CANADA

DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH

GEOLOGICAL SURVEY

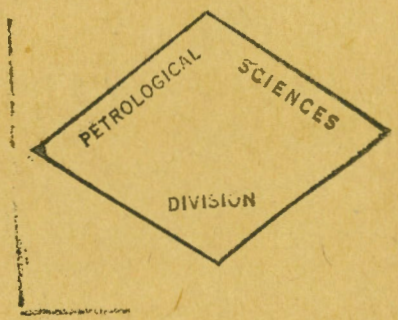
PAPER 45-22

GEOLOGICAL RECONNAISSANCE ALONG LOWER LIARD RIVER, NORTHWEST TERRITORIES, YUKON, AND BRITISH COLUMBIA

(Report and Map)

BY

C. O. Hage



OTTAWA

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Illustration

INTRODUCTION

AREA EXPLORED

During the summer of 1944 a geological reconnaissance was made along Liard River from below the mouth of Fort Nelson River to Birch River, a distance of about 200 miles. Traverses were run for varying distances up its tributaries, Labiche, Kotaneelee, Petitot (Black)[1], Muskeg, South Nahanni, Blackstone, and Birch Rivers. Three

[1] Petitot River was named originally Black River, a name still in local use.

weeks were spent around Trout Lake south of Liard River. The greater part of the region explored lies north of latitude 60 degrees in the Northwest Territories, but a small part is in Yukon, and, south of 60 degrees, a stretch 35 miles long below the mouth of Fort Nelson River is in British Columbia. The area investigated lies between longitudes 121 and 124 degrees.

PREVIOUS GEOLOGICAL WORK

A geological reconnaissance of the region was first made by R. G. McConnell in 1888[2]. G. S. Hume and M. Y. Williams descended

[2] A list of references is given at the end of this report.

Fort Nelson and Liard Rivers on their way to the Mackenzie River district below Fort Simpson in 1922. A. E. Cameron ascended the first 80 miles of South Nahanni River in 1935. A. W. Nauss, working for Imperial Oil, Limited, Canol Project, descended Fort Nelson and Liard Rivers in 1943. In the same year E. D. Kindle followed the same route to the mouth of Fort Nelson River and ascended the Liard as far as Hell's Gate. This report is a continuation of Kindle's work below the mouth of Fort Nelson River.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his appreciation for many courtesies extended to him and his party by the post managers of the various trading companies, and by trappers living along the river. Messrs. David Robertson and James F. Davies gave efficient help as student assistants.

PHYSICAL FEATURES

The largest topographical divisions in the area explored are the eastern ranges of Mackenzie Mountains and the Plains to the south and east of them. These divisions are separated, roughly, by Liard River, which skirts the south end of the mountains and then swings north, parallel with the eastern range, as far as the mouth of South Nahanni River, from where it flows northeast to join the Mackenzie at Fort Simpson.

Liard Range is the name given to the mountains that begin a short distance north of Fort Liard. They rise to elevations of between 3,000 and 4,000 feet above sea-level and trend generally in a northerly direction, crossing South Nahanni River about 20 miles above its mouth.

Nahanni Butte, which has a relief of over 4,000 feet, is close to the southern end of another range of mountains that lies to the east of the Liard Range and trends almost due north from the mouth of South Nahanni River to the mouth of the North Nahanni. It is appropriately named Nahanni Range.

Labiche Range lies west of the Liard Range, and is the first range of mountains encountered ascending Labiche River. The range forms an anticlinal structure that plunges to the south and disappears before reaching Liard River. It crosses South Nahanni River about 30 miles above its mouth.

The Plains in this region have been divided into two physiographic units (Camsell, 1921)[1]: (1) the Alberta plateau; and

[1] Author's name and/or dates of publication, shown in brackets, refer to the list of references at the end of this report.

(2) the Mackenzie lowlands. The northern edge of the Alberta plateau is only a short distance south of Liard River, and this physiographic unit forms part of the Great Plains area of northeastern British Columbia, Alberta, and Saskatchewan. The Mackenzie lowlands lie to the north of the Alberta plateau and east of Mackenzie Mountains. Within them are a few erosional remnants of the Alberta plateau, and also that part of Liard River Valley in the area traversed.

Liard River, below its confluence with the Fort Nelson, flows swiftly as a braided stream to Flett Creek, about 35 miles below Fort Liard. Below Flett Creek the current is less rapid, and the river flows in broad meanders. These continue for 30 miles below the mouth of South Nahanni River. The Liard then enters the "Long Reach", where it flows in a straight course for 15 miles at a rate of about 3 miles an hour. Above Fort Liard the river banks are several hundred feet high, but farther downstream the banks become lower and the land rises gradually for a considerable distance back from the river.

The largest tributary streams come from the mountains and include Labiche, Kotaneelee, and South Nahanni Rivers. The last is several times larger than either of the others. Tributary streams from the Plains are fewer and smaller. The largest is Petitot River, which flows from the southeast for over 200 miles. Other streams are Muskeg, Netla, Blackstone, Birch, and Poplar Rivers.

The Plains area contains many lakes, both large and small. Trout Lake is the largest, having a length of 35 miles and a maximum width of 10 miles. It is about 1,200 feet higher than Liard River to the north. The land around the lake is flat and swampy except along and between the southern arms of the lake where it rises to plateau level, between 500 and 600 feet above the lake. Trout Lake is drained by Trout River into the Mackenzie.

The character of the underlying bedrock is one of the main factors in determining relief. Areas of shale, both Cretaceous and Devonian, outline many of the valleys and low areas, whereas the harder members of

limestone, dolomite, sandstone, and quartzite form the higher land, ridges, and mountains.

STRATIGRAPHY

GENERAL STATEMENT

The exposed consolidated rocks within the area range in age from Silurian to Upper Cretaceous or Tertiary. Complete details of the succession and thicknesses of formation were not always obtainable, and further field work will no doubt result in appreciable modifications and additions to the information given here. Two new formational names have been proposed, one in the Devonian and the other in the Cretaceous. E. D. Kindle's classification (1943) was followed as closely as possible, but the scarcity of Lower Cretaceous outcrops did not justify its division into formations for mapping purposes.

TABLE OF FORMATIONS

Era	Period	Epoch	Group	Formation	Thickness Feet
Cenozoic	Quaternary	Recent			
		Pleistocene			
Unconformity					
Mesozoic	Cretaceous	Upper Cretaceous			50 +
				Kotaneelee	500 +
				Fort Nelson	500-800
		Lower Cretaceous	Fort St. John		2,250 +
Unconformity					
Palaeozoic	Carboniferous	Pennsylvanian and/or Mississippian			1,000 +
		Mississippian			1,000 +
	Devonian	Upper Devonian			2,000 +
		Middle Devonian		Nahanni	450
Disconformity					
	Silurian				500 +

DESCRIPTIONS OF FORMATIONS

Silurian

The lowest observed strata in the area are assigned to the Silurian, and form approximately the lower half of the south-facing cliffs on Nahanni Butte. The rocks are bedded and have a banded appearance. They are composed of siliceous limestone and dolomite alternating in dark and light grey beds about 3 feet thick. Most of the rock is fine-grained, hard, and dense, and has been indurated over large areas by siliceous and carbonate solutions. Veinlets of quartz and calcite from $\frac{1}{2}$ inch to 2 inches thick intersect the rock in various directions, and include lenses as much as 10 feet long and 3 feet thick.

The exposed thickness of these beds is about 500 feet. They are overlain conformably by limestone beds of Middle Devonian age. The base of the Silurian section is marked by a thrust fault, and, therefore, its total thickness is not known. On Lone Mountain, at the mouth of North Nahanni River, similar beds were described by E. M. Kindle (1921) and have an exposed thickness of at least 1,500 feet. No fossils were found in these lower beds on Nahanni Butte, but previous workers have agreed that they are of Silurian age. McConnell (1890) stated that three rock series were clearly defined on Nahanni Butte, and assigned a Devonian age to the upper series on fossil evidence. He did not mention the presence of thrust faults. The writer found that McConnell's lower and upper series are the same and are repeated by faulting, and that the middle shale series overlies massive limestone and dolomite beds of Middle Devonian and Silurian ages. The first map (Camsell and Malcolm) indicating a Silurian age for these rocks was published in 1921. No further evidence was given in the accompanying report for this determination. Hume (1923) examined the rocks below those of Middle Devonian age and assigned them to the Silurian, but did not find any fossils in them. Cameron (1938) is the only one reported to have found Silurian fossils on Nahanni Butte. He collected a coral identified as Favosites cf. F. niagarensis Hall. Nauss (1943) assigned these rocks to the Silurian, and on the basis of their stratigraphic position and lithology suggests that they are correlative with the upper part of the Lone Mountain dolomite on North Nahanni River.

