GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 59-6

FORT LIARD AND LA BICHE MAP-AREAS, NORTHWEST TERRITORIES AND YUKON

95 B and 95 C

R. J. W. Douglas and D. K. Norris

Price, 50 cents

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76009-0—1

THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1959

Price: 50 cents Cat. No. M44-59/6

CONTENTS

Illustrations

FORT LIARD AND LA BICHE MAP-AREAS, NORTHWEST TERRITORIES AND YUKON

INTRODUCTION

Fort Liard and La Biche map-areas lie within south-western District of Mackenzie, Northwest Territories and south-eastern Yukon Territory. Fort Liard map-area is bounded by latitudes 60° and 61°N, and longitudes 122° and 124°W. La Biche map-area lies to the west between longitudes 124° and 126°. These map-areas form part of the region investigated geologically in 1957 on Operation Mackenzie, an account of which has been published (Douglas, 1958)[1].

The Geological Survey party on Operation Mackenzie comprised W.B. Brady, B.G. Craig, R.J.W. Douglas, P. Harker, D.J. McLaren, A.W. Norris, D.K. Norris, B.R. Pelletier, and D.F. Stott. They were assisted in the field by D.A. Andrews, F.J.A. Arthur, R.K. Brooker, K.P.R. Cole, W.N. Hamilton, I.M. Harris, R.N. McCowan, D.B. McKennitt, and J.B. Read. The helicopters supplied by Associated Helicopters Ltd. were manned by N.R. Staniland, R. Huff, J. Brochu, and R. Barnes; and the Beaver aircraft supplied by Pacific Western Airlines Ltd., by W. McKinney and J. Furber. The boat and barge were operated by G.P.J. Turner and D. Turner. Other members of the party included W.T. Spratt, radio operator; E. Greyson and A.E. Martin, cooks; C.F. Parnall, labourer; and A. Konisenta, H. Martell and M. McKay, canoemen. To all these men who helped so much, the writers and other officers of the party extend their appreciation.

The geology of the Liard Range was mapped and compiled by D.K. Norris, the remaining part by R.J.W. Douglas. Exposures and sections of the Cretaceous rocks were examined by D.F. Stott; the descriptions here summarized are from a report in preparation (Stott, 1959). The Carboniferous and Permian strata were examined by P. Harker and W.B. Brady, and the Palaeozoic of upper Beaver River by W.B. Brady. Much of the stratigraphy of the Carboniferous and Permian formations is summarized from a report, in preparation by P. Harker, (1959).

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[1] Names and dates in parentheses refer to publications listed in the references.

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PHYSICAL FEATURES

The eastern part of Fort Liard map-area lies within the Interior Plains, bounded west of Liard River by the Yukon Plateau of the Mackenzie Mountain area. Much of the Plains is low-lying, nearly flat ground, covered by muskeg and small lakes lying between low, rolling hills up to about 2,000 feet in elevation. Exposures of bedrock are very rare except along the principal rivers and creeks namely Petitot, Muskeg and Netla Rivers tributary to Liard River from the east, and the lower parts of Kotaneelee and La Biche Rivers west of Liard River. These rivers flow in small canyons where they pass through the more resistant bedrock formations. Liard River flows near the western border of the Plains. Bordering this river are flats, in places several miles wide, laced with abandoned channels and densely covered with trees and brush. The Liard River is navigable by specially constructed river boats between Fort Nelson in British Columbia and Fort Simpson at the junction with Mackenzie River. The settlement of Fort Liard lies at the confluence of the Petitot and Liard Rivers. It includes a school, missions and churches, a Hudson Bay store and an RCMP post.

La Biche map-area and the western part of Fort Liard map-area embrace the greater part of Liard Plateau. The plateau forms the southern part of Mackenzie Mountain area (Bostock, 1948). It is bounded, a short distance west of La Biche map-area, by the Hyland Plateau and extends north to the South Nahanni River and south to the Liard River. The eastern boundary with the Interior Plains is irregular owing to the northeasterly en echelon arrangement of the bordering ranges. These north-trending ranges are termed from east to west, the Liard, Kotaneelee and La Biche Ranges. Some small hills at the north border of Fort Liard map-area form the southernmost projection of the Nahanni Range of Franklin Mountains to the north.

The Liard, Kotaneelee and La Biche Ranges are separated by linear valleys occupied by parts of the Kotaneelee and La Biche Rivers. These rivers, and tributaries to them, exhibit a well-controlled trellis drainage pattern. Kotaneelee and La Biche Ranges in the north merge with the southern part of Tlogotsho Plateau. Liard Range rises abruptly above the flats of Liard River valley; the highest peaks attain 5,000 feet in elevation. Elevations of peaks on the Kotaneelee and La Biche Ranges are somewhat higher, reaching 6,000 feet, but the topography is more subdued. West of La Biche River the remaining part of Liard Plateau is heavily wooded, with low rolling hills rising above timber-line. It is drained by Crow River and Beaver River and its tributaries. The Beaver and Crow Rivers flow in canyons in the western part of the map-area. There, exposures of bedrock are good, but elsewhere the bedrock only comes to the surface sporadically on the higher hills and in small creeks and gullies.

STRATIGRAPHY

Rocks ranging in age from Proterozoic (?) to Upper Cretaceous are present in Fort Liard and La Biche map-areas. The Cretaceous underlie the Plains, and in the Liard Plateau occupy synclinal basins and troughs occupied by the principal rivers between the ranges. Descriptions of the Cretaceous rocks which follow have been summarized from a report on the Cretaceous by D.F. Stott (1959, in preparation). Late Palaeozoic strata underlie most of the Liard Plateau; their descriptions are taken from sections described by P. Harker and W.B. Brady and a report in preparation by P. Harker (1959). The older rocks which appear mainly in western La Biche map-area were not studied in detail.

