SOCONY-VACUUM EXPLORATION COMPANY

GEOLOGY OF THE MAXHAMISH AND BOVIE LAKE PERMIT AREAS

BRITISH COLUMBIA - NORTHWEST TERRITORIES

By

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C O N T E N T S

I L L U S T R A T I O N S

I N T R O D U C T I O N

This report presents the results of a geological investigation of the Maxhamish and Bovie Lake Permit Areas, situated in northern British Columbia and the Northwest Territories (Figure 1). These areas were staked during the summer of 1950 to cover a large anticlinal, and possibly faulted, structure which straddles the British Columbia-Northwest Territories boundary.

The Bovie Lake Permit Areas Nos. 1 and 2, covering the structure in the Northwest Territories, were staked on June 19 and 28 respectively by Socony-Vacuum Exploration Company, following reconnaissance surveys by W. I. Wright's geological parties. The Maxhamish Permit Area was applied for in August by the Northern Foothills Group after their geological party under R. L. Slavin had reported the presence of this anticlinal structure on the Petitot River. Since these permit areas were staked, the Gulf, Shell, and McColl-Frontenac Oil Companies have joined Socony-Vacuum Exploration Company as partners in the exploration and development of the Bovie Lake Permit Areas so that the whole structure is now jointly owned by all members of the Northern Foothills Group. In this report, the structure will be referred to as the Bovie Lake Anticline.

The geological mapping of the Bovie Lake Anticline was carried out in two parts. The first part was undertaken during June and July, 1950, when a 250-mile canoe traverse was made down the Petitot River from Bistcho Lake, Alberta, to Fort Liard, Northwest Territories. The stretch of the river which transects the Bovie Lake Anticline was surveyed with a plane table and the results of this work are illustrated on Plates 1 and 3.

The second part of the field program was completed during the first two weeks of August, 1950. During this period, a Bell helicopter was used for transportation, and the use of this aircraft speeded up the work so much that

it was possible to cover not only the entire area of the Bovie Lake Anticline, but also to visit many outcrop areas far removed.

As this work progressed, it became apparent that in order to determine the age of some of the Paleozoic outcrops on the Bovie Lake Anticline, it would be necessary to examine, for correlation purposes, those Paleozoic beds outside the limits of the map area which had previously been described by the staff of the Canadian Geological Survey (1, 3). Accordingly, considerable time was spent in the foothills areas west of the Liard River where studies were made of the Pennsylvanian and/or Mississippian sandstones exposed on Pointed Mountain (Figure 3), the Mississippian limestones exposed on the Liard Range, and the Devonian and Silurian outcrops on Nahanni Butte.

G E O G R A P H Y

LOCATION AND MAP

The map area discussed in this report straddles the Northwest Territories-British Columbia boundary within longitudes 122°47' and 123°32', and latitudes 59°45' and 60°22'. It is covered by the Fort Nelson-Kotcho Lake and Simpson-Liard Sheets of the National Topographic Series. These sheets are numbered 94 NE and 95 SE respectively, and are on a scale of eight-miles-to-one-inch.

Vertical aerial photographs of the permit areas were taken during September, but they were not available in time for the field work. They have been used in preparing the map which accompanies this report (Plate 1).

Plate 1 has been compiled from the following sources:

(1) An uncontrolled mosaic of aerial photographs of the permit areas (Plate 4).

(2) A plane table survey along part of the Petitot River.

(3) The preliminary map which accompanies the Canadian Geological Survey Paper No. 45-22 (1).

(4) Maps of the National Topographic Series scale eight-miles-to-one-inch (Sheets 94 NE and 95 SW).

This map may vary slightly in orientation and scale from place to place, due to the lack of good geographic control for its compilation. The location of geological data is accurate along the Petitot River, within the limits of the plane table survey. The location of data away from the river is subject to the map error.

One important discrepancy between the map (Plate 1) and the National Government Topographic maps, is the position of the British Columbia-Northwest Territories boundary with respect to the Petitot River and Bovie Lake. The published maps show the boundary approximately one-half mile farther south than it is shown on Plate 1. The position of this boundary on Plate 1, however, is believed to be accurate due to the fact that it is based on the location of one of the two precise astronomical stations which were established along the boundary during the summer of 1950 by Mr. C. H. Ney of the Geodetic Survey of Canada*. These stations and co-ordinates are as follows:

Station	Latitude	Longitude
N8	59°59'56".49 ±0".12	122°59'05".06
N9	59°59'58".80 ±0".09	122°12'59".71

A second noteworthy discrepancy between Plate 1 and the Topographic maps is the position of Bovie Lake. On Plate 1 the position of this lake has been moved over one-half mile farther south than shown on the Government maps.

The importance of those changes in the position of the British Columbia-Northwest Territories boundary and Bovie Lake is that it affects the size of Bovie Lake Permit Area No. 2. At the time when this area was staked, the published maps were used and the distance between the post planted on the shore

* Mr. Ney reports that the Geodetic Survey intends to establish a line of precise levels along the Simpson Road during the winter of 1950-51. The work will start at Fort Nelson, and should be completed as far as the 60th parallel by spring of 1951.

of Bovie Lake and the boundary scaled 12.0 miles, whereas on Plate 1, it is only 10.8 miles. This difference results in the permit area being somewhat smaller than was formerly recorded. However, before this discrepancy can be adjusted with confidence, it will be necessary to survey the permit areas.

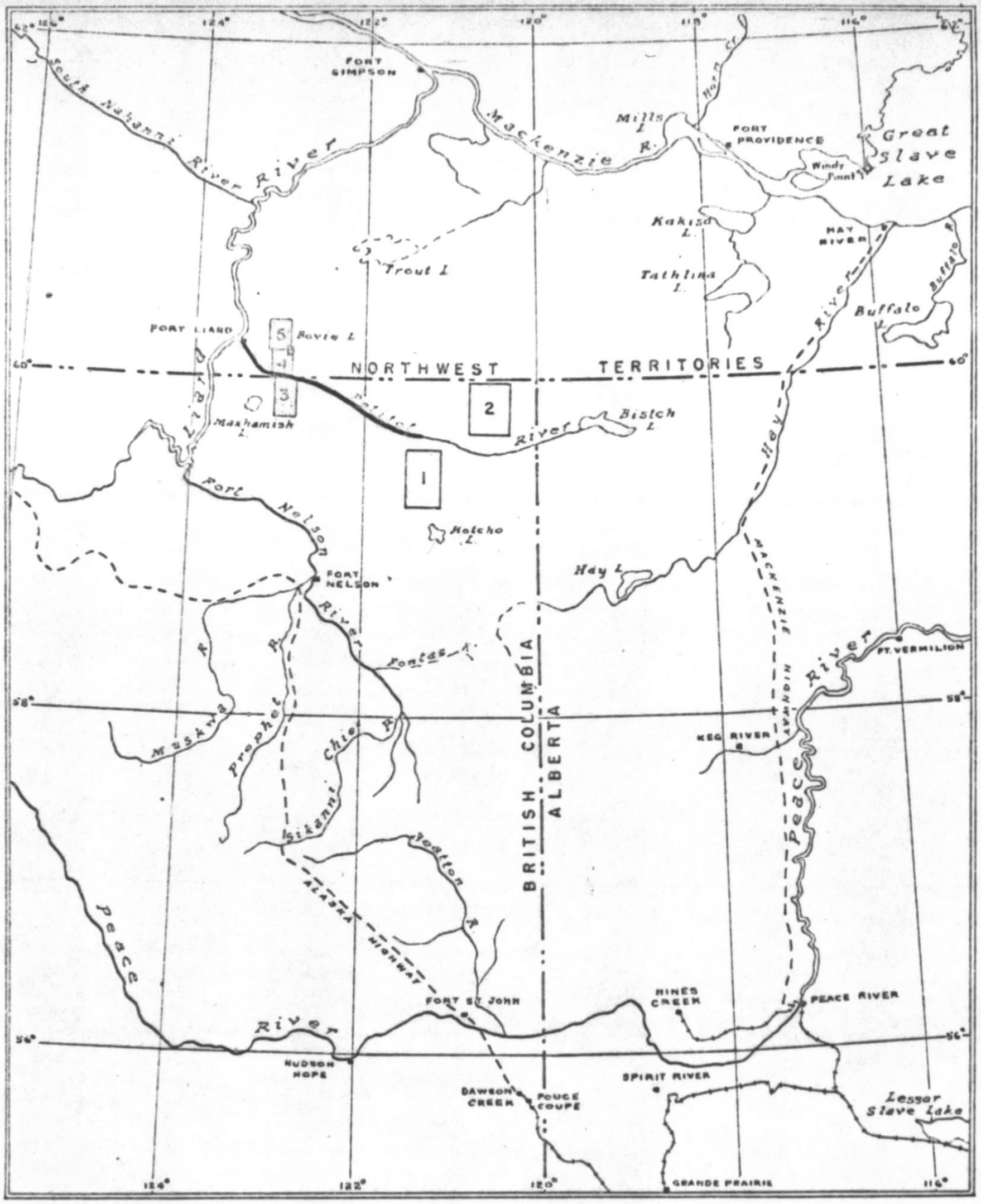
ACCESSIBILITY AND CULTURE

The most accessible route to the Bovie Lake structure is via the Alaska Military Highway to Fort Nelson, a distance of 300 miles on that highway from the railroad terminal at Dawson Creek, thence by boat down the Fort Nelson and Liard Rivers to the settlement of Fort Liard. The Alaska Highway is kept open for traffic all winter. The normal season for barges on the Fort Nelson and Liard Rivers is between May 20 and October 15. From Fort Liard to the Bovie Lake structure a roadwould have to be built for a distance of approximately 20 miles. The greater part of this road could be built on relatively dry ground, along the banks of the Petitot River.

