SURFACE GEOLOGY

of the

MACKENZIE PLAIN AND ADJACENT AREAS

DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

Prepared for

AMOCO CANADA PETROLEUM COMPANY LTD.

By

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January 1972

Respectfully Submitted

M. N. Chernoff, P. Geol.

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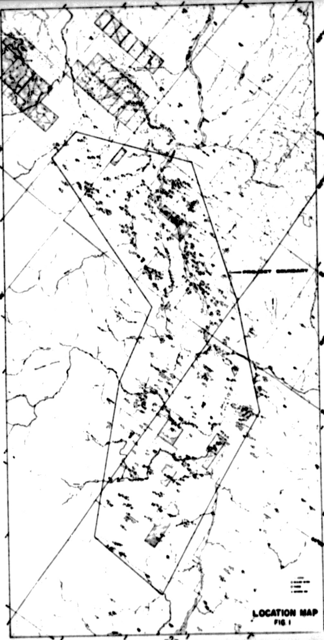
INTRODUCTION

This report covers work performed by C. H. Riddell Geological Consultants Ltd. for Amoco Canada Petroleum Company Ltd. in the Mackenzie Mountain - Franklin Mountain area from Latitude 66°00' N to 63°00' N. The field work was done under the direction of M. N. Chernoff, P. Geol., from May 30, 1971, to August 31, 1971.

The field work was aided by excellent weather during June and most of July, but during late July and August the weather deteriorated and considerable time was lost due to rain and low cloud. Of the ninety-four days comprising the field season, three days were used moving in and out, twenty days were lost due to weather, and six days were used moving camp, leaving a total of sixty-five days worked. This is a little above average performance for this part of Canada's North.

All of the objectives of the field party were completed, although due to the extremely large area mapped, additional detailed information could still be collected.

The field party completed aerial geological mapping covering about 23,000 square miles. During the course of the summer 137 sections were measured comprising about 200,000 feet of strata. In addition 316 spot checks were made. Samples collected were approximately 429 fossil, 5,753 lithology, 83 porosity, and 714 microfossil. These have been forwarded to Amoco who sent many of the paleontological samples to Tulsa for identification, and many of the



LOCATION MAP
FIG 1

micropaleontological samples to C. Pollock (Amoco, Calgary) for processing and identification. The remainder of the samples were sent to Rock Surgery and to Amoco's warehouse for sorting and for storage. This report is being written with the benefit of field fossil identifications and some microfossil identifications, but neither are complete at this writing.

Access, Location and Topography

The field party flew to Norman Wells and established camps at Norman Wells, Florence Lake, Stewart Lake and Wrigley Lake.

The dominant feature of the study area is the Mackenzie River which traverses the middle of the project area. This fast flowing, muddy river is in excess of seven miles wide in places with banks 50 to 400 feet high. Barge traffic on the river is increasing each year and is the main means of transporting heavy equipment into the North. Navigation on the river begins about May 25 at the south end and is usually open to the ocean by June 10. The shipping season lasts about five months. Tanker barges move fuel from Norman Wells to other points along the river.

The Canyon Ranges of the Mackenzie Mountains rise to 7,000 feet above sea level at the western boundary of the project area. The mountains are generally not rugged and in many places resemble an incised high plateau. They are cut by deep, steep sided often spectacular canyons with very colorful walls. Exposures are excellent in these canyons but most are difficult or impossible to traverse. On the east side of the project area the Franklin Mountains rise to a maximum elevation of 5,000 feet. This chain is about ten to twenty miles wide south of Norman Wells, and to the north the chain branches into several discrete ranges, separated by broad flat muskeg and tree covered areas.

South of Norman Wells the project area between the mountains has some good sized hills but is generally not too rugged. Major rivers coming out of the mountains and draining into the Mackenzie River dissect this Mackenzie Plain. The area is mainly wooded, dominantly with spruce and poplar and to à lesser extent, birch. Willow and alder are common, and there are many muskeg areas. Several large lakes are present in this area, most notably Stewart Lake and Tate Lake.

The northwestern portion of the project area is formed by the Peel Plateau, a relatively flat, tree and muskeg covered area rising from a few hundred feet above the river to about 2,000 feet in the Hume River - Ramparts area. This is broken by the Imperial Hills, an east-west chain of hills with a maximum elevation of 2,300 feet. The plateau is dissected by several major rivers including the Carcajou, Imperial, Gayna, Hume, Ramparts and Arctic Red. The area is now characterized by abundant seismic trails made by the oil companies.

The Mackenzie Plain has been glaciated and glacial moraine is common but usually not more than ten to twenty feet thick. Eskers and other glacial features were noted. Glacial transported boulders can be found on top of the Franklin Mountains and on benches of the Canyon Ranges of the Mackenzie Mountains.

The main access to the area is by barge in the summer and winter road in the winter. A road from Hay River to Inuvik follows the telephone line and is open for about four months in the winter. Movement of heavy equipment by land within the area is restricted to the winter months. Winter trails can be readily constructed but must be scouted to find suitable river crossings.

There is an excellent paved airstrip at Norman Wells and a good grass strip at Wrigley. In addition to the Mackenzie River there are many lakes suitable for a float equipped surface geological operation.

Previous Work

The Lower Mackenzie was the scene of some of the earliest exploration for oil and gas in Western Canada, due largely to its relatively easy access by river. Ironically this is one of the last areas to have been mapped in the Geological Survey's 1 inch = 4 miles systematic mapping program.

Oil exploration in the Mackenzie River area dates from 1914 when T. O. Bosworth reported oil seeps at the site now called Norman Wells. In 1920 Imperial Oil Limited, through its subsidiary, the Northwest Oil Company, discovered the Norman Wells oil field. This discovery encouraged considerable work between 1920 and 1923 by the Geological Survey of Canada; notably work by T. O. Bosworth, C. S. Hume, M. Y. Williams, E. M. Kindle and D. B. Dowling.

Due to the distance from market, interest decreased until 1942 when the war with Japan encouraged further exploration and development. The United States of America entered into an agreement with the Government of Canada to develop the field at Norman Wells and to explore for additional oil fields in the Lower Mackenzie. The Canol Project, as it was called, resulted in a massive surface geologic program, four unsuccessful wildcats, fifty-eight development wells at Norman Wells and a 598 mile pipeline connecting the Norman Wells field to Whitehorse. After the war the Whitehorse pipeline was abandoned.

Following the end of the war in 1945, Imperial Oil Limited undertook an aggressive exploration program, drilling fifteen wildcat wells in the Mackenzie Valley region, none of which discovered commercial quantities of hydrocarbons.

Most of the major oil companies and several consultants began large surface mapping programs in the 1950's, and these have continued to the present. Some of this work is now available in permit surrender reports and in various geological journals. A major work by E. J. Tassonyi, Geological Survey of Canada, ties together all work previous to the early 1960's.

Operation Norman was a major mapping and stratigraphic program carried out by the Geological Survey during the years 1968, 1969 and 1970. Published data from this program is fragmental to date, but maps and reports will probably be forthcoming shortly.

In the 1960's an oil land rush occurred and most prospective areas were obtained by purchase or filing by the oil companies. Seismic and drilling activity has increased gradually. The 1971-72 drilling season promises to be the most active ever.

Personnel

M. N. Chernoff	Party Chief
G. Ferguson	Geologist
D. Snowdon	Geologist
L. Love	Geologist
D. Loney	Geologist
A. Enevold	Geologist
D. Rae	Geological Assistant
P. Coleman	Geological Assistant
K. Panchy	Geological Assistant
J. Derby	Paleontologist
M. Dakin	Helicopter Pilot
J. Madden	Helicopter Pilot
G. Smith	Helicopter Engineer
A. Jeffery	Helicopter Engineer
B. Cornock	Otter Pilot
T. Cochrane	Otter Pilot
G. Moore	Otter Engineer
D. Fink	Otter Engineer
W. Hinds	Otter Engineer
J. Steel	Cook
J. Deck	Camp Helper

M. N. Chernoff was replaced by C. H. Riddell for a two week period in late June and early July. Chernoff did the majority of the work on the report following the field season.

Ferguson and Snowdon are permanent employees of Amoco Canada Petroleum Company Ltd. and following the field season returned to other projects with Amoco. Jim Derby spent one month with the field party and may spend some time in the future identifying fossils collected. Derby is a permanent employee of Amoco and is based in Tulsa.

Love, Loney, Enevold, Rae, Coleman and Panchy were temporary employees hired by C. H. Riddell Geological Consultants Ltd. for the summer program.

L. Bell and M. Reynolds spent a few days with the field party visiting particular localities of interest. J. Fuller spent about ten days with the surface party, and C. Pollock spent about two weeks collecting microfossil samples from particular sections and localities.

Bakin, Madden, Smith and Jeffery were employed by Alpine Helicopters, and Cornock, Cochrane, Moore, Fink and Hinds were employed by Wardair.

Objectives of the Field Party

The objectives of the field party within the project area (see Figure 1) were as follows: (per contract between Riddell and Amoco dated April 28, 1971)

(a) Map in detail the structures outlined. This will involve exact strike and dip measurement in addition to examination and identification of outcrop in the core and on the flanks of the structures.

(b) Establish the four units of the Ronning Formation, recently put forward by the Geological Survey of Canada, with a regard to ascertaining the extent of the sub-Bear Rock unconformity.

(c) Carry out a porosity study to establish whether or not the Mount Kindle is the only potential reservoir within the Ronning Group.

(d) Carry out a facies and porosity study of the Bear Rock Formation.

(e) Examine briefly the Cretaceous and Tertiary exposures for reservoir potential.

Method of Operation

The camp and personnel were transported to Norman Wells by Amoco aircraft (CF-AMO) on May 30, 1971, where a base camp was set up. On June 9 the base camp was moved by single Otter to Florence Lake. Base camps were also set up at Stewart Lake (July 10 to July 29) and at Wrigley Lake (July 30 to August 29).

Staging lakes were used from all base camps. Lakes used in this manner included Jan Lake, Yadek Lake, Mirror Lake, Sill Lake, Slim Lake and D. O. T. Lake at Wrigley. When staging lakes were used, the Otter and helicopters would transport all personnel and fuel to the lake in the morning and the helicopters would put out the crews. All aircraft would bring all the personnel home in the evening. This procedure saves a lot of helicopter time.

The field personnel were divided into two man traversing and section measuring crews, each consisting of a geologist and a geological assistant. The helicopter placed the crews on sections and traverses selected by the party chief. Sections were measured using three methods; Jacobs Staff, tape and brunton, and reconnaissance sections done by traversing and obtaining attitudes and calculating thicknesses with the aid of aerial photographs. After the crews were out, the party chief used one of the helicopters to do aerial geological mapping, locate sections and to make selected structural and stratigraphic observations. The other helicopter was generally used by another member of the crew (generally Ferguson, Snowdon, Derby, Pollock or Fuller) to make specific observations or collections. Both Ferguson and Snowdon did some aerial mapping.

All geologists were assigned letters to identify sections or outcrop localities. The subscript "x" was used to differentiate between measured sections and outcrop localities or traverses. Thus, A-1-71 is a section measured by Snowdon while Ax-2-71 is a spot locality visited by Snowdon. Similarly, B = Love, C = Chernoff, D = Loney, E = Enevold, F = Ferguson, J = Riddell, K = Derby and N = Rae.

Appendix I is a series of tables listing all measured sections, all outcrop localities and all traverses.

Samples were collected at ten foot intervals through most sections measured and are labelled as to section number and footage. Fossil samples were collected where available and microfossil samples were collected at most spot localities and throughout sections.

This report is accompanied by a folder containing complete surface geologic maps, stratigraphic and structural cross sections and isopach-lithofacies maps. A complete set of files was prepared and supplied to Amoco with each measured section in a separate file containing original and typed notes and a plotted strip log. Fossil identifications should be added when received.

A 150 slide photo library complete with slide description was prepared and supplied to Amoco.

Acknowledgements

The party chief is indebted to the work of everyone on the field crew for making the summer's operation a successful one. All the geological personnel made significant contributions to the data presented herein. The cooperation and skill of the air crew contributed greatly to the work.

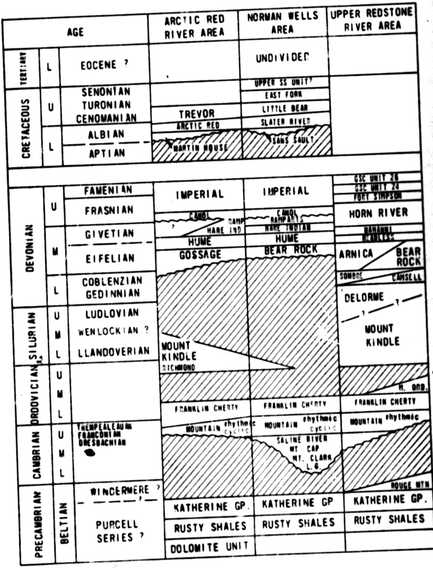
C. H. Riddell Geological Consultants Ltd. appreciates the excellent cooperation of Amoco personnel in expediting equipment, personnel and provisions throughout the duration of operations.

GENERAL GEOLOGY

Phanerozoic sedimentary rocks comprising marine platform carbonates and evaporites and mainly marine wedges of clastics approach an aggregate thickness of 30,000 feet within parts of the project area. Geological periods or systems not represented include the Mississippian, the Pennsylvanian, the Permian, the Triassic and the Jurassic. Epeirogenic uplifts and subsequent erosion are indicated by regional unconformities recognized at the base of the Middle Ordovician, the base of Upper Ordovician, base of Devonian, base of Upper Devonian (?) and base of Cretaceous (Albian). Orogenic movements are recognized and are all referred to the Laramide period of structural uplift with associated folding and faulting.

Rapid facies changes have been observed within Siluro-Ordovician, Early and Middle Devonian, Upper Devonian, Cretaceous and Tertiary units.

Figure 3 is a summary, in table form, of formational units mapped during the project. The chart indicates the correlation of these units as they occur in three sub-areas within the project boundary.



CORRELATION OF STRATIGRAPHIC UNITS

FIGURE 3

STRATIGRAPHY

Precambrian

Precambrian sedimentary rocks are exposed in the McConnell Range of the Franklin Mountains and in the Canyon Ranges of the Mackenzie Mountains. They are not exposed in the Norman Range or in the Mackenzie Plain area. No great effort was made to map, measure or define stratigraphic units within the Precambrian. The section, however, does break down into several recognizable stratigraphic units, and these were mapped separately on the accompanying series of surface geological maps.

Dolomite Unit

This unit is recognized as the oldest Precambrian unit exposed in the Mackenzie and Franklin Mountains. Cherty and noncherty, sheared and marmorized, well bedded dolomites were observed at the headwaters of the Ramparts River (Cx-33) and in the upper Carcajou River area (Cx-47). At both localities the unit surfaces along large thrust faults and total stratigraphic thickness may exceed 1,000 feet. In the former area, the dolomites are cut by several continuous dykes, however, short traverses along contact zones revealed no associated mineralization.

This unit is overlain by rusty shales and quartzites assigned to the Katherine Group. In the upper Ramparts River area some unusual stratigraphic relationships suggest an unconformity between the dolomite unit and overlying rusty shales and argillites.

As previously stated, it is believed that this unit represents the oldest exposed Precambrian beds within the Cordillera region of the Yukon and Northwest Territories.

Rusty Shale - Argillite Unit (Katherine Group)

A relatively recessive rusty weathering unit comprising shales, argillites, siltstone and minor sandstone overlies the dolomite unit and is in turn overlain by resistant weathering quartzites. This unit outcrops extensively in the cores of structures comprising the Canyon Ranges of the Mackenzie Mountains and in the shorter wavelength folds, the unit is intensely folded. In the upper Ramparts River area, the unit hosts several extensive diabase rills and is cut by numerous syenite dykes. The intrusions which are confined to Precambrian sediments are assumed to predate Paleozoic (mid Cambrian?) dolomites in this area. No measured thicknesses were obtained for this unit; however, it is estimated that the unit approaches a thickness of 5,000 feet in the Mountain River area and probably exceeds this thickness in the upper Ramparts River area. The unit appears to be transitional with the overlying Katherine quartzites.

Quartzite Unit (Katherine Quartzites)

This unit is widespread in the Canyon Ranges of the Mackenzie Mountains and is recognized at Mount Clark. The unit is characterized by relatively resistant dark grey weathering beds of blocky bedded quartzitic sandstone which is typically lichen covered. Approximately

2,000 feet of the unit was measured and described at B-7-71 and upper beds were measured and described at several other localities (D-10-71, D-11-71, D-13-71). At B-7-71 and at Mount Clark, the highest beds are generally less quartzitic, appear reworked and are porous. Similar porous sandstones occur at the base of the Phanerozoic section encountered in wells drilled in the Peel Plateau and there is a suggestion, by these observations, that the upper beds which may approach 200 feet in thickness represent basal Paleozoic sands. Because of the apparent weathering and lithologic continuity, it was not practical to map these upper sands separately. It is estimated that the unit generally exceeds 1,000 feet in thickness and is significantly thicker in the upper Ramparts River area. It was not determined whether the apparent thickening in the latter area was due to preservation of younger quartzites beneath an overlying unconformity or due to facies changes between this unit and the rusty shale unit.

Rouge Mountain Beds

The above name has been applied informally to a series of chocolate, green and red shales, brilliant orange weathered dolomites and limestones and minor siltstone and sandstone which overlie the Katherine quartzites and are exposed mainly in the upper Little Bear and Carcajou River areas within the project boundary. Elsewhere, these beds are absent due to Precambrian erosion. Upper beds assigned to this unit were measured and described at A-21-71 and B-22-71 and were observed at Cx-48 (Figure 5). At the former locality in Dodo Canyon, the upper

250 feet of Rouge Mountain beds were described as slightly calcareous siltstone with minor micritic limestone. Our interpretation suggests that some Rouge Mountain beds were included in the MacDougal Group as defined by Link in 1921 and since, in our opinion, both Precambrian and Cambrian strata comprise this Group, and since the MacDougal Group has limited areal extent, it is suggested that the use of this name be dropped. At B-22-71 on Rouge Mountain River, 550 feet of very fine grained limestones with red and blue-green shale partings underlie the Saline River Formation. The limestones are underlain by 220 feet of grey calcareous mudstone/slate with minor quartzite banding. In this area the limestones weather a brilliant orange, hence the name Rouge Mountain.

A maximum of 2,000 feet of section is estimated for Rouge Mountain beds in this area.

In the upper Mountain River and upper Ramparts River areas, Katherine quartzites are overlain by a wedge of shales, dolomite and gypsum which exceed several thousands of feet in thickness. The dolomite appears to form small "pinnacles" and large banks within a shale envelope which is overlain by white gypsum. The stratigraphic relationships are abrupt and spectacular and are interpreted to represent Precambrian "reefing". The position of this sequence in the section suggests a correlation with the Rouge Mountain beds described previously.