TABLE OF FORMATIONS

Era	Period or epoch	Group, formation (map-unit)			Lithology	Thickness (feet)
CENOZOIC	Pleistocene and Recent	(22)			Alluvial sands and silts of Liard River	
		(21)			Lithology not known	
		Unconformity				
	Upper Cretaceous	Wapiti (20)			Sandstone; coal	25+
		Kotaneelee (19)			Concretionary shale; mudstone; sandstone	525
		Fort Nelson (18)			Conglomerate; sandstone; mudstone; coal	500
MESOZOIC	Lower Cretaceous	FORT ST. JOHN GROUP (17)	Sikanni	Upper (16)	Concretionary, fissile, and gypsiferous shale	1,000-1,500
				Lower (15)	Fine-grained sandstone; shale; siltstone	250-350
			Buckinghorse (14)	Upper (13)	Concretionary shale	1,700
				Middle (12)	Fine-grained sandstone	168-247
				Lower (11)	Concretionary shale; bentonite; sandstone; conglomerate	900
				(10)	Shale; sandstone; unknown lithology (may include pre-Cretaceous strata)	0-1,000?
Unconformity						

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Era	Period or epoch	Group, formation (map-unit)		Lithology	Thickness (feet)
PALAEOZOIC	Permian ?	(9)		Chert; sandstone; mudstone	0-400
	Unconformity ?				
	Carboniferous and Permian	Mattson (8)	Upper (8c)	Calcareous sandstone; limestone; shale	1,176-1,740
			Middle (8b)	Sandstone, massive and thick bedded	752-1,574
			Lower (8a)	Sandstone, thinly bedded; shale; coal	1,164-1,732
		(7)		Limestone, crinoidal, sandy and argillaceous; shale	1,200-1,920
		(6)		Dark shale; limestone	550-611
		(5)		Sandstone, thinly bedded	600
	Devonian and Mississippian	(4)		Dark grey shale; sandstone (4a); (may include equivalents of Nahanni formation and map-units 5 to 7)	3,400-7,500
	Middle Devonian and Older	(3)		Banded dolomite; coarse vuggy dolomite; limestone; (includes Nahanni formation)	8,000±
		(2)		Quartzite conglomerate	10+
	Unconformity ?				
PROTEROZOIC ?		(1)		Green argillite	

PROTEROZOIC (?) (map-unit 1)

The rocks tentatively referred to the Proterozoic were examined at two localities. They consist of massive to thinly bedded and platy, green and greenish grey argillites, in part finely siliceous with fine and even lamination or irregular wavy bands. Some red coloration was observed from the air. These rocks resemble the Proterozoic of southern Alberta, particularly the Appekunni formation. As the strike is different from that of the overlying conglomerate of map-unit 2, and the trace of some beds may be seen to be truncated by the conglomerate, it would appear that a small angular unconformity is present.

PALAEOZOIC

Middle Devonian and Older (map-units 2-3)

Map-unit 2

Map-unit 2 consists of massive boulder conglomerate, ten feet of which was seen. The boulders are up to a foot in diameter, well-rounded, and composed of white and grey quartzite, banded grey quartzite (?) and grey chert (?). The matrix is sparse and interstitial and composed of similar material, coarse-grained, white and grey in colour with some limonite stain. Cementation of the boulders and pebbles is rather loose.

No fossils were found in this conglomerate and it is tentatively considered to mark the base of the Palaeozoic succession for the reasons given previously.

Map-unit 3

In southwestern La Biche map-area strata which appear to lie in stratigraphic position between map-unit 2 and map-unit 8 are undivided and included in map-unit 3.

The upper part of this succession was examined by W.B. Brady on Beaver River in the vicinity of Pool Creek. The uppermost strata on Pool Creek, overlain by the shales of map-unit 8, consist of 25 feet of fine- to medium-grained dolomite with brecciated, black chert, in part vuggy and weathering brown. This is underlain with irregular contact by about 600 feet of massive fine- to coarse-grained, soft, crumbly, granular dolomite with scattered crinoid remains. Porosity varies from intergranular to small vugs. These beds are underlain by several hundreds of feet of banded dark and medium grey weathering dolomites. They were examined on the creek from the south about a mile upstream from Pool Creek. The dolomite is thin to medium bedded, fine to very fine grained, dark to light grey partly mottled with pink, partly finely laminated or with a few calcite-filled vugs, greyish buff to dark brownish grey

weathering with occasional thin argillaceous beds. These beds in turn, appear to be underlain by similar, or poorly exposed strata which were not examined. They are less resistant, less banded, possibly more argillaceous, and in part weather light brownish grey. Total thickness of map-unit 3 may be of the order of 8,000 feet.

At the north border of Fort Liard map-area, some low hills east of Liard Range are underlain by the Nahanni formation and some underlying dolomites. These strata were examined on Nahanni Butte in Sibbeston Lake map-area. The upper 700 feet is fine-grained, medium-bedded, dark grey, coralliferous limestone interbedded with fine- to coarse-grained, cherty dolomite grading downwards into massive, coarse-grained, recrystallized, porous and vuggy dolomite. In Virginia Falls map-area which lies north of La Biche map-area, the Nahanni formation grades laterally southward and westward into dark shales and shaly limestones. This change was observed on ranges lying approximately north of the headwaters of La Biche River and it is presumed that the Nahanni formation is not present as such in southwestern La Biche map-area, equivalent strata being included in map-unit 4.

DEVONIAN AND MISSISSIPPIAN (map-unit 4)

Map-unit 4 consists mainly of dark grey shales and varies considerably in its stratigraphic limits (see Figure 1).

