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Summary Report, 1922, Part B

CONTENTS

PAGE

PEACE RIVER CANYON COAL AREA, B.C.: F. H. McLEARN 1

GEOLOGY OF THE NORMAN OIL FIELDS AND A RECONNAISSANCE OF A PART OF LIARD RIVER: G. S. HUME 47

RECONNAISSANCE ACROSS NORTHEASTERN BRITISH COLUMBIA AND THE GEOLOGY OF THE NORTHERN EXTENSION OF FRANKLIN MOUNTAINS, N.W.T.: M. Y. WILLIAMS 65

MACKENZIE RIVER DISTRICT BETWEEN PROVIDENCE AND SIMPSON, N.W.T.: E. J. WHITTAKER 88

INVESTIGATION OF ARTESIAN WATER, COAL, PETROLEUM AND NATURAL GAS IN ALBERTA: D. B. DOWLING 101

INDEX 133

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SUMMARY REPORT, 1922, PART B

PEACE RIVER CANYON COAL AREA, B.C.

By F. H. McLearn

CONTENTS

	PAGE
Introduction	1
Character of country	3
Transportation	3
Stratigraphy	3
Structure	8
Coal	8
Appendix—details of columnar sections	30

Illustrations

Figure 1. Diagram showing geology of Peace River Canyon coal area and location of measured columnar sections (A 1—A 2, etc.) shown in Figure 2 and described in text.. 2

2. Columnar sections showing correlation of coal seams in Gething member of the Bullhead Mountain formation.... 9

3. Plan of No. 1 tunnel at west end of Grant flat.... 20

INTRODUCTION

Peace River canyon, or Rocky Mountain canyon, or Canyon of the Mountain of Rocks—as it has been called by various explorers—is in eastern British Columbia, in Peace River mining division and a few miles west of the Peace River block. The 56th parallel of latitude crosses near the head and near the lower end of the canyon. The 122nd meridian is near the lower end. The coal deposits described in this report are on either side of the canyon from a little below its head to Contact point.

There is an earlier report on this area by C. F. J. Galloway.[1] Although it demonstrates the presence of coal of good grade, it is based on an examination of only some of the smaller seams. As thicker seams occur, a further study was advisable in order to work out the thickness, quality, and continuity of the more important coal beds and so determine the possibilities and limitations of this coal area as a commercial producer. The conclusions reached in this preliminary report are based on the detailed measurement of strata exposed in the main and tributary canyons, and on an examination of all coal beds in natural exposures, pits, and prospect tunnels. The sections studied are:

North shore section, from Fossil-tree point to Milligan point (B1–B2).
North shore section, from Fossil-tree point to Grant flat (C1–C2).
South shore at Earle narrows (D).
Aylard Creek section (E1–E2–E3).
Small section in draw west of Mogul creek (F).
Mogul Creek section (lower part) (G1–G2).
Moosebar Creek section (upper part) (H1–H2).
Contact Point section (J1–J2).

[1]Ann. Rept. Minister of Mines, B.C., 1912, pp. 118 to 136.

The above sections are shown in Figure 2 and are described in detail in the appendix. There was not time to measure the sections on Coal and Johnson creeks, on lower Moosebar creek, upper Mogul creek and neighbouring cliffs and ravines, Gething creek, and the north shore from Milligan point west. All Gething creek and parts of Johnson creek were seen, however,

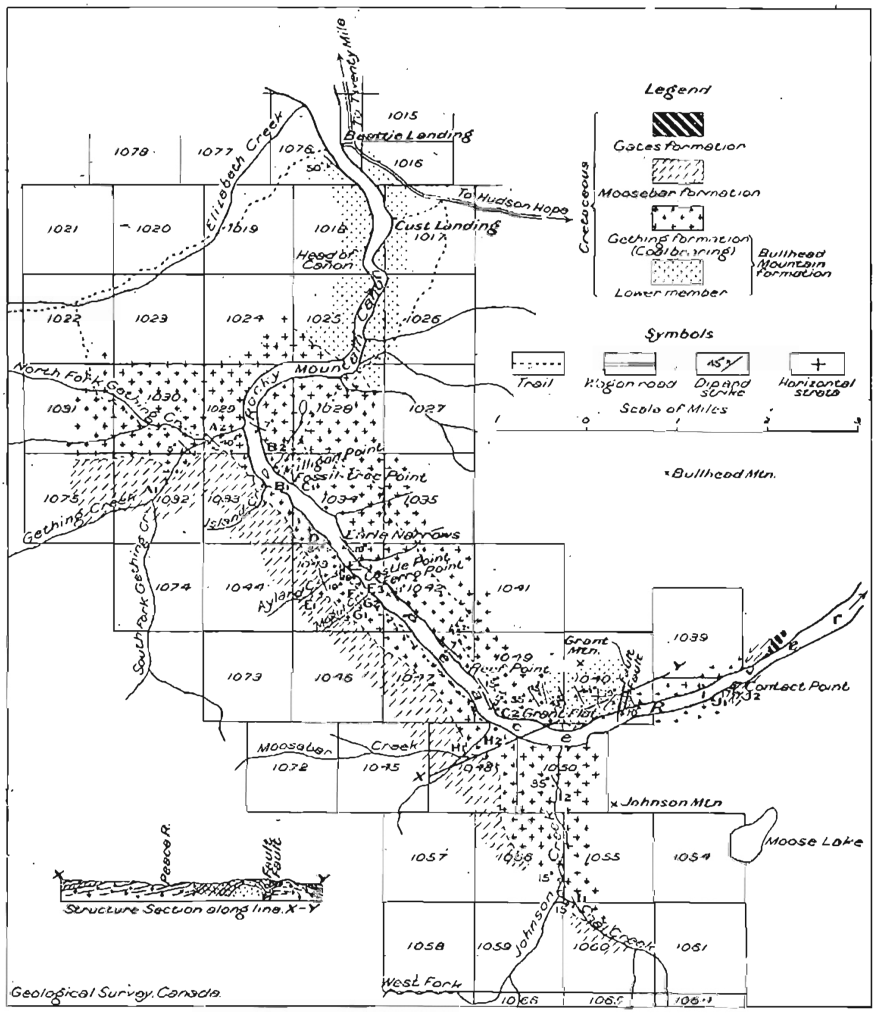

Figure 1. Diagram showing geology of Peace River Canyon coal area, Peace River district, B.C., and the location of measured columnar sections A1-A2, B1-B2, etc., shown on Figure 2 and described in report. (Base-map from surveys by Gray and Milligan Brothers).

and the important seams were measured (*See* A1-A2 and I1-I2 in Figure 2). In all, thirty-five samples, of twelve seams, were taken. Enough work was done to determine the important structural features and the general areal extent of the coal-bearing strata (*See* Figure 1).

Two months were given to field work. Acknowledgment is made to Messrs. Neil Gething and C. L. Aylard for assistance and many courtesies. That part of the report relating to coal has been discussed with D. B. Dowling.

CHARACTER OF COUNTRY

Peace River canyon is on the eastern border of the foothills. The country is rugged. To the north rise the long slopes of Bullhead mountain, on the southern flank of which is Grant mountain, a minor eminence. To the west and south are irregular undulating plateaus and higher hills, but all are below the summit of Bullhead mountain. The canyon has steep slopes and in many places from the head of the canyon to Grant flat it has precipitous walls. Below this and to Contact point there are gentler but fairly steep slopes and no precipitous walls. All the tributary creeks, Gething, Aylard, Mogul, Moosebar, and Johnson, have steep-walled canyons in their lower courses.

TRANSPORTATION

The future development of the Peace River Canyon coal area depends largely on transportation. It is at present about 125 miles from a railway; Spirit River, Alberta, is the nearest point on the Edmonton, Dunvegan, and British Columbia railway. Grading, however, has been done as far as the east boundary of the Peace River block, i.e. to within about 75 miles of the canyon. An extension of any railway through the mountains by way of the Peace River pass would bring the head of steel to within a few miles of the coal. A route through the mountains via Pine pass and Pine river would bring transportation within 25 miles, but a spur line to the canyon would be longer. Until a railway is built any coal shipped out will have to be transported in the summer months 300 miles down stream to Peace River Crossing, a station on the Edmonton, Dunvegan, and British Columbia railway. There is no difficulty in the navigation of the Peace from Hudson Hope to Peace River Crossing. The problem is to convey the coal from the middle of the canyon to Hudson Hope (from Grant flat a distance of about 12 miles). This will have to be solved by navigation of the lower canyon or by building a narrow-gauge railway, or by some other method.

STRATIGRAPHY

System	Formation	Member	Thickness in feet	Lithology
Cretaceous...	Gates..........	....	50–80	Sandstone
	Moosebar.......	....	800	Shale, clay ironstone concretions
	Bullhead Mountain	Gething, or Upper..	+1,400	Sandstone, shale, clay ironstone, coal
		Lower.............	+3,000	Conglomerate, grit, sandstone, shale

LOWER BULLHEAD MOUNTAIN

The strata of the lower member of the Bullhead Mountain formation are exposed on Grant mountain and at the east end of Grant flat; they occur also in the upper part of the canyon. The thickness is known to be over 3,000 feet, but only the upper part is exposed in the canyon. The beds consist of conglomerates, grits, and coarse sandstones, also smaller amounts of medium to fine sandstones and shale. Large-scale cross-bedding is found in some of the grits and sandstones. Some layers are ripple-marked. The upper part of this member, including all exposed in the area, is probably of non-marine origin. A few thin coal seams have been found, but none is thick enough to be worked. Before, however, rejecting the lower member of the Bullhead Mountain as a productive unit, further exploration should be made for seams in it. A very careful examination of the beds exposed in the upper part of the canyon, and a bore-hole located at the head of the canyon would give a thorough test. Uncovering of the concealed parts of the section exposed on the south flank of Grant mountain, together with a bore-hole located on Grant flat, preferably near the axis of the anticline, would also furnish a test. A study of the 8-mile, 10-mile, and 12-mile creek sections would yield important information regarding this member.

GETHING

The contact between the lower and the upper or Gething member is drawn arbitrarily where conglomerates and grits disappear, coarse sandstone becomes rare, and medium to fine sandstone, shale, clay ironstone, and coal beds become common.

The strata of the Gething member underlie both sides of the canyon from the bend above the mouth of Gething creek to Grant mountain on the north side and to Johnson mountain on the south side. They extend up main Gething creek as far as the upper falls, and up the north branch of Gething creek far beyond the boundary of the area studied. They are also found downstream, on both banks, from a little east of Grant mountain to Contact point. The section exposed along the north bank westward from Grant flat and up Aylard creek may be considered the type one of this member.

The thickness, as measured in columnar sections from the horizon of the Riverside seam to the contact with the overlying Moosebar shales, is 1,250 feet. A deduction should be made for error of measurement, which is cumulative and tends to be too high. About 1,125 feet is a fair estimate of the above thickness. The Riverside seam is not quite at the bottom of the Gething member and about 300 feet of lower strata, chiefly concealed, should probably be placed in this member. The total thickness is somewhat over 1,400 feet.

This is the coal-bearing unit of the section and as such has been studied with much care. But a consideration of all the details of the sediments and their interpretation is not within the scope of this report. There are massive, medium to fine, rarely coarse, sandstones, also bedded or layered sandstones. Some of the layered sandstones have the surface of each layer covered with ripple-marks; the finer-grained and thinner layers are crossbedded, having wavy, cut-off, fine bands of dark grains or films of shale. Large-scale crossbedding is very rare. A few sandstone beds have rootlets. There are a few beds of argillaceous sandstone, of carbonaceous sandstone, and of micaceous sandstone. No coarse grits are present. An 18-inch bed of sandstone at the top of the formation contains small scattered pebbles and is the nearest approach to a conglomerate in the Gething member. The coarser sandstones are light in colour, white, cream, or pale yellow; finer sandstones are light grey or slightly brownish. The shales are grey to black in colour, in no place green or red, and are in beds 2 inches to 10 feet thick. They break in layers having curved surfaces, i.e., they have the shaly structure; these layers further break into smaller sizes as angular fragments. Some shales have rootlets. The black carbonaceous shales are thin, and mostly break in flat planes parallel to the bedding, i.e., they are somewhat fissile. The true shales grade into arenaceous shales. Banded shales and sandstones, having the shales mud-cracked and the sandstones ripple-marked, are common in parts of the section. Clay ironstone occurs in beds 5 inches to 5 feet thick. All ripple-marks, so far observed, are symmetrical.

Driftwood fragments are found in some of the sandstones. A few short tree stumps have been observed; from one, roots appear to extend down into a shale below, carrying rootlets, etc. A number of silicified wood pieces occur in the coal seams. In no place is the wood attacked by boring molluscs. Bedded sandstones contain burrows and trails. Footprints of dinosaurs are found east of Ferro point on the north bank; there appear to be impressions of claws, suggesting a carnivorous dinosaur. One or two small, rather faint, impressions may be of the fore limbs.

The abundance of plant remains, the absence of marine fossils, presence of rootlets, absence of boring molluscs in the wood fragments, tracks of land animals—all these, taken together, suggest a non-marine origin for the strata of the Gething member.

MOOSEBAR

The Moosebar formation outcrops in the southwestern part of the area between Gething and Coal creeks; good exposures are found on main Gething creek above the upper falls, on upper Aylard creek, on Moosebar creek above the forks, and on upper Coal creek. Exposures are also found east of Contact point on both banks of the river. The thickness has been estimated[1] at 800 feet in the type exposure on the north side of the canyon opposite Contact point.

Although at the lower contact (i.e. with the Gething member of the Bullhead Mountain) the change from the top sandstone or conglomerate of the Gething to the shale of the Moosebar is abrupt, no evidence of an actual break has been observed. The Moosebar consists in this area of dark friable shale and thin bands and irregular concretions of clay ironstone. No fossils have as yet been found in surface exposures, but in bore-hole No. 6 on Lynx creek north of Hudson Hope an ammonite occurs at an horizon that probably falls within this formation. The strata of this formation are, therefore, in part at least of marine origin.

[1] Geol. Surv., Can., Sum. Rept. 1917, p. 17 C.

GATES

The Gates sandstone was called the middle sandstone member of the St. John in a former report[1] and is described there. It outcrops a little east of Contact point where it dips to the east. It has not so far been observed on upper Gething, Aylard creeks, etc., but the southwest dip may be too gentle there to bring the beds of this formation down to the cliffs at the creek side. The shales of the St. John follow this formation. The type locality of this formation is at "the Gates" on Peace river below Hudson Hope.

CORRELATION

Before attempting a correlation with southwestern Alberta, it will be well to review the stratigraphy of that region as exemplified in the Blairmore area. The basal Mesozoic formation there is the Fernie, which contains a marine formation of about Callovian age[2] (*Metacephalites*, Buckman, etc.), i.e. about basal Upper Jurassic. It may be noted that the Fernie faunas are of unlike age in different localities. Thus a Fernie fauna from the Fernie district is Argovian (*Cardioceras*) or Middle Upper Jurassic and one from the vicinity of Minnewanka lake is about Bajocian (near *Witchellia*) or Lower Middle Jurassic. The Kootenay is of Barremian or Lower Cretaceous age. It contains an old flora of cycads, conifers, etc., and no dicotyledonous flowering plants have as yet been discovered in it. Collecting by the writer in 1915 revealed the presence of two floras in the Blairmore formation, which record two stages in the introduction of the angiosperms (dicotyledons) into this part of the Canadian interior. The collections have been identified by Professor E. W. Berry. The lower flora contains a liverwort, ferns, cycads, conifers, and very rare dicotyledons. According to Berry the Kootenay flora can be distinguished from the lower Blairmore flora, not only by the absence of angiosperms (dicotyledons), but by the presence of *Oleandra graminæfolia* and *cladophlebis heterophylla*. The upper flora contains nine species of dicotyledons as well as ferns, cycads, and conifers. Berry[3] assigns an Aptian-Albian or Albian age to the lower flora and a Cenomanian age to the upper flora. The upper flora is correlated with that of the Cheyenne sandstone of southern Kansas. There does not appear to be any Dakota, i.e. Turonian, flora in this part of southwestern Alberta. The Blairmore is succeeded above by the Crowsnest volcanics and Colorado shale. The Colorado shale has yielded in places traces of the Lower Colorado fauna (Turonian) with *Prionotropis* and a fairly abundant Upper Colorado fauna (Emscherian) with *Scaphites ventricosus*.

In the Peace River Canyon coal area the Gething member contains a small flora, collected a few years ago and submitted to Professor Berry for examination. He correlates it with the flora of the Kootenay of the south, i.e. the age is Barremian. It contains *Oleandra graminæfolia*, one of the species by means of which the Kootenay flora can be distinguished from the lower Blairmore flora.

[1] Geol. Surv., Can., Sum. Rept., 1917, p. 17 C.
[2] The age of this fauna and the range of the macrocephalitids are discussed by S. S. Buckman in an unpublished report.
[3] Correlations discussed in unpublished manuscript.

The lower member of the Bullhead Mountain formation has not yielded any fossils, except near the base where a few marine bivalves have been found. These shells are not very diagnostic, but the possibility of their being Jurassic need not be rejected, although they may be of Cretaceous time. The upper part of the lower member is probably Cretaceous. The Moosebar formation is known to contain only one fossil and no correlation can be offered at present. No fossils have been collected from the Gates formation.

Comparing the Peace River Canyon section with that of southwestern Alberta it may be noted that the non-marine Blairmore formation of conglomerates, sandstones, and shales loses its identity northward and a shale (the Moosebar), partly marine at least, occupies its stratigraphic position. On the other hand the Kootenay formation of the Blairmore area of southwestern Alberta is not preceded by a series of conglomerates and coarse sands comparable with those of the lower Bullhead Mountain of the Peace River localities.

It is not considered advisable at present to attempt a correlation of the formations of Peace River canyon with those of the eastern Peace River region. Not until the faunas of the Loon River shale and Peace River sandstone are studied in detail, will such a correlation be possible.

Correlation Table

System		Europe	Southwestern Alberta	Peace River canyon	
Cretaceous	Upper[1]	Cenomanian	Upper Blairmore	? Gates	
	Lower	Albian	Lower Blairmore	? Moosebar	
		Aptian			
		Barremian	Kootenay	Bullhead Mountain	Gething or Upper member
		Neocomian			Lower member
Jurassic	Upper	Kimmeridgian			
		Argovian			
		Divesian			
		Callovian	Fernie		

[1] Taking Cenomanian as the base of the Upper Cretaceous, Upper and Lower Cretaceous have little significance in southwestern Alberta, for the division line must be drawn within a formation (the Blairmore) which is a well-defined lithological unit.

STRUCTURE

On either side of the canyon from the west end of Grant flat to Milligan point there is a simple structure, a southwest dip of 7 to 15 degrees, with minor changes in strike; the same simple structure obtains northward toward the head of the canyon except that the dip is more to the south. This structure also persists up Johnson, Moosebar, and the other tributaries flowing in from the southwest and west. Within this structural area there are a few monoclines having the steep dip on the southwest side. In places these folds have a very short northeast limb and are not monoclines in the strict sense. Of the two larger and more important ones so far located, one extends along the north bank of the canyon from Ferro point almost to Fossil-tree point. The average direction of the axis is about northwest-southeast, i.e. about the trend of the general structure; the long southwest limb is steep and the very short northeast limb where present has a gentle dip or is flat. Another and greater fold, a monocline, is located on Gething creek below the fork with north Gething creek, and above Galloway falls; the steep dip is on the southwest side. Smaller folds or rolls are present on main Gething creek between the third and upper falls, and on Aylard creek below the upper falls.

To the east of the structural area described above is a zone of steep southwest dip, from 35 to 45 degrees. This structural zone lies on the west slope of Grant mountain and on lower Johnson creek. The steeply dipping strata described above form the west limb of an anticline, the axis of which crosses Grant mountain. This anticline brings up the strata of the lower Bullhead which are exposed on Grant mountain. At the east end of Grant flat there is a fault, to the east of which are exposed beds of the lower Bullhead. Still farther to the east a second fault is inferred. Beyond this fault, and extending to the eastern border of the area studied, is a structural zone of eastward dip in which the strata of the Gething member are again exposed at the surface. The structure on, and south of, Johnson mountain is not known.

In the planning of mines the monoclines, folds, or rolls will have to be considered. For instance, the larger folds would not be suitable for driving a slope through. As far as possible shafts, slopes, etc., should be located so as to leave the rolls and folds at the maximum distance mined from the shaft. In the western part of the field, dips from 7 to 9 degrees will be met with, but where seams enter the zone of high dip, steep slopes up to 45 degrees must be counted on. It is unlikely that for some distance up Gething, Aylard, and other creeks the dips are steep enough to carry the seams below a workable depth, and some of the area underlain by the Moosebar shale is likely to fall into the productive area for that reason. More field work, however, would strengthen this statement.

COAL

The north bank section from Grant flat to Ferro point, and the whole of the Aylard Creek section, together give a complete column of the coal-bearing Gething member, with the exception of a few concealed portions, from the horizon of the Riverside seam up to the Moosebar contact. This represents a thickness, as measured, of 1,250 feet. In this combined section there are fifty coal seams. The concealed parts in other sections are also known to carry coal seams, although they are thin; moreover the talus indicates that the lowest beds of the Gething member which lie below the horizon of the Riverside seam and are chiefly concealed, carry one or more coal seams of unknown thickness. It is, therefore, safe to estimate the total number of coal seams in the Gething member as over sixty. Most of the seams are small. Of the measured fifty, referred to above, nineteen are 11 inches thick or less, fifteen vary from 1 foot to 1 foot 11 inches, four vary from 2 feet to 2 feet 6 inches, eleven are from 2 feet 7 inches to 4 feet, and one is over 4 feet thick; three of the eleven seams expand to more than 4 feet in at least one other section studied. Ten seams, chosen in accordance with an arbitrary standard, are described in detail. These ten are the Superior, Trojan, Titan, Falls, Little Mogul, Mogul, Castle Point, Milligan, Grant, and Riverside. In addition, several seams from the unmeasured Johnson and Gething Creek sections, which cannot at present be correlated with the above ten, are also described. Two of the ten better seams are well down in the lower half of the Gething member and the remaining eight are in the upper half. It is worth noting that some of the seams are paired in position; thus the Titan and the Falls, the Little Mogul and the Mogul, the Castle Point and the Milligan, and the Grant and the Riverside. For thicknesses and stratigraphic position of the undescribed seams, including all the thin seams, reference should be made to the diagram of columnar sections (Figure 2) and to the appendix.

The arbitrary standard, in accordance with which the seams for detailed description have been chosen, is set forth below. It is by no means offered as a standard of commercial or workable seam; the definition of such a standard is not within the province of this report. Seams having a thickness of $2\frac{1}{2}$ feet or over are accepted, but those from $2\frac{1}{2}$ feet to 3 feet are considered to meet the standard only where they are in proximity to other and preferably thicker seams, with which they can be worked, i.e. in the development and operation of which the same surface equipment can be used and to some extent the same underground equipment. Seams having more than 1 foot of parting or continuous layer of concretions and at the same time less than 4 feet of coal are below the standard here used. Seams 3 to $3\frac{1}{2}$ feet thick must not have over 4 inches of partings or continuous layers of concretions. Seams $2\frac{1}{2}$ to 3 feet should preferably be free of partings and have not more than scattered small concretions. Where concretions are rare or scattered a larger proportion is allowable at one place. The above requirements must not only be attained in isolated sections, but must be maintained over sufficiently large areas to make mining profitable. It would be desirable to fix the minimum area at one square mile and call for a test every one-quarter mile. However, in the present stage of exploration this requirement of local continuity of seams can be applied only in rare instances.

All the analyses given in this report have been made in the Division of Fuels and Fuel Testing, Mines Branch, by R. E. Gilmore, chief engineering chemist. The analyses are reported by Harold Kohl, chemist. Statements in regard to coking quality are based on the laboratory tests. In classification and assignment of rank, M. R. Campbell[1] is followed. Can-

[1] Campbell, M. R., Prof. Paper, 100A, U.S.G.S., 1922, pp. 3–9.

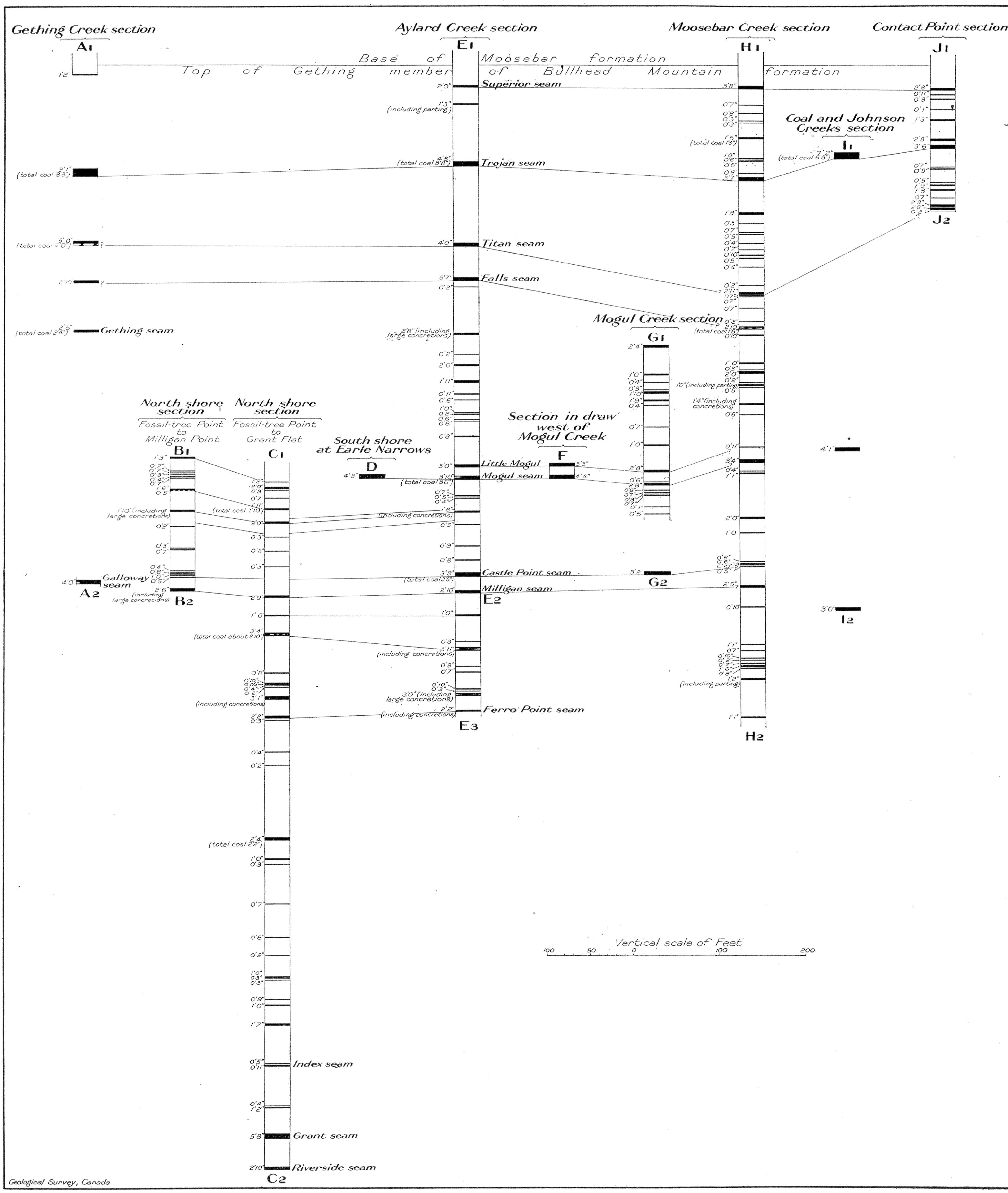

Figure 2. Columnar sections showing correlation of coal seams in Gething member of the Bullhead Mountain formation, Peace River Canyon coal-area, Peace River district, B.C. For location of sections A1–A2, B1–B2, etc., *see* Figure 1.

neloid, as used in this report, refers to coals having the grain and fracture of cannel coal, but not the chemical characters.

SUPERIOR SEAM

The Superior seam is from 23 to 26 feet below the Moosebar contact. On Aylard creek it is exposed at the upper falls, where it is 2 feet thick. On Moosebar creek it is exposed at the upper falls, where the creek forks, and is 3 feet 8 inches thick there. A third known exposure is at Contact point where the Superior seam is present in a low cliff at the river side; the thickness is 2 feet 8 inches. At each of these localities it consists of clean-looking coal, but no samples were taken, so that nothing is known of the grade or rank. On Moosebar creek and at Contact point this seam falls within the standard set. On Aylard creek it is below it. The test of continuity cannot be applied until further exploration is given to this seam. On main Gething creek, if present, it is in the high cliff at the upper falls; unfortunately, the position at which this seam would lie in this cliff is inaccessible, but the size of talus blocks in front of the cliff indicates that a seam at least 2 feet 6 inches thick is present. This may be the Superior seam. It should also be sought in the higher cliffs of Island creek and near the top of the high cliff opposite Fossil-tree point. The highest cliffs on, and east and west of, Mogul creek should be examined and, if the contact with the Moosebar shale can be located, this seam may be just below it. In the eastern part of the area it should be prospected for on the north shore northeast of Contact point.

TROJAN SEAM

In the central and western part of the area the Trojan is from 115 to 130 feet below the Moosebar contact and in the east, at Contact point, is 93 feet below. It is exposed on the north branch of Gething creek, some distance above the forks; a short tunnel or drift, about 35 feet long, has been driven along the coal in the cliff on the north bank. On main Gething creek it is exposed above the forks between the third and upper falls. The outcrop runs to the northeast and exposures should be sought in the higher cliffs of Island creek and near the top of the high cliff opposite Fossil-tree point. On Aylard creek this seam is exposed between the small third falls and the upper falls. From Aylard creek the outcrop is estimated to have a southeasterly course to Moosebar creek, where there is an exposure a short distance below the upper falls. No intervening exposures are at present known, but the highest cliffs about Mogul creek should be examined, and particular attention be given to any exposure a little over 100 feet below the Moosebar contact, if the latter can be located. The exact course of the outcrop to Johnson and Coal creeks is difficult to estimate, but the Trojan seam is exposed on the east bank of Coal creek some distance above its junction with Johnson creek; a tunnel about 35 feet long has been driven to the coal, and a drift about 65 feet long has been driven on the coal. In the east this seam is exposed at Contact point on the south bank of the river.

In the tunnel on the north branch of Gething creek this seam has the following section, including 5 feet 6 inches of coal and two partings aggregating 6 inches:

	Feet	Inches
Coal	2	1
Sandstone	0	2
Coal	2	1
Sandstone	0	4
Coal	1	4

On main Gething creek one-third mile to the south the Trojan has the following section and includes 8 feet 4 inches of coal and four partings of sandstone, aggregating 10 inches:

	Feet	Inches
Shale	-	-
Coal	0	5
Sandstone	0	2
Coal	0	7
Sandstone	0	2
Coal	3	3
Sandstone	0	3
Coal	2	5
Sandstone	0	3
Coal	1	8
Shale	-	-

Comparing the two above sections, it is probable that on north Gething creek the two thin top benches and a part of the third bench from the top of the seam in the main Gething Creek section are gone. To the southeast, 2·1 miles, on Aylard creek, the section is as follows and includes only 3 feet 8 inches of clean coal, 4 inches of bone coal, and two partings aggregating 8 inches:

	Feet	Inches
Shale	-	-
Coal	0	3
Shaly sandstone	0	2
Coal	1	11
Shale	0	6
Coal	1	6
Bone coal	0	4
Black carbonaceous shale	-	-

On Moosebar creek, 2·5 miles to the southeast, there is 3 feet 7 inches of coal and a 4-inch parting.

	Feet	Inches
Shale	-	-
Coal	2	1
Sandstone	0	4
Coal	1	6
Carbonaceous shale	-	-

Two feet six inches above, and separated by shale and sandstone, is a 6-inch layer of coal. This coal may be equivalent to the higher coal of this seam in other localities and the intervening clastic sediments may be lateral replacements or widening of partings or both. On Coal creek, a branch of Johnson creek, and 2·1 miles southeast from the Moosebar Creek exposure, the section is as follows, including 6 feet 8 inches of coal and two partings aggregating 6 inches of coal:

	Feet	Inches
Canneloid coal	0	4½
Coal	1	7½
White argillaceous sandstone	0	2
Coal	2	2
White argillaceous sandstone	0	4
Coal	2	6

The section here is more comparable with those of main Gething and north Gething creeks. At Contact point, 3 miles to the northeast, there is 3 feet 6 inches of coal, but a little above it there is another bed of coal; both beds may be equivalent to the whole seam in the west and the intervening sediments may be due to the widening of a parting. The section is as follows:

	Feet	Inches
Coal	2	8
Arenaceous shale and sandstone bands	4	6
Coal	3	6

The lower coal has two very thin sandstone partings. White sandstone partings are typical of this seam. The sections described above show that this seam is thickest in the vicinity of Gething creek and also on Coal creek. On Aylard and Moosebar creeks it is much thinner. On Moosebar creek this seam approaches very close to the minimum of the standard assumed. The fact that the thickness of coal between main and north Gething creeks—a distance of about one-half mile—changes only from 8 feet 3 inches to 5 feet 6 inches, gives promise, in the Gething locality at least, of this seam, conforming to the called-for standard of continuity.

Trojan Seam. Analyses

—	Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash	S	B.T.U.
Upper half seam, Contact point....	0·7	16·1	24·8	58·4	2·35	Agglomerates	Grey		
Lower half seam, Contact point....	0·6	11·2	26·7	61·5	2·3	Good	Cream		
Coal creek, top 4½ feet............	1·1	21·5	18·8	58·6	3·1	Non	White		
Coal creek, middle 1 foot 7 inches and 2 feet 2 inches benches	1·2	10·6	24·1	64·1	2·65	Very poor	Flesh		
Coal creek, lowest bench, upper 1 foot 3 inches	0·7	6·1	28·6	64·6	2·25	Good	Flesh		
Main Gething creek...............	1·6	8·4	26·0	64·0	2·45	Non	Light brown	0·5	13,350
North branch Gething creek.......	1·0	8·6	24·5	65·9	2·65	Non	Grey	0·7	13,820

The grade is best in the Coal Creek and Gething Creek localities, where the ash is from 8·4 to 10·6 per cent; in the east at Contact point the ash is very high for this coal area. At Contact point and on Johnson creek the ash increases upward in the coal section. The ash in the top 4½ inches is prohibitive, and the coal from this bench should be rejected in mining; this top bench consists of canneloid coal and can be classified as a semi-bituminous meta-cannel. The coals of all other benches in all localities, from west to east, rank as bituminous having fuel ratios of from 2·25 to 2·65. In the west it may be noted that this seam is non-coking, but on Coal creek the lower bench gives good coke and the upper benches make very poor coke or are non-coking. At Contact point the lower bench makes good coke and the coal of the upper bench merely agglomerates.

TITAN SEAM

The Titan seam, in the western part of the area, is from 200 to 255 feet below the Moosebar contact and, in the east, at Contact point, is about 160 feet below. The type locality is on Aylard creek, where the seam is exposed in the creek just above the small third falls. Northwestward the outcrop is estimated to run towards the river and to be in the cliff on the south bank above Earle narrows, where it should be looked for. About one-quarter mile above Earle narrows and high in the cliff on the south bank is a seam locally known as the "ladder seam"; this may be the Titan. In the high cliff opposite Fossil-tree point this seam should be near the middle of the section there exposed. It should also be sought in the cliffs on Island creek. From there the outcrop is estimated roughly to run south from the main canyon towards the lower forks of Gething creek, for on main Gething creek above the third falls there is a thick seam exposed which is correlated with the Titan.

Southeasterly from the type exposure on Aylard creek it is estimated that the outcrop runs a little back from the river. In the vicinity of upper Mogul creek, exposures should be sought in the higher, but not the highest, cliffs. On Moosebar creek a seam exposed some distance above the Big or third falls is correlated with the Titan. The exact course of the outcrop southeast of Moosebar creek is difficult to estimate, and not sufficient work has been done on Johnson creek to locate this seam there. In the east, a seam exposed on the south bank above Contact point is correlated with the Titan.

On main Gething creek the seam correlated with the Titan is 5 feet thick, but includes a layer of thick concretions, over 1 foot thick, near the base. To the southeast 2·1 miles, at the type exposure on Aylard creek, the section is as follows:

	Feet	Inches
Bedded 5-inch layers of fine sandstone and 2-inch layers of shale..	-	-
Coal........	4	0
Concealed........	2	0
Bedded 5-inch layers of fine sandstone and 2-inch layers of shale..	-	-

To the southeast 2·5 miles, on Moosebar creek, the seam correlated with the Titan contains 4 feet 1 inch of coal and two partings aggregating 11 inches:

	Feet	Inches
Dark shale	–	–
Coal	2	11
Shale and argillaceous sandstone	0	9
Coal	0	7
Sandstone	0	2
Coal	0	7
Shale, having jet bands	–	–

Three miles to the east, at Contact point, the seam correlated with the Titan contains 5 feet 2 inches of coal and a 1-foot parting.

	Feet	Inches
Shale	–	–
Coal	2	8
Clay ironstone	1	0
Coal	2	6
Sandstone	–	–

One foot below is a 2-inch band of jet coal

As regards thickness, this seam is best on Aylard creek, not so good on Gething creek and at Contact point, and poorest on Moosebar creek. All exposures meet the assumed standard, but the Gething Creek exposure is at the minimum set. It has not been possible to test the local continuity, i.e. within any mile, but future work may correct this deficiency. In future exploration its extension northwest and southeast from Aylard creek should, in particular, be examined; the localities favourable for exposures are indicated above. Unfortunately neither the rank nor grade of the coal in this seam is known; the only sample taken was lost in transit.

FALLS SEAM

The Falls seam is about 250 feet below the Moosebar contact and 40 feet below the Titan seam. The type exposure is on Aylard creek at the small third falls. From there the outcrop runs northwestward to the canyon and to the cliffs above Earle narrows; about one-third to one-half mile above Earle narrows on the south bank, a seam exposed in the cliff comes nearly to river level and may be the Falls seam. Westward the exposure of this seam rises in the cliff, and in the high cliff opposite Fossil-tree point should be at about the middle of the section there revealed. This seam, also, should be sought in the cliffs up Island creek. Westward, the outcrop is estimated to run back from the river and to the third falls on Gething, where a seam exposed is correlated with the Falls seam. From the type exposure on Aylard creek the outcrop is estimated to run southeasterly in the cliffs a little back from the river, and exposures should be sought in the higher, but not the highest, cliffs up Mogul creek and neighbouring gullies. Continuing, the outcrop probably runs southeasterly back from the river, but no exposures are at present known for 2 miles; the next exposure is on Moosebar creek, where a seam between the third and upper falls is correlated with the Falls seam. It is not at present possible to estimate where this seam would come on Johnson creek.

At the type exposure on Aylard creek the Falls seam has the following section, including 2 feet 7 inches of coal and 1 foot of canneloid coal.

	Feet	Inches
Massive sandstone	–	–
Coal	0	8
Canneloid coal	1	0
Coal	1	11
	3	7
Sandstone and shale in 1 to 5-inch bands		

About one mile to the northwest on the cliff wall above Earle narrows the seam correlated with the Falls seam is 3 feet thick, but this measurement includes large concretions near the base. The upper part is of canneloid coal.

About 1·2 miles to the west, the seam on Gething creek correlated with the Falls has the following section and includes 1 foot 11 inches of coal and 11 inches of canneloid coal:

	Feet	Inches
Coal	0	8
Canneloid coal	0	11
Coal	1	3

The bottom 1½ inches consists of jet coal. To the southeast, 2·5 miles from the type exposure, the Moosebar Creek seam, correlated with the Falls, contains about 1 foot 8 inches of coal and has the following section:

	Feet	Inches
Clay ironstone	–	–
Coal	0	8
Shale	0	2
Coal and clay ironstone concretions 1 foot thick	1	4
Canneloid coal	0	8

The presence of canneloid coal is a characteristic of this seam.

Only the exposure on Gething creek was sampled:

—	Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash
Top 8 inches	1·1	5·5	24·0	69·4	2·90	Very poor	Light brown
Middle 11 inches	1·0	3·3	23·8	71·9	3·00	Non-coking	Grey
Bottom 15 inches	0·9	2·3	25·9	70·9	2·75	Very poor	Light brown

The rank is bituminous in all three benches. The middle canneloid coal should be classified as lean cannel and is non-coking. It is to be noted that the canneloid coal has lost a little more volatile matter than the jet coal. The coal of the uppermost and bottom benches is poor coking. The grade depreciates upward, the percentage of ash increasing progressively from the bottom to the top bench.

Although this seam is depreciated by the presence of large concretions in the exposures on Moosebar creek and above Earle narrows, and is in these localities below the set standard, it is described on account of its thickness on Aylard creek, its quality on Gething creek, its nearness to the Titan seam, and the possibility that it may be of workable thickness and grade in exposures not yet explored. It should be looked for in all the localities suggested above from Moosebar to Gething creeks.

LITTLE MOGUL SEAM

The Little Mogul is a small seam, of only local importance, but is described on account of its proximity to the Mogul seam. It lies about 460 feet below the Moosebar contact and 10 feet above the Mogul seam. The type exposure is on Aylard creek a little above its mouth. From there the outcrop rises eastwardly and the seam is exposed in a draw west of Mogul creek, just above the trail on the west side. It is also exposed on Mogul creek above the trail. Its extension to Moosebar creek is problematical, although a seam there has been tentatively correlated with it. Northwestward from the type exposure on Aylard creek, a small seam in the south bank at Earle narrows is without doubt the Little Mogul.

On Aylard creek this seam is 3 feet thick, but includes a 3-inch concretion. About 0·28 miles to the northwest, at Earle narrows, this seam is only 8 inches thick, and below the assumed standard. It holds its thickness better to the southeast; 0·35 miles in that direction, in a draw west of Mogul creek, it contains 3 feet 3 inches of coal. On Mogul creek, 0·06 miles to the southeast, it contains 2 feet 8 inches of coal. The seam tentatively correlated with it on Moosebar creek is 11 inches thick and below the set standard. For a distance of about 0·4 miles, between Aylard and Mogul creeks, this seam appears to maintain a thickness of from 2 feet 8 inches to 3 feet 3 inches, and may maintain this thickness over a large area, but is known to depreciate toward Earle narrows, in which direction not much can be expected of it. It would have to maintain the above thickness about 0·6 miles east of Mogul creek to meet the standard assumed.

A sample was taken from the exposure on Mogul creek:

Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash
2·7	10·5	24·3	62·5	2·55	Non	Fawn

The rank is bituminous and the grade is low, for 10·5 per cent ash is high for this area.

MOGUL SEAM

The Mogul seam lies about 475 feet below the Moosebar contact, and is separated from the overlying Little Mogul by about 10 feet of strata. The type exposure is on the south bank near river level at Earle narrows. From there the outcrop runs a little back from the shore to Aylard creek where there is an exposure in the bank on the east side a little above the mouth of the creek. Continuing, the outcrop rises somewhat and the next known exposure is in a draw west of Mogul creek, above the trail and on the west side. On Mogul creek there is an exposure above the trail. From Mogul creek the outcrop is estimated to run southeasterly back from the river, and just above the third or High falls on Moosebar creek a seam exposed is correlated with the Mogul. West of the type exposure at Earle narrows the outcrop is estimated to run northwesterly below the river channel and either to the low cliffs at Fossil-tree point, or to below river level in front of Fossil-tree point.

At the type exposure on the south bank at Earle narrows there are 4 feet 8 inches of coal and a couple of small concretions. The bottom 5 inches is of jet coal. To the southeast 0·28 miles, on Aylard creek, the section is as follows and includes 3 feet 6 inches of coal.

	Feet	Inches
Coal	0	2
Concretion	0	4
Coal	3	4

The concretion appears to be local. In the draw west of Mogul creek 0·35 miles distant, there is 4 feet 4 inches of coal. On Mogul creek 0·06 miles distant, there is 3 feet 2 inches of coal:

	Feet	Inches
Coal	0	6
Concretion	1	2
Coal	2	8

To the southwest 2·1 miles, on Moosebar creek, the seam correlated with the Mogul has 3 feet 4 inches of coal. Thus, between Mogul creek and Earle narrows, a distance of about three-quarters of a mile, this seam is known in four places and maintains a thickness of from 3 feet 2 inches to 4 feet 8 inches. It, therefore, promises well to meet the assumed standard of local continuity. Whether this thickness is maintained all the way to Moosebar creek cannot be said, for it is not known to be exposed in that interval.

Samples were taken at two localities:

—	Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash	S	B.T.U.
Mogul creek	1·2	4·6	22·9	71·3	3·10	Non	Dark grey		
Earle narrows	1·4	4·2	22·7	71·7	3·15	Non	Flesh	0·9	14,220

The rank in both samples is semi-bituminous, but not far above bituminous.

CASTLE POINT SEAM

The Castle Point seam is about 585 feet below the Moosebar contact. It is exposed on the north side of the river at Milligan point near the bottom of the cliff. From there the outcrop runs inland and comes to the river again on the north bank at Earle narrows, but there is no exposure there, the seam being concealed on the axis of the roll. From there the outcrop runs southeasterly and crosses the river to Aylard creek; there is an exposure just east of Aylard creek on the south bank. Downstream the outcrop rises in the high cliff on the south side of the canyon. In this cliff the exposure is for the most part inaccessible, but there is an exposure, easily reached at the top of the cliff at the mouth of Mogul creek.

From there the outcrop runs southeasterly back from the river and on Moosebar creek a seam below the third or high falls is tentatively correlated with the Castle Point.

At Milligan point the section of the seam is as follows, including 2 feet 1 inch of coal and two partings aggregating 2 feet:

	Feet	Inches
Sheeted carbonaceous shale	–	–
Coal	0	8
Clay ironstone	1	0
Coal	1	0
Shale	1	0
Coal	0	5
	4	1
Black shale		

At the mouth of Aylard creek, 1·3 miles distant, the seam contains 3 feet 5 inches of coal and a concretionary band 4 inches thick, or 3 feet 9 inches in all; the foot-wall is black carbonaceous shale. To the southeast 0·41 miles, at the mouth of Mogul creek, there is 3 feet 2 inches of coal. Two miles southeast, the seam on Moosebar creek correlated with the Castle Point has 2 feet 3 inches of coal and partings aggregating 2 feet 1 inch:

	Feet	Inches
Shale	–	–
Coal	0	6
Clay ironstone	1	0
Coal	0	6
Shale	0	66
Coal	0	10
Shale	0	7
Coal	0	5
	4	4
Carbonaceous shale		

This seam has been described on account of its fair thickness in the Aylard-Mogul Creeks locality and on account of its proximity to the Milligan seam. At Milligan point and on Moosebar creek it is below standard. The rank and grade of the Castle Point coal are not known, no samples having been taken.

MILLIGAN SEAM

The Milligan seam is about 605 feet below the Moosebar contact and 28 feet below the Castle Point seam. It is exposed at Milligan point on the north shore near the base of the cliff. From there the outcrop runs inland and comes to the river again on the north shore a little below Earle narrows, where the seam is exposed. The outcrop crosses the river, and the seam is exposed on the south bank near river level just below the mouth of Aylard creek. Downstream, the outcrop rises gently in the cliff, and near the mouth of Mogul creek is exposed about halfway up the cliff. From there the outcrop runs inland back from the river, and a seam on Moosebar creek below the third or high falls is correlated with the Milligan.

At Milligan point this seam is 2 feet 6 inches thick and consists of coal and large concretions. One mile southeast, just below Earle narrows, on the north bank this seam is 2 feet 9 inches thick and has small scattered concretions. To the south 0·29 miles, on the south shore at the mouth of

Aylard creek, it is 2 feet 10 inches thick. To the southeast 2·52 miles, on Moosebar creek, below the third or high falls, the seam correlated with the Milligan is 2 feet 5 inches thick. In the west the large concretions are objectionable, and there the seam does not conform to the assumed standard, but in the Earle Narrows-Mogul Creek part of the area the concretions, where present, are much smaller. On Moosebar creek the seam is slightly below the minimum of the standard assumed.

Samples were taken in two localities:

—	Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash
North bank at Earle narrows.....	2·0	3·5	21·8	72·7	3·3	Non	Brown
Moosebar creek..................	2·3	3·5	21·2	73·0	3·45	Non	Brown

The rank is semi-bituminous.

GRANT SEAM

The Grant seam is about 1,215 feet below the Moosebar contact.

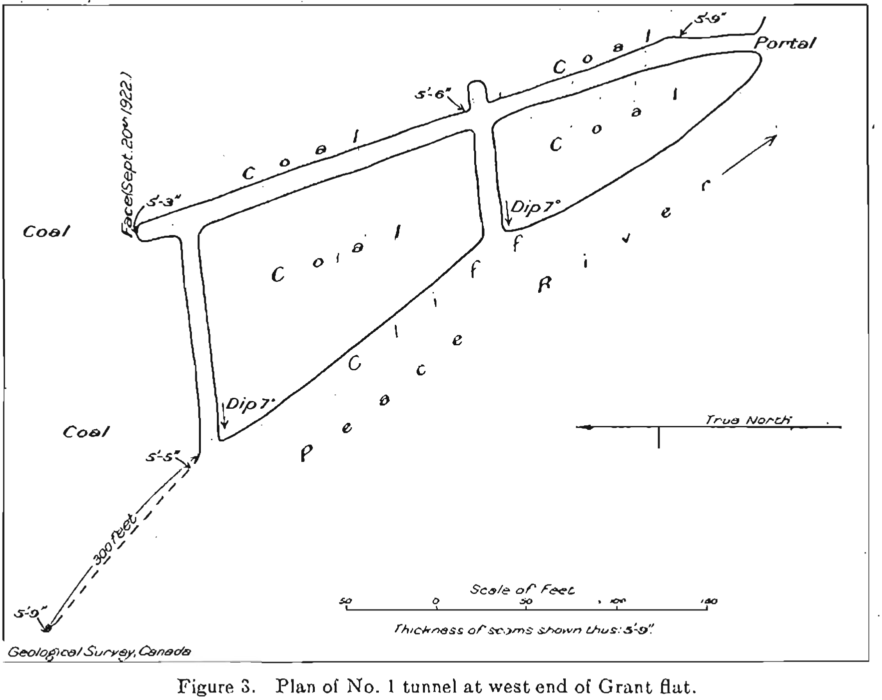

Figure 3. Plan of No. 1 tunnel at west end of Grant flat.

It is known at present in only one locality, just above river level in a low cliff on the north bank at the west end of Grant flat. There, the seam is exposed for a distance of about 680 feet. A tunnel, No. 1 Prospect tunnel,[1]

[1] Technically a drift, as it is driven on the coal.

is driven in about 360 feet on the coal. There are also two crosscuts or rather crossdrifts from the river bank to the main tunnel driven on the coal; the east crosscut is 64 feet long and the west 123 feet long. The direction of the main tunnel is north 24 degrees west. The outcrop is estimated to run up the west slope of Grant mountain and thence northwesterly to the upper part of the canyon far beyond Milligan point. Coal seams are reported from that part of the upper canyon and when the measurement of the section from Fossil-tree point west is carried down far enough it may be possible to identify the Grant seam there. In the intervening area, i.e. between Grant flat and the upper part of the canyon, the Grant seam can be tested by estimating the outcrop from structure and topography and placing shallow drill holes back, i.e. south, of the estimated position of the outcrop. Where the overburden is light, surface pits may be opened. The extension of No. 1 tunnel will also prove this seam. To the southeast of the exposure at the west end of Grant flat the outcrop is estimated to cross the river and extend to the lower part of Johnson creek where, unfortunately, there are no exposures. In the creeks from Moosebar creek west this seam is below creek level and, up the creeks, lies at increasing depths. In most of the area the dip of this seam is estimated to be from 7 to 15 degrees, but on the west slope of Grant mountain and on Johnson creek dips up to 45 degrees may be anticipated.

In the 680-foot exposure in the river bank at Grant flat, the seam, where measured, varies in thickness from 5 feet 5 inches to 5 feet 9 inches. In No. 1 Prospect tunnel at Grant flat the thickness, where measured, varied from 5 feet 3 inches to 5 feet 9 inches. The seam consists of three benches of coal: the lowest varies from 9 to 11 inches in thickness, the middle from 1 foot 9 inches to 1 foot 11 inches, and the uppermost from 2 feet 8 inches to 3 feet 2 inches. The lowest bench is made up of a bright friable jet which with little handling is reduced to small fragments; the coal of this bench is mined separately and sold locally as a blacksmith coal. The upper two benches consist of grey, greasy, dull or matte coal with bands of jet.

Grant Seam. Analyses

—	Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash	S	B.T.U.
Cliff 300 feet west of W. crosscut. Bottom 9 inches	0·6	3·4	23·6	72·4	3·05	Good coke	Flesh		
Cliff 300 feet west of W. crosscut. Middle and top 5 feet	0·8	3·4	20·4	75·4	3·70	Very poor coke	Flesh		
Cliff entrance to W. crosscut. Bottom 11 inches	0·7	2·1	24·6	72·6	2·95	Good	Flesh		
Cliff entrance to W. crosscut. Middle and top 4 feet 6 inches	0·6	2·6	18·7	78·1	4·20	Non	Flesh		
Tunnel 35 feet from portal. Bottom 8 inches	0·7	6·5	22·0	70·8	3·20	Good	Cream	0·7	14,440
Tunnel 35 feet from portal. Middle 1 foot 11 inches	0·6	2·9	19·5	77·0	3·95	Non	Brown	0·7	14,940
Tunnel 35 feet from portal. Top 3 feet 2 inches	0·7	5·3	19·6	74·4	3·80	Non	Brick	0·7	14,420
Tunnel at E. crosscut. Bottom 9 inches....	0·7	2·4	22·9	74·0	3·25	Good	Flesh	0·7	15,130
Tunnel at E. crosscut. Middle 1 foot 9 inches	0·8	2·6	19·3	77·3	4·00	Agglomerates	Flesh	0·7	14,960
Tunnel at E. crosscut. Top 3 feet............	0·7	6·1	18·7	74·5	3·95	Non	Cream	0·6	14,300
Face tunnel Sept. 26, 1923. Bottom 9 inches	0·6	2·4	24·8	72·2	2·90	Good	Flesh		
Face tunnel Sept. 26, 1923. Middle 1 foot 10 inches	0·6	2·6	19·5	77·3	3·95	Non	Cream		
Face tunnel Sept. 26, 1923. Top 2 feet 8 inches	0·6	4·1	20·1	75·2	3·75	Non	Grey		

The grade depreciates upward in the seam, the ash increasing in successive higher benches and the B.T.U. decreasing. The section in the tunnel 35 feet from the portal to some extent exhibits an exception to this rule; the ash in the bottom bench is abnormally high; the middle and upper benches, however, conform to the rule. The grade in the cliff section 300 feet west of the west crosscut is apparently uniform throughout. There is a striking contrast in the fuel ratio between the bottom and the two upper benches. The fuel ratio in the bottom bench varies from 2·90 to 3·25, i.e. the rank fluctuates on either side of the line between bituminous and semi-bituminous. In the two upper benches the fuel ratio is much higher and varies from 3·70 to 4·20; i.e. the rank is semi-bituminous. The fuel ratio in these two higher benches is nearly the same, and if anything higher, on the average, in the middle bench. Another contrast is in coking quality. All samples of the bottom coal are reported as good coking; the coal of the higher benches is poor coking, or agglomerating to non-coking.

RIVERSIDE SEAM

The Riverside is 1,250 feet below the Moosebar contact and 35 feet below the Grant seam. It is exposed at low water on the north bank a little below No. 1 Prospect tunnel at the west end of Grant flat. The seam is so close stratigraphically to the Grant coal that the statements regarding the outcrop and attitude of the Grant apply also to the Riverside.

In the known exposure the thickness of this seam is 2 feet 10 inches. At the bottom is friable jet coal and above there is dark grey, shiny, but not brilliant, coal. The presence of a layer of friable, brilliant jet coal at the base of a seam is a common occurrence in this coal area. A sample gave the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash	S	B.T.U.
0·7	5·6	18·8	74·9	3·95	Agglo-merates	Grey	0·8	14,400

The rank is semi-bituminous.

In addition to the above seams there are a few on Gething and Johnson creeks worthy of description, which have not been correlated with seams in other localities and may or may not be the equivalent of seams already described.

GETHING SEAM

At the junction of main Gething creek and its north branch there is a seam containing 2 feet 4 inches of coal and a 1-inch parting:

	Feet	Inches
Coal	0	6
Shale	0	1
Coal	1	10
	2	5

It lies below the seam correlated with the Falls seam.

Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash
1·0	3·5	25·2	70·3	2·80	Non	Light brown

The rank is bituminous.

GALLOWAY SEAM

The Galloway lies at some depth below the Gething and outcrops at the first or Galloway falls on Gething creek below the forks. It disappears below river level upstream above the falls, but downstream can be followed high in the cliffs almost to the mouth of Gething creek. It contains at the falls:

	Feet	Inches
Canneloid coal	1	6
Coal	2	6
	4	0

The thickness at this locality varies from 3 feet 7 inches to 4 feet 2 inches, but there is an almost continuous line of large concretions near the base at the falls. However, downstream these concretions become small or entirely disappear, for, in the cliffs below, the coal looks clean. The top is a canneloid coal with characteristic fracture and has a banding expressed by layers of finer and coarser granular texture. Analyses are as follows:

—	Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	S	B.T.U.
Upper bench	0·8	3·7	18·9	76·6	4·05	Non	0·8	14,590
Lower bench	0·9	3·7	19·3	76·1	3·95	Non	0·9	14,550

The rank is semi-bituminous on both benches. The coal of the upper bench may be classified as a semi-bituminous meta-cannel. This seam was described and analysed by Galloway[1] and is named for him.

SEAMS ON JOHNSON CREEK

A seam on Johnson creek a little above where the first exposures begin is 2 feet 10 inches to 3 feet in thickness and includes a 2-inch parting of shale. The bottom 5 inches is of jet coal. The hanging-wall consists of

[1] Ann. Rept. Minister of Mines, B.C., 1912, pp. 130, 136.

6 inches of shale followed by arenaceous shale above. The foot-wall is arenaceous shale. A sample gives the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash
0·6	4·1	19·0	76·3	4·0	Non	Light brown

The rank is semi-bituminous.

Higher in the Johnson Creek section is a seam containing 4 feet 1 inch of coal. There is friable shale on the hanging-wall and 1 foot of carbonaceous shale on the foot-wall. A sample taken gives the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash	S	B.T.U.
0·8	7·4	20·7	71·1	3·45	Non	Dark brown	0·07	13,820

The rank is semi-bituminous.

CANNELOID SEAM ON MOOSEBAR CREEK

A small seam on Moosebar just below the second falls is well below the assumed standard in thickness, but is described on account of its canneloid character. It is 10 inches thick and consists entirely of canneloid coal with the characteristic texture and fracture. A sample gave the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Fuel ratio	Coking quality	Colour ash
1·0	10·5	17·7	70·8	4·0	Non	Cream

The ash is high for this area, the grade, therefore, low. The fuel ratio is near the highest for the coals of this area, the coal ranking as a semi-bituminous meta-cannel.

VARIATIONS IN SEAMS

In some coal sections where samples have been taken from separate benches the ash is found to increase progressively upward in successive benches. Examples are the Trojan seam on Coal creek and at Contact point, the Falls seam on Gething creek, and some of the sections sampled of the Grant seam. Other coal sections have the ash about equal in the upper and lower benches. Examples are: one of the Grant coal sections at the west end of Grant flat and the Galloway seam at Galloway falls on Gething creek. One of the sections of the Grant seam examined has the highest ash in the bottom bench. There is also some variation laterally in percentage of ash, but in most of the examples studied this is less than the vertical variation. The bottom bench of the Grant seam varies in percentage of ash from 2·1 to 3·4 in four sections and is 6·1 in a fifth section sampled. The middle bench in three sections varies from 2·6 to 2·9 and the top bench in three sections varies from 4·1 to 6·1. The Trojan seam in three localities varies from 8·4 to 10·6 in percentage of ash, omitting the 6·1 ash content of the lowest bench on Coal creek. At Contact point this seam is very high in ash. The Trojan shows the highest lateral variation at present known for any coal seam in this area. The following seams have a percentage of ash below 5: the Grant, Milligan, Mogul, Gething, Galloway, 3-foot seam on Johnson creek, and the lower and middle benches of the Falls seam on Gething creek. The following seams vary in ash percentage from 5·5 to 7·4: the top bench of the Falls seam on Gething creek, Riverside, lowest bench of the Trojan seam on Coal creek, and the 4 foot seam on Johnson creek. The following vary in ash from 8·4 to 11·2: Trojan seam on main Gething creek and on the north branch of Gething creek, Little Mogul, upper benches of the Trojan on Coal creek, and the lower part of the Trojan seam at Contact point. The following vary from 16·1 to 21·5: the upper part of the Trojan seam at Contact point and the topmost 4½-inch bench of canneloid coal in the Trojan seam on Johnson creek.

The Peace River Canyon coals vary in rank from bituminous to semi-bituminous (lower ranks of semi-bituminous) corresponding to variations in fuel ratio of from 2·25 to 4·25. The variation does not appear to be related to geographic position in the area or to proximity to rolls, or any other disturbance. Rather the variation is with the seam and with the bench within the seam. Thus the coal of the bottom bench of the Grant seam has a fuel ratio of from 2·90 to 3·25, i.e. varying a little on either side of the limit between bituminous and semi-bituminous. The upper two benches consist of semi-bituminous coal with a range of fuel ratio between 3·70 and 4·20. The following seams have bituminous coal: the lowest bench of the Grant, Little Mogul, Falls (on Gething creek), Trojan, and Gething. The following seams contain semi-bituminous coal: Riverside, the middle and top benches of the Grant, Milligan, Mogul, Galloway, the 3-foot seam on Johnson creek, and the 4-foot seam on Johnson creek.

Most of the coal in Peace River canyon is non-coking, poor coking, or merely agglomerating. Very little of it so far examined is good coking coal. (In speaking of coking coal it must be remembered that statements regarding coking quality are based on laboratory tests.) No entire seam studied is coking throughout. This quality is confined to a bench within a seam, and, in all places so far studied in this area, to a lower bench. The lowest 8 to 11-inch bench of the Grant seam makes a good coke. On Coal creek the part of the lowest bench of the Trojan seam sampled yields a good coke. At Contact point the lower part of the Trojan seam is good coking and the upper part agglomerates. In the west, on Gething creek and on the north branch of Gething creek, this seam is non-coking. It was not, however, sampled in separate benches there.

The canneloid coal, cannel-like in grain and fracture but not in chemical character, varies in percentage of ash from 3·3 to 21·5. In all samples it is non-coking. Canneloid coals sampled have a smaller range in fuel ratio than the ordinary coals. The fuel ratio varies between 3·0 and 4·05. Where present as a bench in a seam the rank of the canneloid coal is as high as, or a little higher than, that of the ordinary coal in other benches. The canneloid coal occurs as thin seams or as benches in thicker seams.

Variations in thickness have been described under each seam. It is important to extend the knowledge so far obtained of the regularity of coal beds. Under each seam, suggestions have been given for further exploration.

As compared with coals of similar age in the Kootenay formation of the south, those of the Peace River canyon are comparatively thin; eight of the ten seams described attain a thickness of from 2 feet 6 inches to 4 feet 8 inches in parts of the area; one seam varies from 5 feet 5 inches to 5 feet 9 inches and another, known over a larger area, varies in thickness of coal from 3 feet 7 inches to 8 feet 4 inches. Against the comparative thinness of the seams must be balanced the high grade of some of them.

TONNAGE

In an area like this, where the coal is known only in surface exposures and in short prospect tunnels, an estimate of tonnage does not have the value that it will have when all surface exposures have been examined, pits opened up, drill holes put down, and mine development pushed. At the present stage only a preliminary tentative estimate is possible and its value varies in different parts of the area.

The best estimate can be given for that part of the area lying southwest of the canyon, between Johnson and Gething creeks. Take a strip 1 mile wide and 7 miles long. In this strip the seams are known in four sections approximately 2 to 2·5 miles apart, although some seams are known in sections closer together in the Aylard-Mogul Creeks localities. An average is made for the Aylard creek, Mogul creek, and draw west of Mogul Creek sections and treated as the total of one section. This is averaged with the total coal of the Gething, Moosebar, and Johnson Creeks sections, representing four sections roughly equidistant throughout the length of the strip. For the most part only the seams meeting the adopted standard are included, but where seams come within a couple of inches of the standard, they are taken. The Gething section gives the following:

—	Feet	Inches	Tons per acre	Tons per square mile
Bituminous coal	11	3	11,250	7,200,000
Semi-bituminous coal	2	0	2,000	1,280,000
Coal of unknown rank	6	0	6,000	3,840,000
Canneloid coal	2	5	2,417	1,546,880
Total coal	21	8	21,667	13,866,880

The Aylard-Mogul Creeks section gives the following:

—	Feet	Inches	Tons per acre	Tons per square mile
Bituminous coal	2	9	2,750	1,760,000
Semi-bituminous coal	6	4	6,333	4,053,120
Coal of unknown rank	13	8	13,666	8,746,240
Canneloid coal	1	0	1,000	640,000
Total	23	9	23,749	15,199,360

The Moosebar section gives the following: the coal of the Grant seam, which is everywhere below creek level, is not included:

—	Feet	Inches	Tons per acre	Tons per square mile
Semi-bituminous	2	5	2,416	1,546,240
Coal of unknown rank	14	8	14,666	9,386,240
Total	17	1	17,082	10,932,480

The Johnson-Coal Creeks section gives the following: the coal of the Grant seam is not included: it should be exposed on the lower part, but is concealed by gravel and sand.

—	Feet	Inches	Tons per acre	Tons per square mile
Bituminous coal (1 foot 3 inches coking)	6	3	6,250	4,000,000
Semi-bituminous coal	7	0	7,000	4,480,000
Total	13	3	13,250	8,480,000

The average of the four above sections is as follows:

—	Tons per square mile
Bituminous (a little is coking) coal	3,240,000
Semi-bituminous coal	2,839,800
Coal of unknown rank	5,493,100
Canneloid coal	546,700
Total	12,119,600

The tonnage for the area of 7 square miles is as follows:

—	Tons
Bituminous coal (a very small part coking)	22,680,000
Semi-bituminous coal	19,878,900
Coal of unknown rank	38,451,800
Canneloid coal	3,827,000
Total	84,837,700

In placing a value on the above estimate for the 1 by 7-mile strip southwest of the canyon from Johnson to Gething creeks a number of things must be considered. On the one hand the sections are 2·1 and 2·5 miles apart, except for some of the seams in the Mogul-Aylard Creeks part of the strip, and the assumption is made that the seams maintain their thickness and quality in the stretches between. On the other hand the Grant seam is not included in the Moosebar and Johnson Creeks estimates and there is the possibility that this seam maintains its standard below the creeks and is not at too great a depth to work. It must also be remembered that all of Johnson creek is not yet studied.

It may also be considered whether an estimate can be made of tonnage for another strip of 7 square miles lying southwest of the one for which the 84 odd million tons has been estimated for, a strip in which the coal-bearing strata are buried under the Moosebar shale. Can the same estimate be given to this strip, i.e. can another 84 odd million tons be added, making a total estimate of 169,675,500 tons? Before this can be done two facts must be ascertained: whether the seams are at a workable depth throughout the area of this second strip, and whether the seams maintain the thickness and quality which they have in the first strip, adjoining the canyon. A detailed examination of the structure up Moosebar, Aylard, etc., creeks would make possible an estimate of depth to the seams, and bore-holes located up the same creeks would determine both the depth to seams and their quality and thickness.

For that part of the area north of the canyon from Grant flat to the bend above the mouth of Gething creek it is probable that over 4 square miles are underlain by the Gething coal-bearing member. However, not much is known of the extension of seams through this area. At the west end of Grant flat the Grant seam is known for a distance of about 680 feet and the Riverside seam in one exposure. Should they maintain their grade and thickness the following estimate per acre and per square mile obtains:

—	Feet	Inches	Tons per acre	Tons per square mile
Semi-bituminous	7	6	7,500	4,800,000
Coking bituminous	0	10	833	533,100
Total	8	4	8,333	5,333,100

The coal seams, referred to under Grant seam as occurring in the upper part of the canyon and near the horizon of the Grant seam, have not been examined. Should exploration there, and by drill and mine development in the stretches between that locality and Grant flat (as suggested under Grant seam) demonstrate that the Grant and Riverside seams extend over 4 square miles and preserve the thickness and quality which they possess at the west end of Grant flat, then 21,332,000 tons can be estimated for the area north of the canyon. At the present stage of development, however, this estimate cannot be advanced without making unwarranted assumptions.

The number of square miles underlain by the coal-bearing member east of Johnson and Grant mountains is not known; only several of the top seams are exposed, and in only one locality, at Contact point. All that can be done is to estimate what tonnage these known seams would yield did they maintain their quality and thickness over 1 square mile.

—	Feet	Inches	Tons per acre	Tons per square mile
Bituminous coal (in part coking)	6	0	6,000	3,840,000
Coal of unknown grade and rank	7	10	7,833	5,013,000
Total	13	10	13,833	8,853,000

Most of the 3,840,000 tons is of low grade. Until more is known of this eastern part of the area little should be expected of it.

It may be noted that in the above estimates no account has been taken of the tonnage above or below drainage level. This is very important, but such a calculation would require a topographic map and a more detailed study of the areal extent of the various seams than is possible in this preliminary examination.

APPENDIX

DETAILS OF COLUMNAR SECTIONS[1]

"Thick" refers in general to layers over 6 inches thick; thin to those under 6 inches. "Shale" refers to fine-grained argillaceous beds, having the structure of shale, i.e. breaking in layers that have curved surfaces; these layers further break down into irregular and angular fragments. "Fissile shales" as so designated here are those which break into smooth sheets or plates parallel to bedding. "Flag," "flaggy," and "flagstone" refer to the nature of the bedding and not to the grain and composition of the rock; the rock weathers into layers parallel to the bedding, each layer being a natural stratum.

North Shore, Fossil-tree Point to Milligan Point (B 1 to B 2)

	Feet	Inches
Coal	1	3
Shale, carbonaceous, jet seamlets	0	5
Sandstone, argillaceous, some jet	0	8
Sandstone, fine-grained, massive	1	1
Shale, arenaceous	1	6
Clay ironstone, prostrate plants	6	8
Shale, carbonaceous, somewhat fissile, prostrate plants	2	0
Sandstone, medium grain, ripple-marked	1	0
Coal	0	7
Shale, grey, friable	1	3
Coal	0	7
Sandstone, carbonaceous, with jet	0	3
Coal	0	3
Shale, grey, arenaceous	0	6
Sandstone and shale in irregular 8-inch beds	2	0
Coal	0	4

[1] All sections read from highest beds downward.

North Shore, Fossil-tree Point to Milligan Point (B 1 to B 2)—Continued

	Feet	Inches
Shale, carbonaceous, with jet	0	10
Coal	0	7
Shale, somewhat fissile	1	0
Clay ironstone	0	6
Sandstone, light grey, medium grain, in ripple-marked flags, brown weathering	3	6
Sandstone, light grey, coarse-grained, massive	3	4
Sandstone, films black shale	1	5
Shale, dark	1	11
Coal, 4-inch jet on bottom	1	6
Jet coal and irregular clay ironstone concretions	0	5
Shale, carbonaceous, micaceous	0	6
Sandstone, carbonaceous, micaceous	1	3
Sandstone, yellow and banded above, coarse and massive below	20	3
Coal, having 8-inch concretions in places	1	10
Shale, arenaceous	0	7
Sandstone, light grey, massive	1	10
Sandstone, massive	1	2
Sandstone, fine, yellow weathering	1	4
Sandstone, light grey, medium grain, fine lined; peculiar unsolved plant remains?	4	0
Sandstone, white, coarse; peculiar unsolved plant remains?	5	3
Sandstone, ripple-marked	2	3
Shale	0	3
Coal	0	2
Sandstone, fine, argillaceous	1	4
Sandstone, fine, in ripple-marked beds	5	6
Sandstone, fine, argillaceous in ripple-marked flags	12	6
Sandstone, argillaceous, micaceous, fine lined	4	10
Jet coal	0	3
Shale	0	7
Coal	0	7
Shale, prostrate plants	1	0
Sandstone, medium grain, light grey	0	11
Sandstone, medium grain, weathers yellow	1	6
Sandstone, grey, some ripple-marked surfaces	2	9
Shale, having thin beds of clay ironstone	10	0
Sandstone, fine, some ripple-marked surfaces	8	0
Shale, grey	0	8
Coal	0	4
Shale, carbonaceous, fissile	2	0
Coal	0	8
Clay ironstone	1	0
Coal	1	0
Shale	1	0
Coal	0	5
Shale, black	2	0
Shale, black, carbonaceous	2	0
Shale, black, having bands of jet	1	8
Shale, grey, friable	2	0
Sandstone, banded with shale	2	8
Sandstone, grey, massive	2	3
Shale, dark, somewhat fissile	0	8
Coal—Milligan seam	2	6
Shale, black, carbonaceous, micaceous	0	2

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)

	Feet	Inches
Banded dark shale, light sandstone, and clay ironstone in about 12-inch bands	10	0
Sandstone, light grey, ripple-marked	2	0
Sandstone, light grey, hard, ripple-marked	1	6
Shale, having sandstone lenses	1	6
Shale, fine discontinuous band of white sandstone	5	10
Coal	1	2
Shale, somewhat friable	0	2
Sandstone, medium grain	0	8
Shale, dark, carbonaceous, jet bands	1	4
Clay ironstone	2	0
Shale, carbonaceous, plant remains	0	3
Coal, 3-inch jet on bottom	2	0
Shale, somewhat fissile, having jet bands	1	8

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Coal and clay ironstone concretions	0	9
Shale, arenaceous	1	0
Shale, arenaceous, clay ironstone	1	3
Clay ironstone	2	0
Shale, somewhat fissile, jet bands	0	3
Sandstone	1	0
Shale, clay ironstone nodules	1	6
Shale, carbonaceous, somewhat fissile, jet bands	0	6
Shale, fissile	0	6
Coal	0	7
Shale, carbonaceous	0	6
Shale	0	3
Sandstone, carbonaceous, medium grain	1	0
Clay ironstone	2	0
Sandstone, ripple-marked	0	10
Sandstone, coarse, massive	2	8
Sandstone, medium grain, micaceous	2	0
Shale	2	0
Coal	1	6
Clay ironstone	0	1
Coal	0	4
Shale, coaly	0	5
Sandstone, dark, fine, a few ripple-marked layers, includes 4-inch clay ironstone band	6	0
Sandstone, fine, some ripple-marked layers	3	0
Sandstone, medium grain, massive, unsolved plant remains; good horizon marker	5	0
Shale	0	3
Coal	2	0
Shale, carbonaceous	0	3
Sandstone, medium-grain, argillaceous, rootlets	6	0
Sandstone, coarse, white, in ripple-marked, thick-bedded, unsolved plant remains; good horizon marker	6	6
Sandstone, coarse, in flags, arenaceous shale beds	1	2
Coal	0	3
Sandstone, argillaceous, rootlets	1	8
Shale, arenaceous in thin beds	1	8
Sandstone, ripple-marked, in flags	4	0
Sandstone, fine, in ripple-marked flags, separated by very thin, sun-cracked, arenaceous shale; clay ironstone bands	8	6
Coal	0	8
Shale, coaly, and bands of coal	1	0
Shale, dark	2	4
Sandstone in ripple-marked flags 6 inches to 12 inches	2	5
Sandstone flags, weathering brown	2	5
Shale, arenaceous	3	0
Shale, dark	2	0
Sandstone, finely crossbedded	3	6
Sandstone, dark, argillaceous	0	3
Coal	0	3
Concealed	25	0
Sandstone, fine, brown weathering	8	0
Milligan seam—		
Coal +2 inches concretion ... 2 feet 1 inch		
Coal, jet ... 8 inches	2	9
Shale, black, micaceous	0	7
Sandstone, massive, ripple-marked	4	0
Sandstone, light grey, very fine dark bands	3	0
Shale, dark	1	0
Sandstone, argillaceous, massive	0	9
Sandstone, massive, argillaceous, clay ironstone	5	6
Shale, grey	4	4
Coal	1	0
Shale, dark, somewhat fissile	1	6
Sandstone in thin flags	3	6
Concealed	10	0
Sandstone, light grey, fine, in ripple-marked flags, roots	5	0
Coal ... 0 feet 8 inches		
Shale ... 0 feet ½ inch		

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Coal and irregular concretions 7 inches thick....... 1 foot 11½ inches		
Coal, jet...0 feet 8 inches	3	4
Shale, grey	0	6
Sandstone, dark, fine	2	0
Sandstone, banded, argillaceous, in ripple-marked layers	7	0
Shale, grey	3	9
Shale, fissile, having jet bands	0	3
Shale, grey, having jet bands	1	0
Sandstone, banded	2	8
Shale, dark	2	3
Sandstone, massive	2	0
Clay ironstone	1	6
Sandstone, rather coarse, massive	12	0
Shale, black	1	8
Shale, black, having very thin sandstone lenses	3	6
Shale, black	1	8
Coal and many clay ironstone concretions	0	8
Shale, fissile, having plant remains and jet bands	0	3
Shale, grey, arenaceous	1	0
Shale, carbonaceous, fissile	0	6
Shale, arenaceous, friable	0	6
Shale, carbonaceous, fissile	0	5
Shale, grey	0	3
Sandstone, fine	0	11
Shale, grey, having ironstone concretions	2	2
Sandstone, fine lined	1	0
Shale, arenaceous, some clay ironstone	0	2
Sandstone, fine	1	0
Shale, grey	0	6
Shale, fissile	0	6
Coal, canneloid	0	10
Shale, grey, somewhat fissile	0	8
Coal, canneloid	0	1½
Shale	0	4
Coal, jet	0	4
Shale, coaly	0	4
Coal, jet	0	2
Shale, dark, carbonaceous, somewhat fissile	3	6
Sandstone, fine-grained, argillaceous	1	0
Sandstone in ripple-marked layers, a few bands arenaceous shale	2	6
Sandstone, fine, weathering brown	2	0
Shale, grey, arenaceous	0	6
Coal, irregular concretions 1 foot from bottom, bottom 12 inches chiefly jet	3	1
Shale, somewhat fissile, carbonaceous, seam jet	0	8
Sandstone, argillaceous	0	6
Shale, grey, arenaceous, friable	1	0
Sandstone, medium grain, fine crossbedding	6	8
Sandstone, fine, finely banded	1	3
Shale, arenaceous, having bands of fine sandstone	6	0
Shale, friable	3	0
Coal, Ferro Point seam	2	2
Shale, carbonaceous, friable, jet seamlets	1	6
Coal, jet	0	3
Shale, dark, fissile, jet	0	5
Shale, arenaceous	0	11
Sandstone, finely banded	1	0
Sandstone, medium grain, ripple-marked, yellow weathering	3	0
Sandstone, fine-grained, argillaceous, fine-lined, in 6-inch beds	5	4
Sandstone, very thinly banded with dark shale	2	6
Shale, grey, arenaceous, 3-inch clay ironstone band	2	0
Shale, fissile, jet bands	0	6
Shale, dark, arenaceous	0	8
Sandstone, finely lined, banded with shale	3	8
Sandstone, dark, argillaceous	1	2
Shale, dark grey, arenaceous	2	0
Shale, carbonaceous, fissile	0	5
Clay ironstone	0	9

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Sandstone, medium grain, poorly sorted in flags, some layers ripple-marked	12	0
Shale, arenaceous	2	3
Coal, jet	0	4
Shale, dark, carbonaceous	0	8
Sandstone, dark, fine lined	1	2
Sandstone, medium grain, interbedded with friable shale; clay ironstone bands above; middle beds are ripple-marked layers of sandstone with thin beds sun-cracked shale; thin coal seam above ripple-marked layers	40	0
Shale, dark, somewhat fissile, jet bands	1	0
Concealed	8	0
Shale, arenaceous, clay ironstone concretions	1	0
Shale, friable, 1 jet band	0	7
Sandstone, fine, argillaceous in ripple-marked layers	5	0
Sandstone, coarse, massive, rare ripple-marked surfaces	35	0
Shale, grey, prostrate plants; narrow bands clay ironstone	4	0
Shale, carbonaceous, fissile, jet bands, prostrate stems	0	11
Coal, 1-inch parting 4 inches from top, 1-inch parting 1 inch from bottom	2	4
Sandstone, argillaceous, poorly sorted, upright stems	2	8
Shale, grey	2	0
Clay ironstone, banded with shale	1	8
Sandstone, argillaceous, burrows?	2	8
Shale, dark, friable	1	3
Sandstone, fine, in ripple-marked layers, separated by thin shale bands	2	6
Clay ironstone, three thin bands friable shale	4	3
Shale, grey, friable; thin bands clay ironstone, fine wood debris	1	9
Sandstone, fine banded, and clay ironstone	1	0
Shale, dark, friable	2	0
Coal, jet	1	0
Shale, carbonaceous, fissile, prostrate fronds	0	3
Sandstone, fine, grey, in ½-inch layers, ripple-marked, thin shale layers sun-cracked, Dinosaur tracks	2	6
Shale, dark	0	8
Sandstone, fine, massive	0	6
Shale, black, somewhat fissile	0	10
Coal	0	3
Shale, arenaceous, fine, friable	0	7
Sandstone, fine, argillaceous, flaggy	0	7
Sandstone, medium grain, grey, in ripple-marked layers 1 inch to 4 inches thick, some thin shale bands and films, a few clay ironstone bands 1 inch to 3 inches	10	0
Shale, dark grey, arenaceous, friable, many 2-inch clay ironstone bands	11	0
Sandstone in ripple-marked layers	1	0
Sandstone, dark grey, poorly sorted, mottled, some vertical roots, stems, prostrate wood fragments	3	0
Sandstone, flaggy, much driftwood	2	0
Sandstone, light grey, in thick ripple-marked layers	3	9
Sandstone, fine, thin, ripple-marked layers, thin, dark shale bands	3	3
Sandstone, fine, in flags	3	0
Shale, arenaceous, in very thin flags, ripple-marked, thin bands, films black shale, sun-cracked, burrows, trails, some 2-inch clay ironstone bands	5	8
Shale, grey	0	8
Coal	0	7
Shale, carbonaceous, micaceous, jet	0	6
Sandstone, medium grained, light grey in 4-inch to 6-inch ripple-marked layers	8	0
Concealed	20	0
Shale, arenaceous, prostrate plants	0	9
Sandstone, fine, in ripple-marked layers; weathers brown, a few Dinosaur tracks	3	0
Shale, black, carbonaceous, fissile	0	8
Shale	1	0
Sandstone, fine, dark lined, irregularly platy	2	0
Shale, carbonaceous, fissile, fronds	1	0

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Coal	0	8
Shale, friable	3	0
Clay ironstone and thin layers of friable shale	4	0
Shale, friable, beds of clay ironstone 2 feet thick	8	0
Shale, friable, ½-inch clay ironstone bands	4	6
Coal, jet	0	2
Shale and jet	2	0
Carbonaceous, somewhat fissile shale, jet	0	7
Shale, dark, finely friable	4	8
Sandstone, medium grain, finely crossbedded	0	4
Sandstone, with arenaceous shale	1	0
Sandstone, coarse, massive	2	2
Shale, friable, clay ironstone bands	3	10
Sandstone, medium grain, massive	1	6
Shale, arenaceous, friable	0	5
Sandstone, medium grain, massive	0	9
Shale, friable, clay ironstone bands	6	6
Coal	1	0
Shale	0	7
Coal	0	3
Shale, friable	0	11
Coal	0	3
Shale, dark, friable	0	5
Sandstone, fine grained, shale bands	2	6
Shale, friable, clay ironstone concretions	4	0
Clay ironstone	1	3
Shale, friable, clay ironstone concretions	3	3
Sandstone, fine, thin banded	2	3
Shale, friable	0	7
Sandstone, fine, thin bands shale near bottom	1	1
Shale, dark grey	1	0
Shale, black, friable	1	6
Sandstone, fine, argillaceous, erect stems	1	2
Shale, friable	1	6
Coal	0	9
Shale	0	3
Sandstone, fine; vertical stems?	2	0
Shale, arenaceous, friable, clay ironstone nodules, vertical stems?	3	6
Coal, 4 inches jet at base	1	0
Shale, friable, many roots and stems	2	6
Sandstone, massive, weathers yellow	2	0
Shale, a few rootlets, etc	0	6
Sandstone, massive, weathers yellow	0	5
Sandstone, fine, dark grey, ironstone concretions	2	4
Shale, grey, friable	1	2
Sandstone, fine, dark grey	1	3
Shale, finely friable	0	8
Clay ironstone	0	2
Shale, grey	1	2
Clay ironstone	0	3
Sandstone, fine, ripple-marked on some surfaces, weathers brown	1	0
Sandstone, fine, argillaceous	2	8
Shale, grey	1	9
Shale, carbonaceous, much jet, plant remains	1	1
Coal, having thin parting	1	7
Shale, carbonaceous, fissile	0	3
Sandstone, coarse, grey	4	6
Concealed	30	0
Sandstone, fine, uneven fracture and in 1-inch to 2-inch bands	6	0
Sandstone, coarse	1	2
Sandstone, fine, slightly argillaceous	1	4
Sandstone, coarse, massive	1	8
Index seam— (Inches)		
Coal . . . 5		
Shale . . . 6		
Coal (3-inch jet on bottom) . . . 11	1	10
Shale	3	0
Sandstone	2	6
Shale	6	0

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Sandstone	1	6
Shale, friable	5	0
Sandstone, coarse, grey	10	0
Shale	1	6
Shale, carbonaceous, and coal	0	8
Shale	0	6
Sandstone, coarse	0	6
Shale, arenaceous	2	0
Shale	2	0
Shale, arenaceous, erect stems?, clay ironstone	4	0
Sandstone, coarse, massive, thick bedded	4	6
Coal	0	4
Shale	0	4
Coal	1	2
Shale and clay ironstone	2	0
Sandstone	4	0
Shale, carbonaceous, and coal	1	0
Sandstone	3	0
Clay ironstone	0	6
Sandstone, crossbedded on large scale, one or two ripple-marked layers	3	6
Clay ironstone	1	0
Sandstone, coarse, massive	5	0
Shale	5	0
Sandstone	1	6
Clay ironstone	1	0
Coal -Grant seam	5	8
Concealed	30	0
Clay ironstone	1	0
Shale	1	0
Coal -Riverside seam	2	10

Aylard Creek Section (E 1—E 3)

	Ft.	In.	Feet	Inches
Shale of Moosebar formation				
Concealed			5	0
Sandstone, massive			15	0
Shale			1	6
Sandstone, massive			4	0
Shale, arenaceous			2	5
Coal—Superior seam			2	0
Shale, fissile, with jet bands			0	2
Sandstone, coarse, massive			2	3
Shale			0	5
Sandstone, fine, massive			2	4
Shale, dark, fissile, many jet bands			2	8
Shale, arenaceous			2	0
Concealed			3	0
Shale, arenaceous			1	0
Sandstone, fine, thin, irregular bands and films of shale			3	0
Shale			0	10
Coal, irregular 3-inch parting			1	3
Shale, friable			2	0
Concealed			60	0
Sandstone, massive			0	6
Shale			4	0
Trojan seam ·				
Coal	0	3		
Sandstone	0	2		
Coal	1	11		
Shale	0	6		
Coal	1	6		
Bone coal	0	4	4	8
Shale, black, carbonaceous, fissile			0	6
Shale, dark			0	9
Sandstone, fine			1	0
Shale			1	0
Concealed			82	0

Aylard Creek Section (E 1—E 3)—Continued

	Feet	Inches
Sandstone, brown weathering, fine, in 5-inch beds separated by 2-inch shale beds	4	0
Coal, Titan seam	4	0
Concealed	2	0
Sandstone, brown weathering, fine, in 5-inch beds separated by 2-inch shale beds	3	8
Shale, jet above	2	10
Clay ironstone and carbonaceous shale	1	6
Shale, arenaceous, clay ironstone concretions	1	6
Clay ironstone	1	3
Shale, arenaceous	0	3
Clay ironstone	3	0
Concealed	5	0
Shale	3	4
Shale, black, carbonaceous, fissile	1	6
Shale, arenaceous	1	0
Shale	0	8
Shale, carbonaceous	0	8
Shale	2	6
Sandstone, medium grain, massive	4	7
Falls seam— Ft. In. Coal 0 8 Canneloid coal 1 0 Coal 1 11	3	7
Sandstone and shale in 1-inch to 5-inch beds	5	0
Clay ironstone	0	5
Shale	0	4
Shale, dark, carbonaceous	0	5
Coal	0	2
Shale, dark, carbonaceous	1	0
Concealed	3	0
Sandstone, fine-grained	3	0
Sandstone, massive, argillaceous, in part altered to arenaceous clay ironstone	3	2
Sandstone	1	9
Shale, arenaceous	5	0
Shale, dark	10	0
Sandstone, fine-grained	3	6
Shale, arenaceous	4	8
Shale, clay ironstone bands	13	0
Clay ironstone	3	3
Shale	1	10
Coal, large concretions, and 1 foot 3 inches canneloid coal	2	8
Sandstone, fine, massive, thick layered	10	6
Sandstone in thin flags, films of shale	3	8
Sandstone, fine, massive	1	2
Shale, dark	3	2
Shale, arenaceous	1	2
Shale, dark	2	0
Coal	0	2
Shale	0	9
Clay ironstone	2	8
Shale	1	4
Clay ironstone	0	10
Sandstone, coarse	1	0
Shale	3	6
Sandstone, massive	1	3
Coal, pyrites in bottom bench	2	0
Concealed	9	0
Sandstone, massive	2	6
Shale, arenaceous	0	3
Sandstone, fine, massive	3	0
Shale, friable, jet bands	1	11
Coal, jet	1	11
Shale, carbonaceous, above, plant remains	2	2
Sandstone and shale, banded	2	0
Shale, arenaceous	7	6
Shale, black, carbonaceous	0	4
Coal	0	5

Aylard Creek Section (E 1—E 3)—Continued

	Feet	Inches
Bone coal, granular	0	3
Coal	0	6
Shale, fissile, and coal	0	6
Shale	3	3
Sandstone, fine, massive	0	7
Shale, friable	2	4
Coal	0	6
Shale, carbonaceous, fissile	0	8
Sandstone, fine, with bands of shale	3	0
Sandstone, medium grain	2	10
Shale	9	0
Coal	9	0
Shale	0	2
Coal, jet	0	2
Shale	1	6
Sandstone, fine, having thin shale films	3	9
Shale, grey	0	9
Coal	0	6
Shale, fissile, prostrate fronds	0	5
Coal	0	6
Sandstone, very fine, argillaceous	0	8
Sandstone, medium grain	3	0
Shale, dark, micaceous, two thin bands jet at top	1	9
Sandstone, medium grained, in thick ripple-marked layers	3	0
Sandstone, fine, argillaceous, very thin bands and films shale	7	9
Shale, black, finely friable, some jet bands	0	10
Coal	0	8
Sandstone, medium grain	0	2
Shale, dark, friable, some plant remains	1	3
Sandstone, medium grain in poor flags; several ripple-marked surfaces	7	0
Sandstone, fine, argillaceous, coarsely friable in fracture	4	6
Shale, grey, friable	1	9
Clay ironstone, massive	5	0
Sandstone, medium grain, massive	8	0
Sandstone, fine, argillaceous, friable; plant remains; thin clay ironstone bands	1	6
Shale, carbonaceous, fissile, many fine jet bands	1	5
Sandstone, fine, argillaceous, massive	2	3
Coal, small concretions near top; Little Mogul seam	3	0
Shale, black, arenaceous	0	2
Sandstone, fine, argillaceous, ripple-marked on some surfaces. Thin films shale	10	0
Coal, scattered large (4 inches) concretions near top; Mogul seam	3	10
Sandstone, medium grain, dark, argillaceous, micaceous	1	6
Sandstone, grey, medium	9	0
Sandstone, medium, massive, brown weathering	5	0
Shale	2	3
Shale, carbonaceous, sheeted; jet bands	0	4
Coal	0	7
Shale	0	7
Coal	0	5
Shale with pyrites	0	6
Coal	0	4
Sandstone, fine, micaceous	0	6
Sandstone, fine, ripple-marked in thick to medium flags	5	8
Clay ironstone, massive	0	9
Sandstone, coarse, weathering in knobs and ill-defined layers	2	0
Sandstone, medium grain, in 2-inch flags	1	0
Sandstone, coarse, massive, unsolved plant remains	1	0
Sandstone, coarse, thick layered	2	2
Sandstone, coarse, massive, unsolved plant remains; good horizon marker	2	6
Sandstone, fine, ripple-marked flags	0	10
Coal, concretions near bottom	1	8
Sandstone, fine, dark, carbonaceous	0	3
Sandstone, medium grain, brown weathering, massive	3	0
Sandstone, fine, in ripple-marked flags	4	0

Aylard Creek Section (E 1—E 3)—Continued

	Feet	Inches
Sandstone, coarse, thickly irregularly layered, unsolved plant remains; good horizon marker	3	3
Sandstone, ripple-marked, thin beds films shale, thin flags below, thick flags above	3	2
Coal	0	5
Shale, dark, carbonaceous	1	3
Sandstone, thick, irregularly bedded, some vertical roots or stems	1	8
Sandstone, fine, in thin ripple-marked flags	12	8
Shale, dark, some thin sandstone bands	9	3
Coal	0	9
Sandstone, fine, ripple-marked flags; thin shale bands and films; sun-cracks	10	6
Sandstone, fine	1	6
Shale, grey	1	8
Shale, dark, fissile, jet bands	0	10
Coal, having two thin partings	0	8
Sandstone, thickly layered, clay ironstone	3	0
Sandstone, fine, grey, argillaceous, prostrate plant remains	10	6
Shale, dark	0	6
Coal, irregular, small concretions up to 4 inches, Castle Point seam	3	9
Shale, black, carbonaceous, fissile, plant remains	1	6
Sandstone, medium grain, tree trunks prostrate	1	6
Shale, arenaceous, irregular lenses clay ironstone	4	6
Sandstone, fine, argillaceous	3	0
Sandstone, fine, in thin ripple-marked flags	4	8
Shale, dark, somewhat fissile	0	7
Coal, Milligan seam	2	10
Shale, black, micaceous	0	5
Sandstone, fine, ripple-marked, in flags; thin bands films dark shale; flags 2 inches to 3 inches above, very thin below	7	4
Shale, black, carbonaceous, jet bands	1	4
Sandstone, fine, dark	3	6
Sandstone, fine lined, brown weathering, in flags above	10	0
Shale, arenaceous, friable	3	11
Coal, small irregular parting	1	0
Sandstone, fine, thin layers, dark shale; 100 feet to west changes to shale with fine sandstone bands, i.e. proportion shale greater than sandstone	8	0
Sandstone, fine, mottled, poorly sorted, finely friable	2	0
Sandstone, massive, inclined beds lower strata on either side; estimated	10	0
Sandstone, in thick layers, a few thin beds shale	8	0
Coal, jet	0	3
Sandstone, dark, argillaceous	0	6
Sandstone, white, fine grain, thin flags; roots	4	0
Sandstone in ripple-marked thin flags; also films and very thin bands black shale	1	10
Coal, including concretions up to 2 feet 6 inches, 8 inches jet coal on bottom	3	11
Shale, arenaceous	0	8
Sandstone, medium grain, thickbedded; some ripple-marks	8	9
Shale, arenaceous	4	0
Sandstone, dark, jet bands	0	6
Sandstone, medium grain, massive	4	0
Coal, 4-inch parting in middle	0	9
Shale, sandstone, fine banded and lens-like	4	6
Shale, dark, somewhat fissile	1	4
Coal and 2-inch parting	0	7
Shale, dark, jet	0	1
Sandstone, fine, argillaceous, a few vertical roots or stems	3	6
Shale, grey	0	10
Sandstone, massive, weathering yellowish	5	0
Sandstone, massive, +clay ironstone	8	9
Shale, black	0	6
Coal, canneloid	0	10
Shale, black, clay ironstone band	2	0
Coal, jet	0	3
Shale, black	1	0
Shale, dark, thin sandstone bands	1	0

Aylard Creek Section (E 1—E 3)—Continued

	Feet	Inches
Coal, including in middle large concretions up to 2 feet	3	0
Shale, dark, thin sandstone bands	3	0
Sandstone in thick flags, some ripple-marked surfaces; weathers brown	4	10
Sandstone, fine, in ripple-marked flags	3	9
Sandstone, fine, argillaceous, thin bands of clay ironstone	2	0
Shale, arenaceous	1	5
Shale, grey	2	1
Coal, small concretions, Ferro Point seam	2	2
Shale, grey, some jet; prostrate plant remains	1	10
Sandstone, films of shale	1	4
Sandstone, fine, films shale, weathers yellowish	3	8

Section in Draw West of Mogul Creek (F)

	Feet	Inches
Coal, Little Mogul seam	3	3
Shale, arenaceous	10	0
Coal, Mogul seam	4	4

Sections on Mogul Creek (G 1—G 2)

	Feet	Inches
Coal	2	4
Shale	1	0
Sandstone, fine, argillaceous	10	0
Concealed	8	0
Shale, arenaceous, friable	6	0
Sandstone, fine, hard	6	9
Coal	1	0
Shale, dark	2	11
Shale, arenaceous	3	9
Shale, carbonaceous	0	3
Coal	0	4
Sandstone, medium grained	5	6
Sandstone, massive, medium grained, coarse	3	9
Coal	0	3
Shale	1	6
Coal	1	10
Shale, carbonaceous	1	0
Sandstone	5	0
Shale	1	6
Coal, canneloid above	1	9
Shale, dark	2	7
Sandstone, fine	1	2
Shale, arenaceous	1	6
Coal	0	4
Shale, carbonaceous, jet bands	0	9
Shale, arenaceous	1	1
Sandstone, medium grain	1	11
Shale	1	9
Sandstone, medium grain	2	2
Shale, dark	3	0
Concealed	6	0
Sandstone, massive	8	0
Coal	0	7
Shale	0	3
Concealed	2	0
Sandstone	6	8
Sandstone, fine, films dark shale	11	0
Coal	1	0
Concealed	1	0
Sandstone, fine	10	0
Shale, arenaceous	3	6
Shale, dark	3	2
Clay ironstone	4	3

Sections on Mogul Creek (G 1—G 2)—Continued

			Feet	Inches
Shale, arenaceous			1	7
Sandstone, fine, thin, flaggy			2	0
Shale, dark			1	10
Coal, Little Mogul seam			2	8
Shale			2	0
Sandstone, fine			9	0
Mogul seam—	Ft.	In.		
Coal	0	6		
Concretion	1	2		
Coal	2	8	4	2
Sandstone, fine			4	0
Shale, dark			0	9
Coal			0	6
Sandstone, fine			2	3
Coal			0	7
Shale, carbonaceous, fissile			0	5
Coal			0	3
Shale, dark			0	3
Coal			0	7
Shale, dark			1	5
Sandstone			4	0
Sandstone, massive			3	6
Shale			2	6
Coal			0	1
Shale			4	6
Sandstone, fine			3	1
Coal			0	5
Shale, dark, carbonaceous			0	4
Concealed			1	0
Sandstone, massive			6	0

Moosebar Creek Section (H 1—H 2)

	Feet	Inches
Shale of Moosebar formation		
Sandstone having scattered pebbles	1	6
Sandstone, thickbedded, estimated	9	0
Shale, arenaceous, estimated	1	6
Sandstone, grey, fine, estimated	8	0
Shale, dark, arenaceous	1	0
Shale, black, blocky	1	6
Shale, dark, somewhat fissile	0	3
Coal, Superior seam	3	8
Sandstone, argillaceous, in thick beds (1 foot to 2 feet), surfaces of some beds ripple-marked	15	0
Sandstone, fine, argillaceous, thin bedded	2	8
Shale, arenaceous, somewhat fissile	0	6
Coal	0	7
Shale, carbonaceous, fissile	0	5
Shale, shaly 3-inch clay ironstone band near base	7	6
Coal	0	8
Shale, carbonaceous, fissile	0	4
Sandstone, medium grain, massive	3	2
Sandstone, fine	3	3
Shale, arenaceous, 3-inch clay ironstone band at top	2	5
Shale, carbonaceous, fissile	0	8
Coal	0	3
Shale, fissile	0	3
Coal	0	3
Shale, arenaceous	4	0
Sandstone, massive	11	0
Sandstone, fine	2	0
Coal, 1-inch parting 4 inches from top, ½-inch parting 4 inches from bottom	1	5
Shale, carbonaceous, arenaceous	0	10
Sandstone and thin bands of arenaceous shale	9	6
Shale, dark, a few clay ironstone bands	13	0
Coal	1	0
Sandstone	0	4

Moosebar Creek Section (H 1—H 2)—Continued

	Feet	Inches
Coal	0	6
Sandstone	0	3
Coal	0	5
Shale, carbonaceous, fissile, jet bands, prostrate fronds	3	0
Sandstone, fine, argillaceous, rootlets	2	0
Shale, dark, some clay ironstone	6	6
Sandstone, fine, massive, weathering brown	1	6
Coal	0	8
Shale	0	3
Sandstone, argillaceous	0	9
Sandstone, massive, weathering brown	1	0
Shale	0	6
Trojan seam— Ft. In.		
Coal 2 1		
Sandstone 0 4		
Coal 1 6	3	11
Shale, black, carbonaceous, some jet, fissile	0	9
Sandstone, fine	2	6
Shale, dark	6	0
Sandstone, fine, massive, brown weathering	2	6
Shale	6	0
Sandstone, fine, massive, brown weathering	1	4
Shale, arenaceous	5	6
Sandstone, massive	0	9
Shale	2	0
Sandstone, massive, weathering brown	7	6
Shale	0	5
Shale, carbonaceous, fissile	1	0
Coal	1	8
Clay ironstone	3	9
Shale	1	6
Shale, hard	1	8
Shale, arenaceous	1	10
Shale, hard, carbonaceous	0	8
Coal	0	3
Shale	2	3
Shale, hard	2	0
Shale	1	8
Clay ironstone	4	3
Coal, 1-inch parting in middle	0	7
Shale	1	10
Coal	0	5
Shale, somewhat fissile	0	2
Sandstone, fine, in thin flags, shale films	3	4
Shale, dark	1	0
Shale, somewhat fissile, two jet bands	1	2
Sandstone, fine, massive	3	6
Shale	1	0
Coal	0	4
Sandstone, fine, shale lenses	1	7
Shale and clay ironstone	4	0
Coal	0	7
Shale, some coal and canneloid coal	1	8
Sandstone, hard, argillaceous	0	8
Shale	0	8
Clay ironstone	1	4
Shale	1	0
Coal, canneloid	0	10
Shale	0	6
Sandstone, massive	1	3
Coal	0	5
Shale	0	10
Clay ironstone	1	1
Shale and thick beds clay ironstone	6	0
Shale, carbonaceous, somewhat fissile; has jet bands	1	0
Coal	0	4
Shale, somewhat fissile, and having jet bands	1	0
Clay ironstone	3	0
Shale, jet bands	0	11

Moosebar Creek Section (H 1—H 2)—Continued

			Feet	Inches
Clay ironstone			1	3
Shale			0	2
Clay ironstone			1	3
Shale			6	6
Clay ironstone			0	6
Shale			1	10
Clay ironstone			1	0
Shale			1	10
Coal			0	2
Shale			1	0
Shale and thin clay ironstone bands			2	8
Clay ironstone			3	3
Shale, dark			0	8
Titan seam, correlated with—	Ft.	In.		
Coal	2	11		
Shale and argillaceous sandstone	0	9		
Coal	0	7		
Sandstone	0	2		
Coal	0	7	5	0
Shale, some jet			1	7
Sandstone, fine-grained, argillaceous, altered in places to arenaceous clay ironstone			9	6
Shale			1	6
Coal			0	7
Shale, arenaceous			1	2
Clay ironstone			1	5
Sandstone, fine-grained, thin beds of shale			2	0
Shale, arenaceous			2	0
Sandstone, fine grained			1	7
Shale, arenaceous			3	6
Shale			4	0
Coal			0	3
Clay ironstone			6	0
Coal, 2-inch parting 8 inches from top, 8 inches dull coal on bottom; large concretions; correlated with Falls seam			2	10
Shale, coaly			0	5
Clay ironstone and shale			3	4
Shale			2	0
Coal, canneloid			0	10
Shale, arenaceous			1	0
Clay ironstone			1	2
Shale			1	8
Clay ironstone			0	8
Shale, somewhat fissile, jet bands			1	5
Shale, and a few clay ironstone bands			19	4
Clay ironstone			4	0
Shale, dark			1	0
Shale, dark, a few jet bands			0	8
Coal			1	0
Shale, fissile			0	4
Shale, dark			0	3
Clay ironstone			4	9
Shale			0	7
Shale, dark, fissile			0	4
Coal			0	3
Shale			1	9
Canneloid coal			1	0
Coal			1	0
Shale, carbonaceous, jet bands			1	0
Sandstone, fine, argillaceous			1	5
Clay ironstone			0	4
Shale, dark, somewhat fissile			1	8
Sandstone, fine-grained			2	10
Sandstone, ripple-marked in thin layers; very thin beds and films dark shale			2	2
Sandstone and shale, very thin bedded			0	9
Coal			0	2
Shale, dark			2	0
Coal and 4-inch parting coaly shale			1	0

Moosebar Creek Section (H 1—H 2)—Continued

	Ft.	In.	Feet	Inches
Shale, coaly			0	5
Shale, fissile			0	8
Coal			0	5
Shale			2	0
Sandstone, argillaceous, brown weathering			1	2
Shale			1	8
Sandstone, argillaceous, brown weathering			2	0
Shale			8	0
Sandstone, argillaceous			1	0
Clay ironstone			0	9
Sandstone, argillaceous			1	8
Coal, large concretions			1	4
Shale, jet bands			0	5
Sandstone, fine grained and lined			1	5
Shale and jet bands			9	0
Shale, dark, carbonaceous			0	3
Coal, canneloid above			0	6
Shale			1	6
Sandstone, fine grained			3	8
Shale			6	0
Concealed			4	0
Shale			3	0
Sandstone, fine grained			17	0
Shale			1	0
Coal			0	11
Shale			0	8
Concealed			4	0
Sandstone in thin layers separated by thin shale bands			6	6
Shale			2	6
Coal			3	4
Shale			0	8
Sandstone			2	8
Shale and large clay ironstone concretions			7	0
Coal			0	4
Shale			0	6
Coal			1	1
Sandstone, fine grained, massive			7	0
Inaccessible at high third falls, estimated			44	0
Coal inaccessible, estimated			2	0
Inaccessible, estimated			16	0
Coal inaccessible, estimated			1	0
Inaccessible, estimated			26	0
Shale, carbonaceous, somewhat fissile, jet bands			0	6
Shale, arenaceous, carbonaceous, somewhat fissile			0	6
Sandstone, argillaceous, massive, prostrate plant remains			0	10
Shale, arenaceous, partly altered to arenaceous clay ironstone			2	11
Shale			1	0
Castle Point seam, correlated with—	Ft.	In.		
Coal	0	6		
Clay ironstone	1	0		
Coal	0	6		
Shale	0	6		
Coal	0	10		
Shale	0	7		
Coal	0	5	4	4
Shale, carbonaceous, fissile, jet bands			0	9
Shale and clay ironstone			4	6
Concealed			5	0
Sandstone, fairly coarse, massive			10	0
Shale			0	6
Coal, correlated with Milligan seam			2	5
Sandstone, argillaceous, fine, thin bedded or layered			8	0
Shale			1	11
Sandstone, massive			7	6
Shale, arenaceous			2	10
Shale			0	10
Coal			0	10
Sandstone and thin films black shale			3	0
Sandstone, fine, thick banded			3	0

Moosebar Creek Section (H 1—H 2)—Continued

	Feet	Inches
Sandstone, thin-layered	2	6
Shale, arenaceous, bedded; some clay ironstone and upright tree trunks	10	0
Concealed	10	0
Sandstone, massive	3	0
Sandstone	8	0
Shale	2	6
Coal	1	1
Shale, arenaceous	5	10
Coal, canneloid	0	2
Coal, jet	0	5
Shale, arenaceous, prostrate leaves	1	7
Shale, jet	0	6
Sandstone, medium-grain, massive	5	5
Shale	0	9
Shale, black, carbonaceous	0	6
Coal, canneloid	0	10
Shale, black	0	7
Coal, canneloid	0	2
Shale	0	3
Sandstone, fine, argillaceous	1	4
Shale	0	3
Coal	0	4
Shale, carbonaceous, prostrate plants	1	0
Sandstone, fine, argillaceous, thin layered	1	1
Shale, dark	0	8
Coal	1	6
Coal and shale	0	7
Coal	0	8
Shale, black	0	11
Sandstone, fine, argillaceous, prostrate plants	4	0
Shale, arenaceous	5	0
Shale, dark	1	9
Coal and 1-inch parting	1	2
Shale, dark	1	0
Shale, arenaceous	2	2
Shale, carbonaceous, somewhat fissile, jet	1	5
Sandstone, fine, massive, prostrate fronds	0	8
Sandstone, fine, massive	7	6
Shale and clay ironstone	2	6
Shale, dark, jet bands	2	0
Sandstone, medium grain	9	0
Shale, arenaceous	1	0
Sandstone, medium grain, massive	13	0
Shale	2	0
Coal	1	1
Shale	5	3
Shale, arenaceous	2	0
Sandstone, fine, massive, irregular bands of shale	4	0

South Bank of Peace River at Contact Point (J 1—J 2)

	Feet	Inches
Shale of the Moosebar formation		
Sandstone, having scattered small pebbles up to 3 inches	1	6
Sandstone, very fine, argillaceous, and thin bands of sandstone	11	0
Shale	6	6
Clay ironstone	3	6
Sandstone, and shale, very thin banded	2	0
Shale	0	10
Coal, Superior seam	2	8
Shale, black, carbonaceous	0	7
Sandstone and shale in thick bands	2	8
Sandstone and shale, thin banded	1	6
Coal	0	11
Shale	1	5
Shale and sandstone in thin, discontinuous bands	2	3

South Bank of Peace River at Contact Point (J 1—J 2)—Continued

			Feet	Inches
Coal and irregular parting			0	9
Shale, fissile			0	2
Shale			0	6
Sandstone, fine, carbonaceous, micaceous, argillaceous			1	10
Sandstone, thin bedded above, thick below, ripple-marked, thin shale bands			5	4
Shale, clay ironstone bands			2	3
Shale, fissile			0	7
Shale, somewhat fissile			0	6
Coal			0	1
Shale			1	2
Sandstone, fine, in thin layers; films of shale			4	0
Sandstone, fine, in thin ripple-marked layers; films of shale			4	8
Sandstone, fine, argillaceous			0	6
Coal			1	3
Shale, dark, carbonaceous, fissile, jet bands			0	6
Sandstone, thick layered, a few ripple-marked surfaces			3	10
Sandstone, thick layered, thin shale bands			3	0
Sandstone, fine, argillaceous, and shale, thin banded			3	9
Shale, arenaceous, clay ironstone bands			3	6
Concealed			3	0
Shale and 6-inch clay ironstone bands			4	0
Coal			2	8
Shale, arenaceous, and sandstone bands			4	6
Coal, Trojan seam			3	6
Shale, dark, carbonaceous, many jet bands			0	9
Shale, grey			1	0
Concealed			9	6
Sandstone and bands of arenaceous shale			10	0
Coal			0	7
Shale			0	4
Coal			0	9
Shale, carbonaceous, fissile, jet bands, prostrate plants			2	8
Clay ironstone			4	0
Shale, carbonaceous, fissile			1	0
Sandstone, very fine, argillaceous, layered			1	7
Shale, carbonaceous, jet bands			0	3
Sandstone, argillaceous			1	8
Shale, arenaceous			1	10
Sandstone, fine, argillaceous			0	10
Shale, dark			1	6
Coal			0	5
Shale			0	2
Shale, dark, arenaceous			2	0
Coal			1	9
Shale, dark, clay ironstone concretions			2	8
Coal			1	8
Shale, clay ironstone bands			3	8
Sandstone, fine, argillaceous, massive above, having shale bands below			3	6
Shale, dark, arenaceous, fine bands of sandstone			1	6
Coal, canneloid			0	2
Coal			0	5
Sandstone			0	4
Shale			0	2
Sandstone, fine, massive, argillaceous			1	3
Shale, plant remains			1	6
Shale, arenaceous, plant remains			0	6
Shale			1	6
Shale, dark			1	0
Titan seam, correlated with—	Ft.	In.		
Coal	2	8		
Clay ironstone	1	0		
Coal	2	6	6	2
Sandstone, fine			1	0
Coal, jet			0	2
Shale, dark grey			1	0

GEOLOGY OF THE NORMAN OIL FIELDS AND A RECONNAISSANCE OF A PART OF LIARD RIVER

By G. S. Hume[1]

CONTENTS

	PAGE
Introduction	1
Area of Liard river from Nelson river to South Nahanni river	48
Norman oil area, Mackenzie River district, N.W.T.	50
Copper ore from the north shore of Great Bear lake	63

Illustrations

Map 1977.	Mackenzie river between Norman and Beaver river, District of Mackenzie	50
Plate I.	"Rainbow arch" of Carcajou river. A good example of topography conforming to structure	127
II. A.	Carcajou Canyon section. The disconformity separates the brecciated beds below from the fossiliferous Devonian limestone above	128
B.	Brecciated beds on Bear Rock showing the character of the breccia fragments	128

INTRODUCTION

During the summer of 1922 the writer was engaged in a geological investigation of the Norman area, continuing the stratigraphic studies of the previous year along Mackenzie river and tributaries. The tributary streams investigated were mapped by a micrometer traverse, sextant observations being taken where practicable. The base map of the Mackenzie on a scale of 4 miles to 1 inch was supplied by the Topographical Survey, Department of the Interior, from their surveys of the previous year. The object of the work undertaken was to prepare a geological map and to determine the major structural features and conditions of sedimentation which have a bearing on the oil situation.

G. W. Bain acted ably as assistant and the greater part of the micrometer surveys of the tributary streams was performed by him. The writer wishes to thank the officials and post-managers of the various Trading Companies, and the Imperial Oil Company for courtesies and assistance. He is also indebted to Dr. C. D. Walcott for identification of Cambrian fossils.

[1] *Itinerary of Parties under G. S. Hume and M. Y. Williams.* Through the co-operation of other departments with the Topographical Survey, Department of the Interior, a winter road was constructed from Fort St. John on Peace river northwest to Sikanni Chief river, a distance of approximately 155 miles. This trail was constructed in the expectation that the open water of Mackenzie river could be reached much earlier than by the usual water route across Great Slave lake, and the brief working season in the north would be lengthened. Supplies of horse feed were cached along this road and equipment for the various survey parties was left at a cache on the Sikanni Chief before the snow had melted. This trail is of importance to many interested in the Mackenzie, and the trip will, therefore, be treated in detail.

Following the break-up in the spring, a topographical survey party under B. H. Segré, D.L.S., and an astronomical party from the Dominion Observatory under A. H. Miller, crossed by pack train from Fort St. John to the cache on Sikanni Chief river. Two geological parties, under the direction of Dr. M. