, if any, presumably has been mapped as part of the Delorme of southern Carcajou Canyon map area, and as part of map unit SD in Upper Ramparts and Sans Sault map areas.

Pending more detailed study, there appears to be less risk of creating nomenclatural confusion in the post-Mount Kindle, pre-Arnica interval if that interval is dealt with simply as containing an unnamed, mappable unit, 'SD'.

In Mackenzie Mountains outcrops, map unit SD consists of pale grey dolomite and minor amounts of limestone, both mainly microcrystalline. Silty and sandy beds nearly always are present, especially near the top and base. The presence of one or more beds of dolomite that are argillaceous and siliceous and that weathers deep orange to reddish orange is highly characteristic.

The subsurface equivalent of map unit SD consists of limestone and dolomite whose main distinguishing characteristics are their colour, pale brown, cream, and near-white; thin seams of waxy green shale; a general fineness of texture (microcrystalline to very fine crystalline); and the rare presence of fish remains. Other fossils, generally rare, are ostracodes, crinoids, and brachiopods.

Map unit SD as mapped in surface exposures includes the equivalents of the 'lower limestone member of the Gossage Formation' of Tassonyi (1969). Accordingly, and following a suggestion of MacKenzie (1974), the base of the subsurface Gossage Formation has been drawn beneath the dolomite (middle) member of Tassonyi (see 'Gossage, restricted', Fig. 9). Further work is required before this suggested change in nomenclature, if justified, can be formalized.

The lower contact of map unit SD is abrupt and concordant, and involves a change downward from pale-coloured carbonates with a greenish tinge to dolomites of the Mount Kindle Formation that are dark grey-brown, siliceous, cherty, and usually fossiliferous. Because Middle Silurian strata are unknown in the region, the base of unit SD is considered disconformable; Aitken and Cook (1974c) have discussed evidence for an unconformity beneath the Delorme Formation in Mount Eduni map area.

The upper contact of unit SD with dark brown limestone and dolomite of the Gossage (restricted), Bear Rock and Arnica formations is abrupt and concordant. A problem not yet resolved conclusively is whether the pronounced sub-Bear Rock unconformity continues basinward as a disconformity beneath unit SD, or as a sub-Arnica - Gossage (restricted) unconformity (MacKenzie, 1974). It is significant in this connection that no change to a shoreline facies has been observed in unit SD as its feather edge is approached, as would be expected if that edge were a depositional pinchout. This suggests that the feather edge is a result of erosional truncation at a sub-Arnica - Gossage (restricted) - Bear Rock unconformity (Fig. 9).

The unit thickens westward from a feather edge near the eastern margin of Sans Sault Rapids map area. At Section MN-12-69, the Mackenzie Mountain front immediately west of Arctic Red River (65°23'N, 131°25'W), it is 66 m thick. Projections of isopachs based on well data suggest that it may be as thick as 215 m at the mountain front at the western boundary of Upper Ramparts map area. Subsurface penetrations of unit SD within the report area all are in the east, where the unit is thin. A section 235 m thick (interval 1573 to 1808 m) was penetrated by the Decalta Trans Ocean GCOA Ontaratue I-38 well, 50 km north-northwest of the northwest corner of Upper Ramparts (formation tops by D.C. Pugh, pers. com., 1976). Locally, where unit SD is very thin, it has been included for mapping purposes as the basal part of the Arnica or Bear Rock formations.

Fish remains collected from subsurface beds we would assign to unit SD, in the C.D.R. Tenlen Lake A-73 well (67°52'N, 130°43'W) indicate a Late Silurian to Gedinnian (late Early Devonian) age (Thorsteinsson in MacKenzie, 1974).

Lower Devonian

Stratigraphic nomenclature for the Lower Devonian of the region is complicated by pronounced facies changes and by the partly independent development of nomenclature for surface and subsurface applications.

In broad terms, the stable platform region during the Early Devonian was differentiated into two main elements. The first of these elements was an extensive, stable, slowly subsiding platform characterized by the accumulation of evaporitic carbonate rocks and anhydrite that jointly make up the Bear Rock Formation; this is the Norman Wells High

[1] The writers wish to acknowledge the major contribution to all aspects of Devonian stratigraphy made by W.S. MacKenzie, especially with regard to the unpublished data provided by him. Because the manuscript for this memoir was completed after Dr. MacKenzie's resignation from the Geological Survey of Canada, responsibility for errors of fact or interpretation must rest with the writers.

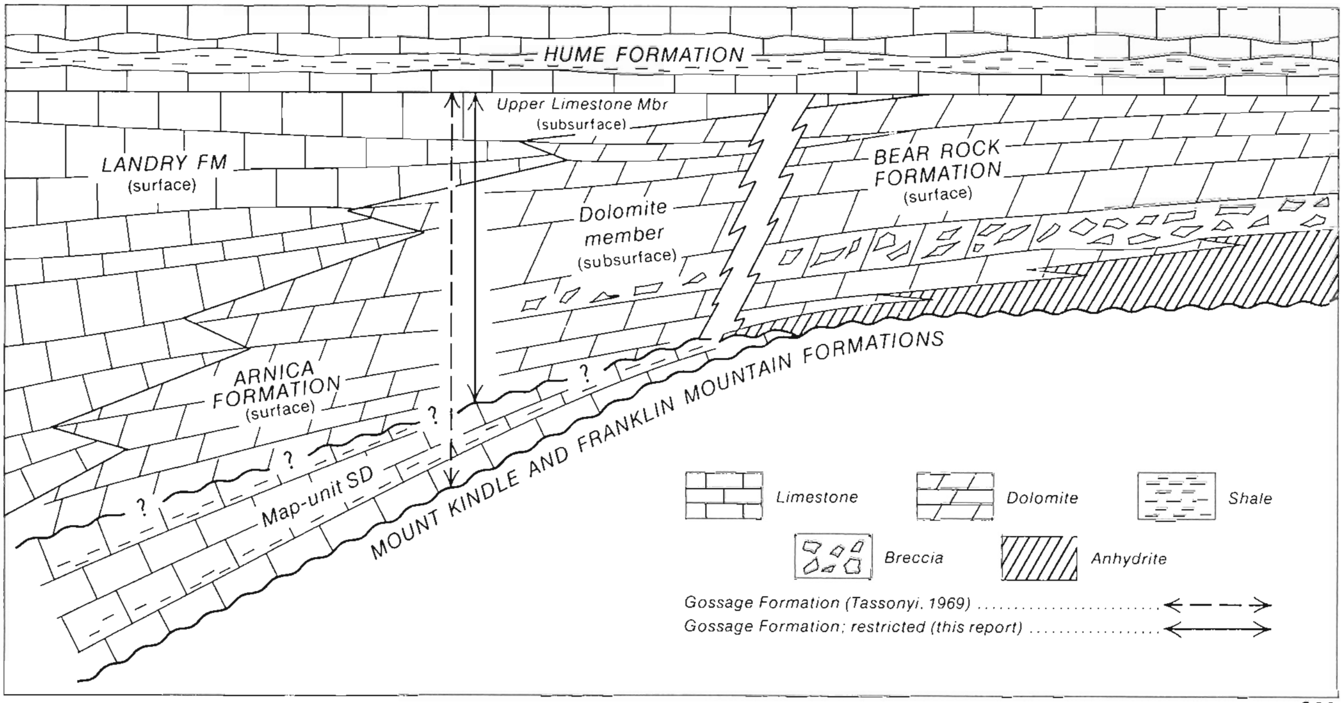

Figure 9. *Lower Devonian stratigraphic relationships.*

(Williams, 1975). Its southwesterly directed salient into Mackenzie Mountains between Keele and Hume rivers (Fig. 10) is here named the Carcajou Salient. The arcuate region flanking the High and Salient on the basinal side subsided more rapidly, and received thicker deposits of carbonates of less strongly evaporitic aspect, the Arnica, Landry, and Gossage formations (Figs. 9, 10).

The Norman Wells High and Carcajou Salient may be outlined either by the zero isopach of the unnamed Silurian and Devonian map unit and Delorme Formation (probably an erosional feather edge), or by the line along which the Bear Rock Formation changes facies to Arnica - Landry or Gossage Formation (Fig. 10); the two lines are roughly coincident. The Arnica and Landry are widely established through surface mapping both east and west of the Carcajou Salient and subsurface mapping east of the Salient. They can be recognized as the dolomite and upper limestone members, respectively, of the Gossage Formation west of the High and Salient, the term Gossage being well established for subsurface usage in that region.

Although it is probable, in view of the unconformity that locally and, perhaps generally, underlies the Arnica - Bear Rock - Gossage (restricted), that the base of the sequence is somewhat older toward the basin than near the craton, nevertheless it is clear that, whatever the lithology, the sequence under discussion is mainly of Early Devonian age. It postdates the Late Silurian to late Gedinnian map unit SD, and is everywhere overlain by the abundantly fossiliferous, Eifelian (lower Middle Devonian) Hume Formation. At Powell Creek (Section MN-6-69; 65°17'N, 128°46'W), conodonts of probable Emsian (late Early Devonian) age have been collected from the top of the Bear Rock Formation ('Gossage'; see Lenz and Pedder, 1972). On the other hand, the Landry Formation in northeasternmost Nahanni map area has yielded a number of fossil collections dated as late Eifelian or early Givetian (A.W. Norris, cited in Gabrielse et al., 1973, p. 84, 85). An Eifelian (early Middle Devonian) age for part or all of the Landry and upper Gossage formations of Upper Ramparts River and Sans Sault Rapids map areas and their Bear Rock equivalents, therefore, is entirely possible.

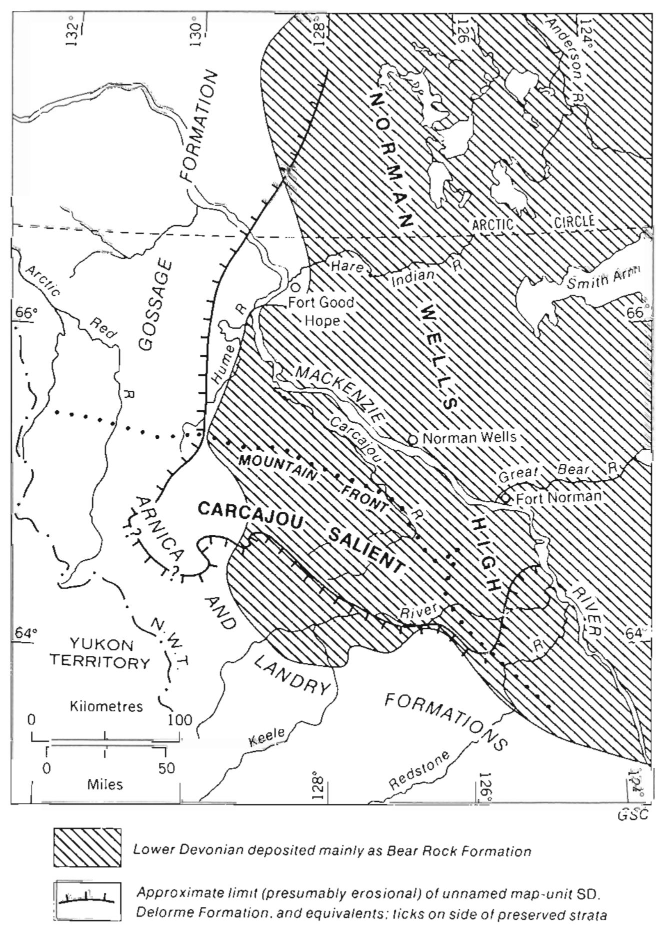

Figure 10. *Sketch map showing the outlines of the Norman Wells High and its Carcajou Salient, paleogeographic features of Early Devonian age. Compiled from various sources cited in the text.*

Arnica Formation. The Arnica Formation (Douglas and Norris, 1961; Gabrielse et al., 1973) consists of alternating thin sequences of beds of pale brown and dark brown dolomite which provide the conspicuous colour banding and strongly ribbed profile of the formation in outcrop (Figs. 8, 11, 31). The dark brown dolomite is commonly argillaceous and very fine crystalline, while the pale dolomite is medium crystalline, sucrosic, and commonly porous. Brecciated intervals and minor beds of dolomite breccia are normal occurrences, especially near the facies change to Bear Rock lithologies. The basal contact of the Arnica is abrupt and concordant, and probably is unconformable at least locally (Douglas and Norris, 1961). The contact with the overlying Landry Formation is gradational by interbedding, and is drawn at the base of the lowest thick interval of pale grey weathering limestone.

The Arnica Formation is 190 m thick at Section MN-12-69 (65°23'N, 131°25'W). Westward from that section, beds of limestone are increasingly important in the Arnica, and the overlying Landry Formation thickens, apparently at the expense of the Arnica.

Landry Formation. The Landry Formation (Douglas and Norris, 1961; Gabrielse et al., 1973) consists of brown and dark brown limestone, characteristically occurring as thick, well-defined beds that weather pale grey, and are notably more resistant than the underlying Arnica and overlying Hume formations (Figs. 8, 11, 28, 31). The rocks are mainly lime mudstones within which scattered granular and pelleted areas are distinguishable. They are sparsely fossiliferous, with a fauna consisting mainly of ostracodes.

The Landry overlies the Arnica at a contact that is interbedded and gradational. The top of the formation is drawn at the abrupt appearance of limestone of the Hume Formation, which is dark grey, rich in skeletal particles and fossiliferous. This contact appears concordant and conformable but, possibly, is disconformable (Bassett, 1961).

The Landry Formation and its subsurface equivalent, the upper limestone member of the Gossage Formation, are coextensive with the Arnica Formation and its subsurface equivalent, the dolomite member of the Gossage. The Landry occurs basinward of the Norman Wells High and Carcajou Salient, but eventually grades southwestward into shaly facies of the upper Road River Formation.

On the western flank of the Carcajou Salient, the Landry thickens westward along the Mackenzie Mountain front from its first appearance as a mappable limestone unit, near 'Shortcut Creek'. It is 382 m thick at Section MN-11-69, near 'Rumbly Creek', and continues to thicken westward, apparently at the expense of the underlying Arnica Formation.

Bear Rock Formation. The Bear Rock Formation (Tassonyi, 1969) consists in the subsurface of a sequence of bedded dolomite, dolomite breccia, limestone and anhydrite. Outcrops of massive dolomite breccia are characteristic of the surface expression of the formation.

Description of Bear Rock lithologies is best commenced with Tassonyi's (ibid.) study of the formation in the subsurface, where circulating groundwater has had 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 309 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 135 m thick, that "....consists of

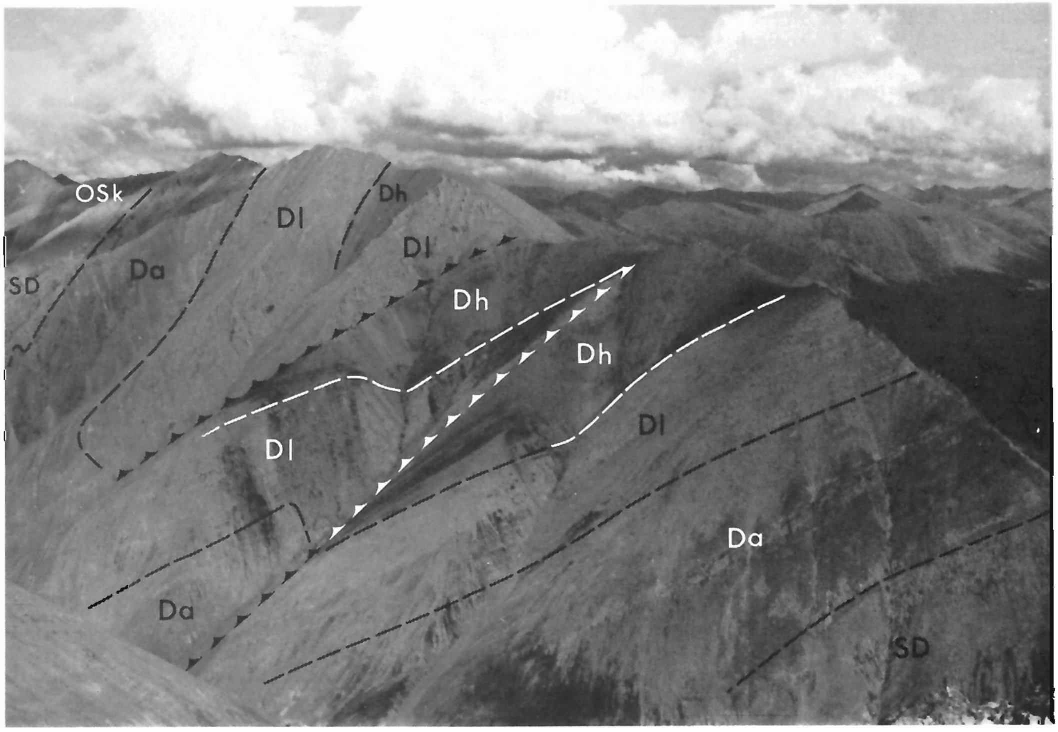

Figure 11. *Characteristic deformation of the Lower to Middle Devonian succession, core of Bolstead Synclinorium, 4.8 km west of the 'Grand Forks' of Arctic Red River. OSk – Mount Kindle Formation; SD – unnamed Silurian and Devonian unit; Da – Arnica Formation; Dl – Landry Formation; Dh – Hume Formation. GSC 163588*

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. "...Minor amounts of anhydrite, in the form of interstitial filling are normally associated with this member" (ibid., p. 44).

Outcrops of the Bear Rock Formation have been affected profoundly by solution, and give a false impression of the original lithology. The evaporitic member is represented by a chaotic, calcareous and gypsiferous breccia of angular to slightly rounded dolomite fragments from sand size to 15 m in diameter. Anhydrite is never seen, and its hydrated descendent, gypsum, outcrops only rarely. The widespread occurrence of active sinkholes along the trace of the Bear Rock and in places the overlying Hume Formation testifies to the presence of evaporites undergoing solution beneath the surface. Loss of circulation of drilling fluid while penetrating the Bear Rock Formation is a regional exploration problem. The fact that the formation accepts coarse materials such as camp garbage and small spruce trees pumped into it shows that the porosity responsible for lost circulation is cavernous. Such cavernous porosity probably is caused by solution related to groundwater circulation, and probably is not characteristic of the formation below the groundwater zone.

The brecciated member at the surface resembles its subsurface counterpart rather more closely. It outcrops as moderately resistant, bedded but partly brecciated, brown, petroliferous dolomite.

Where the Bear Rock Formation outcrops on steep slopes, the breccias commonly support spectacular 'hoodoos'. Elsewhere, the formation tends to be less resistant than overlying and underlying formations, poorly exposed, and poorly vegetated.

Where the Bear Rock rests on pre-Devonian formations, as over the Norman Wells High and the Keele Arch (Cook, 1975), east of the report area, its base clearly is unconformable. Moderate paleotopographic relief has been observed at a number of localities, and the thickness and distribution of the underlying Mount Kindle Formation are, to a large extent, controlled by the sub-Bear Rock unconformity. The question of the stratigraphic position of the corresponding unconformity in more basinward areas is considered above, under 'Map unit SD' (see also Fig. 9).