The contact with the overlying Middle Devonian is placed where the rocks lose their banded character and are less dolomitic. No evidence of an unconformity was found, but the absence of Lower Devonian rocks necessitates a considerable interval of non-deposition. Such an interval would be represented by a disconformity.

Middle Devonian

Nahanni Formation

Overlying the banded Silurian dolomites and limestones disconformably on Nahanni Butte are bedded, dark grey, light grey weathering, dense, dolomitic limestones and finely crystalline and dense limestones that carry a Middle Devonian fauna. It is proposed to introduce the name Nahanni formation for this assemblage of strata. These beds form the upper part of the south-facing cliffs, and have a thickness of 450 feet. The assemblage is repeated by faulting on the eastern and western parts of the butte.

Fossils are not abundant, and those present are difficult to collect owing to the hardness of the enclosing rock. The following collection was identified[1] as of probable Middle Devonian age.

[1] All Palaeozoic fossils collected by the writer and listed in this report were identified by Alice E. Wilson, Geological Survey.

Prismatophyllum sp. cf. P. prisma Lang and Smith; Favosites sp. cf. F. hemispherica (Troost); stromatoporoids, "Columnaria" cf. disjuncta Whiteaves; Syringopora sp.; Aulopora sp. cf. A. montanensis Kindle; Martinia cf. sublineata Meek; cf. Cyrtia rockymontana Warren; cf. Platyceras sp.; Bellerophon sp.; Spirorbis sp.; Proetus sp.; bryozoa.

The Nahanni formation is correlated with the Middle Devonian limestone on Lone Mountain at the mouth of North Nahanni River. The characteristic fossil of the upper limestone member of the Ramparts formation of Middle Devonian age on Mackenzie River below Fort Norman, Stringocephalus burtini, was not found on Nahanni Butte. It appears from air photographs that the beds of Middle Devonian age form continuous outcrops along Nahanni Range between North and South Nahanni Rivers. The assemblage of limestone and dolomitic limestone was studied at only one locality, Nahanni Butte.

Upper Devonian

Overlying the Nahanni formation and underlying a limestone member carrying a lower Mississippian fauna is a thick series of bedded shales assigned to the Upper Devonian. A complete section of these beds was not observed, so that it is not possible to itemize their characters. About 800 feet of beds immediately overlying the Nahanni formation are partly exposed in the saddle between the eastern and western parts of Nahanni Butte. The upper boundary is marked by a thrust-faulted block of Silurian beds. The section as exposed is as follows:

Top of section	Thickness Feet
Shale, dark grey, hard, thinly bedded; limestone beds up to 10 inches thick	50
Shale, dark grey to black, bituminous	25
Concealed	50
Shale, greenish grey, fissile, weathers easily	75
Concealed; some small indications of shale	600
Total thickness	800

This was the only place where the beds immediately overlying the Nahanni formation were observed. No fossils were found in them.

The upper part of what is considered the same shale series is exposed on Bluefish Mountain about 4 miles northwest of Nahanni Butte, where the following section was measured:

Top of section	Thickness Feet
Base of cliff 90 feet high of bedded, sandy grey limestone interbedded with some sandy shale, containing a lower Mississippian fauna.	
Shale, dark grey, thinly bedded; few scattered concretions	215
Shale, interbedded with fine-grained sandstone	20
Shale, dark grey, fissile; with widely separated ironstone beds up to 3 inches thick	100
Concealed	215
Shale, dark grey; contains reddish brown weathering, ellipsoidal concretions	135
Shale, dark grey; in part concealed	100
Shale, dark grey to black, hard, fissile; few ironstone concretions along base of outcrop	400
Total thickness	1,185

No fossils were found in these beds.

Separating Bluefish Mountain and Nahanni Butte is the broad valley of Bluefish Creek. It appears very probable that this valley is underlain by Upper Devonian shale that occupies the stratigraphic interval between the observed upper and lower beds already described. If this should be so, and if there is very little repetition of beds by thrust faulting in the valley, the thickness of the unexposed beds may be several times that of the exposed strata. On North Nahanni River, Hume (1922) measured between 3,100 and 4,600 feet of Upper Devonian beds, with the top not exposed. The succession near Nahanni Butte may be as great or greater than this.

Upper Devonian rocks are scattered along Liard River east of Nahanni Butte. The first observed is about 8 miles below the mouth of Blackstone River and about 21 miles northeast of Nahanni Butte. It consists of thinly bedded, dark grey to black, hard shale in a low outcrop about half a mile long on the south shore of the river. No fossils were found here, but the beds appear similar to the dark, bedded shales on the lower slopes of Bluefish Mountains.

Scattered outcrops occur along the south bank of Liard River for about a mile opposite the mouth of Matou River and close to George Turner's cabin, 40 miles northeast of Nahanni Butte. The rock consists of brown weathering, sandy limestone interbedded with grey shale. The limestone is ripple-marked and occurs in beds from a few inches to a foot in thickness. One bed of limestone shows cone-in-cone structures. The following fossils were collected:

Diphyphyllum sp. nr. D. tubiforme Fenton; cf. Tabulophyllum sp.; Schizophoria sp.; Stropheodonta sp.; Productella sp. cf. P. walcotti Fenton; Atrypa sp.; Martinia sp.

The age of these beds is considered to be Upper Devonian, and the strata are correlated with some part of the Hay River formation (Whittaker, 1922, p. 52).

Birch River was traversed for 5 miles from Liard River. Several outcrops were observed. The largest consisted of 55 feet of grey, fissile shale. A number of thin beds of ripple-marked sandstone and fossiliferous limestone was found in other outcrops, and these may be interbeds in the grey shale. The outcrops were too widely separated to determine their relative stratigraphic positions.

Fossils were very abundant in one of the limestone beds, and those collected were identified as follows:

Spirifer cf. kennicotti Meek; Atrypa reticularis Linnaeus var.; A. sp. cf. A. montanensis Kindle; A. cf. missouriensis Miller; A. sp. small; Cyrtina cf. billingsi Meek; Rhipidomella sp.; Strophonella sp.; Pugna sp.; Aulopora sp.; Diphyphyllum sp.; and bryozoa.

These beds are correlated with some part of the Hay River formation, possibly low in the section.

Carboniferous

Carboniferous strata are exposed in the southern ranges of the Mackenzie Mountains. They were examined at various places between Labiche Range and Bluefish Mountain, a distance of about 80 miles. Rocks of this age were first noted in the area by Hume (1923) who described and assigned a Kinderhook age to the fauna he collected. No complete section was observed by the writer at any one locality, and as there are considerable lateral differences in the sediments from place to place the present summary must be regarded as subject to later modifications. The strata have been divided into two parts, a lower calcareous unit composed predominantly of limestone with some interbedded shale, and an upper unit of sandstone with interbedded black shale capped by chert. Information on the thicknesses of these units and on their contacts with overlying and underlying beds is lacking, so that no formational names have been assigned to them. The lower unit is of Mississippian age, and the upper one is either of late Mississippian or early Pennsylvanian age, or may include strata of both ages.

Mississippian

Strata included in this assemblage of beds overlie the shale beds assigned to the Upper Devonian and underlie a series of sandstone and interbedded dark shale beds. They consist of limestone, cherty limestone, and, particularly in the lower part, include some interbedded shale. Sections were examined on Liard Range 18 miles north of Fort Liard, and on Flett, Sawmill, and Bluefish Mountains.

