62°00'
61°00'
Dn
UDsh
MD-S
M-UDsh
Mls-sh
Mss
Mm
Kg
Klp
Ksc
NAHANNI RANGE
NAHANNI BUTTE
Camp 2
JACKFISH DOME
TLOGOTSHO SYNCLINE
LAFFERTY ANTICLINE
NAHANNI BUTTE FAULT

1 of 2

Kw	KOTANEELEE FORMATION
Kfn	FORT NELSON FORMATION
Klp	LEPINE FORMATION
Ksc	SCATTER FORMATION
Kg	GARBUTT FORMATION
TrT	TRIASSIC UNDIVIDED
Pc	PERMIAN CHERT
Mm	MATTSON FORMATION (PENN.-MISS.)
Mls-sh	MISSISSIPPIAN LIMESTONE and SHALE
Mss	MISSISSIPPIAN (BANFFIAN) SILSTONE and SANDSTONE
M-UDsh	MISSISSIPPIAN–UPPER DEVONIAN SHALE
Dn	MIDDLE DEVONIAN NAHANNI FORMATION
MD-S	MIDDLE DEVONIAN, LOWER ? DEVONIAN–SILURIAN
C	CAMBRIAN
PC	PRE-CAMBRIAN SEDIMENTS
PCi	PRE-CAMBRIAN INTRUSIVES

CRETACEOUS

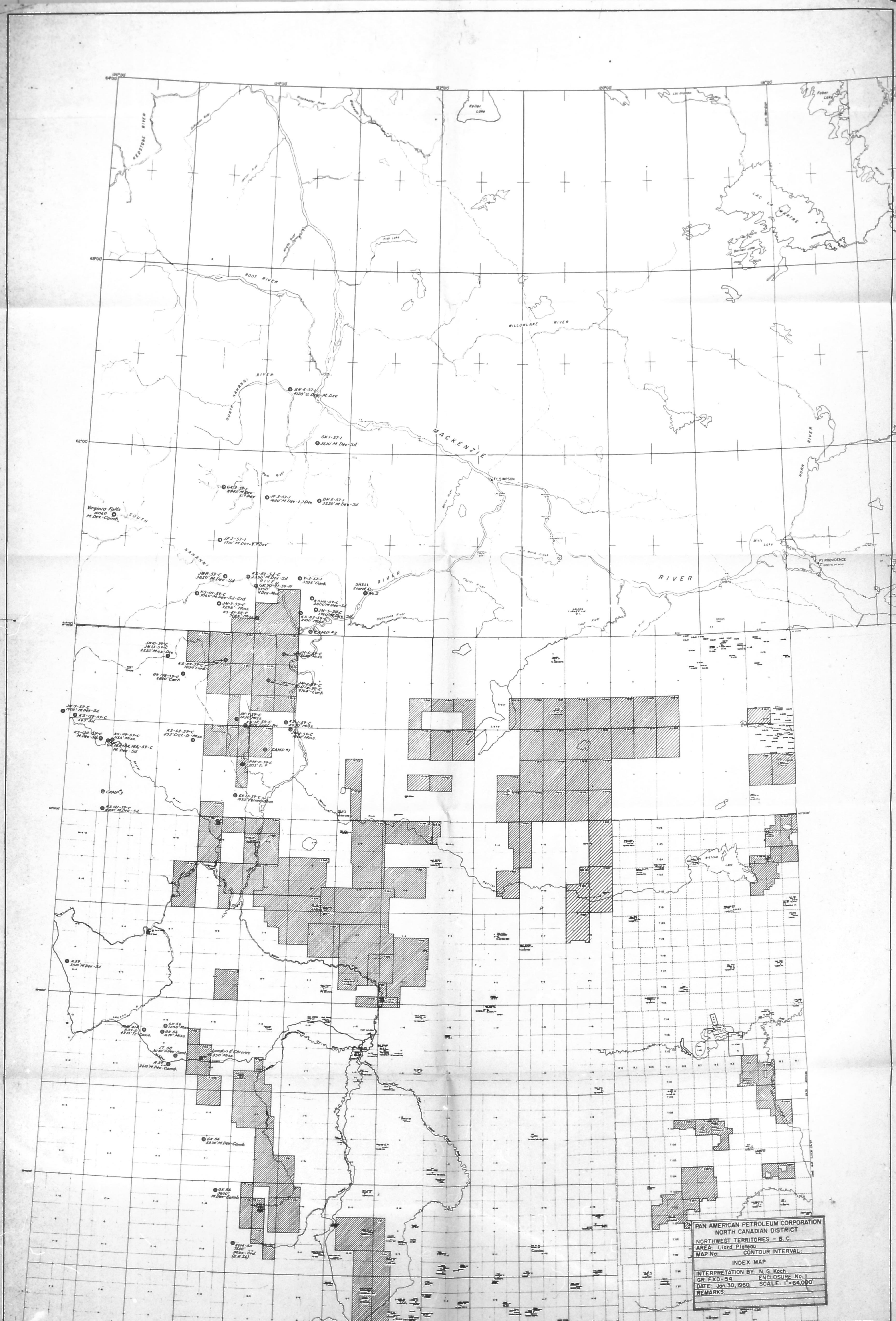
PAN AMERICAN PETROLEUM CORPORATION
NORTH CANADIAN DISTRICT
BRITISH COLUMBIA — N.W.T.

AREA: LIARD PLATEAU
MAP No. CONTOUR INTERVAL:

SURFACE GEOLOGICAL MAP

INTERPRETATION BY: N. G. KOCH
GEOL. REPORT FXD-62 ENCLOSURE No. 12
DATE: APRIL, 1960. SCALE: 1"=16,000'
REMARKS: Formerly Report No. GR-FXD-54
Enclosure No. 2

242



MACKENZIE
RIVER
RIVER
FT. SIMPSON
FT. PROVIDENCE
ROOT RIVER
NORTH NAHANNI RIVER
SOUTH NAHANNI
WILLOWLAKE RIVER
HORN RIVER
Virginia Falls
CAMP #1
CAMP #2
CAMP #3
PAN AMERICAN PETROLEUM CORPORATION
NORTH CANADIAN DISTRICT
NORTHWEST TERRITORIES - B.C.
AREA: Liard Plateau
MAP No:
CONTOUR INTERVAL:
INDEX MAP
INTERPRETATION BY: N. G. Koch
GR FXD-54
ENCLOSURE No. 1
DATE: Jan. 30, 1960.
SCALE: 1" = 64,000'
REMARKS:

REPORT ON SURFACE GEOLOGY

LIARD PLATEAU AREA

NORTHWEST TERRITORIES AND YUKON TERRITORY

Conducted By

N. G. Koch

During the period May 13 to September 11, 1959

on

Northwest & Yukon Territories Permits

998 to 1002
1144 & 1145
1568 to 1570
2513 to 2527
2692 to 2694
2703 & 2704
2717 & 2721

Prepared By

G. F. Stansberry, P.Geol. (Alta.)
(Surface Geologist)

September 14, 1960

Surface Geological Map and Section
Location Map in Separate Folder.

TABLE OF CONTENTS

ENCLOSURES

#1:	Index Map	1" = 64,000'	In Separate folder
#2:	Surface Geological Map	1" = 16,000'	In Separate folder

GEOLOGICAL REPORT FXD-54

INTRODUCTION

Surface Geological Party 'C' under Project #226, worked during the summer of 1959 on the Liard Plateau area of the Northwest Territories and Yukon Territory. Co-ordinates of the project area are 60° - 61°30' N.Lat., and 123° - 126° W.Long. A field party was sent to this area for the following reasons:

1. To produce a geological map of the Liard Plateau and to detail the most promising structures encountered on Pan American acreage.
2. To evaluate Pan American's Yukon-Northwest Territories acreage on the Liard Plateau.
3. To study the stratigraphy encountered on the Liard Plateau particularly horizons which may have reservoir potential.

The project commenced on May 13th and terminated September 11th. Three camps were established - the first at Fisherman Lake, the second at South Nahanni and the third at Larsen Lake. The weather during the summer field season of 1959 was generally consistent with other years. A total of 31 days was lost due to inclement weather, about average for a summer and any surface party in the area should anticipate similar conditions.

Party 'C' consisted of Party Chief N.G. Koch, Sub-Party Chiefs J.P.A. Noble and K.F. Sanderson, and three assistants, G.Steen, C. Williamson, and P.McDonald.

