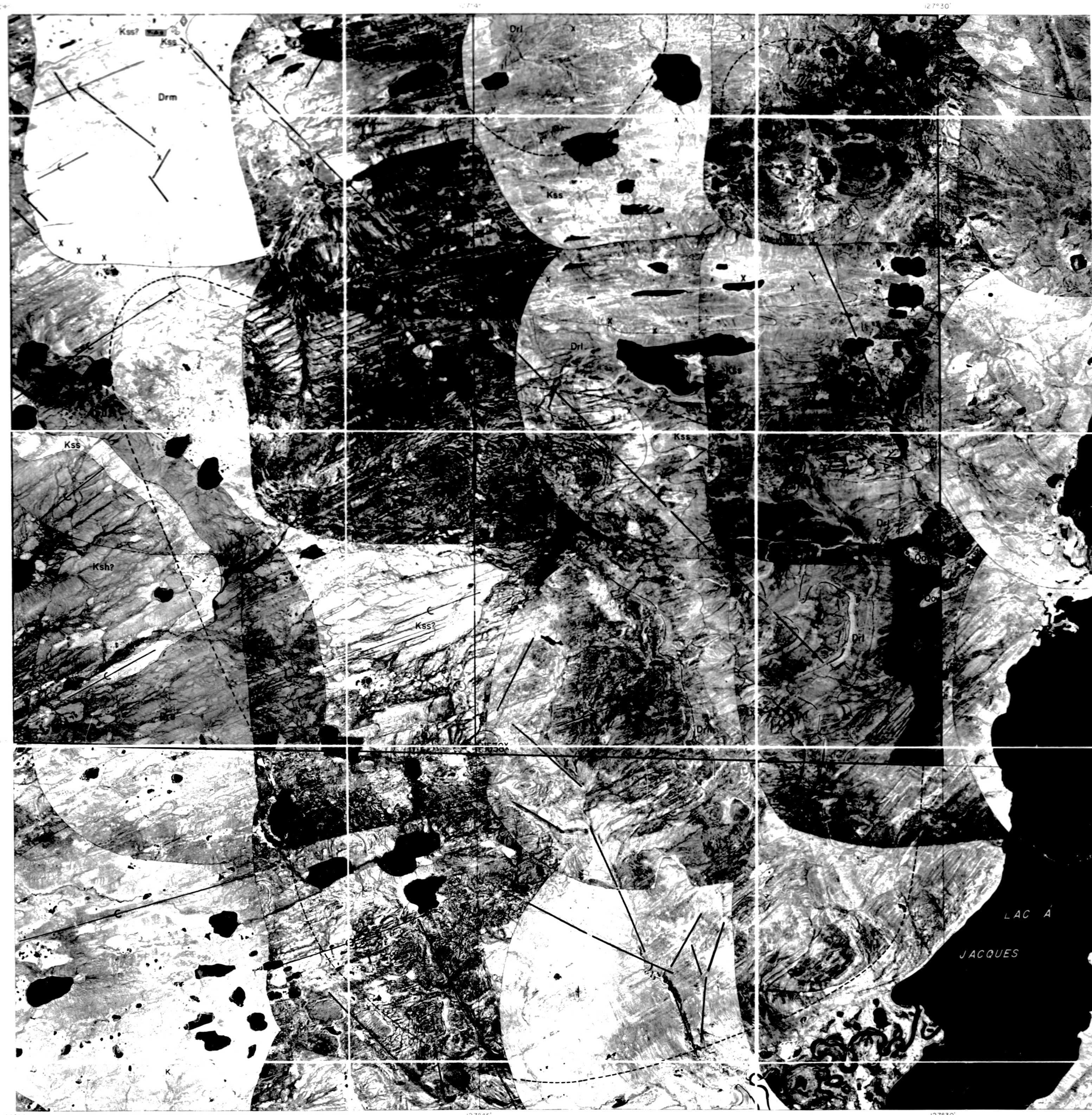

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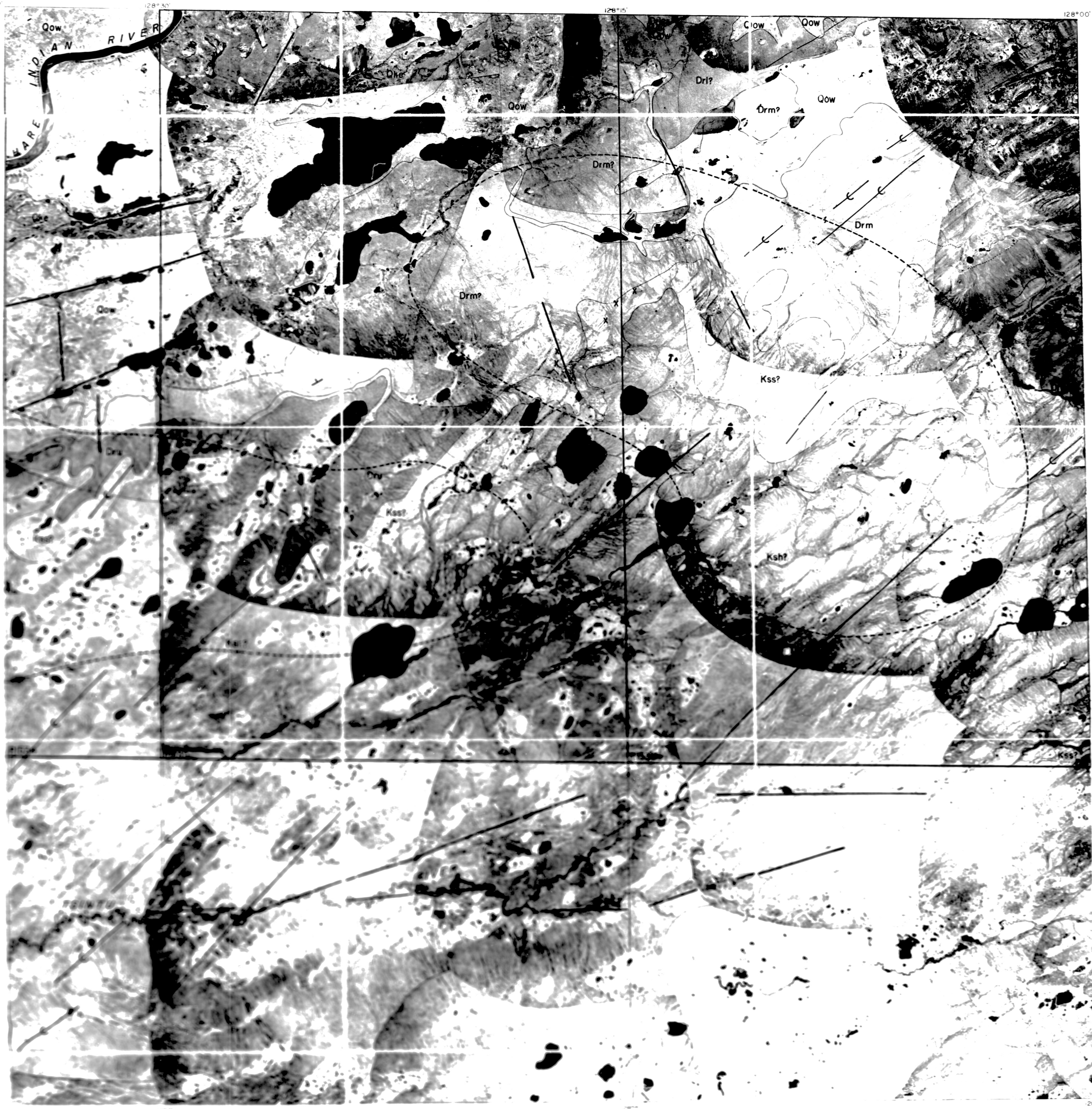

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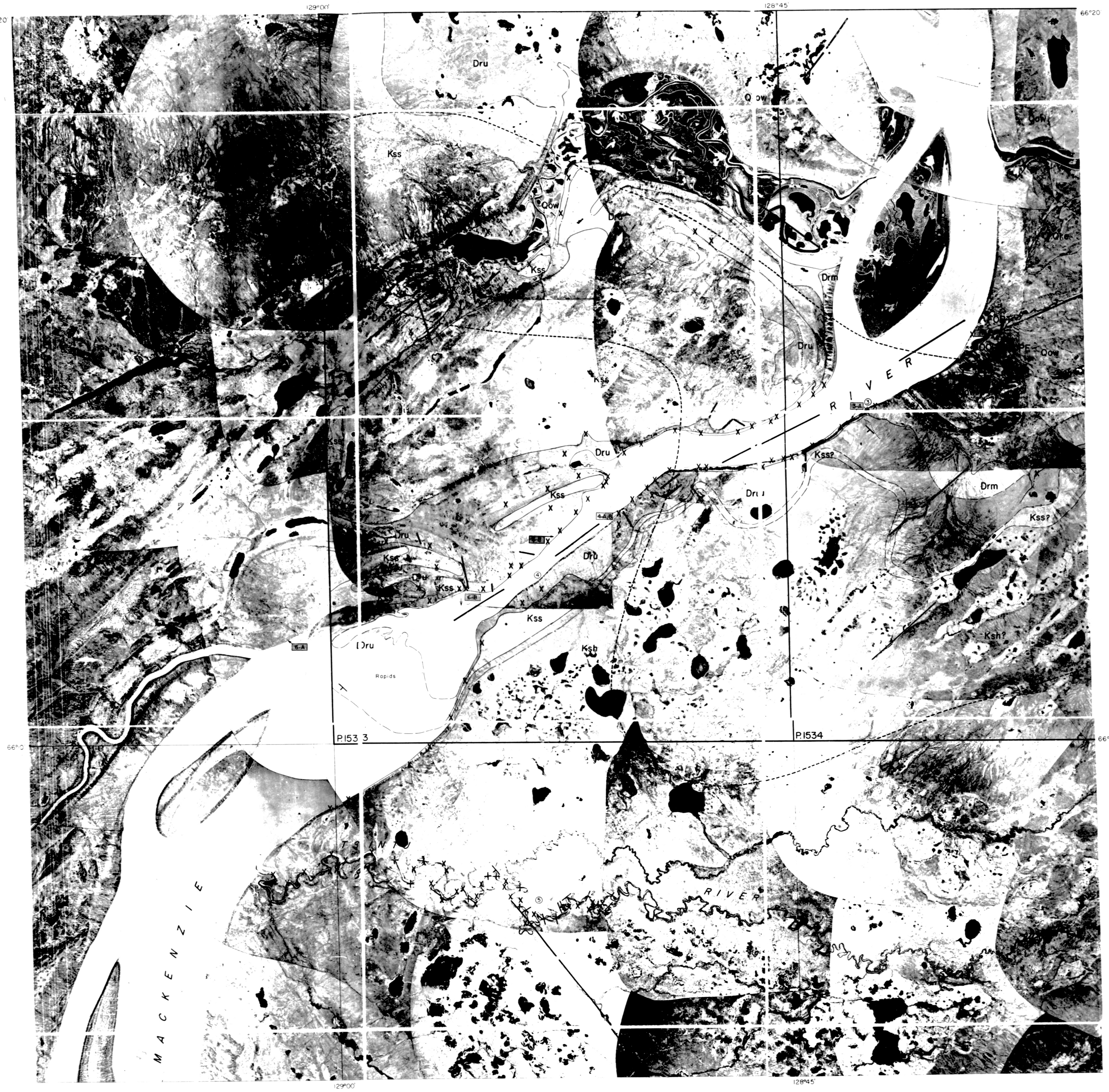

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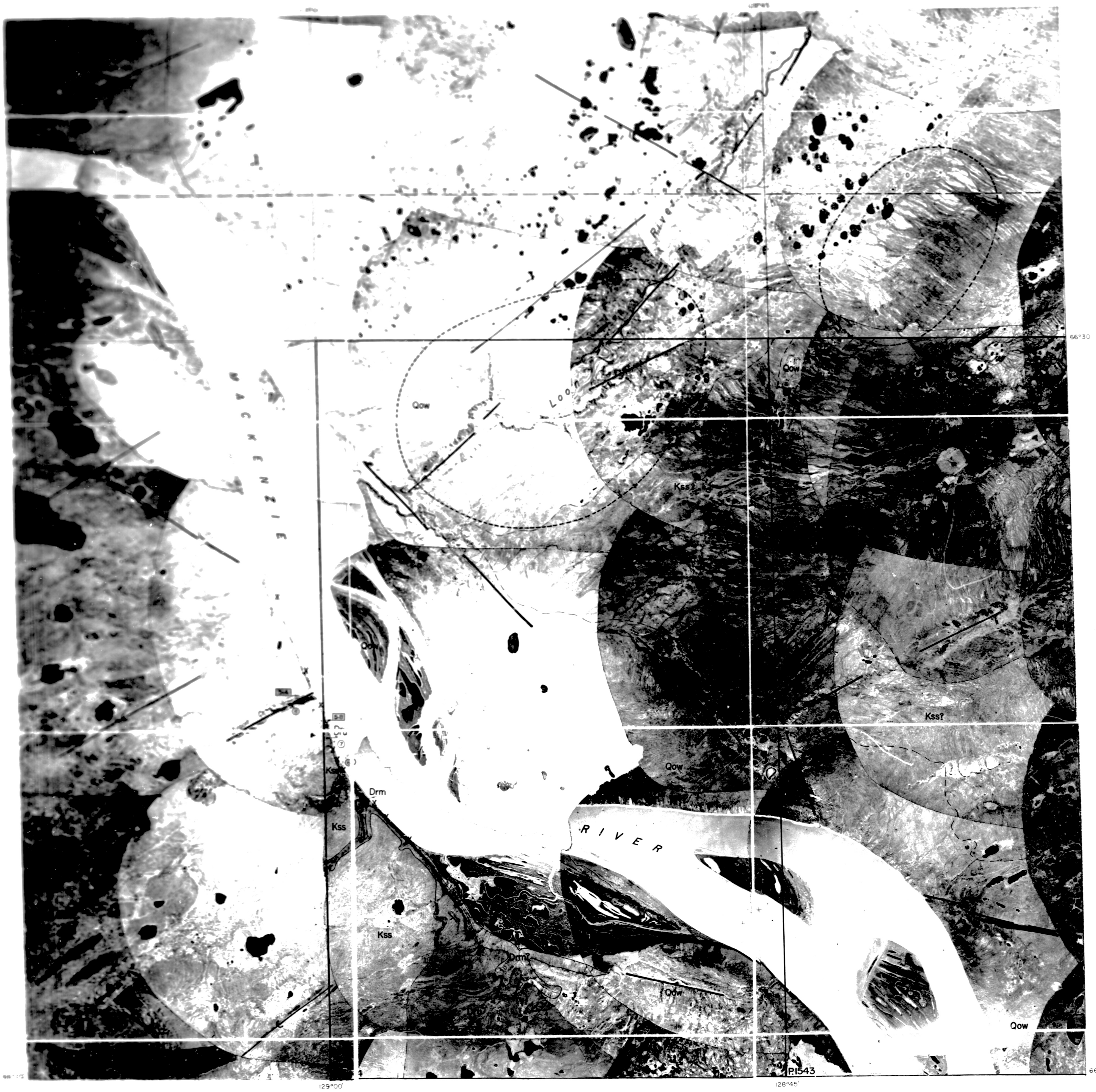

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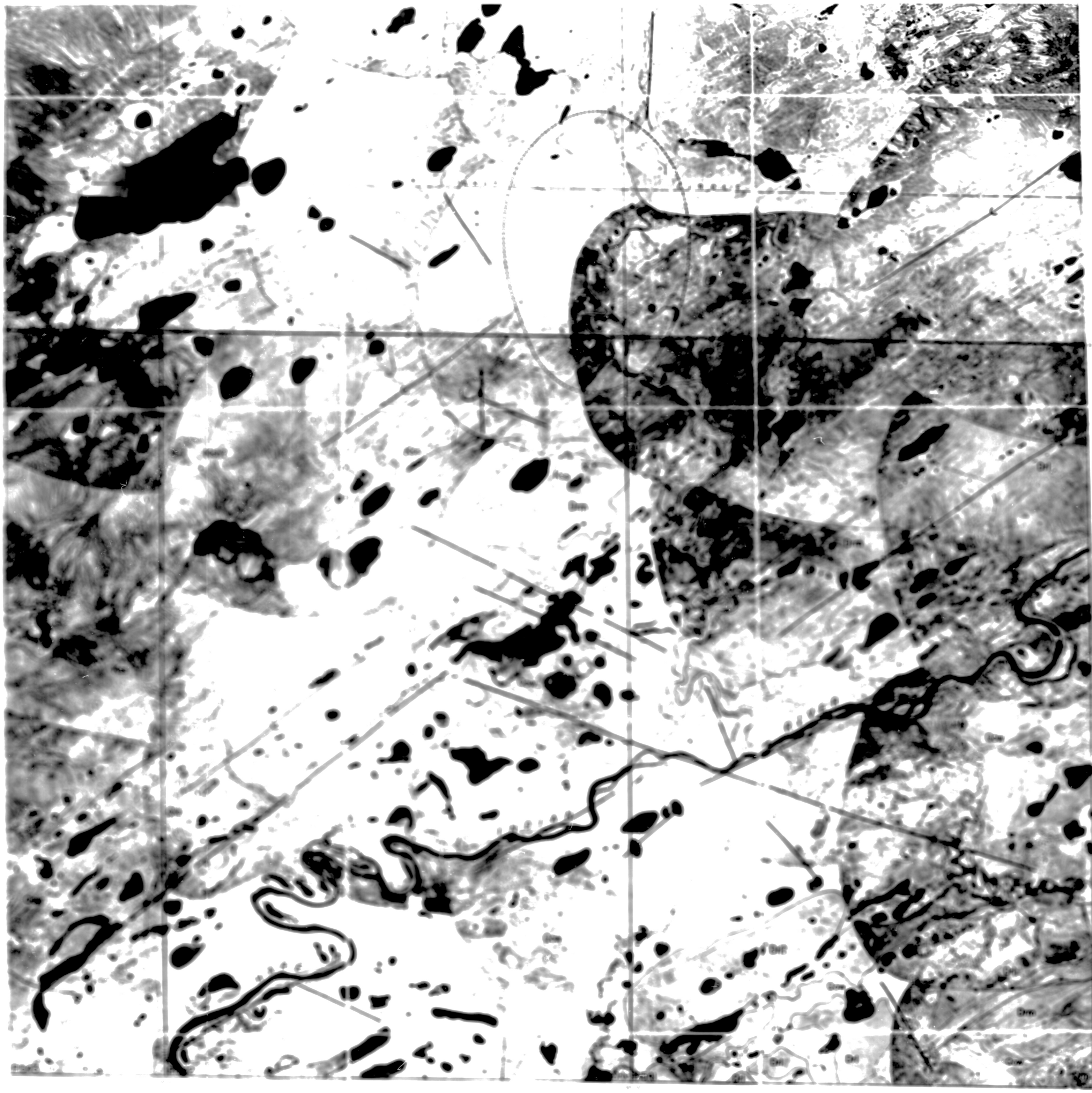

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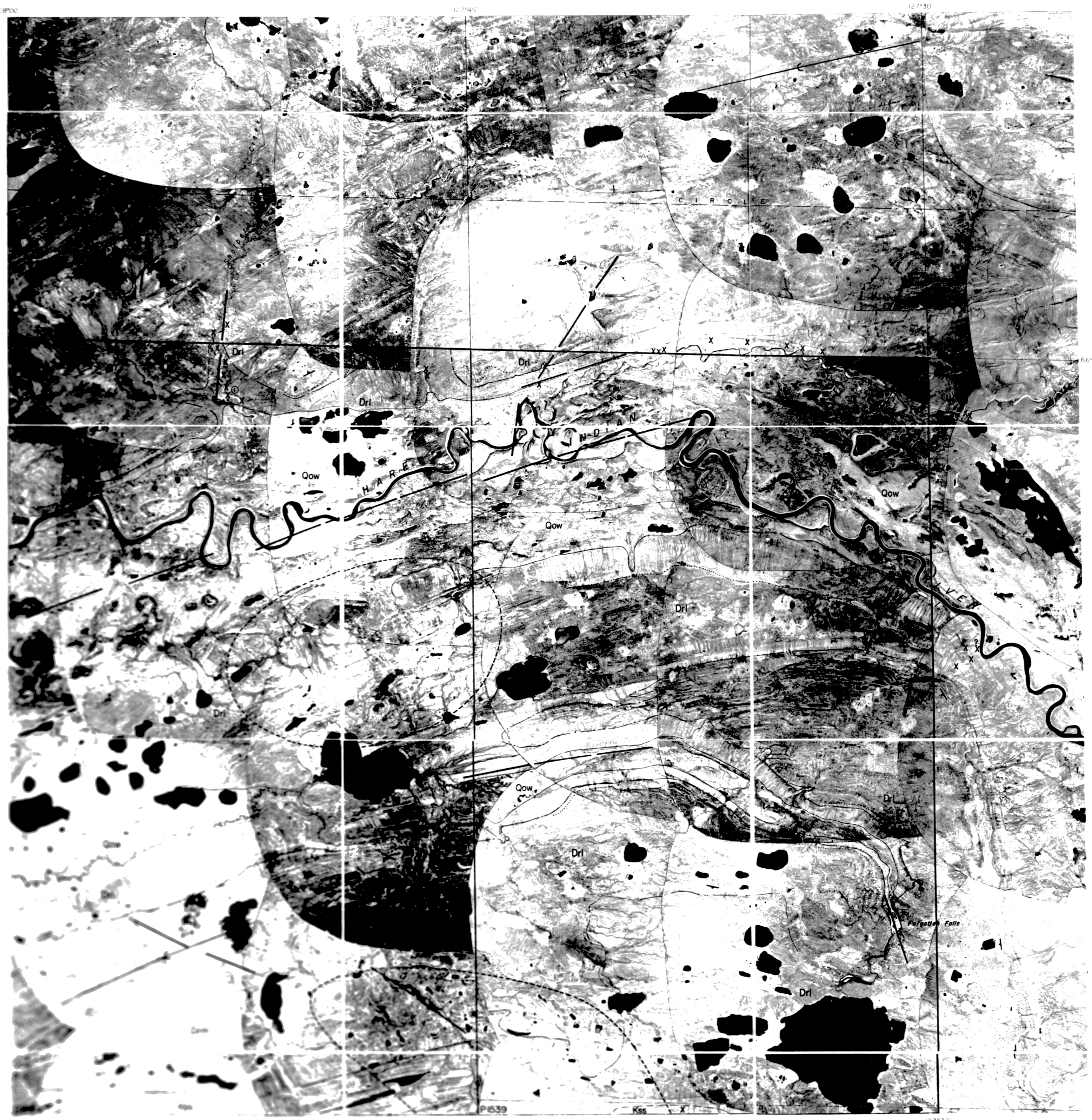

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GEOLOGICAL REPORT

GLACIER EXPLORERS LIMITED P. & N. G. HOLDINGS

FORT GOOD HOPE AREA, N.W.T.

Prepared For

Glacier Explorers Limited

February, 1960

J. C. SPROULE & ASSOCIATES
GEOLOGICAL & EXPLORATION CONSULTANTS

1009 FOURTH AVENUE WEST
CALGARY ALBERTA

TELEPHONE
AMHERST 9-7951

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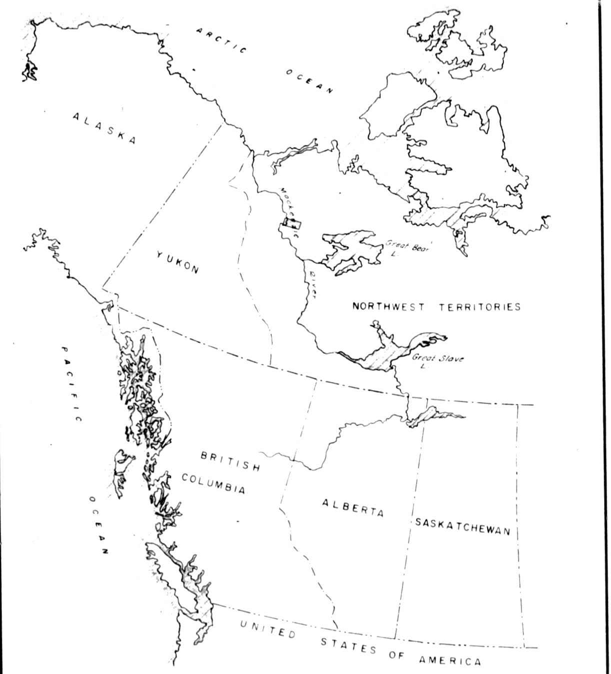

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WESTERN CANADA

Area covered by report

J.C. SPROULE & ASSOCIATES, CALGARY

GEOLOGICAL REPORT

GLACIER EXPLORERS LIMITED P. & N. G. HOLDINGS

FORT GOOD HOPE AREA, N.W.T.

INTRODUCTION

Description of Project

The present report contains the results of a field geological survey of an area that is located in the immediate vicinity of Fort Good Hope, N.W.T. and to the east of that settlement. The work was conducted during the summer of 1959 by a J.C. Sproule & Associates field party, at the request of Mr. H.B. Hicks, acting for Glacier Explorers Limited, hereinafter referred to as "the Company."

The principal objective of the study was to obtain detailed stratigraphic and structural data leading to a preliminary evaluation of the petroleum and natural gas prospects of the Fort Good Hope structural arch, with particular reference to the identification of a suitable structure for a drilling location.

The Company holdings consist of a rectangular block of lands situated on both sides of Mackenzie River, but mainly to the east, comprising Petroleum and Natural Gas Permits numbered 1533 to 1544, inclusive. The holdings total approximately 617,472 acres. The Company retain a full interest in this area, which originally formed part of a more extensive block, the greater part of which was sold to The Atlantic Refining Company.

Reports concerning the original holdings were prepared by J.C. Sproule & Associates and submitted to the Company in two previous years. These were entitled: "Preliminary Geological Reconnaissance Report, Lower Mackenzie Plain Area, N.W.T.," 1957, and "Geological Reconnaissance Report, Glacier Explorers Limited P. & N. G. Holdings, Lower Mackenzie Plain Area, N.W.T.," 1958. Most of the data and conclusions recorded in these reports are still valid, and have been incorporated in part with the present report.