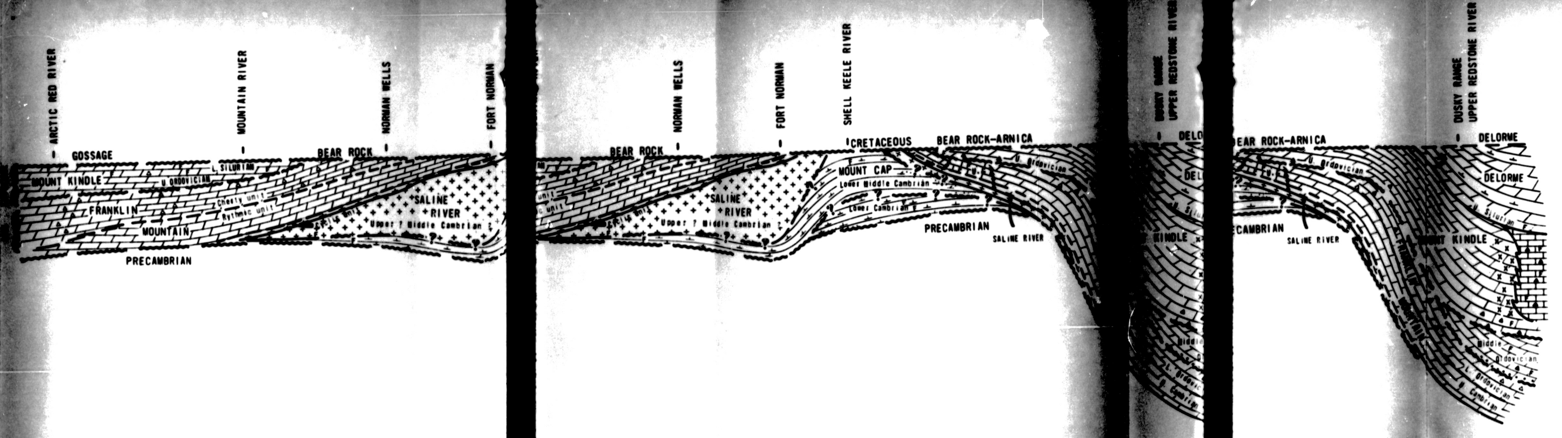
Rouge Mountain beds are not expected to underlie the Peel Plateau or Mackenzie Plain areas.

This unit represents a significant change upward in type of Precambrian sedimentary rocks exposed in the project area. We suggest that whereas lower Precambrian units have been assigned to the Beltian, Purcell series, the Rouge Mountain beds should be assigned to the Windermere series.

In the Carcajou - Little Bear River areas this unit is overlain by early Middle Cambrian black shales of the Mount Cap Formation.

Lower Cambrian

Lower Cambrian rocks were recognized at only one locality, D-13-71, on the north flank of Mount Clark. Here, approximately 1,000 feet of interbedded shale, siltstone and minor limestone were found to be fossiliferous throughout. The unit overlies with apparent conformity quartzites referred to the Precambrian. The quartzites are capped by approximately ten feet of medium grained sandstone which appears to have been reworked and may represent basal Paleozoic beds at this locality. Due to an incomplete section, relationship of lower Cambrian beds with overlying units is unknown, although it is inferred that Mount Cap and Saline River strata are present in the area. Lower Cambrian beds may be present in the subsurface of the Mackenzie Plain specifically at Shell Keele River L4 and at Imperial Vermillion No. 1 where early Middle Cambrian beds have been confirmed; however, to date the Mount Clark locality and basal Paleozoic beds in Dodo Canyon remain the only known occurrences of early Cambrian strata in the project area.



LEGEND

- DOLOMITE
- LIMESTONE
- SALT
- SANDSTONE, CONGLOMERATE
- DOLOMITE, SHALE
- LIMESTONE, SHALE
- FOSSILS
- CHERT, WHITE, DARK
- REEF
- UNCONFORMITY

FIGURE 6

SCHEMATIC CROSS SECTION
LOWER PALEOZOIC STRATIGRAPHY
(Tippecanoe and Sauk)

BY

M.N. CHERNOFF, P. GEOL
C.H. RIDDELL, GEOL. CONS. LTD.

DATUM: TOP TIPPECANOE SAUK
SCALE: HORIZONTAL - NIL
VERTICAL 1" = 2000 FEET

Fossils collected at Mount Clark (D-13-71, Kx-1 to Kx-7-71) include brachiopods and trilobites which suggest an Early Cambrian (Upper Olenellus Zone) age. Except for the thin basal sands, no suitable reservoir rocks are expected in the Lower Cambrian section.

Lower Cambrian strata have been mapped (Sekwi Formation) in the Backbone Ranges of the Mackenzie Mountains and at Mount Cap (GSC Paper 62-33) in the Southern Franklin Mountains; however, they are not known to occur in the Canyon Ranges other than the Dodo locality reported by the Geological Survey of Canada. Olenellid bearing strata at Mount Cap have been assigned to the Mount Cap Formation by earlier workers; however, we would prefer to restrict the name Mount Cap to nonevaporitic strata of Middle Cambrian age.

Middle Cambrian, Mount Cap Formation

The type locality of the Mount Cap formation as defined by Williams (1923, P. 76B - 77B) occurs on the west flank of Mount Cap in the McConnell Range of the Franklin Mountains. Douglas and Norris (1963) report that only a few feet of the formation are exposed and consist of light olive-green, soft, fissile shale bearing Olenellid trilobites (Lower Cambrian). It is reported that Williams (1923) collected Middle Cambrian fossils from basal shales and siltstones on the flank of Cap Mountain. The thickness of the formation at the type locality is not known, but was estimated to be about 200 feet. A covered interval calculated and attached to the base of Section C-131-71 is 400 feet thick and is assumed to include the Mount Cap Formation and possibly lower Saline River beds.

In this report we prefer to restrict the use of the formational name Mount Cap to Middle Cambrian beds which underlie the Saline River Formation. We recognize Mount Cap beds in the McConnell Range at A-28-71, at Shell Keele River L4, and Imperial Vermillion No. 1, and at B-43-71 and A-21-71 in the Canyon Ranges.

At A-28-71 approximately 3,000 feet of section is assigned to the Mount Cap on the basis of widespread occurrence of lower Middle Cambrian trilobites. The lower 1,500 feet are mainly covered but sparse outcrops suggest that the interval is grey siltstone and shale. The covered interval is overlain by 300 feet of fossiliferous black argillaceous limestone and the upper 1,200 feet is 50 per cent covered with outcrops of very fine to medium grained, thin bedded sandstone bands with abundant tracks and trails and sparse trilobites. At Shell Keele River L4, 1,935 feet (2,300 KB - TD) of brown and green shales, dolomitic marls and minor siltstone are all assigned to the Mount Cap on the basis of Middle Cambrian fossils found in a core in the interval 3,233 to 3,255 feet. At Imperial Vermillion Ridge No. 1 the interval 5,580 to 5,972 feet KB comprising green splintery and waxy shales is assigned to the Mount Cap. At B-22, A-21 and B-43 up to several hundred feet of slumping soft black shales underlie the Saline River Formation and bear early Middle Cambrian trilobites. At the latter localities there is a suggestion that the black shales may be transitional with overlying Saline River beds, and this observation prompts one to think that the Mount Cap Formation could be, in part, a lateral or facies equivalent of the Saline River Formation.

Mount Cap beds are confined to the deeper parts of the basin as defined by the isopach and lithofacies map (Enclosure 1) of the Saline River formation. Characteristically "our" Mount Cap formation carries a lower Middle Cambrian faunal assemblage. No significant reservoir beds should be expected in the Mount Cap formation.

<u>Saline River Formation</u> (Middle Cambrian) - (Ref. Figs. 6 to 9; Encls. 1, 11, 12, 13)

The type section of the formation was described by Williams (1923) on Saline River (Fx-62-71). Here, we would assign 65 feet of interbedded gypsum and red weathered dolomite to the Saline River. Overlying buff dolomites and green dolomitic mudstones are assigned to the cyclic unit of the Franklin Mountain Formation. No diagnostic fossils were found at this locality.

The isopach map (Enclosure 1) of this unit shows our control within the project boundary. The occurrence of the Saline River Formation in this area is shown to be confined to a closed basin whose axis occurs along the northerly flowing Mackenzie River. Salt was encountered in the subsurface in the following wells: Atlantic Shoals C-31, Atlantic Beavertail G-26, Atlantic Col Car Manitou L, Imp Vermillion Ridge, Imp Loon Creek No. 2 and Mobil Ontadnek N-39. In outcrop the formation weathers a distinctive red or pink and consists mainly of white gypsum lathes and swallowtail twins. Red and green gypsiferous dolomitic shales with salt casts are also common in the interval. At Imp Vermillion No. 1 2,780 feet (2,800 to 5,580 feet) is assigned to the Saline River whereas the maximum measured thickness in outcrop is slightly in excess of 600 feet at F-14-71 (Sheep Mountain); however, outcrop sections have no salt in the interval, and it is assumed that great thicknesses of salt, now dissolved, may have been present at outcrop localities. Generally the outcrop localities are very poorly exposed, mobile masses of red and green mud. At bedrock exposures the thin bedded unit may be intensely crenulated although the entire interval is structurally simple. Where present, this unit is recognized as the least competent interval in the stratigraphic packet and is considered to be highly mobile. We feel that this unit contributes significantly to the style of the structure involving this and overlying units.

A few fossils have been collected at outcrop localities, and these indicate a Middle Cambrian age. Since outcrop sections are generally a residual of a thick salt section, it may be that the fossils occur in Mount Cap beds which are included in the Saline River at these localities. Also, as previously stated, there is strong evidence for partial lateral correlation of Mount Cap and Saline River beds and residual outcrop localities may be mainly Mount Cap facies.

Franklin Mountain Formation - (Ref. Figs. 6 to 12, Encls. 2, 11, 12, 13).

The type locality of this Formation is on the east slope of Mount Kindle and the name was applied by Williams (1922). Here, at C-131-71, 1,270 feet of beds are assigned to the Franklin Mountain.

The lower 500 feet, a covered interval, is overlain by 200 feet of pelleted, silty and tight algal dolomite. The upper 570 feet comprises grey weathering fine crystalline dolomite with scattered white chert bands, sandstone lenses and thin partings of blue-green shale. The formation is unconformably overlain by argillaceous and fossiliferous Mount Kindle beds. The upper contact (Figure 12) is sharp, clearly showing channelling in the highest Franklin Mountain beds which are chertified to at least ten feet below the contact.

Based on 1968 and 1969 field work by members of Operation Norman, MacQueen (1969, 1970) subdivided the Franklin Mountain into three mappable units: the lower "cyclic" member, the middle "rhythmic" member and the upper "cherty" member. Our work confirmed that these units are indeed easily mappable in the Franklin Mountains and in the Canyon Ranges south and east of Imperial River; however, we did not go into great detail in defining, counting or correlating cycles or rhythms. Most of the sections measured through this interval were collected on a ten foot basis, and these samples are available for detailed microscopic study.

Cyclic Member

The isopach map (Enclosure 2) shows our control for mapping the units in the project area. The lower cyclic unit is widespread, generally 100 to 300 feet thick comprising thin bedded olive grey dolomite, green shale and flat pebble dolomite conglomerates. The unit appears to be transitional with both the underlying Saline River formation and the overlying rhythmic unit. The cyclic member weathers a distinctive recessive pale yellowish olive. Cyclic beds are not recognized in the Mackenzie Mountains west of the Hume River and in the deeper ranges of the Mackenzie Mountains, namely the Rouge Range (E-23-71) and the Tigonan Kweine Range (F-26-71, B-52-71). At these localities rhythmic beds are in contact with underlying Precambrian strata, and it is assumed that the "cyclic" sea did not cover these areas. No suitable reservoir rocks should be expected in this unit.

Rhythmic Member

The rhythmic member is a well bedded algal dolomite which weathers a distinctive banded reddish-buff. The dolomite is generally very fine to micro crystalline and tight throughout. Rare black chert nodules may occur in the unit. Generally the unit is 700 to 1,000 feet thick; however, in the northern part of the project area and in the Peel Plateau, the unit thickens and may approach 2,000 feet (Atlantic Ontaratue H-34). Strata assigned to the rhythmic unit are in a limestone facies at two isolated areas. In the Little Smith Hills area (A-26-71), six miles northwest of Mount Clark, a minimum of 750 feet and possibly as much as 1,000 feet of limestone may be referred to the rhythmic unit. In the North Redstone Range area near the Keele River (A-35-71), approximately 900 feet of section is assigned to the rhythmic unit of which the lower 200 feet is limestone. It is not known whether these pods escaped regional dolomitization of the unit or if the limestone areas represent more basinal or marine conditions within a mainly shelf environment. The limestone sections offer a rare opportunity to study depositional characteristics of this unit. Stromatolitic structures are clearly visible and detailed sedimentary structures can be easily followed along bedding planes. Also, vertical sedimentary changes are clear and offer the observer a rare opportunity to apply stratigraphic principles presented in recent studies on shallow marine and restricted carbonate and evaporite shelves.

The sections were measured on a ten foot basis, and it is recommended that detailed microscopic studies of the samples should give a clear understanding of the depositional environment. For detailed field lithologic observations, at "limestone localities", reference should be made to sections A-26-71 and A-35-71 and to the field notes accompanying these sections.

Trilobite collections were made at both "limestone localities", whereas the rhythmic "dolomite" sections were found to be barren of macrofossils. Comments by J. R. Derby, who collected and studied the faunal collections are as follows:

"A significant new find of the field work was the recognition of a limestone unit characterized by abundant algal stromatolites and containing an abundant lower Upper Cambrian (Crepicephalus Zone of the Dresbachian Stage) fauna. In the field this unit was informally referred to as the "Dresbach Limestone". The fauna was remarkably uniform, consisting of the following trilobite genera:

Terranovella
Kingstonia
Blountia
Welleraspis

"This is a typical shallow-water fauna from cratonic sites throughout southern North America.

"The 'Dresbach Limestone' was found in two areas: (a) east of the Mackenzie River in the 'Little Smith Hills' (Section A-26-71 and Localities Cx-64, Kx-10, Kx-11, Kx-12) mostly micritic limestone with abundant algal mats, low-amptitude stromatolite mounds, and algal-mat pebble conglomerates; (b) near the Keele River about 126°30' West longitude (Sections A-35-71, A-37-71, Localities Ex-20a, Kx-27, Kx-30), large stromatolite mounds, up to eight feet high, with much sandsized limestone between the stromatolites. Sediment types strongly indicate shallower waters to the east towards the craton."

Correlation of Sections A-35-71 and A-26-71 using the base of the rhythmic as a datum shows that the above fauna ranges through 1,000 feet of beds. If this range of thickness is not acceptable after comparison with a "Dresbachian" stage thickness elsewhere, then we must introduce a system of depositional slopes or rapid changing facies involving cyclic, rhythmic and cherty units.

The rhythmic unit is generally non-porous, even at subcrop beneath Devonian (F-5-71) and Cretaceous (Cx-66-71) horizons. West of Mountain River, porosity development in Franklin Mountain beds steps down through the section until in the Arctic Red River area porous beds are present near the base. Actually we prefer to assign lower Franklin Mountain strata in the latter area to the "cherty" unit on basis of general rock facies. This interpretation requires the acceptance of a facies change westward of "rhythmic" type beds to "cherty" type beds (see Enclosure 11).

The upper contact of rhythmic beds with overlying "cherty" strata was picked on the basis of firstly the appearance of white chert in the section, and secondly a change in weathering character of the dolomite from banded reddish-buff (rhythmic) to blocky medium light grey (cherty). Surface mapping methods utilized the latter distinction; however, after traverses or sections through a mapped area it was found that the basal 200 to 300 feet of grey weathered dolomite assigned to the "cherty" unit is generally barren of chert and could be assigned to the rhythmic unit on the basis of the first distinction. Since no unconformity is recognized near this contact and since reservoir continuity is expected between "rhythmic" and "cherty" units, the apparent mapping inconsistency is not a serious matter.

Cherty Member

Since this unit is the highest member of the Franklin Mountain Formation, it shows significant isopach changes due to pre-Mount Kindle and pre-Devonian erosion. "Cherty" dolomites are present throughout most of the project area. This member is not recognized in the southern Franklin Range (B-5-71, I-5-71), in the MacKay Range (F-17, 18 and 19-71), in the Cambill Range (I-13-71), in the north Redstone Range (A-29-71, A-35-71, B-39-71) and in the St. Charles Range (D-15-71, B-35-71). Absence of this unit in these areas indicates that a fairly large area (Norman Arch) was uplifted during Mid-Ordovician time and stripped of many hundreds of feet of Franklin Mountain beds. Enclosure 2 shows the limit of beds referred to the "cherty" member. The occurrence of a thick cherty member at Big Smith Hills (E-15-71, E-14-71, N-2-71, Kx-13, 14 and 15-71) at the south end of the St. Charles Range is considered anomolous, and although Enclosure 2 shows this occurrence as the northern margin of a continuous unit, it can be interpreted that the occurrence is part of an ancient erosional remnant or outlier that stood several hundreds of feet above an erosional datum. The outlier would have been onlapped by Devonian evaporites providing a trapping mechanism similar to porous reef mounds within evaporite basins.

The cherty member varies in thickness from 0 to 600 feet over most of the area but thickens rapidly westward and in the Arctic Red River area (B-23-71 and D-11-71) 1,600 feet of cherty dolomites are assigned to this member. Increased westward thickening is apparently due to the appearance of silica and white chert in beds laterally equivalent to the rhythmic unit and our preference to continue picking the base of the cherty unit at the lowest occurrence of what is considered to be continuous silica and white chert. In actual fact, we did not subdivide the Franklin Mountain Formation west of Florence Lake and the accompanying surface geological maps show the entire Cambro-Ordovician interval as one unit (Franklin Mountain).

The dolomite is typically fine crystalline, grey fresh surface and weathered, blocky bedded with scattered zones of shapeless silica masses and white nodular and bedded chert. Since porous (over 5 per cent) horizons are fairly common in this unit varying from leached to vuggy to intercrystalline, the member should be considered as a reservoir target in any oil and gas prospect. Generally the contact with overlying Mount Kindle strata is covered; however, from subsurface data and selected outcrop localities (C-131-71) it can be shown that the cherty member is capped by a fine clastic zone up to 50 feet thick which could be considered as sufficient cap rock. Where Mount Kindle beds are absent, overlying Devonian evaporites provide an adequate seal.

Diagnostic fossils are very difficult to find in this unit, and it is mainly through the persistence of J. R. Derby that we are able to offer some age dates for this unit. Following are his observations on the collections.

"At locality Kx-33A-71, burrowed, cherty dolomites resembling the "cherty" unit of the Franklin Mountain Formation yielded silicified trilobites. Preservation is very poor, but the trilobites resemble no genera known to me in the Ordovician, but they do closely resemble Dunderbergia sp. which indicates an Upper Cambrian age, just slightly younger than Dresbachian.

"Lower Ordovician rocks were positively identified in the area for the first time. The upper or 'cherty member' of the Franklin

Mountain Formation yielded numerous specimens of the peculiar gastropod operculum Ceratopea at locality Kx-34B-71 (Section B-49-71, Dusky Range). This genus is well known from the Arbuckle - Ellenburger - El Paso formations of the southern United States, where it ranges only through the upper half of the Lower Ordovician.

"At Kx-34B-71 the Ceratopea specimens belong to the Ceratopea unguis - Ceratopea hanie species group which occur only in the uppermost quarter of the Lower Ordovician, that is, in the west Spring Creek formation and equivalent strata.

"At Locality Kx-35C-71 (Rouge Range), silicified fossils tentatively identified in the field as Matthevia are probably a chiton: *Chelodes sp.

"A Lower Ordovician age is suggested, though not proven."

Other "cherty" localities with age dates are E-23-71 (Kx-35C-71) - Uppermost Cambrian (Trempealeau), Kx-15A-71 (Big Smith Hills) - Earliest Early Ordovician and Kx-33A-71 (Nainlin Brook) - Upper Cambrian (younger than Dresbachian).