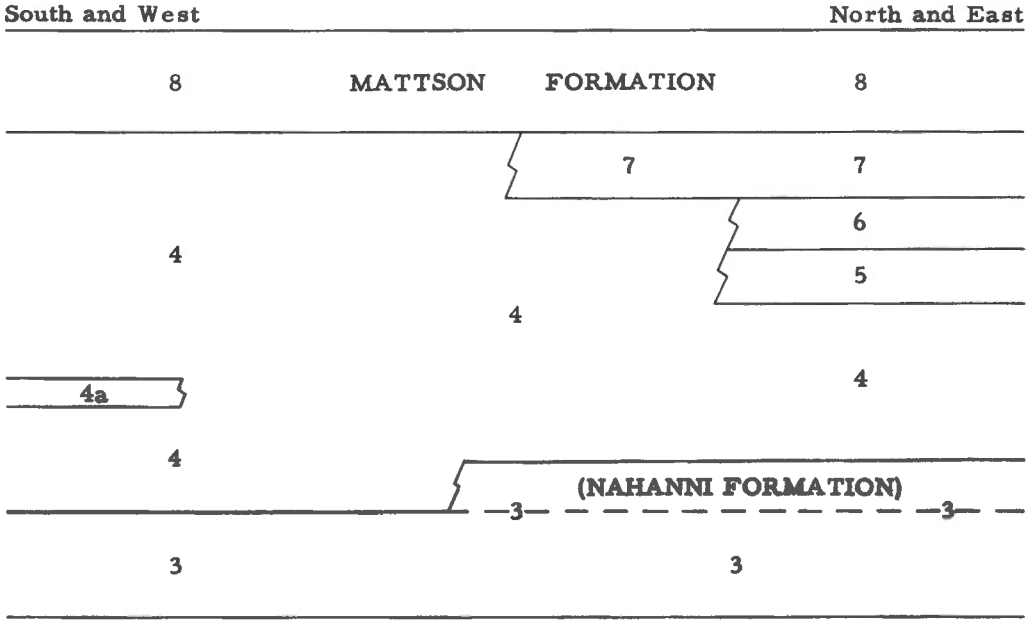

Figure 1. Stratigraphic relationship of map-unit 4 to adjacent units.

In northern Liard Range map-unit 4 is underlain by the Nahanni formation and is succeeded by map-unit 5. Exposures were examined only on the headwaters of Mattson Creek. They are dark shales with thin hard beds. Underlying map-unit 5, on Bluefish Mountain, in Sibbeston Lake map-area, it consists of 200 feet of fissile, black, non-calcareous shale, underlain by 10 feet of thinly bedded, platy, argillaceous, fine-grained limestone, and thence by 285 feet of dark grey shale with nodular mudstone bands. The lower part of the unit is covered. Total thickness is estimated at 5,300 feet. No fossils were found, but equivalent beds in the Sibbeston Lake area yielded fossils of Upper Devonian age.

On the northern flank of Tlogotsho Plateau in Virginia Falls map-area, north of La Biche map-area, map-units 5 and 7 grade laterally westward into dark grey shales, and consequently, the whole shale succession from the underlying Nahanni formation to the overlying Mattson formation comprises map-unit 4. In La Biche map-area, map-unit 4 underlies extensive areas in the western part, and appears in the cores of anticlinal structures in the La Biche and Kotaneelee Ranges in the eastern part. However, as map-unit 7 is present in Fort Liard map-area in Liard Range and on the Bovie structure, the line of facies change between the shales of map-unit 4 and the limestone of map-unit 7 extends from northwestern Tlogotsho Plateau to northeast of Etanda Lakes and the headwaters of Jackfish River, and thence southward between the Liard and Kotaneelee Ranges. (Compare structure-sections, Fort Liard and La Biche map-areas, in pocket). As the facies change between map-units 5 and 4 occurs at about the same position on Tlogotsho Plateau, its position elsewhere is probably comparable, but map-unit 5 does not appear to extend as far south on Liard Range as map-unit 7.

Several sections of the upper part of map-unit 4 were measured on Kotaneelee and La Biche Ranges and on Tika Creek west of the headwaters of La Biche River. The shales are grey to black, calcareous to non-calcareous, fissile to thinly bedded with thin interbeds of sandstone and siltstone, grey, thinly laminated, partly calcareous and rare argillaceous limestone. The sections yielded fossils identified by P. Harker as Mississippian in age, showing that the upper part of map-unit 4 contains shale equivalents of the limestones of map-unit 7. The maximum thickness measured was 1,950 feet at Kotaneelee Gap in Kotaneelee Range. As the base is not exposed, the total thickness of map-unit 4 in eastern La Biche map-area can only be estimated by totalling the stratigraphic interval between the Nahanni and Mattson formations where map-units 3 to 7 are exposed. This is about 7,500 feet. The actual thickness may, however, be less.

In northwestern La Biche map-area, map-unit 4 was examined in only a few places. It is involved in considerable folding and faulting and only intermittently exposed in gullies and creeks. The strata are similar to those described above, being dark grey shale, in part weathering light, silvery or dull grey.

A few thin hard beds weathering light yellowish brown occur at about the middle of the unit.

In the vicinity of Beaver and Crow Rivers map-unit 4 is divisible into three parts. The lower part, at Pool Creek, consists of 675 feet of dark grey, thinly laminated to fissile shales, overlain by fine-grained, quartzose sandstones. These sandstones are indicated separately as map-unit 4a, and were examined at three other localities. Estimated thickness is 700 feet. They are thick-bedded, fine- to medium-grained, light grey to brown quartzose, and weather brown with laminitic stain. Some interbedded dark grey fissile shale and soft black carbonaceous and coaly shale are present near the headwaters of Crow River. No observations were made on the shales of the upper part in southwestern La Biche map-area. Estimated thickness is about 2,000 feet. Total thickness of map-unit 4 in southwestern La Biche map-area is, accordingly, about 3,400 feet.

MISSISSIPPIAN (map-units 5-7)

Map-units 5-6

Map-units 5 and 6 were not examined within the map-areas. Six miles to the north, in southwestern Sibbeston Lake map-area at Jackfish Gap, map-unit 5 consists of about 600 feet of brown-weathering, thinly bedded sandstone, fine- to medium-grained with minor interbedded siltstone and black shale. Map-unit 5 corresponds with "unit 1" described by Patton (1958) and is considered equivalent to the basal Mississippian sandstone described by Hage (1945) from Bluefish Mountain. Map-unit 6 consists of about 550 feet of thinly laminated, calcareous and non-calcareous black shale with a few thin limestone beds and layers of pyritic nodules. It corresponds with "unit 2" of Patton (1958).

Map-unit 7

Sections of map-unit 7 were examined in Petitot River and on the western ridge of Liard Range, one at the headwaters of Mattson Creek near the north border of the map-area and another 25 miles to the south. The latter section is 909 feet thick, but the base of the unit is not exposed. A thickness of 1,920 feet was measured at the Mattson Creek section. This is greater than other nearby sections and may include some duplication by faulting. Map-unit 7 corresponds with the 1,646 feet of strata described by Patton (1958) at Jackfish Gap in Sibbeston Lake map-area as "unit 3". The map-unit consists of medium to thickly bedded, medium- to coarse-grained, grey, crinoidal and fossiliferous limestone interbedded with thin- to medium-bedded, fine-grained, dark grey argillaceous, bioclastic limestone, dark grey, calcareous shale, and thin beds of fine-grained, grey, calcareous sandstone and fine-grained dolomite. Several faunal zones are recognized by P. Harker (1959) ranging in age from upper Kinderhook to lower Chester.