The geological evaluation of the Fort Good Hope Permit area was carried out as a combined air and ground survey. In this project all previous work, in the form of both photogeological and ground studies, was taken into consideration as background material. In the present field work it was planned to study outcrops as fully as the working season permitted. The detailed study of outcrops was to be expanded by the exploration of strategic localities that were covered by soil and vegetation. For this purpose several hand augers and a McCullough Model-99 power auger were flown into Fort Good Hope. These augers are capable of reaching a depth of 20 feet or more under normal circumstances, but after considerable experimentation it was found that the equipment was not adequate to cope with permafrost conditions. As a result, the drilling project was abandoned without much having been accomplished.

The field project was conducted under the supervision of R. deWit, assisted by party chief G.A. Wilson, and junior assistants M. Korostil and A. G. Hicken. Considerable assistance in field mapping and photogeological studies was also received from senior geologists D.L. Campbell and G.P.E. White, and from Dr. W.O. Kupsch, Assistant Professor of Geology, University of Saskatchewan, employed by J.C. Sproule & Associates for the summer months. Dr. J.C. Sproule spent several days at Fort Good Hope reviewing the photogeology and field geology of the area. In addition, the party consisted of helicopter pilot D.E. Sholberg and engineer M.J. Stasek. Acknowledgment is also due to M. Hornby, our Expeditor located at Fort Good Hope, whose responsibility it was to handle and distribute supplies and equipment to all our field parties working in the Northwest Territories. M. Rivet was the cook.

Due to terrain problems most transportation of field crews was carried out by air but a canoe with outboard motor was also used to study the cliffs of the Ramparts and other outcrops along the Mackenzie River. The most used transportation unit was a Bell Model G-2 helicopter, chartered from Vancouver Island Helicopters Ltd. This aircraft had been mounted on rubber floats to enable it to land on both land and water. A Beaver float-equipped aircraft flying under contract for J.C. Sproule & Associates, and owned by Cascade Air Service Ltd. of Chilliwack, B.C., was stationed at Fort Good Hope. This aircraft maintained connections with our other field parties and with Norman Wells, and also provided a safety factor with respect to the extensive airborne operations.

Field operations on the Company holdings began in early August and ended September 25. All personnel involved in the mapping project of the Fort Good Hope area were stationed at Fort Good Hope where a two-storey house had been rented which served as storage, office and sleeping quarters. A small hut was made available to us for cooking and meals by the Department of Northern Affairs. The cooperation of officials, who include personnel of the Department of Transport and the R.C.M.P., is gratefully acknowledged.

In the present report the geological features of the Company holdings are discussed in as much detail as the available data permits. Regional data which have a bearing on the local structural and stratigraphic problems are presented. The report is illustrated by maps, cross-sections, coloured photographs and photomosaics.

Previous Work in the Area

For details regarding early exploration of the Mackenzie Basin we refer to the report we prepared for the Company in 1958. In summary, geological exploration dates back to 1888 when the Geological Survey of Canada sent a small reconnaissance expedition into the general area. In 1920 oil was discovered at Norman Wells, but most development of the field took place during the Second World War. Several wildcat wells were drilled in the general Norman Wells area of the Mackenzie valley during and immediately after the war years. All of these wells were dry. The Sans Sault No. 1 well, nearest to the Company holdings, was drilled in 1945 on the left bank of Mackenzie River at a distance of approximately 70 miles south of the Fort Good Hope Permit area. This drill hole penetrated the Bear Rock formation of Devonian age and reached a depth of 3,291 feet.

PHYSIOGRAPHY AND ACCESSIBILITY

For convenient reference, the physiography and accessibility of the area are summarized below. In reading this summary you are referred also to the accompanying Figure III. For a more complete description please refer to our 1958 report.

Physiography

The Company holdings are situated within the Interior Plains physiographic province. To the south lie the folded and faulted ranges of the Franklin Mountains, which curve from a westerly direction to the southeast. The most northern ranges of the Franklins are the Beavertail anticline and Jacques Ridge, which lie 12 to 20 miles south of the Fort Good Hope Permit area. These mountain ranges reach moderate heights of little more than 1,000 to 2,000 feet. Due to the westward trend of the northern Mackenzie Mountains the Plains area widens considerably and stretches from Fort Good Hope some 180 miles to the west and more than 250 miles eastward to the Precambrian Shield.

The Mackenzie River flows to the north and cuts the project area in two parts, the larger of which lies on the east side. Upstream from Fort Good Hope the river flows between limestone cliffs which rise almost vertically to heights of 200 to 250 feet. This wide canyon is called the Ramparts.

The Company's Fort Good Hope Permit area is largely a plateau, with hills which reach a height of more than 1,100 feet in the southeast corner. Lakes and muskegs cover valleys and flat areas. The wide valley of Hare Indian River occupies a large area within the northern and central portion of the Permit block. Many peculiarities of the relief are directly related to the character of the underlying rock formations. Devonian limestones, which lie near the surface in the south part of the area, have caused the development of canyons and escarpments. Shales have resulted in featureless plains with lakes and extensive muskegs, while many rounded hills are underlain by sandstone or glacial drift.

High lands and the edges of streams and muskegs carry a vegetation of trees which include mainly spruce. In places, tamarack, poplar and birch are also plentiful.

The Company holdings lie within the permafrost region which surrounds the Arctic Ocean and reaches south as far as the province of Alberta. The problems involved with permafrost are now better understood than in the past and are receiving increased attention. The knowledge obtained from studies made in previous years has facilitated greatly the major construction enterprises which are now in progress in the north country. As an exception to general conditions, Fort Good Hope has no permafrost problem. The settlement is located on a ridge between deeply incised valleys. This locality is almost stripped of vegetation and the soil is well drained, which has caused the permafrost layer to recede or to disappear altogether.

Climate

The Company holdings lie immediately south of the Arctic Circle and enjoy long hours of daylight during the middle part of the summer. Temperatures during June, July and August average approximately 55° Fahrenheit and frequently reach 70° during the warmest part of the day. Maximum temperatures as high as 95° Fahrenheit have been recorded at Fort Good Hope, but frost may be expected at any time during the year.

Winters in the area are dark and cold with average daily temperatures of about 50° Fahrenheit below freezing. The lowest temperature on record is -79° Fahrenheit at Fort Good Hope. The period of freeze-up is usually approximately the first week of October, while the spring breakup of ice takes place during the first week in May, but these periods vary from year to year. Precipitation during the year is relatively low and does not exceed 10 inches, but the humidity of the atmosphere is rather high.

Culture

The settlement of Fort Good Hope lies within the Company holdings. The population includes about fifty Indian families. White residents who stay all year at Fort Good Hope include representatives of the Royal Canadian Mounted Police, the Department of Transport, the Department of Northern Affairs, the Hudson's Bay Company, the Roman Catholic mission. The Department of Transport maintains a radio station which provides a very important communication service. As well as the Hudson's Bay store, there is a free trader at Fort Good Hope. The presence of a permanent Government sponsored nursing station is also an asset and adds to the safety of operations in this area.

During several past summers our firm has employed Indians of Fort Good Hope as laborers, guides and cooks, and we have found the services of these men and women most satisfactory.

Accessibility

Access routes to Fort Good Hope by air and on the water, and also the access problems during break-up and freeze-up, are discussed at some length in the 1958 report. Bulk supplies can be most economically shipped into the Fort Good Hope area by barge on the Mackenzie River. The airline connecting Fort Good Hope with Edmonton, Norman Wells and Aklavik, was operated formerly by Canadian Pacific Airlines, and Pacific Western Airlines has maintained the same service since early 1959, with a schedule that has undergone little change. Commercial flights by P.W.A. Otter aircraft between Aklavik and Norman Wells stop at Fort Good Hope once each week. Various major access routes are indicated on a map included with the present report (Figure III).

The interior of the Fort Good Hope Permit area can be reached with heavy equipment in the winter, when lakes and muskeg are frozen. In summer only limited areas adjacent to the Mackenzie River are readily accessible. Flat-bottomed boats can possibly travel some distance on Hare Indian River with high water in early spring, but most of the summer the river is too shallow. Tractors could move a few miles over land northeast of Fort Good Hope by taking advantage of a high esker ridge.

REGIONAL GEOLOGICAL SETTING

The lands held under P. & N. G. Permit by Glacier Explorers Limited, which are the subject of the present geological study, lie within the central portion of the Mackenzie Basin. To the south lie the Franklin Mountains, which consist of sub-parallel anticlinal ranges. The strata exposed in the Franklin Mountains are Cambrian to Pleistocene in age and include several large stratigraphic intervals which, undoubtedly, are in the subsurface within the Fort Good Hope area. Further regional geological information has been derived from outcrop sections in the Mackenzie Mountains and Richardson Mountains and also from smaller exposures on the Plains to the north and east of the project area. Deposition of sediments in the Mackenzie Basin began in Precambrian time and has continued, with many interruptions, to the present. Sand and clay sediments are still accumulating in the Mackenzie delta and layers of peat are forming on the uplands. Periodical uplifts above sea-level in parts of the basin area and, more rarely, emergence of the entire basin, caused destruction of the record of sedimentation in certain intervals of geologic time. The sedimentary succession is most complete in the western Territories and in the Yukon. In the vicinity of the Company holdings a large hiatus exists between beds of Devonian age and Lower Cretaceous sandstones and shales. The late Paleozoic and early Mesozoic deposits, if they were present at any time within the area, have all been removed by erosion, but the sequence from the late Precambrian to the late Devonian is fairly complete.

The Fort Good Hope Permit area lies within the Interior Plains, which are structurally less deformed than the adjacent mountain belts. Upon closer investigation it has become evident, however, that faulting and folding are much more common within the Plains than would appear from a cursory examination. The field work carried out on the Company holdings in 1957 brought out the existence of a structurally high area in the vicinity of Fort Good Hope. A detailed investigation of this feature was the principal objective of the work done during the summer of 1959. The feature concerned appears to be regionally high with the axis disposed in an east-west direction. It dips sharply to the south, whereas the north and east flanks are more indistinct.

STRATIGRAPHY

Parts of the stratigraphic sequence have been studied at various localities within the northern and central Mackenzie Basin. The following list of formations includes only those which have a bearing on the Company holdings.

It should be noted that the nomenclature of the Devonian system is under revision at present. In the spring of 1960, H.G. Bassett of Shell Oil Company Limited, presented a paper entitled "Devonian Stratigraphy, Central Mackenzie Region, Northwest Territories," which will be published later. In his paper Bassett deviated from the existing nomenclature and correlations and proposed a new set of formational names. Our geologists are in full agreement with Bassett's correlations which, in effect, have been employed by our firm for several years, but some of the proposed nomenclature may be revised before the publication of the paper. We have continued the use of our own, more conservative, names in the present report. The relation of our nomenclature to that of Bassett and previous authors is demonstrated in the detailed description of the stratigraphy of the Devonian in pages to follow.

The Fort Creek and Imperial formations have been listed, provisionally, under the heading of Upper Devonian. Paleontological studies are in progress which may cast some light on the boundary between Middle and Upper Devonian rock series.

A composite interpretation of the stratigraphic succession in the vicinity of Fort Good Hope follows:

Table of Formations

Age	Formation or Group	Lithology	Thickness* Feet
CRETACEOUS	Sans Sault	Grey shales, siltstone and sandstone, marine; porous, friable sandstone at base.	0-300
		- UNCONFORMITY -	

* Estimated thicknesses within Company Permits and vicinity.

Age	Formation or Group	Lithology	Thickness* Feet
UPPER DEVONIAN	Imperial	Shales, siltstones and greenish grey to brown sandstones; carbonaceous material common.	0-200
	Fort Creek	Black, bituminous hard platy shale; fossiliferous sandstone at the base in many places.	0-350
MIDDLE DEVONIAN	Ramparts	Upper Limestone Member: Buff to grey limestones, very fossiliferous, in part reefal, bedded to massive; merges in the northern Mackenzie Basin with the Middle Ramparts into a Ramparts Shale unit (undifferentiated).	600
		Middle Shale Member: Greenish grey shales and thin-bedded argillaceous limestones; dark shales in lower part.	600
		Lower Limestone Member: Grey fossiliferous nodular limestones and shales; local bioherms.	500
LOWER DEVONIAN	Bear Rock	Upper Member: Limestone, grey to light brown, fine-grained, thick-bedded.	200
		Lower Member: Dolomite, limestone, gypsum, anhydrite; bedded and in part brecciated.	500
		- UNCONFORMITY -	
SILURIAN AND ORDOVICIAN	Ronning	Hard, light brown, dolomite; chert and vugs common.	2000
CAMBRO-ORDOVICIAN		Bedded dolomites and thin shale beds, unfossiliferous.	300-1000
CAMBRIAN	Macdougal	Coloured shales, evaporites, limestones and dolomites.	1500
EARLY CAMBRIAN AND PRECAMBRIAN	Katherine-Tindir	Quartzites and argillites.	1000+

Description of Formations

Precambrian and Early Cambrian

Tindir Group and Katherine Group

A considerable thickness of sediments occupies a stratigraphic position overlying strongly metamorphosed Precambrian sediments and underlying strata of established Cambrian age. The stratigraphic interval comprises a lower succession of varied lithology called the Tindir group which is overlain by a quartzitic sandstone sequence called the Katherine group.

The name "Tindir group" was given by D.D. Cairnes (1914) to a series consisting largely of slate, quartzite, dolomite, phyllite and occasionally conglomerates, exposed on the Alaska-Yukon International Boundary.

The Katherine group is a series of light coloured quartzites, quartzitic sandstones, and black platy shales which are exposed in the Upper Carcajou River area. The group was named by Link (Hume, 1954) in 1921. This group is possibly of Lower Cambrian age and the Tindir group has been regarded as Proterozoic in age. The boundary between these groups is not well established but both reach, in several places, a thickness of many thousands of feet.

A considerable thickness of Tindir and Katherine strata probably underlies the Company holdings near Fort Good Hope. These beds are generally strongly compacted and are usually well cemented. With the possible exception of some beds of the Katherine quartzitic sandstones, which may be locally porous, the stratigraphic interval is not prospective for oil and gas.

Cambrian

General Description

Cambrian beds have been recognised in several places in the Richardson Mountains and in the Mackenzie Mountains, but due to the scarcity of fossils and also because of changes of facies the correlation of stratigraphic units within the Cambrian system is not yet well understood.

A series consisting of shales, silts, carbonates and evaporites containing rare Middle and Upper Cambrian fossils has been referred to as the Macdougal group in the Carcajou Range of the Mackenzie Mountains, southwest of Norman Wells. It is underlain by the predominantly quartzitic assemblage of rocks which is called the Katherine group (Lower Cambrian?) in the same area. The Katherine group has been discussed briefly under the previous heading.

Macdougal Group

The Macdougal group, which includes beds of Middle and Upper Cambrian age, has been defined in the Mackenzie Mountain area southwest of Norman Wells;

the usage of the term is tentatively extended to various zones in the Yukon Territory which also contain Middle and Upper Cambrian faunas.

In the Mackenzie Mountains west of Norman Wells and in the Franklin Mountains, many outcrops of the Macdougal have been described by Canol Project geologists (Hume, 1954), and several new exposures were found by our field parties. The beds consist of variegated shale, argillite, limestone, dolomite, sandstone, quartzite, gypsum and, locally, rock salt. Shales seem to dominate in most sections, but the sandstone and carbonate content appears to have increased considerably in some places. In the upper part of the Macdougal group, gypsum beds are commonly found with thicknesses sometimes attaining several hundred feet. In many places Paterina and Ptychoparia have been recognized in the Norman Wells area. A thick band of hard limestone occurs a few hundred feet below the evaporites in the Carcajou area of the Mackenzie Mountains. Farther south near Wrigley, fossils were collected from approximately the Macdougal group by Williams (1923), and these include Lingulella, Bathyuriscus, Ptychoparia and Saratogia. This fauna indicates Middle, and possibly Upper, Cambrian age for the shales in which the fossils were found.

In the Franklin Mountains and in the eastern Mackenzies, the Macdougal group rests on predominantly sandy and quartzitic beds of the Katherine group and underlies Cambro-Ordovician dolomites, but neither the upper nor the lower boundary of the group is well established. A persistent zone of thin-bedded dolomites and green shales with edgewise conglomerates overlies the typical variegated Macdougal beds. This thin-bedded zone reaches 700 to 1,000 feet in thickness in the Carcajou River area. As no fossils have been collected from this interval the age of the beds must remain in doubt.

The thickness of the typical Macdougal sequence of rocks varies in the general Norman Wells area from approximately 1,000 feet to more than 3,100 feet. In 1945 Imperial Oil Limited drilled a well named Vermilion Ridge No. 1 at a distance of 25 miles southeast of Norman Wells. The well penetrated 3,173 feet of Macdougal beds which included much anhydrite and more than 1,200 feet of rock salt. Drilling was terminated in shales containing trilobites. The thickness of the Cambrian in the well is probably exaggerated by tilting of the beds and perhaps also by thrust-faulting or crumpling. Nevertheless, the section contains an abnormal quantity of evaporites and must have a considerable thickness. There are several indications that Cambrian evaporites must be common in the entire area occupied by the Franklin Mountains. Probably a local salt basin existed here in Middle and Upper Cambrian time.

In the northern Mackenzie Mountains, a section with lithology similar to that of outcrops in the Norman Wells area was observed near Snake River. The variegated shales, the gypsum beds and the limestone band were recognized at this locality, but the total thickness of roughly 2,700 feet was much greater than that of the Macdougal group as it occurs farther east. Near Hume River, between Snake River and Mackenzie River, the typical Macdougal beds are absent. Here, the dolomites of apparent Siluro-Ordovician character are immediately underlain by an 800-foot thick quartzitic sandstone series. The top part of the sandstone contains casts of salt crystals, indicating evaporitic conditions during deposition. We regard the sandstone series of the Hume River area as belonging to the Katherine group, and we feel that the absence of the Macdougal group is due in part to pre-Ordovician erosion.

A considerable facies change can be noticed in comparing the Macdougal section near Snake River with Cambrian strata of presumably the same age in the southern Richardson Mountains and on Peel River. The greater part of the core of the anticlinorium of the Richardson Mountains consists of hard fine-grained sandstones interbedded with varying amounts of hard, generally non-calcareous, black shales. The sandstones show crossbedding in many places. The shales are commonly siliceous and in part cherty. Stratigraphically low in the section, a zone of poorly bedded, fractured limestone occurs with a thickness of 400 to 500 feet. This may be linked lithologically with a similar limestone zone in the Macdougal beds farther to the south and southeast. Further lithological analogy with the Macdougal group is provided by Martin's report (1957) of the presence of gypsum in the Cambrian on the east side of the southern Richardsons. This occurrence has not been verified by our field parties.

The Cambrian black shales and sandstones of the southern Richardson Mountains may range in age from the Lower to the Upper Cambrian. Certain Tetractinellid sponge spicules, which as a group are relatively common throughout the entire section, may indicate a Lower Cambrian age for part of the beds (Martin, 1957). Other fossils, including Obolus, Protospongea and some graptolites, are indicative of Middle to Upper Cambrian age. It is concluded, on the basis of both fauna and lithology, that a broad correlation exists between the Cambrian black shales and sandstone series of the southern Richardsons and the varicoloured beds of the Macdougal group.

Outcrops were examined on Peel River and at the headwaters of Cannon and Act Creeks in the central part of the southern Richardson Mountains. Solifluction, due to the severe climate, has littered all hills with slabs of the Cambrian sandstone, and outcrop sections in river canyons are disturbed by folding and faulting. Estimates of the total thickness of the Cambrian series in this area are, therefore, no more than rough approximations and range from 4,000 to 7,000 feet.

In the northern Richardson Mountains, 30 miles southwest of Aklavik, a steeply dipping and partly smashed limestone and dolomite section forms the core of a gently folded anticline of Permian and Jurassic strata. These carbonate rocks are probably all of Cambrian age. Most of the section consists of dolomite and limestone, with reddish and greenish shales probably forming the base. The limestones are partly oolitic and fragmental and commonly contain abundant trilobite fragments. Some layers contain the primitive nautiloid form Salterella. Brachiopods and trilobites collected from this locality include Acrothele, Olenellus, Alokistocare, Scenella and Olenoides, indicating Lower to Middle Cambrian age of the beds (Gabrielse, 1957). Some fair porosity was noticed in several limestone and dolomite zones. The total thickness of the reconstructed Cambrian sequence is 1,144 feet, but this probably constitutes only part of the Cambrian in this area.

Near Hermine Mountain, close to the boundary between the Yukon and the Northwest Territories, approximately at Latitude 67°45' North, a spectacular carbonate sequence is exposed with beds ranging in age from pre-Silurian to late Carboniferous. Pre-Silurian limestones and dolomites at this locality have an aggregate thickness conservatively estimated at 3,900 feet, but probably several thousands of feet could be added to this figure. Massive limestones form the upper part of the section and are underlain by several hundred feet of coarsely brecciated dolomites, which are in turn underlain by a thick series of light grey and dark grey bedded dolomites. The entire sequence is unfossiliferous and its age can only be surmised. Tentatively we would place the brecciated dolomite interval at the top of the Cambrian, while the entire dolomite section is broadly correlated with part of the Macdougal group, even though the latter name does not seem applicable here on the basis of lithology. Equivalents of the Cambrian trilobite beds that occur 18 miles to the east were not observed and possibly these still underlie the dolomite series near Hermine Mountain.

In reviewing the stratigraphic interval which is largely occupied by the Macdougal group, the following general observations can be made. The thickness of the interval appears to increase in a westward direction. In the more westerly outcrop areas, sedimentation must have been almost continuous from Cambrian through Ordovician to Silurian time, but, if our interpretation is correct, the Macdougal beds are missing near Hume River, in the Nahanni Range, and farther south near Muncho Lake. This means that in those areas the Cambrian is separated from the Ordovician by an unconformity.

The general increase in thickness from east to west is accompanied by a change in facies from varicoloured shales and sandstones on the cratonic side of the basin, to limestones and dolomites on the Pacific side. In the southern Richardson Mountains, a black shale facies developed which was to persist throughout Ordovician and Silurian deposition. Evaporites appear, in general, to be closely associated with the belt of varicoloured Cambrian clastics.

Beds of Cambrian age are not exposed within the Company holdings near Fort Good Hope, but 1,500 feet, more or less, of Macdougal beds may be expected to occur at depth. Probably the interval consists of red beds with evaporites, with minor carbonates, similar in facies to the beds exposed in the mountains further to the south.

Cambro-Ordovician

Between beds containing Cambrian fossils and massive dolomites of known Ordovician age a rock sequence of undetermined age is found in many places. We shall designate this as the Cambro-Ordovician interval. This sequence is difficult to define in terms of valid stratigraphic criteria; the upper and lower boundaries are vague; it contains no diagnostic fossils; and neither the lithology nor the thickness is entirely consistent. Nevertheless, it seems to have certain constant characteristics and it is remarkably widespread. The interval may be correlated with part of the Franklin Mountain formation as described by Williams (1922).

Lithologically the Cambro-Ordovician interval consists generally of medium- to thick-bedded, hard dolomite layers, grey in colour and light brown to buff weathering. In many places interbedding with thin dark grey or greenish grey waxy shale, silty shale or shaly dolomite can be observed. Edgewise conglomerates and casts of salt crystals have been found in the beds at some localities in the Mackenzie Mountains. These may point to evaporitic conditions or shallow water environment during deposition of the strata. The only fossils found within the interval are algae which are similar to Cambrian forms known as <u>Cryptozoon</u>. Our field parties collected these in the Discovery Range near Norman Wells, in the northern Mackenzie Mountains and at Airport Lake near Inuvik.

The Cambro-Ordovician interval grades upward into more massive dolomite of Ordovician age and its base forms a gradual transition, with the underlying beds belonging to the Macdougal group. Estimates of the thickness depend to a large extent on the arbitrary choice of unit boundaries made by various geologists. This may account for the disparity of thicknesses recorded in the Northwest Territories, which range from 300 to 1,050 feet in the Mackenzie and Franklin Mountains. In the Richardson Mountains and near the International Boundary, the Cambro-Ordovician unit seems to have lost entirely its normal bedded and buff-weathering aspect.

From the previous remarks, it is evident that the interval requires considerably more study in order to settle the questions regarding its age and lateral continuity.

<u>Ordovician and Silurian</u>

The interval comprising rocks of Ordovician and Silurian age is characterized by thick-bedded to massive, buff-coloured dolomites and limestones in most of the Mackenzie Basin. The beds are widespread in the mountain belts and in the Plains farther to the east. It is generally difficult to separate Ordovician beds from the Silurian on the basis of lithology alone. Eventually paleontology will provide useful criteria for stratigraphic subdivision and mapping. Fossiliferous zones occur in many places, but the extensive fossil collections that were made in the past have aided little in solving age and correlation problems. Some of the faunal assemblages which were classed as Niagaran (Middle Silurian) in the past are now considered Richmondian (Upper Ordovician) in age. It will probably require some time for paleontologists to reach agreement regarding the proper stratigraphic position and correlation of the faunas. Hence, the strata that are most probably Silurian or Ordovician in age have been combined under the heading "Ronning group" in the present discussion.

The Ronning group appears to rest conformably on the Cambro-Ordovician unit of bedded dolomites and shales, wherever the latter is present in the eastern Mackenzie and Franklin Mountains. Near Hume River, in the northern Mackenzie Mountains, and in the Nahanni Range, Ordovician dolomite beds rest on quartzites, dolomitic sandstones and siltstones which are thought to belong to the Katherine group. If this assumption is correct, the Macdougal group is absent here. Therefore, some evidence for a "break" in sedimentation at the base of the Ordovician exists locally in the Mackenzie Basin.

A division of the Ronning interval into smaller units is difficult to make on the basis of lithology alone. By comparing various sections a suggestion can be found of the presence of a more fossiliferous upper zone and a more cherty lower zone. Fossils and chert are present, however, in both zones.

In the Mackenzie Mountains and Franklin Mountains the Ronning is represented by dolomites with characteristic buff colour. The dolomites are generally dense and finely crystalline, but in places coarsely crystalline rock with some porosity also has been noted. Chert is common throughout the interval in most localities but is generally more concentrated in the lower portion. It occurs in layers and concretionary nodules or as fossil replacements, and weathers out on the rock surface as irregular rough "encrustations."

In general, the Ronning is thickening in a westward direction. This is accompanied by a decrease in dolomitisation to the west, where limestone has remained an important rock component.