The identifications of faunal collections made in the Franklin Mountain Formation indicate that the Rhythmic unit is mainly early Upper Cambrian (Dresbachian) and the Cherty unit is mainly Early Ordovician. A faunal gap spanning the late Upper Cambrian was suspected, however, one very late Cambrian identification and the confirmation of Earliest Ordovician convinces us that the "Cherty" unit may in part be Late Cambrian, and therefore, the Franklin Mountain Formation represents continuous deposition from earliest Upper Cambrian through very late Lower Ordovician.

Addendum (Rhythmic and Cherty Units)

A significant lithology type was inadvertently omitted from descriptions of the rhythmic and cherty units; specifically, oolite beds which were described in limy rhythmic sections and in bedded chert sections. The oolitic intervals are generally tightly cemented; however, in the subsurface selective leaching could produce prospective reservoirs.

Middle Ordovician (Unnamed Unit)

In the southwestern part of the project area along the Dusky Range, a wedge of dark grey limestones and cherty dolomites was mapped as a distinct unit bounded by unconformities. From a feather edge just south of Section B-48-71 the unit thickens to 1,700 feet at Section A-39-71 in a distance of approximately five miles. Observations of this single occurrence of the unit suggest that the wedge thickens southward.

The base of the unit is marked by a distinct red weathering angular-pebble conglomerate occurring over the basal 50 to 100 feet. The conglomerate comprises variable-sized angular-pebbles of light colored dolomite probably derived from the underlying Franklin Mountain cherty unit. Some constituents appear tuffaceous suggesting that deposition of the basal beds was accompanied by volcanic activity in the area. We suggest that a thin section study of the basal conglomerate should be made to determine the components comprising these interesting beds which were collected at Kx-35-71, B-49-71 and

A-39-71. Overlying strata include platy to blocky beds of mainly dark grey weathered limestone and cherty dolomite. Occasional light grey and orange weathered bands occur in the lower part of the succession. The highest beds are well bedded, slabby to blocky, very fine grained dolomite and limestone which appear to have been deposited in an open marine environment. Several fossil collections were made in this unit; however, at this time no laboratory identifications have been received. Tentative field identifications of brachiopods and the fossil receptaculites indicate that the entire unit is of Middle Ordovician age. As previously mentioned, the base is marked by a conglomeratic unit and the top is visibly truncated by overlying cherty dolomites of the Mount Kindle formation. This unit is correlated with the Sunblood Formation and other Middle Ordovician units mapped by officers of the Geological Survey of Canada south and west of the project area.

No suitable reservoir characteristics were observed at the few localities where the unit was examined; however, the basal clastic unit may develop into porous beds laterally.

Mount Kindle

The type locality of this formation was first described by Williams (1922) at Mount Kindle in the McConnell Range where the unit forms the upper slope of the mountain and continues along the western slope for a fair distance. The type locality is poorly exposed in the middle and upper parts and does not have an exposed top. The basal beds at the type locality were examined (C-131-71) and the full interval was sampled and described at C-130-71 a few miles south along a well exposed ridge called "bald ridge".

At C-130-71 925 feet of section was assigned to the Mount Kindle formation on the basis of faunal distribution and general lithology. At this locality the formation includes a lower dark weathering unit and an upper light weathering unit. The dark weathering unit comprises medium to dark grey, predominantly fine crystalline dolomite with 5 to 60 per cent fossil content. Several bands of intercrystalline and leached organic porosity average 5 per cent. Fossils include crinoid columnals, solitary and chain corals, brachiopods and stroms. The upper part of the formation is characterised by a light grey weathering dolomite which is smooth-rounded weathered and is organic (?stroms, algal, coral) in appearance. Good (4 to 7 per cent) intercrystalline and pinpoint vuggy porosity is present throughout. White chert bands are common.

Over the remainder of the project area the Mount Kindle formation is generally dark grey weathered, well bedded (slabby, blocky) and carries a common faunal assemblage including brachiopods, chain corals, solitary horn corals and orthocone siphuncles. Porosity distribution is erratic throughout the unit; however, it is generally present and the entire formation should be considered as a prospective reservoir system.

Enclosure 3 shows the distribution and thickness of the formation within the project area. The unit is absent over the entire length of the Norman Range and is expected to be absent in the subsurface of most of the Mackenzie Plain west of the Norman Range. The formation thickens rapidly to the southwest from the general vicinity of the Keele River and in the Dusky Range over 4,000 feet of beds have been assigned to the formation at B-48-71.

In the vicinity of the North Redstone Range (A-29-71, Ex-18-71) where the formation begins to thicken southward, occasional bands of white porous dolomite up to 50 feet thick occur in the section and become more common in a southerly direction along the Redstone Range. In the Dusky Range, white porous dolomite banks, referred to as "reefs" in the field, constitute up to 1,500 feet of the section at B-48-71 and A-39-71. In the Redstone Range, near the Redstone River, the Mount Kindle Formation contains massive porous dolomite bodies which have a reef-like relationship to the surrounding strata. The "reefs" are coarse to very coarse grained, light grey massive dolomites with 5 to 15 per cent vuggy and intercrystalline porosity (field estimate) ranging up to 100 feet thick and pinching out to a few tens of feet thick. Capping the reef rock is nonporous black, medium crystalline dolomite with abundant beds and nodules of chert. In the Dusky Range the white porous dolomite units are much thicker and are continuous over 800 feet of section. Dolomitization has generally destroyed all original sedimentary characteristics; however, at A-39-71 there is a suggestion that colonial corals may have formed some of the banks. At the south end of the Dusky Range (D-16-71) the formation is predominantly dark grey weathered limestone with scattered fossil and black chert horizons. The section at D-16-71 is interpreted to be an open marine facies of the formation in contrast to the "bank" facies present over most of the project area. The change from white porous dolomite to dark tight limestone which occurs over a distance of approximately two miles is interpreted to be transitional although it is relatively abrupt considering the widespread uniform character of the formation in the remainder of the project area. The development of massive light grey porous dolomite banks in the Dusky Range is believed to be associated with a bank margin which faced a deep open sea to the south and west. The tract of the bank margin is unknown since the crossing in the Dusky Range is our only control; however, it would be fair to assume that margin may underlie parts of the Mackenzie Plain area in the general vicinity of the Root River.

Field collections of fossils found in the Mount Kindle have not been studied to date; however, previous work and tentative field identifications have established that the Mount Kindle formation is of Upper Ordovician and Silurian age. The base of the formation is recognized as a regional unconformity surface which was subjected to erosion throughout most of the Middle Ordovician and earliest Upper Ordovician. Original work in the vicinity of the type locality in the McConnell Range established a Middle Silurian age for the formation;

however, more recent work (personal knowledge) indicates that Middle Silurian beds are absent over most of the project area and the highest formational strata are probably of Lower Silurian age. In the Redstone and Dusky Ranges where the formation thickens and the contact with the overlying Delorme formation is gradational, the Mount Kindle formation probably includes Middle Silurian beds and may include Upper Silurian beds. Due to incomplete paleontological studies we are not prepared to say whether younger Silurian strata are absent over the most of the project area because of nondeposition or pre-Devonian erosion.

Since the porous Mouht Kindle Formation is generally capped by impermeable Devonian beds, subsurface prospects for hydrocarbons are excellent in stratigraphic, subcrop and structural plays.

Delorme Formation

The type locality (3,250 feet thick) of the Delorme Formation was first described by Douglas and Norris (1961), on the Delorme Range at the headwaters of Pastel Creek south and west of the project area.

In the project area, the Delorme Formation is confined to an area west of the MacKenzie River and south of the Keele River (see Enclosure 4). Basal Devonian clastic carbonate rocks in the McConnell and St. Charles Ranges assume a weathering character similar to that of the Delorme, however, we prefer to assign this unit (up to 500 feet thick) to the Bear Rock.

Generally, the Delorme Formation is 1,500 to 2,000 feet in the project area with the exception of a section measured in the Dusky

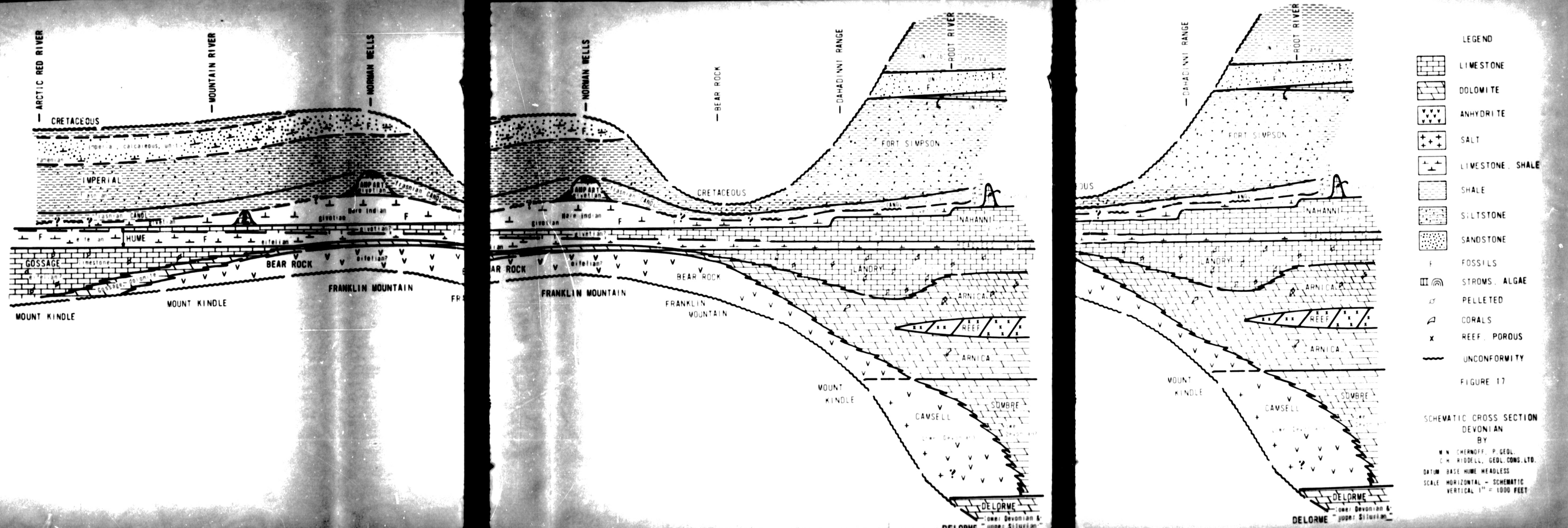


FIGURE 17

SCHEMATIC CROSS SECTION
DEVONIAN
BY
M.N. CHERNOFF, P.GEOL.
C.H. RIDDELL, GEOL.CONS.LTD.

DATUM BASE HUME HEADLESS
SCALE HORIZONTAL - SCHEMATIC
VERTICAL 1" = 1000 FEET

[illegible] information [illegible]

light grey dolomites forming the restricting barrier and referred to the Sombre Formation are lateral seaward equivalents of the Camsell evaporites. Stratigraphic cross section DD' (Enclosure 14) shows the facies relationship between Sombre and Camsell Formations in the central part of the basin.

A collection of fossils at A-34-71 in an interval low in the Camsell Formation was assigned to the Upper Emsian stage of the Devonian. Generally the Camsell Formation is barren. On the basis of regional geology we would prefer to restrict the Camsell to the late Lower Devonian and early Middle Devonian.

With the exception of possible biohermal buildups within the evaporite basin, no suitable reservoir rocks are expected within the Camsell Formation.

Sombre Formation

The type locality of Sombre Formation is on Tundra Ridge south and west of the project area. Douglas and Norris (1960) report that the formation comprises 4,100 feet of dolomite at the type locality.

In the project area the formation is confined to an area west of the Mackenzie River and south of the Keele River and has been mapped in the South Redstone, the Rouge and Dusky Ranges where assigned thicknesses are a trace (Lx-22-71), 1,170 feet (L-21-71), and 480 feet (B-48-71) respectively.

The formation comprises medium and light grey, well bedded dolomites which weather relatively light grey beneath the overlying dark

Arnica beds. The dolomite is predomonantly fine to very fine crystalline with poor intercrystalline and pinpoint vuggy porosity. It is our interpretation that the Sombre dolomites formed a seaward barrier for the Camsell evaporites. The facies relationships as indicated on stratigraphic cross section DD' (Enclosure 14) suggest that the early Devonian sea spread eastward from a basinal axis situated in the Backbone Ranges of the Mackenzie Mountains and the resulting depositional pattern for the Sombre should be considered transgressive to the east.

No fossils were found in this unit at the reference localities. It is our contention that the Sombre and Camsell formations are time equivalents and no evidence for unconformities above or below the former formation was found.

In the southwest part of the project boundary, Sombre dolomite stringers may reach eastward into the Camsell basin beneath the Mackenzie Plain and offer stratigraphic traps for accumulation of hydrocarbons. Also, isolated dolomite banks or bioherms of Sombre facies within the Camsell basin may occur although no field evidence for same was observed.

Arnica Formation

The type locality of the Arnica Formation is in the First Canyon on the South Nahanni River, south of the project area. Here, Douglas and Norris (1960) assigned 1,650 feet of dark grey to black dolomite to the Arnica.

In the project area the use of the formation name Arnica was restricted to medium and dark grey banded dolomites occurring above the Sombre or Camsell formations and below the limestones of the Landry Formation in an area west of the Mackenzie River and south of the Keele River. At Section E-21-71 in the Rouge Range a maximum thickness of 2,940 feet is referred to the Arnica. Other reference localities are F-26-71, N-3-71, Ex-22-71, A-34-71, A-38-71, F-27-71, B-48-71 and Ax-41-71.

The Arnica Formation comprises thick well bedded medium and dark grey, very fine to fine crystalline dolomite with scattered poor intercrystalline and pinpoint vuggy porosity. In the southern Redstone Range (B-51-71), in the southern Dusky Range (Ax-41-71) and in the Iverson Range at Root River gap the interval contains porous white wedges of dolomite up to several hundred feet thick. The massive character and associated porosity suggests that the "wedges" are reefoid.

As indicated by Figure 17 and stratigraphic cross section DD' (Enclosure 14) and EE' (Enclosure 15), the Arnica is interpreted to be a lateral equivalent, at least in part, of the Bear Rock, Gossage and Landry formations. It is our belief that these stratigraphic units represent different rock facies deposited during early Middle Devonian time around and eventually on top of an ancestral arch centred in the Fort Norman - Norman Wells area. For this reason the presentation of the Arnica lithofacies and isopach is included in a single map (Enclosure 5) showing facies and thicknesses of all the early Middle Devonian formations.

The only fossils found in Arnica beds belong to a genera of an aberrant stromatoporoid amphipora, which has a wide range; however, in the project area this is a "typical" Arnica indicator. On the basis of regional geology we prefer to restrict the Arnica Formation and its coeval stratigraphic units to the Eifelian stage of the Middle Devonian.

A complex interfingering of Arnica and Bear Rock facies should be expected beneath the Mackenzie Plain in the southwestern part of the project area. This type of stratigraphic trap, although interesting, will have to await exploration of prospects with greater potential. Although outliers, banks or bioherms of Arnica facies could be expected within evaporites of the laterally equivalent Bear Rock, no field evidence for this occurrence has been reported.

Bear Rock Formation

The type locality of the Bear Rock Formation is at Bear Rock at the junction of the Great Bear and Mackenzie Rivers. Only the basal beds were examined at the type locality (F-5-71) and they include pebble beds and breccia along a surface which visibly truncates underlying dolomites of the Franklin Mountain rhythmic unit.

A wide variation in thickness of surface sections of this unit was obtained. Also large thickness discrepancies occur between wells and nearby outcrop localities. It is generally accepted that the Bear Rock Formation which is predominantly anhydrite in the subsurface and predominantly limestone breccia at outcrop localities, suffers from extensive solutioning of evaporite content at or near the surface.

This theory is supported by occurrence of numerous "sink holes" in areas where Bear Rock strata are gently dipping and are known to be at or near the surface.

The maximum thickness assigned to the Bear Rock is approximately 2,500 feet at the Shell Ochre River well southeast of the project area. In the Norman Wells area approximately 1,000 feet of strata are included in the Bear Rock. A minimum thickness of apparently original section is approximately 800 feet thick in the Carcajou Anticline area.

The formation weathers into a characteristic massive nonbedded, cavernous limestone breccia interval which includes randomly oriented blocks of laminated dolomite and occasionally blocks of limestone derived from the overlying Landry and Hume Formations. As yet unexplained, it is the apparent absence of blocks of younger strata, namely Hare Indian, Canol and Imperial Formations. Where the Bear Rock facies is dominant it may include a basal dolomite, shale and clastic carbonate unit up to 500 feet thick as in the St. Charles Range (B-35 and 37-71) and at Mount Clark (A-25-71). This basal, apparently nonevaporitic, unit includes beds of dolomite with floating angular to well rounded sand grains and beds of buff and green shale and cryptocrystalline hard laminated dolomite. This basal unit is absent due to nondeposition over the Norman Range and adjacent areas. The upper part of the Bear Rock is apparently transitional with overlying Hume beds, and in most areas the top of the Bear Rock includes very fine crystalline dolomite with excellent intercrystalline porosity. Because of the fine texture and small pores, permeability may be low. This dolomite is consistently oil stained in the Norman Wells area, and it is our belief that a very large stratigraphic reservoir may have been breached by erosion of Laramide structures in this area. If this was the case, structures in the Norman Wells area with this horizon at depth could contain oil. The occurrences of oil shows in this unit occur in the Beavertail - Carcajou areas, in the Norman Range and throughout most of the McConnell Range. Generally, the upper dolomite unit is less than 100 feet thick and thins eastward as it gives way to anhydrite in the Bear Rock. There is a fear that this apparently huge stratigraphic trap is connected with similar dolomites which develop in the overlying Hume Formation.

Enclosure 5 shows the distribution of the Bear Rock Formation which is dominant in the area marked as facies unit (4). Stratigraphic cross sections DD', EE', FF' and GG' (respective Enclosures 14, 15, 16 and 17) show the stratigraphic relationship between the Bear Rock and Cossage or Arnica Formations. No fossils were found in the Bear Rock beds; however, on the basis of correlations and stratigraphic position we support an early Middle Devonian age for the Bear Rock Formation.

The lower and upper dolomite units of the Bear Rock Formation should be regarded as prospective horizons, especially the latter which exhibits fair porosity and is consistently stained dark brown by oil.

Cossage Formation

The type locality of the Cossage Formation is the Richfield Oil Corp. Grandview Hill No. 1 well, and the name was proposed by Tassonyi for a sequence of limestone and dolomite occupying the interval 1,871 to 3,460 KB in the well. Reference to the Tassonyi paper should be made for a detailed discussion of the Gossage Formation.

The formational name Cossage is restricted to the northwest part of the project area where the interval between the Mount Kindle and Hume Formations is occupied by a variable mix of pelleted limestone and dark dolomite. The upper part of the formation is generally limestone and is informally referred to as the "Gossage lime" whereas the lower part is predominantly dolomite and informally referred to as the "Gossage dolomite". The two rock units are easily mappable in the field, and this subdivision is presented on the accompanying geological maps.