Spartan Air Services was contracted to supply a Bell Model 47-J helicopter piloted by Frank Harley and engineered by Sam Sirna. Camps were moved by Pan American's Beaver CF-IFG and Otter CF-ITS with the main supply point at Fort Nelson, British Columbia. Canada Catering supplied kitchen equipment, cooks, and foodstuffs. Charles Henley and Syd Olenik were cook and cook's helper respectively. Dr. D. Jackson of Pan American's Technical Group, Division Office, Calgary, identified all the fossils collected in the field.

OUTCROPS AND TERRAIN

The area worked called the Liard Plateau consists of broad, even topped ranges of hills immediately south of the Mackenzie Mountains and north of the Rocky Mountains. Relief up to 3000 feet was encountered in the area. Most of the ridges were devoid of vegetation and offered good landing spots for a helicopter. Sections measured were fair to good and many measured were from 4000 feet to 5000 feet in thickness. Thirty-two sections were located and studied and a total of 76,432 feet of section was measured.

NATURE OF WORK

The prime purpose of the work was to obtain as much knowledge as possible on the stratigraphy and structure in the Liard Plateau area for evaluation and future exploration of Pan American's acreage. Aerial reconnaissance for determining the position of base camps, locating measurable sections and noting structure present was carried out by Otter, Beaver, and helicopter. Structural mapping was done by Brunton compass, Paulin altimeter and radial shooting (Plane Table) when structural detail was necessary. Points were plotted on aerial photographs and later transferred to mosaics on a scale of 1 inch to 4000 feet. The material was then transferred to a lease map on a scale of 1 inch to 16,000 feet supplied by Pan American's Drafting Department. Stratigraphic sections were measured with a five-foot staff. Detailed sampling (approximately one sample for 25 feet) of the sections for stratigraphic purposes was carried out.

STRATIGRAPHY

During the field season, rocks ranging from Pre Cambrian to Recent were examined. Exphasis was placed on beds from Devonian to Ordovician in age. Other beds were mapped in a reconnaissance manner.

Table of Formations

AGE	FORMATION	LITHOLOGY	THICKNESS	REMARKS
Recent		Sands & gravels	Thin or absent	
Pleistocene		Till & lacustrine	Thin but locally thick along L. S. Nahanni R.	
	Lepine	Marine shale	Unknown	
	Scatter	Marine sandstone	200 ±	
	Garbutt	Marine shale & sandstone	1000? ±	
Triassic?		Sh., Sandstone & conglomerate	0 - 500?	May be basal Cret. Conglomerate made up of underlying Permian & Carboniferous
		Unconformity		
Permian?		Chert, sandstone siltst.& siliceous shale.	0 - 600	
		Unconformity		
	Mattson	Sandstone, calc. ss., limestone, shale, coal.	400-6500	Locally 3 units are visible.May include diastems. Thickens to west.
Carboniferous	Mississippian Limestone-Shale Unit	Crinoidal ls. sdy & argil.limestone shale.	2500-2800	No limestone present in the central Plateau area.
	Banffian Sandstone Unit	Sandstone, silt-stone, shale	100-900	Present only in west & NW half of plateau
	Mississippian-Upper Dev. shale unit	Dk.gry, silty & limy shale.		
				Unconformity
Upper Devonian		Ls.& blk.siliceous shale	2500-6000±	May include some Mid.Dev.shale
Middle Devonian	Nahanni	Dense ls.with local secondary dolomite	600-2200	Thickens to west
		Local disconformities		

AGE	FORMATION	LITHOLOGY	THICKNESS	REMARKS
Lower? Devonian	Lone Mountain	Coarse vuggy porous dol.with pontic ls. & sh. facies to west	900-2160	Thickens to west. Probably equivalent to Chinchaga Evaporite of subsurface.
		Local unconformities		
Silurian	Ronning	Poorly porous dol., dolomitic ls. to west.	1200±-2100+	Thickens to west. Absent in subsurface to east. Could be partly Ord.to west.
Ordovician	(Sunblood)	Sandstone & unknown dol. sequence	Unknown in Liard Plateau 2800 at Virginia Falls.	Restricted mainly to the Miogeosyncline west of Liard Plateau.
		Unconformity		
Cambrian		Congl.ss., red & green shale, quartzite	2000-2500	
		Unconformity		
Pre Cambrian		Metasediments, pyroclastics, extrusive & intrusive rocks		

Pre Cambrian

Rocks that are considered basement in the Liard Plateau are definitely Pre-Ordovician, that is, the oldest fossils that are found above this series are Ordovician in age. These rocks are exposed on the eastern side of the Beaver River fault block in the western portion of the map area. In this area, they are represented by a series of metasediments, meta-argillites, quartzites, limestone, siltstones, grits and pyroclastics intruded by basic and acid igneous rocks. The upper boundary of these rocks is formed by a profound angular unconformity. On reconnaissance flights west of the map area around Toobally Lakes, exposures of basic

volcanics and lavas were located. They are believed to be Pre Cambrian in age and roughly correlate with those seen in the map area. The igneous rocks which occur on the east side of the Beaver River fault block, are mainly monzonites and syenites. Various contact metamorphic zones were noted around these intrusions.

Cambrian

Beds ascribed to the Cambrian overlie the aforementioned sequence with profound angular unconformity. They consist of about 2550 feet of quartzitic boulder conglomerates. In the Toobally Lake area, at least 2000 feet of quartzites and red and green shales, often interbedded, overlie Pre Cambrian volcanics.

On the west Grayling fault block (south of Crow River) a similar sequence of white and tan quartzites are the lowest beds exposed.

All these beds, although thinner, are similar to Cambrian sediments found farther south in Northeast British Columbia. The Cambrian carbonate sequence found by Kingston (1951) in the upper South Nahanni River area is unknown in the Liard Plateau region.

Ordovician

A thin bed of sandstone reported to contain Ordovician trilobites occurs on the dip slope of the Beaver River fault block. These sandstones are poorly sorted, very feldspatic, angular to sub-angular, varying in color from white to light grey. The sands are porous in this locality with little or no cement but occasionally the matrix is kaolinitic or limonitic. This sandstone apparently overlies thin dolomites but the age and relationship of the sandstone to the dolomite is unknown. The nature of the Ordovician-Cambrian contact is also unknown.

The lower part of the overlying unfossiliferous carbonates mapped as Middle Devonian to Silurian undivided, especially in the western part of the map area, may be Ordovician in age. At this time, however, they are included in the Silurian.

Kingston (1951) reports 2800 feet of Ordovician in the Virginia Falls section on the upper part of the South Nahanni River. Here they consist of a cyclic sequence that alternates between thin bedded black nodular limestone and massive black medium grained limestone. Kingston has referred to this Ordovician section as the Sunblood Formation and is approximately Black River in age (Middle Ordovician).

Silurian

The Silurian section is referred to as the Ronning formation by the Canol geologists and also by Laudon and Chronic (1949) in the Alaska Highway area and by Kingston (1951) in the Upper South Nahanni region. In the Liard Plateau area, the Ronning is a sequence of porous and non-porous dolomites. The sequence of dolomites becomes limestone farther west as evidenced in the upper South Nahanni River section of Kingston. Silty, grey to black shales, 665 feet thick with Lower Silurian graptolites were measured on Upper Beaver River and are thought to underlie most of the dolomite sequence.

The Silurian section at Virginia Falls on the South Nahanni River as described by Kingston (1951) is approximately 750 feet thick and consists of massive light grey dolomitic limestone and thickly bedded dark grey dolomitic limestone containing abundant silicified corals. The age of these rocks is Niagarian. The upper boundary of Kingston's section is apparently obscured by thrust faulting and it is not known how much of the section is missing.

The Silurian deposition in the Liard Plateau area appears to be one of carbonate deposition onlapping the craton to the east similar to the previous more restricted onlap during Ordovician time. The Silurian is considered a possible potential reservoir rock in the Liard Plateau area.

Lower? Devonian

Beds ascribed to Lower? Devonian are called the Lone Mountain formation and occur throughout the Liard Plateau area. This sequence includes the Lower? Devonian shales and limestones to the west as the pontic equivalent of the Lone Mountain carbonate. The Muncho-McConnell carbonate of the Alaska Highway section is equivalent to the Lone Mountain.

The east and central portion of the Liard Plateau has a carbonate sequence varying from 1000 feet in the east to 2000 feet in the west. The carbonate sequence consists of light grey to dark grey, very fine to coarse crystalline dolomite with porous units occurring in some sections.