The top of the Bear Rock Formation is drawn at the abrupt appearance of limestone of the Hume Formation. The contact is concordant and conformable or, possibly (according to Bassett, 1961), disconformable.

Because of solution and attendant collapse at and near the surface, thicknesses determined from outcrop sections and shallow wells are virtually meaningless. Subsurface thicknesses in Sans Sault Rapids map area range from 184 to 296 m. A distinct westward-thickening trend in the Bear Rock and equivalent formations is well established (Law, 1971; Gilbert, 1973; Kunst, 1973).

The basinward facies change associated with the disappearance of the Bear Rock anhydrite (Figs. 9, 10) has economic significance; oil and gas shows have been encountered in wells drilled near the transition zone.

Gossage Formation (restricted). The name Gossage Formation (Tassonyi, 1969) is established in subsurface practice in the region northwest of the Norman Wells High for the equivalents of the Arnica and Landry formations jointly, plus an underlying unit of pale limestone with intercalated green shale (lower limestone member) which, following a suggestion of MacKenzie (1974) is regarded as belonging to the informal unit SD. This is necessary in order to maintain a clear and easily understood relationship between surface and subsurface nomenclature. We prefer not to use the term Gossage in surface mapping in order to emphasize the fact that the Arnica and Landry formations can be traced completely around the Carcajou Salient (Fig. 10). In the subsurface, the Bear Rock-Gossage cutoff is placed where bedded anhydrite disappears from the Lower Devonian succession (Fig. 9).

The description of Arnica and Landry lithologies (above) serves to characterize the dolomite and upper limestone members of the Gossage Formation, respectively.

The Gossage Formation is about 275 m thick near the facies change to Bear Rock lithology, and thickens westward to 416 m (interval 1330 to 1746 m) at the Amoco PCP A-1 Cranswick A-22 well. This formational thickening is accompanied by expansion of the upper limestone member at the expense of the lower dolomite member.

Middle Devonian

Hume Formation. The Hume Formation (Bassett, 1961) consists of dark grey, variably argillaceous, fossiliferous limestone with subordinate shale interbeds. Generally it can be separated into two members of about equal thickness; a lower, thin-bedded, recessive member containing a few shale beds, and an upper, thick-bedded, resistant member generally lacking shale beds. This twofold character and the recessive nature of the overlying Hare Indian Formation give rise to a distinctive topographic expression, easily recognized on aerial photographs (Figs. 13, 25, 27). The informal lower and upper members correspond to the Headless and Nahanni formations, respectively, of map areas to the southeast; for instance, Dahadinni and Wrigley map areas (Douglas and D.K. Norris, 1960) and Wrigley Lake map area (Gabrielse et al., 1973).

Most of the Hume limestones are characterized by the presence of calcilutite (lime mud, micrite) intermixed with varying amounts of whole and fragmental skeletal remains. The limestones range from calcilutites with less than 10 per cent skeletal material (mudstone, micrite), through varieties richer in skeletal particles (skeletal wackestone, biomicrite), to types in which a self-supporting fabric of skeletal particles is infilled with lime mud (skeletal packstone, biomicrite, muddy biocalcarenite). Biocalcarenites with sparry pore-filling cement (grainstone, biosparite) are rare. Nearly all limestone types yield a significant insoluble residue of clay, and a few per cent of quartz silt is common. Bedding typically is thin and nodular in the lower member, and partings and interbeds of brown to grey shale are common. In the upper member, bedding is mostly thick and relatively regular, and shale is inconspicuous or missing.

The abundant and varied fauna of the Hume Formation is dominated by solitary corals, small colonial corals, brachiopods and stromatoporoids; trilobites and ostracodes occur in a few beds; goniatites are rare.

The abrupt, concordant and possibly disconformable contact at the base of the Hume has been described above (see Landry Formation). The conformable upper contact is marked by the appearance of dark bituminous shale of the Hare Indian Formation.

Typical thickness of the Hume over the Norman Wells High (Fig. 10) is about 90 m. Basinward from the High, thickness increases to about 150 m.

The Hume faunas have been studied thoroughly, and indicate that the formation is almost entirely Eifelian (early Middle Devonian) in age, with a metre or so of Givetian beds at the top (Lenz and Pedder, 1972).

Hare Indian Formation. The Hare Indian Formation (Bassett, 1961) is a recessive interval consisting mostly of shale that overlies the Hume Formation and is overlain by either Ramparts limestone (Figs. 13, 14) or the distinctive shale of the Canol Formation. Throughout the region covered by this report, the formation, where complete, can be divided into two members, a lower, black 'spore-bearing member' (Tassonyi, 1969), and an upper member of grey-green shale.

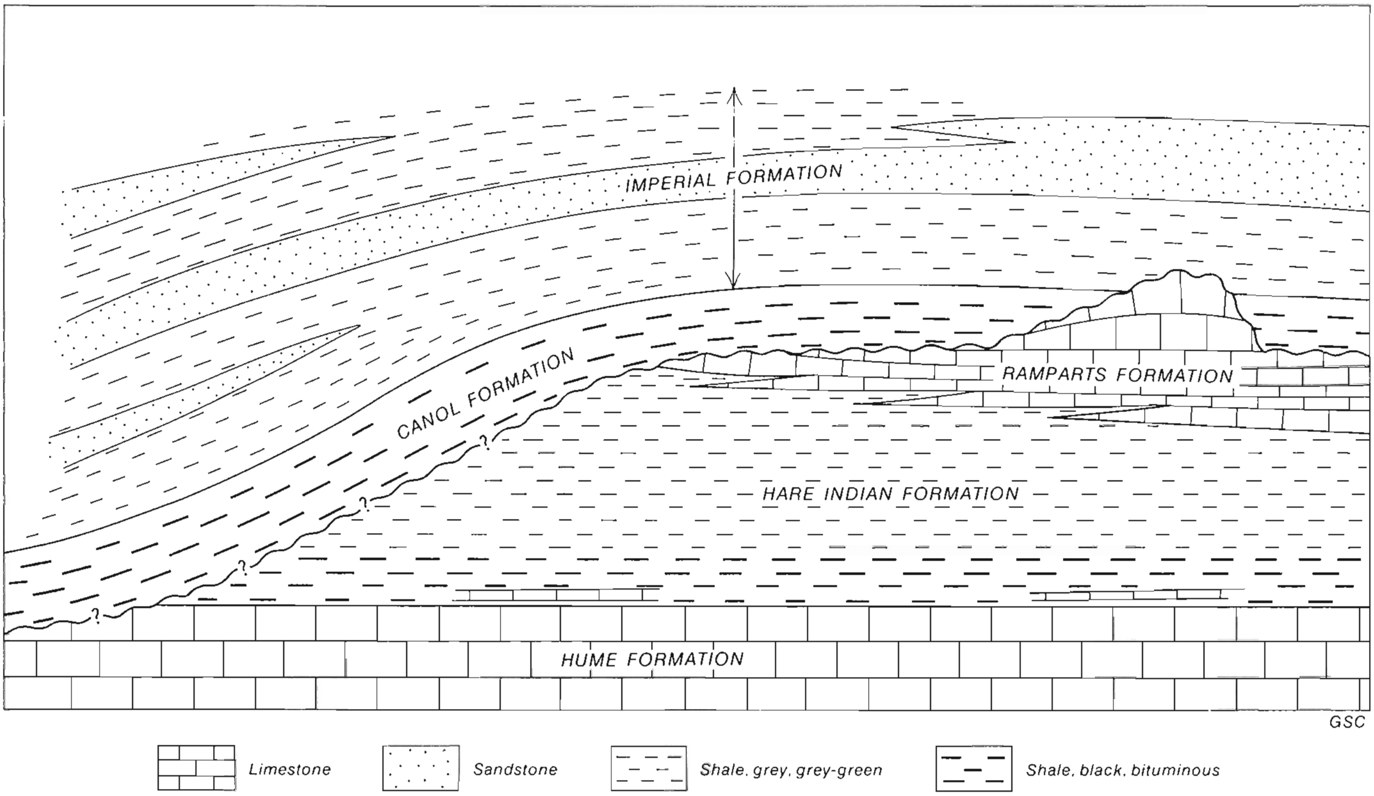

Figure 12. *Middle and Upper Devonian stratigraphic relationships.*

The spore-bearing member, typically about 15 m thick, consists of extremely fissile, brown-black, bituminous shale containing abundant fossils, notably *Styliolina, Tentaculites* and the algocysts *Leiosphaeridia* and *Tasmanites* (the 'trilete spore cases' of Tassonyi, ibid.). The abundance of algocysts decreases from east to west. The presence of one or more thin beds of fibrous calcite is characteristic of the basal part of the member (MacKenzie, 1972).

The upper member consists of grey-green shale, a variable content of thin siltstone beds and, in some exposures, a few thin beds of argillaceous limestone. The sparse macrofauna consists mainly of brachiopods.

The basal contact of the Hare Indian Formation is abrupt at some localitites and gradational at others. There is no evidence of a break in deposition. The contact is drawn beneath the lowest bed of dark bituminous shale. The upper contact also is gradational by interbedding with the platform member of the Ramparts Formation (Fig. 14). Where the latter is missing, the Hare Indian is overlain by the Canol Formation at a contact that is abrupt and unconformable (Fig. 12).

The Hare Indian Formation displays pronounced thickness variations due, in part, to facies change to limestone of the Ramparts Formation and, possibly, in part to erosional truncation of the Hare Indian at a sub-Canol unconformity (Fig. 12). Thickness of the Hare Indian locally exceeds 198 m, but beneath thick developments of the Ramparts Formation, it is as thin as 137 m. The Hare Indian thins westward and disappears along a north-trending line that cuts the Mackenzie Mountain front between 'Rumbly Creek' and the western boundary of the report area. This thinning is due either to erosion at an unconformity beneath the Canol Formation (Bassett and Stout, 1967; Norris, 1967), or to a change of the Hare Indian grey-green shale to black, Canol-like shale (see below, under 'Canol Formation').

In the Atlantic et al. Manitou Lake L-61 well (66°20'45"N, 128°58'00"W), north of Sans Sault Rapids map area, the entire Hare Indian interval is occupied by limestone (Gilbert, 1973). The Hare Indian Formation is of Givetian (late Middle Devonian) age (A.W. Norris, 1968; Lenz and Pedder, 1972).

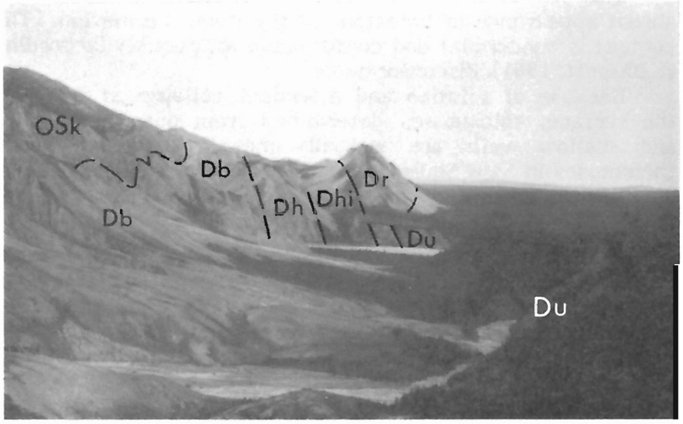

Figure 13. *View west-northwest toward the termination of the bank of Ramparts Formation limestone near Powell Creek. Rapid thinning toward the viewer is obvious; no Ramparts Formation is present in a cross-section through the camera point. OSk - Mount Kindle Formation; Db - Bear Rock Formation; Dh – Hume Formation; Dhi – Hare Indian Formation; Dr - Ramparts Formation; Du - Canol and Imperial formations. GSC 159961*

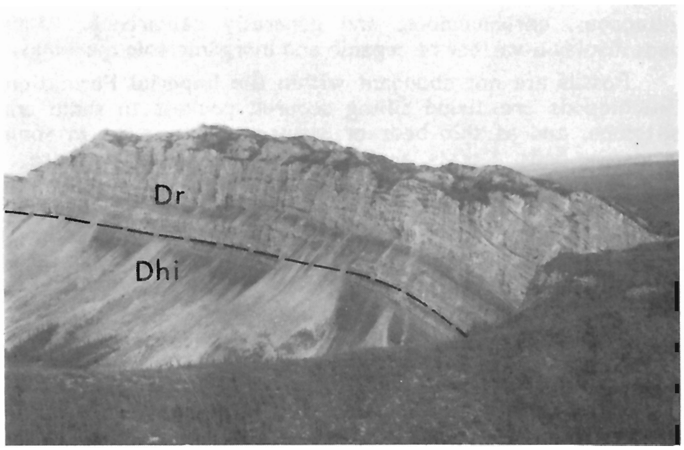

Figure 14. *Thick development of the Ramparts Formation at Bell Creek, view to the northwest. Note the more thickly bedded reef member above, and the less massive platform member below. A unit of dark shale assigned to the platform member pinches out westward. Dhi – Hare Indian Formation; Dr – Ramparts Formation. GSC 159962*

Figure 15. *Sandstone of the Lower Cretaceous Sans Sault Formation, conglomeratic at the base, overlying Middle Devonian Ramparts limestone, Mackenzie River at Bat Hills. Note erosional relief at the contact. Dr – Ramparts Formation; Ks – Sans Sault Formation. GSC 148048*

Ramparts Formation. The Ramparts Formation (Kee Scarp Formation of Bassett, 1961, and others; see Tassonyi, 1969) is a limestone unit, feature-forming where of significant thickness (Figs. 13, 14, 30), that overlies and is partly equivalent to the upper part of the Hare Indian Formation, and is overlain by the Canol Formation or, locally, by the Imperial Formation (Fig. 12), or by Lower Cretaceous sandstone (Fig. 15).

Two members are recognized (Tassonyi, 1969), a lower, 'platform member' and an overlying and somewhat discontinuous 'reef member' that is less extensive than the underlying platform.

The platform member (Fig. 14) is characterized by well-bedded, brown and brownish-grey limestone with shale interbeds. The limestones have a variable content of both lime mud and siliciclastic mud. Beds increase in thickness upward and, locally, become very thick bedded. Fossils, notably brachiopods, are abundant.

The reef member (Fig. 14) is of special importance as the reservoir formation of the Norman Wells oil field. It consists of very thick bedded, resistant, relatively pure limestone that is pale grey to very pale brown in colour; numerous observers use the term 'honey-coloured'. The extent of true reefal facies (in the sense of 'reef core', with abundant framework-building and sediment-binding organisms more or less in situ) is restricted. The reef-forming organisms are corals and stromatoporoids. Much more characteristic of the formation are fine to very coarse coral-stromatoporoid grainstones (biocalcarenites, biocalcirudites; biosparites, biosparrudites; rudstones) composed of well-worn skeletal fragments, generally with primary void space partly or completely filled with sparry cement. Partial dolomitization is observed locally, for example in the Norman Wells reservoir. The fragmental rocks are commonly cross-bedded.

The Ramparts Formation is in conformable and gradational contact with the underlying Hare Indian (Figs. 13, 14); the contact is drawn where limestone becomes dominant. Surface and subsurface observations confirm that the platform member grades laterally also to Hare Indian Formation (Fig. 12); as noted above, Hare Indian Formation shale is absent in the Atlantic et al. Manitou Lake L-61 well and the entire interval is occupied by limestone (Gilbert, 1973, p. 230). Such a gradational relationship is not established for the reef member, possibly because evidence has been removed at a sub-Canol unconformity (see below). Tassonyi (1969) summarized the evidence and the various possibilities. For whatever reason, the upper-lateral contact of the reef member is abrupt. Normally, the Ramparts is overlain by dark siliceous shale of the Canol but, locally (e.g., Imperial Anticline at Mountain River; Bell Creek), where the thickness of the Ramparts Formation is near its maximum, the Canol is missing and the Ramparts is overlain by the Imperial Formation (Fig. 12). In the northeastern corner of Sans Sault Rapids map area, the Ramparts Formation is overlain by Lower Cretaceous sandstone (Fig. 15).

With the exception of the anomalous section at the Manitou Lake L-61 well (see above), the thickness of the platform member ranges up to about 90 m, and that of the 'reef member' up to about 150 m (Bassett, 1961, as 'Kee Scarp Formation'). Gibert (1973, Fig. 10) provided an isopach map of the Ramparts Formation. The variation in thickness is certainly due in part to reef-building; the additional effect of possible sub-Canol erosional sculpturing is difficult to evaluate.

The Ramparts Formation is entirely of Givetian age (A.E.H. Pedder, pers. com., 1974).

Upper Devonian

Allochthonous limestones. A thin unit, rarely exceeding 15 m, comprising beds of limestone of subaqueous debris flow, grain flow, and turbidity-current origin, has been described from several localities in the region where it intervenes between the Ramparts limestone and the Canol shale (Braun, 1966; MacKenzie, 1970, 1973). The allochthonous beds are of early Frasnian age, according to the contained microfossils. Although they are undeniably important to the interpretation of the geological history of the region, these beds lack the thickness, continuity, and ease of field identification necessary to permit their being mapped at the scale of 1:250 000.

Canol Formation. The Canol Formation (Bassett, 1961; Tassonyi, 1969) is recognized as a unit of distinctive, black siliceous shale, somewhat more resistant than the Hare Indian Formation, that overlies the Ramparts and Hare Indian formations.

Two kinds of shale make up the Canol Formation. The first and most characteristic, generally making up the larger part of the formation, is dark grey to black, hard and siliceous, with a distinctive blocky fracture. Some of this shale contains up to 90 per cent silica. The second is fissile and sooty, and indistinguishable from the shale of the spore-bearing member of the Hare Indian Formation. A few, large, oblate-spheroidal, calcareous concretions occur in many exposures. Outcrops of the Canol are characteristically coated with a sulphur-yellow bloom of jarosite (a hydrous iron-potassium sulphate). This, combined with the cliff-forming tendency of the formation in canyon exposures, makes it readily recognizable where exposures are extensive, though difficulty may be experienced in areas of poor outcrop. In the subsurface, the formation is easily recognized on gamma-ray logs by its high radioactivity.

Macrofossils are extremely rare in the Canol Formation. The microfauna consists of radiolaria and conodonts, the latter indicating a Frasnian (early Late Devonian) age (Lenz and Pedder, 1972).

The base of the Canol is abrupt and concordant. Many reports, published and unpublished, have made reference to Canol Formation (or Canol-like black shale) resting on formations down to and including the Hume and even older formations. The prevailing published opinion of petroleum geologists concerned with the region (e.g., Bassett and Stout, 1967; Gilbert, 1973; Kunst, 1973) is that the relationships described record a sub-Canol erosional unconformity. This view has been tentatively followed in Figure 12.

G.K. Williams (pers. com., 1974) suggests that the case for a sub-Canol erosional unconformity is not proved, and that the relationships referred to in the preceding paragraph may record instead extreme condensation of Ramparts and Hare Indian equivalents in a deep basin. D.C. Pugh (pers. com., 1976) has prepared a subsurface correlation section that is readily interpreted in the same way.