The Gossage formation is slightly in excess of 700 feet in the Mackenzie Mountains west of the Cayna River, thickening rapidly beneath the Peel Plateau to a thickness of 2,010 feet at Atlantic Ontaratue H-34. Stratigraphic cross section FF' (Enclosure 16) shows the lateral relationship of limestone, dolomite and anhydrite. It appears that the dark pelleted micro-grained tight limestone represents an open marine shelf facies whereas the dolomite is transitional from the latter facies to a more restricted evaporitic facies of the Bear Rock. The dolomite is generally dark grey, slabby to blocky bedded, very fine to fine crystalline with scattered intercrystalline porosity. It has not been determined if the dolomite facies represents an organic bank between the limestone and evaporite facies, or if it is a dolomitization phenomenon associated with the depositional environment. In any case, the facies change from dolomite to anhydrite is rapid and occurs over a ten to fifteen mile belt trending north-northeasterly through the Mountain River - Mackenzie River areas in the vicinity of Sans Sault Rapids. Subsurface information along this belt indicates that excellent porosity development is common, and it is our opinion that this belt is highly prospective for hydrocarbons. Because of poor subsurface definition offered by the few wells in the area, initial exploration efforts will probably be confined to locating closed structures along the belt.

Field reference localities for the Gossage Formation are B-13-71, B-23-71, A-14-71, A-23-71, A-18-71, B-8-71, F-8-71 and A-11-71. Most of the above sections were collected on a ten foot basis and the samples are available for detailed microscopic study. Strip logs of the above sections offer some general rock descriptions.

The lower contact of the Gossage is interpreted to be an unconformity surface on top of the Mount Kindle Formation. Generally, the basal 50 feet of the Gossage Formation comprise recessive buff weathered sandy dolomite with green shale partings. This detrital zone is also evident in wells drilled on the Peel Plateau and appears on logs as a "dirty" high gamma zone between clean carbonates of the Gossage and Mount Kindle Formations. Stratigraphic cross sections AA' and FF' (Enclosures 11 and 16) indicate that there may have been substantial relief on the unconformity surface before early Middle Devonian seas inundated the area. The upper contact with the Hume Formation is conformable and is picked at the highest occurrence of apparently clean pelleted limestone. Basal Hume beds are generally recessive weathered thin bedded argillaceous limestone and shale.

No diagnostic fossils were found in the Gossage Formation, however, based on regional work we prefer to assign the entire formation in the project area to the early Middle Devonian. On the basis of structural mapping and stratigraphic correlations, it is clear that the "Gossage lime" unit is correlative with the Landry Formation and the "Gossage dolomite" unit is correlative with the Arnica Formation. In addition all of these units are coeval with the Bear Rock Formation.

Landry Formation

The type locality as proposed by Douglas and Norris (1961) is an area in the Delorme and Whittaker Ranges in northwest 95K (NTS). The use of this formation name was restricted during the project to the area west of the Mackenzie River and south of the Keele River where Landry limestone generally overlies Arnica dolomite.

The Landry Formation is composed of well bedded dark grey to black micro-grained pelleted tight limestone which is medium to light grey weathered. Rare fossil fragments of brachiopods and ostracods (?) have been noted. The Landry limestone is part of a large early Middle

Devonian carbonate-evaporite complex which surrounds and buries the pre-Devonian arch centred in the Fort Norman - Norman Wells area. From the stratigraphic models (Enclosures 14 and 15) it is apparent that the Landry Formation represents the seaward margin of any limestone - dolomite - anhydrite layer, and therefore, a normal west to east facies pattern would be Landry limestone, Arnica dolomite and finally Bear Rock anhydrite. This facies relationship is identical to the Gossage "lime" - Gossage "dolomite" - Bear Rock anhydrite facies pattern at the east end of the Peel Plateau. The stratigraphic model (Enclosure 15, cross section EE') along the Dahadinni Range departs from the usual pattern and from our field observations we interpret that the Landry facies changes to Bear Rock facies with no intervening Arnica or dolomite facies.

The maximum measured thickness of Landry limestone is approximately 750 feet at E-21-71 and A-38-71 in the Rouge and Dahadinni Ranges respectively. Other reference localities for the Landry are N-3-71, F-27-71, I-28-71, Ex-22-71, A-34-71, B-51-71, B-48-71, C-130-71 and the Shell wells at Cloverleaf and West Wrigley.

The lower contact of the Landry is transitional with Arnica or Bear Rock beds and the upper contact is conformable with overlying Hume strata.

No diagnostic fossils were found, however, at A-34-71, in the Redstone Range an Eifelian age was assigned to a fossil collection from Landry strata.

The Landry Formation is tight and can be considered as an adequate seal.

Hume Formation

The type section of the Hume Formation is located on the east branch of the Hume River at 65°20'30" N, 129°58'00" W. The name was proposed by Bassett (1961) for a succession of fossiliferous Middle Devonian limestones and in places, shale, which overlies the Bear Rock Formation and underlies the Hare Indian Formation and is 400 feet thick at the type locality.

We extended the use of this formational name throughout the entire project area which creates some conflict in the southwest part of the project where officers of the GSC have used the terms Headless and Nahanni for units occupying the interval defined by Bassett. Our use of the term Hume outside the type area suggests that the Hume Formation is equivalent to the Headless and Nahanni Formations combined. This suggestion is, in fact, supported by faunal evidence; however, in the southwestern part of the project area where Hume isopachs are very thick (Enclosure 6), stratigraphic models indicate that the "extra" section is due to the addition of clean limestone, in the Nahanni interval, which is considered to be younger than type Hume and in this instance the use of the term Hume for the entire Headless-Nahanni interval may not be proper.

In Section A-23-71 at the type locality, 381 feet of strata were assigned to the Hume Formation. Here the dominant lithology is grey weathering black micritic limestone with 10 to 20 per cent inter-beds of black calcareous shale. The bedding character is distinctly nodular and this feature is especially characteristic of the lower part (Headless) of the Hume Formation. The section is fossiliferous throughout with a 10 per cent component of fossil debris. The fossils include coral heads, horn corals, brachiopods and crinoids.

The formation in the Norman Wells area can be conveniently subdivided into a lower shaly unit and an upper massive or resistant unit. This division is noticeable in the field exposures as well as on mechanical logs run in wells drilled in the area. In the Norman Wells area the lower unit is generally 250 feet thick, whereas the upper unit approximates 100 feet thick. In the southwestern part of the area the lower recessive unit is generally 150 feet thick whereas the upper massive beds thicken to almost 800 feet. Most of the thickening is in response to the addition of younger beds atop the section as recognized in the Norman Wells area.

Since the Hume-Headless-Nahanni interval is extremely fossiliferous, many papers have been written on the paleontology of these formations. Our collections when tied to our subdivisions indicate that the lower or "Headless" portion of the Hume Formation is Eifelian. Collections near the top of lower recessive unit in the Norman Wells area are dated as Givetian. Based on our collections, regional stratigraphic models (Enclosure 16, cross section FF') suggest that the type locality of the Hume should be diachronous (that is, Eifelian and Givetian) with most of the section assigned to the Eifelian.

Generally, the thickness (Enclosure 6) of the Hume Formation approximates 400 feet; however, west of the Mackenzie River and south of the Keele River the formation thickens to 900 feet. The isopach thicks have been contoured to represent two large banks which presumably had shallower water over them than the platform beds in the Norman Wells area.

On the other hand, the thickening of the formation in the Redstone and Root River areas may be in response to subsidence in this area and a greater amount of section was accumulated simply because a basin evolved. The "bank" interpretation is more interesting from the standpoint of "creating" prospects for oil and gas in that the "banks" could be rimmed by dolomitized fronts similar to the Slave Point front at Fort Nelson in northeast British Columbia. These alternative interpretations are introduced to emphasize the importance of gaining more subsurface control and also continuing paleontological studies in Nahanni limestones and Hare Indian shales to determine what the time lines are doing. Although the "stepping bank" model is intriguing, we have no field evidence for bank margins or dolomitization of Hume or Nahanni beds except for isolated dolomitized pods in the Big Smith Hills (F-20 and 20A-71) area where an unusual lower Paleozoic section is present.

Although upper Hume strata are highly coralline, the section is very tight. The presence of oil staining in the Big Smith Hills (F-20 and 20A-71) is associated with development of porosity due to dolomitization. East of Mount Cap, a small outcrop of dolomite with

Middle Devonian fossils is also dolomitized and porous. Dolomitization of Hume beds in these areas may be associated with the pre-Cretaceous erosion surface which should be near the level of the Hume Formation at these localities.

Both lower and upper contacts of the formation are conformable with bounding formations. There is evidence that both contacts are facies boundaries, and therefore, underlying or overlying formations may be laterally equivalent in selected areas (for example, Hare Indian - Nahanni; A-16-71).

Hare Indian Formation

The name "Hare Indian River shale" was applied by Kindle and Bosworth (1921) for the stratigraphic unit consisting of "bluish-grey calcareous shale in strata one inch to three inches thick" at the lower end of the Ramparts gorge on the Mackenzie River, near Fort Good Hope.

The isopach map (Enclosure 7) of this formation shows distribution of this formation over the entire project area with observed thicknesses varying from 50 to 800 feet. In the area west of the Mackenzie River and south of the Little Bear River, the Hare Indian shales, for mapping purposes, were included in the Horn River or Undivided Upper Devonian units.

The formation has two distinct shale units which persist throughout most of the project area. The lower unit comprises black calcareous shales and minor limestone carrying abundant tentaculites. On mechanical logs this unit is highly radioactive. These beds vary from a few feet to a maximum of 200 feet thick. The upper unit contains soft greenish-grey calcareous shales and limestones typical of most of the Hare Indian Formation. In the northern part of the area, the upper unit becomes more limy and several observations of lensing resistant weathering fossiliferous limestone units were made. At Atlantic Manitou L-61 the entire interval is occupied by a creamy porous limestone reef resting on platform Hume beds. At the junction of the Root and Landry Rivers (Fx-90-71), a minimum of 500 feet of massive bedded tight limestone, less than one mile across, rests on Nahanni beds occupying an interval mapped as Horn River laterally.

The lower contact of the formation is generally sharp, with the recessive black shales of the Hare Indian resting on resistant, blocky limestone beds of the Hume; however, our interpretation of the depositional history indicates that Hare Indian strata may be laterally equivalent to upper Hume and Nahanni strata. The upper contact is transitional with overlying Ramparts platform beds where the latter are present and is apparently sharply disconformable (?) beneath Canol shales in areas where the Ramparts is absent. At F-16-71 (Figure 35), near the type section of the Hume Formation, nodular - concretionary limestone bands in the Hare Indian appear to be truncated west to east along a well exposed creek wall.

Fossils collected during the project have not been studied in detail; however tentative identifications have been made and all indicate a Givetian age for the Hare Indian Formation.

In the northern part of the project area increased lime content in the shales suggests that more isolated "reef bioherms" similar to the one at Atlantic Manitou L-61 could be found in the subsurface in this area. Isolated Hare Indian "thicks" at the Bluefish and Redstone wells may be indicative of nearby reefing within or above the formation.

Ramparts Formation

The type locality of the section is taken to be at the Ramparts Gorge on the Mackenzie River above Fort Good Hope near the Glacier et al Ramparts No. 11 (Kindle and Bosworth 1921).

The Ramparts Formation comprises clean fossiliferous limestones which are considered to be biostromal in the lower 100 to 200 feet and biohermal in the upper part. For detailed lithology, reference should be made to Sections A-2-71 and F-6-71 where complete sections of the formation were sampled on a ten foot basis. Generally, the lower part of the formation is light to medium grey, well bedded limestone carrying Stringocephalus. These lower beds were observed to lense and intertongue into and with the underlying Hare Indian Formation in the vicinity of F-6-71 west of Powell Creek. The upper part of the section is blocky, well bedded, with cladopora beds and stromatoporoidal beds. Sparry calcite cement has filled most of the original organic porosity. On the flanks of the larger biohermal masses (Kee Scarp, Powell Creek) talus fans include reworked, well rounded cladopora fragments cemented by coral sand and sparry cement. Field localities do not, as a rule, exhibit visible porosity development, however, most beds appear to have good "earthy" porosity which is usually not effective in the subsurface due to extremely poor permeability. However, the potential of this horizon has been established by commercial production of light gravity oil from a "bioherm" beneath and west of Norman Wells.

The maximum thickness of the Ramparts Formation is 900 feet at Triad Carcajou I-24 (Enclosure 8). The producing reef at Norman Wells is approximately 500 feet thick as is the outcropping bioherm along Kee Scarp. Isolated occurrences of clean limy beds at the top of the Hare Indian Formation in the Bluefish, Redstone and Ochre River wells may be indicative of large bioherms in the vicinity. The pattern of isolated Ramparts carbonate masses could have been created by pre-Canol erosion of a uniformly thick carbonate bank; however, field observations of lattice framework and flanking talus fans lead us to believe that each isolated mass is a discrete bioherm and is consistent with the morphology expected from known studies of other well known reef horizons.

The lower contact is transitional with underlying Hare Indian shales whereas the upper contact may be disconformable beneath Canol black shales and is unconformable beneath Cretaceous sands in the northeastern part of the project area.

Generally, only Givetian fossils were collected in the formation; however, some flanking lag and allochthonous beds do contain early Upper Devonian fossils. At this time we do not have a complete paleontological study and cannot say whether reef growth persisted through the end of the Givet and continued during early Frasnian time or if reef growth terminated at the close of the Givet.

Potential for locating Ramparts bioherms in the subsurface exists throughout the entire project area. The occurrence of reef indicators in the southern part of the area is encouraging; however, the absence of known reefs in this area places a higher risk on locating biohermal buildups in the southern Mackenzie Plain. At this stage seismic is the most logical tool to use in exploring for isolated Ramparts reefs.

Upper Devonian

Horn River Formation

The type locality of the Horn River Formation is on Horn River, 9.5 miles above the mouth of Ferguson Creek. Our use of the name Horn River is in the sense of that established by Douglas and Norris (1962) in GSC Paper 62-33. The use of this formational name was restricted to the southwestern part of the project area.

The Horn River Formation was measured, described and systematically sampled at F-25-71 on the east flank of the Prairie Anticline adjacent to the Redstone River. At this locality the formation is 730 feet thick and is divisible into three distinct units which can be recognized in the subsurface of the Mackenzie Plain in the Shell Cloverleaf and Shell West Wrigley wells. The lower unit, 130 feet thick, comprises black calcareous concretionary shale with tentaculites and appears equivalent to the lower unit of the Hare Indian Formation farther north. The middle member is 350 feet thick and is composed of platy black silty pyritic shale recognized as the Canol Formation farther north. The upper member is 250 feet thick consisting of pyritic and argillaceous siltstone which is resistant weathering relative to the underlying and overlying units. Although the Hare Indian and Canol components are recognized locally at well exposed sections, the term Horn River received preference due to extremely poor exposure of these beds in this area. The resistant weathering upper siltstones are mappable, and the interval from the top of the Hume to the top of the "siltstone scarp" becomes a convenient "mappable unit"; hence, the use of the term Horn River.

The lower contact is a sharp break from resistant limestones of the underlying Hume Formation to recessive weathered shales of the lower Horn River. The upper contact is picked at the top of a resistant weathering siltstone interval which appears to be transitional with the overlying Fort Simpson Formation. Both contacts are considered to be conformable. The lower member of the Horn River may be a lateral equivalent of upper Hume beds, an observation partly confirmed by varying thicknesses of this unit at F-25-71, Shell Cloverleaf and Shell West Wrigley.

Regional stratigraphic models (Cross section II', Enclosure 19) indicate that the lower member of the Horn River should be Givetian whereas the middle and upper members should be Frasnian.

Since the formation is tight, no prospective horizons should be expected in Horn River beds.

Canol Formation

Bassett (1961) proposed this name for "the black shale unit which directly overlies the Kee Scarp (Ramparts) Formation". He gave the type locality as Powell Creek at the Mackenzie Mountain front where he assigned 75 feet dark grey to black, predominantly noncalcareous soft to very hard, greenish-yellow weathering shales to this formation.

This formation was recognized throughout the entire area; however, in the southern part of the area it was included in the Horn River map unit.

The Canol beds comprise platy black pyritic, siliceous shales which appear brittle and weather a typical splintery black, stained with white alum, yellow sulphur and orange iron oxide. The shales make a characteristic "tinkling" noise under foot.

A maximum thickness of 580 feet was obtained on Canyon Creek (B-2-71) on strike with Kee Scarp ridge. At this locality, the stratigraphic model (Cross section GG', Enclosure 17) depicts the Canol as a compensatory unit laterally equivalent to the Ramparts bioherm on Kee Scarp. In the Norman Wells oil field area a similar relationship can be demonstrated by subsurface data. This is not the case at Powell Creek where only 75 feet of Canol beds are present at a position almost adjacent to a Ramparts bioherm 700 feet thick. The relationship of the Canol Formation to underlying and apparently lateral units is not clear since there appears to be evidence for both an unconformable relationship and that of a normal fine clastic fill prograding across the basin. Perhaps the results of a detailed paleontological study of the Hare Indian - Ramparts - Canol interval will help to solve some of the problems.

We have supported the theory that the pre-Canol surface was never emergent and that Canol sediments were part of a prograding wedge of clastics smoothing a submarine topography that evolved as a result of complex bank and biohermal growth. However, this year we made several observations which are considered as excellent support for the proposal of an unconformity at the base of the Canol. First, extensive channelling and scouring plus apparent truncation of Ramparts beds on the south flank of Kee Scarp were observed in the Kee Scarp quarry at Norman Wells. Second, at a section (I-16-71) on the Upper Hume River, Canol black shales appear to truncated, west to east, underlying concretionary bands in the Hare Indian. Both observations could be considered insignificant in view of the scale of the observations; however, the evidence is at least present. The upper contact of the Canol appears transitional with overlying Imperial clastics. Cretaceous sands may rest unconformably on the Canol in parts of the project area.

Preliminary studies on samples from the Canol Formation indicate that the unit is early Frasnian in age.

Canol shales are considered to be excellent source rocks as well as excellent cap rock material.

Fort Simpson Formation

Cameron (1918) named the Simpson shale for 150 of soft greenish grey clay shales that occur on the Mackenzie River near Fort Simpson. Our use of the term Fort Simpson is in accordance with the usage of Douglas and Norris (1963) in GSC Paper 62-33.

In the southern part of the project area, the name Fort Simpson was applied to a succession of shales with interbedded siltstone and fine grained sandstones that overlie the Horn River Formation and are overlain by fossiliferous limestone of GSC Unit No. 25 or fossiliferous calcareous sandstone of GSC Unit No. 24. At F-25-71, on the east flank of the Prairie Anticline along the Redstone River, the Fort Simpson Formation is 1,940 feet thick. At Shell Cloverleaf I-46 the unit is 1,790 feet thick. At L-19-71 on the Dahadinni River, a minimum of 1,300 feet of shales and siltstones are assigned to the Fort Simpson Formation.

The Fort Simpson Formation is recognized as a map unit mainly because it is bounded by resistant units which are recognized throughout the southern part of the area. It is believed that both lower and upper contacts are transitional with bounding strata. The Fort Simpson Formation is characterized by lensing, wedging and channelling of stratigraphic horizons to such an extent that unconformities may be introduced within the section. Presently this is a point of contention at locality Cx-65-71 where the GSC has recognized an unconformable relationship between Cretaceous and Upper Devonian beds, whereas our work recognizes this locality entirely as Upper Devonian. At time of writing, samples collected at this locality had not been processed for microfauna and microflora. The GSC interpretation, (GSC Paper 62-33) invokes the use of a pronounced unconformity between Devonian and Cretaceous strata along the Redstone River where nonconformable units are well exposed. Although recognizing the possibility of the unconformity, we prefer (pending microfossil identifications) to refer the entire section to the Fort Simpson Formation.

No diagnostic fossils were found in the interval; however, Frasnian fossils were found in overlying GSC Unit No. 24 and, therefore, the entire formation is assigned to the Frasnian.

No suitable reservoir rocks were described in the marine section. The unit has excellent source beds and is a seal for underlying reservoir beds.