CARBONIFEROUS AND PERMIAN

Mattson Formation (map-unit 8)

The type locality of the Mattson formation is at Jackfish Gap in southwestern Sibbeston Lake map-area. The name was proposed by Patton (1958) to include 3,734 feet of strata overlying his 'unit 3', map-unit 7 of this report. Some 3,161 feet of strata were measured by Brady. Overlying strata are not exposed at the type locality, but as used herein the Mattson formation is considered to be overlain by map-unit 9 of Permian (?) age or by the lower Cretaceous.

Complete sections of the formation were measured at Mattson gap on Liard Range and Tika Creek; partial sections were examined at several other localities. In northeastern La Biche map-area, and western Fort Liard map-area, the Mattson formation is divisible into three parts differing somewhat in composition and general aspect. Owing to insufficient ground control, these divisions are not established with certainty and their validity as stratigraphic units not fully ascertained.

Where the Mattson formation can be divided, the lower part (8a) consists of fine-grained, light grey sandstones mainly thinly 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 partly recessive. The middle part (8b) is mainly fine- to medium-grained, in part coarse-grained to finely conglomeratic, light grey to light brown sandstones, medium-, thick-, and massive-bedded and usually thickly crossbedded. The sandstones weather orangish brown and, being in part friable, form alternating resistant and recessive zones. The unit as a whole, however, is more resistant, cliff- and ridge-forming, than the upper and lower parts. The upper part (8c) includes fine- to coarse-grained, fossiliferous limestones interbedded with fine-grained, light grey, medium-bedded, calcareous sandstones and minor black, fissile, concretionary shale and sandy dolomites.

Thicknesses of the formation and these divisions (feet) at Mattson Gap, Jackfish Gap and Tika Creek sections are respectively: 3,700, 3,161, 4,582; lower part - 1,164, 1,175, 1,732; middle part - 796, 752, 1,574; upper part - 1,740, 1,234, 1,176.

In general, the Mattson formation is thinner and more recessive in the western part of La Biche map-area. Ground control in this part of the area was limited and map-unit 9, if present is mapped with map-unit 8. Estimated thickness of map-unit 8 in the vicinity of Crow and Beaver Rivers is 2,000 feet. The formation is also thinner in southern La Biche and Kotaneelee Ranges as a result of what appears to be general convergence and also possibly bevelling of the formation by an unconformity beneath map-unit 9. Beds similar to the middle part of the Mattson and the basal upper part, underlie map-unit 9 in the southern parts of these ranges.

On Petitot River a covered interval of about 400 feet separates strata referred to map-unit 7 from a few feet of sandstone and chert referred to the lower Mattson (8a) and map-unit 9. These strata were penetrated in the Texaco Northern Foothills Agreement Bovie Lake No. 1 well. (A summary log prepared by H.R. Belyea follows.) The well is reported to have deviated seriously from the vertical and the stratigraphic thickness is probably considerably less than the 1,260 feet drilling thickness encountered.

Log of Texaco Northern Foothills Agreement
Bovie Lake No. 1 Well

Location: Lat. 60°12'09" N; long. 122°58'36" W.

Elevation: 1,756 (Ground), 1,769 (KB).

Summary of log by H.R. Belyea of samples stored at Geological Survey of Canada, Calgary, Alberta.

Depth (feet)	
0- 40	Drift.
	Map-unit 9
40- 120	Chert, grey, black; remnants of sandy dolomite.
	Mattson formation (8a)
120- 800	Sandstone, light grey, fine- to medium-grained.
800- 840	Shale, dark grey and argillaceous siltstone.
840- 950	Sandstone, as above with scattered coarse sand grains.
950-1,000	Shale, dark grey, slickensided.
1,000-1,380	Sandstone, as above.

Where map-unit 9 is absent the Mattson formation is overlain by the Lower Cretaceous Buckinghorse formation. The contact is exposed in several creeks draining the west flank of Liard Range. From west to east across the range, the Mattson formation appears to be rapidly bevelled and still farther to the northeast, the Lower Cretaceous lies on Upper Devonian strata (see Douglas, 1959).

The lower Mattson is considered to be Chester in age as it rests on beds of Lower Chester age, and microflora studies by Hacquebard and Barss (1957) of coal collected by Patton indicate a Mississippian age. No fossils were found in the middle part. Invertebrate fossils from the limestones of the upper part are identified by P. Harker as Pennsylvanian and Permian in age. The Permian beds were found on Tika Creek and are younger than the type Mattson, but are provisionally included in the formation.

PERMIAN (?) (map-unit 9)

Overlying the Mattson formation in the southern parts of the map-areas are chert, sandstone and mudstone included in map-unit 9. The chert is about 150 feet thick and consists of massive or bedded and laminated light and dark grey chert partly sandy and with remnants of sandstone and dolomite. It is succeeded by fine-grained, grey, mottled sandstone and mudstone. These latter beds appear closely allied in distribution to the underlying chert and are, accordingly, considered to comprise a single map-unit. About 300 feet is present on La Biche Range where traversed by La Biche River, whereas on Kotaneelee and southern La Biche Ranges the thickness is less. On southern Liard Range only the chert is present as Hage (1945) reports 85 and 75 feet of chert on Pointed Mountain and the southeastern end of Liard Range respectively. At the former locality, it is overlain by 35 feet of conglomerate with chert pebbles (Hage, 1945) here referred to the Cretaceous. In the northern parts of the map-areas, the map-unit is absent. On Petitot River, chert associated with sandstone overlies map-unit 7 and was penetrated in the Texaco Northern Foothills Agreement Bovie Lake No. 1 well, (see foregoing section). This distribution and relationship to adjacent formations indicate that the map-unit unconformably overlies the Mattson formation, particularly in southern Fort Liard map-area, and that it is, itself, truncated by the pre-Cretaceous unconformity.

Map-unit 9, in the distribution shown, may include other beds as it is thin and subject to some uncertainty in recognition where not observed on the ground. The post-chert beds may be Permian as suggested by the presence of Permian fossils in sandstone talus above the chert at Mount Merrill (Kindle, 1944), but some may possibly be younger. Where the base of the Cretaceous is not established, the basal sandstones of the Buckinghorse formation may be included.