The following section was measured on the west slope of a small mountain about 2 miles west of Big Island in Liard River:

Top of section	Thickness Feet
Limestone, grey, bedded; contains dark grey chert in thin beds and irregular discontinuous bodies; fossils, lot 27	150 +
Shale, brown; interbedded with brown weathering limestone; fossils, lots 28 and 29	100

Shale, dark grey, fissile; with ironstone concretions, in part concealed	200
Limestone, interbedded with calcareous shale; fossils, lot 42	200
Limestone, dark grey, finely crystalline; interbedded with minor amount of shale; fossils, lot 8	100
Shale, calcareous; with some beds of crinoidal limestone	100
Total thickness	850

Neither the top nor the bottom of this assemblage of beds was observed at this locality, but 2 miles farther west the upper part is exposed and consists of the following:

Top of section	Thickness Feet
Base of later Carboniferous section	
Limestone, crinoidal and crystalline; interbedded with grey shale; some black, fissile shale; fossils, lot 32	100
Limestone, dark grey, fine, crystalline; interbedded with shale; fossils, lot 31	60
Concealed	140
Limestone, dark grey, fine, crystalline; some black chert; interbedded with some black shale containing selenite; fossils, lot 30	100
Total thickness	400

The lower beds are believed to be part of the upper beds in the section previously described.

The strata on Flett Mountain are not well exposed where observed, and there appears to be some doubt as to the relation between the beds above and below a covered interval of 800 feet. The lower beds may represent a large slumped section of the upper strata, as suggested by the fossils collected. The uppermost 300 feet form a continuous section.

On Sawmill Mountain, north of Flett Creek, the following section was measured:

Base of Later Carboniferous	Thickness Feet
Limestone, crinoidal; interbedded with black shale	80
Limestone, light grey, coarsely crystalline, bedded	35
Limestone, crystalline and crinoidal; interbedded with thin beds of shale; fossils, lot 41	75

Limestone, crystalline, bedded, cliff forming; chert	100
Limestone, dark grey; interbedded with an equal amount of black shale	60
Shale, dark grey, fissile; fossils, lot 40	20
Limestone, grey, crystalline; interbedded with dark grey shale	80
Total thickness	450

On Bluefish Mountain the Mississippian strata differ considerably from those previously described, as indicated by the following section:

Top of section	Thickness Feet
Shale, dark grey, not measured	
Sandstone, fine-grained, buff weathering; fossils, lot 20	15
Shale, black, fissile	20
Sandstone, bedded, buff weathering	20
Shale, black, fissile	10
Limestone, sandy; interbedded with some grey shale; fossils, lot 19	40
Limestone, nodular; interbedded with grey shale	5
Shale; interbedded with thin, fine-grained sandstone beds	25
Shale; grey, fissile	50
Limestone, bedded; fossils, lot 17	5
Shale, grey, fissile	75
Concealed, believed to be shale	50
Shale, greenish grey, fissile; small concretions; fossils, lot 18	120
Limestone, grey, sandy, cliff forming; interbedded with small amount of sandy shale; fossils, lot 16	90
Contact, Upper Devonian	
Total thickness	525

Beds overlying the above section could be seen exposed farther north, but were not examined. The sandstone and shale of the upper 65 feet of the measured section appear similar to later Carboniferous beds to the southwest. If this is so the Mississippian assemblage is completely exposed at this locality and has a thickness of 460 feet. The strata apparently thin to the east, as no rocks of Carboniferous age have been reported east of Nahanni Butte. The bedrock immediately to the east of this butte is drift covered, but as no fossils were found in the outcrops along Liard River for 21 miles to the northeast, Carboniferous beds could be present in this part of the area.

Fossils are, on the whole, plentiful in the Mississippian beds, and representative collections were made where the rock sections were examined. The fossil horizons have been indicated in the described sections. Collections from Liard Range west of Big Island are listed in the following tables:

The upper limestone members include lots 24, 25, 27, 30, 31 and 32.

	Fossil lots					
	24	25	27	30	31	32
Zaphrentid, new				x		
Coral, new genus						x
Hapsiphyllum cf. calcareforme Hall						x
Pentremites conoidens Hall					x	
Fenestella n.sp.	x		x		x	x
Linoproductus minnewankensis Shimer	x					x
L. sp. close to L. tenuicostus (Hall)			x			
Echinoconchus sp. A. small			x			x
E. cf. alternatus (Norwood and Pratten)	x					
Ripidomella sp.				x		
Schellwienella cf. inaequalis (Hall)				x		
Schellwienella sp. A					x	
Dictyoclostus burlingtonensis Hall	x		x			
D. gallatinensis Girty	x		x			
D. sp. near D. wortheni Hall			x			
D., n.sp.			x	x		
Spiriferella minnewankensis Shimer	x		x			x
Spirifer sp. close to S. cascadensis Warren				x		
Camarotoechia cf. metallica White		x				
Camarotoechia n.sp.			x			
Cliothyridina sp.				x		
Productella cf. concentrica (Hall)	x		x			
Dielasma n.sp.	x	x	x			
Girtyella n.sp.			x			
Rhynchopora n.sp.			x			
Orbiculoidea n.sp.	x					
Schizophoria sp. close to S. chouteauensis Weller	x					
Chonetes	x					
Brachythyris species A.	x					

	24	25	27	30	31	32
Composita sp.	x					
Capulus sp. close to C. parvus Swallow			x			
Phillipsia sp. A.						x
Proetus peroccidens H. and W.	x					
Sandalodus sp. cf. S. crassus Newberry as reported by C.M. Sternberg					x	

Lots 28 and 29 are from beds underlying the previously mentioned strata and include the following fossils:

Coral, new genus 5 species
Syringopora surcularia Girty
Fenestella n.sp.
Schizophoria sp.
Schuchertella cf. fernglenensis Weller
Schellwienella cf. S. inaequalis (Hall)
Dictyoclostus gallatinensis Girty
Camarotoechia cf. metallica White
Camarotoechia, 2 new species
Dielasma, 2 new species
Spirifer cf. albertensis Warren
Reticularia pseudolineata (Hall)
Squamularia ? depressiplicata Shimer
Cliothyridina sp.
Composita humilis Girty
Cf. Brachythyris sp.
Euomphalus sp.
Phillipsia sp. B.

Lot 42, collected from flaggy limestone contains Schellwienella cf. planumbona Weller and Spirifer centronatus Hall and Whitfield.

Lot 8 represents the lowest collection from several horizons at this locality. It contained:

Fenestella, 3 new species
Orbiculoidea sp. D.
Rhipidomella sp.
Schuchertella sp.
Schellwienella cf. planumbona Weller
Chonetes illinoisensis Meek
Echinoconchus, 2 new species
Dictyoclostus sp.
Dielasma sp. F.
Spirifer albapinensis Hall and Whitfield
S. striatiformis Meek
Goniatite fragment
Proetus peroccidens Hall and Whitfield

On Flett Mountain, the upper 300 feet of limestone includes the following forms:

Amplexus sp. A.
Syringopora sp. A.
Pentremites cf. conoideus Hall
P. sp. close to P. elongatus Shumard
Linoproductus ovatus (Hall)
Productid fragment
Camarotoechia sp. aff. C. metallica White
Dielasma chouteauense Weller
Dielasma n.sp.
Spirifer cf. albertensis Warren
Spirifer albapinensis Hall and Whitfield
Spirifer centronatus Winchell
Spiriferella minnewankensis Shimer
Squamularia ? depressiplicata Shimer
Cliothyridina lata Shimer
Rhipidomella sp.
Pugnax sp.
Schellwienella planumbona Weller
Brachythyris n.sp.
Pseudosyrinx sp.
Eumetria verneuiliana (Hall)
Cliothyridina cf. glenparkensis Weller
Composita sp.
Myalina sp.