GSC Unit No. 24

This map unit was recognized in the southern part of the project area and mapped in the sense of Douglas and Norris (1963) who describe "Map Unit 24 as - "a resistant unit that forms most of the ridges and caps the highlands in plateaux of the region underlain by Upper Devonian strata. Fine grained grey sandstone that is medium to thickly bedded and brownish-grey weathering is characteristic, particularly of the lower part, and is interbedded with silty grey shale and grey micaceous, finely laminated siltstone".

At F-25-71 on the Redstone River the unit is 560 feet thick comprising lithologies as described above. In addition, it was noted that the sandstones are slightly calcareous, occasionally glauconitic and carry a sparse coral and brachiopod fauna. The sands are generally porous although quantitative values probably do not exceed 15 per cent.

The unit is recognized as a distinct map unit due to its relative resistant weathering character relative to the underlying Fort Simpson Formation and overlying GSC Unit No. 26. The unit is assigned to the interval 2,400 to 2,770 in the Shell Cloverleaf well.

Map Unit No. 24 is transitional with the underlying Fort Simpson Formation and overlying Unit No. 26. In the Redstone and Keele River areas, the unit probably subcrops beneath basal Cretaceous sands.

Fossil collections at F-25-71 and Cx-87-71 are tentatively identified as Frasnian and on this basis the entire unit is assigned to the Frasnian.

As noted previously the unit is porous, although fine clastics and calcareous cement reduce the effective porosity to a minimum. However, at subcrop localities the unit may be more porous due to leaching etc., and for this reason the interval should be regarded as a potential reservoir horizon in the subsurface of the Keele and Redstone River areas.

GSC Unit No. 25

Map Unit No. 25 as described by Douglas and Norris (1963) was recognized in the southern part of the project area apparently occupying an interval near the base of Map Unit No. 24. On Wrigley Plateau several horizons of limestone mapped as Unit No. 25 occur "within gently folded strata of Map Unit No. 24. Precise and relative stratigraphic positions are not known, and although they are all designated as Map Unit No. 25, they may not necessarily be correlative with the reefs (Map Unit No. 20) of the adjacent Camsell Bend map area" (Douglas and Norris, 1963).

Extremely fossiliferous limestones were examined at Cx-102-71, CX-98-71, Fx-82-71 and Cx-120-71, and all localities are assigned to GSC Unit No. 25. The limestone horizon is 55 feet thick at Cx-120 on the Root River and 35 feet thick at Fx-82 on Crescent Ridge Anticline. The interval 2,770 to 2,800 in the Shell Cloverleaf well is tentatively assigned to GSC Unit No. 25. GSC Map Unit No. 25 is expected to be present in the subsurface in an area bounded on the north by the Keele River, on the west by Longitude 125° West and on the east by the Mackenzie River. Over the southern part of this area the unit is at surface.

The unit comprises highly fossiliferous (mainly brachiopods with coralline and stromatoporoidal beds) "stinking" brown limestone which is fine grained and generally tight. Dark compacted argillaceous and bituminous (?) leaves surround nodular beds and fossils. The lensing character of the unit suggests that the limestones are reefoid. Coralline and stromatoporoidal beds are generally light grey to cream, very fine grained.

The lower contact is transitional with calcareous shales and nodular limestone bands similar to the lower transitional boundary of the Ramparts Formation. The upper contact was not observed, but it is interpreted to be relatively sharp beneath clastic beds of Map Unit No. 24.

Field identification of fossils collected from this unit indicates a Frasnian age.

Although the unit is tight at the outcrop localities, the "reefoid" character of the unit should be recognized as an indicator of possible reservoirs in the subsurface. Because the unit is fairly thin, it should not be regarded as a primary objective.

GSC Map Unit No. 26 (per Douglas and Norris, 1963)

Map Unit No. 26 was recognized and mapped in the southern part of the project area. Outcrops of this unit are confined to the Moose Prairie, Trench Lake and English Chief synclines, in NTS map sheet 95N.

Over 5,000 feet of concretionary greenish grey and black shales and glauconitic siltstones were measured along an east flowing tributary to the Redstone River (Fx-93-71). The shales of this unit feel characteristically "greasy" and a distinct reflective sheen is apparent on fragments of the shale at outcrop. Some of the shales are slightly calcareous. Resistant silty and siltstone bands occur in the interval; however, the unit generally weathers recessive above GSC Unit No. 24. In the Trench Lake and English Chief synclines several discontinuous wooded scarps are mapped within the unit, and it is assumed that silty and sandy intervals support these scarps. The unit is generally poorly exposed, therefore, no subdivision could be made and carried through the areas where it has been mapped.

The lower contact is transitional with beds of underlying GSC Unit No. 24. The upper contact was not observed; however, it is assumed that this unit was unconformably overlain by Cretaceous strata.

No diagnostic fossils were found in this unit. Douglas and Norris (1963) assign the lower part of the interval to the Frasnian and the upper part to the Famenian stages of the Upper Devonian.

The unit is mainly a fine clastic succession, and since it occupies synclinal areas where mapped, no potential for oil and gas in this unit is recognized within the project area.

Imperial Formation

The Imperial Formation is used in the same sense as Bassett (1961) proposed, to include in the project area Upper Devonian shales, siltstones and sandstones, overlying the Canol Formation and overlain unconformably by Cretaceous strata. The type locality has been modified to include 1,988 feet thick exposure on Imperial River (65°07'00" N; 127°51'00" W) described by Hume and Link (1945) plus 361 feet of shale exposed on the northeast flank of the Imperial Anticline as measured by Bassett (1961) and added to the base of the Hume and Link section.

The Imperial Formation was mapped in areas north of Little Bear River within the project area. The formation is subdivided into two members, a lower silty shale and an upper calcareous sandstone. Complete sections of the Imperial Formation were measured on the Little Bear River (B-47-71, D-17-71), on Powell Creek (A-13-71), on

Mountain River (F-7-71), on Hume River (B-9-71) and on a tributary of the Arctic Red River (D-7-71). The lower unit is generally ± 1,000 feet thick and comprises greenish-grey shales with siltstone and sandstone bands and occasional concretionary ironstone bands. Calcareous intervals in the succession do occur but are not common. The resistant weathered bands are usually laminated and carbonaceous streaks are not uncommon in the upper part. At D-7-71, the lower member of the Imperial Formation occupies an interval bounded by resistant silty and sandstone members which are scarp forming. The general weathering character of the interval is similar to that of outcropping Upper Devonian strata in the Redstone and Dahadinni River areas. This long range correlation equates the lower member of the Imperial Formation with the Fort Simpson Formation mapped in the southern part of the project area. Furthermore, at D-7-71 the lower member of the Imperial exhibits lensing, wedging and channelling similar to that observed within the Fort Simpson (see cross section II', Enclosure 19). The upper part of the formation comprises flaggy to slabby, greenish-grey calcareous sandstones with occasional sandy limestone bands interbedded with dark greenish-grey shale and silty shale. Brachiopods, crinoid stems and carbonaceous streaks were found in the unit. The upper unit is approximately 500 feet thick over most of the project area. At Powell Creek (A-13-71) approximately 800 feet of recessive weathered greenish-grey interbedded sands, shales and siltstones overlie the upper member of the Imperial Formation and are tentatively assigned to the Imperial Formation. Cross section II' (Enclosure 19) shows a correlation of these highest beds with GSC Unit No. 26 of the Redstone-Dahadinni River area.

The lower contact with the Canol Formation is a sharp lithological boundary; however, no hiatus is recognized or assumed. The upper contact is an erosional surface beneath Cretaceous sandstones. We have received some fossil identifications which are not consistent with field mapping. It is apparent that in the central part of the area our Imperial Unit may include basal Cretaceous sands and shales of the Sans Sault Formation. The upper member of the Imperial and the Sans Sault Formation comprise similar lithologies and weathering color and character is also quite similar. Although structural mapping may have included Sans Sault beds in the Imperial, stratigraphic sections are correct and do not fall prey to this trap.

Studies of fossil collections from the Imperial Formation are not complete, therefore, only tentative age assignments can be made. On the basis of regional mapping and lithologic correlations the Imperial Formation should be Frasnian in age. This is partly confirmed in Tassonyi's description of the Imperial Formation in the Norman Wells area. Our work confirmed that apparently equivalent lithologic units in the Redstone River area are Frasnian. However, isolated localities on the Mountain River (F-7-71) and near the Arctic Red River area (D-7-71) contain fauna in the upper unit which have been dated as Famenian. Norris (1968) measured and collected the section at D-7-71 and reports late Upper Devonian (Famenian) fossils from the upper member of the Imperial Formation. As previously noted the upper part of the Imperial may be correlated with GSC Unit No. 24 on the basis of stratigraphic position and similar lithology. However, Famenian fossils have been found in the Imperial whereas only Frasnian fossils have been found in GSC Unit No. 24. The ages of the units are not compatible with the lithologic correlation, therefore, the validity of the regional lithologic correlation is doubtful. However, it is possible that GSC Unit No. 24 type beds (Upper Imperial) were deposited as a prograding sequence from south to north (Redstone River to Arctic Red River) and therefore, lateral equivalents in the northern areas should be younger in age although they represent the same depositional environment.

The upper member of the Imperial Formation is porous; however, quantitative values are below 15 per cent. Calcareous cement and fine clastic matrix renders most of porosity ineffective. The Imperial Formation should not be considered a primary objective; however, it should be closely evaluated in all tests in the event that cleaner sands are developed or secondary processes have enhanced porosity.

Canyon Creek Sandstone (Upper Devonian)

The Canyon Creek Sandstone member at the base of the Imperial Formation is developed locally along the west flank of the Norman Range south of Norman Wells. On Canyon Creek (B-2-71) the sandstone is light grey, fine to very fine quartz grained with poor (10 per cent) intergranular porosity. The beds are slabby and are approximately 100 feet thick. The sandstone overlies the Canol Formation and is in a stratigraphic position similar to the upper siltstone member of the Horn River Formation. Although outstanding porosity was not seen in this section, it is interesting to note that clean lentils of sand do develop in the Upper Devonian sequence, and this short discussion of the Canyon Creek sandstone is included to alert the explorationist to the potential of similar Upper Devonian sand bodies in the subsurface.

Jungle Ridge Limestone (Upper Devonian)

The occurrence of the Jungle Ridge limestone is confined to the area in the vicinity of Imp. Bluefish No. 1 downstream from Bear Rock. A short distance upstream from Imp. Bluefish No. 1 at Ax-6-71, 182 feet of very fine grained, grey silty limestone interbedded with brown calcareous shale was measured and assigned to the Jungle Ridge limestone member of the Imperial Formation. The limestone is finely laminated and very tight. In the Bluefish well the interval 1,618 to 1,630 is recognized as Jungle Ridge limestone. An isolated outcrop of this member also occurs on Jungle Ridge proper, a short distance north of the Bluefish well.

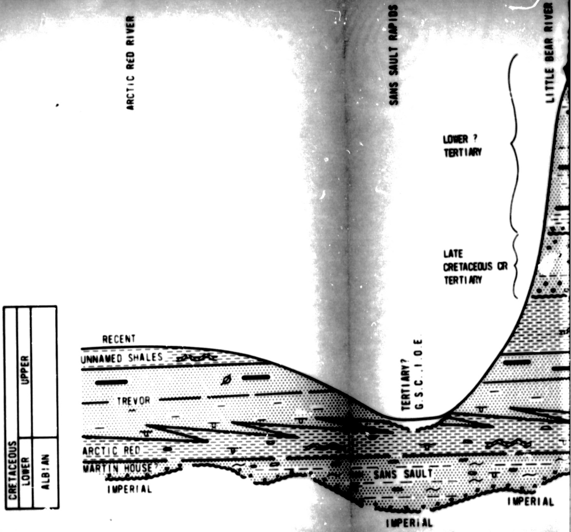
Occurrence of the limestone in the basal part of the Imperial Formation, above the stratigraphic horizon of the Canyon Creek sandstone member, is local and highly anomolous. The section is extremely tight and, on the basis of outcrop observations, has no reservoir potential.

Upper Devonian Undivided

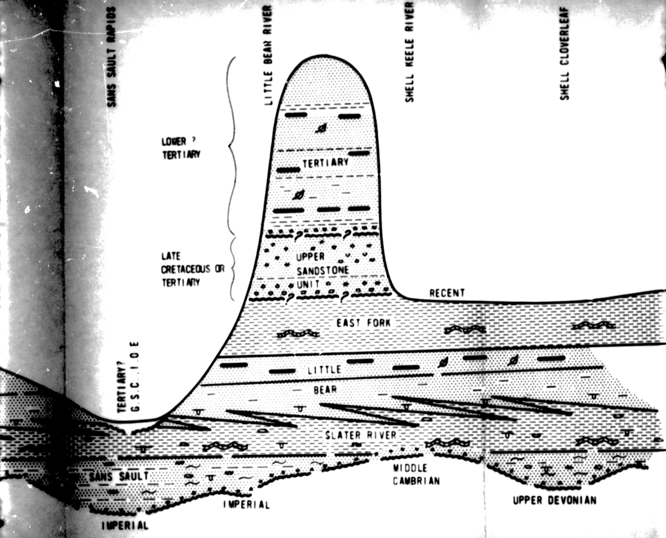
This "basket" term was applied to a map unit in areas where the Devonian clastic succession above the Hume Formation is not readily divisible due to poor exposure. Both Middle Devonian (Horn River, Hare Indian) and Upper Devonian (Horn River, Canol, Fort Simpson, GSC Units Nos. 24, 25, 26 and Imperial) Formations are included in this map unit.

Cretaceous

Exposures of Cretaceous strata are confined to the central part of the Mackenzie Plain area and the Peel Plateau area. In the field several distinct mappable units were defined and contacts were carried throughout the areas of exposure. The Cretaceous is a sand-shale sequence which may be up to 5,000 feet thick in aggregate, and due to striking similarities between different sand units and different shale units our confidence in assigning small exposures to a particular map unit in some areas is weak. Therefore, until samples at all outcrop localities are processed for microfossils and ages are available, we should be very cautious in evaluating structures which are defined by outcropping Cretaceous beds. We are aware of the "weak" spots in our mapping of the Cretaceous units; however, it is an impossible chore to communicate this "feeling" in writing. Therefore, we recommend that age determinations of Cretaceous samples should be made available to



ARCTIC RED RIVER
SANS SAULT RAPIDS
LITTLE BEAR RIVER
LOWER ? TERTIARY
LATE CRETACEOUS OR TERTIARY
RECENT
UNNAMED SHALES
TREVOR
ARCTIC RED
MARTIN HOUSE?
IMPERIAL
TERTIARY? G.S.C. I.O.E.
SANS SAULT
IMPERIAL
IMPERIAL
CRETACEOUS
UPPER
LOWER
ALBIAN



SANS SAULT RAPIDS
LITTLE BEAR RIVER
SHELL KEELE RIVER
SHELL CLOVERLEAF
LOWER ?
TERTIARY
TERTIARY
LATE
CRETACEOUS OR
TERTIARY
UPPER
SANDSTONE
UNIT
RECENT
EAST FORK
TERTIARY?
G.S.C. I.O.E
LITTLE
BEAR
SLATER RIVER
SANS SAULT
MIDDLE
CAMBRIAN
IMPERIAL
IMPERIAL
UPPER DEVONIAN

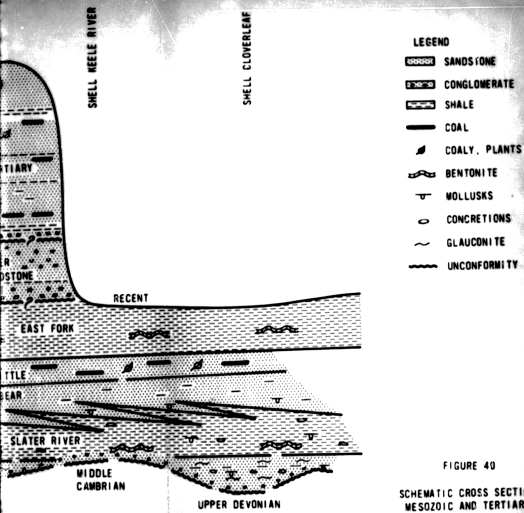


FIGURE 40

SCHEMATIC CROSS SECTION
MESOZOIC AND TERTIARY
BY

M. N. CHERNOFF, P. GEOL.
C. H. RIDDELL, GEOL. CONS. LTD.

DATUM BASE SLATER RIVER
SCALE: HORIZONTAL,

us, and in the event that a serious discrepancy exists between field mapping and paleontological studies, then we could advise on solutions to the mapping problems.

The oldest Cretaceous rocks found in the area are of Albian age. (Neocomian (?) and Aptian (?) shales may be present, Tassonyi.) Succeeding strata apparently represent continuous deposition through the remainder of the Lower Cretaceous and through all of the Upper Cretaceous. The Cretaceous interval was subdivided into five mappable units alternating sand, shale, sand, shale, sand. The upper sand and conglomerate unit may be of Lower Tertiary age. Formation names used in the field are in ascending order Sans Sault, Slater River (Arctic Red), Little Bear (Trevor), East Fork and Upper Sandstone Unit. For a detailed account of the history of nomenclature, reference should be made to Tassonyi.

Sans Sault Formation

The Sans Sault Formation is recognized as the oldest Cretaceous unit in the project area. The unit derives its name from work by Stewart (1945) and others associated with the Canol project. Originally, the sands and shales comprising the unit had a Group status, however, Tassonyi reduced this to a formational status. The type locality of this formational unit is taken to be the Sans Sault Rapids area on the Mackenzie River, where the formation is 1,411 feet thick as described by Parker (1944-6).

In the field we were unable to distinguish upper Imperial beds from the Sans Sault Formation, consequently beds of the latter formation were included in the Imperial. Fossil identifications received after the close of the field season indicate that the Sans Sault Formation is probably widely distributed and present beneath most of the Mackenzie Plain area. Stratigraphic cross section II' attempts to pick formational boundaries in some wells drilled in the project area. In the Norman Wells area the formation is approximately 300 feet thick. It may thin to zero over most of the area between the Little Bear and Keele Rivers and then thicken to over 500 feet on the south flank of the Fort Norman Arch.

The formation comprises greenish-grey fine to coarse grained quartz sandstones interbedded with greenish-grey concretionary shale. Abundant glauconite grains are present, and this occurrence is considered to be characteristic of basal Cretaceous sandstones in the area. Glauconite was found in underlying Devonian beds and overlying Cretaceous beds (Little Bear) but not in abundance.

The formation rests unconformably on a surface which may have had high topographic relief (500 feet + (?)) and is overlain conformably by black shales of the Slater River Formation.

Previous workers have determined that the formation is mainly Albian in age, however, in the Norman Wells area older (Aptian (?), Neocomian (?)) beds may be present.

Since the sands are porous, they should be considered as an objective horizon. The sands probably have an erratic distribution on an unconformity surface, and although this is appealing in the sense that numerous reservoir systems may be present in the subsurface, it is also disturbing in the sense that fields will be risky to develop.

Basal Cretaceous Sands

Basal Cretaceous sands were examined at several localities where the sands appear to be overlain by black shales of the Slater River Formation. At some of the localities, regional studies indicate that the Sans Sault Formation should be present, however, we did not recognize the Sans Sault at these localities. It may be that Sans Sault beds weather similar to the overlying Slater River and the division is not readily apparent. Also local facies changes of Sans Sault beds to Slater River type beds may occur. Another explanation is that Sans Sault beds are not present at these localities; however, as noted previously, our regional studies indicate that the interval should be present.