For winter access to the permit areas, the winter tractor trail which connects Fort Nelson with Fort Simpson could be used for a distance of about 50 miles out of Fort Nelson (Plate 2). From this point to the permit areas a road would have to be built for a distance of approximately 25 miles. Several traverses were made with the helicopter across the country where this road would be built, and it was observed that a large proportion of the terrain is relatively flat-lying muskeg country diversified by numerous small lakes. The entire area, which supports only small scrubby spruce, has been burnt over by forest fires (Figure 2).

The nearest settlement to the map area is at Fort Liard, at the junction of the Liard and Petitot Rivers. At this locality there is a Hudson's Bay post with telegraph facilities, an independent store, a Catholic Mission, a Royal Canadian Mounted Police post, and a Game Warden's office.

Figure 1



INDEX MAP OF REPORT AREA

60 30 0 60 120

Scale 1 inch = 60 miles

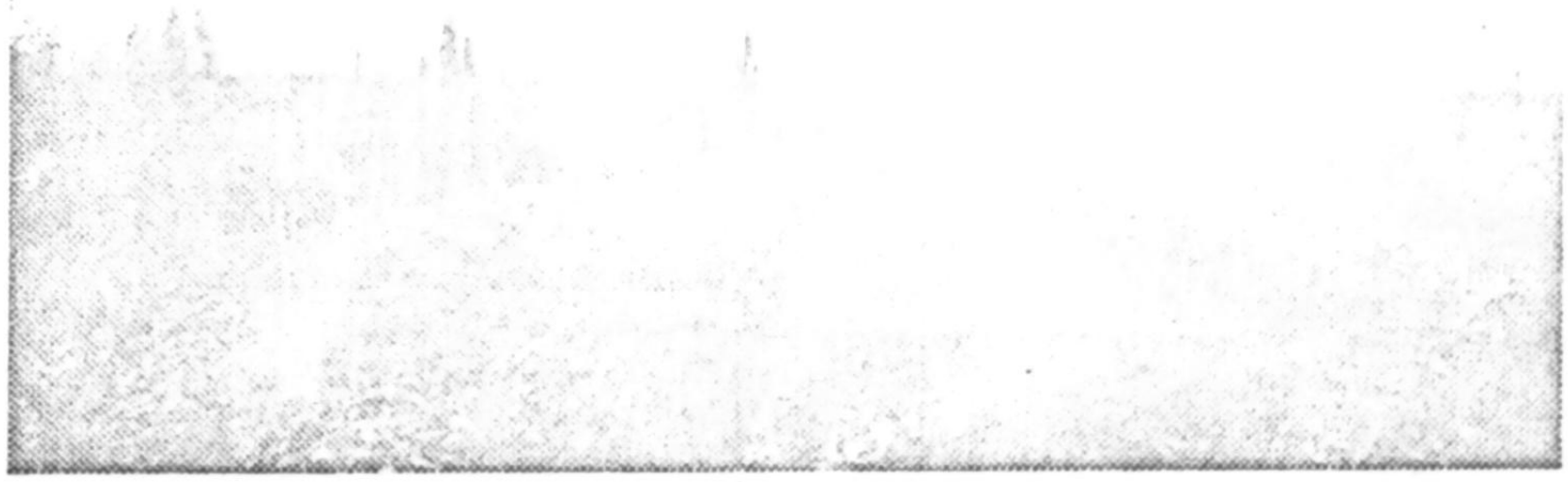
1 Thetlaandoa Creek Block

2 Thinahtea Lake Block

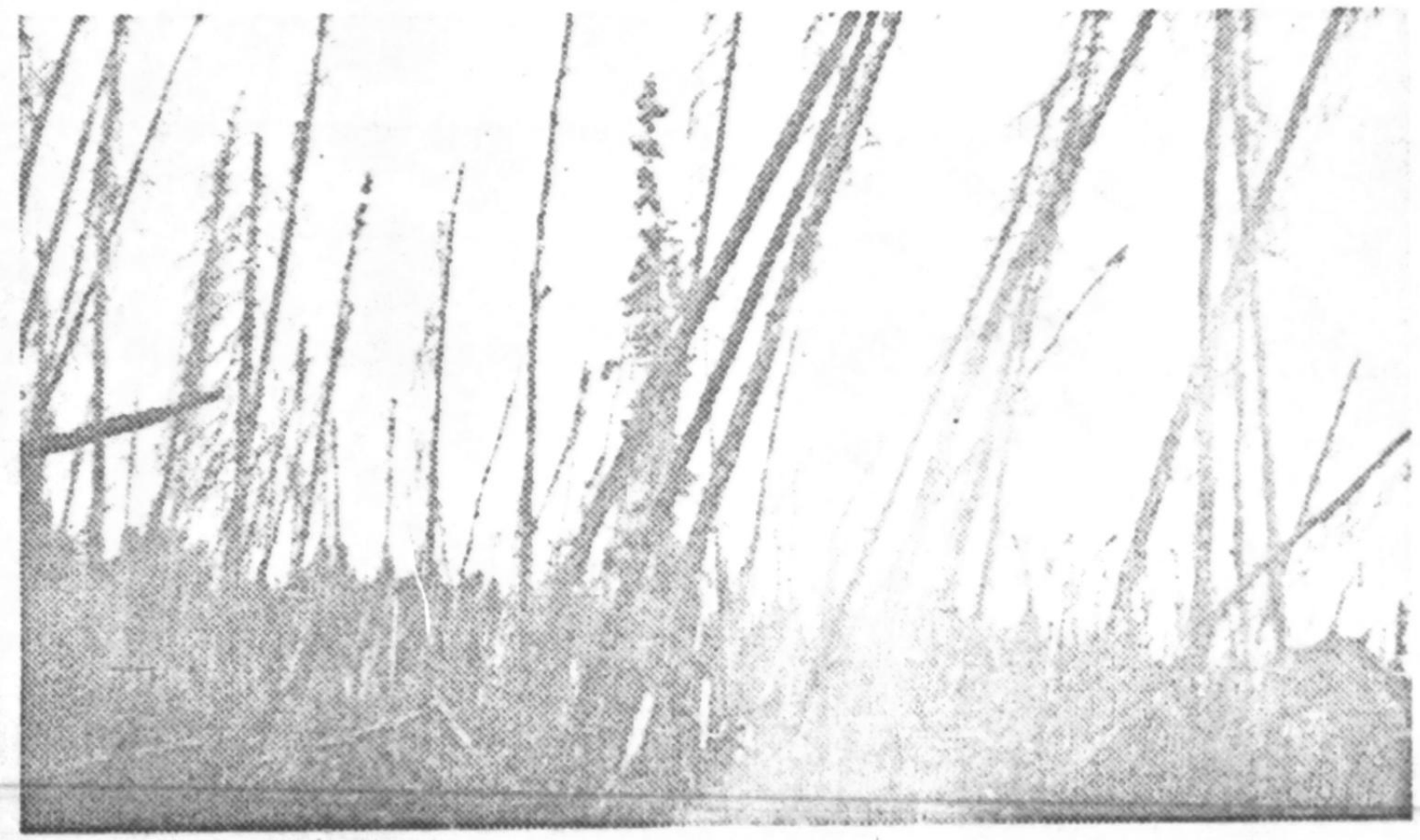
3 Maxhamish Block

4 Bovie Lake Permit Area No. 2

5 Bovie Lake Permit Area No. 1



(a) Photograph showing small scrubby trees and low bushes in burned country.



(b) Photograph showing tangled trees in burned country.

Figure 2

At Fort Nelson and the adjoining settlement of Muskwa there is a Canadian Army and Airforce station, a hotel, garage, and several stores. This locality can be reached via the Canadian Pacific Airlines from Edmonton or, as mentioned above, at Mile 300 on the Alaska Highway.

GEOLOGY

GENERAL STATEMENT

The bedrock observed within the map area ranges in age from Mississippian to Upper Cretaceous. The most continuous exposures occur along the Petitot River from the point where this stream transects the Bovie Lake structure to Fort Liard. Other outcrop areas occur along the east-facing escarpment which forms the east side of the Bovie Lake structure and along the Muskeg River at the north end of the structure.