A striking facies change from dolomite to black shale and sandstone has taken place north and west of the Mackenzie Mountains, in the southern Richardson Mountains and near the Alaska border. A great thickness of black shales and argillites, cherts, thin brownish grey sandstones, and quartzitic sandstones, with a few bands of limestone and brecciated limestone, is exposed in the Peel River canyons and on many creeks on both sides of the Richardsons. The aggregate thickness of this series is in excess of 5,500 feet. These beds rest on some 3,000 feet of limestone of undetermined age. Roughly the lower half of the black shale and argillite series is Ordovician in age, as can be proved from a graptolite assemblage including Tetragraptus among many other forms. The upper half belongs to the Silurian, as indicated by numerous species of graptolites, among which the occurrence of Monograptus is particularly significant.

In the northern Richardsons, a group of rugged peaks, which have been referred to as the White Mountains, lies 50 miles southwest of Aklavik. A section that was studied in this area on Hermine Mountain and vicinity contains a thick limestone sequence including some 3,000 feet of strata which, in part at least, are Ordovician and Silurian in age. In the lower 2,000 feet no distinctive fossil evidence was found, but the upper part contains numerous corals such as Halysites and Favosites, stromatoporoids, and brachiopods similar to Conchidium. Most of the limestone has a smoothly weathered surface which reveals little about the fossil content and the texture of the original components of the rock. It appears upon closer examination that many massive beds contain abundant reef-building organisms such as stromatoporoids and colonial corals. In some places the richly organic layers are associated with breccias, which have to be interpreted as reef talus breccias. Evidently reefs form a substantial part of the Ronning carbonate sequence in this area, and both bioherms and biostromes seem to be represented. Some porosity was noticed in a few beds, particularly in the reef breccia, but most of the section appears to be tight in this locality.

The limestone facies of the Ronning interval is further developed in a westward direction where it was recognized near the International Boundary in the vicinity of Porcupine River (Cairnes, 1914), and in Alaska along the southern flank of the Brooks Range, where thicknesses of 5,000 to 6,000 feet were reported by Mertie (1925, 1929).

A peculiar thick series consisting of slightly tilted, silty dolomites and cherts was observed ten miles north of Rat Lake, or 30 miles southwest of Aklavik. This sequence of beds has been regarded as Ordovician in age (Martin, 1957), but diagnostic fossils are lacking. The section is separated from the overlying Permian beds by an angular unconformity, and it is dissimilar to, and most probably younger than, the disturbed Cambrian strata that lie adjacent to it. We have labelled this section tentatively as Ronning, although neither fossils nor lithology have provided any clue as to its proper stratigraphic position. The exposed beds reach an aggregate thickness of 1,600 feet.

The Ronning interval shows decided thickening to the west. In the past it was generally assumed that Ordovician strata were largely confined to the Yukon. Our field parties collected Ordovician fossils in the vicinity of Sam McRae Lake, 50 miles north of Norman Wells, and the fauna collected on the west side of Great Slave Lake is at present also regarded as Ordovician in age. It seems probable, therefore, that Ordovician strata form a considerable part of the Ronning group spreading over a wide area east of the mountains.

Dolomites appear to be the dominant rock type in the eastern portion of the sedimentary basin. Ordovician dolomites have been found in the north on the Horton and Hornaday Rivers (Mackay, 1958) and to the east on the shores of Great Bear Lake near the edge of the Canadian Shield. Information concerning Ronning sections to the west is scarce and generally incomplete. It is evident, however, that the westward increase in thickness is accompanied by a change in lithology from dolomite to limestone and black, argillaceous, graptolite-bearing rocks. The western black shale belt can be traced by plotting scattered observations from the South Nahanni area and Ross River (Keele, 1910) to the Richardson Mountains and the International Boundary area (Cairnes, 1914). Limestones and graptolitic shales are also known from the Canadian Arctic Islands, an indication that this belt probably curves through the Arctic Ocean to the northeast.

The Ronning group represents an almost perfect setting for the conditions required in a major oil province. The black shale sequence in the west can be regarded as an assemblage of source beds of impressive magnitude, while the reefal and clastic carbonates must have provided excellent reservoirs updip, on the east side of the sedimentary area. How much oil will be found in these potential reservoir beds depends largely on the time when migration of oil took place, on the rate of subsequent erosion of the reservoir beds, and on the presence of impervious cap rocks. The eastern extent of the black shales as interbeds is not known.

Beds of Ordovician and Silurian age do not occur in outcrop within the Company holdings. Dolomites that are probably Silurian in age are exposed in the valley of Hare Indian River, 20 miles east of the Permit block. These dolomites are bedded, light grey to light brown in colour, and are in part vuggy. Southeast of the Permit boundary a section including more than 800 feet of Ordovician and Silurian strata is exposed on Jacques Ridge. The detailed description of this section, by H. A. Gorrell and D. L. Campbell, has been included as Appendix IV in the report prepared by our firm in 1958. The rock sequence consists largely of light grey massive dolomite with bands and nodules of chert. Intergranular and vuggy porosity have been observed at several levels. In view of regional considerations it cannot be doubted that Ordovician and Silurian dolomites, which are partly porous, underlie the entire Company holdings. The section is assumed to have a thickness of approximately 2,000 feet.

Lower Devonian

Bear Rock Formation

General Description

The Bear Rock formation has been the subject of much discussion among geologists. Although many data concerning this unit have been collected over a large portion of the Mackenzie Basin by our field parties, several questions regarding its age, correlation, and origin still remain unanswered. The age of the Bear Rock has long been in doubt. In older publications (Hume, 1954 and others), the formation was thought to be Silurian or possibly Devonian in age. On the basis of our field data it appears that most of the Bear Rock interval belongs to the Devonian system. The western correlative of the Bear Rock has been called the Lone Mountain formation. It consists of thick-bedded dolomites and limestones, and it occurs in the western Mackenzie Mountains. Recently H. G. Bassett, Shell Oil Company of Canada Limited, has suggested an extended usage of the name Bear Rock to include the Lone Mountain formation. We feel that this proposal is acceptable.

The Bear Rock formation forms a widespread and easily recognizable unit in the vicinity of Mackenzie River north of Wrigley. It is characterized by intensive brecciation in most localities. In several places the basal Bear Rock dolomite beds are not brecciated. Fractured, but unbrecciated, beds may also be found within and at the top of the formation. Principal components are dolomite and limestone. Anhydrite and gypsum are also found, but these minerals are not common in the exposed brecciated sections. Some gypsum beds in the Franklin Mountains reach a thickness of approximately 500 feet and may form part of the Bear Rock, but it appears that several other large gypsum deposits in the same area probably belong to the Macdougal group of Cambrian age. As the dolomites and evaporites are rarely exposed in continuous section, the isolated gypsum outcrops have to be treated with much caution in field mapping.

The breccia fragments generally consist of grey or dark grey dolomite and limestone. Rock fragments vary greatly in size and shape, most are angular but some are slightly rounded. The space between the fragments is filled with secondary calcite and dolomite or with fine detritus, and in most places caverns and vugs are common. Dry bitumen and a petroliferous odour from the rock were noted in many outcrops. Minor slump structures are frequently found. Stelck reported that he observed rock fragments within the Bear Rock which were lithologically similar to Silurian beds. Hume (1954) stated that on Canyon Creek, on the west flank of the Norman (Discovery) Range, the cavernous limestone beds of the Bear Rock formation are underlain by sandstone and quartzitic sandstone. He wrote further: ". . . In the cavernous limestone are quartzitic sandstone cobbles up to six inches in diameter together with other pebbles and cobbles of limestone."

North of the Norman Range, the stratigraphic interval of the Bear Rock is largely occupied by brecciated and unbrecciated limestone beds. The unbrecciated beds are bahamites (Beales, 1958) and form thick layers of dense, partly sublithographic limestone with a vague globular texture. The regional relations of bedded and brecciated, purely calcareous and partly or fully dolomitized facies within the Bear Rock are not fully understood due to the lack of well exposed sections and because of the absence of paleontological or lithological markers. These different facies appear in both vertical and lateral transition. In several places, such as the vicinity of Fort Good Hope, the northern Mackenzie Mountains, the Inuvik area, and eastward near the upper Anderson River, the Bear Rock may be roughly divided into an upper part consisting of dense thick-bedded limestone and a lower portion of brecciated or unbrecciated limestone or dolomite with the more "typical" corroded Bear Rock appearance.

The thickness of the Bear Rock is generally about 400 to 500 feet. In the northern Franklin Mountains the interval reaches 700 feet, but farther south in the Norman Wells area the Bear Rock seems to be only a few hundred feet thick. The formation increases in thickness in the interior Mackenzie Mountains.

The Bear Rock formation underlies the Ramparts formation of Middle Devonian age and in most places it overlies Silurian beds or, where these are missing, it rests directly on the Ordovician. The name "Bear Rock" was introduced by the Canol geologists, and Bear Rock, which is situated at the confluence of the Mackenzie and Great Bear Rivers, was designated as the type locality.

In most localities where Bear Rock sections were studied, a marked unconformity separates the Bear Rock from underlying beds of Ordovician or Silurian age. At Morrow Mountain, which is situated some 60 miles northwest of Norman Wells, the Bear Rock breccias are underlain by one hundred feet or more of banded Bear Rock dolomites similar to those of the Lone Mountain formation of the southern Mackenzies, and this banded dolomite section is separated from the underlying Silurian by a clearly developed angular unconformity. Sandstone and silt mark the base of the Bear Rock at various places in the Discovery Range near Norman Wells. These sandy beds also indicate the presence of a major unconformity at the base of the Bear Rock. The base of the formation is the most logical place for the unconformity between the Silurian and Devonian systems.

In most places the Lower Ramparts formation appears to conformably overlie the Bear Rock, and the contact is fairly sharp. The black, shaly, and richly organic Ramparts limestone is well contrasted with the dolomites, the breccias and the brown limestones of the Bear Rock. Hume (1954) mentioned the presence of a sharp contact, accompanied by irregularities, between the formations at Carcajou Canyon, and interpreted these as indications of a disconformity. Laudon (1944) found fish teeth and phosphatic concretions in a basal Ramparts shale bed at Imperial River. Probably a disconformity at this stratigraphic position is more the rule than the exception in the entire lower Mackenzie area.

The Bear Rock interval contains remarkably few fossils. Lately some brachiopods and corals have been found in a few localities. These fossils indicate that the formation is Devonian in age. A number of fossils, largely brachiopods, were collected on the upper Redstone River, south of Fort Norman (Bassett, 1960). This fauna is considered indicative of late Silurian or lowermost Devonian age. The section at this locality may also include stratigraphic intervals older than the Bear Rock and the faunal evidence for the age of the Bear Rock, therefore, is not considered conclusive.

Porosity and oil-staining are common phenomena within the Bear Rock dolomites and breccias in most areas. The formation must be regarded as possibly the most promising horizon within the subject acreage.

<u>Bear Rock Formation within the Company Holdings</u>

The Bear Rock formation is exposed in the eastern part of the Company holdings and at several localities outside the Permit area on Hare Indian River, north of Lac a Jacques.

We refer to Stratigraphic Section 3, Appendix III, of the Geological Reconnaissance Report, 1958, submitted to Glacier Explorers Limited. It contains a detailed description of the Bear Rock succession at Echo Bend. This location and other nearby outcrops were revisited and measured during the past field season. The results were essentially the same as those obtained in 1957. In the vicinity of Lac a Jacques the Bear Rock can be divided into an Upper Limestone member and a Lower breccia member. The same division can be made in the northern Mackenzie Mountains and in the area of exposed Paleozoic beds near Inuvik, east of the Mackenzie delta. The Upper Bear Rock limestones are poorly fossiliferous and are overlain by Lower Ramparts limestones which contain a rich fauna. The contrast between these limestone sequences is sufficiently great that they can be mapped in the field without difficulty. In some areas, for example in the Franklin Mountains, fossiliferous Lower Ramparts limestone immediately overlies brecciated Bear Rock dolomite and limestone, and the unfossiliferous limestone unit is missing. Some people have included the unfossiliferous limestone member with the Lower Ramparts, but our geologists have observed these limestones interfingering with thick breccias. We prefer to place this limestone sequence, therefore, within the Bear Rock formation.

Lower Member: The Lower member of the Bear Rock formation is not exposed within the Company holdings, but outcrops are common in a belt immediately to the east, stretching northward from Jacques Ridge. This unit consists largely of dolomite and calcareous dolomite, and is characterised by breccias which occur irregularly in beds, lenses, or even in vertical funnels, within the formation. The beds, and also the fragments within the breccias, consist of dark brown-grey to grey, crystalline to sugary dolomite. The original rock must have consisted of fragmental or calcarenitic limestone which became dolomitized. The parallel, and in places crossbedded, laminations which are present in most calcarenites are commonly observed on the weathered surfaces of the Bear Rock dolomite beds. A few beds of white gypsum, contaminated with dolomite, were found in the Hare Indian River valley. Traces of fossils were noticed, which may have included gastropods and ostracodes. The breccias consist largely of angular fragments of laminated dolomite, ranging from a few inches to several feet in diameter, that are embedded in a matrix of sugary dolomite and white calcite. Some greenish grey shale seems to be particularly associated with the breccias. Much of the dolomite is finely porous showing pin-point or intercrystalline porosity. Larger vugs are less common. Generally the rock emits a distinct petroliferous odour when freshly broken. Small concentrations of pyrobitumen are frequently found and some brown staining was noticed which may be due to bitumen. The Lower member of the Bear Rock formation is considered an excellent potential reservoir zone.

The maximum thickness of the Lower member of the Bear Rock that was measured in the Hare Indian River valley amounted to 391 feet. The total thickness of the interval is estimated at 500 feet.

Upper Member: The Upper member of the Bear Rock formation consists of tight greyish brown limestones, which are finely crystalline to aphanitic and probably of calcarenitic origin. Thin, light and dark brown laminae can be observed on smoothly weathered surfaces. The limestone contains scattered small cavities, filled with tarry black oil, on the north bank of Hare Indian River at Latitude 127°45' West. Although we have referred to the Upper member as an unfossiliferous unit, scattered fossil fragments have been observed. These include small shells of brachiopods, gastropods and ostracodes. A few thin beds contain abundant crumpled calcareous algae. The fossil fragments are perfectly cemented within the rock and it is impossible to collect them for identification.

In the eastern part of the Company holdings the Upper member forms vertical cliffs that can be traced easily on aerial photographs. Farther to the east, near Echo Bend, the limestone occurs on slopes where it is weathered and thinly bedded. Outcrop sections near the west side of Lac a Jacques have a thickness of almost 100 feet, but the entire member may reach 150 to 200 feet. The contact with the overlying Ramparts formation was covered in the localities visited, but lithologies of the upper Bear Rock and lowermost Ramparts are almost alike. Within this area the formations probably grade into each other.

Middle Devonian

Ramparts Formation

General Description

A few miles upstream from Fort Good Hope, the Mackenzie River narrows into a gorge between vertical limestone cliffs which are called "the Ramparts." The exposed limestone section was named the Ramparts limestone by Kindle and Bosworth (1921). After studying a much wider area, Hume (1954) established the Ramparts formation as the stratigraphic unit that overlies the Bear Rock formation and underlies the Fort Creek formation. The Ramparts formation was divided by Hume into the following members:

Upper Ramparts limestone member
Middle Ramparts shale member
Lower Ramparts limestone member

The Upper Ramparts limestone member includes the "Ramparts limestone" of Kindle and Bosworth. Hume designated the north flank of the Imperial Range on Mountain River (northern Mackenzie Mountains) as the type locality of the Middle Ramparts shale and of the Lower Ramparts limestone.

The terminology in the present report will be clarified before the units of the Ramparts formation are discussed in detail. The names we have applied to the subdivisions are the same as those employed in most of the published literature, but our views on correlation are, in several respects, different from those of previous authors. In this report the Ramparts formation is defined as the rock sequence which is overlain by the Fort Creek formation (re-defined) and underlain by the Bear Rock. The upper contact is probably a disconformity. On Figure II names and correlations used in the present report have been compared with those previously in use. A comparison is also made with the correlations and names presented by H.G. Bassett in 1960.

Our compilation of all available observed and published data has indicated that the "Ramparts" of the Norman Wells area forms only the lower member of the formation. It is our opinion that the Kee Scarp limestone, the producing zone of the Norman Wells oil field, represents the Upper member of the Ramparts formation. In the past the Kee Scarp was generally considered to be Upper Devonian in age and was placed stratigraphically higher than the Ramparts formation.

<table>
<tr><th colspan="11">DEVONIAN NOMENCLATURE CENTRAL MACKENZIE AREA N. W. T.</th></tr>
<tr><th>Lithology</th><th colspan="2">J.C.Sproule & Assoc.
1958</th><th colspan="2">H. G. Bassett
1960</th><th>Early Authors
Fort Good Hope</th><th colspan="2">Parker & Hume
Mountain River</th><th colspan="2">Canol & Hume
Norman Wells</th></tr>
<tr><td>Grey and greenish grey shales, sandstones</td><td colspan="2">Imperial Fm.</td><td colspan="2">Imperial Fm.</td><td>Bosworth ss & sh</td><td colspan="2">Imperial Fm.</td><td colspan="2">Imperial Fm.</td></tr>
<tr><td>Black shale</td><td colspan="2">Fort Creek Fm. ? ?</td><td rowspan="6">Fort Creek Group</td><td rowspan="3">Canol Fm.
?
?</td><td>Fort Creek</td><td colspan="2">Upper Fort Creek</td><td rowspan="6">Fort Creek Formation</td><td>Upper Fort Creek</td></tr>
<tr><td>Massive calcarenites and reefs</td><td rowspan="6">Ramparts Formation</td><td rowspan="3">Upper Limestone Member</td><td rowspan="3">Beavertail Ls.
Ramparts Ls.</td><td colspan="2">Kee Scarp Mbr.</td><td rowspan="3">Kee Scarp Mbr.</td></tr>
<tr><td>Thin bit. shale</td><td colspan="2">Lower Fort Creek</td></tr>
<tr><td>Bedded brown limestone and reef</td><td>Kee Scarp Fm.</td><td rowspan="4">Ramparts Formation</td><td>Upper Ramparts Ls. Member</td></tr>
<tr><td>Grey and green shales and some limestones</td><td rowspan="2">Middle Shale Member</td><td rowspan="2">Hare Indian Fm.</td><td rowspan="2">Hare Indian River shales</td><td rowspan="2">Middle Ramparts Shale Member</td><td rowspan="2">Lower Fort Creek</td></tr>
<tr><td>Black shale</td></tr>
<tr><td>Reefs, argillaceous limestones and shales</td><td>Lower Limestone Member</td><td colspan="2">Hume Fm.</td><td>Not mapped prior to the Canol project</td><td>Lower Ramparts Limestone Member</td><td>Ramparts Fm.</td><td>Upper, Middle & Lower Ramparts Members</td></tr>
<tr><td>Limestone and dolomite, gypsum, breccias</td><td colspan="2">Bear Rock Formation</td><td colspan="2">Bear Rock Formation</td><td>Bear Rock Formation</td><td colspan="2">Bear Rock Formation</td><td colspan="2">Bear Rock Formation</td></tr>
</table>

FIGURE - II

Near Fort Good Hope, the Upper Ramparts limestones are underlain by greenish grey shales which were designated "Hare Indian shales" by Kindle and Bosworth (1921). Hume (1954) renamed this interval the "Middle Ramparts shale member." We have adopted Hume's term in preference to the older, less well-defined name of Hare Indian shale, but contrary to common practice we include the "Lower Fort Creek shales" in the Middle Ramparts member. Thus the name Fort Creek is restricted to the black shale unit that overlies the Upper Ramparts and which can be correlated with the type section at Fort Creek (Thunder River).

It appears that much confusion regarding the correlation of the Ramparts sections near Norman Wells with those in areas to the west and north has resulted from the occurrences of the brachiopod Hypothyridina (Leiorhynchus) castanea. Our field observations have proved that this fossil is not limited to one characteristic zone, but that it occurs in two, and possibly even in three, zones that are, lithologically, almost identical. Other criteria than the presence of this fossil must also be considered in order to arrive at the correct correlation.

It is shown on Figure II that the correlations proposed by H.G. Bassett of Shell Oil Company of Canada Limited agree closely with the subdivision of the Devonian which our firm has employed for several years. The proposed new nomenclature is not quite satisfactory, however, and we hope that some changes can be made before the paper will appear in print. The term "Ramparts formation" has been abandoned by Bassett because the name was previously given to a formation of Mississippian age in Alaska. Most published reports contain wrong correlations between the members of the Ramparts formation in various parts of the Northwest Territories and a new term could be chosen conveniently at this time. The new group name "Fort Creek," as applied by Bassett to the Middle and Upper members of the Ramparts formation and including the Fort Creek (Canol) formation, ignores the important unconformity which marks the top of the Upper Ramparts member in the Fort Good Hope area. At the type locality of the original Fort Creek (Kindle and Bosworth, 1921) at Thunder River, only a small fraction of the proposed Fort Creek group is exposed. Several other objections can be raised. A revision of the existing names is needed, but we shall continue the use of our nomenclature (Figure II) until a satisfactory new terminology will be officially accepted.

Lower Limestone Member

The Lower limestone member persists over a wide area in the Northwest Territories. In most localities it can be divided into an upper massive limestone unit and a thicker, lower interval of bedded limestones which are increasingly argillaceous near the base. The upper unit has a remarkably constant thickness of approximately 100 feet in the eastern Mackenzie Mountains and Franklin Mountains. The massive limestones are generally tight and contain, in places, abundant corals and stromatoporoids. They are biohermal in part. The coral Cystiphyllum, while not confined to this zone, is particularly common. The lower unit has been referred to as "shale" in some publications, indicating a high argillaceous content of the bedded limestones. In the Norman Wells area, it is generally called "Middle Ramparts shale" as a result of miscorrelation with the type section on Mountain River.

The "Ramparts formation," as described by the Canol geologists in the Norman Wells area, is overlain by the "castanea zone" which occurs in the basal 10 or 20 feet of a thick shale interval. These beds containing abundant Hypothyridina castanea were correlated with the "castanea zone" which reportedly overlies the Upper Ramparts limestone in the Mountain River section. It was, therefore, concluded that the "Ramparts formation" near Norman Wells included the entire Ramparts. Our field parties observed the "castanea zone" to overlie the Lower Ramparts member near the Mountain River type locality. Subsequent comparison of a large number of Middle Devonian sections proved that this is the "castanea zone" that correlates with the castanea marker at Norman Wells. We are now convinced that the so-called "Ramparts formation" in the Mackenzie Mountains east of Mountain River and in the Franklin Mountains is in reality the Lower Ramparts limestone member only.

There are several indications that the area northwest of the Mackenzie Mountains was unstable during deposition of the Ramparts formation. Probably restricted basins and isolated highs developed in the northern Yukon within a complicated pattern of block-faulting. Middle Devonian limestones, such as occur in most of the Mackenzie Mountains, have not been observed in the eastern Richardsons, but a thick Devonian carbonate section is again present in the White Mountains, 50 miles northwest of Fort McPherson. In the White Mountains we measured 1,500 feet of limestones and dolomites which were tentatively placed in the Bear Rock interval. This formation is overlain by another 1,500 feet of relatively pure limestones of Middle Devonian age bearing little resemblance to the Ramparts succession. An equivalent of the Lower Ramparts member, if it is present at this locality, cannot be clearly identified.

Middle Shale Member

The Middle shale member, as defined in the present report, incorporates the "Hare Indian River shales" in the Fort Good Hope area (Kindle and Bosworth, 1921) and the "Lower Fort Creek shale" in the Norman Wells area as described by Hume (1954) and others. The type section of the Middle Ramparts shale at Mountain River has a thickness of 700 feet; it consists of grey to greenish grey shales and calcareous shales with very fossiliferous limestone bands in the lower 100 feet. The basal 20 to 50 feet of shales and limestones are dark grey to black in colour and, in the same vicinity, contain abundant Hypothyridina castanea. The contact between the Lower and Middle Ramparts members is drawn at the base of this lower "castanea zone." Other fossils that were found in the Middle Ramparts include numerous species of corals, brachiopods, gastropods and pteropods. At the type locality the Middle Ramparts member is overlain by the Upper Ramparts limestone member, but elsewhere the Fort Creek formation may rest disconformably on the eroded Middle Ramparts shales. It seems impossible to distinguish the Upper and Middle members in some areas where the Upper Ramparts is developed as a shale facies and not as limestone strata or reefs. This is the case in most of the northern Mackenzie Basin, and here the combined Middle and Upper Ramparts shales are referred to as the Ramparts shale unit (undifferentiated).

Dark grey shales, which may represent the Middle Ramparts member, occur in the eastern Richardsons, but the relation of these beds to the type section is rather obscure. In the northern Richardson Mountains and in the adjacent Plains, the member has not been recognized.

The thickness of the Middle Ramparts varies from approximately 500 to 800 feet.

Upper Limestone Member

The Upper limestone member has been defined by Hume (1954, p. 27) as ". . . all limestone beds of Middle Devonian age below the Cretaceous and above the Middle Ramparts shale member. . .," in the section exposed at "the Ramparts" on the Mackenzie River near Fort Good Hope. In the present report this limestone interval has been correlated with the Kee Scarp limestone of Norman Wells and vicinity, and also with the entire limestone succession on Mountain River, which includes "Upper Ramparts limestone," "Beavertail limestone," "Lower Fort Creek shale" and "Fort Creek reef limestone," as described by Parker in 1944.

The Upper Ramparts consists largely of limestones that are partly bedded and partly massive reefal. Biohermal accumulation accounts for some of the rapid changes in thickness that can be observed in places. Most of the limestones are hard, brown-grey to dark grey in colour, and form cliffs at the surface. Thin shale partings are common, but one particular black shale band, which is one to twenty feet thick, forms a widespread marker horizon within the member. The beds carry a rich fauna which includes an index fossil of the Middle Devonian, the brachiopod Stringocephalus cf. burtini. Among the many species of corals the branching form Cladopora is particularly common. The reefal limestone beds and the bioherms contain abundant stromatoporoids and a great variety of corals.

Many beds appear to be bituminous and they generally emit a petroliferous odour. Parker (1944) noticed blebs of asphalt and asphaltite in fractures and interstices of the rock in the Carcajou Ridge area, northwest of Norman Wells. The Norman Wells oil field produces light gravity oil from Upper Ramparts reef.

To the north of Fort Good Hope, the Upper Ramparts limestone is considerably thinner. This is probably due to lateral transition of the limestones into shale. Nauss (1944) was of the opinion, however, that the thinning of the member was caused by pre-Fort Creek erosion and truncation. Both factors may have influenced the observed decrease of the limestones to the north.