Basal Cretaceous sands were examined at Cx-32-71 (Arctic Red River), at D-7-71 (Tributary Arctic Red River), at Cx-37-71 (upper Hume River), at Bx-9-71 (Tributary Cayna River), at A-9-71 (Mountain River), at A-13-71 (Powell Creek), at Jx-18-71 (Lac A Jacques) and at A-25-71 (Mount Clark). The thickness varies from a few feet at Cx-32-71 to 75 feet at Cx-37-71. The sands vary from tight at Cx-37-71 to extremely porous at A-25-71 and to porous and highly oil stained at Jx-18-71.

The sand is characterized by well rounded quartz grains varying from very fine to conglomeratic with abundant green glauconite grains. Another characteristic occurrence is abundant vertical tube casts (Scolithus - like ?)

Where the contact with the underlying Devonian beds is exposed, the surface is uneven and channelled. Basal sand deposits are mainly channel fill and any bed has very little lateral extent. North of the project area (Jx-18-71) oil sands are a common occurrence. On the east flank of Mount Clark (A-25-71) clean quartz sands were estimated to be 30 feet thick. Here the sands are extremely porous and crumbly.

Basal glauconitic sands should be considered an objective horizon in any prospect which may have the section at depth. Distribution of sands is expected to be erratic on an unconformity surface.

Slater River Formation

The type locality of the Slater River Formation is on Slater River, and the unit was first described by Foley (1944a) and first published by Stewart (1945).

The Slater River Formation was mapped in area east of the Mountain River extending south to the Nahadinni River. The formation, which is predominantly black shale, is the first continuous mappable unit recognized above Devonian beds in the project area. The unit was examined at a locality near the type section of Slater River (Cx-10-71), on the Mackenzie River (Cx-11-71, Cx-13-71), on Imperial River (Cx-137-71, Cx-138-71) and Mountain (A-10-71) River.

The formation comprises soft black fissile shales with concretionary ironstone bands, white bentonite seams, fish fragments, pelecypod fragments and abundant clear gypsum lathes along bedding surfaces. Outcrops weather to mobile slumped masses with white alum and yellow sulphur staining. No full section was measured in the field, however, subsurface data indicated that the unit varies from 650 to 1,000 feet thick. Some calcite "beef" bands were found in the interval and when these are recovered as chips in wells, the prismatic fragments could be misinterpreted to be pelecypod fragments.

Both upper and lower contacts are interpreted to be transitional with bounding units.

We have received some fossil identifications on collections made during the project, and they consistently indicate a lower Cretaceous age (Albian).

The section is marine and should be an excellent source rock for generation of hydrocarbons.

Arctic Red Formation

The Arctic Red Formation comprises shales and siltstones similar in character to that of the Slater River, and the two units are interpreted to be coeval. The type locality of the formation is along both sides of the Peel River with exposures along Cranswich and Arctic Red Rivers considered as supplemental. The name was applied by Mountjoy and Chamney (1969) to all recessive lower Cretaceous shales and siltstones that occur beneath the Trevor sandstones and above the Martin House Formation.

The formation was examined at many localities on the Ramparts, Hume and Arctic Red Rivers; however, no estimate of thickness of the formation was determined. Generally, the unit comprises rusty weathered black fissile shales with bentonite seams, concretionary ironstone bands, and silty beds. No diagnostic fossils were found; however, samples processed for microfauna have yielded Lower Cretaceous (Albian) forams.

The unit was mapped in the western part of the project area where Mountjoy and Chamney (1969) report its occurrence. From reconnaissance observations, we feel that the unit is much thicker than the coeval Slater River Formation.

Little Bear Formation

The Little Bear Formation outcrops extensively along the Little Bear River where the type locality was first described by Link and given official recognition by Stewart (1945). Downstream from the area of the type locality we measured a nearly complete section of Little Bear sands at A-24-71. Here, the formation is a minimum of 900 feet thick comprising marine sands in the lower part and nonmarine sands in the upper part. The sands are generally fine grained with porosity ranging 10 to 25 per cent. Large pelecypod fragments were found poorly preserved.

Observations of this unit at other localities on the Redstone River (F-21-71), on the Dahadinni River (Cx-95-71) and below the Cambill Range (Cx-118-71) suggest that the formation comprises a series of regressive sand bars and each complete cycle varies from 150 to 250 feet thick. The upper part of the formation, which contains coal beds and much coaly material, is interpreted to be a deltaic sequence which prograded over previously marine areas. The lower marine sand bars resemble Cardium and Viking sand developments in southern Alberta, and their log expression in the subsurface (Shell Keele River L4) is strikingly similar.

In the lower part of the section each marine cycle is composed of, in ascending order, fissile black shales with concretionary bands and minor siltstone grading upward into argillaceous siltstone beds which are extensively burrowed. The cycle continues transitionally upwards into silty and sandy beds which become progressively cleaner and coarser grained. The top 15 to 50 feet of each cycle is generally capped by a massive, cross-bedded quartz sand unit which is highly porous. Marine shales overlie the highest sand unit in each cycle. Sands comprising the Little Bear Formation are generally grey on fresh surface and weathered surface.

Sands found at the top of Cretaceous intervals in the Mackenzie Plain area, west of the Norman Range, probably belong to the Little Bear Formation; however, because of the isolated occurrences, they were included with the Slater River Formation on the surface maps.

The lower contact is transitional with the Slater River Formation and the upper contact is believed to be conformable with overlying East Fork shales.

Poorly preserved pelecypods were commonly found in the interval, however, very few age dates have been obtained. Beds assigned to the Little Bear Formation on Redstone River (F-21-71) contain Upper Cretaceous forams. On upper Little Bear River at Cx-84-71, samples collected at or below the base of the Little Bear also contain Upper Cretaceous forams. On the basis of these few identifications we prefer to assign the entire Little Bear Formation to the Upper Cretaceous.

The lower part of the formation contains several marine cycles which include well developed sand bars. These beach bars are expected to be extensively developed and will probably have a simple trend along which reservoir type rocks could be expected with very little risk. The marine bars probably have seaward (eastward) margins and large stratigraphic traps are envisioned at these margins. Prograding beach bars across the Mackenzie Plain area could form several parallelling reservoir systems beneath cover between the Little Bear and Dahadinni River areas west of the Mackenzie River. Initial attempts at evaluating these sands will probably take the form of drilling structures which have the formation at depth. Later exploration will probably attempt to locate the margins of the bars to find large stratigraphic traps. Maximum pay in any one cycle will not exceed 50 feet, however, several cycles could be stacked at any location.

Trevor Formation

"The prominent resistant sandstones forming mesa-like hills immediately north of the Mackenzie Mountains and occurring above the recessive shales, silty shales and shales of the Arctic Red Formation are herein named the Trevor Formation" (Mountjoy and Channey, 1969).

The type area is designated as the Cranswich River where more than 1,000 feet of continuous section is exposed.

The formation was observed at several localities on the Hume, Ramparts and Arctic Red Rivers where generally fine grained, grey sandstones with carbonaceous and conglomeratic streaks comprise slabby to blocky beds.

Abundant dark grains give the sand a salt and pepper appearance. White clay (or silica?) infill destroys most of the porosity. This unit is interpreted to be coeval with the Little Bear Formation; however, surface mapping suggests that west of the Mountain River, Trevor sands occur progressively lower in the section westward. Therefore, it is apparent that basal Trevor sands are older than sands in the Little Bear and are, in fact, lateral equivalents of the Slater River Formation.

Mountjoy and Channey (1969) report that the Trevor Formation is mainly of Lower Cretaceous (Albian) age. Field observations suggest that in the project area the formation is probably diachronous (Lower and Upper Cretaceous). Within the project area the Trevor Formation is at surface, therefore, no oil and gas potential is considered.

East Fork Formation

The East Fork Formation overlies the Little Bear Formation and the name was originated by T. A. Link in a private report. The name was used by the Canol Geologists and was given official status by Stewart (1945).

Within the project area, the East Fork Formation was mapped in an area west of the Mackenzie River between the Little Bear and Dahadinni Rivers. Near the type locality at the junction of the Little Bear and East Fork Rivers we measured (A-32-71) 180 feet of grey weathered grey fissile shale with minor bentonite and concretionary ironstone bands. Near the mouth of Keele River (A-33-71) over 300 feet of grey weathered dark grey fissile shales with bentonite and concretionary bands were assigned to the East Fork. At both localities the intervals are characterized by floating sand and chert granules in shales surrounding concretions which occasionally are composed of similar granules. At N-1-71 on a tributary of the East Fork River, a 10 foot bed of white bentonite was described in the lower part of a well exposed grey plastic shale succession. The East Fork Formation weathers to soft flowing masses of mud not unlike the weathering character of the older Slater River Formation. No complete sections of the formation are available, however, we estimate that the section may be up to 1,000 feet thick.

Forams extracted from samples collected at the above mentioned sections indicate an Upper Cretaceous age for the East Fork Formation.

The East Fork is conformably underlain by the Little Bear Formation and transitionally overlain by sandstones of the Upper Sandstone unit of either Cretaceous or Lower Tertiary age.

Upper Sandstone Unit

We applied this name informally to a sandstone interval overlying the East Fork Formation in the Keele and Redstone River areas.

On the Keele River at Cx-53-71 the unit comprises yellow-brown and grey-brown weathered sandstone with shale interbeds. The sandstone is soft dark greenish grey and grey, crumbly, blocky to massive bedded and cross-bedded. The sands contain medium grained quartz and dark chert grains with kaolinitic (?) flecks and carbonaceous partings and plant stems. Some bands of sandstone are extremely hard (concretionary). Porosity is estimated to be 20 per cent with fair permeability. The interbeds of shale are dark greenish grey, very silty to sandy and platy splitting. At locality Cx-77-71 beds assigned to this unit are non-bedded grey gravel containing rounded grey and black chert pebbles. At Cx-93-71 on the Redstone River massive sands were examined and assigned to the Upper Sandstone Unit on the basis of stratigraphic position and the characteristic appearance of extremely hard concretionary bands of sandstone.

No complete section for the unit was obtained. Field mapping indicates that the unit exceeds 500 feet in thickness and may approach 1,000 feet.

To date, we have not received any identifications on microfauna which may be present in the samples collected. On the basis of regional mapping we suggest that the unit probably represents the close of Upper Cretaceous and the start of early Tertiary deposition.

Since the unit is sufficiently covered beneath thick Tertiary clastics in a synclinal area west of Stewart Lake, it could be considered an objective horizon on the basis of much porous sand content.

Tertiary

A broad gentle syncline west of Stewart and Tate Lakes preserves a thick (up to 3,000 feet) succession of poorly consolidated clays, muds, gravels, sands and shales with coal beds and opal horizons. The section is well exposed along Tertiary Creek; however, it is not continuous. Many short sections were measured along the Creek and by using marker beds a composite section was compiled from the following localities, B-24-71 to B-31-71 inclusive, and B-40-71 to B-42-71 inclusive. The Tertiary section in the "Tertiary Hills", west of Stewart Lake, contains striking contrasting colored units and weathers into "badlands" not unlike those in the Drumheller area.

The Tertiary section contains numerous loosely consolidated porous clastic intervals; however, they have limited lateral extent and are extremely dirty. Although the oil and gas potential of the Tertiary in this area should not be overlooked, we do not consider the Tertiary as a primary objective. The potential of coal beds is discussed under a separate heading, "Coal Potential".

To date Tertiary samples processed for microfossil content have proved barren. Earlier workers report that early Tertiary plants were found in the Tertiary basin south and west of Fort Norman.

TECTONIC HISTORY

The oldest Phanerozoic strata found in the area are of late Early Cambrian age and occur as isolated pods with intervening areas of no record. Early Cambrian seas probably covered most of the Mackenzie Plain area within the Project Boundary; however, it is not clear if this sea was connected to or part of a more extensive Lower Cambrian marine sea located in the vicinity of the present day Backbone Ranges of the Mackenzie Mountains. A regional unconformity is recognized at the base of the Paleozoic.

Middle Cambrian seas flooded most of the project area and a thick salt succession was deposited beneath the Mackenzie Plain. Middle Cambrian seas may not have covered the Canyon Ranges area west of Mountain River. During late Cambrian and Early Ordovician time, a thick succession of platform carbonates was deposited over the entire project area. Facies and isopach maps of Cambrian beds suggest that the western Canyon Ranges area was probably positive at the onset of Cambrian sedimentation, but was completely inundated by the close of Cambrian time.

At the close of the Early Ordovician epeirogenic uplift occurred and early Paleozoic sediments were subjected to a minor erosional cycle. The southwest part of the project area remained submerged, accumulating a thick succession of open-marine limestone during the Middle Ordovician. At the close of Mid-Ordovician time, the uplifted areas were subjected to additional movement and areas submerged during Mid-Ordovician time were also elevated. A major erosional period is recognized between the close of Mid-Ordovician and the pre-Richmond stage of the Upper Ordovician. Field observations show that over 1,000 feet of strata were eroded in the Gambill Range and Red Dog areas, and that a recognizable angular unconformity occurs between the Sauk and Tippecanoe sequences.

The Upper Ordovician marked a period of widespread transgression of the sea across most of the area. A small area in the vicinity of the Shell Keele River well may have remained positive. The shelf areas were the site of carbonate deposition accompanied by prolific organic growth. In the southwest part of the area the margin of the shelf was the site of extensive reef growth near a subsiding basin. Deeper water areas lay south and west. This period was the start of the evolution of a subsiding basin located west of the Mackenzie River and south of the Keele River. After Lower Silurian time the sea may have withdrawn to this area and restricted sedimentation of Middle and Upper Silurian and Early Devonian carbonates to the basin area. If Mid-Silurian through Early Devonian seas covered any of the project area north of the Keele River, their record of deposition was eroded prior to early Mid-Devonian time. During Mid-Silurian to Mid-Devonian time an extensive arch developed through the Fort Norman - Norman Wells area. The west flank of the arch was relatively shallow dipping while the east flank was probably steep. During this time the Tippecanoe (Mount Kindle) sequence was completely stripped off the Norman Range and a substantial part of the underlying Sauk (Franklin Mountain) sequence was also lost due to erosion.

Devonian seas slowly encroached upon the arch until it was completely submerged in early Mid-Devonian time. Lower and early Mid-Devonian carbonates and evaporites represent a barrier-shelf facies complex which first surrounded the arch and then moved across the arch towards the shield (eastward). During late Eifelian time a major transgression of the sea across the area left a record of deeper water sediments (Headless). Subsequent withdrawal or standstill permitted the development of limey carbonate banks to form as part of a bank complex in the southwest part of the area. The Norman Wells area continued to receive deeper water sediments.(Hare Indian) until late Givetian time when prolific organic growth formed many island reefs (Ramparts). Reef growth terminated at the close of the Mid-Devonian possibly due to a withdrawal of the sea from the area.

The Upper Devonian period was a time of clastic deposition, interrupted by short periods of carbonate deposition and accompanying biostromal and biohermal reef growth.

No record of the Mississippian through Jurassic periods is available in the area. It is assumed that the seas withdrew at the close of the Devonian and the area was subjected to a long period of erosion.

At sometime prior to the Lower Cretaceous (Albian), an uplift which could be termed orogenic elevated a small area near the Shell Keele River well. Similar pre-Cretaceous structures may be present beneath the cover of Cretaceous and Tertiary sediments in an area between the Little Bear and Keele Rivers. Lower Cretaceous seas flooded the area smoothing topographic relief with marine sand fill. Black marine shales were deposited over the basal sands, and a relative shallowing or withdrawal of sea at the close of the Lower Cretaceous is indicated by the deposition of a thick sand sequence (Little Bear) which prograded west to east across the project area. In late Cretaceous time a second major transgressive cycle left up to 1,000 feet of black marine shales which were eventually covered by a Tertiary clastic sequence derived from the west.

During Mid or Late Tertiary, major orogenic movements resulted in the folding and faulting of Precambrian through Lower Tertiary beds. From the close of Tertiary time to present a major erosional cycle continues.

STRUCTURAL GEOLOGY

Local and regional unconformities, folding and faulting were the dominant structural elements observed during the project study. Isolated occurrences of "diapiric" structures were also noted.

The occurrence and distribution of unconformities in the section has been discussed under the headings Stratigraphy and Tectonic History. The discussion of Laramide structures is presented under subheadings referring to the general areas where structural style appears to be consiste[illegible] due to the involvement of uniform stratigraphic packets.

South Project Area (Keele River - Root River)

This area is characterized by broad synclinal areas of Upper Devonian and Cretaceous strata between narrow north trending anticlinal ranges which expose strata as old as Middle Cambrian. The western part of this area which is within the Canyon Ranges of the Mackenzie Mountains includes broad anticlinal structures exposing Precambrian sediments. The eastern margin of the area is bounded by the McConnell Range which also exposes Precambrian strata locally (Mount Clark).

It is our view that structures in this area evolved through a compressional and shortening system involving principles similar to those documented in the literature pertaining to geological structure in the Canadian Rocky Mountains. We believe that concentric folding and faulting formed west to east above detachment zones which climb in the sedimentary section in an eastward direction. More specifically, structures in the Canyon Ranges exposing Precambrian sediments are probably rooted in a detachment zone deep in the Precambrian. At the longitude of the Redstone Range the effective detachment zone is at the level of the Precambrian - Cambrian contact presumably in Saline River beds. Field evidence for this detachment is the Redstone Range itself, which exposes Saline River beds in the core flanked by steeply dipping Cambrian through Middle Devonian beds. An easterly dipping thrust, the Redstone Fault, has been mapped along the axis of the structure in the southern part of the range. North of Wrigley Lake in the Redstone Range, a west dipping thrust has been mapped along the east flank of the structure. East of the Redstone Range the structures generally expose Devonian carbonate rocks in the core, and here we believe that the effective detachment zone is at the level of the Camsell Formation.

In the areas of the Red Dog Anticline, the Moose Prairie Anticline, the Silvan Anticline, the North Dusky structure and the Dahadinni Range we prefer to interpret the structures as anticlinal folds resulting from the climb of a thrust fault from the Saline River through Cambro-Ordovician and Silurian strata into the relatively incompetent Camsell unit. Therefore, repetition of Mount Kindle and Franklin Mountain strata may occur in the structures providing structural traps.

In this area we expect in the subsurface the presence of both the Saline River and Camsell horizons. Both of these units are considered to be relatively incompetent on the basis of field observations. Therefore, in this area we would expect a variety of structures formed as the result of shortening or slippage atop or within either horizon. It is possible that good structural closure at the Hume level may not persist below the Camsell horizon. Therefore, structures in this area should be evaluated seismically, and the following horizons MUST be identified on the seismic sections to properly interpret the subsurface structural style:

(a) Top Hume/Nahanni

(b) Top Kindle

(c) Saline River

Based on our experience with detachment or décollement zones in the southern Rockies, we predict that all three horizons should be good seismic reflectors.

It is not within the scope of this report to detail the alternate interpretations of subsurface structure in this area. Based on field observations, our feeling is that the accepted structural principles used to explain structural geology in the southern Rockies and Foothills are applicable to this area. Therefore, we would not be surprised to find tear faults, flat thrusts, folded faults or several miles of horizontal displacement along a thrust fault. We propose this structural style for this area without benefit of seismic data or well control, and for this reason extreme caution should be used in adapting our proposals. Without subsurface control we are unable to document any of our theories, and therefore, any structure sections utilizing these principles should be regarded as tentative.