To the west, the Lone Mountain dolomite becomes a pontic facies of limestone and shale. Two sections are the West Ram River section and Kingston's Virginia Falls section. Kingston describes the upper contact of this series of limestones and shales as unconformable with the overlying massive limestone. Approximately 1380 feet of shale are exposed in the West Ram River section. The shales are mainly dark grey, silty, limy and platy to papery. The upper contact seems to be conformable with the overlying massive limestones. Kingston measured a total of 2160 feet of this limestone and shale in the upper South Nahanni region north and east of Cathedral Mountain in the Virginia Falls area.

Middle Devonian

The Middle Devonian in this area is called the Nahanni formation. In measured surface exposures the Nahanni formation thickens remarkably to the west. At Bluefish Lake on the eastern side of the Plateau, the Nahanni formation is 650 feet thick consisting mainly of fine crystalline, dark grey, argillaceous limestone. To the west, the formation thickens consistently as far west as Kingston's Virginia Falls section which is 2200 feet thick.

The Nahanni formation does not appear to be particularly ideal for hydrocarbon accumulation in this area. The limestones are generally dense and often lithographic and only in a few places do we find some fracture and secondary porosity.

Upper Devonian

The Upper Devonian in the Liard Plateau region is mainly shale overlain by Mississippian shale and the two can be separated only on paleontological evidence. Due to the reconnaissance nature of the project, insufficient fossil evidence was accumulated to break the two, therefore, Mississippian-Upper Devonian shales below Banffian silts are undifferentiated on the geological map. Definite Upper Devonian is known in the North Nahanni region where approximately 3400 feet of fossil controlled Upper Devonian beds were described during the 1957 summer field season. This is considerably thinner than the Upper Devonian section around Beaver River but considerably thicker than the section farther southwest in the vicinity of the Toad River high. The only evidence in the Alaska Highway section for any Upper Devonian is the fossil "Tentaculites" which was found by Laudon and Chronic (1949). The South Nahanni River traverse shows about 1300 feet of silty, hard, black, non-calcareous shale overlying Middle Devonian carbonates.

It has been reported from the South Nahanni River area that the shale directly above the Middle Devonian carbonates contains the fossil Nudirostra castanea which in the Norman Wells area occurs at the base of the Hare Indian shale (Middle Ramparts-Middle Devonian). Therefore, it is possible that the shale mapped as Upper Devonian is partly Middle Devonian as well and would be equivalent to Hare Indian and Upper Ramparts formations in the Norman Wells area.

The Upper Devonian is considered an excellent cap rock for the Middle Devonian carbonates in the Liard Plateau region.

Carboniferous Banffian Sandstone Unit

Interbedded sandstones, siltstones and shales of Banffian age (Lower Mississippian) occur in the northwestern part of the area. They are a series of lensing sand and silt of which only the lower unit is widespread and is used as a marker on the geological map. The lower unit is up to 900 feet thick and varies in lithology from limy siltstones to fine grained shaly sandstones to silty and sandy shales. To the west in the Upper Beaver River area, approximately 100 to 500 feet of fairly hard, dark grey, siliceous sandstones are correlated with the Banffian sands found further north. However, no fossils were found in the sandstones in the upper Beaver River area.

The southern limit of the Banffian sands is about the Yukon-British Columbia border, crossing the Liard Plateau in a sinuous trend north to South Nahanni. The general configuration of their limit to the southeast indicates that their source was probably from the northwest or the Yukon High. No porosity is indicated in any of the sections observed during the last field season and they do not appear to represent any possible reservoir rock. They are, however, a fairly good marker in the limited area of their presence.

Mississippian Limestone-Shale Unit

The Mississippian limestone-shale unit is upper Banffian and Osagian in age. Stringers of Banffian sand occur in the lower part of this unit but are not included in the Banffian silt unit which is used as a marker on the geological map. Numerous fossils have been found within this unit and paleontological control is fairly accurate. The upper boundary of the limestone and shale with the Mattson sandstone may be diachronous and is possibly unconformable although field evidence does not suggest the presence of any large unconformity in the Liard Plateau area. The Spirifer rowleyi zone at the base of the Osagian is a fairly good unit for correlation purposes.

The limestone at the top of this unit is dense and argillaceous and becomes more shaly to the west as evidenced in the Upper Jackfish Dome area where no limestone is present below the Mattson sandstone. On the western edge of the Liard Plateau limestone re-occurs below the Mattson sandstone but is not a traceable unit from the Mississippian limestone farther east. The presence of this limestone on the western side may indicate a western side to the shale basin in the Liard Plateau area. This limestone is quite similar to the limestone seen farther east. It is a dense argillaceous, and silty, fine crystalline limestone.

Upper Carboniferous

The Upper Carboniferous is represented by the Mattson sandstone. The Mattson sandstone is of Meramecian, Chesterian and Pennsylvanian age. It is divisible into three lithological units but in this report, it is considered as one major unit. This division cannot be made over the entire area although in some localities the expression of the three units is apparent on the aerial photographs. Where the Mattson formation can be divided, the lower part consists of fine grained, light grey sandstone,

mainly thin bedded and in part carbonaceous and finely cross-bedded, interbedded with minor black silty carbonaceous shale, and coal seams near the top of the unit. The unit weathers light yellowish brown and is generally more easily eroded. The middle part is mainly fine to medium grained, in part coarse grained to finely conglomeratic, light grey to light brown sandstones, medium to thick and massive bedded and usually thickly cross-bedded. The sandstones weather orange-brown and are in part friable. The unit as a whole is resistant and therefore cliff or ridge forming especially in the upper and lower parts. The upper part includes fine grained light grey, medium bedded calcareous sandstones, and minor black fissile concretionary shale.

The lower unit may represent the Meramecian, the middle unit the Chesterian, and the upper unit the Pennsylvanian. These three divisions in paleontology as well as in lithology suggest that the three units may be divisible into three formations at a later date. No unconformities are known between these three units, but it is quite possible that minor diastems do occur in the section. The upper unit is not present in the type section at Jackfish River but is present farther west in the Liard Plateau.

Permian?

Beds of questionable Permian age are mapped on the southern part of the Liard Plateau area. The upper half of the unit is mainly massive or bedded, laminated light and dark grey chert partly sandy with remnants of sandstone and dolomite. The lower part is black silty and siliceous shale with ironstone and siltstone bands.

This chert sequence overlies the Mattson sandstone with pronounced unconformity. Only a poor collection of fossils was collected from the cherts and are tentatively regarded as of Permian age by Dr. Jackson.

Triassic?

A thin sequence of muddy sandstones, siltstones and conglomerates overlies the Permian chert unconformably. This has been mapped as Triassic? but no fossils have been found that indicate any definite age from this sequence. The author feels that it may be Triassic or basal Cretaceous. The sequence underlies definitely known Cretaceous beds.

Cretaceous

The Cretaceous sequence as seen in the Liard Plateau area is similar to the section farther east and the three divisions of Lepine shale, Scatter sandstone and Garbutt shale are used. This sequence is preserved in the synclines on the Plateau.

The Garbutt shale appears to be thinner towards the west than the 2000 feet estimated farther east along the Petitot River. The Scatter sandstone is quite similar to that seen farther east but its thickness is estimated as being 200 feet. The upper contact of the Lepine shale is seen only on the lower part of the Kotaneelee River but no thickness has been estimated for this shale.

Pleistocene

During the Pleistocene epoch, glaciers pushed their way over all but the higher part of the Mackenzie Mountains. The continental glacier may have been joined by an ice mass that had its source west of the Highland Plateau. The meeting place of the ice was probably on the east flank of the Liard-Nahanni ranges. As the ice retreated, lobes of the continental glacier that extended up the South Nahanni River created a glacial lake in the valley west of Nahanni range. This lake extended over the South Nahanni River valley to the south around Yohin Lake and a part of the South Nahanni River called the "Splits" (west of Nahanni Butte and east of Lower Canyon).

No thick deposits of till were noted on the Liard Plateau region indicating that the ice was probably thin or stagnant over the area.

STRUCTURAL GEOLOGY

General Statement

This section deals mainly with the detailed description and interpretation of the more important anticlinal features that are present on the Liard Plateau.