LOWER CRETACEOUS

Fort St. John Group (map-unit 17)

The lower Cretaceous rocks are included in the Fort St. John group comprising the Buckinghorse (14) and Sikanni formations (15, 16). In the region between the Liard and La Biche Ranges the Buckinghorse formation appears to be divisible into four parts which have been mapped separately. The upper

units (11, 12, 13) correspond approximately with the Garbutt, Scatter and lower part of the Lepine formations of the region to the south (see Kindle, 1944). The lowest unit (10) may include some older beds. The Sikanni formation is divided into two parts, mapped separately. The lower (15) is mainly sandstone and the upper (16) mainly shale. Where undivided, rocks of the Fort St. John group are mapped as map-unit 17.

Buckinghorse Formation (map-units 10-14)

Sections of the Buckinghorse formation were described by Stott on Sully and Murky Creeks on the western flank of Liard Range where it is 2,800 feet thick. There the basal beds included with map-unit 11 consist of 33 feet of conglomerate overlain by 20 feet of sandstone. The conglomerate lies with erosional unconformity on the underlying Mattson formation and is composed of angular fragments, 1/2 inch to 6 inches in diameter, of chert, limestone and sandstone pebbles. The sandstone is quartzose, massive-bedded, medium-grained, brownish grey. On Pointed Mountain, Hage (1945) reports 35 feet of conglomerate with chert fragments overlying the massive chert of map-unit 9.

On Kotaneelee River, southwest of Pointed Mountain the basal sandstone and conglomerate of map-unit 11 are underlain by a few feet of micaceous, grey shales (10) containing a fauna of probable Cretaceous age. West of Kotaneelee River, in the southern part of La Biche map-area, the basal beds appear to diverge still further from the underlying map-unit 9 or Mattson formation, so that possibly several hundred feet of strata occur in the interval, mapped separately as map-unit 10. These strata were not examined but, in the Beaver River valley, appear to consist of dark shale near the top and thinly bedded sandstone and shale towards the base. It is not known, however, whether the sandstone considered to mark the base of map-unit 11 is the same throughout or if it is equivalent to the basal beds of the Kotaneelee valley and Liard Range described above. On the east flank of Kotaneelee Range just west of Pointed Mountain, it consists of 80 feet or more of poorly cemented, coarse, yellowish grey sandstone, and, on the headwaters of La Biche River, about 50 feet of fine- to medium-grained sandstone which is brown with a greenish tinge, evenly bedded to thickly crossbedded, soft, poorly cemented, and weathering buff to brown. This sandstone is overlain with sharp contact by 10 feet of black, fissile to rubbly, silty, concretionary shale. Indeterminate fossils from talus blocks indicate a Mesozoic age according to J.A. Jeletzky. Where map-unit 10 is not shown separately, it is included for convenience in undivided Buckinghorse formation (14).

The lower shales (11) are rubbly, micaceous, concretionary and rusty weathering, and contain many thin beds of bentonite. They are about 900 feet thick. A massive quartzose sandstone, glauconitic and carbonaceous, 30 feet thick, lies about 150 feet above the base.

The middle sandstones and shales (12) are 168 to 247 feet thick on Murky and Sully Creeks respectively. The sandstone is quartzose, fine grained, greenish grey, finely crossbedded and glauconitic. It is interbedded with siltstone and rusty-weathering shale on La Biche and Beaver Rivers. East of La Biche Range, these beds appear to be equivalent in part to beds mapped by Kindle (1944) as Scatter formation on Beaver River.

The upper shales (13) are about 1,700 feet thick, rubbly to flaky, concretionary and rusty weathering. They grade upwards into massive, argillaceous, siltstones of the basal beds of the Sikanni formation.

The middle member of the formation is not recognized east of Liard Range. On Petitot River the formation (14) is estimated to be 1,700 feet thick, and on the Plains east of Fort Liard map-area, 615 feet thick in the Imperial Island River No. 1 well (Stott, 1959).

Sikanni Formation (map-units 15-16)

The Sikanni formation is divided into a lower sandstone member (15) and an upper shale member (16).

The lower member of the Sikanni formation on Murky and Sully Creeks is 350 feet thick and consists of greenish grey, fine-grained, quartzose sandstones and dark grey to brownish grey, argillaceous siltstone with some shale. Glauconite is common. It is about 300 feet thick on lower Kotaneelee River, and over 250 feet, base not exposed, at the junction of Petitot and Liard Rivers. East of Fort Liard map-area, 185 feet of fine-grained, light grey sandstone were penetrated in the Imperial Island River No. 1 well (Stott, 1959).

The upper member of the Sikanni formation is approximately 1,500 feet thick on Sully Creek. It consists mainly of rubbly, dark grey, concretionary shales with greyish black, fissile and flaky, sulphur-stained shales with selenite crystals in the middle part. The thickness is estimated at 1,000 feet on Petitot River, and 675 feet were encountered in the Imperial Island River No. 1 well (Stott, 1959).

UPPER CRETACEOUS

The Upper Cretaceous rocks are included in the Fort Nelson, Kotaneelee and Wapiti formations. They occur mainly in southwestern Fort Liard map-area. The Fort Nelson formation also occurs on Kotaneelee River in La Biche map-area, and although it probably underlies much of the eastern part of the Fort Liard map-area, it is not exposed.

Fort Nelson Formation (map-unit 18)

The Fort Nelson formation is best exposed in the canyon of Petitot River where it is 450 to 500 feet thick. The lower part consists of massive, coarse-grained, crossbedded sandstone with scattered pebbles, overlain by mudstone with coal and lenses of conglomerate. The upper part is a massive conglomerate of chert and quartzite pebbles up to 1/2 inch in diameter, interbedded with coarse-grained sandstone. The basal beds are exposed on Sully Creek in La Biche map-area and comprise fine-grained, soft, porous, finely laminated and cross-bedded sandstone grading into the shales of the underlying Sikanni formation. On Kotaneelee River the formation is incompletely exposed and consists mainly of medium-grained sandstone with chert pebbles. In the Imperial Island River No. 1 well, the uppermost 550 feet is assigned by Stott (1959) to the Fort Nelson formation and possibly lower Kotaneelee formation. These beds are coarse-grained, carbonaceous sandstone with shale and fine-grained sandstone in the middle.