The question remains unsettled but, because it has important implications in petroleum exploration as well as scientific importance, the relationship of the Canol to underlying formations merits further intensive study.

An average thickness for the Canol Formation of the region is about 80 m. The formation pinches out completely over the thickest developments of the underlying Ramparts Formation (Fig. 12) and, in the northeast, is removed completely by erosion associated with the sub-Cretaceous unconformity.

Imperial Formation. The Imperial Formation (Bassett, 1961; Tassonyi, 1969) is a thick sequence of marine shale, siltstone and sandstone that overlies the Canol Formation and, locally, the Ramparts Formation, and comprises the youngest Paleozoic strata of the report area.

The formation is dominated by shale that is grey or greenish grey, partly silty, and weakly fissile. Plant fragments commonly are present, and zones with calcareous concretions occur locally.

Siltstone is prominent in the Imperial Formation. It is greenish grey, micaceous and calcareous, generally thin bedded and laminated.

Sandstone forms a subordinate part of the formation; the amount and position of sandstone units within the formation vary from place to place in a manner that has yet to be worked out, but they are clearly more prominent in the upper part of the formation. The sandstone is grey-green to pale brown, very fine and less commonly fine grained, argillaceous, carbonaceous, and generally calcareous. Many beds display a variety of organic and inorganic sole markings.

Fossils are not abundant within the Imperial Formation. Brachiopods are found filling scoured pockets in shale and siltstone, and as thin beds or stringers of coquina in some sandstone beds. Corals, ammonoids and gastropods are rare.

The basal contact of the Imperial is generally gradational over a metre to tens of metres, but has been described as locally abrupt (Bassett, 1961). The formation is overlain unconformably by Cretaceous strata everywhere in the region, and its thickness variation is largely controlled by erosion at that unconformity.

Along the Mackenzie Mountain front, the maximum preserved thickness reaches 850 m. Southward thickening is evident; the Imperial is 1090 m thick at Section MN-8 (64°33'N, 128°36'W), south of Sans Sault Rapids map area. To the northeast, the formation is progressively bevelled at the sub-Cretaceous unconformity, and is missing northeast of a line that trends northwest and passes near West Mountain.

The Imperial Formation is entirely of Late Devonian, Frasnian and Famennian ages (Lenz and Pedder, 1972).

Undifferentiated Hare Indian, Canol, and basal Imperial shales. In continuously exposed sections and areas of good outcrop, little difficulty is encountered in drawing Hare Indian-Canol and Canol-Imperial contacts. Nevertheless, the two lower formations are recessive and usually covered and heavily vegetated, as is the basal shale of the Imperial Formation (the interval beneath the lowest sandstone). As a result, the two contacts normally cannot be traced any distance on airphotos, in the absence of good ground control. On the other hand, the top of the Hume Formation and base of the lowest Imperial sandstone are excellent airphoto markers (Fig. 32). Accordingly, in Upper Ramparts and the southwest corner of Sans Sault, we have mapped the Hare Indian, Canol, and basal Imperial shales (Figs. 26, 28) as a single, undifferentiated map unit (Dhci).

Pre-Mesozoic stratigraphy of Selwyn Basin[1]

Precambrian

Helikian(?)

The exposed Helikian succession of the stable platform region south of Plateau Fault comprises only the Little Dal Formation and the upper two subunits of map unit H5. The base of the Hadrynian(?) Rapitan Group is everywhere in unconformable contact with the underlying Little Dal. The Helikian units of the Plateau Sheet are somewhat thicker than their equivalents of the stable platform, but are identical lithologically.

Hadrynian(?)

Rapitan Group. Within the report area, the Rapitan Group is present only south of the trace of Plateau Fault, in the southwestern corner of Upper Ramparts River map area.

The Rapitan of Upper Ramparts consists of moderately resistant, dark-weathering, almost entirely clastic rocks (Fig. 16). The tripartite subdivision mapped in areas to the south (Gabrielse et al., 1973; Aitken, Macqueen and Usher, 1973) has not been observed. Neither a basal unit dominated by dark red argillite and siltstone nor a middle unit of diamictite is present; apparently only the upper division of the Rapitan Group is represented.

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[1] Selwyn Basin in the present context is viewed as a geographically fixed region whose behaviour was, on average, more strongly negative than that of regions to the north and east, and whose margins are drawn arbitrarily at the feather edge of the Hadrynian succession. Viewed epoch-by-epoch, the margins underwent substantial migrations, as will be clear from the following account.

Figure 16. *Helikian to Lower Cambrian succession in the hanging wall of Plateau Fault, at longitude 130°30' (Bonnet Plume Lake map area). Hld – Little Dal Formation; Hr - Rapitan Group; Hk – Keele Formation; Hs – Sheepbed Formation; Ꞓb - Backbone Ranges Formation; Ꞓsk – Sekwi Formation; Di – Imperial Formation. GSC 163583*

The Upper Rapitan is a flysch-like formation consisting essentially of an alternation of resistant beds of impure sandstone and units composed of shale. The sandstone beds are green to dull dark green and greenish grey in colour, and under the hand lens have a 'pepper and salt' aspect. They are predominantly very fine grained, grading to siltstones; beds as coarse as medium grained are rare. The fabric of the sandstone is grain supported, but nearly all pore space is filled with greenish argillaceous matrix. A small content of calcite is normal. Sole-markings are by no means conspicuous, but flame structure is typical. As is generally the case in fine-grained flysch sandstones, grading is rarely observable.

Beds of pebble conglomerate and grit are fairly conspicuous but are only minor constituents of the Rapitan of Upper Ramparts River map area, where they occur throughout the formation instead of mainly near the top as in map areas to the southwest (see Sections U-8 and AC-540 in Aitken, Macqueen and Usher, 1973). These poorly sorted rocks consist of a grain-supported framework of subangular granules and pebbles that rarely exceed 1 cm in diameter, and an unsorted, dark green matrix of clay and sand. Chert (in part oolitic) and banded ('colloform') chalcedony with some jasper are conspicuous among the coarser clasts; white to pale blue-grey colours are prominent, but pink, green, and other colours are present. Among the other types of clast, quartzite and green, 'Rapitan-like' sandstone are prominent. Well-rounded quartz grains contrast markedly with the other, relatively angular clasts. Most beds contain rip-up clasts of the underlying shales.

Upper Rapitan shale is well indurated and chippy, and ranges from grey to green in colour, although greenish grey is most characteristic. Many intervals composed of shale contain a carbonate component. Brown-weathering, secondary calcite occurs in nodular concretions and as thin, brown-weathering beds, some of which display cone-in-cone structure.

The penecontemporaneously folded and slumped intervals that characterize the Upper Rapitan to the southwest (ibid.) were not noted in the Rapitan during the admittedly cursory examination of the formation in the report area. This, coupled with the apparent increase in pebble conglomerate beds, suggests that these northerly exposures are close to the margin of the Rapitan basin. The northeastward disappearance of the Rapitan, then, may be as much due to depositional pinchout as to subsequent erosion. This suggests the further hypothesis that, during Rapitan deposition, the southwestern flank of Mackenzie Arch may have acted as a hinge line; further investigation is required.

No section of the Rapitan has been measured in Upper Ramparts River map area, but the formation is markedly reduced from the thicknesses of 1.6^{+} km and more that are present to the southwest, and it is missing north of Plateau Fault. By a graphic determination, the Rapitan is about 520 m thick at the south border of the map, near 131°15'W.

The Upper Rapitan lies on the Little Dal Formation with marked unconformity. This relationship records transgressive overstep of the Middle and Lower Rapitan by the Upper Rapitan. In the region under consideration, the Rapitan-Keele contact appears conformable and gradational, and is drawn at the base of the lowest, thick, feature-forming unit of quartzite or dolomite characteristic of the Keele Formation.

Keele Formation. The Keele Formation is a sequence of strata characterized by thick, resistant units of quartzite and dolomite that form a succession of prominent topographic ribs above the moderately resistant Rapitan and beneath the recessive Sheepbed Formation (Fig. 16), and commonly support extensive stripped surfaces.

Most important and characteristic of Keele rock types are limestone and dolomite, distinctive in that, of all of the carbonate strata of the region, these alone are commonly medium and locally coarse crystalline. Notable also is the high proportion of carbonate beds having coarsely particulate depositional textures, including granule to cobble conglomerates. Stromatolitic carbonates are encountered in most sections. The limestone weathers pale grey, and the dolomite orange; both tend to occur in thick beds, but thin-bedded, flaggy intervals also occur.

Quartzite beds also are typical of the Keele, though volumetrically less important. In contrast to the immature Rapitan sandstone, these beds are grey, fine-grained orthoquartzites, commonly rust specked. They are thin to thick bedded, and some of the thin-bedded intervals have black shaly partings. Beds of chert- and jasper-rich grit and pebble conglomerate similar to those in the upper part of the Rapitan Group also occur at some localities, especially near the base of the Keele.

Intervals and beds of shale, mainly black in colour, occur throughout the Keele Formation, but tend to be covered.

The Keele Formation is missing from Sans Sault Rapids map area, and occurs in the southwest corner only of Upper Ramparts. No section of the formation has been measured there, but graphic determinations from the geological map indicate a thickness on the order of 150 m. This indicates pronounced thinning relative to exposures to the southeast, where, in Mount Eduni (106A) map area, for instance, thicknesses are on the order of 460 m.

Our observations suggest that the base of the Keele is conformable and gradational with the Rapitan Group. The contact with the overlying Sheepbed Formation is abrupt and apparently conformable.

Sheepbed Formation. The youngest of the formations assigned to the Proterozoic is the Sheepbed Formation, which is easily identified on the ground and air photographs as a recessive unit of shale that appears black in outcrop (Fig. 16).

The Sheepbed consists of fissile, noncalcareous shale that is dark brownish grey to black. A few thin beds of dolomite that are dark grey, silty and micaceous are present. The formation is usually poorly exposed, although it supports little vegetation.

No section of the Sheepbed has been measured within the report area but the northwestward thinning that is documented for the Sheepbed and other Hadrynian units (Gabrielse et al., 1973; Aitken, Macqueen and Usher, 1973) clearly continues into Upper Ramparts River map area. Graphic determinations along the southern border of the map indicate a thickness of 210 to 270 m.

The base of the Sheepbed apparently is conformable. The contact with overlying Lower Cambrian sandstones is concordant, but Gabrielse et al. (1973) suggest that it is unconformable.

Paleozoic

Lower Cambrian

Backbone Ranges Formation. The Backbone Ranges Formation (Gabrielse et al., 1973) is a thick, very resistant, sandstone-dominated, brightly coloured and well-bedded unit that forms an imposing scarp above the recessive Sheepbed Formation (Fig. 16).

The thin- to thick-bedded sandstones and quartzites are grey, white, dull yellow, pink and deep red. They differ from the Proterozoic orthoquartzites in that, although very fine and fine-grained beds predominate as in older formations, few intervals of any appreciable thickness lack beds that are medium grained or coarser. Many of the sandstone beds are dolomitic, and grade to sandy dolomite. Mud cracks and crossbedding are widespread, ripple marks and burrows are rare. Beds with the trace-fossil *Skolithos*, long slim cylinders oriented perpendicular to bedding, occur in most sections and tend to confirm the Paleozoic age of the formation.

The Backbone Ranges Formation also contains much dolomite that is microcrystalline to very fine crystalline and grey, pink, and lavender in colour, weathering yellow, orange and pink. The dolomite is largely sandy, intergrades with the dolomitic quartzite and displays similar sedimentary structures. Cryptalgal lamination is common, but no stromatolites have been observed.

No complete section of the Backbone Ranges Formation has been measured in Upper Ramparts River map area. It is notably thinner than in its type area far to the south in Glacier Lake map area (Gabrielse et al., 1973; Aitken, Macqueen and Usher, 1973). It is about 600 m thick as determined graphically on the geological map, but this thickness includes a thick unit near the top that is nearly 80 per cent dolomite. Detailed description of a section might result in the Backbone-Sekwi contact being placed lower; the contact to which the above thickness is measured is the lithologic change that can be mapped more or less consistently in the particular area.

The assignment of an Early Cambrian age to the Backbone Ranges Formation is based on two considerations; first, its apparent facies relationship to fossiliferous carbonate beds of the Sekwi Formation (Gabrielse et al., 1973, Fig. 7) and second, the presence in the Backbone of trace-fossils attributed to metazoan animals.

The base of the Backbone Ranges Formation is abrupt and concordant, but probably unconformable. Its contact with the overlying Sekwi Formation is gradational (by interbedding) and conformable, so much so as to cause considerable difficulty in its placement at many localities. We have drawn the contact at the most prominent 'break', traceable on aerial photographs, that serves to separate a mainly arenaceous unit from a mainly carbonate unit.

Sekwi Formation. The Sekwi Formation (Handfield, 1968; Fritz, 1972; Gabrielse et al., 1973) is a thick and resistant carbonate unit (Fig. 16) that overlies the Backbone Ranges Formation and, in the region presently considered, is overlain by the dark, recessive Road River Formation.

The Sekwi is dominated by limestone and derived dolomite. The latter appears to be more developed in the thinner, more northerly sections. Sekwi limestones range from thin-bedded and nodular calcilutites (lime mudstones, micrites) that are commonly argillaceous and silty, to skeletal and nonskeletal calcarenites (grainstones and bio- and intra-sparites) that are commonly sandy. Beds of oolite are fairly common. Limestone-pebble conglomerate is rather rare and tends to occur in association with mudrocks. Mud cracks and ripple marks are well developed in some intervals and testify to a shallow-water origin for at least parts of the Sekwi.

Dolomite of the Sekwi Formation is predominantly microcrystalline to very fine crystalline, and commonly weathers to yellow and orange shades in contrast to the prevailing greys of the limestone. The northernmost mapped panel of Sekwi consists of an upper member of nearly black, very fine crystalline dolomite with oncolites that weathers very dark grey or brownish grey, and a lower member of dolomite that is grey in colour and pale grey weathering, microcrystalline to very fine crystalline, and largely sandy. These units are probably the basal part only of the erosionally thinned Sekwi.

Mudrocks make up a significant proportion of most Sekwi sections, occurring both as interbeds between beds of the predominant carbonate rocks, and as units more than 30 m thick. Usher (Section U-1, in Aitken, Macqueen and Usher, 1973) describes most of them as calcareous argillites, grey or silvery grey to brown and locally green in colour. Some of these argillites weather reddish, red-brown or yellow, and contribute to the colourful, well-bedded aspect of many Sekwi exposures.

Quartzite and sandstone similar to those of the Backbone Ranges Formation occur as isolated members and beds, but appear to be less prominent constituents of the Sekwi in Upper Ramparts River map area than in the type area to the southeast. Thin beds and nodules of chert occur, but are unimportant constitutents.

The base of the Sekwi is conformable, gradational, and probably diachronous (Gabrielse et al., 1973, Fig. 7). The top of the formation is an unconformity at the base of strata of Middle Cambrian or younger age (ibid.); that in Upper Ramparts are included in the Road River Formation (Aitken, Macqueen and Usher, 1973).

No complete section of the Sekwi Formation has been measured in Upper Ramparts or closely adjoining areas. The Sekwi at Section U-1 (64°48'N, 131°35'W), in Bonnet Plume Lake map area, is incomplete at both base and top, hence the true thickness exceeds the 1007 m measured. The map pattern suggests that the thickness of the Sekwi varies markedly along strike. This probably is attributable to erosional thinning at the sub-Road River unconformity.

The limestone of the Sekwi and some of its mudrocks are fossiliferous. The trilobite faunas have been studied by Fritz (1972), who also reported on fossils collected from the described section nearest Upper Ramparts (Section U-1; Aitken, Macqueen and Usher, 1973). The faunas are indicative of Early Cambrian age.

Cambrian and Ordovician

Franklin Mountain Formation and transitional unit. The Franklin Mountain Formation (see previous description) is a formation typical of the stable platform region. However, if the margin of Selwyn Basin is taken as the trace of the Plateau Thrust, the Franklin Mountain Formation does extend a few kilometres into the basin, where it rests unconformably on the Rapitan Group.

The lower Paleozoic transitional unit also straddles the 'long-term average' margin of Selwyn Basin. In Upper Ramparts River map area it rests on Little Dal and Rapitan. To the south, in Bonnet Plume map area, it rests on younger formations up to the Sekwi.

Figure 17. *Lithological detail of a mappable carbonate debris-flow in the Road River Formation, south boundary of Upper Ramparts River map area at longitude 131°47'. Note peripheral silicification of the dolomite clasts. GSC 163604*

Upper Ordovician and Lower Silurian

Mount Kindle Formation. The Mount Kindle extends farther into Selwyn Basin than the Franklin Mountain Formation, implying that during Mount Kindle time the regional carbonate platform extended some kilometres into the basin. The presence of debris flows of Mount Kindle dolomite and limestone in the Road River Formation (Fig. 17) suggests that the Mount Kindle platform terminated abruptly at the edge of the shale basin of that time.

Middle Cambrian to Lower Devonian

Road River Formation. The Road River Formation (Lenz and Pedder, 1972; Gabrielse et al., 1973) is easily identified as a thick unit of dark-coloured, recessive, mainly shaly rocks that overlies the thick carbonates of the Sekwi and is overlain by Devonian carbonate formations.

In exposures immediately east of 'Orthogonal River' at the south boundary of Upper Ramparts River map area, nine tenths of the Road River Formation consists of hard, black to pale grey, well-laminated fissile shale. A unit of dense shaly dolomite and dolomitic shale, weathering pale yellowish brown, is present at the base. In the lower part of the section, beds of limestone (calcilutite, micrite, lime mudstone), grey, very fine crystalline dolomite, and conglomerates of large, slabby carbonate pebbles are present. Nodules of black chert are common in the carbonate beds; black, bedded chert also occurs but is not conspicuous.

Most of the carbonate units that interrupt the Road River shale are conglomerates, consisting of coarse, crudely graded, in part matrix-supported dolomite clasts in a fine-grained dolomite matrix, that obviously originated as debris flows or slides. The thicker of these allochthonous carbonate units are as much as several tens of metres thick, and are mappable individually (as ꞒDrc) though discontinuous. The basal, accessible part of one such mappable unit was examined at the section east of 'Orthogonal River', referred to above. It is a coarse debris flow of dolomite clasts, up to 12 by 50 cm in section, which are peripherally silicified (Fig. 17). A lower, thinner, nonmappable debris flow at the same locality is about 15 m thick, and contains silicified fossils assigned to the Mount Kindle Formation.

No section of the Road River Formation has been described in detail or measured in or near Upper Ramparts River map area. A rough graphic determination indicates a thickness of from 1370 to 1520 m at 64°50'N, 131°20'W, in Bonnet Plume map area, a few kilometres to the south. It is not certain that the formation at that locality is unaffected by tectonic thickening.

The Road River Formation, where observed in the immediate area, is sparsely fossiliferous. Regionally, it encompasses strata ranging in age from Middle Cambrian to Early Devonian, and is the basinal equivalent of platform carbonates of that age range to the northeast (Norford, 1964; Lenz and Pedder, 1972; Gabrielse et al., 1973; Aitken, Macqueen and Usher, 1973).