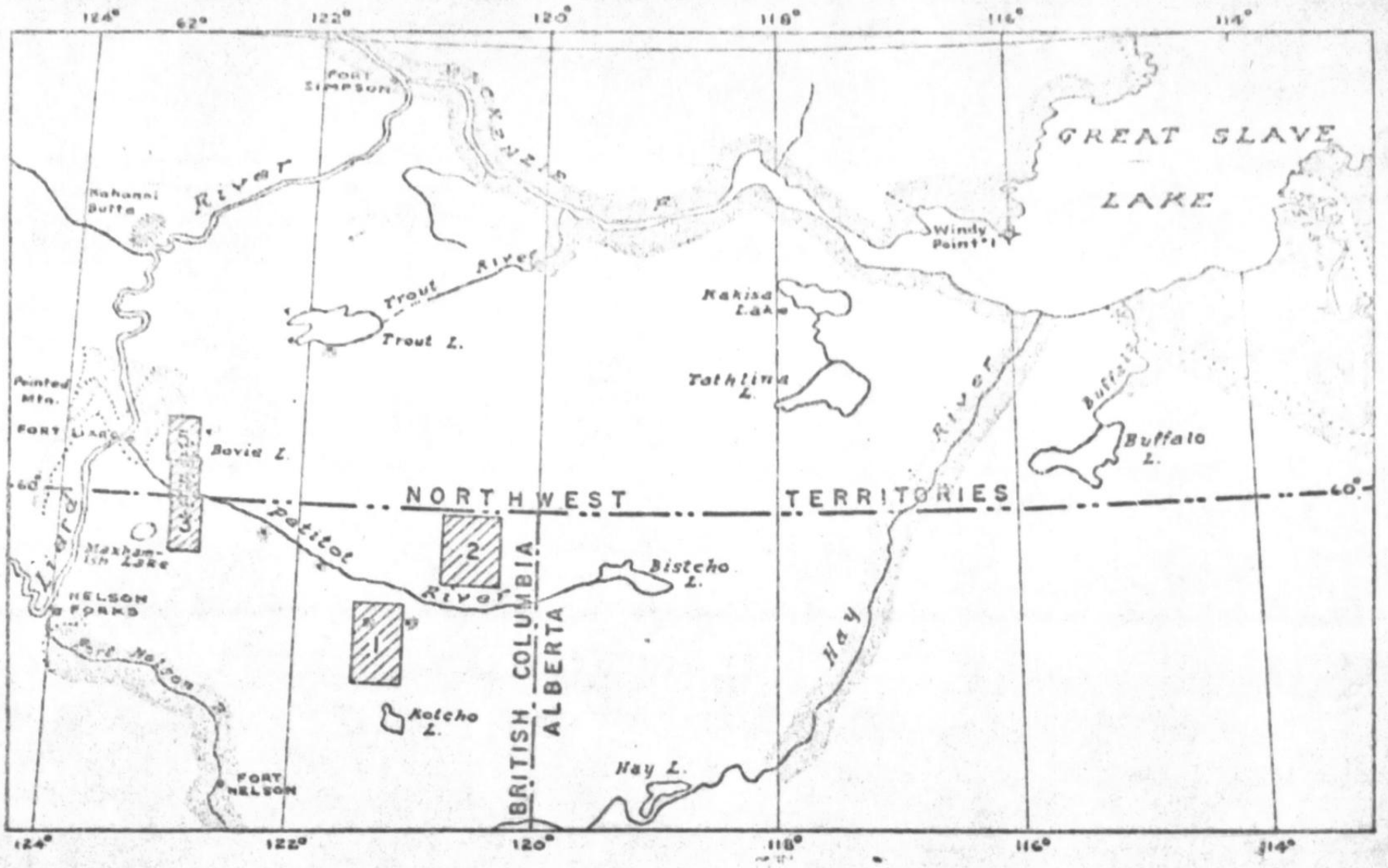
Part of the Petitot River section was measured with a plane table, and the results of this survey are illustrated in the accompanying cross-section (Plate 3) and columnar section (Figure 5). As the beds dip westward along part of this survey, Mississippian, Pennsylvanian and/or Mississippian, Lower and Upper Cretaceous strata are exposed in stratigraphic sequence downstream. No beds of Permian, Triassic or Jurassic age were observed within the map area.

Strata of Silurian and Devonian age are briefly described in this report, although they do not crop out in the area. They do occur to the northwest, the north, and the east of the map area, and presumably underlie it (Figures 3 and 4).

STRATIGRAPHY

Silurian

Hage (1) mapped about 500 feet of beds of Silurian age on Nahanni Butte, located about 60 miles north of the Bovie Lake structure. These beds consist



REGIONAL GEOLOGICAL MAP

SHOWING PARTS OF

BRITISH COLUMBIA, ALBERTA, NORTHWEST TERRITORIES

Scale: 1 inch = 60 miles

LEGEND

MESOZOIC

- Upper Cretaceous
- Lower Cretaceous

PALEOZOIC

- Pennsylvanian and/or Mississippian
- Carboniferous, undivided
- Upper Devonian
- Middle Devonian
- Silurian

PROTEROZOIC

- Pre-Cambrian

PERMIT AREAS

1. Thetlaandoa Creek Block
2. Thinahtea Lake Block
3. Maxhamish Block
4. Bovie Lake Permit Area No. 2
5. Bovie Lake Permit Area No. 1

FIGURE 3

STRATIGRAPHIC CORRELATION CHART

Northeastern British Columbia, Northern Alberta, Northwest Territories

(Thicknesses in Feet)

Era	Period or Epoch		Alaska Highway South of Fort Nelson (C.O. Hage)	Nelson Forks (E.D. Kindle)	Fort Liard Area (C.O. Hage)	Petitot River (W.I. Wright & R.L. Slavin)	Mackenzie River between Simpson and Great Slave Lake (E.J. Whittaker)	Hay and Buffalo Rivers Great Slave Lake (A.E. Cameron)
MESOZOIC	Cretaceous	Upper	Dunvegan 500±	Unnamed 1000± / Fort Nelson 5600	Unnamed 50± / Kotaneelee 500 / Fort Nelson 500-800	Kotaneelee / Fort Nelson 8700±		
		Lower	Fort St. John Grp.: Sikanni 980; Buckinghorse 3000-3600 / Bullhead 1200-1600	Lepine 2000± / Scatter 750± / Garbutt 2000± (?)	Shale Unit 1625± / Sand Unit 625± (?)	Shale Unit 1050± / Sand Unit 600± (?)	Mountain Shales	Meander Shales (Loon River Shales)
	Jurassic		Fernie 18- 240					
	Triassic		Schooler Creek 2500±	Toad 700-2400 / Grayling 500±				
	Permian		?	150 / (?) 1600±				
	Pennsylvanian and/or Mississippian		(observed) 900		1000±	1100?		
	Mississippian				1000±	(observed) 250		
	Devonian	Upper			2000±		Hay River Beds 700 Simpson Shales 150	Hay River Limestone 300 Hay River Shale 400 Simpson Shale 250
		Middle			Mahanni 450		Pine Point Limestone 100 Horn River Shales 100	Slave Point Limestone 200 Presqu'ile Dolomite 375 Pine Point Limestone 595
	Silurian				500±			Fitzgerald Dolomite 270 Red Beds 595

PALEOZOIC

FIGURE 4

COLUMNAR SECTION Scale: 1" = 600'

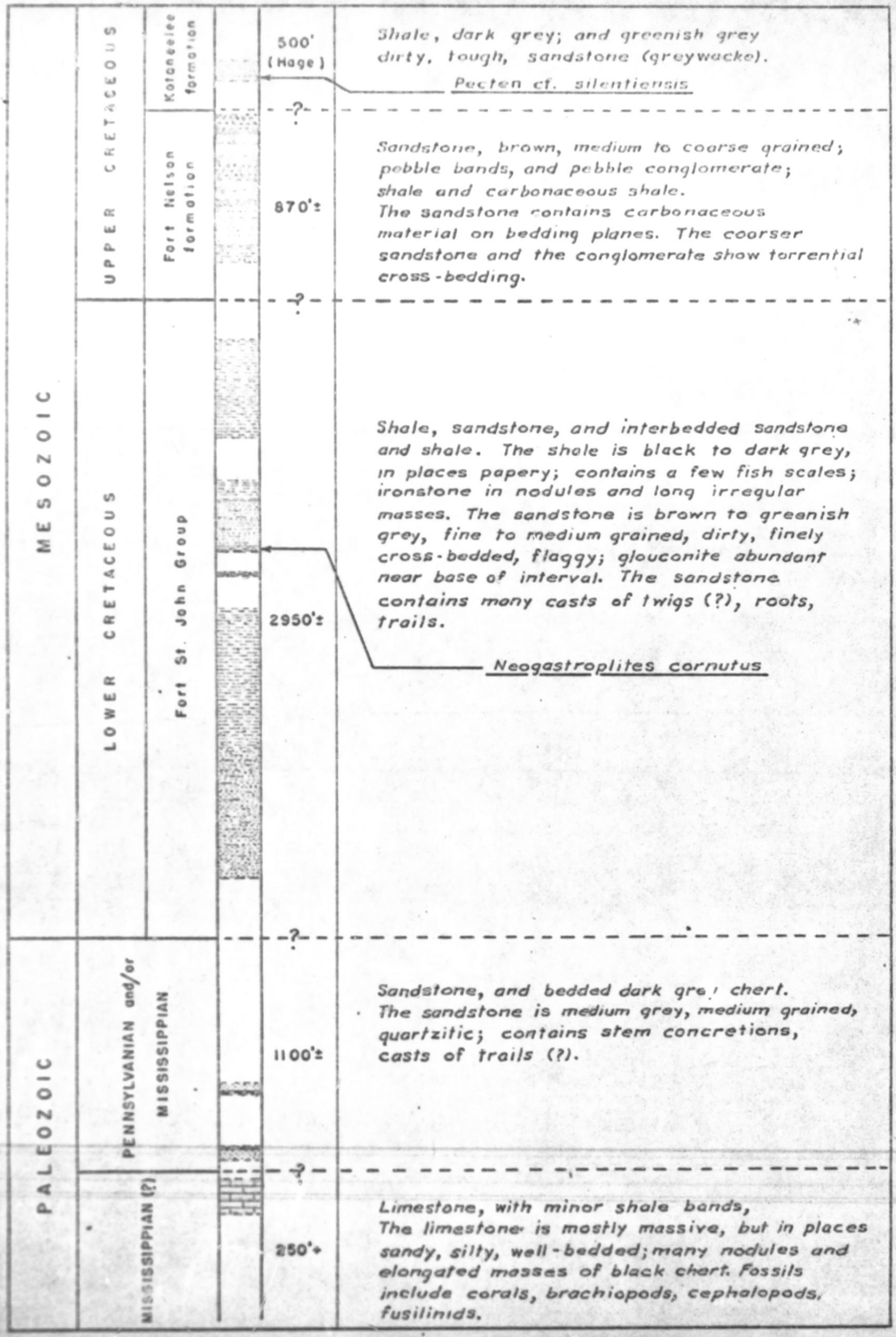


Figure 5

of alternating bands, three feet thick, of siliceous limestone and dolomite. The greater part of the rock is fine-grained, hard, and has been indurated by siliceous and carbonate solutions carrying sulphide minerals. The base of the Silurian section is marked by a thrust fault, so that no estimate of its thickness can be made. Hage reports that the Silurian beds on Mahanni Butte have some porosity but not sufficient to provide good reservoir rock. It would appear, that the porosity has been destroyed by the siliceous and carbonate solutions, but the beds may be less indurated and retain their pore space some distance away from this locality.