We do recommend that geological interpretations of seismic data in this area at least consider the following:

1. Recognize that at least three major detachment or décollement zones may be present within the Phanerozoic section. From field observations we interpret the zones to be in ascending order

   (a) Saline River (Top Precambrian)

   (b) Camsell (Near Top Kindle)

   (c) Base Upper Devonian Clastics (Top Hume)

2. Recognize that there should be uniform and consistent "regional" dip of the Phanerozoic section.

3. Recognize that structures formed west to east and general assymetry is west to east.

4. Recognize that the amount of shortening across regional strike along any line of section should be equal to the amount of shortening along a parallel line of section. It is apparent that whereas the fold is the dominant shortening device in some areas, faulting is the dominant shortening device in adjacent areas along strike. We propose the use of tear faults to transfer motion from one detachment zone to another along regional strike. The tear faults can be recognized as an alignment across regional strike of plunging ends of folds. Surface geological maps in the Redstone - Dahadinni River area show the locations of proposed tear faults.

5. Recognize that many anticlinal structures are present west of the Mackenzie River between the Keele and Root Rivers and that most structures are probably associated with faulting. The problem is to confidently determine which reservoir horizons have closure and which reservoir horizons are not involved (see Surface Geological maps). Seismic data is required to determine which detachment zones are operative at any structure.

Diapir-like structures were noted in the south Dusky Range and at the junction of the Landry and Root Rivers. In the Dusky Range an arcuate fault tract confines Camsell and younger strata to a "pop-out" structure over younger beds. Unusual contact relationships along the fault suggest that flowage of Camsell gypsum has occurred along the fault zone. At the junction of Landry and Root Rivers a mass of reddish stained gypsum and red and green shale of probable Camsell age has apparently intruded through younger Arnica, Landry and Hume strata. Huge blocks of bedded limestone have been assimilated in the complex core, suggesting that the diapir "roofed" overlying strata as it moved upsection. In this area, the diapir-like structures may have been triggered by intense folding and faulting along the Dusky Range during the Laramide orogeny. At the Landry - Root locality, a 500 foot isolated late Givetian bioherm overlies the diapir and in this instance ancestral diapiric movements may have arched overlying Nahanni platform beds providing a shoal favorable for organic reef growth.

Little Bear River - Keele River

The major structural features in this area are west to east:

(a) Gambill Range Thrust (Little Bear Thrust)

(b) Summit Creek Anticline

(c) Tertiary Basin

(d) Mackay Range

(e) Quaternary Basin - east of Mackenzie River

(f) St. Charles Range

The Gambill Range thrust fault is mapped from the Keele River east of Inlin Brook northward and then northeasterly to the junction of the Little Bear and East Fork Rivers. Stratigraphic relationships at the fault vary from Cambrian Saline River over Devonian Hume at the south end to Saline River over Tertiary at the northeast end of Gambill Range. East of Inlin Brook flat lying Cambrian beds overlie overturned Hume beds and Upper Devonian shales. Structural observations at Ax-31-71 clearly show that the fault is flat lying and that several miles of horizontal movement is indicated by the arcuate surface trace of the fault. One small area of Cambrian beds at this locality is actually an outlier (Klippe) above the thrust fault. North of this locality the trace of the fault swings northeasterly perpendicular to regional structural strike. The fault is recognized to be a major thrust fault which may have in excess of twelve miles of horizontal displacement. The northeasterly trending part of the fault trace is interpreted to be a tear fault. Folding of this fault is indicated along the Little Bear River where arching strata reflect the north plunging nose of the Summit Creek Anticline.

The Summit Creek Anticline is a large fold exposing Cambrian Saline River beds in the core. The structure is strongly assymetric to the east along a west dipping thrust fault.

The Tertiary basin is structurally very simple with shallow dipping strata defining a synclinal trend west of Stewart Lake.

The MacKay Range is a narrow sinuous trend of very steeply dipping Cambrian through Mid-Devonian carbonates which are involved in complex structures which change assymetry along strike. It appears as though the entire range composed of competent lower Paleozoic carbonates is diapiric upward into and through Upper Devonian, Cretaceous and Tertiary strata.

A broad glaciated plain between the Mackenzie River and the St. Charles Range is probably underlain by thick Quaternary sediments overlying a very thin Mesozoic and Paleozoic section. We expect that older Paleozoic rocks are at very shallow depth east of the Mackenzie River.

The St. Charles Range is a shattered panel of Cambrian through Middle Devonian carbonates dipping steeply eastward and occasionally overturned. The Range appears to have been elevated along an easterly dipping thrust.

Oscar Creek - Imperial River to Little Bear River

This sector includes the frontal Canyon Ranges of the Mackenzie Mountains, the Mackenzie Plain and the Norman Range of the Franklin Mountains.

The structure of the Canyon Ranges is characterized by broad folds which are best described as "box folds". Precambrian "rusty shales" are exposed in the cores of the anticlinal structures which are up to fifteen miles across. The synclinal areas, generally less than four miles across, preserve early Paleozoic platform beds. The structural style at the present-day erosional level is clearly déjectif, and it is assumed that the structures have formed above a detachment zone low in the Precambrian sedimentary section. The boundary between the Canyon Ranges and the Mackenzie Plain is abrupt along a steeply east-dipping panel of Paleozoic sediments. Although no faulting is evident at the mountain front, we expect that Precambrian over Paleozoic faulting does occur in the subsurface immediately to the east. There, we predict a transfer zone of horizontal displacement from a Precambrian decollement to a Saline River décollement.

The structure of the Mackenzie Plain at this latitude is relatively simple. Shallow west dipping strata of the Norman Range dip below the Mackenzie River, and a continuous gentle west dip persists below the Plain to the east margin of the Canyon Ranges. Since we would prefer to link shortening of the Precambrian section by "box folding" in the Canyon Ranges with shortening of the Paleozoic section by thrust repetition along the Norman Range by transfer of horizontal displacement from a low décollement level (Precambrian) to a higher décollement level (Saline River), we require the Plain area to be a simple homocline gliding above the Saline River décollement. This interpretation tends to down grade the intervening Plain area in the sense that no structures should be expected. Since this conclusion is based on a theoretical interpretation, the explorationist should retain an open mind on the subject and be prepared to accept other interpretations which could lead to the location of a large structure.

The Norman Range starts at Oscar Creek Gap where very little horizontal displacement is evident and then trends southeasterly for approximately sixty miles to Bear Rock. In the southern part of the range, the Cambro-Ordovician (Franklin Mountain) section is repeated several times by westerly dipping thrust fault. Since Precambrian rocks are not involved in the structures, we interpret that thrust faulting originates along the Saline River décollement, cuts charply upsection through the Cambro-Ordovician and then may run along another detachment surface near the base of the Bear Rock.

Carcajou - Beavertail Area

In the Carcajou - Beavertail area, northwest of the Norman Range, deformation differs somewhat from the structural style of the other portions of the project area. This area is generally flat lying except for abrupt linear anticlinal features. These features follow two directions almost without exception, one direction being east-west and the other being northwest-southeast. These directions are very dominant, and if the ridge trends are plotted, the plot resembles a rhombic fracture? pattern. All the structures are assymetrical, but assymetry can be in either direction and assymetry sometimes changes along the feature. The steep limbs are vertical and usually faulted in the structure with greatest relief. The more gently dipping limb dips 10 to 40 degrees until it reaches the regional elevation where it dips ± 100 feet per mile to the southwest. The structures plunge very rapidly in both directions. Bear Rock breccia appears to have been dragged along some fault planes. Taken together, the criteria strongly suggest that these features are basement controlled structures, possibly assisted by evaporite flow in the Saline River Formation.

On the other hand, there is considerable evidence that the majority of the deformation in the Mackenzie Mountains and Discovery Range is compressional. In the Carcajou - Beavertail area there are no exposures of Proterzoic rocks and there is no evidence that Proterozoic beds are deformed. The western limit of deformation apparently coincides with the western limit of Saline River Formation, which would be the presumed décollement if these are compressional features. D. G. Cook of the Geological Survey of Canada (Report of Activities, Paper 69-1 Part A) presented evidence and conclusion that these structures are compressional in nature, although recently he has expressed less certainty of this interpretation (personal communication).

Assuming the objective horizons in this area are post Saline River Formation the nature of deformation is largely academic insofar as predicting the shape of and closure on the objective horizons. Several structures are eroded down to the lower Franklin Mountain and using these as models it is felt that the shape of the structures with cover can be predicted reasonably accurately.

The Mackenzie Plain area southwest of the area under discussion appears to be genetically related in that the dominant structural feature, the Imperial Anticline, contains similar structural trends and reversals of assymetry.

West Project Area (Mountain River - Arctic Red River)

This area has three distinct structural belts: the frontal Canyon Ranges, a foothills fold and the Peel Plateau.

In this area the Canyon Ranges structure is dominated by a large southerly dipping thrust fault which elevates Precambrian strata over Paleozoic platform beds. Straight south of Yadek Lake in the upper Hume River area a panel of Paleozoic carbonates is thrust over Upper Devonian clastics along a northerly dipping thrust fault opposing regional structural symmetry. It appears as though the frontal Canyon Ranges chose to underthrust the Peel Plateau at this locality.

A frontal foothills fold was mapped across the Arctic Red River close to the Mountain Front. In echelon folds persist eastward forming a foothills fold belt.

The Peel Plateau area north of the foothills fold is characterized by a broad syncline in Cretaceous strata. It is probable that the south flank of the syncline has been elevated by underthrusting of Paleozoic strata from the south. A few small folds were mapped in the Peel Plateau area; however, they are considered to be superficial and probably do not involve Paleozoic carbonate rocks.

HYDROCARBON SHOWS AND WATER SPRINGS

Oil and gas seeps associated with the Norman Wells oilfield are well documented in the literature. Development of the oil pool has created a large pollution halo around the field, and today it is very difficult to isolate the natural occurrences from artificial spills. No live oil seeps were encountered during the project study; however, promising shows of oil were recognized at several localities and within several horizons.

In the Franklin Mountain cherty unit good oil staining was described in samples taken from the Big Smith Hills in the vicinity of N-2-71. Bitumen staining in Mount Kindle strata was described at A-12-71 in the core of the Imperial Anticline. Bitumen and oil staining in Arnica and Bear Rock strata was described at N-2-71 in the Big Smith Hills and at A-11-71 in the Imperial Anticline. As previously mentioned the upper dolomite unit of the Bear Rock Formation is consistently dark brown oil stained throughout the Franklin Mountains. Dolomitized Hume strata are porous and oil stained at F-20-71 and F-20A-71 in the Big Smith Hills. Tar was described in Hare Indian beds at A-13-71 on Powell Creek. No shows were seen in Upper Devonian beds; however, GSC Unit No. 25 comprises "stinking" reefal limestone beds. Basal Cretaceous sands are heavily oil stained in the Lac A Jacques area (Jx-18-71).

Several localities of spring water were examined, some warm, others cold.

In the Redstone Range along the Redstone River cold water springs issuing along the Redstone Fault have constructed large white tufa banks (Kx-25-71). Also in the Redstone Range, opposite Wrigley Lake at Cx-88-71, a warm water spring issues from along a fault zone within Mount Kindle beds. At Cx-70-71, on Big Smith Creek, a clear cold water spring with bubbling noncombustible gas occurs near the top of Hume strata. In the core of Walker Creek Anticline, at Cx-25-71 and Cx-133-71, warm sulphurous water gushes out from the base of massive Bear Rock beds. A brilliant green and lush vegetation growth is apparently nourished by this warm spring. At A-11-71, on the Mountain River, another warm sulphurous water spring issues from Bear Rock beds. Samples of the water were collected at most springs and these are available for analysis.

HYDROCARBON POTENTIAL

The following are recognized as potential reservoir horizons:

(a) Franklin Mountain cherty unit - dolomite

(b) Mount Kindle - dolomite

(c) Arnica - porous dolomite stringers

(d) Bear Rock - upper dolomite unit

(e) Hume - where dolomitized as at F-20-71 and Cx-132-71

(f) Ramparts - reef limestone

(g) GSC Unit No. 25 - upper Devonian reef limestone

(h) Imperial - clean sands

(i) Basal Cretaceous sands

(j) Little Bear - marine sand bars

(k) Cretaceous Tertiary - Upper Sandstone Unit

(l) Tertiary - sands, gravels

Since hydrocarbon shows were described in all lower Paleozoic potential horizons and since excellent porosity was described in Cretaceous sands, we consider the oil and gas potential of the Mackenzie Plain area to be good. Although the potential of some of the horizons is severely limited by maximum reservoir thickness, the fact that this area lies in the path of a transportation corridor should encourage exploration for the smaller hydrocarbon reservoirs which would not be considered in other parts of the Arctic.

COAL POTENTIAL

Coal beds were found in the Cretaceous, Little Bear Formation and in Tertiary beds. The coal beds were sampled, however, no laboratory analyses of the samples were made.

On a tributary of the Little Bear River at Cx-118-71, abundant bituminous coal fragments are present along stream bars. We did not find the coal beds in place; however, the large size of the angular coal fragments suggests that the source is very close. Little Bear strata were examined at this locality; however, higher up the slope sands of Upper Sandstone Unit are also present. Therefore, we are not certain from which unit the coals were derived.

Samples of Tertiary lignite coal were collected along the Mackenzie River south of Fort Norman at Cx-56-71, Fx-67-71, Fx-68-71, Fx-72-71 and on Tertiary Creek at B-24-71, B-25-71, B-26-71 and B-41-71. Generally the coal seams in the Tertiary are very thin and of poor quality. Coal seams up to ten feet thick have been reported on the headwaters of the East Fork River. Tertiary coal outcrops are commonly oxidized and are characterized by a red or pink stain.

No attempt was made to determine the extent of the distribution or thickness of the coal seams.

CONCLUSIONS AND RECOMMENDATIONS

The five objectives of the field party were accomplished within the project area.

(a) Structures were mapped in detail and the surface geology of each is presented on 1" = 8,000' maps. A short summary of each prospective structure is included in Appendix II.

(b) The four units of the Ronning Group were mapped throughout the area. Enclosures 2 and 3 show the thickness and distribution of the units below the Bear Rock unconformity.

(c) It was determined that in addition to the Mount Kindle Formation, the Franklin Formation cherty unit should be considered as a potential reservoir within the Ronning Group.

(d) Enclosure 5 shows the facies distribution of the Bear Rock and coeval formations. The upper dolomite unit of the Bear Rock varying in thickness from a few feet to over 200 feet has very fine intercrystalline porosity and is consistently oil stained. This horizon is a potential reservoir in all structures with the horizon at depth.

(e) We determined that in addition to the potential of basal Cretaceous sands, the Little Bear Formation has excellent reservoir characteristics and could be considered a primary reservoir target. Younger Cretaceous sands and Tertiary sands and gravels are generally "dirty" but porous.

Since very little subsurface control is available within the project area, exploration efforts will continue to be confined to evaluating large structural plays. Our work suggests that interpretation of the subsurface configuration of the structures is not easy nor straightforward. We recommend that an attempt should be made to acquire as much seismic coverage as possible and that each line should be interpreted to account for all geological data. In effect a geological cross section should be drawn along every seismic traverse. In time, certain consistent structural principles should evolve and the explorationist should obtain a greater degree of confidence in predicting the attitude and depth of prospective horizons.

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APPENDIX I

LIST OF MEASURED SECTIONS,

TRAVERSES AND SPOT LOCATIONS

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APPENDIX II

LIST OF PROSPECTIVE STRUCTURES

AND

DESCRIPTIVE NOTES

(Ref. Enclosure 21)

1. Arctic Red River Anticline

This anticline is a foothills fold recognized in beds of the Imperial Formation. The anticlinal axis has been mapped for a distance of seven miles and good east closure is indicated. Westward, we have no control since the outcrops are very poor. The structure is approximately 1.5 miles across with strong 30 to 50 degree north dips and shallow (5 to 20 degree) south dips. Critical closure is southward against the Mountain front. This structure appears to be on strike with the Cranswick-Flyaway Anticline. The structure is crossed by many seismic lines; therefore, a seismic evaluation of the structure is available through purchase or trade. Quality of the structure is poor.

2. Mid Arctic Red River Anticline

A shallow reversal in Cretaceous beds along the Arctic Red River was observed at Latitude 65°41' N. South dips vary from ½ to 5 degrees whereas north dip is estimated to be 2 degrees. The reversal is recognized along the river only. It is doubtful that this surface flexure persists at depth. Paleozoic carbonate beds probably pass beneath the structure on a regional plane. Quality is poor.

3. Ramparts Anticline

The Ramparts Anticline is recognized over a length of 7.5 miles along the Ramparts River and adjacent muskeg areas. One degree dips in Cretaceous shales on the flanks of the structure define the structure. The structural reversal is not considered significant and in all probability potential reservoir horizons pass beneath the structure on a regional plane. Quality is poor.

4. Hume River Anticline

The Hume River Anticline is recognized over a length of 12 miles in beds of the Cretaceous Arctic Red Formation. Three degree north dips persist for a distance of at least 2 miles beyond the apparent culmination on the Hume River. Three to five degree dips are estimated on the southwest flank of the structure. Surface studies suggest that the structure has closure to the southwest, southeast and northeast. No control is available to comment on northwest closure. Although this structure is located in the Peel Plateau area where we doubt that structures persist with depth, it is of large proportions, and in this regard it may be significant. Old seismic lines should be available to aid in evaluating this structure. Quality is poor to fair.

5. Mobil Hume Structure

This structure is inferred from outcrop observations of Cretaceous strata. It is apparent from photo and aerial observations that a set of resistant marker beds in the Cretaceous may be repeated. By applying regional geological trends through the area we propose a possible northeasterly trending fault passing south of the Mobil Hume River L-9 well. The thrust fault should dip northwesterly and the northwest side should be up. This fault is on trend with the Hume Fault along the Mountain Front and with the Whirlpool and West Mountain structures. We predict that the fault should involve Paleozoic carbonate rocks; therefore, prospective horizons may be in a trap position. Mobil may have located the structure seismically and drilled the culmination at L-9. Quality is poor. Seismic review is required.

6. Whirlpool Anticline

The Whirlpool structure is defined by outcropping Imperial strata on the west bank of the Mountain River. Six degree north dips were measured in Imperial beds, while 15 and 16 degree north dips were estimated in overlying Cretaceous shales. South dips of 20 degrees give way to more gentle 5 and 1 degree dips on the south flank. Whereas north dipping strata are conformable, it appears that there is insufficient room to turn Imperial beds beneath Cretaceous strata southward; therefore, a northwesterly dipping thrust fault is inferred placing Imperial strata over Cretaceous shales. Intersecting northwesterly and northeasterly structural trends are mapped in the area. A seismic evaluation of the prospect should be made to determine if the Imperial Whirlpool Well was located on the culmination. Quality is poor.

7. Westpool Anticline

A northeasterly trending structure is inferred from bedding plane lineaments in the muskeg between the Whirlpool and West Mountain Anticlines. Fifteen degree southeast dips in Cretaceous or Imperial beds have been estimated. No other attitudes are available. Hopefully this structure has reversal against the higher and larger structures along strike. Seismic data is required for further evaluation. Qulaity is poor.

8. Mountain River Anticline

A northwesterly trending structure shows reversal of Cretaceous strata along the Mountain River west of West Mountain. Five to one degree southwest dips define the southwest flank, and five to two degree dips define the northeast flank. Northwest and southeast closure is indeterminable from surface work. It is doubtful that this structure persists with depth. Quality is poor.

9. West Mountain Anticline

This well defined feature trends northeasterly, exposing Hare Indian shales in the core and Ramparts limestones on the flanks. The axis is mapped over a length of six miles. The structure is slightly in excess of one mile across at the Ramparts level of erosion. Strong 45 degree dips were measured on both flanks of the feature. Vertical closure is estimated to be in excess of 1,000 feet on the Ramparts surface. Objective horizons are the Gossage dolomite and the Mount Kindle Formation and the Franklin Mountain cherty unit. The grade of the prospect is good.