Kotaneelee Formation (map-unit 19)

The Kotaneelee formation is exposed only on lower Kotaneelee River and in the canyon of the Petitot River where it overlies the Fort Nelson formation. On Kotaneelee River the formation is about 525 feet thick. The lower 70 feet are blocky and sandy mudstones, grading upwards into massive-bedded, greenish grey, argillaceous, coarse-grained sandstone 15 feet thick. The overlying 260 feet are rubbly, dark grey, rusty-weathering, concretionary shales grading upwards into the basal massive siltstones of the Wapiti formation.

Wapiti Formation (map-unit 20)

The Wapiti formation is present only as remnants capping some of the hills in southwestern Fort Liard map-area. It is sparsely exposed; the best section is that described by Hage (1945) from the east bank of Liard River as banded, medium- to coarse-grained, feldspathic, buff-weathering, calcareous, massive and thinly bedded sandstones about 25 feet thick overlain by 15 inches of low-grade coal.

CRETACEOUS OR YOUNGER (map-unit 21)

In Petitot River canyon, Hage (1945) reports gravels and 83 feet of sandstone, shale and bentonite which he assigned tentatively to the Tertiary. These beds were not re-examined.

Four small areas in southeastern La Biche map-area are shown as map-unit 21. These were not examined on the ground. The northeastern occurrence was seen to consist of about 75 feet of rock, buff- to brown-weathering, very poorly

bedded to massive, with many irregular vertical joints. These occurrences are bounded by steep scarps and unconformably overlie folded and faulted strata of map-units 4 and 10. They appear to be remnants of a more extensive sheet. The constituent material does not seem to be a glacial deposit, but could possibly be a lava flow.

STRUCTURAL GEOLOGY

The Fort Liard and La Biche map-areas embrace a large part of the Liard Plateau of the eastern Cordillera and the western part of the Interior Plains. In these map-areas, as in many others which span the boundary between the Interior Plains and the Cordillera, the bordering structural elements of the mountains are not coincident with the physiographic boundary of the Plains. As previously noted, the more easterly ranges do not extend as far south as the more westerly ranges, but the fold structures and bordering faults continue south beneath the Plains. Still farther east, the bedrock is deformed in a manner similar to that of the mountains to the west into characterstically broad gentle synclines and faulted anticlines.

In the northeastern part of Fort Liard map-area, bedrock exposures are extremely rare, but suggest the presence of the western flank of a broad basin. In the southeast corner, on Petitot River, essentially flat-lying limestones of map-unit 7 are present in limited outcrop and may be indicative of an anticline or a structurally high region. Down river to the point where the Bovie fault crosses the Petitot, are occasional outcrops of poorly exposed grey and black shales of undifferentiated Fort St. John group which appear to form a broad, gentle syncline with a very slight northward plunge. The syncline is evident in sandstones of the lower Sikanni formation on Muskeg River 25 miles to the north. There the west flank of the structure is interpreted to roll over in a fairly tight anticline beneath the Bovie fault.

On Petitot River, in the vicinity of Lake Bovie, the Bovie thrust fault brings gently west-dipping beds of map-units 7, 8a, and 9 to the surface (see structure-section C-D Fort Liard map-area, in pocket). Approximately 160 feet of Mississippian limestones and shales outcrop in the immediate hanging-wall of the fault, whereas the foot-wall rocks are not exposed. The throw on the fault needs to be of the order of 1,500 feet. At the junction of Arrowhead and Muskeg Rivers, sandstones of the lower Sikanni formation occur on either side forming a north-plunging anticline, broken by the Bovie fault. Throw on the fault is estimated to be of the order of 500 feet.

Within the Liard flood plain at the north border of the map-area, limestones and dolomites of map-unit 3 form a northeast-trending ridge underlain by the Nahanni thrust. South of the flood plain, the thrust may be represented by two faults. In the vicinity of Big Island the more westerly fault brings

west-dipping strata of map-unit 7 on to east-dipping beds referred to the lower Mattson formation and the more easterly fault brings these Mattson beds on to the Sikanni formation (see structure-section A-B Fort Liard map-area, in pocket). The faults end on the west flank of the Petitot River syncline.

Between the Bovie structure and Fort Liard is the Petitot River syncline, with resistant sandstones and conglomerates of the Fort Nelson and Kotaneelee formations forming the canyon of the Petitot. The syncline is flat bottomed and lies beneath the right-hand en echelon, west-dipping Nahanni and Liard thrust faults.

The Liard Range lies en echelon to the northeast of Kotaneelee Range and is limited on the south and north by the Liard and the South Nahanni Rivers respectively. The range is bounded on the east by the Liard fault, a west-dipping thrust extending the full length of the map-area. Between the Liard fault and the Nahanni thrust is the Bluefish syncline, a gently south-plunging structure extending from Bluefish Mountain in the Sibbeston Lake map-area and interpreted to die out just north of Fort Liard.

The Liard Range consists of four structural elements, termed from east to west respectively, Liard fault, anticline, and syncline, and Mattson anticline. Of these the Liard fault and the structural equivalent of the Liard anticline north of Mount Flett are more closely allied to the structures lying above the Nahanni thrust. The Liard anticline and syncline and the Mattson anticline on the other hand, are structures typical of La Biche map-area to the west. Their axial planes have a sinuous trend in harmony with the structures to the west and the anticlines are at least in part faulted close to their axes or on their flanks by steeply dipping thrusts. The folds are the primary structural features and the faults secondary modifications.

The doubly-plunging Liard anticline is flanked on the east by the Liard fault and on the west by the Liard syncline. It is complicated by en echelon folding and minor thrust faults. To the south it plunges and is cut out by the Liard fault. In the mountains immediately west of Big Island on Liard River, the fold is offset left-hand en echelon and continues north to plunge out southwest of Mount Flett. The structural equivalent of the Liard anticline north of Mount Flett is essentially a west-dipping succession cut by two steeply dipping thrust faults.

The Liard syncline follows a sinuous course from the south boundary of the map-area to its northern termination at South Nahanni River. Associated with these variations in the surface trace of the axial plane, are marked variations in the plunge. In general, where the axis rises, it swings northeast, and where it falls it swings northwest.