Devonian

Middle Devonian

Middle Devonian beds occur on Mahanni Butte, disconformably overlying strata of Silurian age. They consist of about 450 feet of bedded dense grey dolomite and finely crystalline limestone. As is the case with the underlying Silurian strata, the Middle Devonian beds also have been indurated by siliceous and carbonate solutions carrying sulphide minerals, and thus any porosity which might have been present has been destroyed.

To the northeast of the Bovie Lake structure, along the shores of Great Slave Lake and along the Slave River, the Middle Devonian beds have been described by Cameron (2) as consisting of three formations. They are, in ascending order, the Pine Point limestone, the Presqu'ile dolomite and the Slave Point limestone. Of these three formations, the Presqu'ile dolomite is considered to be the most favorable for the occurrence of oil. This formation is porous in all outcrops where it has been observed. The pores contain much bituminous material, often in a semi-liquid state. Oil seepages occur at a number of places along the shores of Great Slave Lake where these vuggy dolomites are exposed.

Upper Devonian

Upper Devonian beds occur in the vicinity of Nahanni Butte and along the Liard River to the northeast. The strata have been described by Hage (1) as consisting mostly of dark grey shale, with minor sandstone and limestone beds. They have an estimated thickness of over 2000 feet.

Cameron (2) describes the Upper Devonian series in the Hay River and Great Slave Lake region as consisting of three formations. In ascending order they are the Simpson shales, the Hay River shales, and the Hay River limestones. From the available descriptions of these beds, it would appear that the Hay River limestones can be considered as a favorable section for the occurrence of oil and gas.

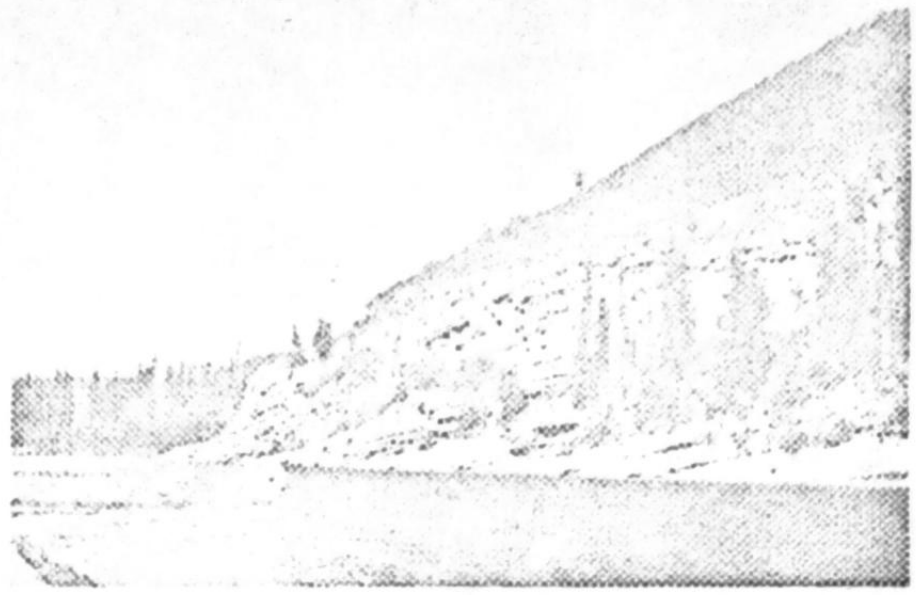
Mississippian

The oldest beds exposed in the core of the Bovie Lake anticline are limestones of possible Mississippian age. These beds occur along the Petitot River and along the east-facing escarpment both to the north and south of the river.

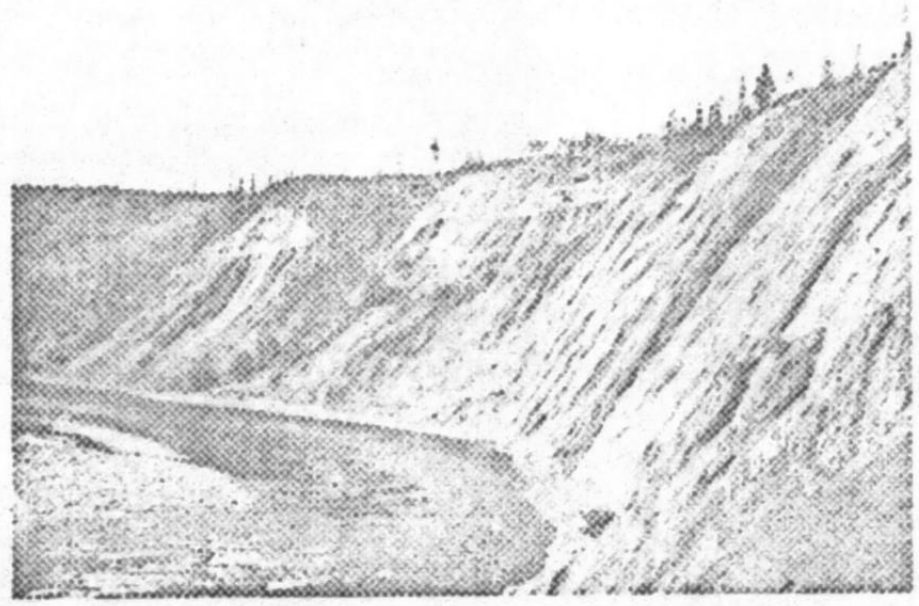
The limestone is dense and finely crystalline, brownish grey on fresh surfaces, and weathers light grey to buff. It is in part massive and poorly bedded, and in part sandy, silty, and well-bedded. Beds up to six inches in thickness of black papery shale occur at irregular intervals throughout the section. When crushed this shale was thought to have a tarry odor. Rounded masses and nodules of dark grey to black chert occur at irregular intervals throughout the limestone, generally along the bedding planes. The nodules vary from three to ten inches in diameter, while some masses several inches thick extend for 20 feet or more along the bedding planes.

On the Petitot River 163.5 feet of Mississippian beds are exposed (Figure 6a). The detailed section is as follows:

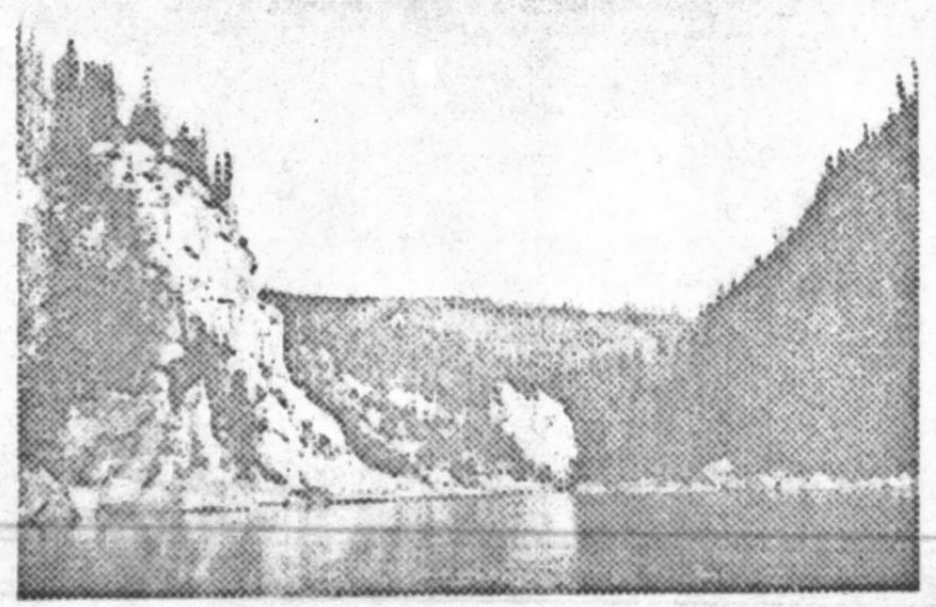
Lithology	Thickness in Feet
Top of Section	
Glacial material	
Limestone, fine grained, buff weathering; some iron staining.	54.0
Limestone, thinly (one-eighth inch) bedded, silty, platy.	3.0
Limestone, silty, many chert nodules; sandy limestone and shale in lenses.	35.0
Limestone, silty.	3.0
Limestone, massive; several four-inch bands of black shale.	8.5
Shale, black, sandy, tarry (?) odor.	1.5
Limestone, silty, bedded.	2.5
Shale, sandy, calcareous; long continuous chert band four inches thick.	1.0
Limestone, massive; bands of shale three inches to four inches thick at two-foot intervals.	17.0
Limestone, silty.	3.5
Shale, black, tarry (?) odor.	0.5
Limestone, sandy, irregularly bedded.	1.5
Limestone, massive, chert nodules.	6.0
Shale, black, sandy; long chert band.	0.5
Limestone, silty, thinly and irregularly bedded; many corals.	2.5
Limestone, massive, fine grained.	0.5
Limestone, silty, platy, many corals.	0.5
Limestone, massive, several thin (three inches) shale bands.	6.0
Limestone, silty, sandy, one-inch beds.	3.5
Limestone, massive, with chert nodules; black shale with tarry (?) odor, in bands up to five inches thick at intervals of two to three feet.	13.0
Total	163.5



(a) Photograph looking northwest, showing west-dipping Mississippian (?) limestone exposed on the Petitot River.



