PROVINCE OF BRITISH COLUMBIA

DEPARTMENT OF LANDS
HON. T. D. PATTULLO
Minister of Lands

# REPORT OF OIL SURVEYS

IN THE

# PEACE RIVER DISTRICT

1920

BY
JOHN A. DRESSER AND EDMUND M. SPIEKER

PRINTED BY
AUTHORITY OF THE LEGISLATIVE ASSEMBLY.

VICTORIA, B.C.:
Printed by WILLIAM H. CULLIN, Printer to the King's Most Excellent Majesty.
1921.

VICTORIA, B.C., January 14th, 1921.

*To His Honour* WALTER CAMERON NICHOL,

*Lieutenant-Governor of the Province of British Columbia.*

MAY IT PLEASE YOUR HONOUR:

Herewith I beg respectfully to submit the Reports of Oil Surveys in the Peace River District of British Columbia in 1920 by John A. Dresser and Edmund M. Spieker.

T. D. PATTULLO,

*Minister of Lands.*

# Oil Survey in the Peace River District, British Columbia.

By John A. Dresser.

The following is a summary report of progress for the season of 1920 in the investigation of the oil and gas resources of the Peace River District in British Columbia which is being carried on by the authority of the Minister of Lands and under the direction of the Comptroller of Water Rights. The area considered in this report lies north of the Peace River, west of Peace River Block, north-east of the foot-hills of the Rocky Mountains, and south of Graham, or the South-west Branch of the Halfway House. A larger part of the district including this area was made the subject of a reconnaissance examination and report during the season of 1919 by the late Professor Gwillim. In his report Professor Gwillim recommended certain areas for detailed examination, of which the field here considered is one.

The work of the past season was begun as nearly as possible at July 1st and continued to September 15th. In this work the writer had the valued aid as field assistant of Professor Alexander Maclean, of the University of Toronto, who had already had several years' experience in geological investigation in the Cretaceous basin of the great plains in the service of the Geological Survey of Canada. The object of the examination was to define as closely as possible the most promising localities for possible operation within the area recommended in Professor Gwillim's report of last year.

## Summary and Conclusions.

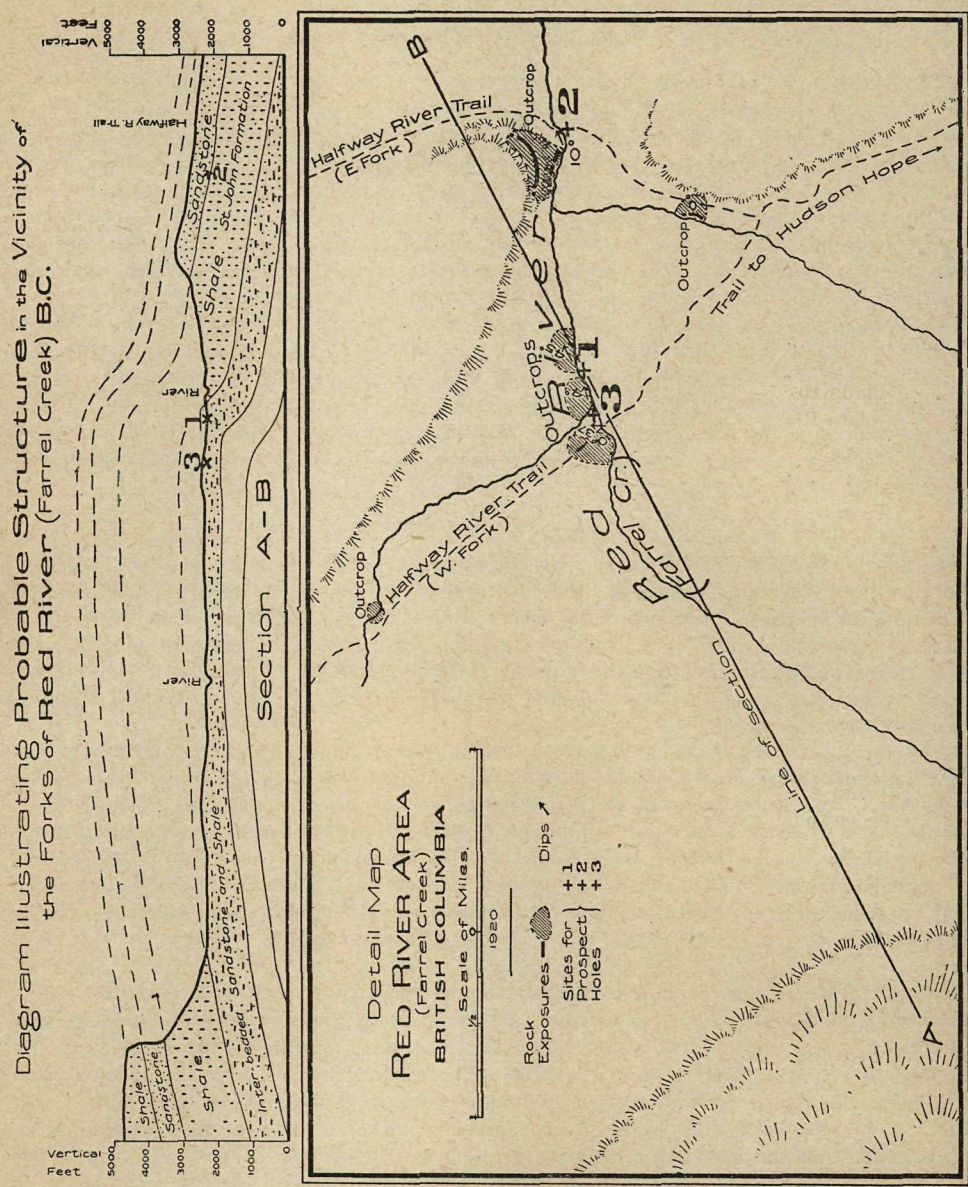
The area as already defined forms a triangle approximately 40 miles from south to north, and 10 or 12 miles wide at the north, the sides practically converging to a point at the Peace River near Hudson Hope. The surface is deeply covered by soil and rock. Exposures are few, which necessitates much work outside of the immediate field. The principal evidences of geologic structure are found along the Peace River in the vicinity of Red River, 20 miles north of Hudson Hope, near the crossing of the trails leading to the Halfway River, and along the South-west Halfway or Graham River.

The underlying rocks of known character are shales and sandstones of Cretaceous age, whose geologic equivalent in some other parts of Western Canada are oil-bearing. The upper portions of these rocks, known as the St. John formation, consist of shales with a less amount of sandstones; a lower part, the Bullhead Mountain formation, is composed of sandstones with a minor amount of shale. These formations are further distinguished by other differences of fossil content, mode of origin, and condition of preservation which it is not necessary to describe for present purposes. Beneath both of these formations rocks of Triassic age probably occur, and though possibly oil-bearing, they are likely to be found only at depths too great to be profitably explored.

The character of the St. John shales strongly suggests that they are oil-bearing, but accumulations of commercial value can only be expected in the porous sandstone-beds within the shales or in the upper parts of the Bullhead sandstones immediately beneath them. Such accumulations are most likely to occur in folds of the rocks, principally in anticlinal or upward folds. Along the Peace River one such fold appears near Hudson Hope and another at the "Gates" of the Peace, 7 miles lower down the river. Other folds, probably related to these, were also found on the Red River near the trail to the South-west Halfway, on Lynx Creek near the trail leading to the forks of the Halfway, and on the South-west Halfway near the trail leading to Hudson Hope. These are the most promising localities for the discovery of oil yet found in the area.

In view of the unlikelihood of finding better structures and of the limited amount of other information likely to be obtained in the area by further field examination alone, it seems advisable that the next step in the search for oil should be made by exploratory drilling. The object of such drilling would be to prove the character of the formation at depth, to ascertain

if there is any accumulation of oil in the porous members, and to better define the structures in which accumulation may occur; in short, the drilling would be done for information rather than for the immediate production of oil. With this object in view certain places were selected while in the field as suitable drilling-sites. Their positions are shown on the accompanying plan and are also marked on the ground by numbered posts. In exploratory drilling especially great care should be taken in collecting, interpreting, and preserving drilling records.




GENERAL DESCRIPTION.

*Surface Features.*—The area examined is a rolling plain bordering the foot-hills of the Rocky Mountains. Its general altitude is between 2,000 and 3,000 feet above sea-level and only exceeds or falls below these limits at rare intervals. The foot-hills which form the south-west boundary rise quite abruptly and have a well-defined north-westerly course.

In places low broad ridges run more or less continuously in direction parallel to the front of the foot-hills. They are very largely soil-covered and it is not clear how far, if at all, they express the structure of the underlying rocks. In places they appear to do so, as is indicated by their parallelism to the foot-hills, but in other instances they seem to be due to pre-glacial erosion or irregular deposits of glacial material. The highest of these is about 300 feet above the prairie-level.

From the Peace River northwards the general surface rises somewhat uniformly for 25 miles and then appears to decline slightly towards the South-west Halfway. From west to east there is a general decline in altitude as shown by the drainage; Lynx Creek, Red River, Kobes Creek, and their branches are all swift-flowing streams with uniform steep gradients.

The most pronounced topographic features, however, are erosional. Near the trail to Hudson Hope the South-west Halfway flows in a broad erosion valley quite 500 feet below the ridge separating it from Kobes Creek. Kobes Valley, which appears to be influenced by the jutting-out of a spur of the foot-hills, is slightly above the South-west Halfway in altitude.

The three branches of Red River and Lynx Creek in its two branches are cut mainly in unconsolidated clays and sands and in most places run in a narrow V-shaped trench. For instance, at the trail from Hudson Hope to the South-west Halfway, Lynch Creek is 100 feet deep and 800 feet wide between prairie-level on either side without exposing bed-rock. Near its mouth, however, the underlying shales and sandstones are cut by the stream in steep-walled gorges to a depth of 40 or 50 feet, often in courses following the joints of the rock. The same is true of the Red River, the Middle Branch of which is entrenched in sandstones and shales near the Halfway trails.

The descent from prairie-level to the Peace River is made on the Halfway trail over an escarpment of 350 feet at about 2 miles from Hudson Hope, followed by a second bench of 100 feet at the north side of the village, and thence by a further descent of 100 feet down the actual bank of the river to the boat-landing.

## Geology.

*General.*—The great plains in the latitude of the area under discussion are underlain by sedimentary rocks which were deposited in Cretaceous time. They extend from the vicinity of the Rocky Mountain Divide easterly to the Lower Athabaska River, and have a still greater extent in a north-westerly and south-easterly direction. Towards the eastern margin they rest on strata of Devonian age and near their western border on Triassic measures. The Cretaceous rocks of the region are shales and sandstones. East of the foot-hills of the Rockies they form a broad synclinal basin within which there are minor undulations or small folds.

*Local.*—The district represented on the accompanying map lies in the western part of the Cretaceous basin, and the rocks, other than surface deposits, belong to the lower part of that system. Two formations must be considered, although only one is actually exposed within the area.

### Formations.

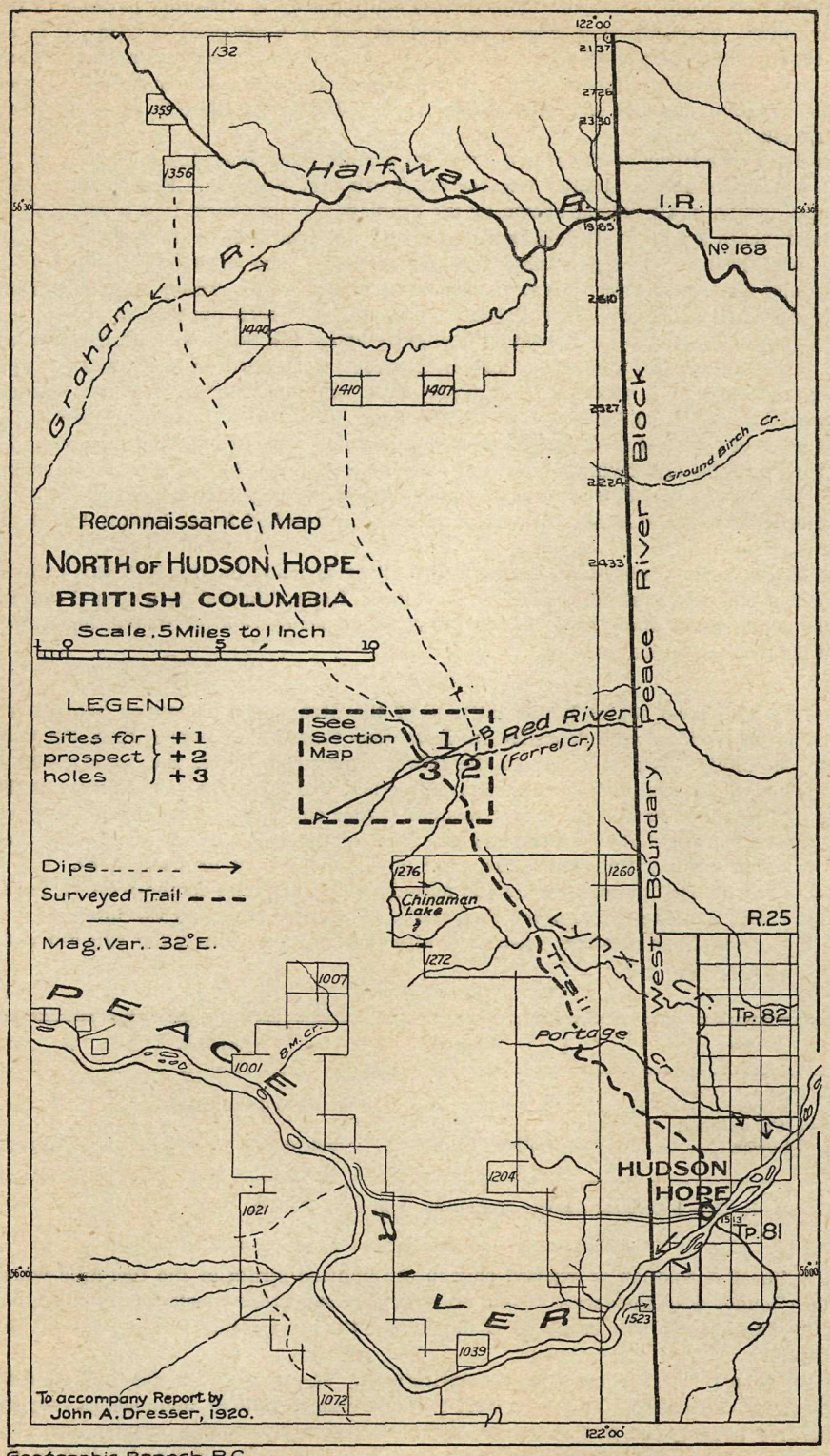
| Age.* | | Formation. | Character. | Origin. |
|---|---|---|---|---|
| Cretaceous | Upper (Coloradoan) | St. John | Shales and sandstone | Marine. |
| | Lower | Bullhead | Sandstone | Terrestrial. |

* McLearn, F. H.: Geological Survey of Canada, Summary Report, 1917.

### Character and Extent of Formations.

The Bullhead formation is exposed only in the uplifted strata of the foot-hills which form the western boundary of the area. It is a grey compact sandstone considerably indurated where folded. In places it contains seams of coal. It is a thick formation possibly several thousand feet in depth.

The St. John formation underlies the entire area. It consists of shales and sandstones in places somewhat calcareous. No fossils were found in either. The St. John shales vary in colour from dark grey to rusty red, and at a short distance commonly present a purplish hue. They are soft and very fissile, easily splitting into thin laminæ. A lump crushed and rolled in the hand




Geographic Branch, B.C.

frequently gives a petroleum odour. The St. John sandstone is a grey friable rock of rather fine even grain. In places the cementing material appears to be calcareous in the thinner beds. Beds vary in thickness from 20 or 30 feet to 1 or 2 inches. The shales form much the greater part of the formation, but in some horizons, apparently in the lower part of the formation, the sandstone approximates the shale in amount.

F. H. McLearn, of the Geological Survey of Canada, from an extensive study of the series, estimates the thickness of the formation to be upwards of 2,200 feet, consisting of an upper shale of 1,300 feet and lower of 800 feet separated by some 50 to 80 feet of sandstone. (Summary Report, 1917, Geological Survey of Canada.)

STRUCTURE.

In the foot-hills which form the west boundary of the area the rocks are folded, in places sharply, into north-westerly running ridges which frequently rise as much as 1,000 feet above the adjacent plain on the east. In this disturbed belt the St. John formation, where not removed by erosion, wraps closely over the underlying Bullhead, apparently in comformable succession. This is well shown on the south end of Portage Mountain.

East of the disturbed belt or foot-hills the dip is towards the north-east, generally at low angles, except where reversed by occasional folds. Two broad anticlines appear in the banks of the Peace River in the first 15 miles east of the foot-hills. The first is near Hudson Hope and the second at the "Gates" of the Peace, a rock-enclosed narrows some 7 miles east of Hudson Hope. In these the dip, which elsewhere is commonly less than 5°, rises very perceptibly on both limbs of the folds. In both there are strong beds of sandstone, indicating the middle horizon of the St. John formation.

Along the river-bank the rocks are largely concealed between these folds. The localities where they are exposed on the Peace River are both within the Peace River Block, about 2 and 9 miles from its west boundary. They trend towards the north-west and doubtless extend beyond this boundary into the soil-covered area.

On Lynx Creek, about a mile from its junction with the Peace, there is a sharp fold giving a south-westerly dip of 45°. Shales predominate here, but sandstone is also present. The exposure is small and the fold may be local. This, too, is within the Peace River Block.

In going northward from the Peace River west of the Block, shale-beds appear in the banks of Lynx Creek a mile or more east of the trail leading to the South-west Halfway. The exposure is small and the altitude of the beds cannot be safely determined.

Between the first and second Red Rivers some 20 miles north of Hudson Hope there are several exposures (*see* plan). From the crossing of the east trail to the South-west Halfway an escarpment about 100 feet high borders the river for a distance of a quarter of a mile westward. The rocks are largely sandstone, but there are a few minor beds of shale and the whole appears to rest on shale at the base. The dip is quite uniformly N. 20° to 25° E. (magnetic) at an angle of 10°. A mile west of this locality shale in a low exposure on the river has a dip of 45° in direction N. 20° E. (magnetic). Some 1,800 feet westerly are several exposures in the vicinity of the crossing of the west trail and the second Red River. In these the rocks are thin-bedded sandstone and shale in about equal amounts. They are nearly horizontal, though there is usually a slight dip towards the north-east.

Northwards from this locality no rock was found, except a small exposure a mile south of Graveyard Prairie on the north-east side of the third Red River, and on a spur of the foot-hills near Kobes Creek, until the South-west Halfway is reached, at a distance of some 20 miles. On this river, for several miles above its junction with the main Halfway, sandstones and shales in rather thick beds dip uniformly down the stream at a low angle of 4° or 5°. Near the crossing of the trail from Hudson Hope the rocks are concealed by soil along the river-banks, but appear in hillsides on the north side of the river. Crossing a break of a mile in this escarpment the rocks reappear on the west, dipping in the opposite direction towards the foot-hills, at about the same angle. There thus appears to be a broad anticline here having its axis in the vicinity of the trail from Hudson Hope to Cypress Creek and northward. This may be a continuation or repetition of one of the folds found on the Peace River, but, of course, the broad concealed interval between the localities makes any definite determination quite impossible. The lithological character of the formation in having sandstone nearly or quite equal in amount to shale suggests that the three localities—viz., South-west Halfway, Red River, and Peace River—may be about the horizon of the middle sandstone defined by McLearn. But in the absence of fossils and the

scarcity of other evidences this conclusion, though quite possible, is as yet little more than conjectural. Small fractures are found in one or two folds, but only such as would be naturally sealed by the compression of the shales.

Oil-seepages are reported in several localities. All such indications were examined that were reported as visible at the time of our examination, but were found to be due to other materials.

### ECONOMIC CONSIDERATIONS.

In composition, and, as far as can be learned by surface examination, in structure also, the St. John formation is favourable for the occurrence of oil and gas. It has large and slightly disturbed beds of marine shales, and these are interbedded with considerable bodies of porous sandstone. Such folds as are known are not accompanied by great faults or dislocations. Other similarly favourable structures are liable to occur beneath the great mantle of drift that conceals so much of the area.

Also, the entire area examined may be regarded as only a small sample of the wide region occupied by this formation. It therefore seems advisable that this area should next be tested, by drilling, as to the actual occurrence of oil within the sandstones at depth. These are the natural places for accumulations of oil to take place, whether in the sandstones of the St. John formation or, possibly, in favourable portions of the immediately underlying Bullhead.

Such drilling, with its results carefully scrutinized and recorded, would be highly valuable, not only in giving information as to the presence of oil in the sandstone actually drilled, but also in disclosing the nature, depth, and all contents of value in the formations concerned. Such data are of greater importance in view of the large extent of this formation in the region.

### TIMBER.

The country is generally wooded, though patches of open prairie of a mile or two in extent are common. Poplar, cottonwood, white birch, spruce, and jack-pine are the common trees. These grow to sizes suitable for fuel, lumber, small building, or drilling operations. A sawmill is badly needed in the district. Prairie-grass grows abundantly in the open spaces, generally affording ample feed for horses on the trail.