From Sawmill Mountain, north of Flett Creek, the following Mississippian forms have been identified:

Lot 40, below cliff of cherty limestone

Coral, new genus, 3 species
Productella sp.
Linoproductus minnewankensis Shimer
Camarotoechia 2 new species
Rhynchopora n.sp.
Dielasma cf. chouteauense Weller
Dielasma n.sp.
Girtyella sp.
Spirifer cf. albertensis Warren
Spirifer centronatus Winchell
Spirifer sp. aff. S. tenuimarginatus Hall
Spiriferella minnewankensis Weller
Reticularia cf. pseudolineata (Hall)
R. n.sp.
Cliothyridina cf. lata Shimer
Composita athabaskensis Warren
C. humilis (Girty)
Orthonychia cf. cyrtolites (McChesney)

Lot 41, above cliff of cherty limestone

Schellwienella planumbona Weller
S. cf. inaequalis (Hall)
Cf. Chonetes illinoisensis Worthen
Productella cf. concentrica (Hall)
Echinoconchus cf. alternatus (Norwood and Pratten)
Igoceras n.sp.
Phillipsia sp. B.

The collections from Bluefish Mountain contain the following forms:

	Fossil lots				
	16	17	18	19	20
Coral, new genus sp.				x	
Bryozoa - undetermined			x		
Schizophoria sp.		x			x
Productella sp.	x		x		
Productus sp.	x				
Camarotoechia cf. metallica White	x				x
Cf. Eumetria sp.					x
Spirifer albapinensis Hall and Whitfield		x			
S. centronatus Winchell ?		x			
S. rutherfordi Warren		x			
Cf. Squamularia ? depressiplicata Shimer		x			
Dictyoclostus jasperensis (Warren)				x	
Cliothyridina lata Shimer var.		x		x	
Cf. Cliothyridina sp.			x		
Composita humilis (Girty)		x			
Composita sp.				x	
Chonetes cf. illinoisensis			x		
Chonetes n.sp.	x				
Cf. Dielasma sp.			x		
Delthyris ? sp.			x		
Amboccelia sp.			x		
Spiriferina sp.			x		
Cf. Palaeoneilo sp.			x		
Schellwienella cf. planumbona Weller	x				
Cf. Nucula sp.			x		
Ammonite cf. Girtyoceras ? sp.			x		
Orthonychia sp.				x	
Euomphalus sp.		x			
Entomis sp.			x		
Primitia ? sp.			x		
Ostracod - Kirkbyidae family and others			x		
Proetus sp.				x	

The outcrops along Liard River, though small, yielded a representative collection, as follows:

	5 miles above Flett Rapids	2 miles below Big Island
Coral, new genus 2 species	x	x
Diphyphyllum cf. mutabile Kelly	x	
Crinoid stems	x	x
Fenestalla sp.	x	
Spirifer centronatus Winchell	x	
S. cf. striatiformis Meek	x	
S. albapinensis Hall and Whitfield	x	
S. sp.	x	x
Spiriferella cf. minnewankensis Shimer	x	
Reticularia pseudolineata Hall	x	
Athyris lamellosa (Léveillé)	x	
Cliothyridina cf. obmaxima (McChesney)	x	

	5 miles above Flett Rapids	2 miles below Big Island
C. lata Shimer	x	
Schellwienella planumbona Weller		x
S. cf. inaequalis (Hall)		x
S. sp.	x	x
Linoproductus minnewankensis Shimer	x	
L. n.sp.	x	
Echinoconchus cf. alternatus (Norwood and Pratten)	x	x
Dictyoclostus n.sp.	x	
Camarotoechia sp.	x	x
Girtyella sp.	x	
Cf. Brachythyris sp. A.	x	
Pseudosyrinx sp. A.	x	
Squamularia ? depressiplicata Shimer	x	x
Composita cf. madisonensis (Girty)	x	
Schizophoria sp.		x
Igoceras cf. banffense Warren	x	
I. sp.	x	
Straparolus sp.	x	
Proetus peroccidens Hall and Whitfield	x	

A lower Mississippian age (Kinderhook) has already been assigned by Hume (1923) to the strata on Liard River above Flett Rapids. The position of these beds with respect to the top of the Carboniferous section is not known, but is believed to be at some distance below it, as higher beds are present in the mountains to the west. The total faunal collection from the Lower Carboniferous shows a decided correlation with the Banff formation of the Rocky Mountains in Alberta. The uppermost beds of this assemblage have also some forms in common with the lower part of the overlying Rundle formation. The fauna characteristic of the upper limestone beds include: Pentrimites conoideus Hall; Spiriferella minnewankensis Shimer; Dictyoclostus gallatinensis Girty; and Rhynchopora. Spirifer centronatus is commonly associated with beds lower in the section and may have a limited vertical range in its distribution. The Spirifer centronatus zone and lower beds also contain Spirifer albapinensis, Spirifer striatiformis, Reticularia pseudolineata, Cliothyridina lata, and Composita cf. humilius.

The fossil content of the Lower Carboniferous strata indicates a lower Mississippian age for the assemblage of limestone and shale beds overlying the Upper Devonian.

Pennsylvanian and/or Mississippian

The assemblage of strata referred to here as of Pennsylvanian and/or Mississippian age consists of sandstone interbedded with dark shale and an upper chert member. So far as could be determined they form a conformable series with the underlying calcareous beds. A complete section of this group of beds was not observed at any one place, but the upper part was examined on Pointed Mountain and at the south end of Liard Range, and the lower part on Sawmill Mountain and in the mountains west of Big Island.

A description of the upper part, on Pointed Mountain, is as follows:

Top of section	Thickness Feet
Conglomerate; chert fragments; sand matrix	35
Chert; beds about 12 inches thick	85
Concealed	200 ±
Sandstone, light grey, bedded, fine-grained; fossils, lot 11	10
Shale, dark grey, fissile	4
Sandstone, buff, fine-grained; fossils, lot 12	20
Shale, dark grey to black, fissile, bituminous	45
Sandstone, fine-grained, bedded, hard; fossils, lot 13	15
Concealed	100
Sandstone, medium- to coarse-grained, quartzitic, crossbedded; beds 4 to 15 feet thick; fossils, lot 15	150 +
Total thickness	614

On Sawmill Mountain the lower part of the section was examined except where sheer cliffs made this impossible. The succession is as follows:

Top of section	Thickness Feet
Sandstone, white, quartzitic; thick beds	75
Sandstone; interbedded with dark grey shale; observed only in part	400
Sandstone, white, fine-grained, cliff-forming	100
Sandstone, bedded, fine-grained, some sandy shale	35
Shale, dark grey, fissile	30
Contact with Lower Carboniferous	
Total thickness	640

No fossils were found in these beds, but the section was not examined throughout. The uppermost bed of quartzitic sandstone is remarkably similar to the lowest bed examined on Pointed Mountain, but apart from the lithology there is no other evidence for this correlation.

On the basis of this similarity the thickness of this group of beds would be in the neighbourhood of 1,000 feet.

The following basal beds were examined on Liard Range 5 miles west of Big Island:

Top of section	Thickness Feet
Sandstone, white, fine- to medium-grained, bedded	50 +
Shale, dark grey to black, fissile; concretions	110
Sandstone interbedded with black shale; sandstone beds up to 3 feet thick; shale beds ½ foot to 2 feet thick	40
Sandstone, white, fine- to medium-grained; beds up to 10 feet thick; ripple-marks ..	60
Shale, black, fissile	40
Contact with Lower Carboniferous	
Total thickness	300

No fossils were found in these beds. Several hundred feet of the overlying sandstone and interbedded shale beds are exposed, but were not examined.

At the south end of Liard Range 75 feet of bedded chert was measured, but its contact with underlying sandstone was not exposed. The upper strata are thinly bedded, and contain branching, plant-like structures similar to those seen in Lower Cretaceous sandstones at the mouth of Petitot River. The chert beds vary in colour from light to dark grey, many are mottled, and some contain fine grains of quartz sand. The texture of the rock, as seen under the microscope, is cryptocrystalline.