The Mattson anticline swings in harmony with the adjacent Liard syncline. It culminates near the north border of

the map-area and is breached by Mattson Creek to form two complimentary east- and west-dipping homoclines. On the west flank of the fold is a west-dipping thrust, which appears to glide in high Mississippian strata and to cut steeply through the lower Mattson formation. The fault begins in strata of map-unit 7 about at the headwaters of Mattson Creek, swings with the anticline, and is folded and breached to form a klippe in upper map-unit 7 and lower Mattson formation. The fault dies out with the south plunge and termination of the fold. The Mattson anticline is offset left-hand en echelon just north of a second culmination about opposite Mount Flett. The thick succession of recessive rocks of map-unit 4 in the core of the fold is evident. At its southern extremity, Mattson anticline is linked right-hand en echelon to the doubly-plunging Pointed Mountain anticline. In contrast to the steeply west-dipping axial plane of the Mattson anticline, the axial plane of the Pointed Mountain anticline dips steeply east south of the culmination of the fold and steeply west, north of it.

West of Liard Range, the Kotaneelee syncline, with Cretaceous rocks in its core, trends north-south and extends from the north border to near the south border of the map-area. The sinuousity of its trend reflects similar trends in the Kotaneelee Range and western Liard Range. In the north it plunges southward and is deepest where the Fort Nelson formation is present. There, a west-dipping thrust fault is inferred mainly to account for the absence of east-dipping strata of that formation. At the southern end, the syncline plunges northward, and is limited by the fault that extends from the east flank of Pointed Mountain to the southern end of Kotaneelee Range.

The north-trending Kotaneelee Range is formed mainly of Mattson strata and is essentially anticlinal in structure. Its dimensions with respect to the present distribution of the base of the Cretaceous are 55 miles long and from 3 to 7 miles wide. In detail, the anticline is multiple, being divided into several en echelon segments by small synclines and faults. The northern elements merge with those of the Etanda Lakes culmination and the Tlogotsho Plateau, (described later in this report). Just south of Etanda Lakes the anticline trends southeastward and plunges south. It is separated by a north-trending, steeply south-plunging syncline from another segment about 6 miles long, also asymmetric westward but trending nearly north-south. The main central part, where the range is widest, is about 30 miles long. The plunge is to the north at the northern end and to the south at the southern end. The pre-Mattson shales of map-unit 4 are exposed in the core of the anticline and mark the culmination. The segment is asymmetric westward, the east flank dipping at low to moderate angles and the west flank vertical to overturned westward, and broken by two steeply east-dipping faults of apparently small displacement where the range is crossed by Kotaneelee River. The more westerly fault brings upper Mattson onto map-unit 9 and the Buckinghorse formation; the more easterly brings middle Mattson onto upper Mattson. A third east-dipping fault breaks

the crest of the fold and is probably also steeply dipping. It cuts across the crest of the fold at the north and south ends. The east flank of the southern end of the segment is broken by a west-dipping fault which thins the lower part of the Buckinghorse formation. The southern segment of the Kotaneelee anticline is irregularly trending and reflects the change from a westward asymmetric fold to an erect and an eastward asymmetric fold. It lies en echelon southeast of the central segment, separated by a small syncline. The northern end plunges steeply north and the southern end very gently southwestward. A west-dipping fault lies on the east flank and possibly merges with the fault on the east flank of Pointed Mountain.

The La Biche syncline with Cretaceous core, lies between the Kotaneelee and La Biche Ranges. The northern part is doubly plunging and asymmetric westward, the eastern flank being vertical, overturned, or faulted. The southern part is also asymmetric westward. It plunges southward, and broadening rapidly, extends south of the map-area to Beaver River within the Scatter formation (see Kindle, 1944).

La Biche Range, like Kotaneelee Range, is underlain mainly by the Mattson formation and, in structure, is essentially a multiple or compound anticline. The structure is, however, broader and more complex, and the various segments are more distinct. The fold extends from near the north border to beyond the south border, a distance of 60 miles within the map-area. With respect to the present distribution of the base of the Cretaceous, the fold is 18 miles wide at its broadest point where crossed by La Biche River, and about 10 miles wide at the north and south ends. The various segments of the anticline lie en echelon northeast with respect to one another and are separated by small synclines or connected by faults. The segments are doubly plunging, with culminations in which the shales of map-unit 4 are exposed.

The northern segment of the La Biche anticline in the north-central part of the range trends northwest to northward, joining the southern extension of a west-dipping fault present to the north. The fold is asymmetric to the southwest, but the flank is broken by the northeast-dipping La Biche fault. To the northwest, however, the fault gives way to a west-dipping thrust fault. Displacement on the La Biche fault is probably small. It has formed where gently west-dipping upper Mattson and map-unit 9 give way to steeply southwest-dipping middle and lower Mattson, the flexure probably initiating the break.

The central segment of the La Biche anticline trends north-south and is asymmetric westward. At the north end it has two crests; the more westerly is broken by the La Biche fault which ends in the crestal region of the fold in the south. The more easterly axis plunges north and fails to join with the axis of the northern segment that plunges southeastward. The west flank of the anticline beneath the La Biche fault is steeply upturned. To the west, upper Mattson and map-unit 9 strata are

almost horizontal and are broken by northwest-trending faults whose displacements are small and apparently normal.

The southernmost segment of the La Biche anticline trends southwestward and is asymmetric westward. The crest at the north end is multiple. The more westerly elements pass northward into converging west- and east-dipping faults. The most easterly axis lies en echelon southwest of the central segment. Map-unit 4 appears in two areas; the more northerly one is probably the culmination, as the more southerly appears to be due to the greater depth of erosion along Beaver River. On the southeast flank is a south-plunging anticlinal nose. The west flank is steeper and broken by an east-dipping fault of small displacement. Southwest of La Biche anticline, beyond the southern continuation of the Fantasque syncline, a north-plunging anticline is present. It is asymmetric westward near the southern border and beyond, but is more erect north of Beaver River and is possibly linked by a small northwest-trending fault with structures that are asymmetric eastward, lying northwest of Fantasque Lake.

The Mattson formation underlying the Tlogotsho Plateau north of the map-area forms what is essentially a broad, flat-bottomed, gently south-plunging syncline, although no axial line is mapped. Within the map-area, the southeast flank is bounded by southwest-trending folds and southeast-dipping faults that form the northernmost elements in the Kotaneelee Range. The southwest flank is similarly bounded by southeast-trending folds and a southwest-dipping fault which extends southward into the crestal region of the La Biche anticline of northern La Biche Range. These various folds end or culminate in the Etanda Lakes culmination where map-unit 4 is exposed. The culmination also marks the northern limit of the south-plunging La Biche syncline and the southern upturned end of Mattson strata of the Tlogotsho Plateau.

The Fantasque syncline lies west of La Biche Range and extends the length of the map-area. The northern part which is followed by the headwaters of La Biche River, is linear and asymmetric eastward. It is underlain by the lower part of the Buckinghorse formation and bounded on the west by an east-dipping homocline of Mattson strata. In the vicinity of Fantasque Lake the southern part is nearly equidimensional, with respect to the distribution of Buckinghorse strata. Near Beaver River the syncline plunges gently northward and lies within the La Biche Range with strata of the Mattson formation and map-unit 9 exposed along its axis.

In the southwestern quarter of the map-area, strata included in the Buckinghorse formation underlie an irregularly shaped basin, the Beaver River basin, essentially synclinal and flanked by strata of the Mattson formation (9e). Minor structures on the north side of the basin trend south and reflect easterly directed release of stress. Those on the southern side of the basin - the southernmost element of the La Biche anticline and two east-dipping thrust faults on the western flank - reflect

westerly directed release of stress. These latter faults and three east-dipping faults farther west, displace east-dipping strata of the Mattson formation and map-units 3 and 4. The stratigraphic throw is greatest on the fault farthest west, the Beaver River fault, and is progressively less on the more easterly faults as the trough of the Beaver River basin is approached. On Beaver River the structure east of the Beaver River fault may be more complex than indicated. North of Beaver River, the fault is assumed to change to a tear fault along which the east-dipping thrust faults with westerly directed displacements give way to west-dipping thrust faults with easterly directed displacements that repeat strata of the Mattson formation and map-unit 4 and extend north into Virginia Falls map-area underlying the Caribou Range. The west side of this range is thought to be underlain by an east-dipping thrust fault that extends southward into the map-area to near Beaver River.

In north-central La Biche map-area, strata of the Mattson formation and map-unit 4 are gently folded, the axes trending irregularly north or northeasterly. Locally, the folding is more intense, and east- and west-dipping faults with apparently small displacement are present. Some of these faults are contraposed, especially in the region just west of the Fantasque syncline. Most of the structures plunge southward towards the Beaver River basin. In general, the central part may be considered structurally high, although lying between east-dipping faults to the east and west-dipping faults to the west. Some faults are continuations of those involving lower Palaeozoic rocks north of the map-area.

ECONOMIC GEOLOGY

Several structures and features of the stratigraphic succession appear favourable for the accumulation of petroleum and natural gas. However, description of specific structures cannot be attempted in this report.

The upper part of map-unit 3, where observed on Beaver River, consists of about 500 feet of soft, granular, dolomite with intergranular and vuggy porosity. It is overlain by dark shales of map-unit 4. If this unit is equivalent to similar, coarse, recrystallized dolomites underlying the Nahanni formation in the map-areas to the north, it may be fairly widespread in Fort Liard and La Biche map-areas. The Nahanni formation of about 500 feet of limestone, in part reefy, grades southwestward to shale in the Virginia Falls map-area and was not recognized in the vicinity of Beaver River in southwestern La Biche map-area. It may be present beneath Fort Liard and eastern La Biche map-areas. Some of the sandstones of map-unit 4a are clean and porous. Their eastern extent is unknown, but they seem to grade northward into shale. The sandstones and limestones of map-units 5 and 7 and of the Mattson formation outcrop in most of the anticlinal folds of the La Biche, Kotaneelee and Liard Ranges or lie close to the surface. East of Liard Range,

however, these beds are unconformably overlain by the Cretaceous, beneath which they are progressively truncated to the east and northeast (see structure-section C-D, Fort Liard map-area, in pocket). Map-units 5 and 7 grade westward into shale between Liard and Kotaneelee Ranges. The limestones of map-unit 7 are mainly dense and argillaceous, but in southeastern Liard Range and on Petitot River they appear coarser and less argillaceous. Cretaceous rocks form the bedrock beneath much of the plains. The sandstones of the Buckinghorse formation grade eastward into shales. The sandstones of the Sikanni formation persist as far as Imperial Island River No. 1 well east of the map-area (Stott, 1959), but it is not known whether this sandstone reaches the surface to the north or still farther east.

The larger structures of the plains and eastern ranges (see structure-sections, in pocket) are mainly simple folds; the synclines are broad to very gentle, and the anticlines more tightly compressed and locally contorted, overturned, and faulted. The faults are reverse, breaking the crests or steeper limbs, and they dip either easterly or westerly, depending largely, but not invariably, on the asymmetry of the anticline. The relationship of the surface structures to lower formations as shown in the structure-sections is provisional, pending study of structures involving older strata in the map-areas to the north. In general, however, it seems probable that the several culminations in the surface anticlines are represented by culminations of comparable magnitude in the Nahanni and older formations, varying in position depending on the asymmetry of the fold, the presence and nature of minor structures and faults, and on the general regional structural relations.

Only one well has been drilled within the area - Texaco Northern Foothills Agreement Bovie Lake No. 1. It lies about 3 miles north of Petitot River near the culmination on the Bovie structure, a faulted anticline. It commenced in chert of map-unit 9 and reached a total depth of 1,380 feet in sandstones of map-unit 8a.

About 2 miles south of the area in northern British Columbia, Pan American Beaver River No. 1 well is reported to have reached a depth of 8,520 feet and to have encountered natural gas with an estimated flow of 10 million cubic feet per day. This well lies on the southern continuation of the Kotaneelee anticline within La Biche map-area and constitutes a favourable test of the southernmost culmination. No geological data are available on the depth or stratigraphic position of the producing horizon, but the test indicates the presence of hydrocarbons within the eastern ranges of the mountains and enhances the possibilities for the several other large culminations within the map-areas.