One point of major consideration with regard to the structures on the Liard Plateau is the nature of the folding of the various competent and incompetent beds seen. It is thought that the shales as well as the more resistant limestones and sandstones were folded together in harmony and therefore the structure represented on the surface should likewise be represented at depth on the top of the carbonate beds. A comparison with the anticlines to the north of the Liard Plateau where the Paleozoic carbonate rocks are breached by erosion, gives a good picture as to the type of folding to expect. A particularly good example is Lafferty Anticline which crosses the South Nahanni River and forms the lower canyon on that river. This anticline in both the shale sequence above the carbonate and the carbonate itself is gently folded into a broad anticline. Structures both to the east and to the west of Lafferty Anticline although faulted do include the carbonate beds. Particularly around Lafferty Anticline, no evidence of disharmonic folding is seen. Likewise on the west side of Deadman's Syncline the attitudes in the shale are similar to the attitudes in the carbonate. Also, on the dip slope of Nahanni Range, the Carboniferous-Upper Devonian shales and sandstones are concordant with the older carbonates of the range itself. It seems then that there is little evidence to suspect the shales underneath the anticlines should be increased in thickness a

great deal due to a decollement type of structure. However, some reasonable thickening of the shales under the anticlines could be expected and in drilling any of these structures, a reasonable allotment for a slightly thicker section should be taken into account.

Mattson Anticline

The fold is essentially of the "box" type, with flat crest and steeply dipping limbs. The axis of the anticline traces a slightly sinuous course in a general N 30° E direction. The west limb is very strong with about 8000 feet of structural relief. The east limb has 5000 feet of structural relief.

The basic structure of the anticline is a flat-topped fairly steep-limbed fold (box fold) resulting from horizontal compression in a WNW-ESE direction. There appears to be no significant rotation as associated minor folds are fairly symmetrical. Some thrust faulting is apparent on the east limb (northeast corner) - the west side of the fault being upthrown probably less than 1000 feet relative to east.

Merrill Anticline

The surface axis of Merrill Anticline trends in a northeast-southwest direction and the structure is essentially a simple one. Merrill Anticline is the southern half of the anticlinal mountain range which has its origin in the Tlogotsho Plateau to the north and which plunges south into the Liard Plain. The east limb has about 7000 feet of structural relief. The west limb has about 5000 feet of structural relief.

The basic structure of the anticline is a sharp crested, fairly gentle limbed fold resulting from horizontal compression in an east-west direction. Some thrust faulting or crushing occurs along the crest in the northern part of the anticline where it crosses La Biche River. It appears that the east side is upthrown slightly relative to the west side.

Jackfish Dome

Jackfish Dome is a large broad feature at the north culmination point of Merrill-La Biche anticlinal range and the Kotaneelee anticlinal range. Dips are generally low on the northeast and southwest limbs but the northwest part and the southeast part are complicated by faulting and crushing. Good closure is indicated on the northeast side and southern and southwest parts of the structure but closure is critical on the northwestern end. Closure here is indicated by dips ranging as high as 10 to 15 degrees, to the west and north. However, this closure is limited because older formations are exposed farther northwest in the faulted structure west of Deadman's Syncline.

Kotaneelee Anticline

Kotaneelee Anticline is the northern extension of Beaver River Anticline. The structure is not thought to have much closure on the north end. The west limb is badly faulted and overturned with a major east dipping thrust, however, the east limb is fairly broad and shallow.

La Biche Anticline

La Biche Anticline lies between Jackfish Dome and Merrill Anticline on a broad anticlinal range. The west limb is faulted slightly although the structure as a whole is broad with gently dipping limbs. Very little closure is indicated on the north end as the structure seems to continue into Jackfish Dome.

Flett Anticline

Flett Anticline is part of the complicated Liard Range. The Flett Anticline is en enchelon to the Mattson Anticline and both are complicated on the west limb by a thrust fault. The structure appears to have closure but the exact amount is not known.

Liard Anticline

Liard Anticline is en enchelon to Flett Anticline and is situated in the same complicated structural belt of the Liard Range. Both the west limb and east limb are faulted. The fault on the east limb is the southern extension of the Liard Range fault. The northern end is overturned to the east.

The structural complexities do not make the anticline an interesting feature.

Fantasque Anticline

Fantasque Anticline was only studied in a very reconnaissance fashion and closure has not been indicated to the north. The structure appears to be badly complicated by east dipping thrust faults which may obliterate the structure to depth.

Liard Range-Nahanni Butte Faults

The Liard Range fault is interpreted as a steep west dipping thrust fault, thrusting Mississippian and Upper Devonian beds against younger beds. The Nahanni Butte fault is expressed as an en enchelon fault to the Nahanni Range fault, and plunges south into the Liard Plain north of Fort Liard.

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Respectfully submitted,

PAN AMERICAN PETROLEUM CORPORATION

By: G.F. Stansberry

G.F. Stansberry, P.Geol.(Alta.)
(Surface Geology Supervisor)

GFS/hh

Edmonton, Alberta,
September 14, 1960.

APPENDIX

List of fossils collected - Liard Plateau Area

Pennsylvanian

Neospirifer sp.
Buxtonia scabricula?
Orbiculoidea sp.
Productid brach.
Neospirifer cameratus
Punctospirifer sp.
Linoproductus sp.
Euphemus carbonarius
Astartella sp.
Yoldia sp.
Nucula sp.
Modiola sp.
Squamularia sp.
Fenestellid bryozoan
Chothyridinia sp. nr. orbicularis
Crinoid
Neospirifer sp. (of cameratus type)
Lima sp.
Dielasma cf. illinoisensis
Spirifer of grimesi type
Brachythyris sp.
Productus cf. inflatus
Buxtonia sp.
Neospirifer sp.
Buxtonia sp.
Sphenofus sp.
Buxtonia nr. semicircularis
Echinoconchus nr. genevievensis
Echinoconchus sp.
Composita
Large stony bryozoa
Crinoid ossicle
Spirifer pellaensis?
Gastropod
Eumetria sp.

Mississippian-Pennsylvanian

Syringpopra sp.
Spirifer
Bracythyris
Camerophoroa? sp.
Allorisma sp.
Goniatite
Parallelodon
Productus sp.
Neospirifer? sp.

Mississippian

Rynchopora sp.
Reticularia setigera?
Caneyella sp.
Ostracods
Sphenotus telamon?
Eumetria?
Bellerophen sp.
Neospirifer
Productus inflatus?
Martinia cf. sulcata
Pecten?
Tetracamera sp.
Modiola?
Schizodus
Ambocoelia
Spirifer cf. louisianensis
Sphenotus sp.
Spirifer cf. latior
Platyrachella sp.
Brachythyris peculiaris
Spirifer nearest Stratiformus
Chaenomya
"Platyrachella" rutherfordi
Crinoid ossicles (ovate type)
Rhinidictya sp.
Productus nearest sampsoni
Pseudozaphrentoides sp.
Schizophoria subelliptica
Pterinea sp.
Reticularia pseudolineata
Choenetes multicostata
? Athyris nr. densa
Linoproductus sp.
Athyris sp.
Composita trinuclea
Gonialite Impression
Gonialites
Gonialite (with Muensteroceras suture)
Lingula sp.
Gastropod
Griffithides? sp.
Letpaena? sp.
Orthotetes sp.
Schuchertella
Spirifer rowelyi
Michelinia sp.
Aviculopecten sp.
Dictyoclostus sp.
Spirifer nr. misourienses
Athyris lamellosa
Ekvasophyllum sp.
Spirifid brachiopod
Dielasma nr. chouteauensis

Spirifer forbesi
Reticularia sp.
Spirifer nr. norwoodana
Spirifer logani?
Grammysia sp.
Ekvasophyllum inclinatum
Ptoructus scitulus
Phipidomella sp.
Spirifer aff. arkansanus
Syringothyris sp.
Echinochus biseriatus
Schellwienella
Fenestellid bryozoan
Penniretopora sp.
Productid brach.
Stony bryozoan
Eotrochus sp.
Choentes sp.
Camarotoechia sp.
Organic cast
Fenestrellina sp.
Bryozoa
Phillipsia sp.
Productus sp.
Orbiculoidea sp.
Cliothyridina
Dielasma
Horn coral
Cliothyridinea sublamellosa
Composita laevis
Brachythyris sp.
Spirifer
Stigmaria
Neuropteris
Straparollus
Spirifer cf. leidyi
Paracaninia? sp.
Thamniscus? sp.
Palaeoneilo sp.
Productus nr. parvulus
Crinoids
Syringopora sp.
Brachythyris nr. fernglenensis
Pugnax quadrirostris
Spiriferina spirosa?
? Leptaena convexa
Derbya sp.
Murchisonia sp.
Sigillarian plant
Lithostrotion sp.
Penniretopora sp.
Strelolotrypa
Spirifer albertensis
Camarophorella cf. missouriensis
Torynifesa cooperensis