In the Norman Wells oil field, the Upper Ramparts (Kee Scarp limestone) has been thoroughly described by Boggs (1944). The member varies in thickness from 200 to 500 feet. It was divided by Boggs into a lower bedded limestone unit, 75 to 125 feet thick, and the overlying true reef which has a maximum thickness of 425 feet. These two zones are separated by a few feet of black shale, as observed in cores taken in the Goose Island No. 3 well on the northwest edge of the field. The shale zone has probably a wider distribution within the field, but in some cases it may have been overlooked in samples, while many wells did not reach it. The porous productive upper reef zone is largely composed of corals, bryozoa and stromatoporoids, which are embedded in coral sand (calcarenite). The porosity is not evenly distributed, but varies within the field. In some wells at the edges of the field no reef is developed, proving that it has a lenticular character. Seismic surveys show that the Norman Wells reef has a general trend to the west. It is separated from another bioherm which is exposed north and east of the settlement of Norman Wells at Kee Scarp, a ridge on the southwestern slope of the Discovery Range. The lower bedded limestone unit of Boggs seems to have formed the substratum for local reef growth. It is more widely distributed than the organic limestone bodies, but in several places it is also entirely missing.

Ramparts Formation within the Company Holdings

Members of the Ramparts formation are well exposed within the Company Permits. The Upper limestone member forms the walls of the wide canyon, which is known as the Ramparts on Mackenzie River, a few miles southwest of Fort Good Hope. At the northeast end of the canyon the upper part of the Middle shale member can be examined. The Lower limestone member is exposed at several localities in the east part of the project area.

Lower Limestone Member: Completely exposed sections of the Lower limestone member have not been observed within the Company holdings, but parts of the section can be assembled into a fair representative succession. A composite section was presented in Appendix III of the Geological Reconnaissance Report of 1958.

The Lower limestone member consists of alternating limestone beds, argillaceous limestones and shales. The rocks are abundantly fossiliferous and contain a rich fauna of corals and brachiopods. At a small creek which flows into Hare Indian River from the north, at a distance of one mile west of the mouth of Sholberg Creek, a biohermal reef knoll was observed. This bioherm (Stratigraphic Section No. 2, and Plates 2-A and -B) is approximately 23 feet high. It forms a mass of tightly intergrowing reef-building organisms and is capped by a few feet of detrital clastic limestone. On the other side of the creek the off-reef beds are exposed. These consist of grey-brown, finely crystalline limestone layers with abundant crinoid and shell fragments, and a few large coral colonies. Probably the bioherm rests on fossiliferous bedded limestone. For comparison with the reefal section, a brief description of a normal fossiliferous limestone and shale sequence is presented in Stratigraphic Section No. 1 (Appendix); this sequence was observed on Sholberg Creek. The beds in the last section correspond partly with those containing the bioherm.

A preliminary identification in the field of fossils collected from the Lower limestone member includes the following forms:

Corals: Cystiphyllum, both solitary and colonial forms, Disphyllum, Phillipsastrea, Amplexus, Synaptophyllum, Hexagonaria, Alveolites, Coenites, Grypophyllum, Favosites.

Brachiopods: Atrypa, Schizophoria, Schuchertella, Ambocoelia Productella.

Sponges: Sphaerospongia.

Gastropods: Mastigospira, Loxonema.

Trilobite fragments and crinoid fragments.

The Lower Ramparts succession has an estimated thickness of 450 to 500 feet within the Company holdings. This is approximately 100 feet more than thicknesses observed in the vicinity of Norman Wells. The contact with the underlying Bear Rock formation appears to be gradational. The Middle Ramparts black shales are sharply contrasted with the underlying Lower limestone member, but no evidence of erosion was observed at the contact.

Middle Shale Member: The Middle shale member of the Ramparts formation lies near the surface over a large part of the Company holdings, but due to the nature of the rock it is poorly exposed. The upper part of the section is exposed at the northeast end of the Ramparts on Mackenzie River (Stratigraphic Section No. 3). The beds consist of greenish grey calcareous shale interbedded with platy argillaceous limestone. Farther east within the Company Permit area, the Middle shale member is more calcareous and it contains some medium-bedded limestone, which forms small escarpments at several places. The basal part of the Middle shale member consists of thin-platy to fissile black shale, containing Tentaculites. The well known Leiorhynchus castanea zone, which overlies the Lower limestone member in many places outside the Company holdings, was not observed. The fauna of the Middle shale member consists largely of brachiopods, including Atrypa, Schuchertella, Cyrtina, Martinia and Productella. Where these fossils occur in green shale they seem to be dwarfed, while the same assemblage, but with larger forms, occurs in the more calcareous beds.

The thickness of the Middle shale member cannot be measured within the Company holdings. We have estimated on a basis of regional data that the member is 500 to 600 feet thick. The boundaries of the member cannot be accurately mapped except in a few places where the contacts are exposed. The lower contact was examined at Sholberg Creek, where the basal black shale beds of the Middle shale member are sharply divided from the underlying limestone member. This is the only place where the lower contact was observed within the Company holdings. The contact with the overlying Upper Ramparts limestone is exposed at several localities on Mackenzie River to the southwest and northwest of Fort Good Hope. The shaly limestones of the Middle member are separated from the overlying massive Upper Ramparts limestone by an interval of "transitional beds." The transition zone is five to ten feet thick and it consists of irregular medium-bedded limestones, which contain abundant corals and brachiopods. This zone has been included with the Upper member. The contact with the Middle member is gradational and has been drawn arbitrarily below the first occurrence of corals.

Upper Limestone Member: The Upper member was extensively studied by our field crews during the past summer in order to obtain an insight into its lithological components, and also to gather detailed structural data. Some of the results are presented in Figures VI and XI, and on Stratigraphic Sections Nos. 3, 4 and 7.

The Upper limestone member is well exposed in the Ramparts of Mackenzie River to the southwest of Fort Good Hope, and in many places west of this settlement (see the Photomosaics). In this area the member consists of bedded to massive cliff-forming limestones. The limestones are in part clastic in character and these alternate with large lenses and zones of stromatoporoidal reef. The more persistent lithological markers lie at the base of the member. These consist of the basal transitional interval of about ten feet, and the overlying massive calcarenitic and bioclastic sequence, which may be termed "the Rensselandia zone" in this particular area. As described previously, the transition zone consists of irregular beds of brown detrital and fossiliferous limestone which overlie the Middle shale member. In places, the zone is almost biohermal in character and contains platy and small bulbous stromatoporoids, colonial and solitary corals, and brachiopods. The zone forms a recession at the foot of the upper limestone cliffs and is generally covered by talus. The Rensselandia zone has a thickness of 25 to 40 feet. It forms layered cliffs of light brown to grey-brown, finely crystalline limestone. Fossil fragments are scattered within the unit, but they are most numerous near the base where the following genera commonly occur: Rensselandia, Stringocephalus, Martinia, Atrypa, Amphipora, Thamnopora, Favosites, Coenites, Disphyllum, Stromatoporoids and solitary corals.

The Rensselandia zone is overlain by a lithological succession which can be described as a "reef complex." It consists of alternating lenses of stromatoporoidal reefs which are several miles long with thicknesses varying from a few feet to 50 feet. Stromatoporoids form the main constituent of these reefs. Bulbous forms dominate and some of these have a diameter of several feet. They must have grown in place, but most of them lie on their side, indicating that they were rolling on the reef surface due to strong waves during later stages of growth. Other fossils that are common in the reef beds are Coenites and Amphipora. The material which fills the space between the stromatoporoids consists of bioclastic and calcarenitic limestone. In places, the detrital limestone is slightly porous and stained with brown oil and has a fresh oily odour. The reef masses grade laterally into fossiliferous clastic limestone. Reef banks are separated by persistent thin zones of dark brown argillaceous limestone, which form prominent ledges on the cliff faces on Mackenzie River. One of these shale bands is particularly prominent. It lies some 100 to 125 feet above the base of the Rensselandia zone and it separates light cream-coloured limestones from the underlying light brown to brown limestones which we described above.

The upper beds of the Upper limestone member are exposed at Mackenzie River in the southwest part of the Ramparts cliffs. Their character differs slightly from that of the lower beds because light grey-brown detrital limestone dominates. Stromatoporoidal reefs are present but they are much smaller than those that occur in the lower part of the section. In places, bryozoa, of a type similar to Cladopora or Thamnopora, are abundant and also form bioherms. Oil staining was noticed but it is less common than in the lower stromatopora reefs. Massive bedding is apparent on the cliffs that are formed by the upper light coloured limestones. A number of sections were measured in detail in order to determine the structural position of the Rensselandia zone, which lies below the surface in the southwestern Ramparts. It became obvious, however, that the beds and ledges, which can be seen from a distance above the black shale marker, are discontinuous and that they are of little use in detailed structural mapping.

The upper limestone member has a maximum thickness of approximately 250 feet at the Ramparts. Within the entire area it has been truncated by pre-Cretaceous erosion. On Airport Creek, at a distance of 16 miles northwest of Fort Good Hope, the Upper Ramparts is disconformably overlain by Fort Creek shale (Plate 5-A). Less than a mile to the south, Ramparts limestone is overlain by Cretaceous sandstone (Plate 5-B) which rests on the profoundly eroded Ramparts surface. In the vicinity, the entire Upper member has been removed by erosion and the Cretaceous rests directly on the Middle Shale member (Stratigraphic Section No. 6). Considerable relief, therefore, marks the pre-Cretaceous erosion surface of the Middle Devonian within the Company holdings. This is particularly obvious near Airport Creek.

The lateral equivalent of the Upper Ramparts member within the subject Permits, as described above, is best known to the north, along the banks of the Mackenzie River and its tributary streams. This outcrop sequence for approximately 75 miles downstream is very significant from the standpoint of the regional petroleum and natural gas possibilities, inasmuch as it shows a regular gradation northward from massive reefoid deposits in the vicinity of the Fort Good Hope Permit, over which we have postulated in this area a broad regional high, known as the Fort Good Hope High, to rubbly limestones and thence into thinly bedded limestones. Still farther north the lateral equivalents of this series become crossbedded silts and more massive silts. This sequence is a natural off-reef sedimentary sequence that in our opinion proves that the subject Permits indicate the position of a large regionally high area, probably representing a Precambrian High at depth, over and around which reefoid and other clastic reservoirs would tend to be better developed. Thus, although we do not yet know the exact shape and size of this regional high, it is of sufficient interest to justify considerable attention being paid to the identification of any local structural features that may be present. In other words, the conditions are excellent from the standpoint of the generation and accumulation of oil and gas providing the structural conditions are satisfactory.

Upper Devonian

Fort Creek Formation

General Description

The Fort Creek formation of Upper Devonian age consists of black bituminous shales, in places containing limestone and silt bands. Locally, the shales are indurated with siliceous material and pyrite. The bitumen content is high and the reddish colouring on outcrops of the Fort Creek has been ascribed by many geologists to burning. It is probable, however, that most of the reddish staining is commonly due to the slow oxidation of iron compounds. The basal Fort Creek beds contain Hypothyridina sp. in several widely scattered places. Other fossils that occur sparsely in the Fort Creek shales are Buchiola and Tentaculites.

The base of the Fort Creek is marked in several areas by the occurrence of sandstones. Dark, platy, bituminous sandstones with a thickness of 45 feet, containing brachiopods and plant remains, underlie black shales at Thunder River (Fort Creek), near its confluence with the Mackenzie River. Calcareous quartz sandstones with a thickness of two to ten feet, commonly containing brachiopods, occupy a similar stratigraphic position in a wide region surrounding Fort Good Hope and Little Chicago. North of Little Chicago in the vicinity of Pen Lake the basal Fort Creek sandstones are approximately 15 feet thick and form a conspicuous marker bed, which can be easily followed on aerial photographs. In this area, the sandstone is commonly impregnated with stiff, tarry and asphaltic oil. Hume (1954) reported the presence of sandstones in the Discovery (Norman) Range. These have been described under the name of Canyon member in several wells drilled in the Mackenzie valley.

The basal sandstones indicate the presence of a disconformity which separates the Fort Creek from the underlying Ramparts formation. Crickmay (1957) came to this conclusion several years ago.

In previous pages we have pointed out that, in our opinion, the Middle Ramparts shale in the Discovery Range and in the western Mackenzie Mountains has been erroneously referred to as "Fort Creek" and "Lower Fort Creek" by the Canol geologists (Figure II). The lower boundary of the Fort Creek formation should be placed below the basal Fort Creek sandstones, or at the top of the Upper Ramparts limestone member if it is present in the section. In a number of published descriptions of the Middle Ramparts-Fort Creek shale interval, no sandstones or Upper Ramparts limestones have been mentioned. This is the case in sections recorded to the west and southwest of Norman Wells, in the Mackenzie Mountains.

At the type locality on Thunder River (Fort Creek), near Fort Good Hope, the Fort Creek formation consists of 200 feet of hard black shales, underlain by 45 feet of sandstone. In this general area, the formation is overlain by the Imperial formation of Upper Devonian age to the west of the Mackenzie River, while on the east side of the river an erosional wedge of Fort Creek is directly in contact with strata of Cretaceous age.

The upper stratigraphic boundary of the Fort Creek formation is generally chosen above the black shales. The typical black bituminous Fort Creek shales are overlain by a grey shale zone which contains an increasing number of siltstone beds towards the top. The grey shales have been called

"Norman" or "Lower Norman" shales (Imperial formation) by several of the Canol geologists. The relationship of the black and grey shale intervals in the Norman Wells field has been well described by Boggs (1944). This author recognized the presence of a lower "Bituminous Zone" overlain by a "Non-Bituminous Zone," which he combined under the name of "Upper Fort Creek shale." The bituminous zone consists of brownish black to almost coal black shales and contains in places pyrite and cherty materials which make the rock very hard. The black shale interval varies in thickness from 97 feet to 410 feet and it covers the Upper Ramparts (Kee Scarp) reef. Numerous cross-sections in the field show that where the reef is thick the overlying shale is thin. In places where the reef is thin or entirely absent, the shale is thicker and reaches a maximum of 410 feet. The thickness of the non-bituminous zone is more uniform than that of the underlying unit and varies from 687 feet to 800 feet. The upper part of the grey shale interval contains some silt and sand and is overlain by a thick sandstone zone, which has been mentioned by several Canol geologists under the name of "Bosworth sandstone."

We prefer to confine the name "Fort Creek formation" to the black shale interval and to place the grey shales in the Imperial formation of Upper Devonian age.

In most places outside the Norman Wells field, the total thickness of the Fort Creek is not precisely known. The black bituminous shale section of 410 feet observed in the "C" Location well (south of Norman Wells on the left bank) is probably the largest seen in the Mackenzie Basin. To the north and west, the presence of the Fort Creek formation, as defined in this report, has not been established. At several places in the southeastern Richardson Mountains black shales have been observed underlying the Imperial formation. It is difficult to determine the stratigraphic position of these shales at this time. They may belong to one or more of the following units: Middle Ramparts, Fort Creek or Imperial.

Fort Creek Formation within the Company Holdings

The Fort Creek formation is not exposed within the Company holdings. It may occur in places near the north boundary of the Permit area, but most probably it has been removed by pre-Cretaceous erosion. The formation can be examined in outcrops on Airport Creek, approximately 16 miles northwest of Fort Good Hope and less than a mile west of the Permit boundary. Some 40 feet of indurated black shales disconformably overlie the Upper Ramparts limestone. The contact is marked by rusty staining in the upper beds of the Ramparts formation. Some black crystalline limestone is found at the base of the Fort Creek in some places, but basal sandstone has not been observed on Airport Creek.

Imperial Formation

General Description

Beds belonging to the Imperial formation occur within a belt which stretches from the southern Richardson Mountains to the area near Fort Simpson. The name Imperial was proposed by Hume and Link (1945) for the Upper Devonian beds between the Fort Creek formation and the Cretaceous. The type section was designated on the northeast flank of the Imperial anticline on Imperial River. In the northwest the formation consists of coarse-grained clastics of continental origin, which grade into finer material to the southeast, while the character of the deposits changes to marine. The Shale Unit of the Upper Mackenzie area and northern Alberta may correlate with most of the Imperial formation. The facies of the typical Imperial sandstones and shales strongly resembles that of Cretaceous strata in Alberta, and indicates connection with a rising land area to the north during an early stage of Acadian (Devonian) orogeny. Provenance of the Imperial sediments appears to have been mainly from the northwest. The Imperial formation has not been observed in the Keele Range nor in the northern Richardson Mountains. In these areas the formation probably was never very thick, and it was entirely eroded in Mississippian or early Permian time. Removal of Imperial beds has also taken place in the southern Richardson Mountains, but there erosion probably began in late Cretaceous time.

A thick section of interbedded sandstones and black shales of Upper Devonian age was observed near the upper reaches of Vitrekwa River in the central Richardson Mountains. Part of this series has been marked as Ordovician and Silurian on Geological Survey of Canada Map No. 1048A. The rocks have a superficial similarity to the graptolite beds of Ordovician and Silurian age which occur farther to the south within the same mountain range. The sandstone and shale sequence on the south fork of Vitrekwa River belongs, however, to the Imperial formation. The beds are strongly disturbed by folding and faulting, and it seems impossible to determine the thickness with accuracy. An estimated 6,000 feet are exposed at this locality. The lower 2,000 feet of the formation consist of regularly alternating beds of sandstone and shale, with a thickness of approximately one foot each, which create a ribboned appearance on the rock surface. This lower part is overlain by some 3,000 feet of similar strata in which, however, the sandstones predominate. The upper portion consists of firm, dark grey shale with a few thin sandstone layers. Sandstones throughout the exposed interval are dark grey to brownish grey, fine to medium grained, hard, and of the "salt and pepper" type. Fine crossbedding, ripple marks, flute casts, worm burrowings, flat clay pebbles and carbonized plant fragments (Calamites) are common features. The shales are grey to dark grey, in part black, firm with scattered chert and rare ironstone. The Imperial formation is unconformably overlain by basal shales and conglomerates of the Lower Cretaceous.

Imperial Formation within the Company Holdings

The Imperial formation is not present within the Company holdings. It occurs to the north, west and south of the project lands, but the formation has been removed by pre-Cretaceous erosion on the structurally high area surrounding Fort Good Hope.

Cretaceous

General Description

Strata of Cretaceous age are widespread in the Northwest Territories and the Yukon, but they have been inadequately studied. Well exposed, thick sections are extremely rare, as the Cretaceous sandstones and shales are generally soft and easily converted to debris. Considerable change in lithology may be noted between outcrops that lie within relatively short distances of each other. Thick, shaly or sandy units are recognized in certain areas, but in most places the stratigraphic position and the age of these intervals has not been determined. Paleontology is the most important tool for the subdivision and correlation of the Cretaceous system in this region, but unfortunately fossils are scarce and poorly preserved in large parts of the sequence.

The regional distribution of Mesozoic strata, which belong largely to the Cretaceous, is shown in a generalized manner on Figure IV. Thick sections of Cretaceous strata have been preserved in a trough which fringes the eastern margins of the Richardson and Mackenzie Mountains. Exposures of Cretaceous beds with an aggregate thickness of more than 2,000 to 3,000 feet have been observed at several places in the eastern Mackenzie Mountains, such as the flanks of the Imperial anticline, the upper Carcajou River and the Fort Norman area. Probably the belt of thick sandstones and shales follows the northern edge of the Mackenzie Mountains, curving to the north on the east side of the Richardson Mountains. Northwest of Fort McPherson and west of Aklavik the section thickens to more than 3,000 feet within a narrow belt. These deposits may be connected with the Cretaceous sections of northern Alaska which reach a thickness of at least 13,000 feet. East of this long trough, which is parallel with the mountain fronts, the Cretaceous sections are generally less than 1,000 feet thick and occur on hills and plateau areas. Devonian, Silurian and Ordovician beds surround most Cretaceous hills and are partly exposed in broad valleys east of Mackenzie River. In large areas the Cretaceous may be entirely missing.

It seems that subsidence and sedimentation in early Cretaceous time began in the north, near the present Mackenzie delta, progressing later towards the centre of the present Mackenzie Basin. The character of the sediments points to the temporary existence of slowly emerging land masses to the north and west, which supplied the enormous quantities of clastics that were deposited. Conditions must have been unstable, as indicated by several gaps in the sedimentary record. At times the transgression may have advanced from the south rather than from the north. One cannot escape noticing the parallel between the distribution of Cretaceous strata with that of the beds belonging to the Imperial formation of Devonian age. In previous pages we have drawn attention to the fact that the character of the Cretaceous sediments is very similar to that of the Imperial strata. The regional distribution of the strata of both stratigraphic intervals may have been determined largely by a tectonic framework created by emergence of the edges of the continent. This tectonic pattern seems to be intimately connected with the position of the "troughs" which contain thick series of Imperial and Cretaceous sediments and which follow a major part of the Mackenzie River valley.

Cretaceous within the Company Holdings

Strata of Cretaceous age cover a considerable area within the Company holdings. These beds are particularly common in the southwest part of the lands, but scattered remnants of the Cretaceous can be found in several other places. The entire sequence probably belongs to the Sans Sault formation of Lower Cretaceous age. It consists of basal sandstone and conglomeratic beds which are overlain by dark grey shales.

The basal beds rest unconformably on the strongly eroded surface of Paleozoic formations. The relief of the Paleozoic surface is probably several hundred feet. Basal sands have filled the depressions and, in places, remnants of the Cretaceous are surrounded at present by higher cliffs of the Ramparts formation. The basal clastic deposits are probably of continental or litoral origin and they consist of a mixture of foreign and local material.

Near Airport Creek, Cretaceous sandstones overlie the Fort Creek formation and, a short distance farther south, they lie on the Ramparts formation (Stratigraphic Sections No. 6 and 7, Plate 5-B). In this area the lower 20 feet consist of conglomerate, breccia and sandstone lenses. The most conspicuous components are hard, black, angular, siliceous shale fragments that were derived from nearby Fort Creek shale outcrops. Smoothly rounded pebbles of chert are also common and these must have been transported from a considerable distance, until they were embedded in the Cretaceous conglomerates. The sandstone lenses consist of soft, medium to coarse-grained quartzose sands that are crossbedded and light buff to grey-white in colour. Sand grains are subangular to subrounded and are in part well sorted, but in most places poorly sorted. Minor quantities of lignite are also found. Several sand lenses, which may reach one foot in thickness, are stained by oil with fresh light brown dolour. The conglomeratic beds are overlain by soft, medium to coarse-grained sandstones. On the left bank of Mackenzie River, a few miles south of Airport Creek, these thick-bedded, crossbedded sandstones form 50-foot high cliffs. In places, initial dips within the deposit reach an angle of 25 degrees.

At the south end of the Ramparts (Plate 6-A) the basal Cretaceous sandstones are less conglomeratic than those near Airport Creek. The sandstones are argillaceous, fine to medium grained, and largely tight with a few porous streaks. Some thin gritty layers, containing small pebbles of clear quartz, white quartz and chert, occur near the base. The sandstone beds are characterized by the occurrence of glauconite and by the presence of worm trails and ripple marks. A mile farther to the north, the Ramparts formation is locally overlain by five to ten feet of coal and carbonaceous shale, and also by some black carbonaceous(?) sandstone.

East of Fort Good Hope basal Cretaceous sandstones are commonly exposed, but the sections are less complete than those on Mackenzie River. The sandstones in this area are composed of clean, medium to coarse grained, grey-white quartzose sand and are generally highly porous (Plate 8). In some places, the sandstone is impregnated with dried brown bitumen (Plates 7-A and -B).

The shales which overlie the basal sandstones of the Sans Sault formation were examined on Mackenzie River and on Tsintu River, a few miles south of the Company holdings. The shale is dark grey to black and contains a few layers and lenses of glauconitic sandy shale and siltstone (Stratigraphic Section No. 5). Ironstone concretions, irregular small masses of bentonite, and a few thin zones with cone-in-cone structure were observed in several places. A small ammonite was collected from the lower part of the shale sequence. This fossil has been identified as Cleoniceras sp. by Dr. C.R. Stelck. It indicates that the stratigraphic position of the shale is at the top of the Lower Albian or at the base of the Middle Albian.

The shale series forms an excellent cap rock on the basal Cretaceous sands. It may have sealed fault reservoirs that formed within the area where the shale is present.

Pleistocene

Most of the lower Mackenzie area has been covered by continental ice during the glacial stages of the Pleistocene epoch. Many glacial features such as various moraines, kame-and-kettle topography, fluting, gouging, eskers and drumlins can be observed.

General data on the direction of ice movement have been compiled and recorded on the Glacial Map of Canada, published by the Geological Association of Canada, 1958. Much ice flowed from Hudson Bay toward the Cordilleran region which formed a western barrier. North of Great Slave Lake the western ice diverted to the north, in a broad sense following the direction of the Mackenzie valley. In the region to the northwest of Great Bear Lake, ice movements appear to have been following irregular directions. Probably the ice no longer took the shape of a continuous sheet but rather that of broad separate lobes.

The continental ice which moved westward from the north arm of Great Bear Lake flowed in a southwest direction in the vicinity of Hare Indian River toward Fort Good Hope. West of Fort Good Hope the ice masses joined the glaciers that came down the Mackenzie valley and then proceeded jointly to the north toward the Mackenzie delta. The general southwest direction of ice flow within the Company holdings is clearly indicated by parallel striations and lineations on the photomosaics.

The deposits of Pleistocene and "Recent" origin are largely covered by vegetation within the Company holdings. In many places, such as on elevated plateaus and ridges of bedrock, the Quaternary sands and gravels have been removed by erosion. Probably the overburden is thin within the entire area and, outside the main river valleys, it may seldom reach a thickness greater than 50 feet. Weathered boulder clay was observed in a few places, but most Quaternary deposits consist of sand and gravel outwash. A few eskers were observed near Hare Indian River. The most prominent esker lies a few miles to the northeast of Fort Good Hope. It has an easterly orientation and it is flanked by elongated lakes which mark depressions on both sides of the ridge.

STRUCTURAL GEOLOGY

Regional Structure

The major tectonic trends of the Lower Mackenzie region are shown on the accompanying generalized Geological Map of Northwestern Canada (Figure IV). The project area is situated in the central Mackenzie Sedimentary Basin. To the west of the basin, sediments have been folded to form the mountain ranges of the northern Yukon and the Mackenzie Mountains. The Interior Plains were much less affected by orogenic forces, but close examination reveals abundant evidence of significant tectonic disturbance throughout the region.