(b) Photograph of the steeply west-dipping Lower Cretaceous shales on the Petitot River. The left edge of the photo is in the fault zone. The picture was taken almost in the direction of the strike (N. 07° W.). Dips measure 55° to 70°.



(c) Photograph showing beds of the Fort Nelson formation forming the steep walls of the Petitot River Canyon.

Figure 6

The limestone beds which are exposed along the escarpment were not measured in detail and, therefore, no correlation between them and those occurring along the Petitot River can be attempted. However, on the basis of elevations and positions of the two outcrops as observed on aerial photographs, it is believed that the beds on the escarpment represent a higher horizon than the section which is described in detail above. If this is correct, the total exposed section of Mississippian beds on the Bovie Lake structure is approximately 250 feet thick.

Although fossils are not abundant, and are difficult to collect in these hard beds, a fairly large collection was obtained and it has been sent to the Canadian Geological Survey for identification and age determination. A Mississippian age has been tentatively assigned to these limestone beds, and they are correlated, on the basis of good lithological evidence, with the Mississippian beds exposed on the Liard Range, located about 30 miles to the northwest of the Bovie Lake structure.

On the Liard Range, the Mississippian beds, according to Hage (1), have an estimated thickness of over 1000 feet. These beds are believed to thin out to the east and northeast, because they have not been reported in the Paleozoic sections exposed along Hay River and Great Slave Lake. However, since the rate of thinning is not known, it is impossible to predict the thickness of the Mississippian limestone in the Bovie Lake structure, although it is suspected that it would be less than 1000 feet.

Pennsylvanian and/or Mississippian

Sandstone and chert of probable Pennsylvanian and/or Mississippian age were observed at the south end of the Bovie Lake anticline on both its east and west flanks, and along the Petitot River.

On the west flank of the anticline, at its southern end, an unexposed

stratigraphic interval of about 90 feet separates the Pennsylvanian and/or Mississippian sandstone from the underlying Mississippian limestone. On this outcrop, approximately 50 feet of light grey medium grained massive and bedded sandstone was observed. It is composed almost entirely of subangular quartz grains. No fossils were found in this section, but worm (?) borings, stone concretions, and indefinite cylindrical casts of roots, twigs or trails are common. The casts vary from one-eighth to one-quarter inch in diameter, and from a few inches to ten inches in length.

This 50-foot section of Pennsylvanian and/or Mississippian sandstone outcrop forms a scarp which is continuous around the south end of the structure, and extends for some distance along the east flank. The scarp faces inward towards the core of the anticline (Plate 1). The strata are not well exposed on the east flank, but at one place 10 feet of fractured ferruginous chert overlie 20 feet of quartzitic sandstone. Two specimens of brachiopods were found in this sandstone. These have been sent to the Geological Survey of Canada for identification.

On the Petitot River, an unexposed interval of about 395 feet separates the Mississippian limestone from the overlying chert and sandstone sequence. The outcrop consists of 15 feet of fractured, iron-stained, bedded chert overlain by 35 feet of sandstone. The sandstone is light grey, medium grained, clean, irregularly bedded and platy. It is composed of about 80 percent subangular quartz, 18 percent feldspar, and 2 percent dark mineral. No fossils were found in this Petitot River section, but indefinite casts similar to those found in the outcrops at the south end of the anticline are present.

The exact age of these sandstone and chert beds is not known. On the basis of lithological and fossil identification made in the field, they are believed to correlate with the sandstone, chert and conglomerate series exposed on Pointed Mountain, situated about 20 miles to the west of Fort Liard. Hage (1)

refers to the beds on Pointed Mountain as Pennsylvanian and/or Mississippian. The writers collected numerous fossils from the beds on Pointed Mountain and these have been sent to the Canadian Geological Survey for examination. The thickness of the exposed beds on this mountain is estimated to be 2000 feet.

No accurate estimate of the thickness of the Pennsylvanian and/or Mississippian beds can be made on the Bovie Lake structure because of the scarcity of outcrops. However, there is a stratigraphic interval of 1585 feet, although largely drift covered, between the Mississippian limestone and the Lower Cretaceous shale, the greater part of which may be made up largely of these sandstone and chert beds.

Lower Cretaceous

Lower Cretaceous strata crop out along the Petitot, Muskeg, and Liard Rivers. These beds consist of thick sandstone, interbedded shale and sandstone, and shale. They have a thickness of over 2458 feet.

The sandstones are greenish-grey, greenish-brown, or brown in color, fine grained, dirty, cross-bedded, and flaggy. Their composition varies, but it averages 65 to 75 percent angular quartz grains, 5 to 15 percent glauconite, and the remainder fine clay and iron oxide.

The shales are dark grey to black in color, and are sandy in places. They contain many nodules, up to three feet in diameter, and discontinuous masses of ironstone. Cone-in-cone structure in the shale is sometimes associated with the top of the larger nodules.

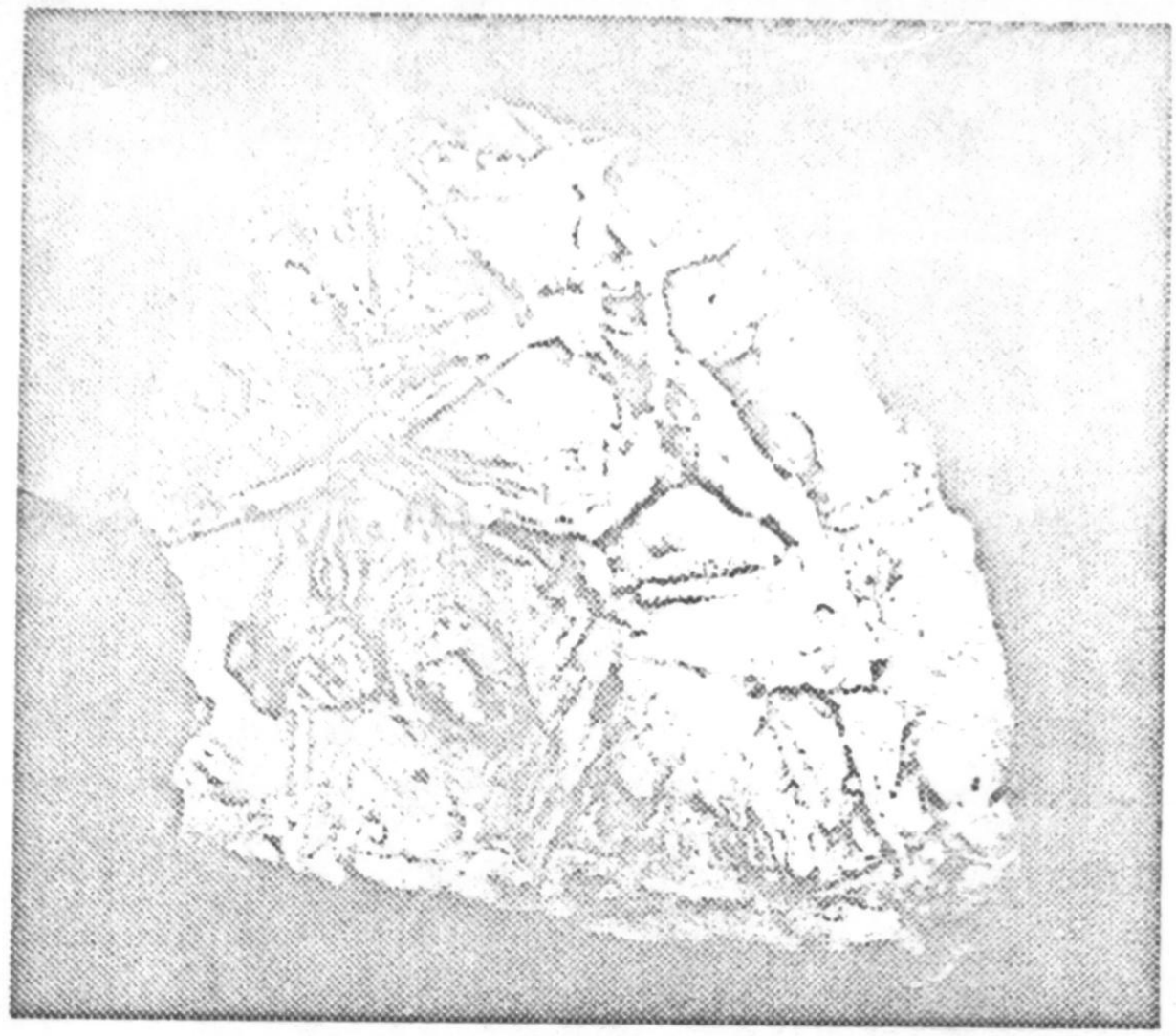
The following composite section of the Lower Cretaceous beds was measured along the Petitot River on the west flank of the Bovie Lake Anticline (Figure 5):