Camarotoechia cf. tuta
Orbiculoidea cf. sampsoni
Brachythyris buborbicularis
Delthyris sp.
Chonetes cf. logani
Productus arkansanus var. multiliratus
Deltopecten? sp.
Chonetes sericeus?
Productus subsulcatus var. janus?
Tetracamera sp.
Pectinid pelecypod
Toryniferea cf. psuedolineata
Chonetes geniculatus
Chinetes illionoisensis
Allorisma sp.
Rhipidomella? burlingtonensis
Grammysia cf. longwelli
Spirifer "centronatus" type
Amplexi-Zaphrentis
Spirifer centronatus minnewankensis
Echinoconchus alternatus
Allorhynchus? sp.
Strophomenid
Caninia sp.
Dictyoclostus cf. inflatus
Camerotoechia allani
Lepidodendron sp.
Pelecypod (smooth shelled)

Devonian

Proetus sp.
Atrypa sp.
Receptaculites sp.
Productella sp.
Atrypa cf. borealis
Martinia sp.
Cyathophyllum
Atrypa aff. clarkei
Tentaculites
Hypothyridina nearest cameroni
Chonetes sp.
Cystiphylloides sp.
Favosites
Cyathopaedium? sp.
Disphyllid ceroid coral cf. Australophyllum
Phacelloid Tetracoral
Aulopora sp.
Amphipora
Stromatoporoid
Ambocoelia
Atrypa cf. andersonensis
Coenites
Bryozoa

Devonian-Silurian

Crinoids
Favosites

Silurian

Monograptus sp.
Orthid type brachiopod
Monograptus of priodon type
Monograptus of convolutus type


Major monocline
MAINLY ORDOVICIAN
PROBABLY SOME CAMBRIAN
VIRGINIA FALLS
LAFFERTY
NORTH-WEST ANTICLINE
DOME
M-Dsh mainly
P 2731
P 2732
P 2518
P 2515
P 2516
P 2517
P 2717
P 2514
CRETACEOUS
Kk Kotaneelee Formation
Kfn Ft. Nelson Formation
Klp Lepine Formation
Ksc Scatter Formation
Kg Garbutt Formation
TRIASSIC
Tl Liard Formation
Tt Toad Formation
Tg Grayling Formation
T Triassic undivided
Pc P-Mm Mattson Formation with Permian Chert member
Mss Miss-Dsh Mississippian - Devonian Shales (incl. Miss. Sandstone member)
DEVONIAN
Dn Nahanni Formation
Dlm Lone Mountain Formation
SILURIAN
Sr Ronning Formation
D-S Devonian - Silurian undiv.
S-O Silurian - Ordovician
C Cambrian
Pre C Pre - Cambrian
Granite
PAN AMERICAN PETROLEUM CORPORATION
EDMONTON DISTRICT
Y.T.-N.W.T. CANADA
AREA: NAHANNI RIVER - TOAD RIVER, B.C., N.W.T. & Y.T.
SURFACE GEOLOGIC MAP
INTERPRETATION BY: J. NOBLE
GEOL. REPORT: FXD - 72 ENCLOSURE Nº: 2
DATE: JANUARY 5, 1961 SCALE: 1" = 16,000'
REMARKS:

1 of 2

Kk Kotaneelee Formation
Kfn Ft. Nelson Formation
Klp Lepine Formation
Ksc Scatter Formation
Kg Garbutt Formation
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Tkl Liard Formation
Tkt Toad Formation
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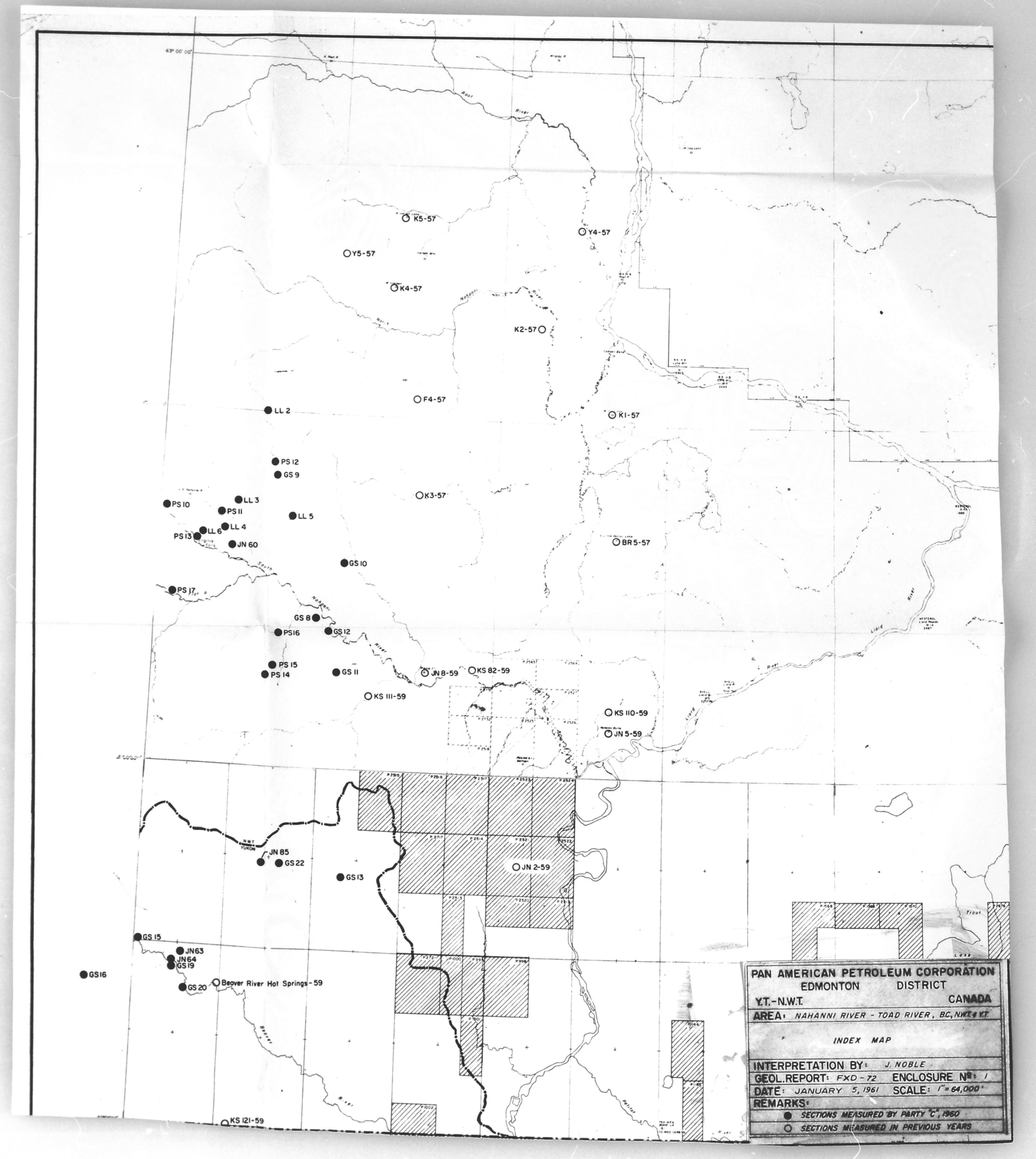
AREA: NAHANNI RIVER - TOAD RIVER, BC, NWT & YT
SURFACE GEOLOGIC MAP
INTERPRETATION BY: J. NOBLE
GEOL. REPORT: FXD-72 ENCLOSURE Nº: 2
DATE: JANUARY 5, 1961 SCALE: 1" = 16,000'
REMARKS:
NO OUTCROPS
PROBABLY MOSTLY D-S
BEAVER RIVER HOT SPRINGS
M-Dsh mainly
NORTH-WEST ANTICLINE
MERRILL ANTICLINE
P 2731
P 2732
P 2518
P 2519
P 2717
P 2514
P 2721
P 1000
P 999