Devonian

Devonian carbonate formations up to and including the Hume locally overlie the Road River Formation in the immediate region, and record a further extension in post-Mount Kindle times of carbonate-platform conditions into what had earlier been Selwyn Basin. Regionally, however, most or all of the Devonian carbonates change facies southwestward or westward to shales of the Road River.

Mesozoic stratigraphy

Mesozoic rocks in the Upper Ramparts River and Sans Sault Rapids map areas belong entirely to the Cretaceous System so far as is known.

The Cretaceous succession consists of sandstones and shales which, in general, are exposed only in river valleys in Mackenzie and Peel plains, on Peel Plateau, and on the flanks of structural uplifts of northern Franklin Mountains. With few exceptions, exposures are poor and discontinuous, particularly in the plains region. In the larger river valleys proximal to the Mackenzie Mountains front, units composed mainly of sandstone tend to be well exposed, whereas thick shale or mudstone units are largely covered.

Cretaceous

Nomenclature for the Cretaceous rocks of the map areas is derived from that applied in the Snake-Peel River areas to the west, and from the area around East Mountain in Sans Sault Rapids map area. In the former region, Mountjoy and Chamney (1969) subdivided the Cretaceous strata into the Martin House, Arctic Red and Trevor formations in upward stratigraphic order. The latter two formation names are used in this report on the basis of similar lithology and age. The Sans Sault Formation derives its name from 'Sans Sault Group' (Stewart, 1945) and has its type section at Sans Sault Rapids on Mackenzie River. The term is used herein only in the vicinity of the type-section and in the closely adjacent subsurface where arenites constitute a significant proportion of the lithology of the correlative interval.

The application of Cretaceous nomenclature based on studies carried out under the Canol Project in 1943 in the Mackenzie Valley region has led to confusion, particularly in regard to the Lower Cretaceous succession along the Mackenzie Mountain front. There, the lithostratigraphy of Albian rocks is substantially different from that of the type section of the Sans Sault Formation. Accordingly, use of the term 'Sans Sault Formation' is inappropriate for the mountain front section. For a full discussion of the use of the term, the reader is referred to Hume (1954) and Tassonyi (1969).

The nomenclature, age assignments and correlation of Cretaceous strata in this report are tentative and subject to revision. Detailed micropaleontological studies are needed to define precisely biostratigraphic boundaries and relationships between adjacent facies.

Arctic Red Formation. Arctic Red Formation is the term herein used for a succession of concretionary, silty, recessive shales, and mudstones[1] (Fig. 18) with a basal sandstone and conglomerate unit (Fig. 19) that overlies disconformably strata of the Upper Devonian Imperial Formation along the Mackenzie Mountain front and along the flanks of Imperial Anticline. In Peel Plateau, it underlies interbedded sandstones and mudstones of the Trevor Formation.

The most complete sections of the Arctic Red Formation occur along a small creek, tributary to Hume River, (65°25'N, 129°57'W) and along Mountain River (65°26'N, 129°57'W). In both areas the formation is in unconformable contact with structurally concordant strata of the Devonian Imperial Formation.

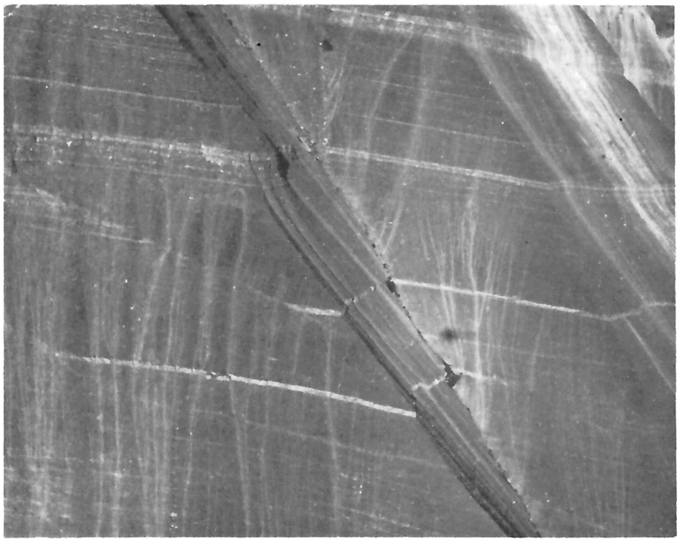

Figure 18. *Shale and subordinate thin sandstone beds in the Arctic Red Formation, north limb of Lichen Syncline, Arctic Red River. Sandstone beds are visibly offset by a small thrust fault. GSC 159376*

Figure 19. *Basal glauconitic sandstone member of the Arctic Red Formation; north flank of Imperial Anticline at Mountain River. Hammer head marks the erosional contact with shale of the Imperial Formation. GSC 199233*

[1] In the discussion of Cretaceous rocks, the following classification is used:
Shales- clay rock with less than 5 per cent visible silt or sand grains by volume.
Mudstone- clay rock with between 5 per cent and 50 per cent visible silt or sand grain by volume.

In the Hume River area, the Arctic Red Formation is 1220 m thick, in a section dipping 45 degrees northward. The basal 12 m of the formation consists of medium brown weathering, generally medium-bedded, fine-grained, well-sorted, argillaceous and glauconitic sandstone; sandy mudstone and minor shale-chip and chert-pebble conglomerate occur at the base in discontinuous lenses. A prominent horizon of clay-ironstone concretions occurs in the middle of the unit. The sandstones are commonly vertically burrowed, and display small tool marks, small-scale flute casts and convolute laminations. Above the basal sandstone are 590 m of dark grey to black, blocky and locally fissile, concretionary shales. The concretions contain poorly- to well-preserved ammonites and in the lower part of the section display a 'disk-and-ball' geometry which is common to concretionary shales near the basal glauconitic sandstone in adjacent areas (e.g., on Ontaratue River, 106J). In the uppermost 180 m of this member, thin 2.5 to 1.2 cm seams of pale grey to pale yellow bentonite occur in irregularly distributed intervals. Within this same part of the section, the silt content of the shale increases and, near the top, argillaceous siltstone occurs interbedded with nodular and rusty weathering mudstone. The remainder of the Arctic Red Formation at Hume River consists of 635 m (graphic estimate) of poorly exposed, locally concretionary, interbedded dark grey and rusty-weathering mudstone, and medium grey, commonly rusty-weathering, calcareous and argillaceous siltstone, and minor fine-grained sandstone. This unit lacks well-preserved fossils. In the Hume River section, this member occurs between the mouth of the small tributary creek mentioned above and the southward-flowing segment of Hume River, approximately 1.6 km to the west, where the gradationally overlying Trevor Formation is well exposed.

On Mountain River, the Arctic Red Formation is 616 m thick in the north flank of the Imperial Anticline (65°26'N, 129°57'W). It is moderately well exposed and consists of a basal conglomerate and glauconitic sandstone member, 15 m thick, and an overlying concretionary shale member 601 m thick. The upper siltstone and mudstone member of Hume River is not represented. Black, rusty-weathering, plastic shale is the most common rock type in the Mountain River section where 'disk-and-ball' concretions occur close to the basal glauconitic sandstone, and thin bentonite seams and siltstone laminae near the top. Only one ammonite, *'Gastroplites'* n. sp. A (GSC loc. C-10032), was collected; this came from immediately below the basal contact of the overlying Trevor Formation. A few poorly preserved ammonites were observed in broken concretions in the scree.

The Arctic Red Formation has been penetrated by a number of wells in Upper Ramparts River map area. In the Candel Texaco et al. Arctic Red F-47 well, the formation is 1590 m thick (605 - 2195 m); the basal sandstone member measures 15 m, the middle concretionary shale member 935 m, and the upper mudstone and siltstone member 640 m. To the south, the Candel Mobil et al. N. Ramparts A-59 well penetrated an incomplete section of the formation 1268 m thick (75 - 1343 m), comprising 15 m of basal sandstone member, 838 m of middle concretionary shale member, and 415 m of upper mudstone and siltstone member. In each of these wells, the underlying strata consist of grey-green fissile shale and sandstone of the Devonian Imperial Formation. To the west of Arctic Red River, the Amoco PCP A-1 Cranswick A-22 well penetrated about 70 m (68 - 138 m) of Arctic Red Formation overlying shale of reported Mississippian age[1].

In Sans Sault Rapids map area, two exploratory wells penetrated strata assigned to the Arctic Red Formation. In Mobil Hume River L-09, 605 m (surface to 605 m) of beds assigned to the Arctic Red Formation overlie 240 m of sandstone and mudstone that are either Cretaceous Sans Sault or Devonian Imperial Formation. In the Candel et al. SOBC Mountain River A-23 well, 376 m (surface to 376 m) of Arctic Red Formation overlie Imperial shale.

Additional partial exposures of the Arctic Red Formation occur widely throughout the map areas. On Arctic Red River, at 65°27'N, a thin basal sandstone and interbedded mudstone unit containing thin, low-grade coal seams is succeeded by discontinuous outcrops of poorly exposed concretionary shale for about 11 km downstream. Incomplete exposures occur beneath the sandstone of the Trevor Formation within stream valleys in Lichen Syncline. Along Ramparts River poor exposures are seen both south and north of Peel Plateau. On the south flank of Imperial Anticline on Gayna River and other streams tributary to Mountain River, small outcrops of the lowermost part of the concretionary shale member and basal, glauconitic sandstone member are exposed above the Imperial Formation.

Sans Sault Formation. The Sans Sault Formation was described first in an unpublished Canol report by Parker (1944), the name being derived from the 'Sans Sault group' of Stewart (1945). The type section of the formation, adjacent to Sans Sault Rapids in Mackenzie River, is well exposed on the east bank close to the Middle Devonian Ramparts Formation, on the north flank of East Mountain Anticline.

At the type section, the lowest exposed beds of the Sans Sault Formation are separated by 12 m of covered interval from the highest exposed strata of the Ramparts Formation. The two formations are concordant and dip northward at 68 degrees. The exposed section is 442 m thick and consists of a lower, sandstone and mudstone unit, 69 m thick, a middle concretionary mudstone unit containing minor amounts of sandstone, 274 m thick, and an upper concretionary sandstone and mudstone unit, 99 m thick. A steep fault with small displacement, north side down, occurs at 328 m above the base of the section, and results in some omission of strata. The top of the formation is not exposed.

The lower sandstone and mudstone unit consists of thin-bedded, relatively dense, fine-grained, thinly laminated, calcareous sandstone, weathering light to medium brown, interbedded with 0.15 to 0.6 m thick intervals of dark grey, blocky, dense, sandy mudstone that commonly weathers rusty. Scattered ironstone concretions occur near the top of the unit.

The continuity of the middle concretionary mudstone and sandstone unit is broken by covered intervals. Scattered outcrops of the lower and middle parts of the unit consist of rusty and dark grey weathering, blocky, calcareous mudstone and argillaceous siltstone interbedded with lesser amounts of thin-bedded, laminated, fine-grained sandstone weathering light to medium brown. Toward the top of the unit, sandstone and siltstone gradually become dominant and more friable. Sedimentary structures in the sandstone units are rare low-angle crossbedding and rare burrows and trails.

In the upper concretionary sandstone and mudstone unit, the sandstone is less calcareous, low-angle crossbedding is more conspicuous, and the numerous concretions contain well-preserved *Pleuromya borealis* and *Sonneratia* aff. *kitchini* (GSC loc. 84788, 84792). It is the upper member, dipping at about 10 degrees northward, that forms the rapids in the Mackenzie River adjacent to the type section.

The Sans Sault Formation appears to be restricted in its distribution to the eastern half of the Sans Sault Rapids map area (Fig. 21). Outcrops of the formation occur in the Bat Hills, on Donnelly River, and Maida Creek and on the west side of Mackenzie River immediately across from the type section. In the subsurface, where the maximum known thickness is 700 m, the Sans Sault Formation is recognizable in cuttings from exploratory wells drilled near the west bank of Mackenzie River. The following table lists those wells in which the Sans Sault Formation occurs, its thickness, and the underlying formation. The threefold

[1] Well history report, Amoco PCP A-1 Cranswick A-22.

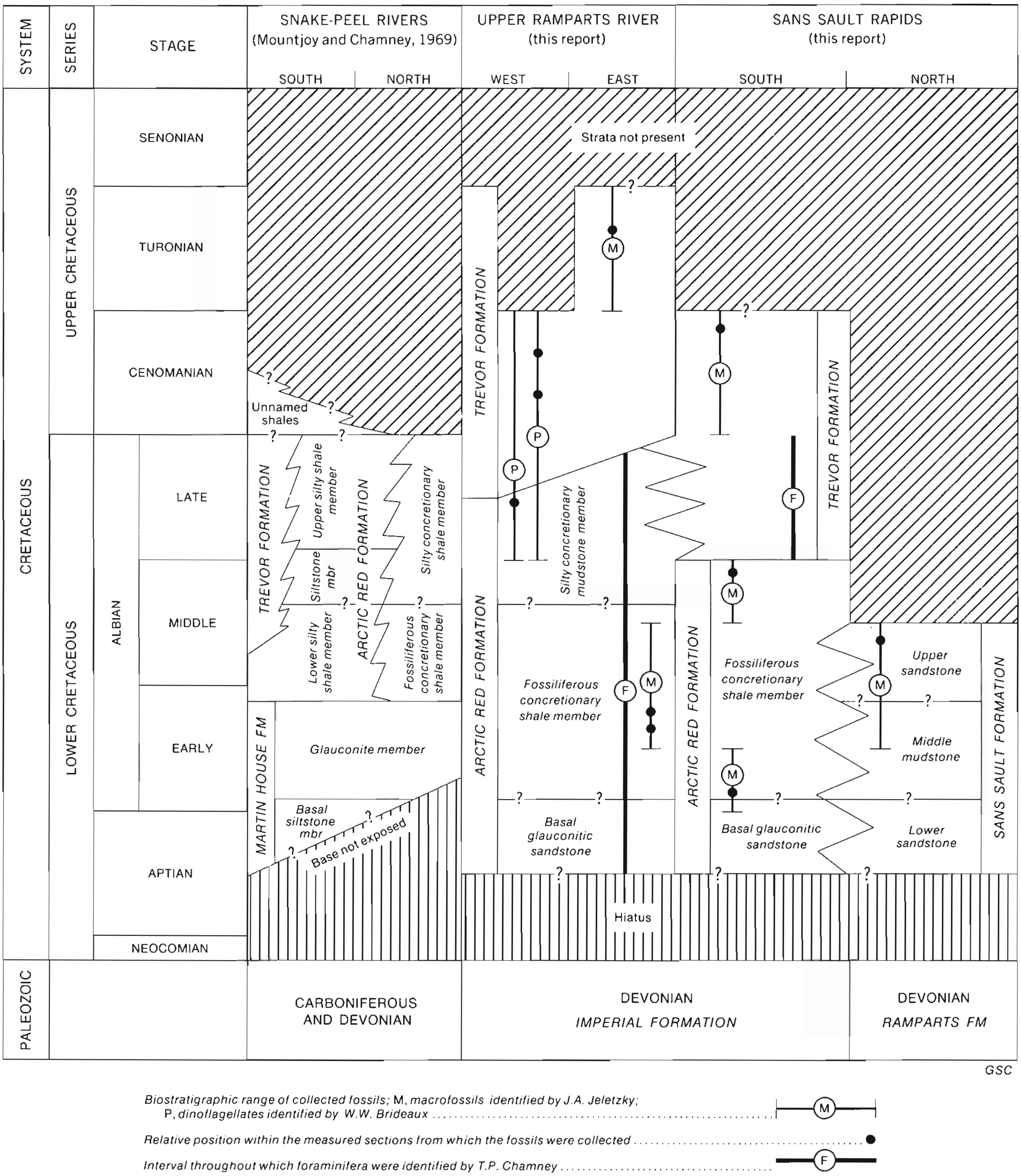

Figure 20. *Correlation of Cretaceous formations of Upper Ramparts River, Sans Sault Rapids, and Snake River map areas.*

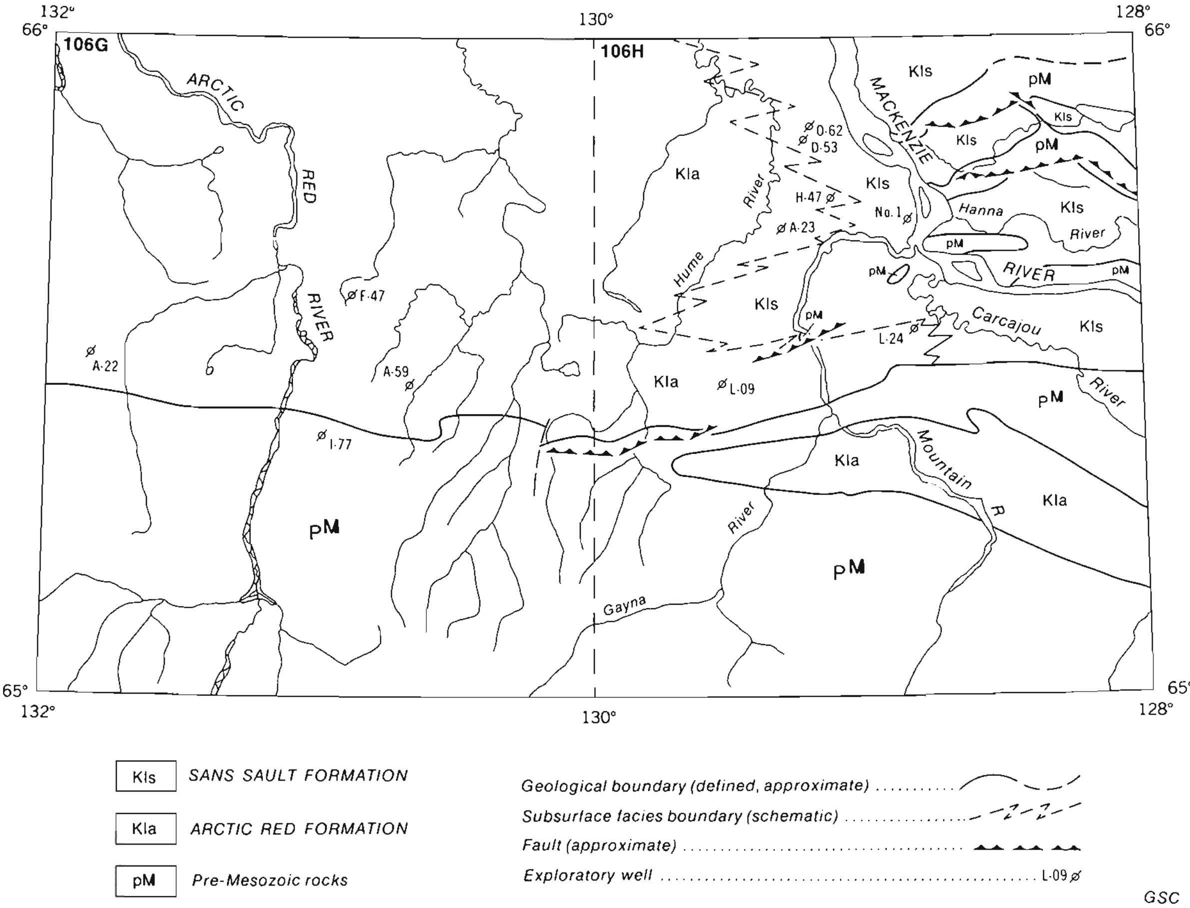

Figure 21. *Distribution of Lower Cretaceous facies.*

division of the formation, recognizable in the type section and in the Imperial Sans Sault No. 1 well (Tassonyi, 1969), has not been established in the other boreholes of the list.