These later Carboniferous beds are well exposed at several places on Labiche Range adjacent to Labiche River. Circumstances, however, permitted only incomplete measurements of this section, as follows:

Top of section	Thickness Feet
Sandstone, medium-grained (not measured)	
Shale, black, fissile, bituminous; fossils, lot 4	10
Concealed	40
Sandstone, grey, buff weathering	55
Concealed	75
Sandstone, light buff	18
Sandstone, calcareous; fossils, lot 3	10
Shale, thinly bedded, calcareous	45

	Thickness Feet
Concealed	45
Limestone, light grey, bedded, cherty; fossils, lot 2	18
Sandstone, light grey; crossbedded	29
Limestone, dense; some chert	12
Sandstone, light buff	30
Limestone, light grey, dense	10
Sandstone, light grey, calcareous	20
Sandstone, medium-grained, crossbedded	60
Limestone, light grey, beds 1 to 4 feet thick, some sandy others cherty; fossils, lot 1 ..	130
Total thickness	607

The contact between the later Carboniferous beds and those of definite Mississippian age may be at the top of the uppermost limestone bed or at the base of the lowest sandstone.

Fossils are not abundant in the later Carboniferous strata, but a small collection was made from the upper beds on Pointed Mountain and the lower beds on Labiche Range. The specimens are listed in the following table:

	Pointed Mountain				Labiche Range			
	Fossil lots				Fossil lots			
	11	12	13	15	1	2	3	4
Reticularia sp.	x					x		
Orbiculoidea sp. A.		x		x		x		
O. sp. B.				x				
Pustula sp. fragment			x					
Dictyoclostus cf. portlockianus crassicostatus						x		
D. sp. A.				x				
D. sp. B.							x	
Leiorhynchus sp.				x				x
Pugnoides sp. A.				x		x		
Spirifer sp.				x				x
Spirifer cf. occidentalis Girty							x	
Spirifer similar to S. rutherfordi					x			
Composita sp. A. aff. C trinuclea (Hall)							x	
Composita sp.					x			
Composita cf. ovata Mather						x		
Productella sp. A.						x		
Athyris sp.						x		

	Pointed Mountain				Labiche Range			
	Fossil lots				Fossil lots			
	11	12	13	15	1	2	3	4
Dielasma sp.					x			
Edmondia sp.	x							
Cf. Acanthopecten sp.	x							
Aviculopecten sp.				x				
Leda cf. arata sp.			x					
Nucula sp.				x				
Allorisma sp. A. close to A. subcuneata M. and H.				x				
A. sp. B.				x				
A. sp. C.								x

Fossils in lot 1 undoubtedly belong to the Mississippian. The age of the remaining strata, as determined from the fauna collected, is either late Mississippian or early Pennsylvanian or both.

The upper chert member is correlated with the chert beds as reported by E. D. Kindle (1944) from Beaver River, Yukon. He included the chert beds with overlying sandstone from which he collected Permian fossils, but as a conglomerate 35 feet thick overlies the chert on Pointed Mountain it is here included with the lower beds. The later Carboniferous strata within the area mapped cannot be correlated with any known sections in the Rocky Mountains on the basis of lithology, except that the upper part may be equivalent to the Rocky Mountain formation. The assemblage of sandstone and shale beds indicate near-shore conditions of deposition.

Beds immediately overlying the chert member were not observed in the area mapped. If Permian and Triassic strata are present, as indicated on E. D. Kindle's map (1944) of the area to the southwest, their thickness cannot be very great. On the accompanying map the chert member of the later Carboniferous series is shown as overlain by Lower Cretaceous beds.

Lower Cretaceous

Lower Cretaceous strata were observed on Labiche and Petitot Rivers. On the former only a few outcrops were examined in the course of a traverse to the mountains to study the upper Palaeozoic section. On Petitot River outcrops are almost continuous along the river for 4 miles above Fort Liard. Except in the first mile, where the dips are steep and the section is broken by faulting, the beds dip gently to the east.

The lowest beds exposed consist of grey, crossbedded, medium-grained, buff weathering sandstone containing large ironstone concretions, interbedded with minor amounts of dark grey shale. The sandstone is characterized by large, branching, palm-like plant structures similar to those observed in the upper Palaeozoic chert beds on Liard Range. About 200 feet of sandstone and interbedded shale is exposed in a cliff on the south bank of Petitot River close to its mouth. The sandstone member is overlain by dark grey shale containing concretions, and is interbedded with thin, fine-grained sandstone beds. No fossils were found, but McConnell reports specimens

of Inoceramus at this locality. A marked change in lithology occurs about 2 miles above the mouth of the river. The shales become darker, more fissile, and contain selenite crystals and ironstone concretions. In the upper part of these fissile shales the concretions are ellipsoidal, and evidence of bedding is retained in them.

The Lower Cretaceous section exposed along Petitot River consists of a lower, sandy and sandstone unit, about 625 feet thick, and an upper, fissile shale unit about 1,625 feet thick.

Two fossil collections from the fissile shale unit were identified by F. H. McLearn of the Geological Survey. In the lower half were found Neogastroplites cornutus?, Arctica?, and other pelecypods. From the upper half were collected two specimens of Beudanticeras sp. McLearn comments as follows: "The lower lot contains a very poorly preserved ammonite. It may be Neogastroplites cornutus, but an exact correlation is not justified. This species occurs high in the Lower Cretaceous, Shaftesbury formation on Peace River, and represents an horizon above that occupied by the Lower Cretaceous Gastroplites fauna. The ammonite in the upper lot is of Lower Cretaceous age, and represents some horizon in the Fort St. John group".

The lower sandstone member is believed to correlate with the Scatter formation on Liard River above Nelson Forks, as described by Kindle (1944). The upper fissile shale member is the equivalent of Kindle's Lépine formation. The lower part of the Cretaceous, Garbutt formation, is not exposed on Petitot River in the Fort Liard area, but on Garbutt Creek, the type locality, it is about 2,000 feet thick.

A large outcrop on the east bank of the Liard at the mouth of Muskeg River is composed of bedded sandstone, shale, and sandy shale, and is believed to be similar to strata exposed near the mouth of Petitot River, which are stratigraphically equivalent to the Scatter formation.

Upper Cretaceous

Upper Cretaceous strata are exposed along Liard River and its tributaries from below the mouth of Fort Nelson River to Kotaneelee River. In this distance the river flows close to the axis of a syncline in which the greatest thickness of Upper Cretaceous beds are found. The strata are composed of non-marine beds of sandstone, shale, and conglomerate, and marine beds of dark grey shale. The assemblage has been divided into three formations.

Fort Nelson Formation

Overlying the dark grey, fissile, marine shales of Lower Cretaceous age on Petitot River are grey, banded sandstones and interbedded, dark grey, chunky shale transitional from the marine shale to the overlying medium-grained, grey, buff weathering sandstone. Thirty feet of the transitional beds are exposed at this locality. Above them the section is only partly exposed to where the uppermost 250 feet of conglomerate and coarse, grey, crossbedded sandstone forms continuous outcrops along the banks for 4 miles through the canyon. A section in the partly exposed interval shows 130 feet of beds composed of dark grey shale interbedded with medium- to fine-grained sandstone overlain by medium to corase-grained sandstone beds and a 15-foot bed of loosely cemented pebble-conglomerate. Carbonaceous fragments were observed along some of the bedding planes. The upper conglomerate member contains pebbles of quartz, quartzite, grey, green, and

black chert, and grey and black argillites. These are as much as an inch in diameter, and are fairly well sorted. The sandstone associated with the conglomerate is coarse grained and crossbedded. The estimated thickness for the formation is from 500 to 800 feet.

No fossils were found in the Fort Nelson formation, but the beds are correlated with those described by E. D. Kindle (1944) as equivalent to the Dunvegan sandstone, and mark the beginning of Upper Cretaceous sedimentation.

Kotaneelee Formation

Overlying the Fort Nelson formation are dark grey shales, some thin sandstone beds, and a bed of conglomerate. It is proposed to introduce the name Kotaneelee formation for this assemblage of marine strata. At the lower end of the canyon on Petitot River the following section was measured:

Top of section	Thickness Feet
Shale, dark grey	5
Sandstone, medium-grained; Inoceramus lundbreckensis	10
Shale, grey, soft, chunky, few concretions; Inoceramus pontoni?	175
Sandstone, fine, brown weathering	10
Conglomerate, unconsolidated; pebbles in sandy shale	5
Shale, sandy; and fine-grained sandstone	20
Concealed	100
Shale, bedded, grey	20
Contact, Fort Nelson formation	
Total thickness	345

On Kotaneelee River, about 7 miles above its mouth, sections of the Kotaneelee formation are exposed, though its upper and lower contacts were not observed. The following section was measured:

Top of section	Thickness Feet
Shale, dark grey; with concretions	150
Sandstone, bedded, medium-grained	8
Shale, sandy	20
Shale, grey, chunky, brown; with ironstone concretions	150
River level	
Total thickness	328

The fossils collected from the lower 200 feet and identified by F. H. McLearn are: Oxytoma nebrascana, Inoceramus lundbreckensis, Anomia cf. subquadrata, Baculites ovatus.