2 of 2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K5-57
Y4-57
Y5-57
K4-57
K2-57
F4-57
LL 2
K1-57
PS 12
GS 9
K3-57
LL 3
PS 10
PS 11
LL 5
LL 4
LL 6
PS 13
JN 60
BR 5-57
GS 10
PS 17
GS 8
PS16
GS 12
PS 15
PS 14
GS 11
JN 8-59
KS 82-59
KS 111-59
KS 110-59
JN 5-59
JN 85
GS 22
GS 13
JN 2-59
GS 15
JN63
JN64
GS 19
GS16
GS 20
Beaver River Hot Springs-59
KS 121-59
PAN AMERICAN PETROLEUM CORPORATION
EDMONTON DISTRICT
Y.T.-N.W.T. CANADA
AREA: NAHANNI RIVER - TOAD RIVER, B.C., N.W.T. & Y.T.
INDEX MAP
INTERPRETATION BY: J. NOBLE
GEOL. REPORT: FXD-72 ENCLOSURE Nº: 1
DATE: JANUARY 5, 1961 SCALE: 1"= 64,000'
REMARKS:
SECTIONS MEASURED BY PARTY 'C', 1960
SECTIONS MEASURED IN PREVIOUS YEARS

GEOLOGY OF NAHANNI RIVER-TOAD RIVER AREA

Conducted by

J. P. A. Noble

During the period June 15th to August 28th, 1960

on

NORTHWEST TERRITORIES PERMITS

998 - 1002 incl.
2513 - 2527 incl.
2717
2721

March 16, 1961

Surface Geological Map and Section
Location Map in Separate Folder.

TABLE OF CONTENTS

ENCLOSURES

#1: Index Map (1960) 1" = 64,000'
In Separate Folder

#2: Surface Geologic Map (1960) 1" = 16,000'
In Separate Folder

GEOLOGY OF NAHANNI RIVER-TOAD RIVER AREA

INTRODUCTION

The project area covered by Surface Geological Party 'C' during the summer of 1960 comprises the southern end of the Mackenzie Mountains, the western part of the Liard Plateau and the northern end of the Rocky Mountains and Foothills. The area is bounded roughly by latitudes 60° and 62° and longitudes 124°30' and 127°.

Party 'C' consisted of Noble, Stringer, Steen, Lorincz, Van Vliet (geologists), Tichenor (helicopter pilot), Page (engineer), and Pearce and Wright (cooks). In addition Frost (palaeontologist) and Jaroch (pilot) assisted for part of the season. Jackson, together with Frost, identified most of the palaeontological material collected in the field. Foothills supplied the G-2 helicopter, pilot and engineer, and a Pan American Beaver and Otter provided support.

The project commenced June 15th and terminated August 28th. Field camps were established at Virginia Falls and Larsen Lake. The party's objectives were as follows:

1) To map the project area
2) To collect as much stratigraphic information as possible, especially on the Paleozoics
3) To study the following structures:
    a) Jackfish Dome
    b) Fantasque Anticline (north end)
4) To locate and evaluate any other structures of possible economic significance.

All sections measured were examined and logged in the field with a binocular microscope.

OUTCROPS AND TERRAIN

The area worked comprises the south end of the Mackenzie Mountains, the Liard Plateau and the northern plunge out of the Rocky Mtns. The eastern edge of the Hyland Plateau was also cursorily examined. Most

of the sections measured were in the Mackenzie Mountains in the vicinity of the South Nahanni River where the topography is less rugged than the Rockies and peaks average about 5000 feet. Eighteen sections were located and measured and a total of about 50,000 feet examined, mostly with the binocular microscope.

NATURE OF WORK

The main purpose of this operation was to obtain as much knowledge as possible of the stratigraphy and structure in the project area with a view to possible acquisition of new land and further evaluation of existing Pan American acreage. Structural mapping was done with Brunton compass, Paulin Altimeter and alidade and plane table. Points were plotted on aerial photographs and later transferred to mosaics (scale 1" = 4000') and finally to base maps of 1" = 16000' scale. Stratigraphic sections were measured with a five-foot rod and sampled at frequent intervals (approximately every twenty feet).

STRATIGRAPHY

(see following page)

Stage	System	Formation	Lithology	Thickness
Cenomanian	U. Cretaceous	Kotaneelee Ft. Nelson	Shale, sandstones, Conglomerate and sandstone	525' 500-800'
Albian	L. Cretaceous	Lepine Scatter Garbutt	Shales, marine Siltstones, marine, some shales. Shales, marine, blk, bentonite.	2000' ±? 750' ± 1000' ±
Karnian Ladinian Anisian	Triassic	Liard Toad Grayling	Sandstones, with shales and silts Silts, shales Shales with thin sandstone and silts	0-800 +(thickens W.) 800-1800'(" ") 1000' ±
?	Permian	- - -	Chert, sandstones, silts, siliceous shale.	0-600'(variable) cht.marker 0-200'
Pennsylvanian Chesterian Meramecian Osagian Kinderhookian	Carboniferous	Mattson	Deltaic. Sandstone, silts, shales, coals limestones in upper part.	0-4600'
?	U.Devonian	Miss.-Dev. shale unit	Shales, occasional thick silts.	1200-7000'
Givetian Eifelian	Lower-Mid Dev.	Nahanni Lone Mtn.	Limestone, with shale facies Dolomites with calc. shale facies and evaporitic facies.	600-1200'± 200-2700'
Keyserian Niagaran	Silurian	Ronning	Dolomites with calc. shale facies and evaporitic facies.	0-4400'
?	L.Sil-Ord.	- - -	Limestones, silty, shaly, some dolomites and sandstones.	6000' ±
?	Cambrian	- - -	Sandstones, with limestones	2500' ±
?	Pre-Cambrian	- - -	Metasediments, pyroclastics, extrusive and intrusive rocks.	?

PRE RONNING ROCKS

Below the unconformity at the base of the Ronning formation are beds of varying lithology and uncertain age. As no prospective reservoir horizons were encountered, they will be dealt with very briefly.

Cambrian and Older

These rocks consist largely of quarzites and thick conglomerates with subordinate argillites and red shales. Current bedding and other shallow water phenomena are common and the lithology in general is characteristic of sedimentation on or close to an actively rising land mass.

Ordovician-Lower Silurian

In the Virginia Falls area occurs a very thick sequence of limestones about 5000-6000 feet. They are characterized in the lower part by a shaly graptolitic facies and in the upper part by a shelly facies with gastropods, brachiopods, ostracods and bryozoa especially common. Pyrite is prevalent throughout. The faunal evidence indicates an age ranging from Lower Ordovician through Middle and Upper Ordovician to Lower Silurian. A few dolomites occur at the top. Ordovician-L. Silurian sediments are again seen at Beaver River where they are very silty, shaly limestones, and at Toobally Lakes where they are similar gastroped limestones to those of the Virginia Falls area.

SILURIAN-DEVONIAN

This group comprises a predominantly carbonate (mostly dolomite) sequence which is clearly differentiated in type of sediments from the underlying Ordovician-L. Silurian on the one hand and the overlying Upper Devonian on the other. It can be further divided into three recognizable formations on the basis of lithology and palaeontology. These are the Ronning formation at the base, the Lone Mountain formation, and the Nahanni formation at the top. These names have been chosen in accordance with current usage though as defined in this area they are probably not exact equivalents of the type-area formations.

Ronning Formation

This formation was originally defined in the Fort Norman area as the carbonate sequence below the Bear Rock dolomite breccias and above the MacDougal sandstones, and of presumed Silurian age.

In This report the Ronning of the Liard Plateau area is defined as the dolomites with a typical Mid Silurian (Niagaran) shelly fauna at the base and a Keyserian (U. Silurian-L. Devonian) shelly fauna at the top, and a characteristic basal quartzite member developed over most of the mountain area. This quartzite is typically 100-200 feet thick and in several places lies, with marked angular unconformity on older rocks. The beds underlying this unconformity vary in type and age from place to place. Above the quartzite a thin shaly or sandy limestone with worm markings is sometimes developed and the thick dolomites above have the following general characteristics differentiating them from the dolomites of the Lone Mountain formation.

Typically, Niagaran fossils occur at the base, usually associated with chert. Varying proportions of sand and silt are found throughout the formation in contrast to the Lone Mountain dolomites above which are generally devoid of terrigenous material. There is very often an unconformity developed at the top of the Ronning formation as well as at the base, for example in the Virginia Falls and Beaver River areas. The palaeontological control, lithologic characteristics and the fact that both the upper and lower boundaries are marked by unconformities makes the Ronning formation a fairly well defined unit, in the mountain area at least.