(1) *Imperial Sans Sault No. 1*

Sans Sault Formation -	thickness 428 m (surface to 428 m)
Underlying formation:	Ramparts Formation

(2) *Triad Carcajou L-24*

Sans Sault Formation -	thickness 700 m (surface to 700 m). This thickness is tentative; strata of the underlying Imperial Formation may be included.

(3) *Triad BP Arco CC Hume River 0-62*

Sans Sault Formation -	thickness 484 m (20 to 504 m interval)
Underlying formation:	Ramparts Formation

(4) *Amoco Mountain River H-47*

Sans Sault Formation -	thickness 69 m? (surface to 69 m)
Underlying formation:	Imperial Formation. The uppermost 49 m assigned to the Imperial (concretionary shale and siltstone) are possibly Sans Sault Formation.

Facies relationships between the Arctic Red and Sans Sault formations are sketched in Figure 21. The sandy facies (Sans Sault Formation) appears to be distributed in an arc about the northwestern termination of the northern Franklin Mountains. Distribution of the sandy facies in the vicinity of Imperial Anticline is speculative, although equivalent rocks at the base of the Cretaceous succession on Imperial River in the Normal Wells map area to the east are arenaceous and could be assigned to the Sans Sault Formation.

Trevor Formation. Trevor Formation (Mountjoy and Chamney, 1969) is the term herein used for the thick succession of sandstone and interbedded mudstone that gradationally overlies the Arctic Red Formation. It is the youngest unit in the map areas.

The most complete and best exposed section of the Trevor Formation occurs along Hume River (65°25'N, 130°01'W) where 1150 m of strata are nearly continuously exposed in a northward-dipping succession above the Arctic Red Formation. Other less well exposed sections occur on Mountain River, Ramparts River and Arctic Red River and its tributaries heading in Peel Plateau. The uppermost part of the formation occurs as plateau-forming sandstones which are distributed over a wide area extending from Trevor Range in Yukon Territory (Mountjoy and Chamney, ibid.) to the vicinity of 'Yadek' Lake (65°30'N, 130°05'W).

On Hume River, the Trevor Formation appears to be in gradational contact with the underlying Arctic Red Formation, although the contact is difficult to observe because the river turns sharply eastward along the contact.

Figure 22. *'Plateau-forming' sandstones of the upper part of the Trevor Formation Peel Plateau. Low ground in the northern one fifth of the photograph is Peel Plain, underlain by equivalents of the Arctic Red Formation. Airphoto centre is at latitude 65°45', longitude 131°52'. (A12145-262)*

The succession consists of interbedded sandstone and mudstone. The sandstone is thin to more commonly medium bedded, medium brown and grey weathering, flaggy, hard, dense, fine grained, laminated, locally calcareous and rarely glauconitic. Bedding planes commonly display well-developed interference ripple marks and small channels. Ball and pillow structures are common; microcrossbedding and flaser structures are rare in the lower part of the succession and more common toward the top. A characteristic feature of the sandstone is its degree of immaturity, which in thin section is displayed by abundant rock fragments, grains of tripolitic chert and feldspar. A frequent component of the more massive sandstone beds is 'conglomeratic' ironstone lenses. These consist of rounded to subrounded pebbles of clay-ironstone in a matrix of dense sandstone. The pebbles commonly appear to be 'floating' as individuals or loosely clustered in aggregates and most commonly occur above ripple-marked bedding planes. The mudstone is blocky and sandy, and weathers recessively in dark grey to rusty colours. Bedding planes commonly display small wood fragments and small-scale tool marks.

A section, 220 m thick, of concretionary, black, soft, plastic shale occurs 920 m above the base of the formation at Hume River. The shale is sparsely laminated with pale yellow weathering sulphurous bentonite seams. Overlying this shale, the interbedded sandstone and mudstone reappear in a succession approximately 30 m in thickness. A covered interval no more than 30 m thick extends from there to the lowest 'plateau-forming' sandstone, about 1.6 km to the north.

The 'plateau-forming' sandstone units that are the upper part of the Trevor Formation are well displayed on air photographs from the Arctic Red River region to the east of 'Yadek' Lake in Ramparts River map area (Fig. 22). Outcrops of these sandstones consist of heaps of frost-riven blocks and flagstones, displayed as a succession of bands which are separated by covered intervals of a few metres to as much as 30 m. The number of such sandstone units varies from place to place; a maximum of six occurs on the west side of Arctic Red River. The sandstone is light to medium grey weathering, hard, dense, and fine grained in the lower units to medium and locally coarse grained in the upper units. It is compositionally immature and consists of quartz, feldspar, rock fragments and substantial quantities of tripolitic chert that locally comprises more than 50 per cent of the rock.

On Mountain River in Sans Sault Rapids map area, the Trevor Formation is about 520 m thick and gradationally overlies the 'fossiliferous concretionary shale member' of the Arctic Red Formation. At this locality, the sandstone units are fewer and thinner bedded than at the Hume River section, and the shale units are poorly and discontinuously exposed. These shales are soft, black, plastic and slightly bentonitic, similar to those near the top of the Hume River section. At the base of the section the arenite components comprise argillaceous siltstone with intercalated thin beds of hard, calcareous sandstone. Toward the top of the formation, the sandstone units become coarser grained and locally conglomeratic. Ripple marks, small flute casts and vertical burrows are common. The uppermost sandstone unit observed contains very thin coal laminae. Throughout the formation, ironstone concretions are more common than in the Hume River section. A few of these concretions contain broken and poorly preserved pelecypod valves.

In the subsurface of the region the Trevor is poorly known. In the Candel Texaco et al. Arctic Red F-47 well, which spudded in the 'plateau-forming' sandstones, 610 m of the formation overlie strata assigned to the Arctic Red Formation.

Age and correlation of Cretaceous formations. Figure 20 illustrates the tentative age assignments and correlation of Cretaceous strata in the Sans Sault and Upper Ramparts River map areas and in the Snake and Peel rivers region to the west.

In its type area on Snake and Peel rivers, the Arctic Red Formation was assigned a latest Early to Late Albian age by Mountjoy and Chamney (1969). The underlying Martin House Formation was assigned a late Aptian to Early Albian age (ibid.). Ammonites collected from the fossiliferous concretionary shale member on Arctic Red River to the north of Upper Ramparts River map area and on Peel River belong to the *Lemuroceras* or *Beudanticeras affine* faunal zone of late Early Albian age (Jeletzky, 1968). In the Hume River section, several specimens of *Beudanticeras (Grantziceras)* cf. *affine* were collected from a number of horizons within the fossiliferous concretionary shale member (GSC locs. C-10025, C-10026, C-10027) indicating a late Early to early Middle Albian age (Paleontology Report Km-3-1972-JAJ). One specimen of *Cleoniceras (Grycia)* ex gr. *sablei* (GSC loc. C-10030), collected in the scree about 457 m, above the base of the formation has been tentatively dated by Jeletzky (ibid.) as Middle Albian.

T.P. Chamney (1978) carried out detailed micropaleontological studies of the complete Arctic Red Formation on Hume River and concluded that the formation ranged from Aptian *(Quadrimorphina albertensis - Siphotextularia* spp. zone) at the base to latest Late Albian *(Psamminopelta - Miliammina manitobensis* zone) at the top. The Aptian age for the basal glauconitic sandstone further is supported by a collection of *Cleoniceras (Cleoniceras)* aff. *C.* (*C.*) *antigum* (GSC loc. C-10035) of early Early Albian age from near the base of the fossiliferous concretionary shale member on the south side of Imperial Anticline on a small tributary to Mountain River (65°23'N, 129°07'W). Although the underlying glauconitic sandstone was not observed at this locality, rocks of the Devonian Imperial Formation lie in proximity, and the basal glauconitic sandstone occurs in the banks of adjacent streams. The basal glauconitic sandstone and lower fossiliferous concretionary mudstone members of the Arctic Red Formation in the Hume River area thus are equivalent in part to the Martin House Formation of the Peel and Snake rivers region.

On Mountain River on the north side of Imperial Anticline, only one ammonite, *'Gastroplites'* n. sp. A (GSC loc. C-10032), was collected from the top of the fossiliferous concretionary mudstone member, immediately below beds assigned to the Trevor Formation. This specimen was dated as late Middle Albian by Jeletzky (Paleontology Report Km-3-1972-JAJ).

At its type section, the uppermost member of the Sans Sault Formation contains pelecypods and ammonites representing portions of the *Sonneratia* cf. *kitchini* and *Beudanticeras affine* zones; these indicate an earliest Early Albian to late Early Albian age (GSC locs. 84788, 84792 - Paleontology Report Km-1-1970-JAJ). Similar faunas from this member are reported in Hume (1954) and Tassonyi (1969). Furthermore, a specimen of *Beudanticeras (Grantziceras)* cf. *affine* was collected from an isolated exposure of the Sans Sault Formation on Donnelly River (GSC loc. 84795) and this, in addition to collections of *Beudanticeras (Grantziceras)* cf. *glabrum* and *Inoceramus* cf. *anglicus* from the formation on Maida Creek (GSC loc. C-10023), confirms a general Early Albian age. In Figure 20, the formation is shown as extending into the early Middle Albian because the fossils collected have the range indicated. Thus, the top of the section may be placed anywhere within that range. No fossils, however, have been reported from beds known to belong to the lower portion of the formation and, thus, in Figure 20 the formation is shown tentatively as extending into the Aptian Stage.

The Sans Sault Formation is correlated with the basal glauconitic sandstone and fossiliferous concretionary shale members of the Arctic Red Formation (Fig. 20).

The age limits of the Trevor Formation are difficult to define because of sparse paleontological data and differing age assignments based on macrofossils, foraminifera and microflora.

At its type section in the Trevor Range of the Snake and Peel rivers region, poorly preserved *Posidonia* cf. *nahwisi* s.l. and *Inoceramus* ex gr. *anglicus* were collected from the basal beds of the formation (GSC loc. 52598). As reported by Mountjoy and Chamney (1969), these fossils usually suggest a Late Albian age. From a section located at 65°50'N, 134°10'W, F.G. Young collected several well-preserved specimens of *Posidonia? nahwisi* var. *goodrichensis* from about 120 m above the base of the formation (GSC loc. 85360). These specimens were identified by Jeletzky as most likely representing the lower part (i.e., lower Upper Albian) of the Upper Albian to lowermost(?) Cenomanian generalized *Neogastroplites* zone, although the range of this form has not been worked out precisely. At another locality at the south end of Trevor Range, about 19 km from the type section, Chevron Standard Company geologists collected *Gastroplites* (s.l.) n. sp. aff. *G. liardense* (GSC loc. 42635) from a position which Mountjoy and Chamney (1969) estimated to be between 210 and 300 m above the base of the Trevor Formation. Jeletzky (in Mountjoy and Chamney, 1969) identified the fauna and assigned a Late Albian age to the collection. Although there appears to be a zone inversion involving GSC localities 42635 with 52598 and 85360 (*Gastroplites* occurs below *Neogastroplites*, Jeletzky (1968)), all macrofauna collections to date suggest a Late Albian age for the lower and middle parts of the formation in the Trevor Range. Mountjoy and Chamney (1969) suggested a Middle Albian age for the base of the Trevor Formation on the basis of the occurrence of early Early Albian foraminifera of the *Saracenaria trollopei* zone which were reported from underlying beds of the Arctic Red Formation. A Late Albian to Cenomanian age for the base of the formation on Cranswick River, immediately west of the Upper Ramparts River map area (65°48'N, 132°02'W) is supported by a collection of dinoflagellates (Paleontology Report 7-WWB-1975K) recovered from Arctic Red Formation shale immediately below the base of the Trevor Formation (D.K. Norris, pers. com., 1975). On the basis of Chamney's biostratigraphic studies of the Arctic Red Formation at Hume River, at the western border of the Sans Sault Rapids map area, the base of the Trevor Formation at that locality is latest Late Albian or earliest Cenomanian in age. On the basis of the paleontological data described above, it appears that the base of the Trevor Formation is either Late Albian in age throughout much of its lateral extent or is diachronous from Middle Albian in Trevor Range to Late Albian and earliest Cenomanian at Hume River. Mountjoy and Chamney (1969) described a similar relationship for the base of the formation from south to north in the Snake and Peel rivers region.

It should be pointed out, however, that our attempts to map individual sandstone units of the Trevor suggest that successively lower (i.e., older) sandstone units define the base of the formation in an easterly direction toward Hume River. Further detailed studies in this region are needed to relieve the apparent conflict between biostratigraphic and lithostratigraphic data.

On Mountain River, T.P. Chamney (pers. com., Oct. 1975) identified Late Albian foraminifera collected from the lowermost 130 m of the Trevor Formation. This, in conjunction with the late Middle Albian *'Gastroplites'* n. sp. A (GSC loc. 10032) collected from the immediately underlying beds of the fossiliferous concretionary shale member of the Arctic Red Formation, suggests that the absence of the silty concretionary mudstone member is due to a change in facies through replacement of that member by sandstones of the Trevor Formation. This relationship tends to support the physical stratigraphic evidence described above although continuity of exposure between the Hume River and Mountain River sections was not observed. Alternatively, the sandstones of the Trevor Formation at these localities may have been derived from different source areas, and deposition may have started at different times.

In the Snake and Peel rivers region, the upper age limit of the Trevor Formation is unknown and Mountjoy and Chamney (1969) suggest that the upper part of the unit may contain beds of Late Cretaceous age. In the Candel et al. Texaco Arctic Red F-47 well (GSC loc. C-33952), Brideaux reports Late Albian to Cenomanian dinoflagellates in the uppermost 270 m of the formation (Paleontology Report 9-WWB-1974K). In the upper part of the formation on Hume River, two collections comprising several species of *Inoceramus* (GSC loc. 84798, 84800) were identified by Jeletzky as Early to Middle and Late Turonian in age respectively (Paleontology Report Km-1-1970-JAJ). On Mountain River, pelecypods collected from near the top of the section were identified by Jeletzky as *Inoceramus* cf. *dunveganensis*, indicating a Cenomanian age (GSC loc. C-10033; Paleontology Report Km-3-1972-JAJ). Thus, deposition of the Trevor Formation within the Upper Ramparts River - Sans Sault Rapids map areas took place from Late Albian to at least Late Turonian time. It follows that the formation apparently is at least partly correlative with shale of the incompletely dated Slater River Formation of the Carcajou Canyon (96D) map area (Yorath in Aitken and Cook, 1974) and Norman Wells region.

TECTONICS

Diastrophic history

The distribution and geometry of lithostratigraphic units in the subject region, as in any other, are the results of a long history of depositional events, interrupted by and alternating with tectonic disturbances of the depositional arrangement, each such disturbance normally being followed by an erosional event. Thus, the Laramide (s.l.) deformation that produced the large-scale and obvious structures easily visible today was the culmination of a long history of diastrophic events recorded by less obvious structures.

The earliest diastrophic event recorded in the rocks exposed is the Racklan Orogeny, second only to the Laramide Orogeny in the magnitude of its effects. It is recorded in the sub-Rapitan unconformity and in the regional set of steeply dipping faults striking north to north-northwest and affecting, in most places, only Helikian strata. Aitken and Cook (1974b) have summarized the ways in which the presence of these ancient faults has influenced the Laramide deformation of the region.

Most of the post-Racklan, pre-Laramide diastrophic events produced effects manifested by unconformities revealed through stratigraphic studies. The sub-Cambrian unconformity records one of the upward movements of Mackenzie Arch (Aitken, Macqueen and Usher, 1973) and also pronounced operation of a hinge line near and parallel to the Arch (negative behaviour to the southwest, neutral to positive behaviour to the northeast). The sub-Upper Cambrian unconformity records another, final pulse of uplift on Mackenzie Arch (establishing a restricted basin for Saline River deposition) and renewed or continued differentiation of the region across the previously established hinge line. This differentiation resulted in sedimentation in the stable platform region, northeast of the hinge line, remaining almost entirely of shallow-water carbonate type with several hiatuses until the Middle Devonian whereas, southwest of the hinge line, shales and deeper-water carbonates accumulated continuously or nearly so. Aitken and Cook (1974c) have presented evidence for pre-Mount Cap and pre-Saline River - Franklin Mountain faulting in Carcajou Canyon map area.

The sub-Upper Ordovician (sub-Mount Kindle) unconformity of the subject region is a feature revealed only by erosional thinning or absence of the 'cherty' member of the Franklin Mountain Formation. In map areas to the southeast, it is much more pronounced, to the extent that the Whittaker Formation (Mount Kindle equivalent) there locally overlies rocks as old as Hadrynian (Gabrielse et al., 1973).

A pronounced regional unconformity recording mainly broad tilting or arching and erosional bevelling is evident beneath the Devonian succession of the stable platform region (e.g., Cook, 1975). It is as yet uncertain whether the same unconformity extends beneath the Delorme Formation and is therefore pre-Late Silurian. The relationship mapped in Mount Eduni map area, wherein strata mapped as Delorme Formation overlie strata as old as Helikian (Aitken and Cook, 1974a) implies pronounced local pre-Delorme (pre-map unit SD) movements. Evidence for a sub-Arnica unconformity is equivocal. If such an unconformity indeed exists, it records mainly broad, gentle uplift[1]. Evidence for the widely accepted sub-Canol, or sub-Upper Devonian unconformity also is somewhat equivocal. In any event, if it exists, that break is a minor one and no pronounced or local structural effects are known to be associated with it.

The sub-Cretaceous (generally sub-Albian) unconformity represents a hiatus at which the Carboniferous, Permian, Triassic and Jurassic systems are missing. This unconformity records pronounced southwestward tilting followed by deep erosion, so that basal Cretaceous deposits overlie Upper Devonian strata along the Mackenzie Mountain front and strata as old as Franklin Mountain (Upper Cambrian to Lower Ordovician) north and south of Great Bear Lake. More localized pre-Cretaceous and (or) pre-Late Cretaceous uplift is recorded by such features as Keele Arch (Cook, 1975), and suggested by the distribution of Lower Cretaceous sandy facies (Fig. 21).

The final, and most important tectonic event was the Laramide Orogeny (s.l.), dated as latest Cretaceous or Paleocene in the subject region. It brought about significant shortening of the sedimentary cover, and created the Mackenzie and Franklin Mountains.

The remainder of this chapter deals with a new analysis of the Laramide tectonics, not only of Upper Ramparts River and Sans Sault Rapids map areas, but of neighbouring regions as well.

Structural subregions

The Laramide tectonics of the region can be described conveniently in terms of four subregions of different structural styles (Fig. 23); these are, the Plateau Sheet, southwest of Plateau Fault; the Outer Fold Belt, between Plateau Fault and the Mackenzie Mountain front; northern Franklin Mountains and Mackenzie Plain Synclinorium, jointly; and Peel Plateau and Peel Plain, jointly.

Plateau Sheet

The Plateau Thrust Sheet and the bounding Plateau Fault have been traced continuously from their 'type area' in Wrigley Lake map area (Gabrielse et al., 1972) across the intervening Sekwi Mountain map area (Blusson, 1971) and Mount Eduni and Bonnet Plume Lake map areas (Aitken and Cook, 1974a). Along this course, the Plateau Sheet becomes progressively more deformed. Essentially a single, large, unbroken plate to the southeast, it becomes, to the northwest, increasingly broken by southwest-dipping splays from the sole fault. In Upper Ramparts River map area, it is essentially an imbricate stack of fault slices (Map 1452A, in pocket) whose traces are subparallel to the trace of Plateau Fault. This major thrust fault maintains near-parallelism to bedding in the hanging wall. In Upper Ramparts, as in the 'type area' and along most of its intervening trace, the immediate hanging wall is generally the gypsum subunit or, less commonly, the rusty shale subunit of map unit H5 (Figs. 16; 24, in pocket). At several localities, lenses of H5 gypsum lie beneath, and in tectonic contact with, one or other of the two overlying units (Fig. 25). These relationships suggest that the fault roots in a detachment zone within the gypsum subunit of map unit H5. Furthermore, in Bonnet Plume Lake and Mount Eduni map areas, the Plateau Sheet overlies a subthrust imbricate zone (Fig. 24 and Aitken and Cook, 1974a). This zone of thrust-imbrication has many features in common with examples of subthrust imbricate zones in the southern Rocky Mountains, figured by Dahlstrom (1970), but the individual imbricate thrusts in the sub-Plateau zone are more widely spaced and of larger displacement. The faults and related folds in the subthrust imbricate zone occur in a dominantly left-hand *en echelon* pattern as described by Norris (1972) for this part of Mackenzie Arc.

Major folds are not a characteristic of the Plateau Sheet in Upper Ramparts. Such folds as are present appear to be drag folds related to splays from the sole fault.

Stratigraphic throw across the Plateau Fault in Upper Ramparts map area is on the order of 2290 m. The corresponding horizontal displacement of the sheet is difficult to assess. On the one hand, the abrupt appearance of thick Hadrynian and Lower Cambrian sequences in the Plateau Sheet and their virtual exclusion from the Outer Fold Belt to the northeast imply that two stratigraphic successions originally deposited tens of kilometres apart are juxtaposed through large horizontal displacement on Plateau Fault (c.f. Gabrielse et al., 1973, p. 110). On the other hand, at the stratigraphic level of the Franklin Mountain Formation, contrasting facies are not clearly juxtaposed across the fault. Instead, the transitional facies between Franklin Mountain and Road River formations crosses Plateau Fault obliquely in the southwestern part of Upper Ramparts River map area. This implies that the cumulative horizontal displacement on the Plateau and related faults is only a few kilometres. If so, the dramatic appearance of Hadrynian and Lower Cambrian rocks must be attributed primarily to the Selwyn Basin hinge line and only secondarily to juxtaposition of sequences originally deposited kilometres apart from each other.

A third possibility, Laramide reactivation of a pre-Late Cambrian thrust of large displacement, as the Plateau Fault of modest displacement, is not supported by available knowledge of the stratigraphy, and cannot be further assessed at the present stage of mapping.

Outer Fold Belt

Structures in the Outer Fold Belt (Figs. 26 - 28) are broad, flat-topped anticlines up to 32 km across, and intervening, narrow, steep-limbed, generally complex synclines or synclinoria up to 5 km across ['dejective' style of Stille (1917); see also Dahlstrom (1969, 1970)]. The scale of the folding is such that, in Sans Sault Rapids map area and in Mount Eduni map area adjoining to the south, the entire Outer Fold Belt, up to 80 km wide, consists of only three anticlines and three synclines or synclinoria (Fig. 24). These large folds are as much as 225 km long. Regionally, they too display the left-hand *en echelon* pattern noted by Norris (1972). These are parallel folds and, as such, cannot extend indefinitely downward; they must terminate at an underlying surface of structural detachment or *decollement* (e.g., Dahlstrom, 1969, 1970). The oldest strata exposed in the region are involved concordantly in the folding (see structural cross-sections A-A' and B-B') and, therefore, the detachment surface lies deeper.

[1] The relationship mapped in the southwest corner of Sans Sault Rapids map area, in which the Mount Kindle is shown as missing beneath the Arnica, is based entirely on airphoto interpretation. No conclusion should be drawn regarding this until the outcrops have been examined.

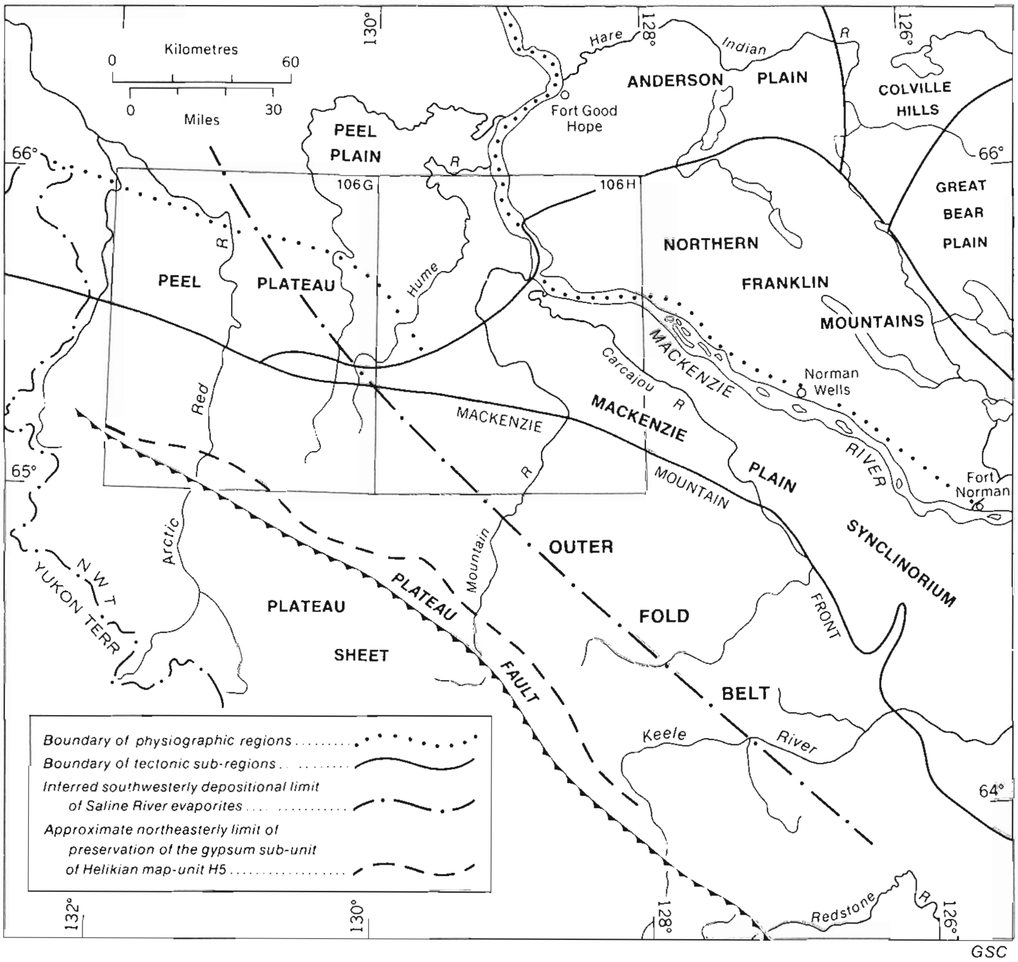

Figure 23. *Sketch map of tectonic subregions and distribution of Cambrian and Helikian evaporites.*

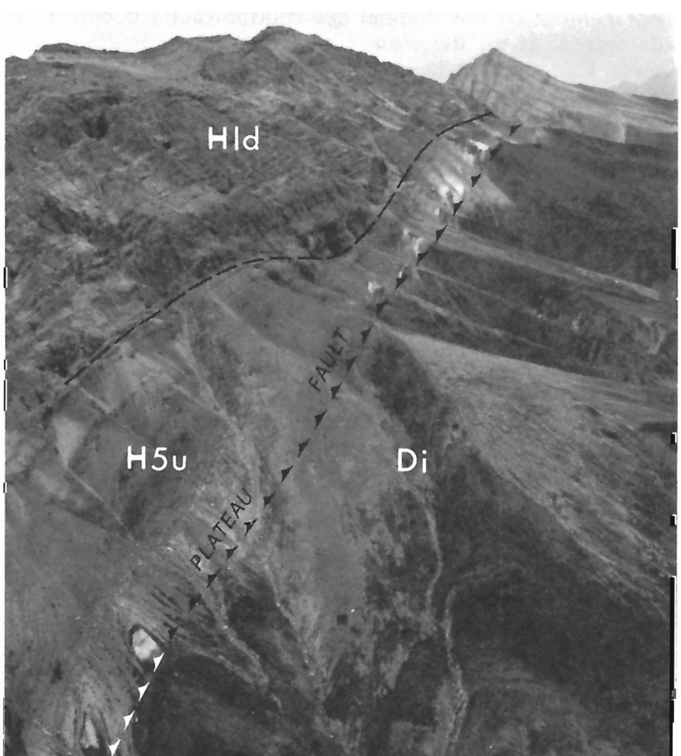

Figure 25. *Plateau Fault at latitude 64°43', longitude 129°56' (Mount Eduni map area, 106A). Di – Imperial Formation; Hld – Little Dal Formation; H5u – unnamed Helikian map unit H5, rusty shale (dark) and gypsum (white) subunits. GSC 163519*

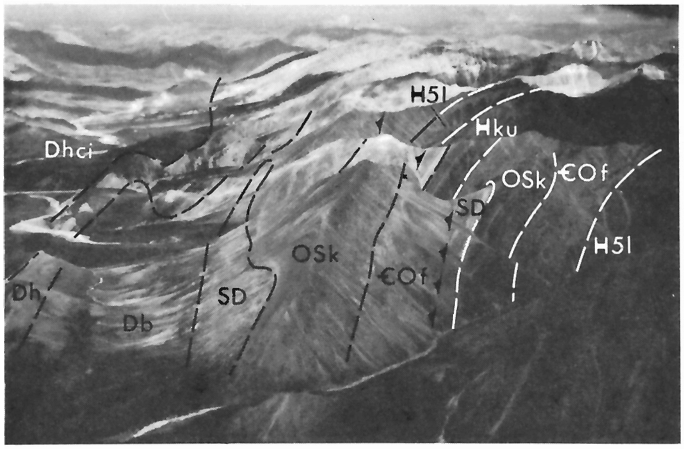

Figure 26. *South limb of Shattered Range Anticline; view to west-northwest from point about latitude 64°27, longitude 128°37' (Mount Eduni map area, 106A). Hku – Katherine Group (upper division); H5l – unnamed Helikian map unit H5, lower division; €Of – Franklin Mountain Formation; OSk – Mount Kindle Formation; SD – unnamed Silurian and Devonian unit; Db – Bear Rock Formation; Dh - Hume Formation; Dhci – Hare Indian-Canol-Imperial, undifferentiated. GSC 199231*

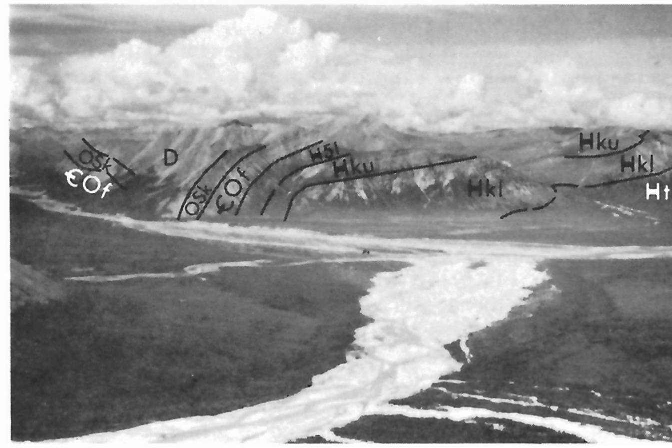

Figure 27. *Sharp monoclinal bend forming the south limb of Tawu Anticline; view to west-northwest across the 'Grand Forks' of Arctic Red River. Bolstead Synclinorium, complicated by faulting, adjoins to the south. Ht – Tsezotene Formation; Hkl, Hku – lower and upper Katherine Group; H5l - unnamed Helikian map unit H5, (lower division); €Of – Franklin Mountain Formation; OSk – Mount Kindle Formation; D – Devonian formations, undifferentiated (see Fig. 11). GSC 199232*

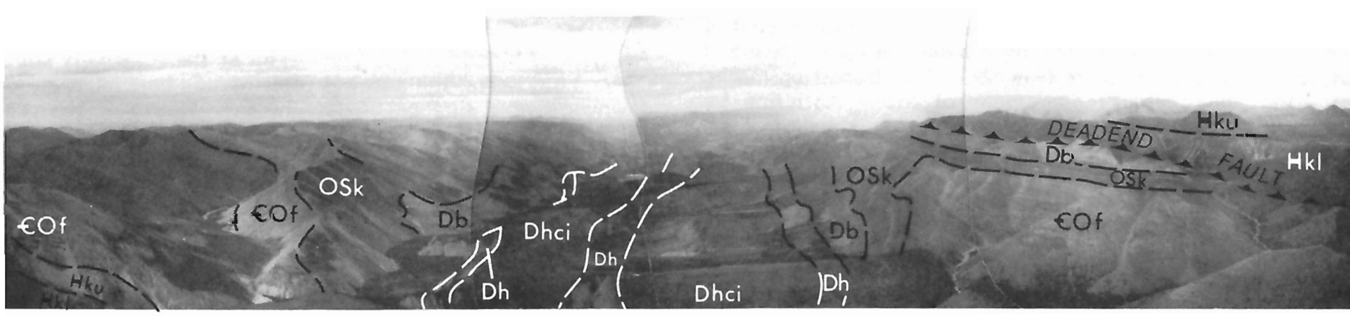

Figure 28. *Houdini Synclinorium, view east-southeast; Stony Anticline on left, unnamed anticline and Deadend Fault on right. Hkl, Hku - lower and upper Katherine Group; €Of – Franklin Mountain Formation; OSk – Mount Kindle Formation; Db – Bear Rock Formation; Dh – Hume Formation; Dhci - Hare Indian-Canol-Imperial, undifferentiated. GSC 159971, 159972, 159973, 159974*

Shortening was measured on a complete cross-section of the Outer Fold Belt drawn across Mount Eduni and Norman Wells map areas, near the widest part of the Outer Fold Belt and the locus of most rapid change of strike. Shortening measured at the top of the Katherine Group is about 12.5 km or about 12.3 per cent, and is entirely due to folding. Shortening within the much narrower (45 km) Outer Fold belt of Upper Ramparts River map area, as determined for the top of the Katherine (cross-section A-A'), is 7.4 km or about 14.3 per cent, and is in large part due to contraction on reverse faults, which are not characteristic of the Outer Fold Belt in general (see below).

A set of ancient faults striking N5° - 20°W, considered pre-Rapitan in age (Aitken and Cook, 1974b), is recognized easily on the shoulders and broad flat crests of anticlines where Helikian strata are exposed. Many faults belonging to this antecedent set are identifiable readily on the accompanying maps; the most notable is the Grand Forks Fault (Map 1452A; Fig. 24) which, within its 42 km length, illustrates phenomena ascribed by Aitken and Cook (ibid.) to Laramide rejuvenation of faults belonging to the set. Specifically, the Grand Forks Fault, because of its orientation with regard to the greatest principal stress during Laramide folding, has behaved on rejuvenation as a dextral tear-fault. In addition, it has allowed to a marked degree, as have other faults of the antecedent set, the independent development of contractional structures in the adjacent blocks.

Within the two map areas presently considered, a westward progression is noted from essentially unbroken folds to folds that are increasingly complicated by contractional faults. With the exception of Tabasco Fault, and a few other minor faults, the reverse faults dip southwest. Some strike more northerly than the fold axes, so that they pass gradually across the anticlines from limb to axial positions. At the western boundary of Upper Ramparts, the folded character of the belt is nearly obscured by faulting.

The Outer Fold Belt is bounded to the southwest by the trace of the Plateau Fault, or the outer limit of the sub-Plateau imbricate zone. The northeastern or outer boundary is the Mackenzie Mountain front, typically defined by mountain-front flexures. Between Ramparts and Arctic Red rivers, however, the mountain front is defined by Deadend Fault (Figs. 28-30), the largest of the contractional faults discussed above. Thus, the mountain front is formed successively westward by Gayna Flexure, Deadend Fault, and Cranswick Flexure (Fig. 24). This transition marks a left-hand *en echelon* replacement of Stony Anticline by Tawu Anticline as the frontal anticline. Houdini Synclinorium is obliterated where Deadend Fault and Tawu Anticline override the westward termination of Stony Anticline.

Northern Franklin Mountains and Mackenzie Plain Synclinorium

As previously summarized by Cook and Aitken (1972), the characteristics of the northern Franklins are narrow, linear to arcuate ridges that expose no strata older than Saline River, separated by broad, flat-bottomed synclines with little bedrock exposure ['ejective' style of Stille (1917); see also Dahlstrom (1969, 1970)]. Some of the ridges are homoclines thrust up along clearly mappable, steep reverse faults; Gibson Ridge (cross-section G-G') is an example. Others, in so far as can be observed at the surface, are simply steep-limbed anticlines (Fig. 31). The presence of repetitions of the stratigraphic sequence beneath Carcajou Ridge Anticline, as established in the Amoco et al. Carcajou K-68 (Cook and Aitken, 1976) well, however, proves that a thrust or reverse fault whose surface trace is covered underlies the surface anticline. We have assumed such a fault to underlie other anticlines of similar geometry (cross-sections F-F', G-G'). The fault-bounded homoclines and faulted(?) anticlines display a variety of structural trends (northerly, easterly, northwesterly and, in Sans Sault Rapids map area, northeasterly) and reversals of the sense of relative tectonic transport, not only from ridge to ridge, but also within individual ridges.

Although physiographically distinct, Mackenzie Plain shares a common structural style with Franklin Mountains and is in essence a depressed region of the former in which the widespread presence of nonresistant Cretaceous rocks at the surface has led to the development of areas of relatively flat terrain.

Within the region presently considered, structures of Franklin Mountains type meet the Mackenzie Mountain front only in the vicinity of 'Ovis' and 'Southbound' ridges, between the Hume and Ramparts rivers. Development of both Franklin and Mackenzie structures has produced unusual complications (Fig. 32).