Lithology	Thickness in Feet
Top of Section	
Shale, black, soft, weathering dark grey and papery; a few thin (up to four inches) sandstone lenses; a few iron-nodule bands; several one-quarter inch bands of bentonite (?); abundant selenite crystals in needles and rosettes. Some poorly preserved fish scales.	452
Unexposed	191
Shale, dark grey, fissile, fractured and broken; nodules and discontinuous bodies of ironstone. Minor thin (six inches max.) bands and lenses of sandstone make up less than 10 percent of the interval.	90
Sandstone, grey, dirty, buff-weathering, fine to medium grained, cross bedded, flaggy; casts of trails and tubes, and "palm-like" structures. Minor shale beds less than six inches thick containing fish scales make up less than 10 percent of interval. Ironstone in nodules and discontinuous bodies. Neogastroplites cornutus.	205
Shale, dark grey, interbedded with fine grained, dirty, buff weathering, cross-laminated sandstone, in alternating beds five to eight inches thick.	30
Unexposed	90
Shale, dark grey, interbedded with fine to medium grained, dirty, buff weathering, cross-laminated sandstone, in alternating beds five to eight inches thick.	20
Unexposed	146 approx.
Shale, black to dark grey, fissile. The shale is iron stained, and contains many nodules and discontinuous bodies of ironstone. Thin lensing sandstone beds make up less than 10 percent of the interval. The upper 200 feet of shale shows slickensides.	634
Sandstone, greenish-brown to greenish-grey, fine grained, thinly bedded, with shale partings, finely cross-laminated, flaggy, lenticular, glauconitic. Interbedded with thin beds of sandy shale. Shale forms 10 percent of the interval. Abundant nodules and bodies of ironstone. Some of the latter extend for 20 feet along bedding planes. The sandstone contains casts of worm (?) or gastropod (?) trails, worm (?) tubes, and crushed gastropod casts, stem concretions and "palm-like" structures. This section is gradational into the shale above.	600
Total	2458

An exact thickness of the Lower Cretaceous series in the area cannot be given, because neither the upper nor the lower contact is exposed. An estimated thickness of 2950 feet is shown on Figure 5. The lower contact is placed in a drift-covered interval of 940 feet between thinly bedded flaggy cross-laminated glauconitic sandstone, and the quartzitic sandstone believed to be of Pennsylvanian and/or Mississippian age. The upper contact of the Lower Cretaceous is placed in an unexposed interval of 360 feet between soft black shales and a sequence of interbedded sandstone and shale of Upper Cretaceous age.

The unexposed interval of approximately 146 feet shown in the above section occurs between beds dipping 65° to 70° to the west, and beds dipping 24° to the west. The beds have the same strike. The value of 146 feet was obtained by computation, using the mean dip. It is believed that the beds are faulted here, with the east side moved up relative to the west. The amount of displacement or the thickness of section lost could not be determined. However, it is believed that the movement has been mainly slippage along the bedding planes in the shale, and that the estimated stratigraphic interval at this point is reasonable.

Only one recognizable fossil was found in the section described above. This was found in the talus below the highest sandstone of the section and was identified by Dr. F. H. McLearn of the Canadian Geological Survey as Neogastroplites cornutus. He gives the age as "late Lower Cretaceous (late Albian)" and suggests a correlation of this horizon with "the upper part of the Fort St. John group, and particularly with the lower part of the Sikanni formation on Sikanni Chief River, and the Goodrich formation on Pine River". The section below the horizon where Neogastroplites cornutus was found would, therefore, correlate with the Buckinghorse formation of the Alaska Highway area.



Photographs showing indefinite casts of trails and/or twigs in Lower Cretaceous sandstone from the Petitot River (x ½).

Figure 7

Other undeterminable fossil remains, very common in the Lower Cretaceous sandstones, are indefinite cylindrical or flat-elongated casts which may be filled borings, or worm or gastropod trails (Figure 7). Stem concretions and "palm-like" structures are also common. The latter term is used by Hage (1) to describe swirly branching features which may be casts of grasses or of sea-weeds. These casts vary in diameter from four to fourteen inches. They are similar to those found in the underlying Pennsylvanian and/or Mississippian sandstone, but are more abundant, larger, and better defined in the Lower Cretaceous beds.

The nearest exposure of Lower Cretaceous strata on the east side of the Bovie Lake anticline occurs about four and one-half miles distant on the Petitot River (Plate 2). This outcrop, which is outside the limits of the present map area, contains a 30-foot section of black, dark grey weathering fissile shale. The shale contains indefinite fish scales, and ostracod shells.

Still further east on the Petitot River, Lower Cretaceous strata occur in isolated outcrops. The best of these is found on a south tributary of the Petitot River at longitude 121°48' (Plate 2). The outcrop begins about one mile from the mouth of the creek and extends for one-half mile upstream. The section along the creek was not measured in detail, but is approximately as follows:

Lithology	Thickness in Feet
Top of Section	
Sandstone, brownish-grey to buff, fine to medium grained, thinly bedded, cross-laminated, glauconitic; minor thin beds of shale. The sandstone contains stem concretions and indefinite casts of worm (?) tubes and trails.	60
Shale, dark grey, sandy, iron nodules, with interbeds up to six inches thick of fine-grained cross-laminated sandstone.	40

Cont'd.

Lithology	Thickness in Feet
Unexposed	20
Shale, dark grey, silty; with thin lenses of fine-grained cross-laminated sandstone.	12
Total	132

The most easterly outcrop on the Petitot River occurs at longitude 121°36' where there is a 40-foot section of sandstone with interbeds of shale. The sandstone contains stem concretions and indefinite casts of worm (?) tubes and trails. These beds are correlated with the predominantly sandstone member of the section described above. Only a tentative correlation can be made between the Lower Cretaceous beds exposed on the west and east side of the Bovie Lake anticline. Lithologically, the sandstones appear to be identical and contain the same fossil casts. However, no definite marker beds were found.

Upper Cretaceous

The Upper Cretaceous series in the vicinity of Fort Liard, and in the area southwest of Fort Liard, has been divided by Kindle (3) and Hage (1) into the Fort Nelson formation, the Kotaneelee formation and an uppermost unnamed member. Both the Fort Nelson and the Kotaneelee formations were recognized within the map area. They occur stratigraphically above and to the west of the Lower Cretaceous strata on the Petitot River.

Fort Nelson Formation

The Fort Nelson formation exposed within the map area consists of over 679 feet of grey to buff colored sandstone, pebble conglomerate and some interbeds of sandstone and shale (Figure 6c). Carbonaceous shale and coal beds were observed near the top of the formation. The sandstones are generally cleaner and coarser grained than the underlying Lower Cretaceous strata. They are also less flinty, not so thinly bedded, not so finely laminated, and do not contain

the fossil casts so abundant in the Lower Cretaceous beds. The sandstones of the Fort Nelson formation are characterized by flecks of carbonaceous material on the bedding planes.

Exposures of the Fort Nelson formation are not continuous, and the lack of definite marker beds, the character of the sediments, and the low angle of dips, makes correlation between outcrops difficult. However, an attempt has been made to correlate the strata on the basis of lithology. The result is the composite section which is given below:

Lithology	Thickness in Feet
Top of Section	
Interval to base of exposed Kotaneelee formation.	150?
Sandstone, brown, coarse grained, carbonaceous flecks on bedding planes; pebble bands two to six inches thick and conglomerate beds four to eight feet thick through the interval. The conglomerate is composed of well rounded chert, milky quartz, ironstone, and granitic pebbles up to one and one-half inches in diameter in a matrix of coarse sandstone. It shows torrential cross-bedding.	80
Shale, sandy, interbedded with brown to buff, medium grained sandstone with carbonaceous material on the bedding planes.	10
Sandstone, grey, weathering buff, massive, coarse grained, carbonaceous material on bedding planes	45
Unexposed	51
Shale, dark grey, sandy, interbedded with sandstone bands up to six inches thick.	30
Sandstone, brown, coarse grained, carbonaceous matter; and pebble conglomerate, cross-bedded, in part torrential. Conglomerate contains pebbles up to one and one-half inches in diameter of milky quartz, chert, ironstone, and granitic material.	90+
Unexposed	5+
Shale, black, carbonaceous, in part sandy; minor sandstone beds.	55
Sandstone, grey to brown, medium grained, massive, carbonaceous material on bedding planes.	10

Cont'd.

Lithology	Thickness in Feet
Shale, black, carbonaceous; abundant plant remains.	20
Coal.	2
Sandstone, and sandy shale.	30
Coal.	1
Sandstone, and sandy shale.	10
Sandstone, brown, medium grained, cross-bedded, carbonaceous material on bedding planes.	30
Unexposed	30
Sandstone, grey, buff weathering, coarse to fine grained, dirty, carbonaceous material on bedding planes; in part massive, in part cross-bedded and flaggy.	120
Shale, dark grey to black, interbedded with light brown, medium grained, dirty, cross-bedded sandstone having mica and carbonaceous material on bedding planes.	80
Total thickness of the described beds	679.
Interval to top of exposed Lower Cretaceous	360

No fossils were found in the Fort Nelson formation, but the beds are lithologically similar and occupy an equivalent stratigraphic position to the Fort Nelson formation which is exposed in the vicinity of Nelson Forks (Plate 2) and described by Kindle (3). He gives a thickness of 560 feet for the formation in that area. Hage (1) states that its thickness along the Petitot River, downstream from the section measured by writers, is between 500 and 800 feet.

Kindle (3) suggests that the Fort Nelson formation might be correlative with the Dunvegan formation exposed in the area west and south of the village of Fort Nelson. If this is so, it represents the beginning of Upper Cretaceous sedimentation.

Kotaneelee Formation

Beds of the Kotaneelee formation were examined only along a south tributary of the Petitot River at 60°04' latitude and 123°03' longitude. Northwestward from this point, the beds of the Kotaneelee formation form a cliff, or second step, several miles back from the river. The contact with underlying Fort Nelson formation was placed at the base of the second step.

Hage (1) estimates the thickness of the Kotaneelee formation to be more than 500 feet. However, the only section examined by the writers is as follows:

Lithology	Thickness in Feet
Top of Section	
Shale, dark grey, rusty, fissile, secondary selenite.	100
Sandstone, greenish-grey, fine grained, dirty; contains pebbles of chert and quartz, carbonaceous material, wood fragments; many cylindrical concretions (?) varying from one to four inches in diameter and from two to eight inches in length. Pecten cf. silentiensis.	30
Total	130

One fossil was collected from the sandstone described above. This fossil was identified by Dr. F. H. McLearn of the Canadian Geological Survey. He states, "Pecten silentiensis is not a very diagnostic species. The type specimen is from the Upper Cretaceous Smoky Group".

S T R U C T U R E

BOVIE LAKE ANTICLINE

The Bovie Lake Anticline forms a prominent topographic ridge about three-quarters of a mile wide and 25 miles long, with a relief of about 400 feet. This ridge is asymmetrical in cross-section, and has an abrupt east-facing escarpment which is cliff-like for the uppermost 150 feet. The slope on the

west side is gentle and forms a dip slope.

The main exposures of this structure occur along the Petitot and Muskeg Rivers and along the east-facing escarpment which trends parallel to the strike of the beds.

On the Petitot River where the west flank has an exposed width of about six miles, 165 feet of Mississippian and possibly as much as 1380 feet of Pennsylvanian and/or Mississippian beds are present. These in turn are overlain by a thick section of both Lower and Upper Cretaceous sediments. To the east of the structure, along the Petitot River, outcrops are lacking for a distance of four and one-half miles. At this locality one outcrop of shale occurs in which the bedding is almost horizontal.

The maximum dip observed on the west flank, along the Petitot River, is 70°, and on the east flank, along the south end of the escarpment, dips up to 62° have been recorded. Northwest from the northern end of the escarpment, along the projected strike of the anticline, the nearest outcrops are seven miles distant along the Muskeg River. In this locality a reversal of dip occurs in beds of Lower Cretaceous age.

Although the anticline has a well-defined west flank, the east flank was observed only at three localities. Throughout the greater length of the structure, the ridge is cliff-like, and the beds are either horizontal or dip to the west. The lack of an exposed east flank could be due to erosion, but the straightness and length of the scarp is suggestive of faulting. The east dipping beds, mentioned above, were found only near the axis of the fold. The absence of hard resistant limestone ledges farther east suggests either a very steep east limb for the anticline, or that the beds have been displaced by faulting.

It is highly probable that the escarpment represents a fault line along which Paleozoic beds have been pushed up against, and probably over, the Lower Cretaceous shales. Based on the thickness of the beds overlying the Paleozoic,

the vertical uplift involved in the folding and/or faulting is estimated to be at least 2500 feet.

A minor fault is suspected on the west flank of the structure (Plate 3 and Figure 6b). Here, the dip of the Lower Cretaceous beds, exposed on the Petitot River, changes abruptly from 70° to 24°. No measurements of the displacement could be made, but it is believed that the east side has moved up relative to the west.

The convergence of strike of the beds on the Muskeg River, and the presence of Lower Cretaceous strata on the axis of the fold on that river at a surface elevation at least 700 feet lower than the most northwesterly Paleozoic outcrop, indicates that the Bovie Lake structure plunges northward at a rate of at least 100 feet to the mile.

Southward plunge of the structure is shown by the topography. The ridge which is the topographic expression of the anticline dies out about eight miles south of the British Columbia-Northwest Territories boundary. As the ridge decreases in height, the Pennsylvanian and/or Mississippian sandstone forms a scarp facing inward towards the core of the anticline, which extends completely around the southern end of the structure. As seen from the air or on aerial photographs, this evidence of southern plunge is very convincing, and the structure is considered by the writers to have southern closure equal to that of its northern end.

The attitude of the beds, as seen in the field and on aerial photographs, indicates that there is a break in the structure at the gap formed by the Petitot River. The strike of N.48°E., dip 10°N.W. was measured at several places along the escarpment about one mile south of the Petitot River. The strike and dip determinations in this locality when compared to the trend of the structure suggest a northward plunge of the anticline at this point. Under the stereoscope, the aerial photographs reveal a decrease in the height of the

ridge along the same beds.

Surface indications suggest that the beds immediately to the north of the Petitot River plunge southward, and that the gap in the ridge at the river represents a structural break. This break indicates either an "en echelon" arrangement of folds north and south of the river, or a structural saddle in a continuous fold. The two alternatives are suggested by:

(1) The offset of the anticlinal axes north and south of the river;

(2) the attitude of the beds;

(3) the topography.

From the foregoing description of the available surface information, the Bovie Lake structure is a long narrow tightly folded and possibly faulted anticlinal structure with a pronounced plunge at both its northern and southern ends.

This structure compares with the tightly folded and faulted Liard and Nahanni Ranges, which are considered to be foreland structures of the main Mackenzie Mountains. Hage (1) mapped the Liard and Nahanni Ranges as long narrow anticlinal structures, bounded on the east by an east-facing escarpment which represents a fault on their east flanks, and on the west by a broad syncline, in which the beds are comparatively undisturbed. The faults are the block type in contrast with the low angle over-thrusts characteristic of the Rocky Mountains and foothills.

From the evidence available, it is suggested that the Bovie Lake structure can be considered as one of the aforementioned foreland structures, offset from the Liard Range by a broad synclinal valley, and probably linking up with the same line of folding and faulting which formed the Nahanni Range. This range is located about 50 miles to the northwest and directly in the line of strike of the Bovie Lake anticline.

The mechanics which would produce such structures are not completely

understood. However, it is believed that they result from high-angle faults in the basement rocks. The undisturbed nature of the beds in the synclinal areas to the west of the Bovie Lake structure and the pattern of dips shown on the cross-section indicate largely vertical, rather than horizontal movement. The vertical pressure apparently was confined to a narrow area close to the axis of the fold. The vertical displacement of the Mississippian beds involved in the folding and/or faulting is, as mentioned elsewhere, estimated to be at least 2500 feet.

S U M M A R Y

The Bovie Lake and Markhamish permit areas were staked during the summer of 1950 to cover the area of a large anticlinal, and possibly faulted, structure situated in northern British Columbia and the Northwest Territories.

Beds of Mississippian, Pennsylvanian and/or Mississippian, and Lower and Upper Cretaceous strata are exposed on this structure.

In the subsurface Upper and Middle Devonian and Silurian strata are believed to be present. Based on observations of these beds in distant localities, it is believed that parts of the Upper and Middle Devonian series have characteristics favorable for reservoir rocks. The depth to such zones on the Bovie Lake structure cannot be estimated because of the lack of precise stratigraphic information of the beds below the Lower Cretaceous.

The Bovie Lake structure has a length of over 30 miles which is expressed topographically by a long narrow ridge with a relief of over 400 feet. The east side of this ridge is marked by an escarpment, while the west side has a gentle dip slope.

The structure has a well-defined northern and southern plunge, estimated to be over 100 feet to the mile. A structural saddle or an "en echelon" arrangement of folds is developed in the vicinity of the Petitot River.

The anticline has a well-defined west flank throughout its entire length with dips up to 70°. The east flank, however, was observed only at three localities. Throughout the greater part of the structure the ridge is cliff-like and the beds are either flat-lying or dip to the west.

The lack of an east flank could be a result of erosion, but the straightness of the scarp and the absence of the hard resistant Mississippian limestone ledges farther east suggest either a very steep east limb on the fold, or that the beds have been displaced by faulting.

It is believed that the escarpment represents a fault line along which the Mississippian limestone has been pushed up, and probably over, the Lower Cretaceous. It is estimated that this uplift, whether by folding or faulting or a combination of both, is at least 2500 feet. The uplift appears to be the result of near vertical movements which were confined to a narrow area close to the axis of the fold.

RECOMMENDATIONS

The fundamental problem for future exploration on the Bovie Lake structure is to determine the nature of the subsurface structural conditions and their relation to a possible oil trap. The fact that the evidence available suggests faulting on the east flank of the structure presents many problems which should be solved before a location for a deep test can be made.

It is doubtful if detailed surface work on the structure alone would give the necessary information to solve these problems. However, surface work in the areas to the west, that is on the Liard and Nahanni structures, where outcrops are abundant and the faults clearly defined, probably would give a structural interpretation which could be applied to the Bovie Lake feature. It would be an indirect approach, but in the writers' opinion, these foreland structures have a common origin and type, and differ only in the intensity of

folding and faulting.

Additional surface work on the Maxhamish and Bovie Lake Permit Areas should include a plane table survey of the structure. One purpose of this work would be to establish fixed points so that a controlled mosaic of aerial photographs could be built up. The map which accompanies this report has been drawn from an uncontrolled mosaic and may be inaccurate in scale and orientation. The primary purpose of this plane table survey would be to locate the outcrops more accurately to obtain more dip and strike determinations, and to trace the axis of the fold.

Additional stratigraphic information on the Paleozoic sections of the region is also desirable. The work done to date on these sections by the Canadian Geological Survey has been of the reconnaissance nature, and only sections in the most accessible areas have been examined.

The proposed program of mapping on the Liard, Nahanni, and adjacent ranges, as well as the additional work on the Bovie Lake structure would give a better understanding of both the stratigraphy and structure of the region. It is a job that would require a large field party, at least three two-man parties and the use of a helicopter for about two months.

After the completion of the geological investigation, it is suggested that a geophysical program be attempted. At the outset of this program, it is recommended that an airborne magnetometer survey be made covering not only the Bovie Lake structure, but also a large regional area so as to include the Liard and adjacent ranges. The primary purpose of this work would be to assist in determining the extent of faulting in the region.

A limited amount of seismograph work probably will be essential before a recommendation for a deep test can be made. However, it is believed that the stratigraphic and structural information obtained from the geological and magnetometer surveys would be very useful for the interpretation of the seismic results.

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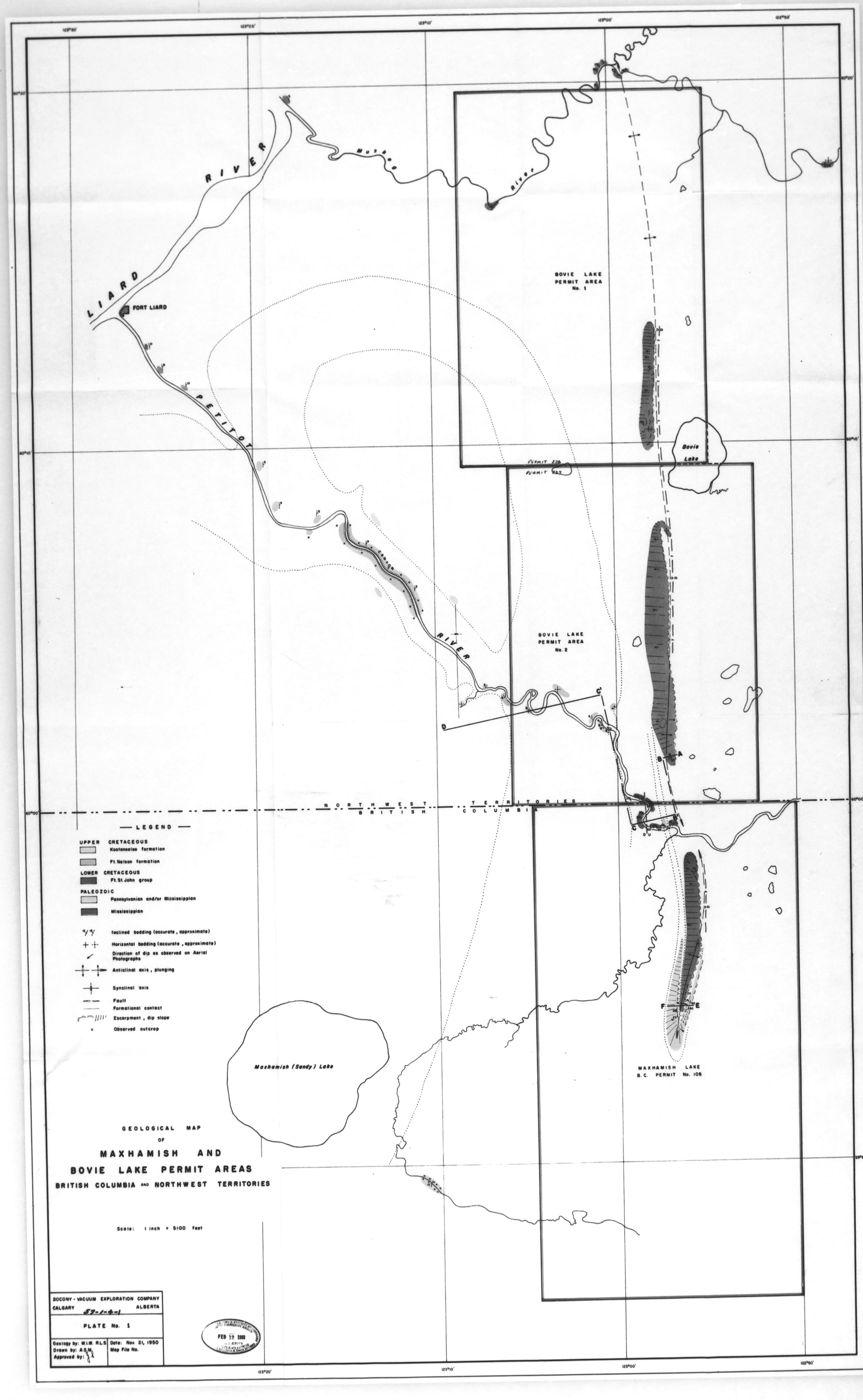
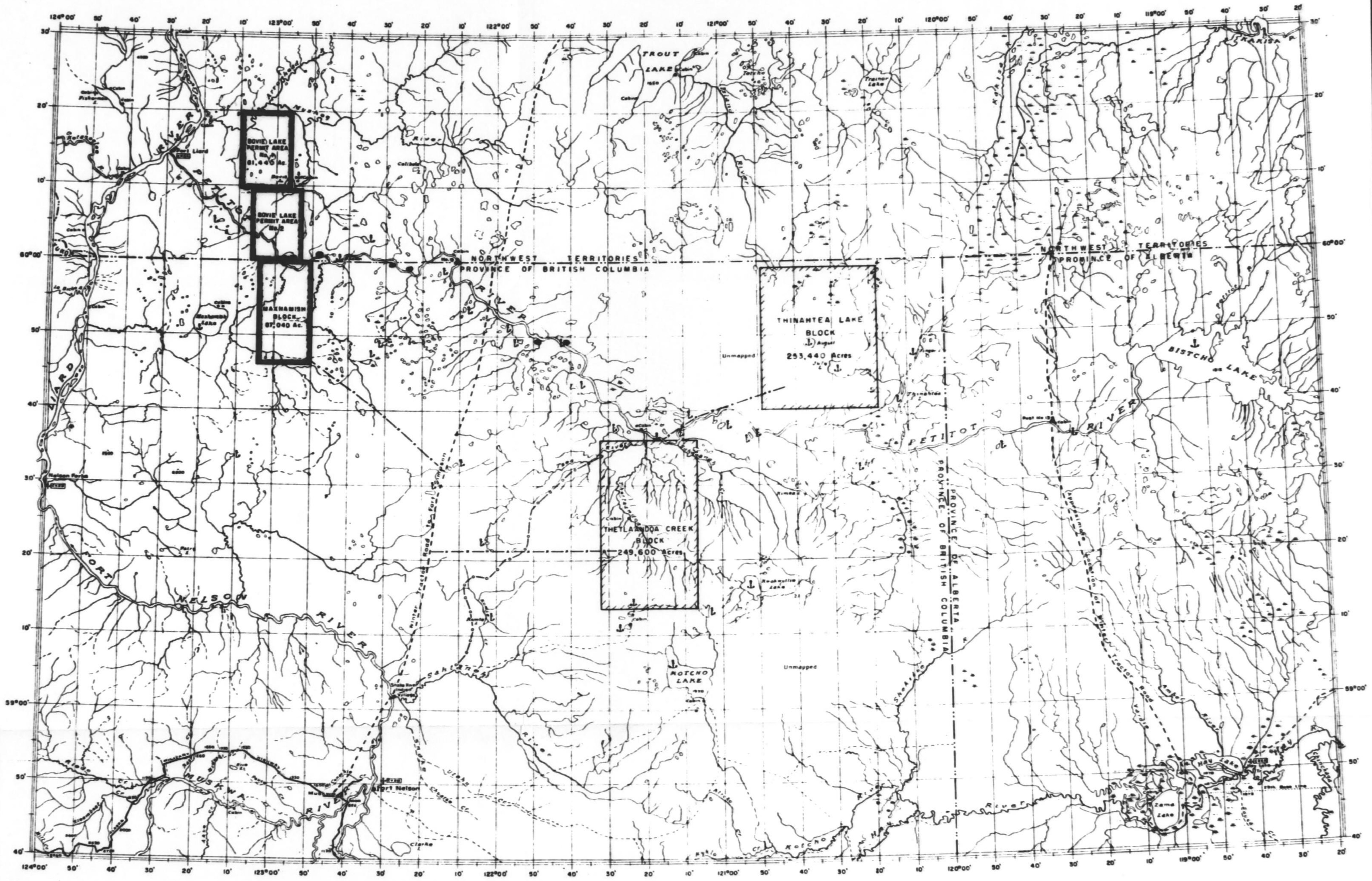

GEOLOGICAL MAP
OF
MAXHAMISH AND
BOVIE LAKE PERMIT AREAS
BRITISH COLUMBIA AND NORTHWEST TERRITORIES
Scale: 1 inch = 5100 feet
— LEGEND —
UPPER CRETACEOUS
Kootaneelee formation
Ft. Nelson formation
LOWER CRETACEOUS
Ft. St. John group
PALEOZOIC
Pennsylvanian and/or Mississippian
Mississippian
Inclined bedding (accurate, approximate)
Horizontal bedding (accurate, approximate)
Direction of dip as observed on Aerial Photographs
Anticlinal axis, plunging
Synclinal axis
Fault
Formational contact
Escarpment, dip slope
Observed outcrop
SOCONY - VACUUM EXPLORATION COMPANY
CALGARY ALBERTA
57-1-4-1
PLATE No. 1
Geology by: W.I.W. R.L.S.
Drawn by: A.S.M.
Approved by:
Date: Nov. 21, 1950
Map File No.
FEB 12
BOVIE LAKE PERMIT AREA No. 1
BOVIE LAKE PERMIT AREA No. 2
MAXHAMISH LAKE B.C. PERMIT No. 106
PERMIT 228
PERMIT 229
Bovie Lake
Maxhamish (Sandy) Lake
LIARD RIVER
FORT LIARD
PETITOT RIVER
Muskeg River
NORTHWEST TERRITORIES
BRITISH COLUMBIA
60°00'
60°10'
60°20'
59°50'
123°30'
123°20'
123°10'
123°00'
122°50'



—LEGEND—

Provincial Boundary	
Winter Tractor Road	
Trail	
Suggested Route, Summer Access	
Suggested Route, Winter Access	
Cabin	
Seaplane Landing, Low Water	
Seaplane Landing, High Water	
Accurately surveyed point	
Lower Cretaceous outcrops on Petitot River not shown on Geological Map	
Swamp	
Height in feet approximate	1260
Wireless Station with call letters	

REGIONAL TOPOGRAPHIC MAP

OF

PARTS OF BRITISH COLUMBIA ALBERTA AND NORTHWEST TERRITORIES

Scale 1 inch = 8 miles

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CALGARY, 57-1-4-1 ALBERTA

PLATE No. 2

Compiled by: R.L.S. Drawn by: G.W.P. Approved by: J.J.	Date: January, 1951 Map File No.

FEB 21 1951 SUBMITTED WITH J-256