10. East Mountain Anticline

This anticline is an east-west trending assymetrical anticline enechelon to the northwest of the Carcajou anticline. The north limb of the structure dips 80 degrees to vertical while the south limb dips 15 to 20 degrees. West plunge is very abrupt at 10 to 20 degrees while east plunge is about 5 to 10 degrees. The structure is controlled by spot locations, traverses and measured sections on both limbs.

The structure is outlined by the Ramparts and the oldest beds in the core of the structure are upper Bear Rock Formation. The length of the structure is about seven miles and the width about one mile. Vertical closure is about 3,000 feet and aerial closure about 3,200 acres. Exposures are good, and closure and shape are reliable.

11. Hat Hills Structure

This structure is poorly exposed and its shape and closure are in doubt. The oldest beds found in the core were Bear Rock. A tail of the structure goes northwest from the main feature. The critical closure is probably to the northeast where exposures are very poor.

As mapped, the feature would have about 2,000 feet of vertical closure and about 1,500 acres of aerial closure. Control is supplied by aerial mapping and ground structural traverse.

12. West Beavertail Anticline

This structure at the west end of Beavertail Mountain is formed by the Ramparts Formation. The feature is assymetrical to the south with south dips of 40 to 60 degrees and north dips of 10 to 15 degrees. East and west plunge is about 60 degrees. Depth to the Ronning Group is about 2,500 feet. A well on the flank of this structure had an oil show from the upper Bear Rock.

Aerial closure is small, probably 900 to 1,000 acres, with vertical closure of about 1,000 to 1,500 feet.

13. Beavertail Anticline

This is a larger structure enechelon to the east of West Beavertail. The structure is assymetric to the south with faults on this limb. North dips are 5 to 20 degrees.

The oldest beds in the core are lower Bear Rock. The Ronning Group was not found but could be very shallow. East closure is very suspect. The shallow cover and the questionable east closure make this feature less desirable.

13A. Horseshoe Structure

This structure is poorly defined. The oldest beds in the core are Bear Rock but it is not known if there is any east closure, as the flats to the east have no exposures. Seismic would be required before considering this structure.

14. Carcajou Anticline

Map enclosure 22 is a display map covering the Carcajou Anticline. Several traverse, spot checks and detailed aerial mapping provide the data presented.

The structure trends east-west with steep to vertical dips on the south and 10 to 30 degree dips on the north. The oldest beds in the core are the Hume Formation. Critical closure is to the east, vertical closure is about 1,000 feet and aerial closure is about 3,000 acres. This structure along with East Mountain are the best defined structures in this immediate area.

15. Greenhorn Anticline

This feature is a narrow anticline just east of Paige Mountain. Exposures are poor, and north and south closure is suspect although there is probably at least a small culmination. The oldest exposed beds are Ramparts Formation. The structures are best seen on the east-west creeks cutting through the feature.

Vertical closure is small on this feature, and aerial closure also is small and is not considered as good for an initial test.

16. West Imperial Anticline

A sharp fold in Bear Rock crosses the Mountain River along the Imperial Range. Very steep to vertical south dips with associated faulting oppose 30 degree north dips. East plunge is well documented by field mapping; however, westward the structure may rise and connect with Mount Kindle outcrops at Cx-35-71. Quality is poor.

17. West Imperial Anticline

This southward assymetric fold is enechelon to the West Imperial Anticline and is recognized over a distance of 4.5 miles in Hume strata. Critical closure is against the West Imperial Anticline. The fold is probably associated with faulting in Cambro-Ordovician-Silurian strata. Quality is poor.

18. Mid Imperial Anticline

This fold is the largest structure in the Imperial Range exposing Mount Kindle strata in the core. The fold is strongly assymetric northward along a thrust fault. The deep erosion level of this structure eliminates it as a prospective structure. Quality, no prospects available.

19. Shovetail Anticline

The Shovetail Anticline is recognized in Imperial or Sans Sault (Cretaceous) greenish-grey sandstone for a distance of six miles. The structure trends easterly across Trail Creek. North dips of 42 degrees were measured at Cx-44-71; meanwhile, 45 to 65 degree dips were estimated on the south flank. The structure is 1.2 miles across. We could not, due to poor outcrop, define west closure against the Imperial Anticline nor east closure against the Hoosier Ridge Anticline. Many seismic lines were seen crossing the structure, therefore the fold could be seismically evaluated through purchase or trade of data. Objective horizons are the upper dolomite unit of the Bear Rock and the Mount Kindle and Franklin Mountain cherty units. The quality is fair.

20. Hoosier Ridge Anticline

This structure is defined by outcropping Ramparts strata which show shallow 10 to 20 degree south dips and 70 degree to vertical north dips. A fault is interpreted along the north flank. At the Ramparts level of exposure, the structure is four miles long and approximately one mile across. From field observations closure at the Ramparts level is estimated to be a minimum of 1,000 feet over 3,500 acres. The Imp Canol Hoosier Ridge No. 1 well is located on the south flank of structure and was drilled to a total depth of 2,718 feet. It is reported that vertical beds in the Bear Rock were encountered toward the bottom. Since the potential reservoir horizons of the Mount Kindle and Franklin Mountain cherty units were not evaluated by this well, this structure is considered to be prospective. Quality is good.

21. Sammons Creek Anticline

This complex structure exposing Bear Rock gypsum in the core is located along the Imperial Range at the junction of the Carcajou River and Sammons Creek. At the Hume level of erosion the structure is 7.5 miles long and 4.5 miles across. Critical closure will be at the northwest end of structure as it begins to climb toward the Mid Imperial Anticline which exposes Mount Kindle beds in the core. Since the Mount Kindle Formation may be at very shallow depth at the Sammons Creek structure, the potential of this prospect must be down graded. Quality is poor.

22. Walker Creek Anticline

The Walker Creek Anticline is another closed structure in the Imperial Range. The structure exposes Bear Rock breccias in the core, and at the Hume level of erosion is six miles long and 1.5 miles across. The structure shows a minimum of 1,000 feet of closure over 9,000 acres at the Hume Level. Warm sulphurous water springs flow from the core of the structure. Prospective Mount Kindle and/or Franklin Mountain horizons may be at very shallow depth. Quality is fair.

23. West Walker Anticline

This structure is defined by very poor outcrops in a muskeg area. At the Hume level, the structure is five miles long and two miles across. Mount Kindle beds were sampled in the core at Cx-134-71. Quality, no prospective horizons are sufficiently buried.

24. Imperial River - Jordan Lake Culmination(?)

A structural culmination is inferred in the general area of 65°10' N.; 128°00' W. The inference is based on the apparent separation of the Imperial and Link Bend Synclines by a structural high. The culmination is interpreted to be over an area three miles in radius around the above stated co-ordinates. No requirement for a culmination is necessary if the two synclines are separated by a northeasterly trending tear fault. Seismic data is required to evaluate this area. Quality is poor.

25. Carcajou - Imperial Anticline

The surface culmination of this structure occurs in Canol beds near the junction of the Imperial and Carcajou Rivers. The fold trends north-northwesterly and has 10 to 15 degree dips on the west flank and 20 to 25 degree dips on the east flank. South plunge is well defined, whereas north plunge is indicated by only a small saddle of Imperial strata separating the structure from the much higher Walker Creek Anticline. Seismic data is required to confirm separation of the structure from the Walker Creek Anticline. Quality is poor.

26. West Bluefish Structure

This culmination is inferred from structural relationships of Cretaceous and possibly Imperial strata in the vicinity of the Imp. Bluefish 1a well.

Immediately west of the well, along the east bank of the Mackenzie River, we mapped an area of green-grey shales and sands as Imperial. Because of the similarity between Imperial beds and Cretaceous Sans Sault Formation, the age of the outcrop is not definite. Nevertheless, the occurrence of older beds west of the Bluefish well suggests that a plate of Paleozoic sediments may have been placed in a trap position along a southwesterly dipping thrust fault. The culmination is indicated to be six miles long and 1.5 miles across. The Mobil Slater River well is situated well down the west flank of the structure. Seismic data is required to determine the validity of this structure. Quality is fair.

27. Tate Lake Anticline

A south plunging anticlinal fold is inferred from outcropping Tertiary beds northwest of Tate Lake. Unfortunately, it is apparent that the beds are expressing a "wrap around" the south end of the MacKay Range which exposes Cambrian Saline River beds. Quality is poor.

28. Keele Mouth Feature

An anomolous photo and geomorphic feature is recognized at the junction of Keele and Mackenzie Rivers. No outcrops occur in the area for geologic control. The feature is five miles long and three miles across and appears to be domal. Seismic lines were seen in the vicinity and one line crosses the feature. It is interpreted that Cretaceous East Fork or Little Bear beds would be the oldest beds at surface. It would be interesting to acquire a seismic line across the feature to determine the cause of the geomorphic anomally.

28A. Redstone River Anticline

The northwesterly trending Redstone River Anticline is defined by shallow dipping Cretaceous Little Bear sands. The axis can be mapped over a length of ten miles. The structure is a minimum of two miles across along the Redstone River. Bedding attitude observations indicate west dip, east dip and probable northwest plunge. Due to scarcity of outcrop we cannot show southeast plunge. Since the Mount Kindle horizon was not tested by the Imp. Redstone No. 1 well, we consider the structure prospective. A seismic review should be made to determine closure and the configuaration and depth of prospective horizons. Quality is good.

29. Stewart Lake Anticline

A structural culmination in Tertiary beds south of Stewart Lake is inferred from aerial observations of topographic expression of Tertiary strata in this area. We have no outcrop data to support the inference. Several seismic lines cross the feature. If the structure holds up, Cretaceous and Paleozoic horizons would be prospective. Quality is poor.

30. Summit Creek Anticline

This structure is a large (20 miles by 3 miles) anticlinal feature assymetric eastward along a thrust fault. Oldest beds exposed in the core are Saline River. No prospective horizons are buried.

31. North Red Dog Structure

The north Red Dog structure is a complex system of folds involving Bear Rock through Imperial strata. The surface culmination occurs along the Keele River opposite Red Dog Mountain. This structure is separated from the Red Dog Anticline by an inferred tear fault which apparently accommodated a different system of shortening to occur on either side. The wavelength of the north Red Dog structure is approximately one-half of the much broader Red Dog Anticline. If the Red Dog Anticline well were successful, the north Red Dog structure would be a logical follow-up.

The north Red Dog Anticline is over six miles long and two miles wide at the Hume level of erosion. Good north plunge has been mapped. A syncline separates the north Red Dog structure from the breached Summit Creek Anticline. Quality is fair.

32. Red Dog Anticline

This huge structure is defined by gently arched Middle Devonian carbonates of the Hume and Landry Formations. Oldest beds exposed in the core are of Bear Rock age. At the Hume level of erosion the structure is twelve miles long and six miles across.

The west flank has dips of 10 to 20 degrees, and the east flank steepens from 5 to 30 degrees. A thrust fault along the east flank is inferred. The central part of the structure exposes gently rolling beds which define several continuous folds. The structure plunges steeply beneath the Keele River or against an inferred tear fault which separates this anticline from the North Red Dog Structure. Maximum vertical closure may exceed 2,000 feet. Mount Kindle reservoir beds are expected to be the prime objective in this structure. Quality is good.

33. Moose Prairie Anticline

This structure extends for over 30 miles from the Keele River to Redstone River. In the vicinity of the Keele River, the structure is primarily a large thrust fault with Saline River beds exposed in the hanging wall. The structure plunges southward to the vicinity of the Redstone Rever where Upper Devonian shales of GSC Unit No. 26 are the oldest rocks exposed. Although it is possible that this large structure could be broken into three separate culminations by tear faults, preliminary investigations show continuous southward plunge with all potential reservoirs exposed at the north end. Quality is poor.

34. Middle Creek Anticline

The Middle Creek Anticline exposes Cretaceous East Fork shales in the core and Cretaceous Upper Sandstone Unit beds on the flanks. The structure has been mapped over a distance of ten miles and may be in excess of three miles across. In the field, strong 10 to 35 degree west dips have been measured. Reversal to the east is inferred from surface distribution of Cretaceous formations. Local geology also suggests that good northwesterly and southeasterly plunges are probable. Since Cretaceous and Paleozoic potential reservoir horizons are buried, the structure ranks very high. Some seismic control will be required to confirm closure and determine location of the culmination.

35. West Middle Creek Nose

This tight fold occurs east of the Red Dog structure and may plunge beneath the eastern part. At the north end the structure exposes Cretaceous Slater River shales in the core while at the south end beds as old as Hume are exposed along a thrust fault which apparently dies northward into the axis of the fold. The structure is of very low priority; however, if hydrocarbon reserves are established in other structures in the area, a subsurface evaluation of this structure should be made.

36. North Crescent Anticline

The anticline is enechelon to the Crescent Ridge Anticline which was partly evaluated by a test well drilled by Candex. The structure is defined by good 10 to 15 degree west dips and by distribution of Cretaceous formations in the vicinity. The closed area in Cretaceous East Fork shales is approximately eight miles long and three miles wide. The structure probably represents surface expression of a thrust fault repeating Paleozoic carbonates in the subsurface. Seismic control is required to confirm separation of this culmination from the Crescent Ridge Anticline. Quality is fair.

37. Cloverleaf Anticline

The Cloverleaf Anticline is approximately twelve miles long trending northwesterly between the Redstone and Dahadinni Rivers near Cloverleaf Lake. Wooded Cretaceous scarps suggest west, north and east closure. South closure could not be confirmed from surface studies. The structure was evaluated by the Shell Cloverleaf Well which bottomed at 11,318 feet in dolomites which may be Mount Kindle. If it can be shown that Mount Kindle beds were reached, we would then consider the structure as evaluated and, therefore, not prospective.

38. Crescent Ridge Anticline

Upper Devonian beds of GSC Unit No. 25 are exposed in the core of the structure on and south of the Dahadinni River. A westerly dipping wooded Cretaceous sandstone scarp defines the west flank while 20 to 30 degree east dips in Upper Devonian limestone define the east flank. A westerly dipping thrust fault is inferred along the east flank of the structure. The limited extent of outcropping Upper Devonian limestone beds demonstrate that good plunges are present and structural closure is present.

The Candex exploratory test well was drilled on the west flank of the structure. To date no well data is available to determine the significance of the test.

39. North Dahadinni Structure

The structure comprises north trending occurrences of Middle Devonian limestone outcrops which have apparently surfaced along a major thrust system which continues southward along the Dahadinni Range. The "high" structural trend is of very low priority; however, if Imperial's Dahadinni well were successful, then this trend would be of interest in that the surface exposures may represent a repetition of potential reservoir horizons at depth. Quality is poor.

40. Silvan Anticline

The Silvan Anticline is one of several folds in the Upper Redstone and Dahadinni River area. The Silvan anticlinal axis can be mapped for a distance of twelve miles. The structure, which exposes Horn River shales in the core, has a wavelength of five to six miles. North plunge is demonstrable on surface geological maps while south closure is inferred against a tear fault. Across the tear fault the west Dahadinni Anticline rises on strike exposing beds as old as Bear Rock. If the tear fault is not an effective barrier, then south closure for the Silvan Anticline cannot be demonstrated. Quality is fair.

41. West Silvan Anticline

This small anticlinal flexure with Fort Simpson shales in the core is situated between the Silvan and Prairie Anticlines. The structure was mapped for a distance of 7.5 miles. The wavelength is approximately three miles. Good north plunge can be demonstrated; meanwhile, south closure is inferred against a tear fault. The structure has shallow 5 to 15 degree east dips and strong 37 to 70 degrees on the west flank. The structure may not persist with depth. Quality is poor.

42. Prairie Anticline

The Prairie Anticline is a large fold exposing Landry limestones in the core. The structure has been mapped over a distance of fifteen miles. The width of the anticline at the Hume level of erosion is one mile. A minimum of 2,000 feet of vertical closure is expected. We expect that potential reservoir horizons in the Mount Kindle Formation will be in trap position at depth. The west flank of the structure has 30 degree dips in Hume beds and 15 degree dips in Upper Devonian shales. East dips range from 45 to 70 degrees. Quality is good.

43. North Dusky Structure

This structure is a large anticlinal fold exposing Camsell beds in the core along an easterly dipping thrust fault which passes southward into bedding of the Camsell Formation along the east flank of the Dusky Range which exposes Franklin Mountain strata.

The feature is over eighteen miles long and three miles broad at the Hume erosional level. We feel that the structure is of such large magnitude that prospective Mount Kindle beds should be involved. A seismic evaluation of this structure would require the identification of the Mount Kindle horizon. The attractiveness of this feature is dependent on the success of the Imperial Cobles Dahadinni well. Quality is fair.

44. Mid Dahadinni Range

The Mid Dahadinni Range is a complex anticlinal structure with a west dipping thrust along the east flank. The oldest beds exposed in core are Arnica dolomites. The range is approximately two miles wide and over twenty miles long. West dips average 45 degrees while east dips vary from 70 degrees to overturned. It is possible that the range is a surface expression of a major culmination in prospective Mount Kindle beds. The attractiveness of this prospect is dependent on the success at the Imperial Gobles Dahadinni well. Quality is fair.

45. West Dahadinni Anticline

This easterly assymetric anticlinal fold appears to join the Silvan Anticline with the Mid Dahadinni Range. The West Dahadinni fold is eighteen miles long and over two miles across at the Hume level of erosion. West dips average 25 degrees while east dips are in excess of 70 degrees. The oldest rocks exposed in the core are Bear Rock. The critical area of closure is at the south end where the feature runs into the backside of the Mid Dahadinni Range. Our feeling is that there should be effective fault separation of prospective horizons in the subsurface, therefore the West Dahadinni structure ranks high.

46. South Dahadinni Range

The Range extends for thirty miles changing assymetry along its length from easterly at the north end to westerly at the south end. Arnica dolomites in the core of the structure are complicated by thrust faults which change dip direction also. Both Hume flanks dip in excess of 45 degrees. The range may overlie a large culmination in prospective Mount Kindle beds. The structure will be tested in early 1972 by a 10,000 foot hole located on the west flank (Imperial Gobles Dahadinni).

47. Iverson Thrust

In the event of success at Imperial Gobles Dahadinni, faulted ranges, like the Iverson Range, will be considered prospective for deep potential horizons. Presently, our fear is that the Iverson thrust flattens into bedding of the Camsell Formation and older horizons will not be involved. Seismic will be required to identify the Mount Kindle horizon.

48. Wrigley Anticline

The north plunge of the Wrigley Anticline was mapped in Upper Devonian shales and sandstones in the vicinity of the Johnson River. The structure rises southeasterly culminating in a Fort Simpson shale exposure outside the project boundary. The surface culmination is presently (January 11, 1972) being drilled as Decalta et al Gulf Amhess Wrigley J-54.

49. West Wrigley Anticline

The West Wrigley Anticline is defined by outcropping bands of Upper Devonian limestone of GSC Unit 25. The oldest beds exposed in the core are Fort Simpson shales. West dips average 10 degrees while east dips range from 1 to 10 degrees. Surface distribution of Upper Devonian units indicated northwest and southeast plunge. Our field observations do not indicate strong east closure.

The structure is considered to have been adequately tested by the Shell West Wrigley G-70 well.

50. Southwest Wrigley Nose

Southwest of the West Wrigley Anticline a strongly northward plunging anticlinal nose was mapped in Upper Devonian units. The structure appears to rise southward to become the Carlson Lake - Ram Anticlinal trend.