### LABOUR AND SUPPLIES.

For operations requiring any considerable amount of labour men must be brought from outside. A few pack-trains and outfits for wagon or sleigh transport, with good packers, may be engaged at Hudson Hope, also several good guides. But the population is small and there are few unemployed men. Ordinary living supplies and common implements can be purchased at Hudson Hope.

### TRANSPORTATION.

Except for a wagon-road across the Rocky Mountain Portage and for a few miles along the Peace, the only means of overland transport in the district in summer is by pack-trains over saddle-trails. This is of necessity slow and expensive. The nearest railway communication is reached at Peace River Crossing, or Spirit River, on the Edmonton, Dunvegan & British Columbia Railway, or at Prince George on the Grand Trunk Pacific Railway. The last route is little used except the district in summer, when advantage is taken of the down-stream course of nearly 300 miles on the Peace and the Parsnip and its tributaries. The most common route in summer is by way of the Peace River, either to Peace River, 240 miles by boat, or to Dunvegan, 170 miles by boat, and some 15 miles by road to Spirit River Station. Automobiles and auto-trucks are used on this road. In winter there is travel by sleigh on the river to the same points and also by an overland route via Pouce Coupe to Spirit River. In summer this route is still impossible for wagons between Moberly Lake and Pouce Coupe for a distance of 100 miles or more.

The Peace is a strong swift-flowing river with frequently changing bars and a wide range in the depth of water. Consequently, it is difficult to get draught for boats of sufficient power to stem the currents. A rate of $4.50 per 100 lb. is quoted by freighters between Spirit River and Hudson Hope for winter traffic, and $3 per hundredweight by boats in summer. All shipments, at least in winter, must be arranged for by specific order. Mail from Hudson Hope is conveyed by boat or trail to Fort St. John, and thence overland to Pouce Coupe, twenty-five times per year. There is also a Government telegraph-office at Hudson Hope which greatly facilitates outside communication.

# The Geology and Oil Resources of the Foot-hills South of Peace River in North-eastern British Columbia.

BY EDMUND M. SPIEKER.

## INTRODUCTION.

The attention of those interested in the development of the world's oil resources has in recent years been turned with some keenness of anticipation towards the region of moderately folded rocks between the foot-hills of the Canadian Rocky Mountains and the plains. In the effort to ascertain the promise of the area at least two prominent oil companies have had parts of it examined in geologic reconnaissance. That part of the belt which lies in British Columbia has appeared worthy of study. In his report to the Department of Lands, Professor J. C. Gwillim* recommended the furtherance of geologic work to determine more exactly the possibilities of the area, and the work on which this report is based was done in fulfilment of that recommendation.

The object of the writer's work was to determine as completely as possible in the time available the degree of promise as a possible oilfield offered by the region in British Columbia fronting the foot-hills of the Rocky Mountains between the Peace River in the general longitude of Hudson Hope and the Murray (East Pine) River in the latitude of Flat Creek. (*See* map for location of area.) This it was planned to accomplish through a general geologic reconnaissance, supplemented by detailed work in localities which the general examination showed worthy of further attention.

The field-work was done by the writer, assisted by W. R. Smith, during the summer of 1920. Unprecedented weather conditions delayed progress materially, cutting in half the amount of time in which observations could be made, and it was not possible to complete all of the work planned; however, a reconnaissance map of the entire area was made, and such detailed work as extremes of unfavourable weather would allow was done on the Pine River at Boulder Creek and about Hudson Hope.

## ACKNOWLEDGMENTS.

The writer wishes to express his sincere appreciation of the assistance given by many with whom he came into contact during the progress of the work. Acknowledgment is due Dr. F. H. McLearn, of the Geological Survey of Canada, for advice and criticism given in the field and office; to Professor Edward W. Berry, of the Johns Hopkins University, for the determination of fossil plants and for general criticism; to Dr. T. W. Stanton, of the United States Geological Survey, for advice concerning the invertebrates collected; to the Geological Department of Johns Hopkins University for facilities accorded during the preparation of the report; and to A. R. Barrow, B.C.L.S., for the loan of instruments in the field to replace some of those spoiled in an accident. Special acknowledgment of the perfect service given by H. C. Garbitt, packer, and Bert Meikle, cook, of the writer's party, is due; without the efficiency and willingness of these men much of the work could not have been done. The generosity of many of the residents of Hudson Hope, and in particular Charles Paquette, facilitated work materially. And as a word of final acknowledgment the writer desires to express full appreciation of the cordiality and goodwill with which every convenience for carrying on the work was accorded by the Department of Lands.

## THE MAP.

Beyond those areas directly adjacent to surveyed land-lines no mapping of much worth has been done in the region, and in order to locate approximately such natural features as are important to a geologic study a pace traverse was carried along all of the routes taken by the writer's party. In the area north of the twentieth base-line the traverse was checked as frequently as possible on land corners, whereas to the south of the Pine River, in the region with no accurately

*Gwillim, J. C.: Report Oil Survey, Peace River District, B.C. Dept. Lands, Victoria, 1919.

located surveys, the writer's traverse was carried in loop form, and was checked on the land survey from which it started.

Numerous difficulties attend the making of an accurate map in rough and forested country. However, the experience of explorers has shown that corrections to pace traverses intelligently made fall well within an allowable percentage of error, and for the purpose of this work the method was chosen in preference to the making of astronomic determination of position, which involves the disadvantage of having to carry delicate chronometers by pack-travel, and offers little, if any, advantage in accuracy in the form available to geologic workers.

The accompanying map was prepared by the addition of the writer's traverses to those maps of the area which existed prior to this work.

## LOCATION AND GENERAL CHARACTER OF THE REGION.

As the accompanying map shows, the region described in this report lies to the south of the Peace River, extending as a belt 10 to 40 miles wide from Hudson Hope south-easterly to the Murray River at the mouth of Flat Creek. This area forms physiographically a transition zone between the more abrupt foot-hills and the gently rolling plains; the topography is varied, and in places sharply sloped hills break the rolling nature of the terrane, although as a whole the marked roughness of surface of the true foot-hills is absent.

The region is drained by the Peace River and its tributaries. The portion drained more or less directly by the Peace is small, extending from Hudson Hope to the divide north of Moberly Lake. Adjoining this to the south is a belt occupied by the Moberly River and its tributaries; this, too, is small, being about 10 miles wide and extending the width of the belt in an east-west direction. The major portion of the area is drained by the Pine River system, the three main branches of which have cut deep valleys across it.

The Peace River occupies a valley about 800 feet deep, which in the vicinity of Hudson Hope is from 2 to 3 miles wide. The upper levels of land adjacent to the valley are more or less flat-lying, but 7 miles to the south hills break the evenness of the plateau, and from the general neighbourhood of Moberly Lake south-eastward along the entire area the topography is broken by hills and the dissection of the Pine River drainage.

The valley of Moberly River, which is occupied south of Hudson Hope by Moberly Lake, varies from 1 to 2½ miles in width. In the region studied its valley is U-shaped, with many flats and a meandering stream-bed. It offers no serious difficulty to travel; roads might be cut along it at a minimum of expense.

The Pine River flows from Falls Creek to the mouth of Wabi Creek in a deep, U-shaped valley which was undoubtedly the pre-glacial course of the stream. Below Wabi Creek the present bed of the river is post-glacial, the extensive morainic deposits thereabout having deflected its waters south-eastward to cut the existing V-shaped gorge through the St. John shales. The old course of the Pine is now occupied by Wabi Creek; it is a broad valley filled with glacial material, in which are many kettles and lakes of glacial origin, and it is clearly discernible from the hills west of Wabi Creek as the course formerly followed by the Pine directly north-eastward to the Peace. At the Middle Forks the Pine enters the pre-glacial course of the Sukunka River.

The Sukunka River is the central member of the Pine River system. Locally it is known as the "Middle Pine" River, the name "Sukunka" not having been adopted by the few residents of the region, but for purposes of clearness it will be referred to in this report as the Sukunka River. It is somewhat larger in volume of water than the Pine River. Its valley varies in width from 1 to 3 miles in its lower part and does not narrow materially as far as can be seen from the hills at the mouth of Burnt River. For a distance of about 22 miles from its mouth the valley is heavily forested with poplar, willow, and spruce. Above this stretch the timber has been burned, leaving the country bare and open as far as the bend above the mouth of Burnt River.

The Murray (East Pine) River is the easternmost and largest of the three main branches of Pine River. The matter of its nomenclature is similar to that of the Sukunka; the inhabitants of the region know it as the "East Pine" or "East Fork," and reference among them to the Murray River conveys no intelligence. However, to avoid the confusion attendant upon the modification of the word "Pine" to refer to distinct streams, the writer will use the name "Murray."

The valley of the Murray differs somewhat from those of the Sukunka and Pine. Physiographically it is infantile, having long stretches of V-shaped channel, with almost continuous cut-banks of shale and sandstone forming its sides, and in places the stream flows in a true box canyon. The Murray presents a profusion of rock-exposures at the river's edge throughout its length in the area, whereas the other rivers named, occupying more mature valleys, show few cut-banks and expose the more resistant beds only in the upper reaches of their valley-sides. The Murray Valley is heavily timbered, but there, as in most other parts of the area, the timber is small and has accordingly no present commercial value.

The two larger lakes in the area, Moberly Lake and Rocky Mountain Lake, are of common origin, each having been formed through the damming of its parent stream by glacial material. In each case the localization of the morainic material was undoubtedly determined by the presence at the surface of the resistant sandstones of the Dunvegan formation. The main bodies of these two lakes, and of Moose Lake as well, occupy beds cut in the St. John shales, but at the east ends of the lakes the overlying Dunvegan formation is brought to water-level by east dips, and its presence there undoubtedly determined the placing of the dams which caused the lakes. It is interesting that the geologic conditions surrounding these lakes are identical.

The entire area is generally well forested with young spruce, pine, poplar, willow, and alder. Localities which are not largely forest are rare. As a rule the northern banks of the rivers have less vegetation, particularly of the forest type, than the southern banks. This is due to the closeness of balance between precipitation and dissipation of moisture; the greater amount of sunshine which reaches the northern valley-sides is sufficient to carry away just the amount of water needed to make up the minimum for forest-growth, and since the shaded southern exposures retain this amount they support trees, whereas in many cases the northern banks are bare.

With the exception of a few localities on the Pine River, there is little or no timber of commercial value in the area. Above Peavine Flat on the Pine River are flats on which spruce as large as 30 inches in diameter is growing. Elsewhere, with the possible exception of a small area on the divide between Marten Creek and Rocky Mountain Lake, the writer observed no timber of commercial value.

## STRATIGRAPHY.

The formations exposed in the region fronting the Rocky Mountains of Northern British Columbia embrace a series of sedimentary rocks ranging in age from Triassic to Upper Cretaceous. A general review of the entire series is given in the following table of formations:—

*Table of Formations.*

| System. | Group | Formation. | Character. | Thickness (in Feet). |
|---|---|---|---|---|
| Upper Cretaceous | Montana | Wapiti | Subaerial sandstones, massive, cross-bedded, with shales and lignite | 900+ (top not exposed). |
| | Colorado | Smoky River | Dark, friable shales, marine, with median sandstone member | 800 |
| | | Sukunka member | Coarse subaerial sandstones, hardened continental muds, green shales, lignite | 1,000+ |
| | | Dunvegan | Massive to thin-bedded sandstones, varying in origin from littoral to subaerial, with some shale and few thin seams of lignite | 1,000+ |
| | | St. John | Black marine shales, usually arenaceous, with intercalated sandstone-bands and marine sandstone locally | 1,400-2,200 |

*Table of Formations*—Continued.

| System. | Group. | Formation. | Character. | Thickness (in Feet). |
|---|---|---|---|---|
| Lower Cretaceous (?) | (?) | Bullhead Mountain | Hard green-grey conglomerates, coarse-grained, massive sandstones, and shales with many seams of high-grade coal | 1,500–3,000 |
| Jurassic (?) | | Pine River..... | Blue-black marine shales with intercalated limestones and some sandstone | 300+ (base not exposed). |
| Triassic | ..... | ..... | Purple limestones and fine-grained sandstones; limestones vesicular near top | As yet unknown. |

The Wapiti and Smoky River formations are not recognizable in the area described in this report; they are found in the broad syncline of the plains to the east, and may occupy the upper hillsides just east of the Murray River, at the eastern edge of the area. Since their importance for the purposes of this work is small discussion of them will be omitted.

The preliminary results of work on the development of this section on the Peace and Smoky Rivers by Dr. F. H. McLearn will be found in Part C of the Summary Reports of the Geological Survey of Canada for 1917 and 1918.

*Triassic.*—Rocks of Triassic age do not outcrop in the area here described, but inasmuch as they would probably be penetrated by a borehole on the Pine River anticline, some mention of such information as exists concerning them is pertinent.

On the Peace River, above the Rocky Mountain Portage, McLearn* has found the Triassic series to consist of dark-purple limestones and hardened, fine-grained sandstones with *Pseudomonotis subcircularis* Gabb, and many ammonites. These beds are probably all of marine origin. The series is thick; at the time of submitting this report a definite figure is not available, but it is known to be measurable in thousands of feet. The sandstones of the Peace River section are firmly cemented with calcium carbonate, and their general appearance does not indicate that they might make good reservoir rock. However, in the area here considered the series has undergone less metamorphism than on the Peace, and in addition there is the chance that the sandstones may be more open.

The limestones of the Peace River section are vesicular in the upper part of the formation, the cavities having a length of from 1 to 3 inches and being spaced about a foot apart. It is not known at the time of writing whether the vesicularity is the result of dolomitization or not, but its presence on the Peace hints at the possibility of cavernous structure elsewhere, and although the observed data make possible no predictions as far as the area here considered is involved, they leave more open the possibility of reservoir rock beneath the Pine River anticline.

*Pine River Formation.*—This formation is the lowest of the series exposed within the area examined. It occurs at the surface on the crest of the Pine River anticline, being exposed in the narrow valley of Pass Creek for a distance of about 4 miles above its mouth. It consists chiefly of firm blue-black clay shales, the lowest observable beds of which are remarkably pure, being almost entirely free from sand and presenting the appearance of a hardened, uncontaminated black clay. In this respect it differs from most other marine black shales of the general region, which are almost uniformly sandy. Interspersed with the shales are bands of limestone and sandstone in thicknesses from a few inches up to 20 feet or more; the limestone is very compact and hard, steel-grey on fresh fracture, and, varying with changes in purity, weathers into shapes ranging from angular to gnarled or rounded in outline. The colour of its weathered surface is a greyish-yellow. No fossils were found in the limestone at any of the exposures visited by the writer.

* McLearn, F. H.: Personal communication.

The section of the Pine River formation exposed in Pass Creek is as follows, beginning at the top:—

| Thickness (in Feet). | Character of Beds. |
|---|---|
| 200 | Sandstones of Bullhead Mountain formation. |
| 20-30 | Concealed (shale ?). |
| 10± | Limestone, hard, grey, siliceous. |
| 65 | Shale, blue-black, marine, pure, in which are intercalated bands of limestone 8 inches to a foot thick separated uniformly by about 4 feet of shale. |
| 20+ | Limestone, massive, hard, blue-grey on fracture, weathers dirty yellow, forms cliff. |
| 40± | Shale, black, hard, hackly in large proportion, marine. |
| 3 | Limestone, weathers into gnarled shapes, blue-grey on fracture. |
| 3 | Sandstone and limestone alternating, layers prominent, weathers into flat surface. |
| 3 | Shale of same composition as others, but breaking to angular fragments with more or less plane surfaces. |
| 5/6 | Limestone, very siliceous, hard, weathers into angular surface of yellow-grey colour; is steel-grey on fresh fracture. |
| 2 3/4 | Shale, black, hard, hackly. |
| 5 | Limestone, with 6-inch median parting of shale; hard, steel-grey on fresh fracture, appears pure, weathers yellowish-grey. |
| 100± | Shale, blue-black, firm, pure, hackly in large proportion, contains very few fossils. |

Since the upper part only of the formation is exposed an estimate of its thickness is impossible. It was planned to examine the upper valley of the Moberly River in a search for more extensive exposures which might yeld a section more nearly complete, but field-work was stopped by unusual weather before this could be begun. Information concerning the downward extent of these shales, therefore, and their relation to the Triassic limestones is not available.

Prior to the writer's work the existence of the Pine River formation was unknown. Its age is not certain; since in Pass Creek it contains very few fossils, a statement concerning its time position cannot bear much weight. However, three fossil forms, a species each of *Pinna*, *Pecten* (?), and *Lima* (?), which were found after considerable search, indicate, according to Dr. T. W. Stanton and Dr. J. B. Reeside, Jr., of the United States Geological Survey, the broad possibility that the beds are Jurassic in age. Further study of these beds will prove of great interest in the matter of their relationship to the prominent development of the Jurassic in Alaska and to the Fernie shales farther south in British Columbia.

*Bullhead Mountain Formation.*—The section west of Hudson Hope on the Peace River discloses beneath the St. John shales a thick series of coarse sandstones and shales of continental origin which have been described by McLearn* as the Bullhead Mountain formation. On the Peace River the upper part of the formation consists of sandstones and shales, with many seams of high-grade coal, and the lower part consists of massive, coarse-grained, cross-bedded sandstones. The total thickness there is about 3,000 feet.

The formation is exposed in the area here considered on Pine River east of Pass Creek, where the upturning series brings it high into the valley-sides on the east flank of the Pine River anticline, and at the mouth of Boulder Creek, where the contact with the overlying St. John shales is approximately 300 feet above the level of Pine River on the crest of the Boulder Creek fold. At the latter locality the upper 200 feet of the formation are well exposed in the canyon of Boulder Creek.

The upper member of the Bullhead Mountain formation has been called by the writer, for purposes of reference, the Boulder Creek conglomerate. It is well exposed in the canyon below the falls in Boulder Creek. There it consists of about 130 feet of extremely hard, resistant conglomerate, the pebbles of which are almost uniformly ⅛ to ¼ inch in diameter, and which consist of flint, chert, and quartz. They are firmly bound by a silica cement. A green chert, which appears to have been stained by glauconite, is prominent as a rule, and inasmuch as it does not exist in any of the clastic rocks above the Bullhead Mountain, it is interesting as a means of identification of the rock, as well as an index to changes in the continental mass to the west as a result of whose disintegration the Cretaceous clastic rocks were formed.

* McLearn, F. H.: Peace River Section, Geol. Surv. Can., Summ. Rept., 1917, Pt. C, p. 16.

The pebbles are as a rule well rounded and have been well sorted into a very compact mass, which with the firm silica cement forms a rock more resistant than any other known to the writer in North-west Canada. It forms cliffs, the weathering of which, having been much slower then that of the surrounding rocks, stand out prominently wherever the bed is exposed. The cliffs have disintegrated into huge boulders, the striking array of which in the canyon of Boulder Creek suggested the name of the stream.

The conglomerate is characteristic in appearance, its distinct mineral content and habit making it lithologically the most easily recognized of any of the Cretaceous series of the region. Pebbles and small boulders of it are found in all of the larger stream-beds of the area, and although it is clear in some places that they have been transported there by glacial agents, their widespread occurrence gives evidence of the great lateral extent of the formation.

Below the Boulder Creek conglomerate are sandstones which decrease gradually in hardness for a vertical distance of 600 feet. Below these sandstones is another massive bed which was seen at a distance in the Upper Pine Valley; this may also be conglomerate. Below that bed less massive sandstones and possibly shales with coal occupy the remaining 600 feet to the top of the Pine River formation. The entire thickness of the formation is contained in the hill east of Pass Creek and north of the Pine River, but none of it is exposed save the massive members mentioned, the remainder being covered by the soil and the dense sub-arctic vegetation. Information given by H. C. Garbitt, who was the writer's packer, indicates the presence of coals in the creek whose headwaters abut on those of Pass Creek, and an inference drawn from the disposition of the beds in the general region suggests that the coals are probably in the middle or lower part of the Bullhead Mountain formation.

*St. John Formation.*—The Bullhead Mountain series is followed in upward succession by the St. John formation, which embodies 1,400 to 2,200 feet of blue-black to grey shales with intercalated sandstone members. On the Peace the formation is divisible into three members—an upper shale member 1,300 feet thick, a sandstone 80 feet thick, and a lower shale member 800 feet thick. The upper member consists of typical marine black shales, with little or no sandstone, but the lower member contains many small thicknesses of sandstone. The Peace River section has been described by Dr. F. H. McLearn.*

The St. John shales are distributed in outcrop over the entire area. They form the valley-sides of the Peace River in the vicinity of Hudson Hope. To the south, in the hills north of Moberly Lake, the overlying Dunvegan sandstones form the surface, but in the valley of Moberly River the shales reappear. They outcrop in the valleys of the Pine River, the Sukunka (above Marten Creek), and the Murray River; on Tyskoola and Table Mountains; and in the area south-west of Rocky Mountain Lake, the shales forming the lower valley-sides as a rule, and the Dunvegan sandstones capping the ridges. In the area south of the Peace River the lower part of the formation contains many irregular sandstone members, and the differentiation of the middle member of the Peace section is not clear.

All known exposures which reveal the contact between the St. John shales and the Dunvegan formation show a gradual transition from beds of distinctly marine origin to continental sandstones and shales with lignite and plant impressions. In Paquette Creek, on the north shore of Moberly Lake, the following section was measured at the top of the St. John formation:—

| Formation. | Character. | Thickness (in Feet). |
|---|---|---|
| Dunvegan | Sandstone, fine-grained at bottom, increasing in coarseness of grain to top | 200 |
| Transition zone | Sandstone and shale, predominantly sandstone | 22 |
| | Shale and sandstone, predominantly shale | 16 |
| | Shale, black, sandy, with concretions of sandstone and ironstone | 18 |
| | Sandstone, massive, fine-grained, grey | 1 |
| | Shale as above | 20 |
| | Sandstone, platy, with shale intercalations | 1 |
| St. John | Shale, black, sandy in places, with limestone concretions and bits of comminuted plant remains | 80 |
| | Creek-bottom. | |

* McLearn, F. H.: Peace River Section, Geol. Surv. Can., Summ. Rept., 1917, Pt. C.

A transition similar to this was noted wherever the contact between the two formations was observed. The upper part of the formation is exposed in the vicinity of Moberly Lake, in the narrow valleys of the creeks tributary to the lake, and in the lower valley of Miller Creek. There it consists of marine shales, arenaceous as a rule, varying in character from fissile to hackly, and locally calcareous. On the Pine River the upper shales are not frequently exposed, the hillsides being covered with vegetation, but such occurrences as were noted revealed at least 500 feet of shale with no important sandstone members. In the area south-east of the Middle Fork the upper shales of the formation are entirely similar.

The lower part of the formation consists of a series of alternating shales and sandstones at all exposures seen by the writer. A typical section of this part of the formation is exposed in the valley of Boulder Creek above the falls. It is as follows:—

| Formation. | Character. | Thickness (in Feet). |
|---|---|---|
| St. John | Sandstone, massive, yellow-grey | 70± |
| | Shale, black, marine, thin-bedded, arenaceous, with even lines of ironstone concretions and thin bands of sandstone | 550± |
| | Sandstone, massive, medium-grained | 25 |
| | Sandstone, soft, friable, with carbonaceous matter | 2 |
| | Shale, black, sandy | 3 |
| | Lignite-seam | 1 |
| | Shale, sandy, with bands of carbonaceous matter approaching lignite in composition. | 35 |
| | Sandstone, continental in origin, soft, friable, containing carbonaceous matter and leaf impressions | 20 |
| Bullhead Mountain | Conglomerates of Bullhead Mountain formation | 130 |

On the northern escarpment of Tuskoola Mountain is exposed a series of shales and sandstones which have been determined tentatively, chiefly on the basis of fossil evidence, as the upper part of the St. John formation. The areal relationship of these beds to the Dunvegan-Sukunka series on the Sukunka River is not entirely clear, and will remain an open question until the region between Elephant Mountain and the Sukunka River has been examined in some detail. Circumstances prevented such an examination during the course of this work. Something of the nature of a distinct downfold or fault must exist in this area to carry the Dunvegan from its elevation of about 4,500 feet on Tuskoola Mountain to the elevation of about 2,000 feet on the Sukunka River, at which the St. John-Dunvegan contact is dipping beneath the surface, and inasmuch as such structure is not at all evident in any exposures seen, the relationships on the Sukunka suggesting rather that the Dunvegan series were dipping under the shales of Tuskoola Mountain, it was thought at first that the series on Tuskoola Mountain must represent higher horizons. But fossils collected indicate in general facies that the shales of Tuskoola Mountain are probably of the same age as the St. John formation, and until further areal evidence is obtained they must be regarded as such. The shales in Table Mountain, which is separated from Tuskoola Mountain by the broad valley of Lone Prairie, are undoubtedly St. John in age, but the extreme paucity of exposures on Lone Prairie makes their correlation with the Tuskoola Mountain beds a matter of question. However, despite the fact that they might dip under Tuskoola Mountain, and thus place the shales there as an upper series, it is much more rational to suppose them to continue their nearly horizontal attitude and to occupy the same general horizon as the beds in Tuskoola Mountain.

The section exposed in Tuskoola Mountain, beginning with the uppermost beds, is as follows:—

*Section on Tuskoola Mountain.*

| Formation. | Character. | Thickness (in Feet). |
|---|---|---|
| Dunvegan | Sandstones, forming the peak of Tuskoola Mountain; very thin-bedded at top, more massive below; ripple-marked, with rootlet markings | 100 |
| | Sandstone, shaly, hard, apparently somewhat calcareous, with ironstone concretions and band of pure sandstone; poorly exposed | 25 |
| | Softer sandstones, not visible in detail | 110± |
| | Sandstone, hard, massive, forms sharp cliff; grades laterally to softer, pillow-weathering sandstone. Forms top of main mass of east end of mountain. Contains oysters at top and beds of stream-laid conglomerate, 2 to 5 feet thick, pebbles up to ½ inch | 50 |
| | Softer sandstones, concealed for the most part, with intermittently massive ledge in middle | 240± |
| | Sandstone, massive | 50± |
| St. John | Softer sandstones, fine-grained, grey to yellow, with ferruginous lentils containing many pelecypods, gastropods, and few ammonites | 330± |
| | Shale, dark, hackly to irregular, with ferruginous concretions and bands of argillaceous grey sandstone | 25 |
| | Sandstone, massive, fine-grained, grey | 12 |
| | Sandstone, as preceding, but softer | 5 |
| | Sandstone, massive to platy, grey | 70 |
| | Sandstone, non-marine, concretionary, with sandstone nodules 3 feet in diameter merging into another with no bedding-planes, very irregular, grey, fine-grained. | 7 |
| | Marine sandstone similar to those above | 10 |
| | Shale, grey, sandy, rectangular fracture-planes | 10 |
| | Sandstone, hard, dark grey | 6 |
| | Dark marine shales with limestone concretion bands, most concretions flat | 175 |
| | Sandstone, massive, hard, yellow-grey | 30 |
| | Shale, dark marine | 20 |
| | Harder shale, very arenaceous, with irregular bedding-planes, grades to pure sandstone below | 40 |
| | Dark marine shales, base not exposed | 400± |

Fossils collected in the vicinity of the mouth of Fish Creek on the Murray River support the areal determination that the shales there are coeval with the Tuskoola Mountain shales. In the canyon of Gordon Creek there are no marine sandstones at the top of the St. John, the conglomerate and oyster-beds of the Tuskoola Mountain section being followed directly in downward succession by pure marine shale. The shales of Gordon Creek are traceable along the valleys of Murray River and Fish Creek to Rocky Mountain Lake, and thence to the south-easternmost part of the area, on Flat Creek. The essential characteristics of the formation are constant over this area.

The thickness of the St. John formation is about 1,400 feet on the Pine River. In the valley of the Murray River between the crest of the Canyon anticline and the mouth of the Wolverine River, where the only other nearly complete section of the formation is exposed, 1,500 feet were measured without reaching the base of the shales. There is thus a decrease in thickness from the Peace southward and westward; this is without doubt due to a westward replacement of the upper shale horizons by the continental beds of the Dunvegan formation.

*Dunvegan Formation.*—Directly overlying the marine shales of the St. John formation is a series of sandstones and continental shales named by Dawson the Dunvegan formation and studied recently by McLearn.* These beds, which for the most part are moderately resistant to weathering agencies, form the main body of most of the hills in the area, extending in surface outcrop along the belt of moderate folding for the entire length of the region under consideration, and forming the upper reaches of all the prominent hills save those at the edge of the disturbed belt, where the older formations have been brought up by the folding.

In the vicinity of Moberly Lake the lower beds of the Dunvegan formation form the upper reaches of the range of hills extending south-easterly from Hudson Hope to the Pine River.

* McLearn, F. H.: Peace River Section, Geol. Surv. Can., Summ. Rept, 1917, Pt. C, p. 18. Also McLearn, F. H.: Cretaceous, Lower Smoky River, Geol. Surv. Can., Summ. Rept., 1918, Pt. C.

These beds are more or less heterogeneous in composition and origin. At the contact with the underlying St. John formation there is a true gradation between marine shale and continental sandstone, the marine beds below passing conformably into brackish- and fresh-water argillaceous sandstones, with fresh-water limestone in places. On the south shore of Moberly Lake two thin seams of lignite occur 45 and 65 feet above the base of the formation. Occasional lentils of hard limestone, as well as some sandy layers, contain a few fresh-water gastropods and pelecypods. These beds are succeeded above by subaerial sandstones, for the most part coarse-grained, massive, and cross-bedded, containing leaf fragments whose disposition gives clear evidence of non-aqueous distribution of the materials.

This series of sandstones, with irregular lateral variation from continental to shore facies, extends in the higher elevations from Moberly Lake to the Middle Forks, where its base is approximately 150 feet above river-level, and a thickness of 600 feet, more or less, is irregularly exposed in the hill north of the fork. From this point south, in the valley of the Sukunka, the south-west dip carries the series under, and at 7-Mile Creek, where the base of the formation is estimated to be at least 1,000 feet beneath the surface, the facies changes from the sandstones typical of the Dunvegan as developed to the north to a series of continental green shales, hardened calcareous muds, and grey, platy, cross-bedded, lenticular sandstones with flat nodules of black shales and occasional shaly layers. These beds are undoubtedly continental in origin. They contain seams of carbonaceous material and some low-grade coal.

The complete change in lithologic characteristics presented by these beds affords reason for their consideration as a separate unit, and to meet the needs of his field terminology the writer called them the Sukunka beds. At present they may perhaps be included with the Dunvegan as an upper member of that formation, but future detailed work may reveal the necessity for their adoption as a separate formational unit. They may represent the westward phase of the Lower Smoky River formation.

The thickness of the Sukunka beds is not known, their upper reaches not having been seen in detail by the writer, but their apparent continuation up the Sukunka River from 7-Mile Creek to the synclinal axis beyond Marten Creek shows a thickness estimated at 1,000 feet or more. The valley-sides here are well clothed with soil and grassy vegetation, and since the harder, cliff-making members of the series are the only ones which appear a detailed examination of the beds was not possible.

The Sukunka beds appear also in the canyon of a small creek at the south-west corner of Rocky Mountain Lake. Here they consist of massive sandstone layers 5 feet thick, granular grey-brown shales 2 to 4 feet thick, thin layers of micaceous grey sandstone breaking to feather-shaped fragments, hard, green-grey shales weathering brown, hackly to fissile, paper-thin black shales in thicknesses up to 2 feet, and thin-bedded sandstones. The beds at this locality are estimated to extend possibly 100 feet higher stratigraphically than the section examined in 7-Mile Creek.

At this locality, as well as in 7-Mile Creek, five species of fossil plants were found. These have been determined by Professor Edward W. Berry, of the Johns Hopkins University, as follows: *Anemia fremonti* Knowlton; *Dryopteris coloradoensis* Knowlton; *Populus* cf. *elegans* Lesquereux; *Pterophyllum* sp. nov.; *Podozamites* sp.

Of these the *Anemia* and *Dryopteris* are common in the Frontier formation of the western interior of the United States; the *Populus* is a typical Dakota species, and the other two are older types, the *Pterophyllum* not being known elsewhere in beds above the basal Upper Cretaceous, and the *Podozamites* being an older form which survived in limited numbers as late as the Senonian (Montana group of western interior). The forms thus present two things which are of interest in the development of stratigraphic knowledge in the Canadian North-west: First, evidence additional to that afforded by invertebrate faunas from the Peace River area which points more clearly at each new discovery to the Colorado age of the series; and, second, further evidence of an interesting vertical persistence in North-western North America of certain floras which to the south and elsewhere occur at earlier horizons, and representatives of which are found in Alaska in beds as young as Tertiary in age.

The Dunvegan proper—i.e., the series underlying the Sukunka beds—yielded the following plant species: *Protophyllum lecontianum* Lesquereux; *Platanus latior subintigrefolia* (Lesq.) Knowlton; *Menispermites reniformis* Dawson (?); *Aspidophyllum trilobatum* Lesquereux; *Cycadites unjiga* Dawson; *Platanus* sp.; *Taxodium* sp.

The general aspect of this assemblage is Dakota rather than Colorado, and its occurrence in the Dunvegan formation, which has been shown rather definitely to be Colorado in age, presents more evidence of the persistence of many Dakota forms. The *Menispermites* and the *Cycadites* are typical Dunvegan species, the former having been collected by the writer and others in previous work, and the latter having been found by Dawson in his exploration of the Peace River district in 1879.* The *Aspidophyllum* is identical with the form described as *Protophyllum* by Dawson.

The Dunvegan series increases materially in thickness south of the Peace in the region between Hudson Hope and Moose Lake; the change from 530 feet at Cache Creek to upwards of 2,000 feet on the Sukunka (including the Sukunka series) is marked. If the whole series is found to be more or less coeval with the Dunvegan of Peace River, there was a basin in which deposition of sediments was much more rapid than to the north. However, further work may show parts of the thick series to represent overlapping of either the St. John or Smoky River periods, or both, by the Dunvegan type of sedimentation, and it is not improbable that the Sukunka beds may represent the westward extension of the deposits laid down in early Smoky River time.

## GEOLOGY AS APPLIED TO OIL AND GAS.

The geologic conditions which control the accumulation in commercial quantity of oil and gas have been presented in reports similar to this so often of late that no stress need be laid on their discussion here. For the purposes of application to the data under review they may be grouped into four general heads:—

(1.) The occurrence of rocks in which petroleum could have originated.

(2.) The presence near the "mother-rock" of a porous rock which might act as a reservoir.

(3.) The presence of a relatively impervious cover or "cap-rock."

(4.) The disposition of such a series in structural form which would trap the oil, effecting its accumulation.

The first three of these concern the rocks themselves in their sequence, and, applying their principle to the foregoing stratigraphic data, three general parts of the column are seen to fulfil the requirements. In consideration of these, however, it must be understood that actual evidence of petroleum has not been found in any part of the series within the area, and that all consideration of the promise offered by the formations discussed is made with the lack of this sort of *prima facie* evidence in mind.

The Triassic limestones and sandstones offer a possibility. They are not distinctly petroliferous at any of the exposures thus far known, but they may well have yielded petroleum in places, and inasmuch as they probably lie within reach of a drill on the Pine River anticline they must be mentioned as a possible source of oil.

The Pine River shales may be oil-bearing. In exposure they give no evidence of petroleum, but they are of the sedimentary type which gives most promise, and inasmuch as such oil might have been formed in them could have found reservoirs in the neighbouring sandstones, or, possibly, the limestones of the section, they are worthy of a test if it is decided to prove the resources of the area.

The St. John shales offer the most nearly ideal conditions that could exist in the absence of definite evidence of petroleum itself. A series of from 1,400 to 2,000 feet of shales with intercalated sandstone members from a foot or so to 80 or 100 feet in thickness, they present a fulfilment of stratigraphic conditions for the origin and accumulation of petroleum perhaps more complete than that of any other member of the series, and in those places wherein structural disposition of the shales has afforded opportunity for petroleum to collect they are worthy of consideration.

## STRUCTURE.

The fourth consideration named above concerns the structure. The geologic structure of the belt fronting the foot-hills of North-west Canada consists of a series of moderate undulations of the strata, the crests of the folds lying in the main parallel to the axis of the Rocky Mountain chain, and the continuity of many single structures being remarkable. The folds are nearly all open—i.e., the beds have not been compressed to the extreme—and many of them are of dimensions and conformation ideal to the retention of any oil and gas which might have existed in the rocks they embrace beneath the surface.

* Dawson, G. M.: Geol. Surv. Canada, Report for 1879, p. 120B.

The region between the western limit of the area and the mountains proper is known geologically as the Disturbed Belt. Within its confines the rocks have been folded and faulted to high degree, the forces which built up the Rocky Mountains having reacted on them with great intensity on account of their proximity to the region of great thrusting. To the east and south-east the effect of these huge forces was absorbed gradually until in the region which now forms the plains the strata underwent no displacement from their natural horizontal position. The belt considered in this report lies between these two extreme areas, and there, although the full strength of the forces had been partially dissipated, enough pressure due to the thrusting penetrated the local rocks to cause ordinarily unbroken flexures of comparatively gentle slope. The structures occur along two to three principal lines of folding, and although it is not possible to trace the continuity of more than one of the anticlines in the area over great length, those which exist are seen to lie along definite lines. The sharpness of the folding decreases regularly from west to east.

In the region under consideration the structures are not as well defined along the lines of folding as are those to the south-east in the Alberta foot-hills. In the region between the Brazeau River and the Wapiti River the open, unbroken folds that characterize the belt are traceable as distinct entities for considerable distances along the general strike of the belt; there is but slight deviation from the direction of the lines of structural weakness, which are parallel with remarkable consistency to the strike of the Rocky Mountain chain. In the area here reported on some differences occur.

Some continuity of structural lines is observable in the southern half of the area; the folds between Flat Creek and Rocky Mountain Lake are apparently more or less true to the mountain-front type existing in Alberta, but from the general region of the Sukunka anticline north-westward marked variations from the north-westerly strike of the rocks occur with some frequency. These irregularities are probably due to adjustment between the forces acting along lines of tectonic weakness which differ in direction to the north and south. Clear evidence of this change is seen in the abrupt bending to the north of the eastern limit of the Disturbed Belt in the region between Pine River and the Peace.

### Anticlines that may contain Oil and Gas.

A determination of the possibilities for oil and gas requires for its completion in the large a consideration of those points at which the stratigraphically hopeful formations mentioned above lie within drilling depth on the anticlines of the area, and in the interest of conciseness it may be best to incorporate such evidence into the description of the structures.

The major anticlines of the area, in the order of their distance from Hudson Hope, are as follows: Hudson Hope anticline; Moberly Lake anticline; Miller Creek anticlines; Pine River anticline; Boulder Creek dome; Table Mountain anticline; Sukunka anticline; Rocky Mountain Lake-Moose Lake-Flat Creek anticline; Canyon anticline; Bullmoose Creek anticline.

*Hudson Hope Anticline.*—The Hudson Hope fold occurs entirely within the Peace River Block; that consideration, in addition to the fact that it is hardly pronounced enough to afford an ideal reservoir, prompts the omission here of its detailed discussion.

*Moberly Lake Anticline.*—The Moberly Lake structure, too, occurs within the Peace River Block at all points conveniently accessible to drilling equipment, and although it presents geologically favourable conditions its discussion would lack point in this report.

*Miller Creek Anticlines.*—The Miller Creek anticlines are the most easily accessible of all the structures. The northernmost major fold crosses Miller Creek 4 miles from its mouth, and is about 30 miles by trail from Hudson Hope. On its east flank the dips are moderate, ranging from 2° to 8°, but the west flank plunges sharply, having a maximum observed dip of 62°, and flexing upward again in a rather acute syncline whose axis is not farther than one-quarter mile from the crest of the fold. The St. John shales outcrop at the axis of this anticline, and the sandstones in the lower part of that formation are estimated to be from 1,000 to 1,200 feet below the surface on Miller Creek. This anticline is followed by one to the south which is not so steeply folded, the dips of its flanks averaging about 8°. Beyond are several minor undulations which are not of sufficient prominence to warrant their consideration here.

The conformation of the first anticline mentioned forbids its consideration as an ideal structure, and inasmuch as others of the region excel it in most essential characteristics, it may be dismissed with the statement that although it may offer promise in the future, in face of

better economic conditions, its present consideration must be limited in view of the great difficulties that will attend exploratory drilling in the region. The second structure is better formed than the first, and if the locality is to be tested it will merit the first attempt; however, it is apparently local in nature and the area of its flanks is too small.

*The Pine River Anticline.*—The Pine River anticline, as reference to the map will show, is a pronounced structure of some magnitude. On its east flank the dips attain a maximum of 25° in the hills east of Pass Creek, and decrease gradually in steepness to Peavine Flat, where the beds are horizontally disposed. On the west flank dips as high as 60° occur. The fold is thus distinctly asymmetric, the west flank being the steeper. Its degree of sharpness is somewhat higher than that of an ideal mountain-front oil structure, but the large areal extent of its flanks and their apparent freedom from sharp changes in degree of dip place it among those structures which are to be classed as hopeful. A difficulty which as yet clouds the way to entirely intelligent prospecting lies in the lack of information concerning the section beneath it; inasmuch as the lowest beds seen by the writer outcrop on its crest in Pass Creek, nothing is known as to the thickness and type of the beds which a drill on it would penetrate. The apparent absence of the Pine River shales in the Peace River section observed by McLearn* makes it difficult to presume what might be expected to underlie the fold, but it is probable that the upper limits of the Triassic limestones lie within 1,000 feet of the surface, and if future work should show this to be the case the structure will afford a very good opportunity to test the Triassic as well as the unknown lower part of the Pine River formation.

*The Boulder Creek Dome.*—The Boulder Creek dome occurs along the same general line of folding as that found on Miller Creek. Its outlines are exposed in the rude crosscut into the rocks by the Pine River, Boulder Creek, and Goodrich Creek, and inspection of the outcrops presented there shows the fold to have a roughly elliptical form, the long axis extending in a direction a few degrees west of north, and the dips being steeper on the north side. The existence of the structure has undoubtedly determined the location of Boulder and Goodrich Creeks; hence its almost perfect quadrisection by the three drainage-channels.

The top of the Bullhead Mountain formation is about 300 feet above the level of the Pine River at the apex of the fold, and the underlying section consists accordingly of approximately 1,200 feet of the sandstones, shales, and coals of the Bullhead formation, with the Pine River shales and limestones below. The possibility of oil-bearing horizons below the Bullhead Mountain formation, coupled with the dome-like shape of the structure, presents a geologically attractive situation as far as oil and gas are concerned, and inasmuch as no other locality of the area appeared as promising as did this, the writer planned to study the structure in detail for the purpose of making a drilling location. Such work as was possible in the weather of September was done and a location was made.

The Boulder Creek structure promises most of all the folds in the area for the following reasons:—

(1.) Its dome-like shape makes it almost perfect as a reservoir structure.

(2.) It is underlain within 1,300 feet of the surface by the lower sandstones of the Bullhead Mountain formation and the upper shales and limestones of the Pine River formation, a series of at least 300 feet in thickness, and probably more, which may contain petroleum.

(3.) The extremely hard Boulder Creek member of the Bullhead Mountain formation has been cut away by erosion at the apex of the dome; the amount of hard rock to be penetrated in order to reach the lower section is less than it would be elsewhere.

*The Table Mountain Anticline.*—This fold occurs on a structural line which is probably the extension of that on which the Moberly Lake anticline lies, and which is apparently the outermost of the axes of distinct plication. Its crest appears to have the usual north-west and south-east direction and it crosses the Pine River near the eastern end of Table Mountain. It is not a pronounced structure; the dips on the east flank are at most 3°, and on the west flank the average dip is approximately the same, although on a structural terrace visible in the eastern end of the hill north of the Middle Forks west dips as high as 10° are measurable over a short distance.

The Table Mountain anticline is in conformation well worthy of consideration as a possible reservoir of oil, but it has the disadvantage of embracing beneath the surface and within reach of a drill too limited a section of possibly petroliferous rocks. The St. John shales outcrop at

* McLearn, F. H.: Personal communication.

its crest. In the Pine River Valley, where a drilling location would be most advisable in the interest of accessibility, depth of worth-while drilling, and general economy of prospecting, the top of the St. John shales is at least 1,000 feet above river-level. The total thickness of the St. John shales is not known exactly in this locality, but it is not likely to be much different from the 1,400 feet measured on the Pine at Boulder Creek, and a simple subtraction shows at once that the thickness of hopeful strata below the surface is probably not more than 400 feet. Below that lies the 1,500 feet or more of the Bullhead Mountain formation, in the main body of which no oil need be expected. A prediction concerning the possibilities in beds below these is not entirely safe; the Pine River shales may be present at a depth of from 1,900 to 2,200 feet, but since nothing is known as to their lateral persistence to the east it is not possible to make a valuable estimate of the chances in deep drilling on the Table Mountain fold. A borehole on the Boulder Creek dome would yield information which might throw considerable light on this question, and, at all events, if it is desired to test the Pine River formation the Boulder Creek locality far excels any other in point of drilling depth, amount of hard rock to be penetrated, and degree of sureness of the presence of the formation underground.

The Table Mountain anticline should, in view of these limitations, be held in abeyance as a possibility whose investigation will be well worth while if oil is discovered elsewhere in either the Lower St. John shales or the Pine River formation.

*Remaining Folds in Southern Part of Area.*—The folds south of the Pine River are at present so difficult of access that their consideration may in the interest of space be brief.

The structure along the Sukunka Valley is synclinal for about 10 miles above its mouth. The first major anticline observable occurs near the mouth of Brush Creek; it is mapped as the Sukunka anticline. Its relation to the other structures of the area is not entirely clear. Its crest probably follows the north-westerly trend of the belt, but this is by no means certain. Extreme irregularities of strike on its flanks make it impossible to define its contour without detailed work involving far more time than that available to the writer, and its inaccessibility discouraged giving it more attention than that possible in reconnaissance. It may form the rim of the wide synclinal basin south of the Pine River, and as such may be continuous with the Boulder Creek-Miller Creek fold-line to the north and the Rocky Mountain Lake fold-line to the south, but its local irregularities reduce such a consideration to the status of an assumption.

As a possible oil-container the Sukunka anticline may be worthy of attention if other parts of the region prove productive; its conformation is good, dips on the east flank ranging from 5° to 10° in the vicinity of the crest and on the west flank from 15° to 40°, and the strata consisting of St. John shale and sandstone to a probable depth of 800 feet. However, a well-location on this fold should not be made except after a study in great detail of the general locality, for its obvious irregularity of contour suggests strongly the presence of structural conditions which must be known as well as possible if the location is to be wisely placed.

The longest apparently continuous fold in the area occurs between Rocky Mountain Lake and Flat Creek. Its presence has been observed by the writer at the forks of Flat Creek, 18 miles from the Murray River; at the mouth of Flat Creek; on Bullmoose Creek near its mouth and 2 miles up-stream; at the west end of Moose Lake and at the west end of Rocky Mountain Lake. Although nothing is known of its presence between these localities, their alignment indicates the strong possibility of its continuity. This long fold, which for clearness may be called the Flat Creek anticline, is flexed moderately at most of the points which have been observed, and is accordingly worthy of consideration as a possible reservoir structure.

At its exposures in the valleys of Flat Creek, the Murray River, and Bullmoose Creek, the fold embraces beneath the surface a limited thickness of the St. John shales and the full thickness of the Bullhead Mountain formation. It brings to the surface at its crest the lowest beds known in this part of the area, and in consequence an accurate estimate of the strata which would be penetrated by a drill is not feasible; however, it is likely that the top of the Bullhead Mountain formation is not far beneath the surface in the general vicinity of the Murray River, and that accordingly the value of the structure in terms of present knowledge is questionable.

The most favourable localities, geologically considered, on this fold are those at the western ends of Rocky Mountain and Moose Lakes, where the underlying strata consist of nearly the entire thickness of the St. John shales. Of these the Moose Lake locality is possibly the better on account of its lack of structural irregularity.

It was planned to determine approximately the amount and direction of plunge of structures such as this, but the accidental destruction of the writer's instrumental equipment made it impossible to obtain the elevations necessary to derive such data. However, results of visual observation, despite the fact that they are often misleading, indicate that the Flat Creek fold probably plunges to the south-east from Moose Lake to Flat Creek forks, and that to the north-west from Moose Lake there is probably little variation in the elevation of the crest, the plunge, if any, being to the north-west.

The extreme inaccessibility of this structure places it in the class of those which will be worthy of attention if the region is shown elsewhere to be productive.

About 6 miles below the mouth of Flat Creek a fold which has been called the Canyon anticline crosses the valley of the Murray River. In degree of flexure it is less pronounced than the Flat Creek fold, which succeeds it to the south-west, but it is clearly defined, the dips on the east flank being in the general neighbourhood of 9° and on the west flank between 7° and 15°. It probably dies out to the north-west, and to the south-west its extension is not certain, although a fold which may be integral with it occurs in the valley of the East Fork of Flat Creek about 3 miles above the forks of the creek. Its contour on the Murray River is favourable to the storing of oil, and inasmuch as the major portion of the St. John shales probably underlies the surface at its crest, it is worthy of note geologically, but it is at present too difficult of access to be considered on economic grounds.

A pronounced fold of almost symmetrical proportion occurs in the hills west of Bullmoose Creek in the vicinity of the trail from Moose Lake to the Wolverine River. It is indicated on the map as the Bullmoose Creek anticline. North-west and south-east of this locality the structure along the line of the fold is much broken up and really forms the outer edge of the Disturbed Belt, but at the locality mentioned a somewhat hurried examination revealed no extreme contortion of the strata. At some point along the crest of the fold and in the general vicinity of the trail mentioned a test would be advisable in the existence of some sort of transportation facility, but the great cost of exploratory drilling at so great a distance from existing lines of freight-travel precludes active interest in the structure for some time to come. It is probable that at least half of the St. John formation underlies the surface at the apex of the fold.

*Minor Folds.*—The flanks of the major structures mentioned above are, in some places where the dip is low, flexed slightly into minor folds of local extent. These smaller structures should not be considered as places for preliminary tests of the region, but inasmuch as certain of them include beneath the surface the most attractive formations of the series, they may well be considered briefly in view of their possible importance should oil be discovered in commercial quantities on one of the larger folds.

Several minor undulations occur in the valley of Miller Creek. Their location and degree of flexure are indicated on the map. One north of the main Miller Creek folds includes the major part of the St. John shales beneath its crest, and those to the south include the entire thickness of these shales with part of the overlying Dunvegan formation.

Reversals of dip, indicating a small local "roll" in the structure, occurs in 7-Mile Creek, in the Sukunka drainage area. This fold embraces in sub-surface formation the lower half of the Dunvegan formation and the underlying St. John shales, and consequently may merit attention if these formations are found to contain oil.

Another minor fold exists in the narrow valley of Fish Creek near its mouth. This is perhaps the most interesting of the minor folds observed, since its flanks are steep enough to give it a pronounced character, and the section underlying it embodies the most promising part of the St. John shales. The dips on its flanks near the crest vary from 4° to 6°.

Close examination of the smaller stream-courses will probably reveal the presence of other such structures in regions where the attitude of the beds is nearly horizontal. However, consideration of these minor folds must be tempered by a weighing of the probability of their persistence in depth. It is frequently true that smaller warpings of strata such as these die out in depth, and locations on them, should any prove advisable, should be made with allowance for that fact in mind. The persistence of the structures above noted may be assumed with safety to be sufficient to ensure a reservoir within shallow depths, but, depending on the character of the underlying formations, it is not policy to expect results from drilling on local upwarps. If the surface strata are harder than those in which oil is sought the structure may well continue

to some depth, and may even grow more pronounced; but if the rocks below are harder they may not have yielded to the pressure which folded the softer strata, and the anticline may not exist below.

### Indications of Petroleum and Gas.

No unquestionable seepages of petroleum were observed by the writer, and none have been noticed by any of a number of residents who were questioned.

The only well-established seepages known in this part of British Columbia occur about 45 miles east of the eastern limit of the area examined. One of these, for whose existence the writer can vouch, occurs on the Pouce Coupe River east of Rolla, B.C., and the other, whose general location was made known to the writer by E. Mast, of Rolla, in 1919, exists on Moose Creek about 4 miles north of its mouth on the Peace. These seepages occur at a horizon which is probably at the top of the Dunvegan sandstone. They offer no direct encouragement to prospective development in the area covered by this report, but they indicate that petroleum does exist at places in the series.

The writer observed a thin film of oil on the surface of water in an old well east of Hudson Hope on the homestead of Joseph Lemieux, to whom thanks are due for calling attention to the occurrence. The well penetrates the St. John shales to a distance of about 15 feet. It was not possible to collect any of the oil, and proof of its composition is hence not offerable.

Thin films of some sort of oil were noticed on the water of the Pine River east of Pass Creek. The film did not have the brilliant iridescence peculiar to petroleum, and inasmuch as the quantities were much too small to permit the collection of a sample the value of its evidence is small; furthermore, the point at which the oil was noticed is so far from the nearest outcrop of country-rock that its source is at best very inexactly determinable.

A seepage of gas was found on the west flank of the Boulder Creek dome, at the base of the cliff of Boulder Creek conglomerate, and north-west of the drilling location. The gas bubbles up intermittently through water in a hole at the base of a tree. The roots of the tree have undoubtedly afforded a channel through which the gas may escape from the underlying sandstone to the surface. The gas is highly inflammable and contains a considerable percentage of hydrogen sulphide. When it is burned the odour of sulphur dioxide is strong.

### Transportation.

At present the region is accessible via three routes of travel, one from the west and two from the east. The western route, from Fort George via the Giscome Portage, Crooked River, and the Parsnip River to the peace, is a water route, and is preferred by some prospectors, travellers, and engineers for comparatively light travel. It is not a good route for the transportation of heavy equipment. The routes from the east leave the end of steel on the Edmonton, Dunvegan & British Columbia Railway at Peace River Crossing and Spirit River or Grande Prairie respectively. The first of these is the most used and is the best for the transportation of all classes of freight; it makes use of the Peace River, which is navigable by vessels of light draught between Fort Vermilion and Hudson Hope. The season for navigation on the stretch between Peace River Crossing and Hudson Hope embraces the months of June, July, and August as a rule, and in some years the large steamer makes the trip in September. Smaller craft ply the river as late as the first formation of ice.

The third route mentioned is a land route. From the railway points of Spirit River and Grande Prairie wagon-trails lead to Pouce Coupe, whence a more or less passable wagon-trail leads to the Pine River at the mouth of the Murray, at the eastern edge of the area in question. The trail from Spirit River to Pouce Coupe is not used in summer on account of muskeg: it is a winter trail, and is used chiefly by the farmers of the Pouce Coupe Prairie for the haulage of their grain to the railroad. The road from Grande Prairie to Pouce Coupe is by far the better; it is passable to automobiles in dry weather and is extensively used for freighting into the Pouce Coupe District.

West of the Pine River at the mouth of the Murray travel by wagon would involve much road-cutting. A road is supposed to exist as far as Hudson Hope, but it is not used by teams, and it is not likely that a wagon could make the trip without much road-building work.

Within the area travel is nearly all by pack-train in summer and by sleigh in winter. Wagon-roads exist about Hudson Hope and on Lone Prairie, but they are of local importance only, and most of them would not suffice in their present state for the haulage of heavy freight.

The transportation of equipment from the end of steel to any of the localities at which drilling might be contemplated would involve the cutting and grading of road if the materials were to be hauled in summer. In winter the frozen rivers offer roadways to sleighs when the ice is favourable, and the problem of present-day transportation of drilling materials to the region must not be considered without examining the possibilities of winter travel.

### GENERAL CONSIDERATIONS.

With the main facts concerning the stratigraphy, structure, and economic features of the region in hand, a brief summation of their application in general concerning the prospects for oil may be worth while. A conclusion regarding the advisability of attempting exploration with the drill must naturally be based on a balancing against one another of the favourable and unfavourable facts (not opinions) which have been gathered. Without attempt at the differentiation of geologic from economic data, these facts may be summed up as follows:—

#### *Unfavourable Factors.*

(1.) Absence of evidence through seepage or other appearance of the presence of petroleum in the rocks.

(2.) The great cost of transporting drilling equipment to any of the advisable locations.

(3.) In corollary to the preceding, the expense attached to the disposal of such petroleum as might be found.

#### *Favourable Factors.*

(1.) The presence of a number of formations in which oil could occur.

(2.) The presence of anticlines which dispose the possibly oil-bearing strata favourably to the retention of petroleum.

(3.) The comparatively reasonable depth within which the beds to be tested may be reached.

A balance of these facts against one another is not easy. No matter with what accuracy the information concerning their details is obtained, the measure of probabilities inevitably to be drawn in makes an unqualified conclusion difficult to reach. However, as far as the geologic factors are concerned, it is possible to arrive at a conclusion as to the advisability of further exploration, and although the dictates of such evidence must be qualified by the consideration of economic problems incident to development, a review of all the factors will tend to make the situation clearer.

Of the unfavourable factors, the first may or may not tell the whole story. Vast oilfields, to-day yielding millions of dollars in petroleum, exist without a single surface indication within their limits. Oil-seepages would offer in their presence a decidedly encouraging circumstance, but their absence need not be entirely unfavourable if other features of the rocks involved contribute no negative evidence. And this condition exists in the area considered.

The second and third of the unfavourable factors, those involving expense, are difficult of calculation through lack of precedent. Inasmuch as there is no freight traffic to those points at which drilling equipment would be necessary, no transportation rates exist. They might be approximated roughly, however, if drilling were considered, from rates existing elsewhere in the north.

All three of the favourable factors indicate possibilities. They offer positive evidence only in so far as they do not deny the possibility of an oilfield within the area. But the facts that oil could have originated in the rocks considered, and that it could have accumulated at the points mentioned as favourable, point toward a possibility, the degree of whose suggestion would certainly be strong enough to have attracted investment in drilling operations long ago if transportation were less difficult and cheaper. If the oil resources of North-west Canada are to be proven, these factors show clearly that the area must not be slighted.

If, then, the presence of oil there is to be ascertained, the data given in this report will serve as a guide to exploratory drilling. Transportation difficulties, which at present are the chief obstacles to unqualified recommendation of the area, might well be solved, and if oil were found a railroad, long in contemplation, might be called into active existence before the time which would normally see its presence.

As a whole the region may be classed on the basis of geologic evidence as a fair prospect. If transportation of materials can be arranged satisfactorily to the interests of drilling operations, tests should be made on the structures which can best be reached. Proof of the evidence *of petroleum in commercial quantity must rest on the results of intelligently placed drilling*; the value of geologic evidence in the case lies in its statement of either the presence of petroleum or the likelihood of its presence, and of the points at which such petroleum might have accumulated. In the region examined the likelihood cannot be denied (although the actual presence of oil is not proven) and the structures are known. All else depends upon the drill.

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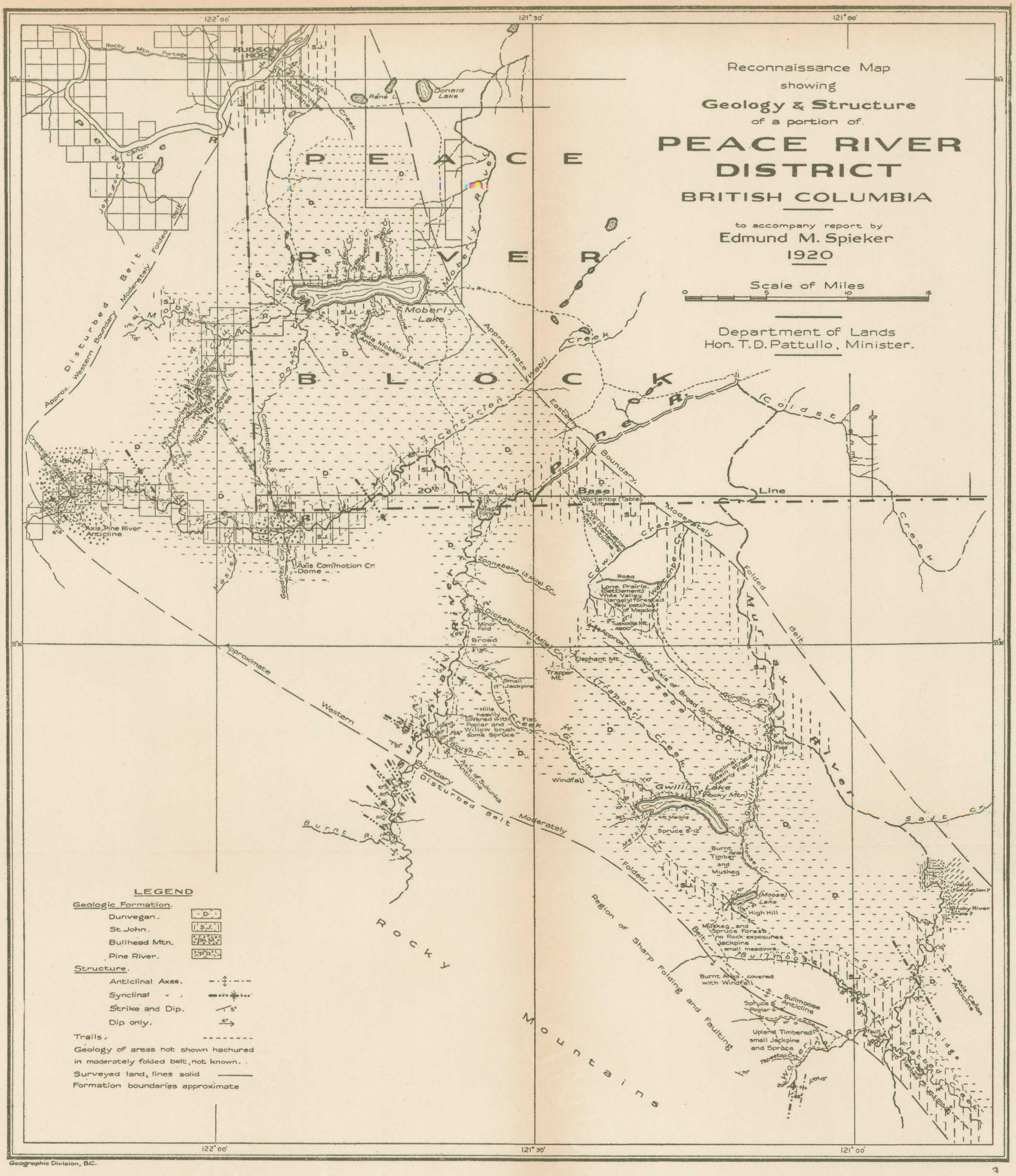
1921.

Reconnaissance Map
showing
**Geology & Structure**
of a portion of
# PEACE RIVER DISTRICT
## BRITISH COLUMBIA

to accompany report by
Edmund M. Spieker
1920

Scale of Miles
0 5 10 15

Department of Lands
Hon. T. D. Pattullo, Minister.




Geographic Division, B.C.