Peel Plateau and Peel Plain

Peel Plateau and Plain are structurally a single entity. The physiographic expression of the Plateau is due entirely to the presence of resistant sandstone units of the Trevor Formation that mostly have been stripped from the rest of the region. The Plateau and Plain cap a single, regional, deep basin filled with Cretaceous rocks. Because both Lower and Upper Cretaceous series thicken toward the basin, it appears to have originated as a depositional basin, and to have been merely accentuated by gentle Laramide folding, as expressed by the regional Lichen Syncline.

Although Peel Plateau and Plain are but slightly deformed compared with neighbouring regions, thrust faults of several metres of displacement are observed to break the Cretaceous strata there (Fig. 18). The obvious physiographic break from Mackenzie Mountains to Peel Plateau follows Gayna and Cranswick flexures; however, both east and west of Arctic Red River the structural boundary would be more appropriately placed along the major but unmapped thrust fault north of Cranswick Flexure (Map 1452A).

Kinematics

Analysis of kinematics is best begun at the relatively simple Outer Fold Belt. The parallel folds of this belt must die out downward at a surface of detachment. However, the great width of the anticlines and the strongly expressed 'dejective' style show that the detachment is deep, well below unit H1, as is clear also from examination of the structural cross-sections accompanying the maps. Any consideration that the folds might be shallow responses to steep faults affecting the basement appears to be completely ruled out by their symmetry and great persistence along strike.

Like the folds of the Outer Fold Belt, those of the northern Franklin Mountains and Mackenzie Plain Synclinorium are concentric folds that must overlie a detachment surface; however, the contrast in their style with that of the Outer Fold Belt ['ejective' versus 'dejective' style; Stille, 1917; Dahlstrom, 1969, 1970] shows that the detachment surface of the northern Franklins must lie much closer to the present topographic surface than that of the Mackenzie Mountains folds. Because documented thrust faults in the northern Franklins consistently have their hanging walls either low in the Franklin Mountain Formation or in the Saline River Formation, we have postulated that the structural detachment is in the Saline River Formation (Cook and Aitken, 1973).

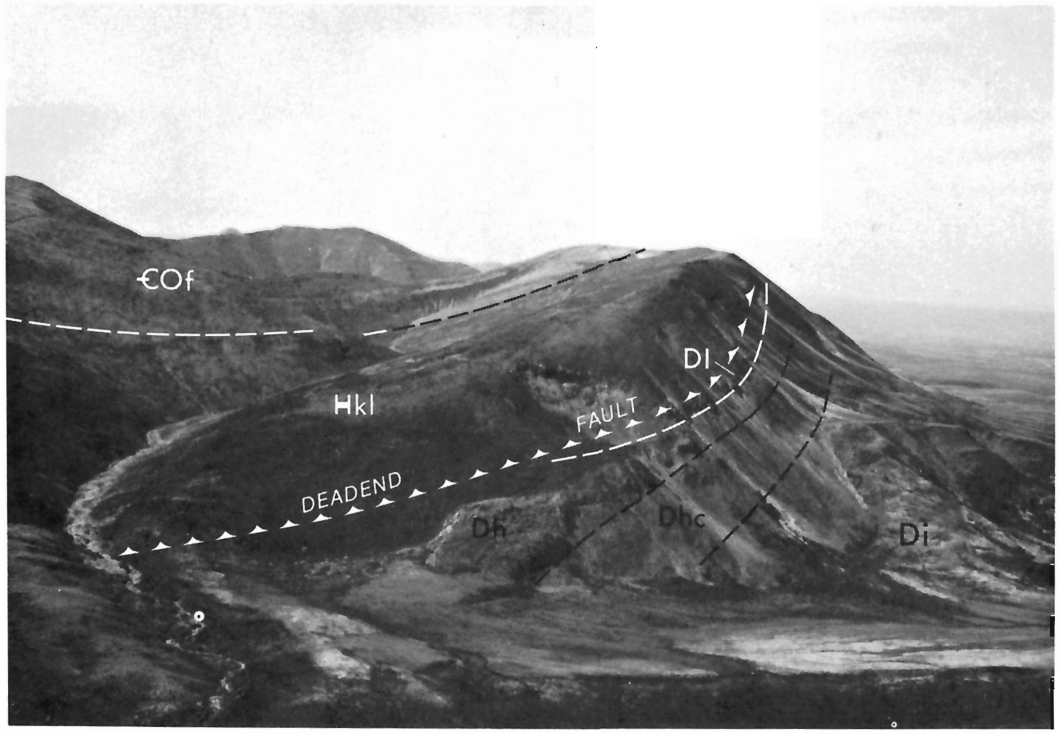

Figure 29. *Deadend Fault, defining the mountain front east of Arctic Red River; view to the west. Note inversion of Devonian succession in the footwall. Hkl – Katherine Group, lower division; €Of – Franklin Mountain Formation; Dl – Landry Formation; Dh – Hume Formation; Dhc – Hare Indian and Canol formations, undifferentiated; Di – Imperial Formation. GSC 202865*

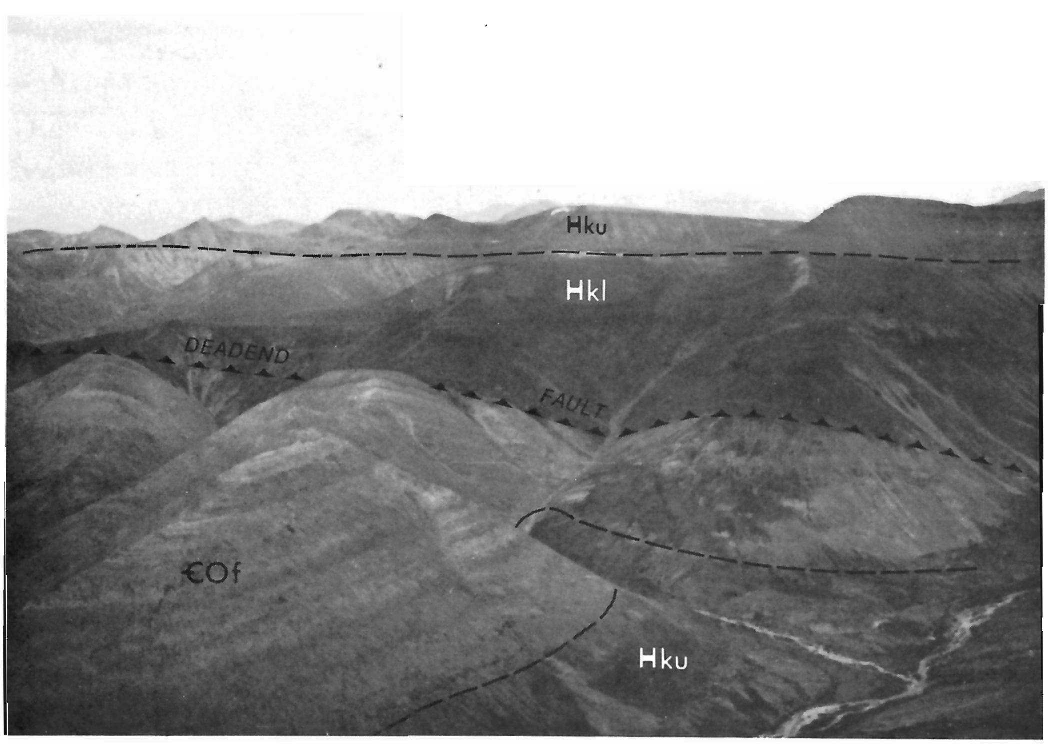

Figure 30. *Deadend Fault at longitude 129°33'. Hkl, Hku – lower and upper Katherine Group; €Of – Franklin Mountain Formation. GSC 159969*

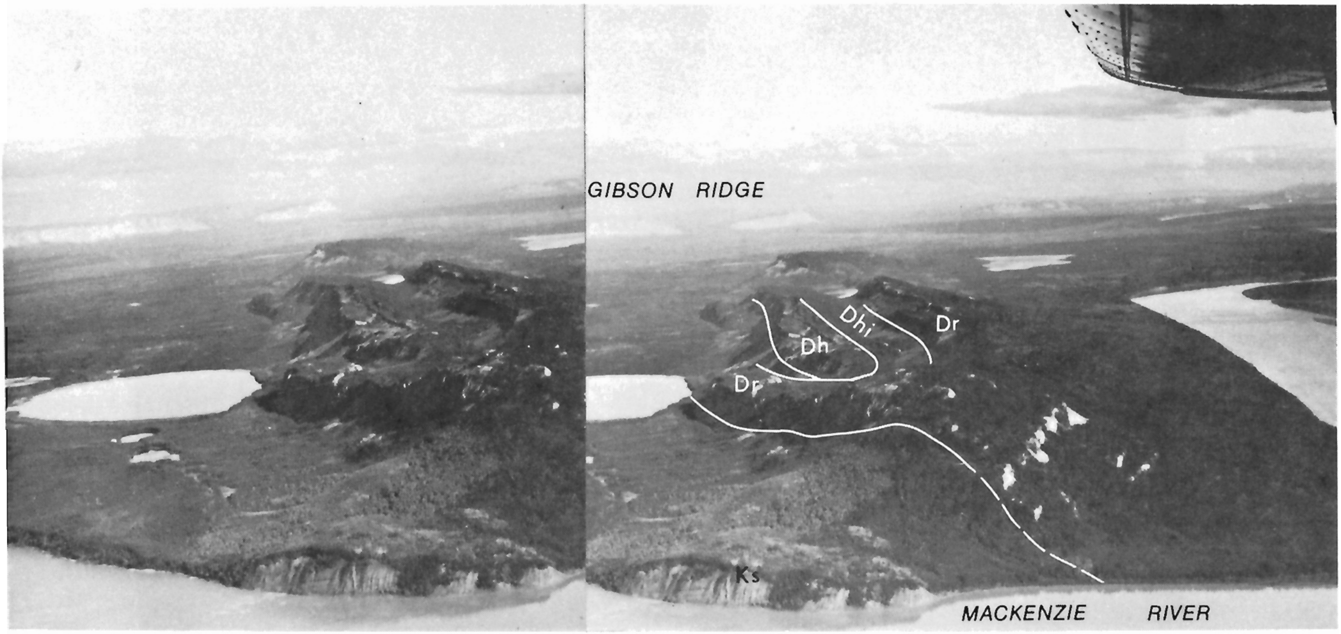

Figure 31. *East Mountain Anticline (stereographic pair); view to the east. Dh – Hume Formation; Dhi – Hare Indian Formation; Dr – Ramparts Formation; Ks – Sans Sault Formation (type section). GSC 160006, 160007*

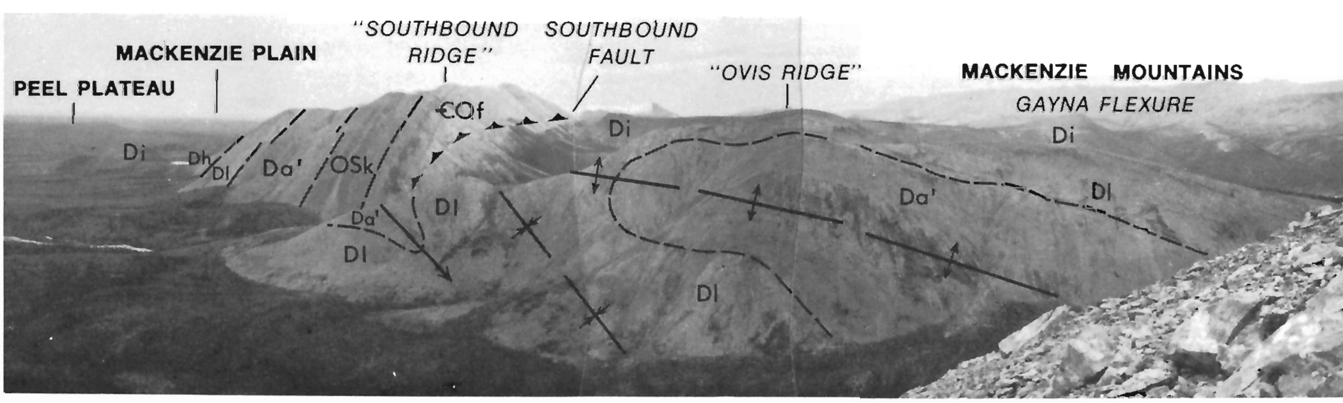

Figure 32. *Structural complexities at 'Southbound Ridge' and 'Ovis Ridge'. Southbound Fault, a structure of Franklin Mountains type, here encounters the Mackenzie Mountain front as defined by Gayna Flexure. €Of – Franklin Mountain Formation; OSk – Mount Kindle Formation; Da – Arnica Formation (including thin unit SD at base); Dl – Landry Formation; Dh – Hume Formation; Di - Imperial Formation. GSC 159966, 159967, 159968*

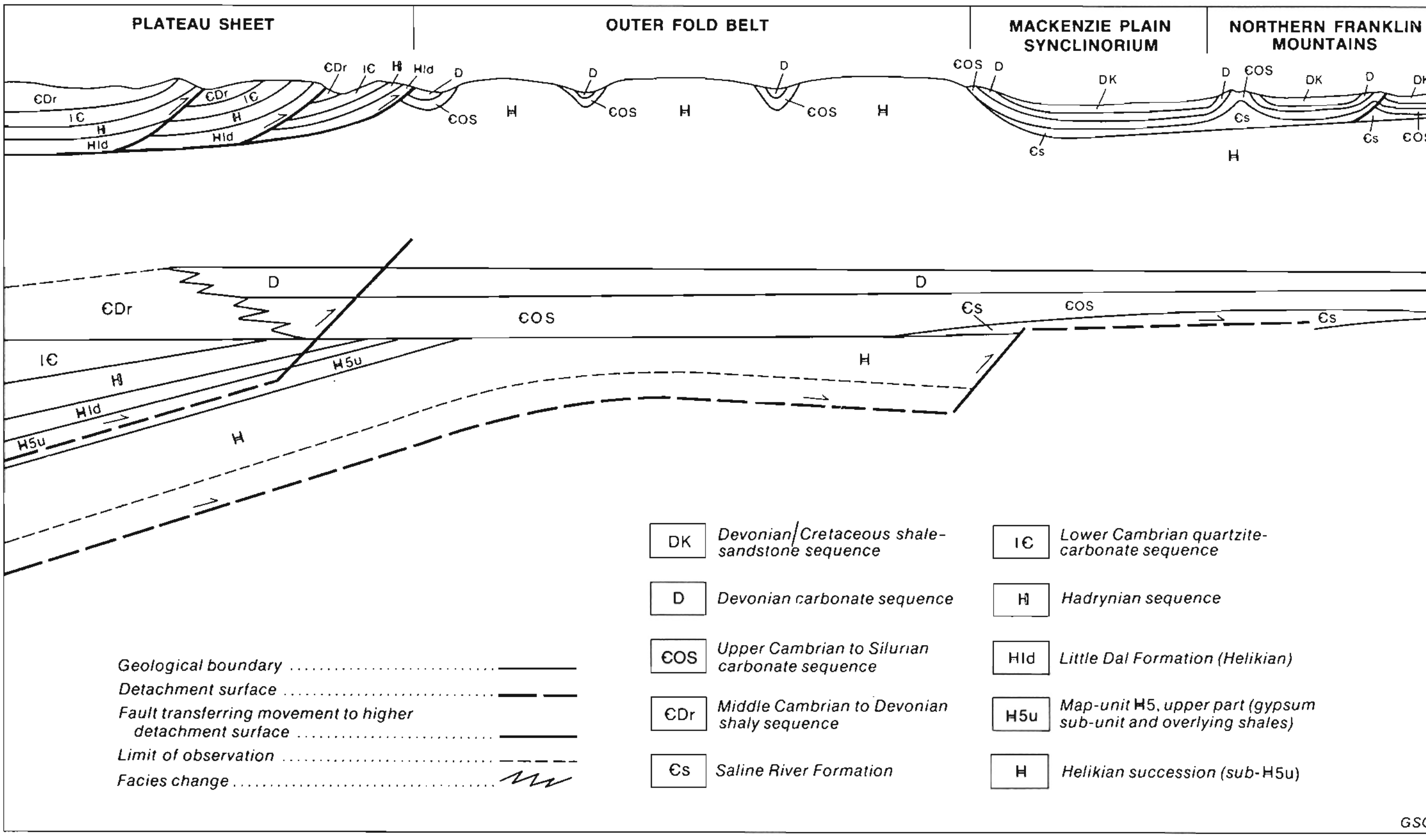

Figure 33. *Stratigraphic control of major levels of structural detachment.*

A corollary of the hypothesis of two different levels of detachment is that the abrupt mountain-front flexures probably mark 'steps' at which the surface of translation moves upward relative to hanging-wall stratigraphy. In the case of Gayna Flexure, the surface of translation shifts from the 'deep' (Helikian) level to the shallow detachment beneath the northern Franklin Mountains (Fig. 33). In the case of Cranswick Flexure, the Saline River is missing along the mountain front and the surface of translation passes into the concealed thrust fault that reaches the surface just north of the mountain front. Interpretive cross-sections illustrating this postulated transfer of tectonic translation from deep to shallow detachment levels are not presented because ignorance of deeper Precambrian stratigraphy and the depth to crystalline basement[1] allow an excess of freedom in depicting deep structure.

The contrasting tectonics of Peel Plateau and Plain versus Mackenzie Plain and Franklin Mountains are consistent with the hypothesis of a deep detachment physically linked to a shallow one. The principal difference between the latter subregion, with its 'ejective' uplifts, and the former, which lacks such uplifts, is that the Saline River Formation is missing from the mountain front adjacent to the latter. The Saline River underlies much of Peel Plateau and Plain, but its zero edge crosses the Mackenzie Mountain front more or less coincident with the westernmost occurrence of structures of Franklin Mountains type (Fig. 23). Apparently, the presence of Saline River evaporites at the mountain front is a prerequisite to the development of such structures through transfer of translation from deep to shallow detachments. In the absence of these evaporites at the mountain front, Upper Cambrian and younger strata are 'pinned' to deeper formations. Once this is recognized, then the pronounced swing of Franklin Mountains structures to a southwesterly trend, precisely along the western termination of the Franklins (Fig. 24), acquires new significance. It can be seen now as a drag or wrench zone between the Franklin Mountains detachment sheet moving northward on the underlying Saline River evaporites and the sheet to the west, which was 'pinned' to its substratum at the Mackenzie Mountain front because of the absence there of Saline River evaporites.

The prominence of large thrust and reverse faults, notably the Deadend and Tabasco faults, in the western part of the Outer Fold Belt, appears to be consistent with the foregoing postulates as to the 'deep' and 'shallow' detachments. These faults may take up the shortening that farther east is represented by Franklin Mountains deformation. However, this does not appear to provide a complete answer, because the equation:

$$W = C + F$$

required by the interpretation, does not balance, where:

- W = Shortening (by folding and faulting) in the western part of the Outer Fold Belt
- C = Shortening (mainly or entirely by folding) in the central part of the Outer Fold Belt
- F = Shortening (by folding and faulting) in the Northern Franklin Mountains

The following determinations have been made for W, C and F. W was determined in cross-section A-A'. The length of the top of the Katherine Group, measured from the trough of the syncline in the footwall of Plateau Fault to the

[1]Seismic surveys of Mackenzie Plain and Anderson Plain reveal that gently deformed, bedded Precambrian rocks at least four times as thick as the total Phanerozoic section underlie the Paleozoics (eg., Petersen, 1974).

trough of the syncline in the footwall of the hidden thrust fault in front of Cranswick Flexure, is 52 km in a present width of 45 km. Shortening is therefore 7.4 km or 14.3 per cent, approximately. C was determined in a complete cross-section of the Outer Fold Belt in Mount Eduni and Norman Wells map areas, passing close to the mutual corner of the two maps. The top of the Katherine, from the trough of the syncline immediately in front of the sub-Plateau Imbricate Zone to the trough of Imperial Syncline, is 101.5 km in a present width of 89 km. This gives a shortening of 12.5 km or 12.3 per cent, approximately. Determination of F is less straightforward because of the limited length of Franklin Mountains structures and the variety of structural trends. Shortening determined directly from cross-sections F-F' and G-G' at the base of the Mount Kindle Formation is 5.6 km, and is probably of the correct order of magnitude.

Thus, shortening in the western part of the Outer Fold Belt is apparently much less than the sum of shortening in the central part of the Outer Fold Belt plus that in the northern Franklins. Possible interpretations of this inequality are as follows:

1. The hypothesis of substitution of contractional faulting in the western part of the Outer Fold Belt for equivalent shortening in the northern Franklins is invalid.

2. The value of C in the above equation is determined where Mackenzie Mountains and the Outer Fold Belt, as well as Franklin Mountains, are near their greatest width, which is also the locus of greatest convexity of Mackenzie Arch and the trace of Plateau Thrust; this may be the locus of maximum shortening for the entire Mackenzie Fold Belt. W is determined where the Outer Fold Belt is much narrower. The belt narrows progressively westward toward its termination immediately east of Snake River (D.K. Norris, pers. com., 1976), with probable consequent decrease in shortening across it. Thus, if total shortening decreases westward, it follows that the equation $W = C + F$ cannot balance.

Turning now to the Plateau Fault, we note that its trace coincides roughly with two important changes in the stratigraphic succession of the Mackenzie Mountains; first, the limit toward the craton of the thick wedge of Hadrynian and Lower Cambrian strata and, second, the erosional limit toward the craton of evaporites in map unit H5 (Figs. 23, 33). Our interpretation is that the total package of strata in Selwyn Basin, thickened as it was by the above-mentioned Hadrynian-Lower Cambrian wedge, was too thick to undergo the harmonic folding that affected the adjoining, thinner, and partly equivalent package of the Outer Fold Belt. As a result, part of the thickened package, overlying a suitably situated ductile zone (the evaporites of map unit H5) detached from the deeper strata, and as the latter underwent folding, advanced above them as a thrust sheet. The relationship exemplifies the 'upper detachment' of Dahlstrom (1969, 1970). This analysis implies that shortening achieved by displacement on the detachment within map unit H5 would be equivalent to shortening achieved by underlying and unseen folding (ibid.). This is an additional argument that cumulative horizontal displacement on the Plateau and related faults is moderate.

The timing of folding in the Outer Fold Belt can be bracketed broadly by stratigraphic considerations. Distribution of the Lower and Middle Albian Sans Sault Formation (sandy facies) and Arctic Red Formation (shaly facies) indicates source areas on the craton to the northeast (Fig. 21). The absence of comparable flanking sands to the south suggests that the southern margin of the basin of the Arctic Red Formation was well south of the present Mackenzie Mountain front. Uplift to the south is indicated first by the Upper Albian to Turonian sandstones of the Trevor Formation (see Fig. 20). It is doubtful that the Trevor, characterized by fine-grained sandstone and lacking significant conglomerates, could have been deposited only a few kilometres in front of fold mountains rising in the Outer Fold Belt. On the other hand, Paleocene[1] coarse clastic strata of Carcajou Canyon (96D) and Fort Norman (96C) map areas, though themselves gently deformed, appear to record the presence of high ground, exposing Paleozoic rocks not far to the west (Yorath in Aitken and Cook, 1974c). Moreover, Late Cretaceous or post-Cretaceous deformation southwest of Plateau Fault is confirmed by deformed nonmarine Cretaceous rocks reported by Blusson (1971) in Sekwi Mountain map area (105P). These considerations suggest that the Outer Fold Belt came into being in latest Cretaceous or Paleocene time.

The arguments given above, that relate the kinematics of the Plateau Sheet to those of the Outer Fold Belt, strongly support contemporaneity of deformation in the two subregions. Nevertheless, the rise of the Plateau Sheet has left no stratigraphic record of which the writers are aware, and the possibility cannot be excluded that movement took place on Plateau Fault prior to folding in the Outer Fold Belt and beneath the Plateau Sheet. This does not invalidate the earlier arguments relative to structural detachments. In any event, even if movement on Plateau Fault preceded folding in the Outer Fold Belt, the Plateau Sheet must have arrived in its present position during the folding, being carried forward on the Outer Fold Belt and the deep detachment beneath it.

The kinematic relationship between the Outer Fold Belt and the northern Franklins, as well as stratigraphic relationships, require that deformation in these two subregions be at least broadly contemporaneous. This does not exclude the possibility that deformation began earlier in the interior Mackenzies than in the Franklins. Support for this possibility is found in the thrust and reverse faults that become prominent west of Mountain River, are postulated to be kinematic equivalents of Franklin Mountains deformation, and clearly disrupt pre-existing folds (note in particular their preference for the north limbs of anticlines). The strike of these faults, slightly more northerly than the trends of the folds, further suggests a later reorientation of the axis of greatest principal stress.

In summary, four subregions of contrasting tectonic style are recognized. It has been demonstrated that each of these subregions has a unique stratigraphic succession that, by controlling the levels of structural detachments, has dictated the tectonic style.

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[1]Bell (in Hume, 1922, p. 76) assigned the Tertiary macroflora from localities near Fort Norman to the Eocene, but recent palynological investigations suggest a slightly older date. Coal from the west bank of the Mackenzie River, south of Police Island, yielded palynomorphs identified by A.R. Sweet as Paleocene in age (GSC locs. C-29068-70; Paleontology Report 6-AS-1973). W.W. Brideaux reached a similar conclusion regarding samples collected between 70 and 108 m above the base of the exposed section in the Tertiary Hills (GSC locs. C-41897-96; Paleontology Report WWB-16-1975). On these data, the Tertiary succession of the areas cited appears to be Paleocene to early Eocene in age.

ECONOMIC GEOLOGY

Petroleum and natural gas

The potential of the region for hydrocarbon production has been summarized by Tassonyi (1969), Gilbert (1973), and Kunst (1973); accordingly, what follows is largely a review.

The crestal regions of exposed structures of Franklin Mountains type are judged to have very low potential because all prospective formations are deeply breached, and, because the structure of formations not exposed is likely to be weakly related or unrelated to the structure observable at surface. It follows that only the Mackenzie and Peel plains, the Peel Plateau, the flanks of Franklin Mountains uplifts, and the frontal homocline of the Mackenzies are considered potentially productive of oil or gas.

Precambrian

The Precambrian of the two map areas has virtually no hydrocarbon potential. Although completely unmetamorphosed, the sandstones display little or no porosity, and the carbonate rocks hold out little promise of porosity other than fracture porosity.

Cambrian to Silurian

Basal Cambrian clastic strata equivalent to the gas-bearing sandstones (Petersen, 1974) encountered in the Tedji Lake F-24 well (67°43'38"N, 126°46'46"W) are present in the subsurface northeast of a feather edge which apparently marks, in part, the northeast flank of Mackenzie Arch. The locus of the feather edge is very poorly defined, and the extent and character of sandstones within the interval are unknown.

Evaporites of the Saline River Formation provide a potential updip seal to any permeable equivalents present to the southwest (Gilbert, 1973), and there is a possibility of encountering a sandy facies against the northeast flank of the Mackenzie Arch (Aitken, Macqueen and Usher, 1973, p. 31). On the other hand, solution of evaporites and attendant collapse may have breached any traps that existed formerly.

Dolomites of the Franklin Mountain and Mount Kindle formations contain intervals of vuggy porosity at some localities. No shows of gas or oil have been encountered in those wells that penetrate the lower Paleozoic carbonate succession, but large flows of water on drillstem test confirm the existence of significant porosity in the following wells:

Atlantic Columbian Carbon et al. Manitou Lake L-61
Triad BP Arco CC Hume River O-62
Atlantic Columbian Carbon Arctic Circle Ontaratue K-4
Decalta Trans Ocean GCOA Ontaratue I-38
Mobil Hume River L-09
Candel Mobil et al. North Ramparts A-59
McDermott Canada-GCO Maida Creek F-57
Mesa Murphy GCOA Hanna River J-05
Amoco et al. A-1 Carcajou K-68
Candel et al. SOBC Mountain River A-23
Atlantic et al. Shoals C-31
Arco Clarke et al. Mountain River H-47

Devonian

Map unit SD (Delorme Formation equivalent in part) pinches out in a regionally updip direction. This creates a regional stratigraphic trap beneath the Lower Devonian evaporites, but no significant porosity has been encountered within the unit.

A regional stratigraphic trap of great extent probably once existed where the porous carbonates of the Gossage (Arnica-Landry) Formation passed updip into impermeable Bear Rock anhydrite; this probably explains the oil shows in the Hume River D-53, Shoals C-31, and Hanna River J-05 wells, and the gas show at Mountain River H-47. Unfortunately, circulating fresh groundwater has dissolved Bear Rock anhydrite on a large scale, causing collapse of the overlying strata and breaching of the trap. On the other hand, it is possible that exposure of pooled Bear Rock oil to fresh water has created a tar seal and thus a secondary trap. The possibilities of finding an unbreached major pool appear to have been fairly well exhausted by exploratory drilling.

No porosity of significance has been encountered in the many penetrations of the Hume Formation, although a trace of oil 'bleeding' from a core in the Hume was reported from the R.O.C. et al. Grandview Hills No. 1 well (67°06'12"N, 130°52'30"W). The formation appears to be devoid of potential, but may have served as a platform for younger carbonate buildups, of which there is only one known example, that encountered in the Atlantic et al. Manitou Lake L-61 well (66°20'40"N, 128°58'00"W), between depths of 168 and 321 m.

The Ramparts Formation was a prime early target for hydrocarbon exploration in the region, as drillers attempted to find another pool like that at Norman Wells. Unfortunately, the formation generally has had poor porosity where encountered, an apparent exception being the Hanna River J-05 well. Two minor shows of gas have been encountered in Sans Sault map area, at the Hume River O-62 and Carcajou L-24 wells. In considering any remaining possibilities for the discovery of new fields in the Ramparts Formation, it should be kept in mind that the Norman Wells pool is a stratigraphic, not a structural trap.

Sandstones of the Imperial Formation are unpromising as possible hydrocarbon reservoirs, as judged by the fact that only a single drillstem test (at Hume River D-53) has been conducted within the two map areas, and that without significant result.

Cretaceous

Cretaceous sandstones are commonly porous in outcrop. This may be a surface weathering effect because the paucity of drillstem tests on Cretaceous intervals suggests that, in the subsurface, Cretaceous sandstones, including the widespread basal sandstone, have little effective porosity. On the other hand, where Cretaceous oil may have migrated into sandstone traps prior to deep burial, it can be expected to have preserved much of the initial porosity of the sandstones. If such oil has escaped degradation by exposure to circulating groundwater, the possibilities of Peel Plateau and Plain for hydrocarbons pooled in Cretaceous rocks would appear not to be exhausted. A Cretaceous interval tested in the Hanna River J-05 well gave up 18 m of oil-cut fresh water (oil gravity 25° - 35° API).

Metallic minerals

Prior to the field season of 1970, the immediate region had received little attention from prospectors, and certainly had not been subjected to the large-scale, unified, geochemistry-oriented methods that were developed and widely and successfully applied in the Cordillera during the 1960s. During the period 1970 - 74, large exploration programs using such techniques were carried on in the region. Their success in finding a number of showings immediately along strike to the southeast of Upper Ramparts River map area, and the staking of a large group of zinc-lead claims on its south border in 1974 (Brock, 1975), demonstrate that the region is potentially productive of metallic minerals.

Zinc-lead

A large group of mineral claims, referred to as the RT Group, was staked in 1974 on what are informally known as the Gayna River showings, which lie along the axis of Shattered Range Anticline immediately south of the south border of Upper Ramparts River map area, at 130°45'W to 131°00'W. The first showing is understood to have been found by checking a geochemical anomaly, and is in the Franklin Mountain Formation. The better showings, more than twenty in number, are all in map unit H5, especially the grainstone subunit. The principal ore mineral is sphalerite in a range of colours from pale yellow to red. A minor amount of galena is present also. The gangue is chiefly country-rock dolomite and late, coarsely crystalline white dolomite. Both open-space-filling and replacement processes have been operative during ore-mineral deposition, and the mineralization is clearly of Mississippi Valley type. The property was undergoing active exploration in the summers of 1975, 1976 and 1977.

It appears to the writers improbable that the grainstone subunit of map unit H5 would be host to only a single small area of stratabound mineralization throughout its great regional extent; it therefore merits further careful prospecting.

The Sekwi Formation regionally is host to a large number of zinc-lead showings (Dawson, 1975) and therefore merits careful attention wherever it occurs. Two groups of zinc-lead claims have been staked on showings in the Sekwi along strike to the southeast of Upper Ramparts River map area (ibid.).

Although zinc-lead showings in Silurian and Devonian carbonate rocks are much less numerous in the region than those in the Lower Cambrian, some properties have been staked on such showings, including the AJ claims in Bonnet Plume Lake map area, at 64°46'N, 130°29'W (Dawson, 1975).

Copper

The Helikian of western North America tends to be cupriferous (Harrison, 1972). This tendency persists in the rocks assigned to the Helikian in the Mackenzie Mountains (Gabrielse et al., 1972, p. 113, 114). The Helikian succession of Upper Ramparts and Sans Sault map areas therefore merits attention as a possible host to stratabound copper mineralization. Traces of copper minerals have been noted in the Tsezotene Formation at a number of localities; one specific occurrence of malachite and azurite is in very thin sandstone beds of the Tsezotene at 65°19'N, 131°42'W.

The Redstone River Formation, which is host to stratabound copper mineralization in Glacier Lake, Wrigley Lake and Mount Eduni map areas, has been erosionally stripped from Upper Ramparts and Sans Sault map areas.

Iron

The Rapitan Group is host to a major iron deposit on the Snake River, Yukon (Gross, 1965). The Snake River deposit, however, is in the lower Rapitan, considered to be missing from the region described in this report, and neither the Rapitan nor any other formation of the two map areas is known to have potential as a host to iron ore.

Nonmetallic minerals

Fluorite

Fluorite occurs in at least two beds in the upper part of map unit H1, at 65°14'N, 130°48'W. The richer bed, estimated to contain about 5 per cent fluorite, is a dolomitic sandstone. Two varieties of fluorite are present, one amethyst-coloured and easily recognized, the other white and easily overlooked in the presence of white, sparry carbonate minerals.

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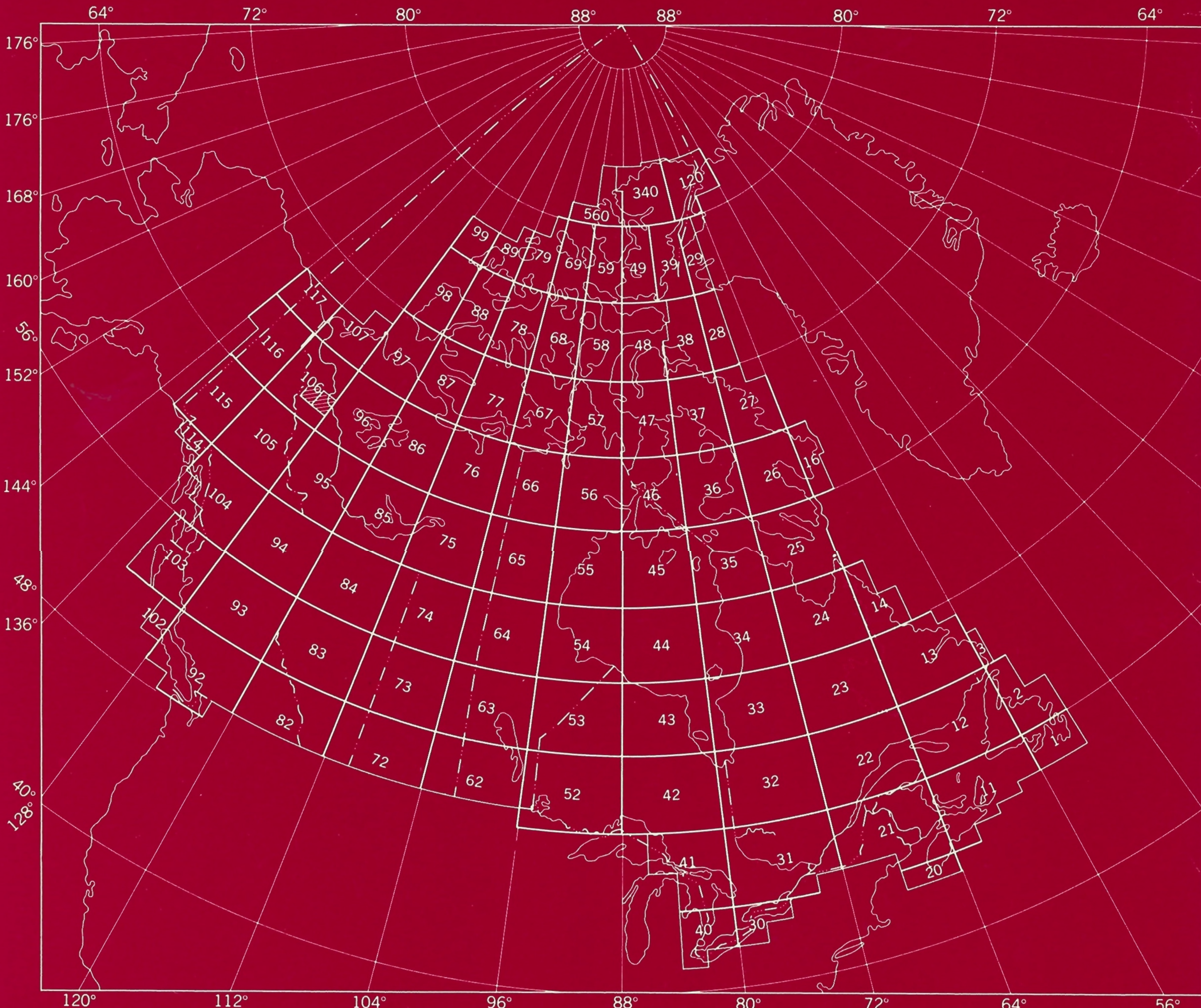

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