The folded and faulted Mackenzie Mountains have a northwest trend from Camsell Bend to an area northwest of Norman Wells, where their general direction changes to almost due west. Nevertheless, a continuing northwest trend across the Interior Plains appears evident in the presence of faults, fractures and possibly some folding. The Franklin Mountains consist of a number of relatively widely spaced anticlines that are cut by several transverse faults and which form a frontal belt curving around the periphery of the Mackenzie Mountains. The Franklins are separated from the Mackenzie Mountains by the Mackenzie Plain, a wide flat area which includes the valley of Mackenzie River. The Mackenzie Plain and parts of the adjacent mountains seem to have been the site of a large, relatively narrow trough which subsided during deposition of Upper Devonian and Cretaceous strata.

Another sharp northward change in direction of the mountain front takes place near Peel River, where the Richardson Mountains trend towards the north. The long eastern front of the Canadian Cordillera seems to come to an end at the Arctic coast north of the Richardson Mountains, and its projection is a matter of conjecture at this time. Both the southern and northern Richardson Mountains can be interpreted as older tectonic units, which were not affected as actively by the Laramide orogeny as most other Cordilleran ranges. A major tectonic hinge line can be drawn from the headwaters of Peel River, west of the southern Richardson Mountains to the Mackenzie delta. To the west of this line lie the Eagle Plain, the Porcupine Plain, the Arctic Plateau and the northern Richardson Mountains. In these areas, beds of Mississippian, Permo-Pennsylvanian, Triassic, Jurassic and early Cretaceous age are widespread, but the same units do not occur to the east of the hinge line.

It is obvious from the position of the principal mountain trends that the structure of the Mackenzie Basin is much more complex than that of the Alberta Basin. The fundamental cause of this difference in character can be ascribed to the greater intensity and variety of pre-Laramide tectonic disturbances that have taken place within the Mackenzie Basin. In the course of our field work we found evidence of Caledonian (early Ordovician) and Appalachian (early Permian) tectonism. It can be easily visualized that the Laramide (late Cretaceous and Tertiary) orogenic trends were strongly influenced by the preexisting pattern of folded belts, horsts, grabens and major faults. It is extremely difficult, however, to analyse these phenomena and their relations in space and time, particularly within areas with small isolated outcrops.

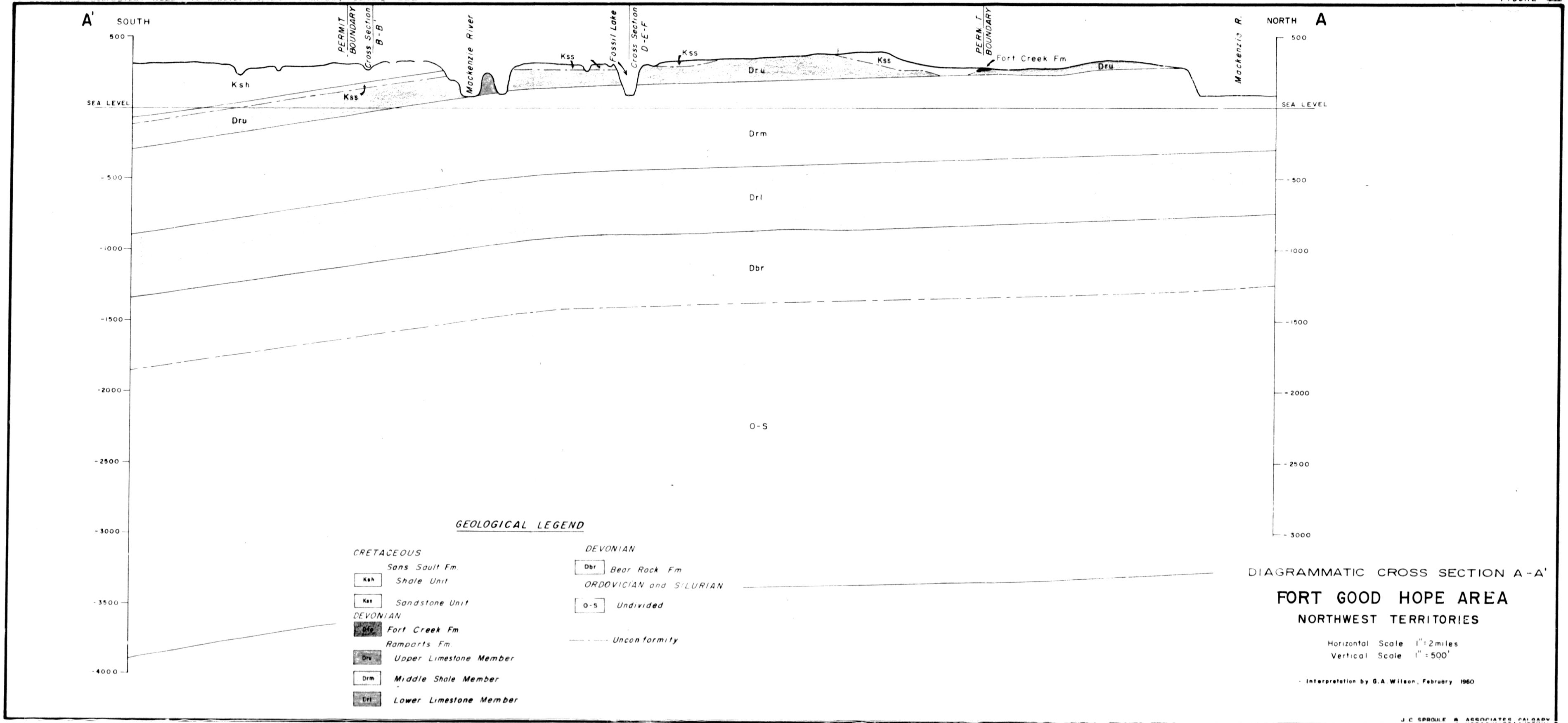
Structure within the Company Holdings

Structural conditions within the Company holdings are illustrated on the accompanying structure contour map (Figure VI) and on five structural cross-sections (Figures VII - XI). Regional geological data clearly indicate that the project area is situated on a broad uplifted structural arch. As is shown on Figure VI, the dip and strike is not uniform but is interrupted by a broad plunging nose known as the Fort Good Hope High. Whether or not the Fort Good Hope High was once roughly horizontal and later tilted to its present plunging position, the setting is one that favours the generation and accumulation of oil. The abundance of oil seepages over and around the Good Hope feature, as described elsewhere in this report, adds considerably to the idea that the oil and gas prospects in this area are good.

Over most of the Permit area the strata are gently dipping to the west and southwest at a rate of approximately 35 feet per mile. Beds are more steeply inclined in the southeast corner at the rate of 125 feet per mile, but in the northwest quarter of the map area they dip to the west and northwest at the rate of approximately 25 feet per mile. The structure map (Figure VI) shows contours on top of the Middle shale member of the Ramparts formation, which has been mapped at the base of cliffs formed by the Upper limestone member. Where the Upper member is removed by erosion, the top of the Middle shale has been reconstructed. The map indicates the presence of some broad structural anomalies which include closed domal or anticlinal structures. One of these is situated near the confluence of Bluefish River and Hare Indian River and the other dome lies west of Lac a Jacques. The presence of reversed dips to the east and the amount of closure have not been established by accurate measurements, but they are based on evidence from the structural cross sections. Their presence is also supported from photogeological interpretation. The domes are subsidiary "highs" on two structural "noses" which trend in westerly and southwesterly directions. The wide valley of Hare Indian River between Sholberg Creek and Mackenzie River coincides with one such structural nose or anticline. The noses are separated by a synclinal feature with a southwest-trending axis.

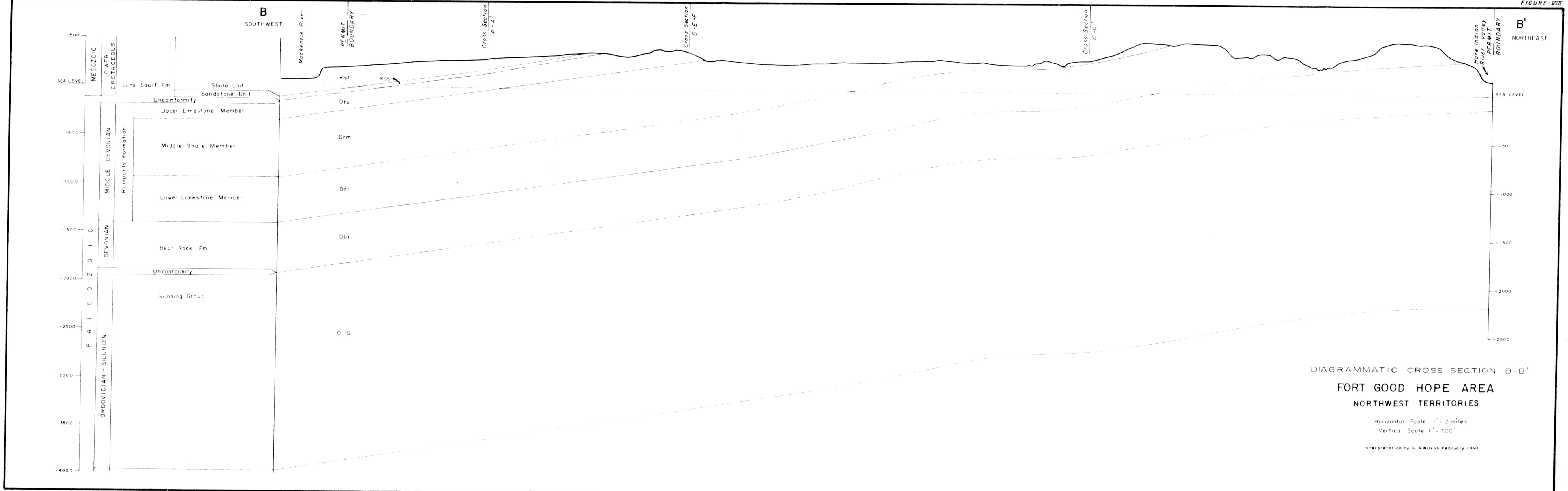
Several structural features, such as folding and faulting of lesser magnitude, are present in the area. Some of these features are possibly of equal importance with regard to oil and gas accumulation as the larger regional structures shown on Figure VI. Small gentle domes can be observed at the cliffs of the Ramparts of Mackenzie River (Figure XI). These domes appear at the cliff face as arches which span a distance of less than half a mile and with a height of no more than 20 feet. In other places the beds have erratic gentle dips, which indicate the presence of small folds and faults. Three disturbed areas have been marked in Figure VI. Their origin has not been established, but it is inferred that they may be connected with collapse features associated with dissolved gypsum lenses in the underlying Bear Rock formation.

No faults of significance have been observed in outcrop, but faulting must be fairly common in the area, as indicated by photogeological evidence.

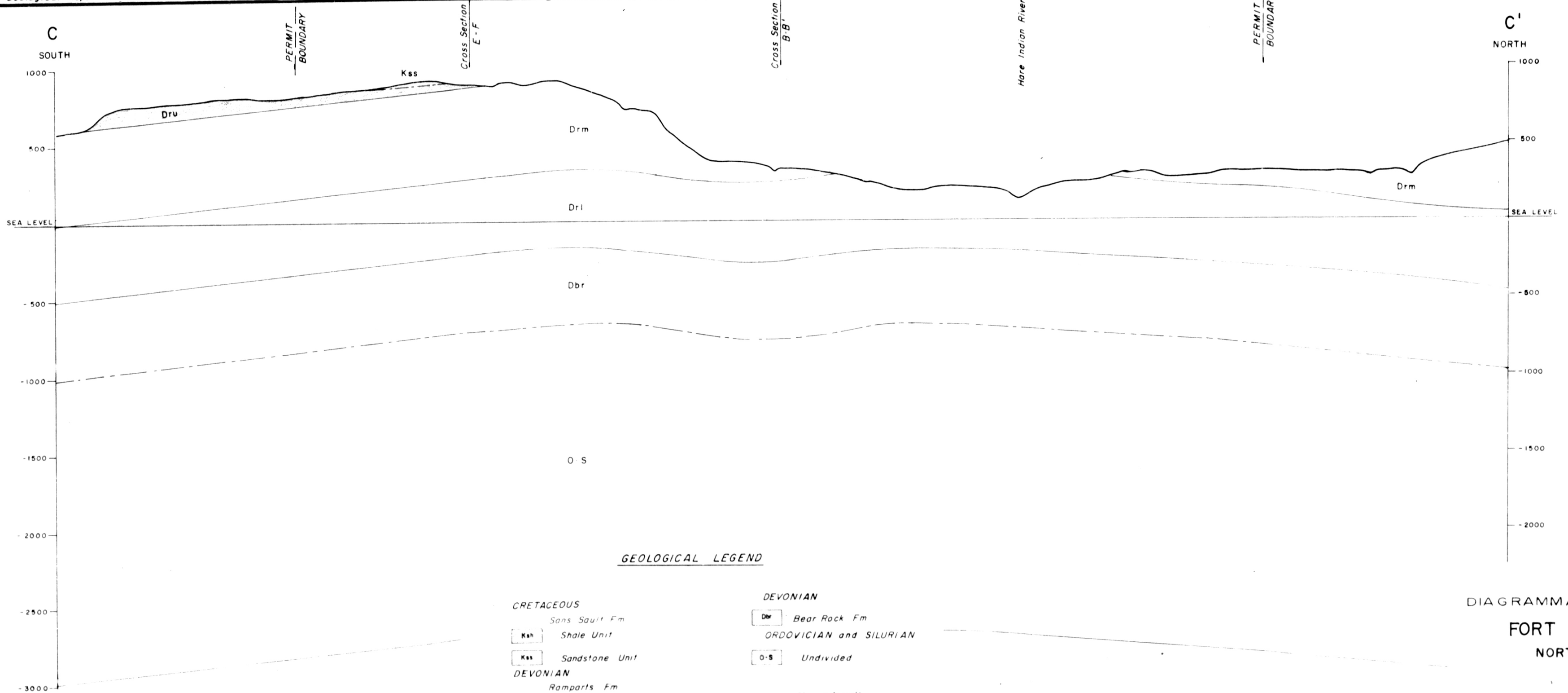

A'
SOUTH
NORTH
A
PERMIT BOUNDARY
Cross Section B-B
Mackenzie River
Fossil Lake
Cross Section D-E-F
PERMIT BOUNDARY
Fort Creek Fm
Mackenzie R.
Ksh
Kss
Dru
Drm
Drl
Dbr
O-S
SEA LEVEL
500
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
GEOLOGICAL LEGEND
CRETACEOUS
Sans Sault Fm
Ksh Shale Unit
Kss Sandstone Unit
DEVONIAN
Dfc Fort Creek Fm
Ramparts Fm
Dru Upper Limestone Member
Drm Middle Shale Member
Drl Lower Limestone Member
DEVONIAN
Dbr Bear Rock Fm
ORDOVICIAN and SILURIAN
O-S Undivided
Unconformity
DIAGRAMMATIC CROSS SECTION A-A'
FORT GOOD HOPE AREA
NORTHWEST TERRITORIES
Horizontal Scale 1" = 2 miles
Vertical Scale 1" = 500'
Interpretation by G.A. Wilson, February 1960
J.C. SPROULE & ASSOCIATES, CALGARY

To accompany Geological Report to Glacier Explorers Limited, February 1960

FIGURE-VIII



To accompany Geological Report to Glacier Explorers Limited, February 1960



GEOLOGICAL LEGEND

CRETACEOUS
Sans Sault Fm
Ksh — *Shale Unit*
Kss — *Sandstone Unit*
DEVONIAN
Ramparts Fm
Dru — *Upper Limestone Member*
Drm — *Middle Shale Member*
Drl — *Lower Limestone Member*

DEVONIAN
Dbr — *Bear Rock Fm*
ORDOVICIAN and SILURIAN
O-S — *Undivided*

— · — *Unconformity*

DIAGRAMMATIC CROSS SECTION C-C'

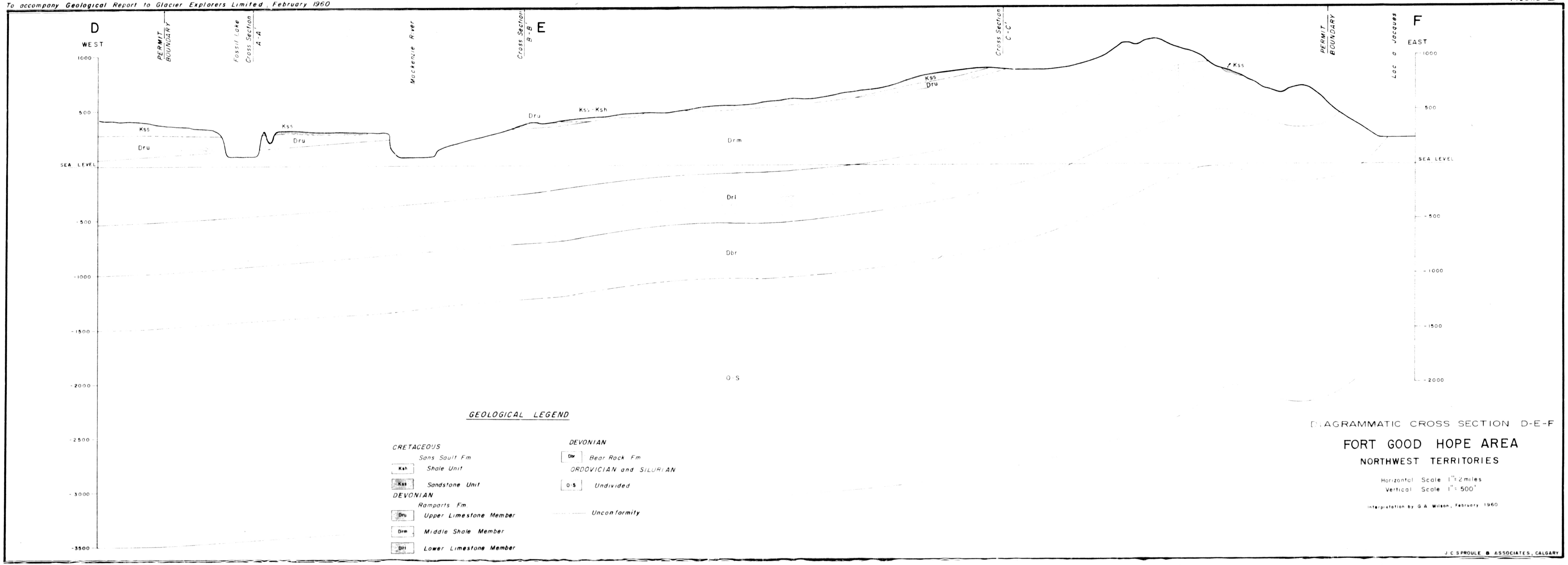
FORT GOOD HOPE AREA

NORTHWEST TERRITORIES

Horizontal Scale 1" = 2 miles
Vertical Scale 1" = 500'

Interpretation by G.A. Wilson, February 1960

J.C. SPROULE & ASSOCIATES, CALGARY



DIAGRAMMATIC CROSS SECTION D-E-F

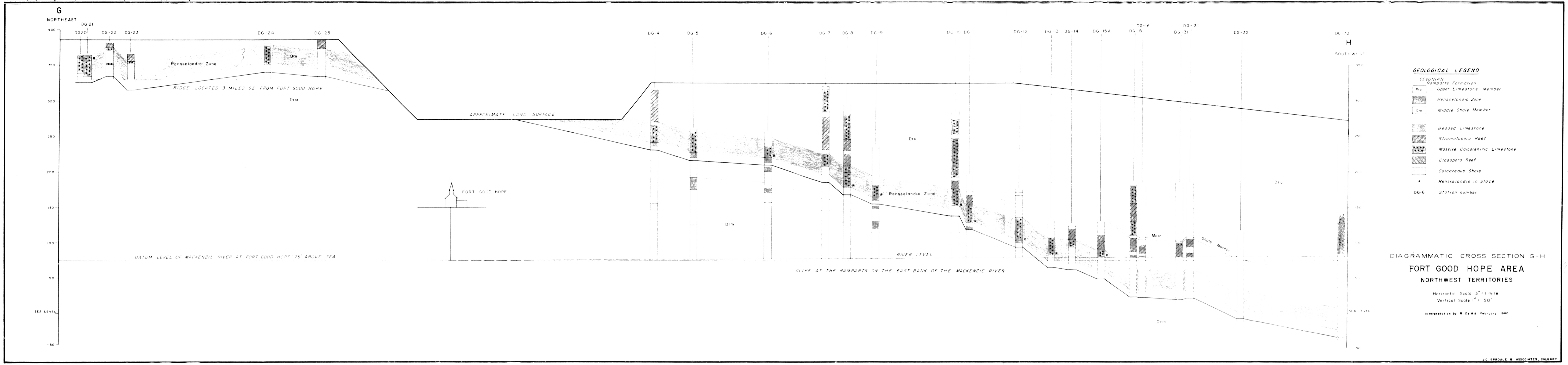
FORT GOOD HOPE AREA

NORTHWEST TERRITORIES

Horizontal Scale 1" = 2 miles
Vertical Scale 1" = 500'

Interpretation by G.A. Wilson, February 1960

J.C. SPROULE & ASSOCIATES, CALGARY


G
NORTHEAST
H
DG-21
DG-20
DG-22
DG-23
DG-24
DG-25
DG-4
DG-5
DG-6
DG-7
DG-8
DG-9
DG-10
DG-11
DG-12
DG-13
DG-14
DG-15A
DG-15
DG-16
DG-31
DG-32
Rensselandia Zone
Dru
Drm
RIDGE LOCATED 3 MILES SE FROM FORT GOOD HOPE
APPROXIMATE LAND SURFACE
FORT GOOD HOPE
DATUM LEVEL OF MACKENZIE RIVER AT FORT GOOD HOPE 75' ABOVE SEA
RIVER LEVEL
CLIFF AT THE RAMPARTS ON THE EAST BANK OF THE MACKENZIE RIVER
Main
Shale Marker
400
350
300
250
200
150
100
50
SEA LEVEL
-50
GEOLOGICAL LEGEND
DEVONIAN
Ramparts Formation
Dru Upper Limestone Member
Rensselandia Zone
Drm Middle Shale Member
Bedded Limestone
Stromatopora Reef
Massive Calcarenitic Limestone
Cladopora Reef
Calcareous Shale
R Rensselandia in place
DG-6 Station number
DIAGRAMMATIC CROSS SECTION G-H
FORT GOOD HOPE AREA
NORTHWEST TERRITORIES
Horizontal Scale 3" = 1 mile
Vertical Scale 1" = 50'
Interpretation by R. De Wit, February 1960
J.C. SPROULE & ASSOCIATES, CALGARY

Approximately 25 miles east of Fort Good Hope, basal Cretaceous sands are locally impregnated with oil. Equally porous, but non-bituminous, sands of the same age lie adjacent to the oil sand. It has been concluded, therefore, that the oil must have seeped into the sandstone along a fault or fissure in the underlying Paleozoic beds. The gas seepage near Hare Indian River, which is indicated on the Photomosaics and on Figure V, has a linear trend and is also suggestive of faulting or fracturing in the bedrock. The same is true of the seepage on the Ontaratue River described in our first report to Glacier as a result of the 1957 field operation.

It is in part such confirmations as this that lead us to describe many of the strongly developed lines controlling vegetation, and even physiography on the Plains, as probable faults or major joints, rather than lineations. "Lineation" as applied to these and similar features is a non-descript term that is a confession of ignorance that we do not feel is applicable. Other supporting evidence must also, of course, be available before we can apply the term "probable fault" or major joint to a lineation, but we feel we have that evidence where the term has been used.

The Fort Good Hope structural arch, which occupies the Company holdings, and their immediate vicinity, emerged prior to Cretaceous deposition. The Imperial formation, the Fort Creek formation and part of the Upper limestone member of the Ramparts formation were removed by erosion from the elevated area prior to the deposition of Cretaceous beds. The uplift may have been caused by block faulting or by gently compressive forces. Basal Cretaceous beds fill the depressions on the uneven surface of the Paleozoic, and they directly overlie the Fort Creek formation and the Upper, Middle as well as the Lower member of the Ramparts formation within the area and the immediate vicinity. Stability of the Fort Good Hope area, or slight positive movement in Middle Devonian time is indicated by the distribution of reefs in the Upper member of the Ramparts formation.

Renewed uplift took place after Lower Cretaceous time, presumably during the Laramide orogenic period. This conclusion is deduced from the occurrence of bedded glauconitic sandstone at the base of the Cretaceous rock sequence near the rapids at the south end of the Ramparts and on Tsintu River. The glauconitic beds are not present in most of the Company holdings. The many Cretaceous outcrops within the area are of an entirely different type and consist of littoral deposits that represent an early phase of the Lower Cretaceous transgression. The glauconitic beds, on the other hand, are of marine origin and probably formed a widespread deposit which overlay the basal sandstones and conglomerates. The absence of the glauconitic interval within the larger portion of the Company holdings means that it has been removed by erosion subsequent to uplift of the area in late Cretaceous or Tertiary time.

Interpretation of the air photos covering the project area shows abundant evidence of locally high structural relief. In an area such as the Fort Good Hope structural arch, this is to be expected. The most conspicuous areas of locally high structural relief have been marked on the geological map (Figure V) and on the Photomosaics. The numerous faults and fissures that have been marked on the mosaics show preferential trends in fracturing within the area. It is not possible, however, to indicate the amount of displacement which may have taken place along the faults.

In summary, it can be stated that there are several indications of the abundance of structural anomalies within the area. Faults and folds may have formed potential reservoirs in porous beds of Paleozoic age. Repeated emergence of the area prior to Cretaceous deposition and in late Cretaceous or Tertiary time may have stimulated migration of oil toward the Fort Good Hope area.

OIL AND GAS POSSIBILITIES

Oil and Gas Indications

There are numerous indications of oil and gas widely scattered throughout the Mackenzie Basin. The most important discoveries are the Norman Wells oil field, producing light gravity oil from the Upper limestone member of the Ramparts formation (Kee Scarp limestone), and the recent gas and light oil discovery in "Permo-Pennsylvanian" strata on the Eagle Plain.

Many seepages have been observed in the Mackenzie Basin by our geologists and several others are reported to have been found by trappers and explorers. Oil and gas seepages led to the discovery of the Norman Wells field. One of the best known seepages of live oil occurs on a hill overlooking the east shore of Rond Lake, about 60 miles north of Fort Good Hope. At this locality, two large seeps, an acre or more in extent, are separated by a narrow band of trees. These seeps have been known for many years and the Hudson's Bay Company used to obtain supplies of pitch from them. Analytical data concerning the oil were included in the Geological Reconnaissance Report of 1958.

Oil-stained and pyrobituminous rocks are commonly observed on outcropping strata of Ordovician, Silurian and Middle Devonian age.

Numerous gas seeps have been observed in the Lower Mackenzie Basin. One of the better known seepages was found on the Ontaratue River, a short distance from its junction with Circle River. This occurrence has been made public by Glacier Explorers Limited. The gas bubbling up from the river bottom will burn with a deep blue flame.

Seepages of oil and gas have been reported by trappers from the vicinity of the Richardson Mountains, but none of these have been investigated by our field parties.

Sandstones of Cretaceous age are impregnated with tarry oil at several known localities east and northeast of Fort Good Hope. The most prominent occurrence of oil sand lies about 22 miles east of Fort Good Hope within the Company holdings. The locality has been marked on Photomosaic, Sheet No. 1. The basal quartz sandstone of the Sans Sault formation rests disconformably on shaly limestone which belongs to the Middle shale member of the Ramparts formation. The sequence of bedded, and in part crossbedded, sandstone is approximately 80 feet thick. The impregnated sandstone is dark brown in colour and has some similarity with parts of the McMurray "tar sands." Near the saturated sands, equally porous sands were found which did not contain bitumen. It is concluded that the oil migrated upward into the sand from faults or fissures in the underlying limestone and shale series and that the original reservoir must lie within the Paleozoic strata.

Bitumen and fresh light brown oil-staining were noticed in the basal Cretaceous sandstones at several places on Mackenzie River. Oil-saturated sandstone lenses, reaching an aggregate thickness of several feet, form part of the basal zone of conglomerates and sands near Airport Creek. The oil has a different aspect from the "tar sand" east of Fort Good Hope. Its origin cannot be determined but, possibly, it has migrated up-dip from sources farther west.

A gas seepage was found on a small creek which flows from the south into Hare Indian River, three miles east of the mouth of Bluefish River. The locality is marked on Photomosaic Sheet No. 4. Gas bubbles rise from the river bottom and between pebbles on the shore. The gas is coming to the surface along a straight line with north-northwest direction which is at least 285 feet long. It is associated with hydrogen sulphide, which causes a white coating on pebbles at the edge of the creek. Due to difficulties in shipping, the sampling equipment did not arrive when it was needed. Unfortunately gas samples were, therefore, not taken. An attempt to ignite the gas failed, probably because the flow was not strong enough. The linear shape of the gas seep suggests that it is associated with faulting. The Middle shale member of the Ramparts formation forms the bedrock at this locality, but it is not exposed. The steep bank of the creek consists of 30 feet of sandy gravel which is overlain by 45 feet of reddish coloured sand of late Pleistocene or recent origin.

In assessing the value of the numerous seepages known in the Lower Mackenzie area, it is obvious that the incidence of such occurrences is extremely high, relative to those known in the more southern portions of the Western Canadian Sedimentary Basin. This is in part due to the abundance of outcrop and near-outcrop in the northern area, and, on balance, it indicates that we are dealing with a sedimentary basin that has at least as favourable prospects as the southern area. It may also be worthy of note that there are more seepages known on and around the Fort Good Hope High than are known anywhere else in the Western Canadian Sedimentary Basin. This may easily be due to the influence through geological time of the Fort Good Hope High as an old buried feature, or group of features, as suggested under the heading of "Structure within the Company Holdings."

<u>Prospective Formations</u>

The following stratigraphic intervals are considered to provide the best prospects for the occurrence of hydrocarbons. Any of them may contain reservoir beds within the Company holdings. They are the Cambrian, the Ordovician and Silurian series, the Bear Rock formation and the Lower limestone member of the Ramparts formation. Cretaceous sandstones and the Upper limestone member of the Ramparts show porosity and oil staining, but these beds are too close to the surface to promise accumulations of commercial significance, except in the southern part of the Permit holdings. Brief comments on the prospects of each of these rock groups follow.

Katherine Group. A thick sandstone series, which we have tentatively designated as the Katherine group, forms the basal part of the Cambrian in most of the Mackenzie Sedimentary Basin. The sandstones are generally quartzitic and tight, but in places they are porous. It is estimated on a basis of regional data that the top of the sandstone series lies at a depth of approximately 5,000 to 6,000 feet below the surface in the Fort Good Hope area. Prospects in the Katherine group may be compared with oil occurrences in the so-called Granite Wash of Alberta which are related to topographic and structural features of the basement. The geological data, available within the Company holdings and their vicinity, provide no direct indication of potential reservoirs within the basal Cambrian sandstones. The evaluation of these strata must await the results of deep drilling.

Ordovician and Silurian. Dolomite beds of Ordovician and Silurian age show vuggy and intercrystalline porosity in most outcrops in the Mackenzie Mountains. Porosity is also common within beds belonging to this stratigraphic interval in the entire area where they are exposed east of Mackenzie River. Black shales and argillites of approximately the same age as the dolomites occur in a wide belt on the west side of the Mackenzie Basin. These shales are at present partly in a down-dip position with regard to the dolomite beds of the eastern platform. The black shales may have been excellent source beds for hydrocarbons. Faults and anticlines may have formed excellent traps for oil and gas which migrated laterally into the porous Lower Paleozoic dolomites. The Ordovician and Silurian rock series is regarded to have potential as an oil and gas producing zone within the Company holdings. Accumulation may have taken place in porous beds below the sub-Devonian unconformity, or below the highly siliceous zones in the Silurian, at depths not exceeding 2,500 feet within the project area.

Bear Rock Formation. The lower part of the Bear Rock formation is porous in most outcrops which were examined in areas to the south and east of the Company holdings. Intercrystalline porosity and vugs were observed in many places. Under favourable conditions oil and gas may have accumulated in breccia reservoirs, which are sealed by the impervious dense limestones that form the upper part of the Bear Rock and by argillaceous beds belonging to the Ramparts formation.

Ramparts Formation, Lower Limestone Member. The presence of a porous bioherm in the Lower member of the Ramparts formation has been established within the Company holdings. Other bioherms may occur in the west part of the area, where, if present, they are buried and sealed, and may contain oil. The situation can be compared with that existing at Norman Wells, where the producing Kee Scarp (Upper Ramparts) reef is only a short distance west of the exposed Kee Scarp.

SUMMARY AND CONCLUSIONS

The subject area is located in the Lower Mackenzie Basin near Fort Good Hope, on and adjacent to the Mackenzie River. The geographic location of this area means that it is readily accessible.

Heavy freight shipments can reach the area by riverboat, and Fort Good Hope is on a regular airline route.

The terrain in the area poses no particular difficulties, although there are many lakes and several small streams.

Bedrock is at or close to the surface over most of the area. The exposed bedrock consists of Cretaceous shale and sandstone and Devonian Ramparts and Bear Rock shales and limestones.

The regional structural position of the area on a broad, indistinct structural feature known as the Fort Good Hope "High," is favourable from the standpoint of the accumulation of both oil and gas.

The total prospective stratigraphic section in the area is approximately 5,000 to 6,000 feet or more.

Potential oil and gas horizons are in rocks of Cambrian, Ordovician, Silurian, Lower (?) and Middle Devonian and Lower Cretaceous age.

Local areas of structurally high relief suggest that faulted, folded or stratigraphic-trap type reservoirs are likely to be present.

The numerous seepages of oil and gas that are located on and immediately adjacent to the subject acreage add considerably to its interest.

Several deep tests have been drilled in the Northwest Territories over the past few years and additional deep wells are currently being drilled. The experience gained on these ventures will provide useful guidance in further exploratory drilling in the area.

In view of the above, the following recommendations are made regarding exploration within the Company holdings:

1. A structure test program should be carried out to test one or more of the structures indicated on Figures V and VI. The most convenient and probably the most likely structure is indicated by the closed 900-foot contour on Figure VI, as being located on the axis of the Fort Good Hope "High." It should, at the same time, be noted that this structural interpretation depends on rather limited control provided by outcrop locations along the lines of cross-section of Figures VIII and IX. Under the circumstances, the control station on cross-section B-B' (Figure VI) showing an elevation of 800 feet, is a key point, inasmuch as it is possible that the adjacent area to the south, indicated as being structurally high on a basis of photo interpretation (Figures

V and VI) is a more favourable prospect. The first two or three holes in that area should be drilled on each of the two features, and at the key position between them, regardless of which interpretation is accepted. They would provide the data indicating which of these two structural features should be further tested by additional structure tests.

2. A second structure that should be tested, but which may be regarded as a secondary objective because of its distance from Fort Good Hope and the Mackenzie River, is located in the southeast corner of the Permit area, immediately to the west of Lac a Jacques. This feature shows as a "High" on both the structure contour interpretation and the photo interpretation which might possibly make it the prime objective, if it were not for the fact that it is not as accessible as the other feature. In any event, either one, or both, of these features should be logical objectives for further exploratory activity. It is anticipated that structure test holes on this structure and the one referred to above would be from 150 to 200 feet deep.

3. If the presence of folded or faulted structures should be confirmed by the above structure test program, one or more deep tests should be drilled to a depth sufficient to evaluate strata of Devonian, Silurian, Ordovician and possibly of Cambrian age.

R. de Wit, P. Eng.

J.C. Sproule, P. Eng.

February 29, 1960
1009 Fourth Avenue West,
Calgary, Alberta.

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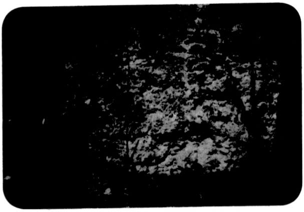
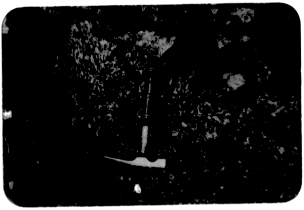
A. The main street of Fort Good Hope, N.W.T., showing Indian houses in the foreground. Visible in the background and to the right, are the church with mission buildings, and R.C.M.P. quarters.

B. Helicopter at its base, Fort Good Hope. In the background the Ramparts on Mackenzie River.

Photos by R. de Wit

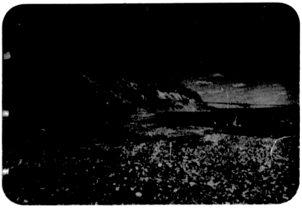


A. Bioherm in Lower limestone member of the Ramparts formation at an unnamed tributary of Hare Indian River. The bioherm is composed of the remains of reef-building organisms, which form a structureless mass.



B. Large coral colony in Lower Ramparts limestone beds which underlie the bioherm, shown above.

Photos by R. de Wit



A. Middle shale member of the Ramparts formation exposed on Mackenzie River. In the background are the limestone cliffs of the Upper Ramparts member.

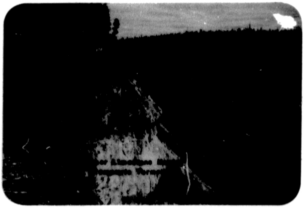
B. Mackenzie River flowing through the Ramparts. The cliffs on both sides of the river consist of massive limestones which belong to the Upper limestone member of the Ramparts formation.

Photos by G. A. Wilson

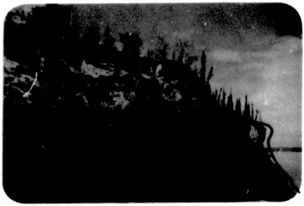
A. Upper limestone member of the Ramparts formation. The cliffs have a bedded appearance due to large reefal lenses and widespread thin argillaceous intervals. Concealed by talus, a prominent interval of dark brown shale lies at the bottom of the cliff.

B. Stromatopora reef in the Upper limestone member. The limestone is partly stained with oil.

Photos by G. A. Wilson and W. O. Kupsch



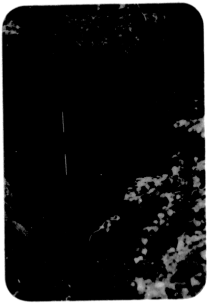
A. Contact of Ramparts formation (Upper limestone member) with the Fort Creek formation at Airport Creek. Black shales of the Fort Creek formation overlie the limestone unconformably.



B. Cretaceous sandstones unconformably overlying the Upper limestone member of the Ramparts formation. The eroded surface of the Ramparts formation slopes toward the foreground of the photograph. The limestone shows a relief of approximately 30 feet. The outcrop is located on the left bank of Mackenzie River, near the mouth of Airport Creek.

Photos by R. de Wit

A. Angular unconformity between the Ramparts formation and Cretaceous sandstones. This outcrop is located near the rapids on Mackenzie River, at the southwest end of the Ramparts.



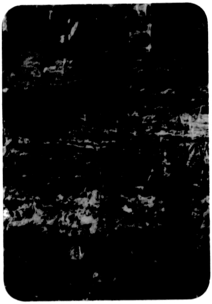
B. Thick lens of coal in basal Cretaceous beds. Outcrop is located near the rapids on Mackenzie River, at the southwest end of the Ramparts.

Photos by R. de Wit and G. A. Wilson

A. View of impregnated basal Cretaceous sands from the air.

B. Crossbedded basal Cretaceous sands, impregnated with dried oil. Locality is 20 miles east of Fort Good Hope.

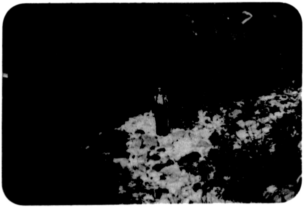
Photos by J.C. Sproule



A. Basal Cretaceous conglomerate at Mackenzie River near Airport Creek. Lenses of sandstone are impregnated with oil.

B. Basal Cretaceous sandstone exposed 25 miles east of Fort Good Hope. The sandstone consists of clean quartz grains and is not stained with oil.

Photos by R. de Wit



Gas seepage on a tributary of Hare Indian River. Gas bubbles rise from a linear fissure over a distance of approximately 100 yards at the water edge.

Photo by R. de Wit

STRATIGRAPHIC SECTION NO. 1

SHOLBERG CREEK

FORT GOOD HOPE AREA, N.W.T.

(Latitude 66° 29' North, Longitude 127° 54' West)

This section was measured on Sholberg Creek, a tributary of Hare Indian River. The creek was named by us after helicopter pilot D. Sholberg. The beds are intermittently exposed on the creek, but they show a fair section of the upper part of the Lower limestone member of the Ramparts and of the basal part of the Middle shale member. The latter consists of black shale which appears to be identical to the Fort Creek shale. Measurements were made with a five-foot staff and with compass. The description is recorded from the top downward.

Description and measurement by W. O. Kupsch and R. de Wit.

STRATIGRAPHIC SUMMARY

MIDDLE DEVONIAN

Ramparts Formation

Middle Shale Member (incomplete)	30 feet
Lower Limestone Member (incomplete)	257 feet
Total Measured Section	287 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
MIDDLE DEVONIAN		
		Ramparts Formation
		Middle Shale Member
0-30	30	Shale - black, thin-bedded, platy, containing abundant *Tentaculites* and *Styliolina*, possibly some fish scales.

Interval Feet	Thickness Feet	Description
		Lower Limestone Member
30-159	129	Limestone - grey, coarse-grained, coquinoidal with abundant brachiopod fragments; beds nodular, reaching a thickness of three inches; grey-weathering. This limestone is interbedded with shale to a ratio of 60% limestone and 40% shale. The shale is greyish green, calcareous, and breaks in paper-thin fragments. The contact with the overlying black shales is sharp.
159-223	64	Limestone - grey, nodular, with minor shale partings, very fossiliferous; greyish green weathering. Most fossils are in position of growth, but some coral heads were found in inverted position. Fossils recognized in the field include: <u>Favosites</u>, <u>Hexagonaria</u>, <u>Alveolites</u>, various horn corals, <u>Atrypa</u>, <u>Schizophoria</u>, <u>Coenites</u>, <u>Productella</u>, <u>Sphaerospongia</u>, <u>Mastigospira</u>, gastropods, crinoid and trilobite fragments.
223-225	2	Shale - greyish green, calcareous, with some limestone nodules about two to four inches long.
225-235	10	Covered.
235-238	3	Limestone - greenish grey, fine-grained, argillaceous, with green shale partings; scattered fossil fragments; grey-weathering.
238-273	35	Shale - greyish green, calcareous, paper-thin; interbedded with bluish grey limestone composed of coarse-grained coquina. The upper part of the interval has more interbedded limestone than the lower part. Fossils include: <u>Phillipsastrea</u>, <u>Atrypa</u>, <u>Schuchertella</u>, spores.
273-287	14	Covered.
287		Base of exposed section.

FIGURE - XII

STRATIGRAPHIC SECTION NO. 1

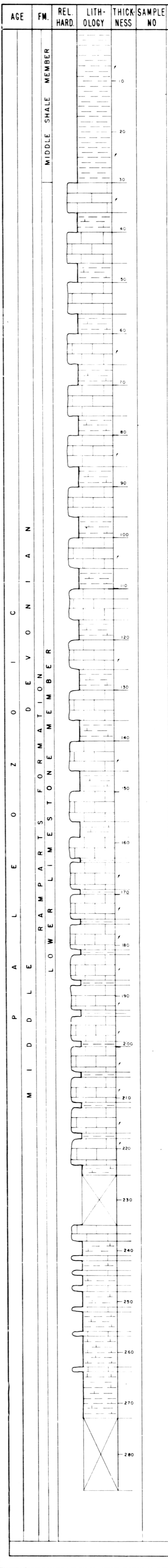
SHOLBERG CREEK

(Tributary of Hare Indian River)

FORT GOOD HOPE AREA, N.W.T.

(Lat 66°29' N., Long 127°54' W)

Field study by W.O. Kupsch, 1959



DESCRIPTION

Sh - blk, thn-plty, abnt Tent & Styliolin.

30-159 Ls - gy, c-gr, abnt Brac frags; bds nod, 3" intbd / gy-gn sh, calc.

159-223 Ls - gy, nod, mnr sh ptg v fos; gy-gn wthr
Favosites, Hexagonaria, Alveolites, horn corals, Coenites
Atrypa, Schizophoria, Productella
Mastigospira, gastropods
Sphaerospongia
Crin, Trilo frags.

223-225 Sh - gy-gn, calc / ls nod.
225-235 Covered.

235-238 Ls - gnsh gy, f gr, arg, gn sh ptg; sc fos frags.

238-273 Sh - gysh gn, calc, intbd gy ls.
Phillipsastrea, Atrypa, Schuchertella, spores.

273-287 Covered.

J.C. SPROULE & ASSOCIATES, CALGARY

STRATIGRAPHIC SECTION NO. 2

UNNAMED SIDE CREEK OF HARE INDIAN RIVER

FORT GOOD HOPE AREA, N.W.T.

(Latitude 66° 28' North, Longitude 128° West)

This section was measured at a creek which flows from the north into Hare Indian River less than one mile west of the mouth of Sholberg Creek. The outcrop can be reached by walking along the creek approximately one mile upstream. The reef is probably situated within the stratigraphic interval described in Stratigraphic Section No. 1. Off-reef limestone beds are poorly exposed on the same creek. The description of the outcrop is recorded from the top downward.

Description and measurement by R. de Wit and M. Korostil.

STRATIGRAPHIC SUMMARY

MIDDLE DEVONIAN

Ramparts Formation

Lower Limestone Member (incomplete) 53 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
MIDDLE DEVONIAN		
		Ramparts Formation
		Lower Limestone Member
9-35	35	Limestone - grey-brown, bioherm composed of the remains of reef-building organisms; in part angular coarse reef talus breccia. The upper two feet of the bioherm consist of crudely bedded calcarenites and calcirudites. The fauna is characterised by abundant colonial corals including *Cystiphyllum*, *Disphyllum* and *Hexagonaria*. The reef surface is pitted and cavernous, but porosity in fresh rock is

Interval Feet	Thickness Feet	Description
		confined to the interior of corals. Off-reef beds are exposed at a distance of 75 feet from the bioherm and consist of grey-brown, finely crystalline limestone which is composed of fine fossil detritus of crinoids and brachiopods, with scattered colonial corals. These limestone beds reach a thickness of six inches.
35-39	4	Covered.
39-53	14	Limestone - light brown, finely crystalline, slightly argillaceous, detrital, calcarenitic to finely coquinoidal; beds are nodular, three to five inches thick, and interbedded with thin bands of brown-grey to grey calcareous shale. This interval contains a prolific fauna which includes: Cystiphyllum (colonial and solitary forms), Favosites, Phillipsastrea, Amplexus, Disphyllum, Synaptophyllum, Hexagonaria, Alveolites, Coenites, Sphaerospongia, Atrypa, Ambocoelia, ostracodes and crinoid fragments.
53		Base of exposed section.

STRATIGRAPHIC SECTION NO. 2

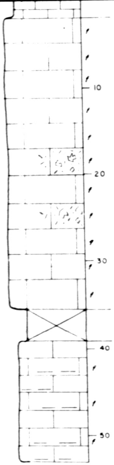
UNNAMED TRIBUTARY OF HARE INDIAN RIVER

FORT GOOD HOPE AREA, N.W.T.

(Lat 66° 28' N, Long 128° W)

Field study by R De Wit, 1959

AGE	FM.	REL. HARD.	LITHOLOGY	THICKNESS	SAMPLE NO	DESCRIPTION
PALEOZOIC MIDDLE DEVONIAN	RAMPARTS FORMATION LOWER LIMESTONE MEMBER					



0-2 Ls - gy-brn, Calcarn.

2-35 Ls - gy-brn, bioherm, Cystiphyllum, Disphyllum, Hexagonaria.

35-39 Covered.

39-53 Ls - lt brn, f xl, sl arg, calcarn, nod, thn-m bd. Cystiphyllum, Favosites, Phillipsastrea, Amplexus, Disphyllum, Synaptophyllum, Hexagonaria, Alveolites, Coenites, Sphaerospongia, Atrypa, Ambocoelia, Ostracodes, Crin. frags.

STRATIGRAPHIC SECTION NO. 3

EAST BANK OF MACKENZIE RIVER NEAR FORT GOOD HOPE, N.W.T.

(Latitude 66° 14' 30" North, Longitude 128° 42' 20" West)

The section was measured on the right bank of Mackenzie River at a distance of approximately two miles southwest of Fort Good Hope. Parts of another section which was measured at an adjacent locality, have been used to substitute covered intervals. Measurements were carried out with a five-foot staff. The section is recorded from the top downward.

Description and measurement by R. de Wit and M. Korostil.

STRATIGRAPHIC SUMMARY

MIDDLE DEVONIAN

Ramparts Formation

Upper Limestone Member (incomplete)	81 feet
Middle Shale Member (incomplete)	161 feet
Total Measured Section	242 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
MIDDLE DEVONIAN		
		Ramparts Formation
		Upper Limestone Member
0-45	45	Limestone - brown to grey-brown, finely crystalline, massive, with abundant stromatoporoids; stromatoporoidal reef zone.

Interval Feet	Thickness Feet	Description
45-50	5	Limestone - nodular, slightly softer interval, inaccessible.
50-73	23	Rensselandia zone:
		Limestone - light brown to grey-brown, finely crystalline, calcarenitic to finely coquinoidal, deposited in horizontal layers, but massive, cliff-forming, light brown weathering, numerous scattered brachiopods and corals. Other fossils include: _Stringocephalus_, _Coenites_, scattered stromatoporoids, and streaks of abundant _Rensselandia_ in lower 10 feet.
73-81	8	Limestone - argillaceous, light grey-brown, finely crystalline, interbedded with grey to dark brown shale, bedded, bed thicknesses three to five inches, with rough, somewhat nodular surfaces, very fossiliferous, with crusty algae, small stromatoporoids, _Synaptophyllum_, _Hexagonaria_, _Cyathophyllum_, _Thamnopora_, solitary corals, _Schizophoria_, various species of _Atrypa_. At one place the rock is almost reefal.
		Middle Shale Member
81-109	28	Limestone - argillaceous, grey, finely crystalline, interbedded with greenish grey shale; limestone beds two to four inches thick; interval softer than underlying beds and poorly exposed.
109-127	18	Limestone - argillaceous, grey, finely crystalline, medium bedded, eight to ten inches thick, interbedded with minor bands of greenish brown to greenish grey calcareous shale, scattered _Cyrtina_ and _Schuchertella_.
127-180	53	Limestone - argillaceous, grey, finely crystalline, thin-bedded, regularly interbanded with greenish grey calcareous shale, scattered small _Atrypa_, _Martinia_.
180-242	62	Covered.
242		River level.

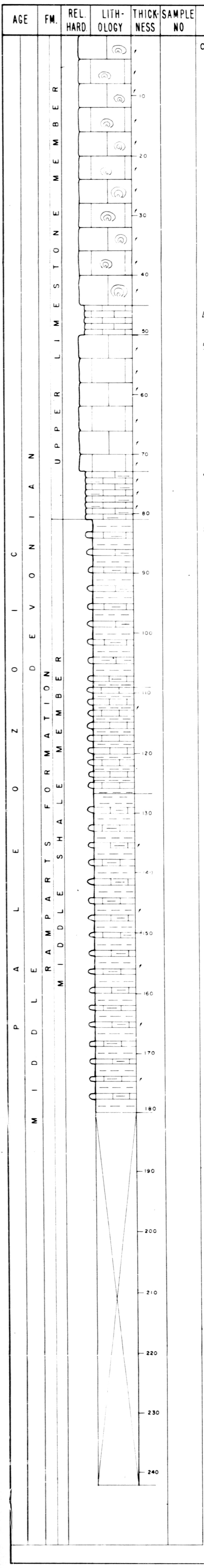
STRATIGRAPHIC SECTION NO. 3

EAST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Lat 66° 14' 30" N, Long 128° 42' 20" W)

Field study by R. De Wit, 1959



DESCRIPTION

0-45 Ls - brn, gy-brn, f xl, abnt Strom, reef zn, mas.

45-50 Ls - nod.

50-73 Ls - lt brn, gy-brn, f xl, calc.
<u>Rensselandia</u>, <u>Stringocephalus</u>, <u>Coenites</u>, Strom.

73-81 Ls - arg, lt gy-brn, f xl, imbd dk brn sh, v fos, thn-m bd.
<u>Synaptophyllum</u>, <u>Hexagonaria</u>, <u>Cyathophyllum</u>, <u>Thamnopora</u>, <u>Schizophoria</u>, <u>Atrypa</u>, Strom, Alg.

81-109 Ls - arg, gy, f xl, intbd gy sh, thn-m bd.

109-127 Ls - arg, gy, f xl, m bd / intbd gn-gy sh.
<u>Cyrtina</u>, <u>Schuchertella</u>.

127-180 Ls - arg, gy f xl, thn bd, intbd gn-gy calc sh.
<u>Atrypa</u>, <u>Martinia</u>.

180-242 Covered.

242 River level.

STRATIGRAPHIC SECTION NO. 4

EAST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Latitude 66° 12' 12" North, Longitude 128° 52' 30" West)

This is a composite section which incorporates parts of three sections which were measured within short distance from each other on the east bank of Mackenzie River. The outcrop locality lies approximately six miles southwest of Fort Good Hope. The sections were measured from river level to the highest accessible point on the cliff, but the composite description is recorded from the highest bed downward.

Measurement and description by R. de Wit and M. Korostil.

STRATIGRAPHIC SUMMARY

MIDDLE DEVONIAN

Ramparts Formation

Upper Limestone Member (incomplete)	157 feet
Total Measured Section	157 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
MIDDLE DEVONIAN		
		Ramparts Formation
		Upper Limestone Member
0-16	16	Limestone - light brown to brown, calcarenitic, few poorly preserved brachiopods and scattered stromatoporoids; rubbly, creamy weathering; the interval forms a resistant band at the top of the cliff.

Interval Feet	Thickness Feet	Description
16-26	10	Limestone - light brown, finely detrital, massive, reefal with abundant platy stromatoporoids and few bulbous forms; other fossils include Cladopora(?) and large Alveolites. This reefal lens is approximately 50 feet long and is continuous with clastic limestone within the same interval.
26-48	22	Limestone - reef, cream to light brown, massive, largely composed of Cladopora (?); fair brown dead oil-staining in the ground mass between organic remains.
48-67	19	Limestone - light brown, finely crystalline, pure calcarenite with thin lenses of organic material containing corals and stromatoporoids; massive, light brown weathering.
67-88	21	Limestone - reef, cream to light brown, largely composed of Cladopora(?) with a few large stromatoporoids (including Stylodictyon); spotty dark brown oil-staining and small veinlets of pyrobitumen; massive, grey-white weathering.
88-122	34	Limestone - brown, finely crystalline, detrital, with abundant Thamnopora and scattered platy and bulbous stromatoporoids which reach a diameter of three feet.
122-125	3	Shale marker: Shale - black, non-calcareous, firm, with abundant Thamnopora, Alveolites and several types of stromatoporoids.
125-138	13	Limestone - light brown to brown, finely crystalline, calcarenitic, abundant bulbous stromatoporoids, almost reefal with scattered Stringocephalus; a few thin shaly layers occur in the centre of this interval; vaguely bedded.
138-141	3	Limestone - light brown, finely crystalline, finely detrital, medium bedded, abundant Atrypa; at the top four inches of dark grey-brown to black shale, non-calcareous.
141-157	16	Limestone - brown, stromatoporoidal reef.
157		Base of composite section.

STRATIGRAPHIC SECTION NO. 4

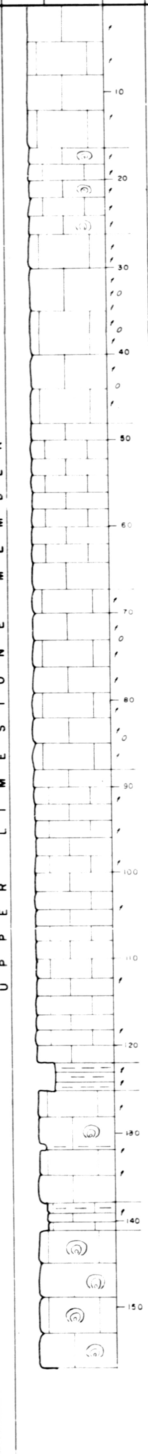
EAST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Lat 66° 12' 12" N, Long 128° 52' 30" W)

Field study by R De Wit, 1959

AGE	FM.	REL. HARD.	LITHOLOGY	THICKNESS	SAMPLE NO	DESCRIPTION
PALEOZOIC – MIDDLE DEVONIAN	RAMPARTS FORMATION – UPPER LIMESTONE MEMBER					



0-16 Ls - lt brn, brn, calc, few Bracs, Stroms.

16-26 Ls - lt brn, f dtrl, mas, reefal, abnt Strom. Cladopora(?), Alveolites.

26-43 Ls - reef, crm-lt brn, mas, abnt Cladopora(?) brn dd oil-stn.

43-67 Ls - lt brn, f xl, calc, mas; lenses / Cor, Strom.

67-88 Ls - reef, crm-lt brn, mass, abnt Cladopora(?), few Strom, dk brn oil-stn, pyrbit.

88-122 Ls - brn, f xl, dtrl, abnt Thamnopora, sct Stroms.

122-125 Sh marker: Sh - blk, non-calc, abnt Thamnopora, Alveolites, Stroms.

125-133 Ls - lt brn, brn, f xl, calc, almost reefal; thn sh bds, abnt Stroms, sct Stringocephalus.

133-141 Ls - lt brn, f xl, m-bdd, abnt Atrypa.

141-157 Ls - brn, Strom. reef.

157 Base of composite section.

STRATIGRAPHIC SECTION NO. 5

TSINTU RIVER - MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Latitude 66° 10' North, Longitude 128° 44' West)

This section has been compiled from observations on a large number of outcrops on Tsintu River and Mackenzie River. The Tsintu River is a tributary on the east side of Mackenzie River approximately 14 miles upstream from Fort Good Hope. The sections measured along Mackenzie River are one half to three miles downstream from the mouth of the Tsintu River. Measurements were made using an aneroid barometer and a five-foot staff. The description is recorded from top to bottom.

Description and measurement by D.L. Campbell, G.P.E. White, and G.A. Wilson.

STRATIGRAPHIC SUMMARY

CRETACEOUS

Sans Sault Formation

Shale Unit (incomplete)	289 feet
Sandstone Unit (complete)	9 feet
Total Measured Section	298 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
CRETACEOUS		
		Sans Sault Formation
		Shale Unit
0-27	27	Shale - grey to grey-black, slightly silty, soft,

Interval Feet	Thickness Feet	Description
		commonly poorly exposed and weathering into slopes covered by talus of shale fragments.
27-55	28	Shale - grey to grey-black, nodular, slightly calcareous, grey to black weathering with occasional concretionary clay-ironstone, hard, siliceous or calcareous, rust-brown weathering. The top of this interval is formed by a horizon marker, one inch thick, composed of silty mudstone and siltstone. The lower half of the marker zone is slightly calcareous, fine grained, brownish yellow, containing slender branching carbonaceous streaks; it is overlain by 0.5 inch of siltstone, calcareous, grey, very fine-grained, with cone-in-cone structure. At 51 feet there is a fairly consistent horizon of ironstone concretions which is capped by shale, grey, calcareous, grey to yellow weathering, with cone-in-cone structure. The concretionary zone averages one foot in thickness, while the cone-in-cone layer is usually 2 to 3 inches thick.
55-139	84	Shale - grey, silty, fissile, weathers grey and contains occasional clay-ironstone concretions. At 122 feet is a well developed concretionary zone, grey, hard, calcareous, up to 2 feet thick, generally capped by 2 to 3 inches of shale, grey, calcareous, cone-in-cone structure, yellow weathering; local thin beds of bentonite at 128' and 130'.
139-142	3	Shale - brownish grey with glauconite and glauconitic sand. The sand is green, fine- to medium-grained, angular, poorly sorted, unconsolidated, light green weathering. Ironstone concretions and cone-in-cone structure are present at the top of the interval.
142-163	21	Shale - similar to interval 55' to 139', but not as concretionary.
163-173	10	Shale - brownish grey, soft, grey weathering; containing oval blobs of bentonite, light yellow, up to 3 inches long and small lenses of bentonite.
173-249	76	Shale - dark grey to black, blocky, slightly silty, weathers grey, and contains a few grey, rusty weathering ironstone concretions throughout the interval.

Interval Feet	Thickness Feet	Description
249-262	13	Shale, ironstone and sandstone, interbedded. Shale - dark grey, flaky, weathers grey. Ironstone, (shale) - dense, hard, weathers rusty, up to 2 feet thick. Sandstone - green-grey, fine-grained, with good to fair porosity, weathers grey.
262-289	27	Covered interval.
		Sandstone Unit
289-298	9	Sandstone - locally oil-stained, light grey, medium- to coarse-grained with scattered pebbles; fragments consist predominantly of quartz, subangular, poorly sorted; carbonaceous, crossbedded, massive, hard, cliff-forming, good porosity.
298		Contact with the underlying Upper limestone member of the Ramparts formation.

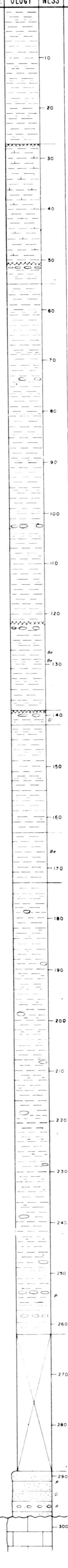
STRATIGRAPHIC SECTION NO. 5

TSINTU RIVER - MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Lat. 66° 10' N., Long. 128° 44' W.)

Field study by D.L. Campbell, 1959



AGE	FM.	REL. HARD.	SAMPLE NO	DESCRIPTION
MESOZOIC — LOWER CRETACEOUS	SANS SAULT FORMATION			0-27 Sh - gy, gy blk, sl slty, sft.
				27 Calc. sltst marker / c-in-c struc.
				27-55 Sh - gy, blk, sl calc, nod; cly-Fe-st conc.
				51 Zn of Fe-st a c-in-c struc.
				55-139 Sh - gy, slty, fis, scat Fe-st conc.
				Cly-Fe-st a c-in-c struc.
				139-142 Sh - brn-gy / gl u a glau ss; Fe-st conc a c-in-c at 139.
				142-163 Sh - gy, slty.
				163-173 Sh - brn gy, sft, s lenses of bent.
				173-249 Sh - dk gy, blk, sl slty, occ cly-Fe-st conc.
				249-262 Sh, ss, Fe-st intbd. Ss - gn gy, f gr, g por. Sh - dk gy. Fe-st - dns, hd.
				262-289 Covered.
				289-298 Ss - lt gy, m c gr, cgl; xbd hd, mas, g por, oil stn.
				Unconformity.
PALEOZOIC — MIDDLE DEVONIAN	RAMPARTS FORMATION			Ls.

J.C. SPROULE & ASSOCIATES, CALGARY

STRATIGRAPHIC SECTION NO. 6

WEST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Latitude 66° 24' 18" North, Longitude 128° 59' 17" West)

This section was measured on the west bank of Mackenzie River, at a distance of 1.25 miles south of the mouth of Airport Creek. Measurements were made with a five-foot staff. The description is recorded from the top downward.

Description and measurement by R. de Wit and G. A. Wilson.

STRATIGRAPHIC SUMMARY

CRETACEOUS	
Sans Sault Formation (incomplete)	37 feet
MIDDLE DEVONIAN	
Ramparts Formation	
Middle Shale Member (incomplete)	137 feet
Total Measured Section	174 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
CRETACEOUS		
		Sans Sault Formation
0-20	20	Sandstone - grey-white, medium to coarse-grained, very porous.
20-27	7	Covered.

Interval Feet	Thickness Feet	Description
27-32	5	Breccia of angular, black, siliceous shale fragments (Fort Creek?) in sandstone matrix; several sandstone lenses reaching a thickness of one foot, in part with brown oil-staining.
32-37	5	Breccia, as above, containing also subrounded grey-brown chert pebbles with diameter of two to three inches.
MIDDLE DEVONIAN		
		Ramparts Formation
		Middle Shale Member
37-44	7	Limestone, argillaceous and calcareous shale - brown to dark brown, impregnated with limonite.
44-90	46	Shale, very calcareous and argillaceous limestone - grey to light grey, little contrast, vaguely bedded, with beds two to four inches thick, rubbly, grey to rusty brown weathering.
90-101	11	Shale - calcareous, grey with slight greenish tinge, finely micaceous, interbedded with some thin, slightly harder beds of argillaceous limestone; interval softer than overlying beds, grey, rubbly weathering.
101-174	73	Covered.
174		River level.

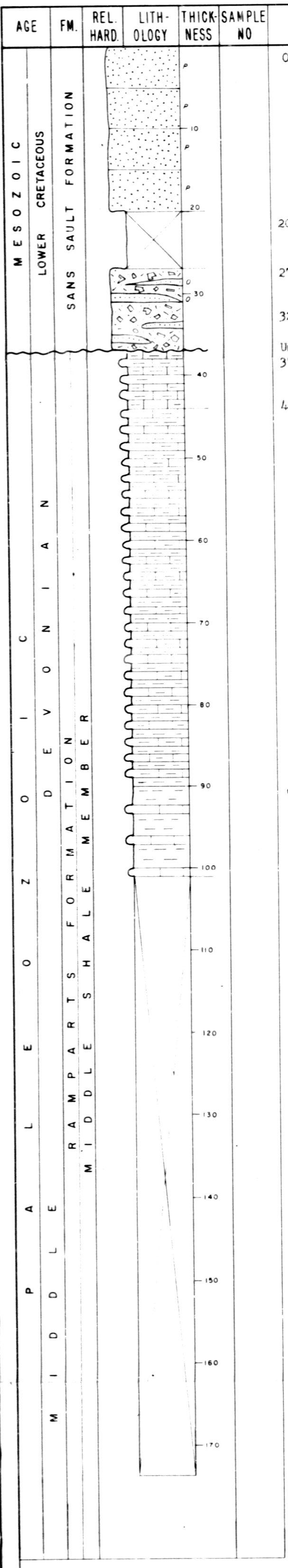
STRATIGRAPHIC SECTION NO. 6

WEST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Lat. 66° 24' 18" N, Long. 128° 59' 17" W)

Field study by R. De Wit, 1959



DESCRIPTION

0-20 Ss - gy-wh, m-c gr, v por.

20-27 Covered.

27-32 Cgl a brec - blk sil sh frags in ss mtx; ss lenses; brn oil-stn.

32-37 Cgl a brec - aa / rdd cht pbls.

Unconformity.

37-44 Ls - arg a sh calc, brn-dk brn, impregnated / lmr.

44-90 Sh; v calc a ls, arg - gy-lt gy, thn-m bdd.

90-101 Sh, calc gy, gn-gy, intbd / arg ls.

101-174 Covered.

174 River level.

J.C. SPROULE & ASSOCIATES, CALGARY

STRATIGRAPHIC SECTION NO. 7

WEST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Latitude 66° 24' North, Longitude 129° West)

This section was measured on the west bank of Mackenzie River, at a distance of slightly less than one mile south of the mouth of Airport Creek. The outcrop was measured from water level to the top of the river bank with a five-foot rod. The following description is recorded from the top downward.

Description and measurement by G.A. Wilson and R. de Wit.

STRATIGRAPHIC SUMMARY

CRETACEOUS	
Sans Sault Formation (incomplete)	36 feet
MIDDLE DEVONIAN	
Ramparts Formation	
Upper Limestone Member (incomplete)	17 feet
Middle Shale Member (incomplete)	155 feet
Total Measured Section	208 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
CRETACEOUS		
		Sans Sault Formation
0-28	28	Sandstone - grey-white, fine to medium-grained, crossbedded, small lenticular brown patches may be due to oil-staining.

Interval Feet	Thickness Feet	Description
28-36	8	Covered, probably basal sand and conglomerate layer.
MIDDLE DEVONIAN		
		Ramparts Formation
		Upper Limestone Member
36-48	12	Limestone - pinkish grey to brownish grey, fine-grained, in part fossiliferous, containing *Rensselandia*, beds six to eight inches thick, light grey weathering.
48-53	5	Limestone - light grey, fine-grained, crystalline, irregular nodular bedding, beds thin, alternating with greenish grey soft shale bands of less than one inch.
		Middle Shale Member
53-129	76	Covered.
129-136	7	Limestone - argillaceous, light grey, fine-grained, beds less than six inches thick, interbedded with one-inch bands of greenish brown calcareous shale.
136-208	72	Covered, probably argillaceous limestone and calcareous shale, as above.
208		Water level.

STRATIGRAPHIC SECTION NO. 7

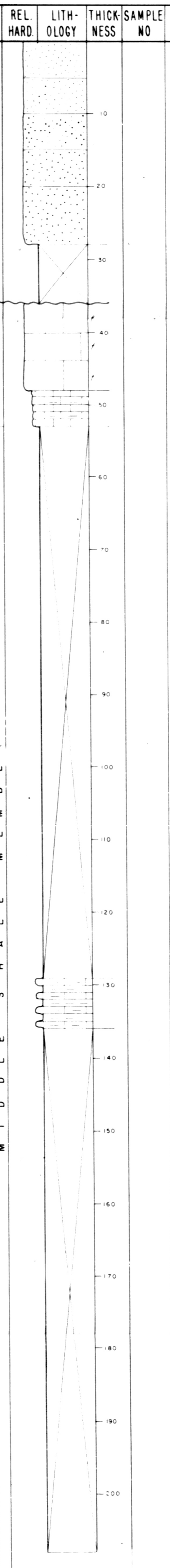
WEST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Lat 66° 24' N, Long 129° W.)

Field study by G.A. Wilson, 1959

AGE		FM.		DESCRIPTION
MESOZOIC	LOWER CRETACEOUS	SANS SAULT FORMATION		0–28 Ss - gy-wh, f-med gr, xbd, oil-st?
				28–36 Covered.
				Unconformity.
PALEOZOIC	MIDDLE DEVONIAN	RAMPARTS FORMATION	UPPER LIMESTONE MBR	36–48 Ls - pinkish gy-brn gy, f gr, foss, med bdd, Rensselandia.
				48–53 Ls - lt gy, f gr, xl, nod bdd, thn bdd, intb gn-ty sh.
			MIDDLE SHALE MEMBER	53–129 Covered.
				129–136 Ls - arg, lt gy, f gr, thn-med bdd; intbdd gn-brn calc sh.
				136–208 Covered.
				208 River level.



STRATIGRAPHIC SECTION NO. 7

WEST BANK OF MACKENZIE RIVER

FORT GOOD HOPE AREA, N.W.T.

(Lat 66° 24' N., Long 129° W.)

Field study by G.A. Wilson, 1959

AGE		FM.		REL. HARD. / LITH-OLOGY / THICKNESS	SAMPLE NO	DESCRIPTION
MESOZOIC	LOWER CRETACEOUS	SANS SAULT FORMATION				0–28 Ss - gy-wh, f-med gr, xbd, oil-st?
						28–36 Covered.
						Unconformity.
PALEOZOIC	MIDDLE ? DEVONIAN	RAMPARTS FORMATION	UPPER LIMESTONE MBR			36–48 Ls - pinkish gy-brn gy, f gr, foss, med bdd, *Rensselandia*.
						48–53 Ls - lt gy, f gr, xl, nod bdd, thn bdd, intb gn-gy sh.
			MIDDLE SHALE MEMBER			53–129 Covered.
						129–136 Ls - arg, lt gy, f gr, thn-med bdd; intbdd gn-brn calc sh.
						136–208 Covered.
						208 River level.

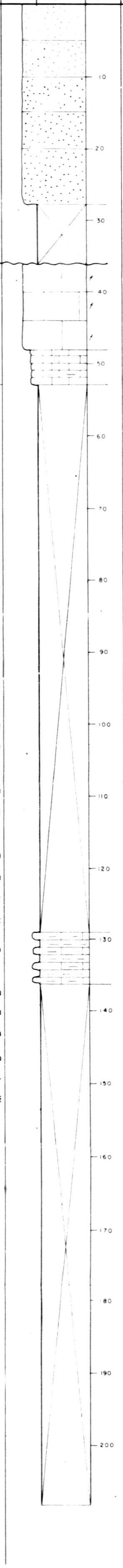


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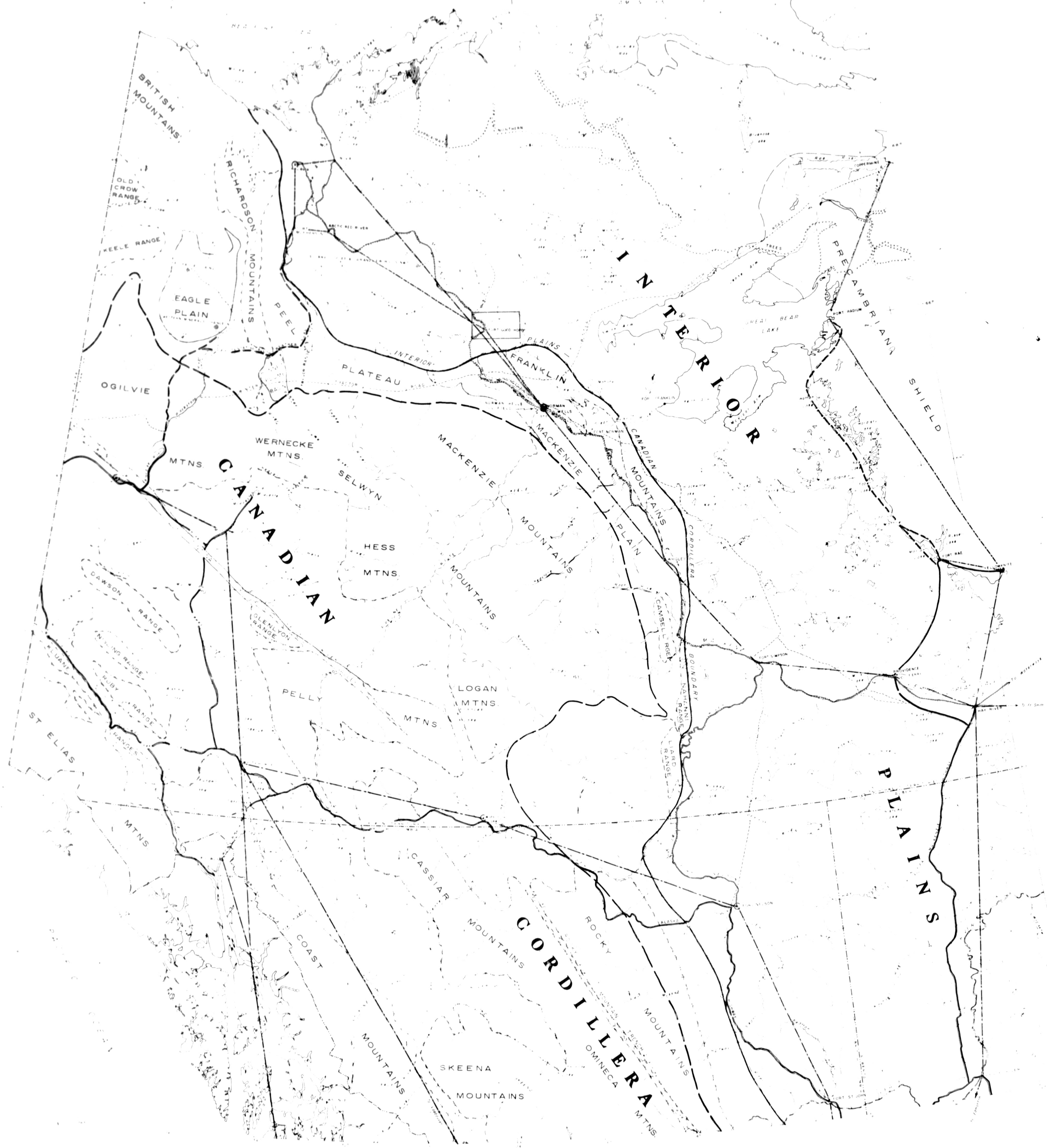
FIGURE - XVIII