Facies Changes

Some of the criteria described above for the Ronning formation do not apply in certain areas. In the north and west (Virginia Falls and Ram River areas) the Ronning develops into a lime-shale-silt facies. That these terrigenous deposits are the time equivalents of dolomites further south and east is clearly indicated by faunal evidence.

Apart from these terrigenous influences the Ronning changes facies as one would expect in going seaward from east to west. The evaporitic sequence of the eastern areas give way seaward (westward) to the dense uniform dolomites of the stable shelf region where warm shallow

and highly saline waters prevailed. The edge of this shallow shelf area is marked by a shoal zone. Further seaward (northwest) the Ronning develops into a lime-shale-silt facies and presumably terrigenous material from the northwest did not extend beyond the barrier reef except to a limited extent. Thicknesses of the Ronning formation fit the facies picture perfectly in that there is a gradual increase in thickness from east to west with the most rapid increase taking place exactly in the zone where the dolomites are developed. It is apparent that this zone was a hinge-line separating the stable shelf from the less stable ocean area to the west.

Though there is a great increase in Ronning thickness east to west this does not necessarily imply a rapidly deepening basin. No deep water facies are found anywhere. It does indicate, however, that the rate of sedimentation (and rate of downwarp of the sea-floor) increased rapidly in the less stable part of the basin seaward from the barrier reef.

Lone Mountain Formation

This name applies in this report to the dolomites between the Ronning formation below and the limestones of the Nahanni formation above. These dolomites are fine to coarse crystalline, dense to porous and generally devoid of terrigenous material. They are typically and characteristically banded, unlike the Ronning below. Fossils are usually poorly preserved brachiopods and corals, amphipora and stromatoporoids indicating a probable Devonian age. An unconformity is often present at the base. Isopachs of this formation trend north-northeast as in the Ronning formation and indicate an appreciable thickening to the west.

Nahanni Formation

The type area of this formation is in the vicinity of the South Nahanni River. No clear definition has yet been published. Here it is defined as those limestones, about 800 feet thick, which directly overlie the Lone Mountain dolomites and which are in turn overlain by shales of Mid and Upper Devonian age. A good fauna from the top of this formation indicates an age close to the top of the Emanuella meristoides zone, about equivalent to the top of the Pine Point in the Slave Lake area, and definitely older than Slave Point.

The limestone in the South Nahanni River area is typically lithographic to fine grained, slightly argillaceous to silty, very often cherty and fossiliferous. In places it is pelletoidal and generally has the character of a shelf carbonate influenced to some extent by terrigenous material and deposited under medium energy conditions. The shelf seas were probably deeper during Nahanni times than previously and the widespread change from magnesium carbonate to calcium carbonate deposition may have been the result of a decrease in salinity consequent upon such deepening, perhaps a lowering of the magnesium content of seawater below a certain threshold value.

UPPER PALAEOZOICS

Mississippian-Devonian Shales

This unit is defined as the shales above the Mid. Devonian carbonates and below the Mattson formation. It includes rocks of different ages, different facies and varying thickness. In the eastern part of the Liard Plateau, it is 7000-8000 feet thick and has about 1000 feet of limestone developed at the top. These limestones yield a fauna ranging from Kinderhookian to Meramecian and possibly Chesterian (Liard Range).

Lower down in the shales several silt zones are developed which seem to vary in their stratigraphic position. Westwards and southwards the shales thin and the limestones disappear.

Mattson Formation

The Mattson is here defined as the sequence of sands, silts and shales of Carboniferous age resting on the limestones and shales of the Mississippian and overlain by Permian sands and chert. At the type section on Jackfish River only rocks of Meramec and Chester age are present but at Dall Sheep Mountain (Enclosure #2) and at Tika Creek to the west Pennsylvanian is present. The lower (Meramecian) beds are typical deltaic deposits with sands, silts, shales, and coals and numerous plant remains. In Chester and later periods the sands became calcareous and some shelly limestones were deposited. The basal contact of the Mattson is probably diachronous, becoming younger to the south and possibly also to the east. Fossil evidence suggests for instance that in the north Liard Plateau area the lowermost beds are Chester in age (Harker and Sutherland) while to the south in the Beaver River area the Mattson is thin and entirely Pennsylvanian (Hage). In addition the upper calcareous

unit of the Mattson does not thin east or south in direct contrast to the non-calcareous beds below it.

A gradual on-lapping of the Mattson sands to the east and south is thus indicated, probably from a source somewhere to the northwest.

Permian

Rocks of this age extend over most of the area south of about latitude 60°30', but are generally thin and of irregular thickness due to pre-Triassic and pre-Cretaceous erosion. At Tika Creek they consist of about 450 feet of calcareous sandstones resting with basal conglomerates on Pennsylvanian (?) beds, and elsewhere they consist of the same calcareous sandstones capped by a chert of varying thickness. The sandstones below the chert have a characteristic fauna which has been identified as Permian. In the region of Toad River these sandstones rest with a marked unconformity on shales of Upper Devonian age and this unconformity is probably fairly widespread.

Above the chert occur more sandstones with Permain fossils (Mt. Merrill and Grayling areas) but very often pre-Triassic erosion has removed them and Triassic shales rest directly on Permian Chert. Conglomerates of probable equivalent age are found above the chert at Pointed Mountain.

STRUCTURE

The following structures were examined in some detail by reconnaissance flying, traversing with Brunton and Altimeter and in some cases by Alidade and Planetable.

Jackfish Dome

This structure is located between Latitudes 60°45' and 61° and Longitudes 124°15' and 124°45'. It is essentially a northwest trending anticline with distinct northeast trending cross-structure. It is about 14 miles long and 9 miles wide at its widest point.

Fantasque Anticline

A number of field checks were made on the north end of this structure (about latitude 60°45' and longitude 125°) but no definite northerly plunge was evident. In addition the northern end of this structure is very much complicated by faulting.

Northwest Anticline

This structure is located 12 miles west of the north end of Fantasque Anticline. It is a long structure (15-20 miles) with a slightly sinuous course. It has reasonable south plunge but only very slight north plunge so that the overall closure would be doubtful. In addition a window of porous carbonates is exposed in the core to the south.

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Submitted by: J.P.A. Noble

JPAN/hh

Approved by: H.A.Baker, P.Geol.(Alta.)

Edmonton, Alberta,
March 16, 1961.

APPENDIX II

All sections measured from top down unless otherwise indicated

PS-11-60C - Cathedral Mountain

0-2600	Dolomite, pale grey, weathering lt.grey, thick bedded, parts finely laminated, f.xln.to med.xln. w/interbedded sublithographic beds; some brecias interbedded, calcite infilling fractures.
2600-4350	Limestone, lt.-med.grey (some brownish) weathered, dk.grey in fresh surface, 80% thick bedded, 20% med.bedded. Cryptoxln. to f.xln., shaly and silty in part. Sporadic beds richly fossiliferous, most bedding planes uneven.

LL-6, PS-13 Composite Section - Sunblood Mtn.

0-410	Limestone, med.grey, wea.dk.grey, f.xln., med.bedded, sli.shaly, silty. Blotches of maroon hematite and limonite staining. Contains 50 ft. band of silty dolomite near base.
410-550	Dolomite, dk.grey, coarse xln., silty, very shaly.
550-640	Limestone, f.xln., dk.grey, shaly and silty w/thin interbedded sandstone, med.-coarse grained, conglomeratic in part.
640-1900	Limestone, dk.grey, lt.grey wea., sublithographic to cryptoxln., thin bedded and shaly, silty in part. A few interbedded thin dolomite bands weathering buff, orange or pale grey.
1900-4664	Limestone, med.grey, lt.grey, mostly sublithographic to cryptoxln., med.to thick bedded, sli.shaly becoming more shaly and pyritic towards base.

GS-15-60C - Beaver Bend Section

0-250	Siltstone, med.-dk.brown grey, wea.rusty grey, laminated and thin bedded, quite calc., sli.shaly, calcite veining.
250-510	Shale, slightly calc., w/thin interbedded siltstones 10%.

GS-9-60C - Wrigley Forks Section

0-490	Limestone, med.-dk.grey, wea.chalky med.grey, massive, cryptoxln., dense, pyritic, some dark grey beds. Generally sli.shaly and occasionally silty. A few interbedded thin limy shales.
490-1250	Limestone, dk.grey, limonite, very shaly and interbedded w/limy shales 50%.
1250-1340	Dolomite, not measured in detail.