Along the east bank of Liard River, about 2 miles above the mouth of Kotaneelee River, dark grey shales with concretions overlie brown weathering sandstone containing small ironstone concretions and small chert pebbles. The fossils from the shale include Oxytoma nebrascana and Baculites.

On Pretty Hill, east of the Liard and 10 miles below the mouth of Fort Nelson River, are several outcrops of shale and thin beds of sandstone from 300 to 500 feet above the rivers. Collections of fossils from these rocks included: Inoceramus lundbreckensis (?); Protocardium; and Inoceramus cf. tuberculatus.

Four miles down the river from Pretty Hill and on the east bank the following section was measured:

Top of section	Thickness Feet
Loose blocks of grey sandstone	
Shale, dark grey, chunky, with ironstone concretions; Inoceramus cf. tuberculatus	100
Pebble layer of black chert	0.2
Sandstone, grey, interbedded with grey shale; Protocardium	15
Shale, dark grey, chunky; ironstone concretions	100
Total thickness	215.2

Fossils collected from the talus below the outcrop contain Placenticeras, Baculites, Inoceramus cf. tuberculatus, and Protocardium. Regarding these, McLearn comments as follows: "Fossil collections containing Inoceramus lundbreckensis and Inoceramus cf. tuberculatus contain a fauna comparable with that of the upper Wapiabi formation in the central and southern Foothills of Alberta".

Strata containing Inoceramus lundbreckensis were found to overlie I. cf. tuberculatus. Inoceramus pontoni represents an horizon in the lower Wapiabi of the central and southern Foothills.

The total thickness of the Kotaneelee formation cannot be stated accurately, but it is believed to be in excess of 500 feet in the Kotaneelee River area. On Petitot River there are 340 feet of beds from the base of the formation to where a specimen of Inoceramus lundbreckensis was found. The top of the formation was not observed at this locality. On Pretty Hill Inoceramus lundbreckensis was found 500 feet above river-level in a bedded sandstone member 20 feet thick. This sandstone lies 220 feet below thicker beds of sandstone and conglomerate of the overlying formation. No outcrops of the underlying Fort Nelson beds were noticed at this locality.

It is not known if the Kotaneelee formation represents beds equivalent to the Alberta group of the southern Foothills or only of the upper Wapiabi formation. No fossils were found in the lower 120 feet of beds below a sandstone and conglomerate, and these beds could represent the equivalents of the underlying Bighorn and Blackstone formations of the Alberta group.

Late Upper Cretaceous

Overlying the Kotaneelee formation at several localities are medium-grained, grey sandstone and fine pebble-conglomerate beds. On Pretty Hill 720 feet above the river are 25 feet of medium-grained, banded sandstone and pebble-conglomerate. Along the east bank of Liard River, 2 miles above the mouth of Kotaneelee River, a sandstone bed at least 25 feet thick occurs 400 feet above river-level. The sandstone is banded, medium- to coarse-grained, feldspathic, buff weathering, calcareous, and both massive and thinly bedded. It is overlain by a seam of low-grade coal 15 inches thick. Coal of better quality was observed in a slump block 20 inches thick, close to river-level and below the other seam. The slumped coal is believed to have come from the concealed interval below the sandstone outcrop. No fossils were found in the upper sandstone beds, but a non-marine origin is indicated by the coal and carbonaceous material present. The stratigraphic position of this non-marine assemblage above the marine Kotaneelee formation indicates that it is correlative with the Wapiti group (McLearn and Henderson, 1944).

Tertiary (?)

Possible Tertiary strata are limited to a small area along Petitot River from 3 to 4 miles above the canyon. The presence of rocks of this age was suggested by the occurrence, on the east bank and about 75 feet above present river-level of poorly consolidated gravels lying unconformably in an old stream channel in the Fort Nelson formation. The gravels have an exposed thickness of 5 feet, are very rusty, and are composed of pebbles from the Fort Nelson formation and light grey and pink quartzite and sandstone pebbles up to 8 inches in diameter. The sandstone pebbles resemble the later Carboniferous sandstone exposed in the Liard and Labiche Ranges. These gravels are believed to be pre-glacial in age.

Two miles upstream from the gravels and also on the northeast bank is a section of strata, 83 feet thick, that may be of Tertiary age. Where these beds were examined in the field they were thought to represent an upper part of the Fort Nelson formation, although lithologically unlike corresponding strata seen elsewhere. Fossil plants found at the top of the exposed section were identified by W. A. Bell of the Geological Survey as tuberous rhizomes of Equisetum **arcticum** Heer. He comments that the species occurs in Arctic Paleocene, and if the beds containing it on Petitot River are actually Upper Cretaceous the range of the species must be extended. The section is as follows:

Top of section	Thickness Feet
Shale, interbedded with fine-grained sandstone; contains plant remains	5.0
Conglomerate; chert and quartzite pebbles and coarse sandstone	25.0

	Thickness Feet
Shale, dark grey, and sandy shale; beds 10 to 12 inches thick	21.0
Sandstone, medium-grained	2.0
Shale, dark grey	1.0
Sandstone, feldspathic, medium-grained	7.0
Shale, light grey	1.0
Sandstone, fine-grained, thinly bedded	3.0
Bentonite, and streaks of carbonaceous matter	0.1
Shale, light and dark grey	6.3
Shale, sandy	1.0
Shale, fissile, dark grey	10.0
Bentonite	0.05
Sandstone	1.0
Total thickness	83.45

These beds are assigned tentatively to the Tertiary, but, as definite proof of age is lacking and as field observations were limited to a single outcrop, they have not been mapped separately from the late Upper Cretaceous on the accompanying map.

Criteria favouring a possible Tertiary age are:

(1) The strata contain Equisetum arcticum Herr, previously recorded from the Paleocene.

(2) The presence nearby of pre-glacial gravels overlying the Fort Nelson formation.

(3) Bentonite was not observed in the Fort Nelson formation elsewhere, but is present in Tertiary strata at Fort Norman.

Pleistocene

Till forms the surface deposits over most of the Plains area east of the mountains. The underlying bedrock is concealed by this mantle of drift, and it is only where post-glacial streams have eroded through it that bedrock is exposed.

In Liard River Valley till was observed to underlie recent bedded silts, sands, and gravels. The till is exposed close to river-level for 20 miles above and below the mouth of South Nahanni River. This suggests that the river valley is pre-glacial in origin; that during

Pleistocene time it was partly filled with till; and later, that river silts and sands have been deposited on top of the till. Above the mouth of Muskeg River till is present along the river banks at a number of places. Streams tributary to the Liard have their beds paved with glacial boulders, and rapids form where there are appreciable gradients.

Glacial erratics were seen on top of all the mountains climbed, and quartzite boulders were found on top of Nahanni Butte, at an elevation of nearly 4,500 feet. Boulders of quartzite and granite were observed on Sawmill Mountain.

The boulder clay on the plains south and east of the mountains is composed of various granites, schists, gneisses, and, in lesser amounts, limestone and sandstone. A common rock is a dark cordierite-biotite schist. The cordierite, or its alteration product, occurs as round and irregular masses up to an inch in length. This rock is one of the characteristic Precambrian sediments of the Yellowknife area, Northwest Territories, and it is concluded, therefore, that the continental glacier came from that general direction, a conclusion supported by the direction of glacial striae that runs south 60 degrees west at Yellowknife and south 67 degrees west on Trout River west of the Mackenzie. Boulders of cordierite schist were not found in the mountains, and the erratics there were deposited by a different ice-mass that had its source to the west or northwest.