ACCESSIBILITY MAP

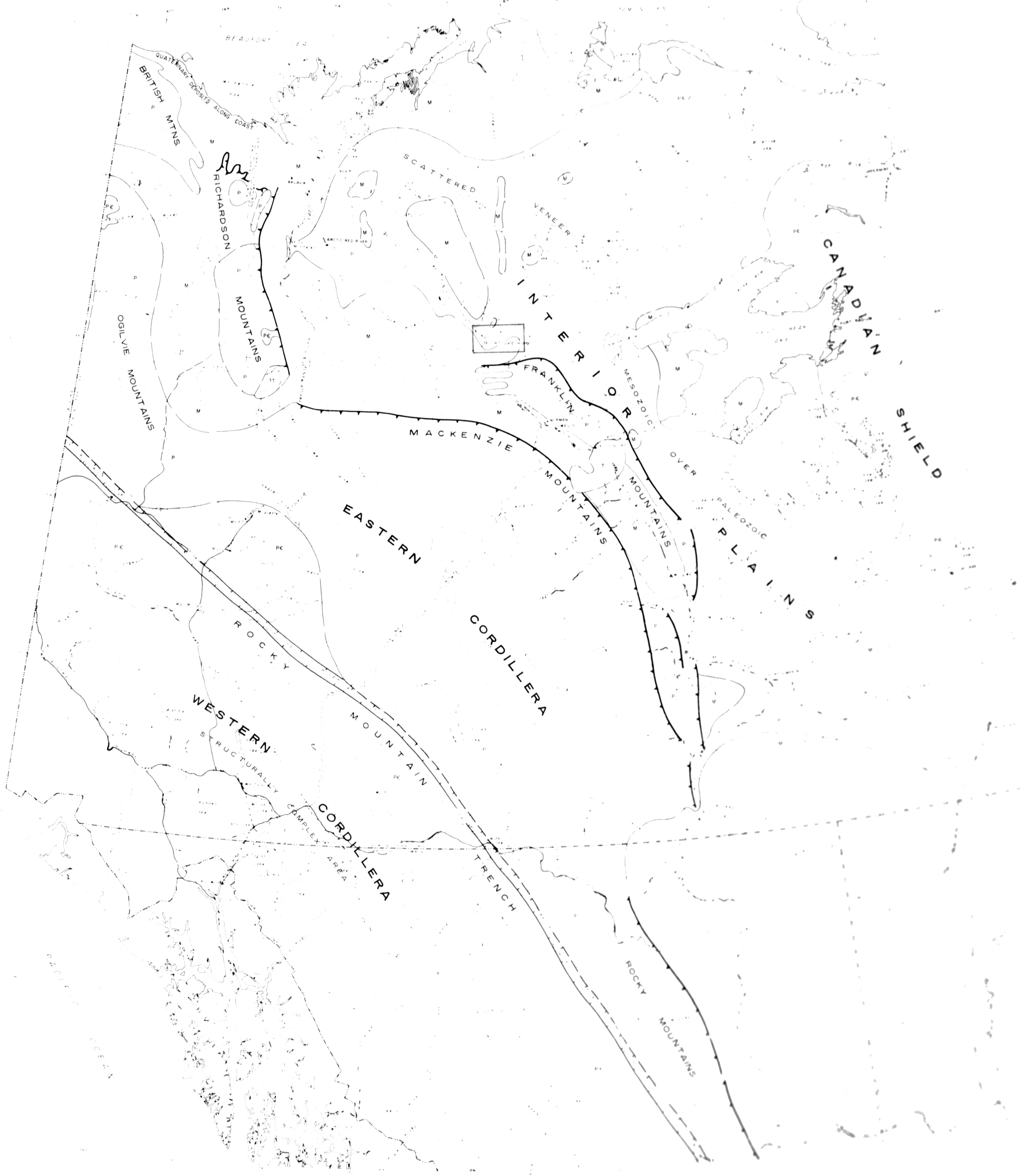
NORTHWESTERN CANADA

AIR, WATER, LAND ROUTES

& PRINCIPAL MOUNTAIN AREAS

LEGEND

530-1-6-5

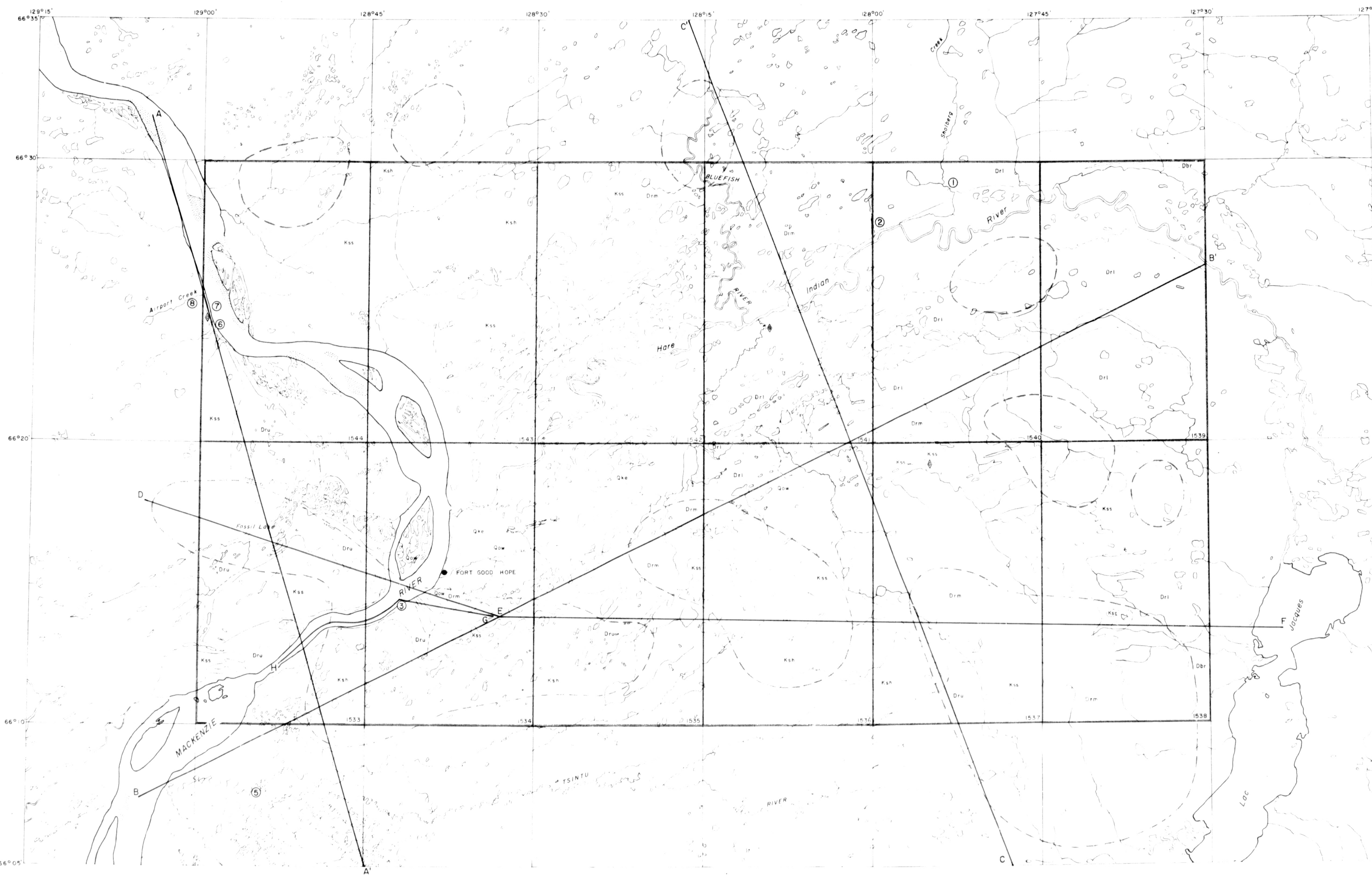


GENERALIZED GEOLOGICAL MAP
NORTHWESTERN CANADA

GLACIER EXPLORERS LIMITED

GEOLOGICAL LEGEND

- T — TERTIARY — Shale, Conglomerate, Sandstone, Limestone & Coal, Non - Marine
- M — MESOZOIC — Sandstone, Shale, Coal, Conglomerate, Marine & Non - Marine
- P — PALEOZOIC — Sandstone, Shale, Dolomite, Limestone, Gypsum — Marine
- P€ — PRE CAMBRIAN — Igneous and Metamorphic Rocks



LEGEND

QUATERNARY
- Qow — Outwash Sands
- Qke — Esker

CRETACEOUS
Sans Sault Formation
- Ksh — Shale Series
- Kss — Basal Sandstone and Conglomerate Series

MIDDLE DEVONIAN
Ramparts Formation
- Dru — Upper Limestone Member
- Drm — Middle Shale Member
- Drl — Lower Limestone Member

LOWER DEVONIAN (?)
- Dbr — Bear Rock Formation

Geological Boundary (mapped)
Geological Boundary (conjectural)
Line of Cross Section
Oil Seep
Gas Seep
Area of High Structural Relief
Outline of P&NG Permit
③ Stratigraphic Section

GEOLOGICAL MAP

FORT GOOD HOPE AREA

NORTHWEST TERRITORIES

2 0 2 4 6
SCALE 1" = 2 MILES

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530-1-6-5

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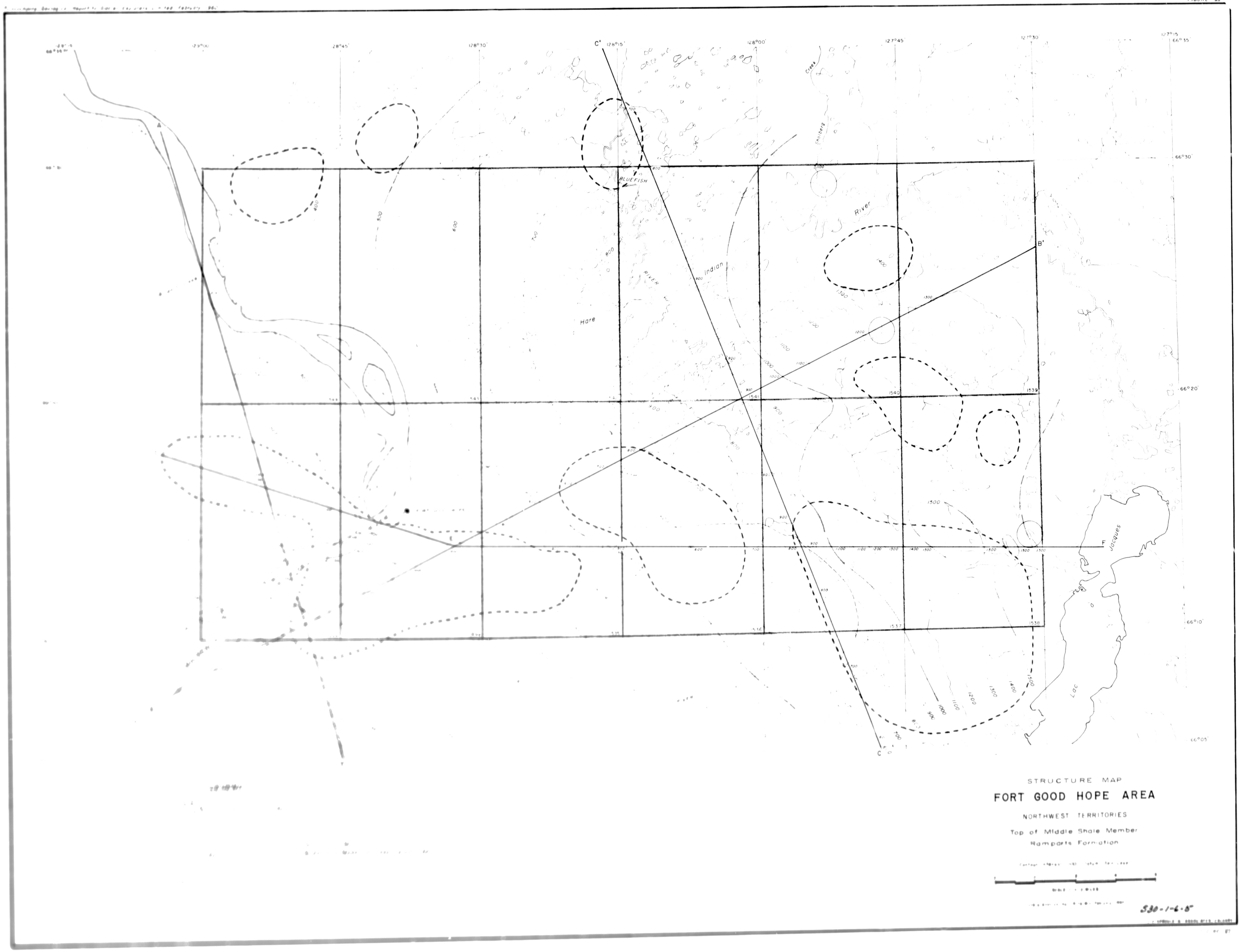


STRUCTURE MAP

FORT GOOD HOPE AREA

NORTHWEST TERRITORIES

Top of Middle Shale Member
Ramparts Formation

530-1-6-5

STRATIGRAPHIC SECTION NO. 8

AIRPORT CREEK

FORT GOOD HOPE AREA, N.W.T.

(Latitude 66° 25' North, Longitude 129° West)

This section was measured on the south bank of Airport Creek, 2400 feet upstream from the mouth of the creek. Airport Creek is approximately 17 miles northwest from Fort Good Hope. The section was measured with a five-foot staff from creek level to the top of the cliff. The description is recorded from the top downward.

Description and measurement by G.A. Wilson and A. Hicken.

STRATIGRAPHIC SUMMARY

UPPER DEVONIAN	
Fort Creek Formation (incomplete)	60 feet
MIDDLE DEVONIAN	
Ramparts Formation (incomplete)	64 feet
Total Measured Section	124 feet

STRATIGRAPHIC DESCRIPTION

Interval Feet	Thickness Feet	Description
UPPER DEVONIAN		
		Fort Creek Formation
0-22	22	Shale - siliceous, dark brown to brown, dense, hard, pyritic, interbedded with some soft shale, evenly thin-bedded; brownish grey weathering with fluffy alkali in places on the rock surface.

Interval Feet	Thickness Feet	Description
22-60	38	Shale - siliceous, dark brown, fine-grained to dense, hard, subconchoidal fractures, evenly thin-bedded, yellowish grey weathering with fluffy alkali on the surface.

MIDDLE DEVONIAN

Ramparts Formation

Upper Limestone Member

60-61	1	Covered.
61-76	15	Limestone - in part dolomitic, reefal, grey to brown-grey, stromatoporoidal with calcarenitic ground mass, massive.
76-98	22	Covered.
98-107	9	Limestone - brownish grey, fine-grained, calcarenitic, fossiliferous, containing corals, brachiopods and crinoid fragments, thick-bedded to massive.
107-111	4	Limestone - light brown, fine-grained, crystalline, thin-bedded, forms break of the slope.
111-119	8	Limestone - light brown, fine-grained,crystalline, thin to medium-bedded, abundant Rensselandia, unidentified brachiopods and corals.
119-124	5	Covered.
124		Creek level, coinciding with the base of the Upper limestone member at this locality.

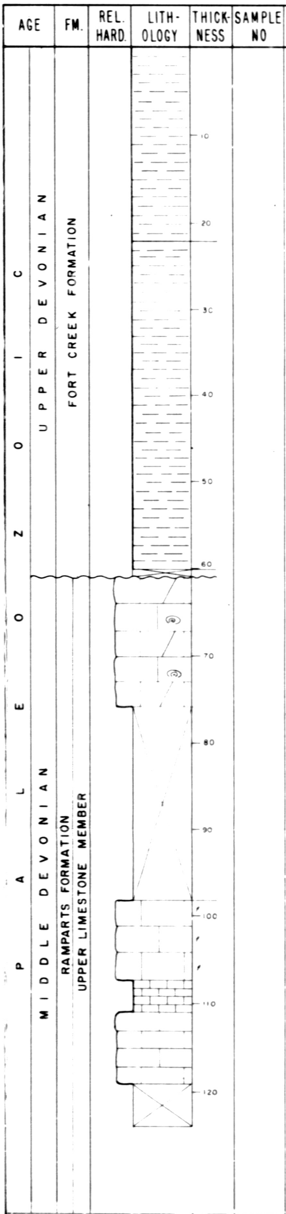
STRATIGRAPHIC SECTION NO. 8

AIRPORT CREEK

FORT GOOD HOPE AREA, N.W.T.

(Lat 66° 25' N., Long 129° W)

Field study by , A Wilson, 1959



DESCRIPTION

0-22 Sh - sil, dk brn-brn, dns, hd, pyr / intbd sft sh; thn bdd.

22-60 Sh - sil, dk brn, dns hd.

60-61 Covered - Unconformity.
61-76 Ls - in p. dol, reefal, gy, brn-gy, mas, abnt Strom.

76-98 Covered.

98-107 Ls - brn-gy, f gr, calc, fos, Cors, Bracs, Crins; thk bdd.

107-111 Ls - lt brn, f gr, xl, thn bdd.

111-119 Ls - lt brn, f gr, xl, thn-m bdd; Brachs, Cors, abnt *Rensselandia*.

119-124 Covered.

124 Creek level.

LITHOLOGICAL CONVENTIONS

Limestone	Calcareous
Dolomite	Dolomitic
Shale	Carbonaceous
Siltstone	Breccia
Sandstone	Gypsum
Conglomerate	Tuff
Quartzite	Unconformity
Coal	Minor Unconformity
Covered Section	Algae
Igneous Rock Diabase	

f Fossil

Concretion

Chert

P Porosity

Be Bentonite

Gl Glauconite

ABBREVIATIONS

a .... And
abnt....... Abundant
abv .... Above
acic ...... Acicular
aft .... After
agg .... Aggregate
aglm ...... Agglomerate
Alg .... Algae (al)
alt .... Altered (ing)
amb .... Amber
amor ...... Amorphous
amt .... Amount
andes ..... Andesite (ic)
ang .... Angular
anhed ..... Anhedral
anhy ...... Anhydrite (ic)
apr .... Apparent
aprox ..... Approximate (ly)
arag ...... Aragonite
aren ...... Arenaceous
arg .... Argillaceous
ark .... Arkose (ic)
asph ...... Asphalt (ic)
av .... Average

bar .... Barite (ic)
bcm .... Become (ing)
bd .... Bed
bdd .... Bedded
bdg .... Bedding
Belm ...... Belemnites
bent ...... Bentonite (ic)
bf .... Buff
biot ...... Biotite
bit .... Bitumen (inous)
bl .... Blue (ish)
bldr ...... Boulder
blk .... Black
blky ...... Blocky
bnd .... Band (ed)
Brac ...... Brachiopod
brec ...... Breccia (ed)
bri .... Bright
brit ...... Brittle
brn .... Brown
Bry .... Bryozoa
btry ...... Botryoidal

c .... Coarse (ly)
c .... Core
c-gr ...... Coarse-grained
calc ...... Calcite (areous)
Calcarn ... Calcarenite (tic)
carb ...... Carbonaceous
cbl .... Cobble
Ceph ...... Cephalopod
cgl .... Conglomerate
Chaet ..... Chaetetes
chal ...... Chalcedony
chit ...... Chitin (ous)
chk .... Chalk (y)
choc ...... Chocolate
cht .... Chert
chty ...... Cherty
c-in-c .... Cone-in-Cone
clas ...... Clastic
cln .... Clean
clr .... Clear
clus ...... Cluster
cly .... Clay (ey)
clyst ..... Claystone
cmt .... Cement (ed)
cncn ...... Concentric
cntr ...... Center (ed)
col .... Color (ed)
com .... Common
conc ...... Concretion (ionary)
conch ..... Conchoidal
Cono ...... Conodont
cons ...... Considerably
contm...... Contaminated
coq .... Coquina
Cor .... Coral
cpct ...... Compact
cren ...... Crenulated
Crin ...... Crinoid (al)
crm .... Cream
crnk ...... Crinkled
crpxl ..... Cryptocrystalline
ctc .... Contact
ctgs ...... Cuttings
cvg .... Cavings
cxl .... Coarsely crystalline

dd .... Dead
deb .... Debris
decr ...... Decrease (ing)
dend ...... Dendrite (ic)
dia .... Diameter

dif ...... Difference
dism ..... Disseminated
dk .... Dark (er)
dns ...... Dense (er)
do .... Ditto
dol ...... Dolomite (ic)
dolc ..... Dolocast (ic)
dolm ..... Dolomold (ic)
dolst .... Dolostone
drlg ..... Drilling
drsy ..... Druse (y)
dtrl ..... Detrital (us)

Ech ...... Echinoid
elg ...... Elongate
elip ..... Elliptical
Endo ..... Endothyra
enl ...... Enlarged
equiv .... Equivalent
euhed .... Euhedral
evap ..... Evaporitic
extr ..... Extrusion (ive)

fg or f(x) Fine-grained (crystalline)
f .... Fine (ly)
fac ...... Facet (ed)
fau ...... Fauna
Fvst ..... Favosites
Fe .... Iron-Ferruginous
Fe-st .... Ironstone
fib ...... Fibrous
fig ...... Figure (d)
fis ...... Fissile
flat ..... Flattened
fld ...... Feldspar (thic)
flk ...... Flake
flky ..... Flaky
flor ..... Fluorescence
fls ...... flesh
flt ...... fault (ed)
fltg ..... Floating
fm .... Formation
fnt ...... Faint (ly)
fol ...... Foliated
Foram .... Foraminifera
fos ...... Fossil (iferous)
fr .... Fair
frac ..... Fracture (ed)
frag ..... Fragment (al)
fri ...... Friable
fros ..... Frosted
frs ...... Fresh

Fus ...... Fusulinid

g .... Good
Gast ..... Gastropod
gil ...... Gilsonite
gl .... Glass (y)
glau ..... Glauconite (ic)
glos ..... Gloss (y)
gn .... Green
gns ...... Gneiss
gr .... Grain (ed)
gran ..... Granular
Grap ..... Graptolite
grd ...... Grade (ed)
grdg ..... Grading
grnl ..... Granule
grnt ..... Granite
grnt.w ... Granite wash
grty ..... Gritty
gsy ...... Greasy
gvl ...... Gravel
gy .... Gray
gyp ...... Gypsum (iferous)
gywk ..... Graywacke

hd .... Hard
hem ...... Hematite (ic)
hex ...... Hexagonal
hi .... High
hky ...... Hackly
hvy ...... Heavy
Hydc ..... Hydrocarbon

ig .... Igneous
imbd ..... Imbedded
imp ...... Impression
incl ..... Included (sion)
incr ..... Increase (ing)
ind ...... Indurated
indst .... Indistinct
Inoc ..... Inoceramus
intbd .... Interbedded (i/b)
intfm .... Intraformational
intgran .. Intergranular
intgwn ... Intergrown
intlam ... Interlaminated
intstl ... Interstitial
intr ..... Intrusion (ive)
intv ..... Interval
intxl .... Intercrystalline
invrtb ... Invertebrate

ireg ...... Irregular
irid ...... Iridescent
i/p .... In part

jasp ...... Jasper (oid)

kao .... Kaolin

lam .... Laminated
lav .... Lavender
lchd ...... Leached
len .... Lentil (cular)
lg .... Long
lig .... Lignite (ic)
lith ...... Lithographic
lmn .... Limonite (ic)
lmpy ...... Lumpy
lmy .... Limy
Lngl ...... Linguloid
low .... Lower
lrg .... Large (er)
ls .... Limestone
lse .... Loose
lstr ...... Lustre
lt .... Light (er)
ltl .... Little

m .... Medium
magn ...... Magnetic
mar .... Maroon
mas .... Massive
mat .... Material, matter
mbr .... Member
mdst ...... Mudstone
meta ...... Metamorphic
mica ...... Mica (ceous)
micfos .... Microfossil (iferous)
mic-mica .. Micro-micaceous
micxl ..... Microcrystalline
mid .... Middle
mky .... Milky
mnr .... Minor
mnrl ...... Mineral (ized)
mnut ...... Minute
mod .... Moderate
Mol .... Mollusca
mot .... Mottled
mrlst ..... Marlstone
mtx .... Matrix
musc ...... Muscovite

n .... no, non
nac .... Nacreous
nod .... Nodule (ar)
num .... Numerous

oil .... Oil
obj .... Object
occ .... Occasional
och .... Ochre
od .... Odour
olv .... Olive
ooc .... Oolicast (ic)
ool .... Oolite (ic)
oom .... Oomold (ic)
op .... Opaque
org .... Organic
orng ...... Orange
orth ...... Orthoclase
Ost .... Ostracod
ox .... Oxidized

p .... Poor (ly)
pap .... Paper (y)
pbl .... Pebble
pbly ...... Pebbly
pch .... Peach
Pdct ...... Productids
pel .... Pellet
perm ...... Permeability
pet .... Petroleum (iferous)
phos ...... Phosphate (ic)
piso ...... Pisolite (ic)
pit .... Pitted
pk .... Pink
Plag ...... Plagioclase
plas ...... Plastic
Plcy ...... Pelecypod
pl fos .... Plant fossils
plty ...... Platy
pol .... Polish (ed)
por .... Porous (sity)
porc ...... Porcelaneous
pos .... Possible (ility)
p-p .... Pin point
pred ...... Predominate (ly)
pres ...... Preserved (ation)
prim ...... Primary
pris ...... Prism (atic)
prly ...... Pearly
prob ...... Probable (ly)
prom ...... Prominent (ly)
psdo ...... Pseudo
pt .... Part (ly)

ptg ...... Parting
purp ..... Purple
pyr ...... Pyrite (ic) (ized)
pyrbit ... Pyrobitumen
pyrclas .. Pryoclastic

qtz ...... Quartz
qtzc ..... Quartzitic
qtzs ..... Quartzose
qtzt ..... Quartzite

rad ...... Radiate (ing)
rd .... Round (ed)
red ...... Red (dish)
reg ...... Regular
repl ..... Replaced (ing)(ment)
resd ..... Residue (al)
rhmb ..... Rhomb (ic)
rk .... Rock
rmn ...... Remains (nant)
rng ...... Range (ing)
ro .... Rose
rr .... Rare
rsns ..... Resinous
rthy ..... Earthy

s .... Small
sa .... Salt
sa-c ..... Salt cast (ic)
S .... Sulphur
sach ..... Saccharoidal
sal ...... Salmon
s&p ...... Salt & pepper
sat ...... Saturated
sb .... Sub
sc .... Scales
scat ..... Scattered
sch ...... Schist
Scol ..... Scolecodonts
sd .... Sand
sdy ...... Sandy
sec ...... Secondary
sed ...... Sediment (ary)
sel ...... Selenite
sft ...... Soft
sh .... Shale
shad ..... Shadow
shy ...... Shaly
sid ...... Siderite (ic)
sil ...... Silica (eous)

sks ...... Slickensided
sl .... Slight (ly)
slky ..... Silky
slt ...... Silt
sltst .... Siltstone
slty ..... Silty
sm .... Smooth
sol ...... Solution
sp .... Spot (ted)(ty)
spec ..... Speck (led)
Spfr ..... Spirifers
Spg ...... Sponge
sph ...... Spherules
sphal .... Sphalerite
spic ..... Spicule (ar)
spl ...... Sample
splty .... Splintery
Spr ...... Spore
srt ...... Sort
srtd ..... Sorted
srtg ..... Sorting
ss .... Sandstone
st .... Stone
stn ...... Stain (ed)(ing
str ...... Streak
strat .... Strata (ified)
strg ..... Stringer
stri ..... Striated
Strom .... Stromatoporoid
struc .... Structure
styl ..... Stylolite (ic)
suc ...... Sucrosic
sug ...... Sugary
surf ..... Surface
sz .... Size
sublith .. Sublithographic

tab ...... Tabular
Tent ..... Tentaculites
tex ...... Texture
tgh ...... Tough
thk ...... Thick
thn ...... Thin
thru ..... Throughout
tr .... Trace
Trilo .... Trilobite
trip ..... Tripolite (ic)
trnsl .... Translucent
trnsp .... Transparent
tt .... Tight (ly)
tub ...... Tubular
tuf ...... Tuffaceous

unconf ... Unconformity
uncons ... Unconsolidated
uni ...... Uniform
up .... Upper

v .... Very
var ...... Variable
vcol ..... Varicoloured
ves ...... Vesicular
vg .... Varigated
vit ...... Vitreous
vn .... Vein
volc ..... Volcanics
vps ...... Very poor sample
vrtb ..... Vertebrate
vrtl ..... Vertical
vrvd ..... Varved
vug ...... Vug (gy)(ular)

/ .... With
w .... Well
wh ...... White
wk ...... Weak
wthr .... Weather
wthrd ... Weathered
wtr ..... Water
wvy ..... Wavy
wxy ..... Waxy

xbd ..... Crossbedded
xbdg .... Crossbedding
xl ...... Crystal (line)
xlam .... Cross-laminated

yel ..... Yellow

zn ...... Zone