GS-12-60C - Gate Section

0-260	Dolomite, med.grey, chalky grey weath., med.bedded, black cherty lenses.
260-420	Sandstone, lt.brown grey, weath.tan grey, v.f.grained, thick bedded, sli.calc.
420-880	Limestone, med.grey, cryptoxln. to sublithographic, shaly w/a few thin sandstone members towards base.
880-3035	Dolomite, med.grey, cryptoxln. to f.xln., thin to med. bedded, silty in part. A few bands of shaly limestone interbedded, and thin coarse grained sandstone bands at 1080' and 1140'.

GS-8-60C - Doll Lamb Section

0-50	Sandstone, dk.grey, mottled, med.grey weath., poorly sorted, v.f. to f.quartzose, conglomeratic at base.
50-560	Limestone, dk.grey, med.bedded, sublithographic, interbedded w/dolomite, med.grey, rusty weath. thin bedded.
560-1540	Limestone, yellow brown, weath.rusty tan, thinly laminated, mostly lithographic, very much fractured.

GS-20-60C - Syenite Ridge

0-600	Dolomite, dk.grey, cryptoxln., thin-med.bedded, cherty at top.
600-725	Covered interval
725-1075	Sandstone, dk.grey, lt.grey weath., thin-med.bedded, numerous argillaceous partings, fine-med.grained.
1075-1225	Covered interval
1225-1800	Dolomite, med.grey, f.xln., dense, med.bedded, cryptoxln. in part.
1800-3900	Covered interval w/intermittent exposures of limestone, dk.blue grey, cryptoxln.
3900-4600	Sandstone, white, fine-med.grained, med.-thick bedded, dense, contains v.coarse conglomerate at base.
4600-7550	Syenite, fairly coarse xln,, probably a sill.
7550-7625	Argillite, metamorphosed shales and quartzites, probably of Pre Cambrian age.

LL-2-60C - Lost Mountain Section

0-990	Limestone, dk.grey, sublithographic, v.arg., silty, fetid massive, highly fract'd, interbeds of calc.shale, also sli.silty, some pyrite.
990-2500	Shale, sli.to v.calc., interbedded w/thin shaly limestone, pyritic.

LL-3-60C - E.Clearwater Section

0-810	Shale, lt.-dk.grey, v.limy, grading to limestone in part, and interbedded w/v.shaly limestone.
810-1000	Dolomite, med.grey, med.-coarse crystalline, sli.shaly in part, much secondary dolomitization, thick bedded.

PS-10-60C - Hematite Mt.

0-140	Dolomite, med.grey, weath.dk.brown grey, f.xln., w/ occasional bands of med.-coarse xln., thin bedded and fract'd, cherty.
140-1140	Limestone, med.grey, f.xln.to sublithographic, sparse vugs, mostly thin bedded, cherty in part, and shaly or silty in part.
1140-1870	Limestone, grey, lithographic, laminated, interbedded (units of 80') with dolomite containing chert stringers
1870-6056	Limestone, med.-dk.grey, lt.grey weath., cryptoxln. to sublithographic, some med.-coarse crystalline, some staining and pyrite common, much fracturing.

LL-5-60C - Paradise Mt.

0-176	Limestone, dk.grey, weath.lt.grey, cryptoxln.to f.xln, thin bedded, shaly, sli.silty, pyritic, hematitic and limonitic, some lithographic bands.
176-200	Dolomite, med.grey, sublithographic, med.-thick bedded.
200-900	Limestone, as above.
900-1820	Limestone, olive green-grey, only sli.shaly and not silty, becomes laminated in part.

LL-4-60C - Clearwater Bend

0-510	Dolomite, lt.blue grey weath., med.xln., massive, highly fract'd, much sec.dolomite, some pyrite, cherty at base.
510-2440	Limestone and shale interbedded, dk.grey, sublithographic, silty, pyritic, the shales are very limy and the limestones are very shaly and silty.

GS-10-60C - West Prairie Creek

0-260	Limestone, med.grey, weath.chalky grey, cryptoxln. & shaly, thin bedded, much chert interbedded and in leases, extensively fract'd.
260-390	Siltstone, dk.grey, calc.and sli.shaly, med.bedded, w/ interbedded calc.shales, rusty weath.
390-490	Covered interval.
490-835	Shales, sands and silts interbedded, sli.calc. The sands are med.grey, v.f.grained, calc.and med.bedded. The silts are often laminated. There is rapid interbedding, occasional cherty bands.

835-855 Limestone, med.grey, cryptoxln., dense, siliceous, w/ round chert bodies, med.bedded.

855-965 Shales, sands and silts as above.

PS-12-60C - E.Wrigley Creek - measured from base of section upwards.

0-200 Shales, dk.grey, weath.dk.brown grey, v.thin bedded and fissile, a few v.thin silty laminations, shaly limestone nodules (2' diam.) occur sporadically.

200-340 Shale, as above but a few interbedded siltstone bands about 1" thick.

340-2200 Shales, med.grey-dk.brown, 85% v.thin bedded, fissile, 15% thinly laminated silty shales.

GS-13-60C - Tika Creek - measured from base of section upwards.

0-260 Shales, sandstones and siltstones, interbedded. Ss. f.grained w/silty laminae and shale partings. Thin bedded to med.bedded. Shales are silty or sandy, dk. grey, and fissile and friable.

260-1480 Sandstone, med.grey, f.grained, med.bedded, often rusty weathered, sometimes laminated, contains irregular interbeds of shale and silt and iron-rich bands, much carbonaceous material in bedding planes, becomes calc. towards the top.

1480-1760 Shales, dk.grey, silty, carb., fissile, w/a few interbedded thick sandstones.

1760-2785 Sandstone, med.grey, v.f.-med.grained, silty and shaly laminae, calc. intermittently, interbedded shales and siltstones, also calc.

2785-3265 Sandstone as above, but w/a few interbedded bands (3-10') of sandy dolomite.

3265-4026 Sandstone, lt.-med.grey, thin bedded, silty and calc. w/ a few thin limestone bands and occasional shale beds.

PS-17-60C - L'Allegro Mt.

0-1620 Limestone, med.grey or buff weath., dk.grey fresh, cryptoxln, to f.xln., thin bedded, sec.calcite, sporadic pyrite cubes, much fracturing, v.shaly, sli.silty.

1620-1820 Limestone, sublithographic to cryptoxln., shaly and v. silty, fract'd.

1820-3260 Limestone, med.grey weath., dk.grey fresh, sublithographic to cryptoxln., 60% med.bedded, 40% thin bedded, pyritic, very shaly, silty in part.

PS-14 and PS-15-60C - Coldwynd Mt.

0-100	Limestone, med.-dk.grey, cryptoxln, 1"-15" bedding, intensely fract'd, rubbly bedding surfaces, 15% of strata are thin f.grained dolomite interbeds.
100-250	Dolomite, med.grey, brownish weath., f.xln. 2"-18" bedding, mostly laminated, 10% of strata are limestone.
250-645	Limestone as above
645-725	Covered interval
725-900	Dolomite and limestone interbedded, med.grey, f.xln. to cryptoxln.
900-950	Covered interval
950-1030	Dolomite and limestone interbedded as above.
1030-3070	Limestone, med.grey weath., dk.grey fresh, cryptoxln.to f.xln. 2-10" beds, thin-med.bedded, mostly shaly, partly silty, occasional thin dolomite bands. Faulted at the base.

GS-16-60C - Aurora Creek

0-520	Limestone, med.grey, cryptoxln, thin bedded, dense, minutely fract'd w/limonite fillings, rubbly bedding surfaces, one interbed of dolomite at 230-240'.
520-850	Covered interval
850-1080	Sandstone, flesh grey-yellow brown, v.f.grained, dense, med.bedded, arg.partings, calc. matrix.
1080-2120	Covered interval
2120-2350	Dolomite, med.grey, cryptoxln, med.-thick bedded.
2350-2420	Covered interval
2420-2460	Sandstone, coarse xln, calc.
2460-3720	Covered interval containing sporadic outcrops of dolomite and sandstones and red beds.
3720-3800	Basic sill
3800-3850	Sandstone
3850-3920	Basic sill
3920-4830	Sandstone, v.f.grained, calc.
4830-5300	Covered interval
5300-6060	Shale, blue grey, fissile, intensely laminated, silty in part, calc.