A striking glacial feature, plainly visible on air photographs, consists of narrow, straight, parallel ridges, some of them several miles long and very uniform in width and height. They trend 75 to 85 degrees east of north. Areas of such parallel ridges are on both sides of Petitot River, east of Muskeg River, along Blackstone River, and north of Trout Lake. Where examined they are gentle undulations with a relief of from 5 to 20 feet, and are composed of till. South of Petitot River smaller ridges are superimposed on the larger ones, and trend north almost at right angles to them. They carry a greater concentration of boulders than the main ridges. The main ridges are accentuated on air photographs by the different types of trees on the higher ground from those on the lower ground between them.

So far as could be determined, these small parallel ridges are in alinement with the direction of ice movement and, as might be expected, lie almost at right angles to the morainal belt northwest of Trout Lake. Northwest trending ridges of uncertain origin were seen from the air northwest of Cormack Lake between Liard and Blackstone Rivers. Somewhat similar features have been referred to as drumlinoids. They are formed by the ice depositing an overload of material or by the ice overriding a relatively soft surface with a furrowing action, leaving ridges and vales (ridge and swale topography). Air photographs show that these ridges are not present on a bedrock hill that trends almost due north and south. Another suggestion is that they may be associated with fractures in a stagnating ice mass. In such a case the present drainage would be expected to conform more closely to these fracturesthan it actually does.

Rusty river gravels containing granite pebbles were found along Petitot River 1 mile above the canyon and about 200 feet above the river. The deposit is about 50 feet thick and is overlain by till. Similar gravels were seen along Muskeg River and form a deposit in the main valley. They are probably of pre-glacial or inter-glacial origin.

Within the area traversed good agricultural soil is limited essentially to Liard River Valley. Here the soil is composed of silts, sandy silts, and smaller amounts of clay. Good gardens are grown annually at Fort Liard, Netla, South Nahanni, and at other localities along the river. Glacial-lake clay deposits were not observed,

and the widespread deposit of till is too rocky for cultivation. Liard River Valley is in part subject to floods, and, therefore, the lower levels cannot be cultivated successfully. The soil on the higher terraces is less extensive and more variable in composition. The largest areas of agricultural soil are found along Liard River for 25 miles above and 20 miles below the mouth of the South Nahanni. Bedded silts and clays 30 feet thick were seen along Flett Creek, 5 miles west of Liard River.

STRUCTURE

GENERAL DESCRIPTION

The structures of the southern end of Mackenzie Mountains are broad, plunging anticlines and synclines that pass from the mountainous area south into the Plains. The eastern ranges of mountains, Liard and Nahanni Ranges, are bounded on the east by west-dipping thrust faults. East of the mountains little is known of either bedrock or structures as the country is almost wholly drift covered.

LIARD RANGE

Liard Range includes the mountains north of Fort Liard and east of Kotaneelee River. It forms a continuous chain to South Nahanni River and marks the eastern boundary of Mackenzie Mountains in this area. The range comprises two or more anticlines. The most westerly fold, as shown by air photographs, makes a large curve to the northwest, an unusual trend for which an explanation is not at present available. The eastern side of these anticlines is bounded by a west-dipping thrust fault.

Pointed Mountain is an anticlinal structure at the southern end of Liard Range. It strikes north 30 degrees east, plunges to the southwest, and appears to reverse its plunge to the northeast as the main part of the range is approached. An examination of this part of the mountain was not made in the field. The mountain is divided in two by an old stream channel of Kotaneelee River flowing through Fish Lake. Along this channel more than 2,000 feet of strata are exposed, of which only the upper 1,000 feet of sandstone, shale, and chert were examined.

LIARD SYNCLINE

Liard syncline is the name given to the large structure that extends from the south end of the eastern ranges of Mackenzie Mountains to the eastern Foothills of the Rocky Mountains. It has a length of about 70 miles and trends north 15 degrees east. Liard River flows close to its axis from the mouth of Fort Nelson River to Kotaneelee River. At its northern end the syncline is joined by other structures and passes into Liard Range.

LABICHE RANGE

Labiche Range is a large anticlinal fold that trends due north, west of Kotaneelee River. At its southern end Labiche River has cut its channel across the range, exposing Carboniferous strata. Farther south the fold plunges beneath a cover of Cretaceous rocks, and its eastern limb forms the west limb of Liard syncline. From air photographs it appears that beds beneath the Carboniferous are exposed along the anticline to the north.

NAHANNI BUTTE AND NAHANNI RANGE

Nahanni Range is a large fault block that has been thrust upward along a west-dipping fault. Silurian strata have been thrust over what are believed to be Mississippian or Upper Devonian beds. No outcrops of beds below the faults were observed. Nahanni Range trends almost due north to the mouth of North Nahanni River. The Nahanni thrust fault is believed to be en échelon to the thrust fault on the east side of Liard Range. Nahanni Butte is separated from the rest of the range by a subsidiary thrust fault.

PETITOT RIVER SYNCLINE

The axis of a large, north-trending syncline in Cretaceous strata was observed on Petitot River about 20 miles above its mouth. The east limb was not outlined for any distance, but air photographs suggest that it is of considerable extent. The length of the syncline and its relationship with the Liard syncline were not determined, but it is known that the Liard thrust fault separates the two synclines in the vicinity of Fort Liard. The fault undoubtedly passes into a fold to the south.

BIRCH RIVER ANTICLINE

A small fold in the grey, Upper Devonian shales was mapped close to the mouth of Birch River. It trends north 12 degrees east. The fold may be small and of no significance, but it indicates that other larger folds may be present.

MINOR FOLDS, LONG REACH, LIARD RIVER

Close to the lower end of "Long Reach" on the south bank of Liard River, from George Turner's cabin east for three-quarters of a mile, is a series of small folds, some with steep dips striking mostly northeast. They could be superficial folds produced by glacial action, but the writer is of the opinion that they have been produced by forces that had a source in the underlying rocks. Further work is necessary to decide whether these conditions are local or regional. A ridge of bedrock seen from the air 6 miles south of Turner's cabin has a uniform trend of south 60 degrees west.

PLAINS AREA

The eastern ranges of Mackenzie Mountains are bounded on the east by thrust faults developed during the period of mountain building. These faults prevented some of the deformative stresses from being transmitted into areas farther east, but there are no reasons for assuming that deformation did not extend in some measure east of the main faults. Folds may, therefore, be present, but they will be difficult to find and outline owing to the cover of glacial drift.

TROUT LAKE AREA

Several outcrops of sandstone and shale were observed around the south end of Trout Lake. These appeared to have some dip, but as the outcrops are all small it is not known whether the recorded dips are on slumped blocks or on folded structures.

TIME OF MOUNTAIN BUILDING

Evidence for the time of mountain building is meagre in the area studied. The nature of the Palaeozoic-Mesozoic contact and the problems associated with it remain to be investigated. Structures in Lower and Upper Cretaceous strata appear to conform and merge with those in the Palaeozoic. From this it is concluded that the time of mountain building and folding was late Cretaceous or early Tertiary. This does not preclude the possibility of some early Mesozoic uplift in the Mackenzie Mountains area.

ECONOMIC GEOLOGY

OIL POSSIBILITIES

Source Rocks

Bituminous shale, considered as a possible source rock for oil, is found in the Carboniferous and Upper Devonian formations of this area. Black bituminous shales from which oil has been distilled occur in the Upper Carboniferous rocks on Labiche Range. Similar shales are found on Pointed Mountain. These shales are interbedded with sandstones. The extent of the Carboniferous beds, including the upper shales and sandstones, away from the mountains is not known. In the mountainous area they thin to the east, and their extent beyond Liard Range may be limited to only a few miles. Southward the eastern margin of Carboniferous strata would be in the vicinity of Fort Nelson. In this direction, too, a change in lithology would be expected, as the section of later Carboniferous rocks exposed in the eastern Mackenzie Mountains is not present in the mountains along the Alaska Highway west of Fort Nelson.

Upper Devonian strata contain a great deal of dark marine shale that is in part bituminous and would provide source beds for petroleum. Its regional extent is not known. The upper part may correlate with the Simpson shales at Fort Simpson. Southward, the Upper Devonian shales may extend as a thick formation for a considerable distance.

Reservoir Rocks

The sandstone interbedded with the bituminous shale in the later Carboniferous strata is considered suitable as a reservoir rock. Where examined in the mountains some of the members are quartzitic, but less induration would be expected in the Plains.

Reservoir beds are less evident in the Devonian section than in the Carboniferous strata. Middle Devonian limestone and dolomitic limestone beds on Nahanni Butte did not exhibit any well developed porous zones. The underlying, unfossiliferous beds, presumably of Silurian age, have some porosity but not sufficient to provide good reservoir beds. On Nahanni Butte the porosity has been reduced through the action of percolating siliceous and carbonate-bearing solutions. At some distance from these places the Middle Devonian rocks may be more porous. On Great Slave Lake, the Middle Devonian, Presqu'ile dolomite is porous, and would make an excellent reservoir rock. It seems reasonable to assume that this dolomite will extend some distance west from Great Slave Lake under the Plains area.

Seepages

No live seepages of oil were seen during the course of field work. A sample of tarry bitumen was shown to the writer by an Indian at Fort Liard, and is reported to have come from Pointed Mountain. Similar seepages of bitumen are reported by an Indian to occur in the mountains along upper Flett Creek west of Liard River. As this substance was not seen in place no comment on the seepages from which, presumably, it was derived can be made, other than to note that such material is probably a residue from a previous oil accumulation.

Unconformities

The presence of a chert conglomerate on top of the Carboniferous section on Pointed Mountain indicates a period of erosion and a hiatus covering the Permian, Triassic, and Jurassic periods. The distribution and the nature of the Carboniferous surface under the Plains area is a matter of speculation. There is the possibility that the distribution of the chert member may be less extensive than the underlying Carboniferous beds, and that an eroded porous limestone suitable as an oil reservoir may be present.

Cretaceous strata rest on Upper Devonian beds on Hay and Trout Rivers (Cameron, 1922; Whittaker, 1922), and this condition is thought to prevail over the greater part of the Plains area south of Liard River and at some distance east of the mountains. As the Upper Devonian rocks in the Nahanni Butte area are composed largely of shale the presence of an unconformity does not offer the same possibilities for reservoir rocks along the old erosional surface as if this surface were in limestone, but it is possible that limestone beds may be present at the unconformity under part of the area.

Structures

Large anticlinal folds exposing Palaeozoic strata are present in the mountain ranges bordering Liard River, but they are not considered suitable structures for the accumulation and retention of oil. A possible exception to this might be the Pointed Mountain anticline, provided it has the necessary northeast closure. Possible oil horizons on this structure would be those in the Devonian.

The only fold found in Upper Devonian beds is the one on Birch River. Its extent was not outlined, and it may be too small to warrant consideration as a possible oil structure. Other folds may be present in the area between Nahanni Butte and Birch River, but their occurrence will be difficult to prove owing to the thick covering of glacial drift.

Structures in areas underlain by Cretaceous rocks are also obscured by drift. Good outcrops were found along Petitot River for the distance traversed, and it is the writer's opinion that a continuation of this traverse will provide a good structure section of the Plains at some distance from the mountains.

Conclusions

(1) Source beds for oil are present in the Carboniferous and Upper Devonian strata.

(2) Sandstone beds suitable as reservoir rock are present in the Upper Carboniferous section.

(3) The rocks of Middle Devonian age were not considered good reservoir beds where studied on Nahanni Butte, but along Great Slave Lake the Presqu'ile dolomite of the same age is porous and contains oil seepages.

(4) The chert member of the Upper Carboniferous section is more than 100 feet thick and would be extremely hard to drill.

(5) Suitable anticlinal structures were not located, but the search for them was limited.

(6) The presence of thick deposits of bituminous shale in the Carboniferous and Upper Devonian strata lends strong support to the possibilities of finding petroleum in commercial quantities south and east of Mackenzie Mountains, provided structural conditions are favourable and suitable reservoir rocks are present.

COAL

Upper Cretaceous strata overlying the marine Kotaneelee formation contain several thin coal seams. One seam, 15 inches thick, of poor grade coal, overlies a 25-foot sandstone member on the east bank of Liard River about 2 miles above the mouth of Kotaneelee River and 400 feet above river-level. At this locality and close to the river were slumped blocks of coal, 20 inches thick and of good bituminous rank, that are believed to have been derived from seams underlying the exposed sandstone member.

Coal is reported on upper Flett Creek about 12 miles from Liard River by Chau Yeho, an Indian of Netla Indian Village. A sample had the appearance of good bituminous coal. The seam is said to be 6 feet thick. Indians and white trappers, Messrs. George Turner, Ole Loe, and Ole Lindberg of Fort Simpson report the occurrence of seams of coal of good grade on Mattson Creek, 8 miles above its mouth, and on Jackfish Creek. Both of these streams are tributaries of South Nahanni River. The seams are reported as being more than 6 feet thick. Strata of Cretaceous age are believed to be present at each of these localities, but the position of the coal horizon in the section is not known. The coal in the South Nahanni River and Flett Creek areas may represent a different horizon from that in the Upper Cretaceous rocks south of Fort Liard.

Pebbles of coal were found along the stream bed of Blackstone River, indicating a deposit of coal somewhere along its course.

The following is an analysis by the Bureau of Mines, Ottawa, of a sample of coal from late Upper Cretaceous strata on the east bank of Liard River, 2 miles above the mouth of Kotaneelee River.

	As received	Dry
Moisture	16.9	
Ash	3.7	4.5
Volatile matter	30.9	37.1
Fixed carbon (by difference)	48.5	58.4
Sulphur	0.6	0.7
B.T.U. per lb.	10,020	12,050
Caking properties		Non-agglomerating
Fuel ratio		1.57

MINERALIZATION

The Silurian strata around the base of Nahanni Butte contain an abundance of quartz and calcite veinlets cutting the rock in various directions. The enclosing rocks have been silicified to a marked degree, and iron stains are commonly seen over large areas adjacent to faults. This silicification is believed to be common to the Silurian strata at this locality because they were brought to the surface along faults and these acted as channelways for the mineralizing solutions. These solutions carried with them certain metallic minerals, chalcopyrite, chalcocite, pyrite, and galena, which were deposited in small, non-economic amounts.

The siliceous solutions are believed to have been derived from an intrusive, magmatic body at depth, and to have migrated upward and to the surface along fault, fracture, and bedding planes. No well defined, continuous quartz veins were seen. The absence of such was noted by Joseph Keele (1910) around intrusive bodies of granite in east-central Yukon, where silicification has taken place on a large scale resulting in the alteration of argillites to chert but forming only a few quartz veins.

Another silicified zone containing narrow quartz veins and veinlets was found in black, bedded shale on the south shore of Liard River 28 miles below the mouth of South Nahanni River. The silicified zone is 58 feet wide, strikes south 20 degrees east, and occurs in almost horizontal strata. The section from east to west is as follows:

Top of section	Width Feet
Feldspar porphyry, altered, light grey, dyke	1.9
Shale, dark grey to black	5.6
Quartz vein	0.1
Shale, black	3.7
Quartz and some shale	0.5
Shale, black	9.2
Shale, silicified; some quartz	2.0

Shale, black	4.2
Quartz, iron stained	0.7
Shale, black	1.0
Quartz	0.2
Shale, black	2.0
Quartz	.3
Shale, black	5.0
Quartz and silicified shale	2.0
Shale, black	6.1
Quartz, contains pyrite	0.9
Shale, black	2.2
Quartz, contains pyrite	0.2
Shale, with veinlets of quartz	10.0
Total width	57.8

Intermittent outcrops of black shale occur along the river for about half a mile below the locality of the porphyry dyke. A few thin quartz veins were noted in this distance. The interesting feature about this zone is the fact that a dyke and quartz veins are present so far from the mountains. Samples of the quartz were assayed for gold by the Bureau of Mines. The results showed only a trace.

The age of the siliceous veins is not known beyond the fact that they are younger than the rocks in which they occur, presumed to be of Upper Devonian age. They may be associated with the silicification of the Silurian and Devonian beds on Nahanni Butte.

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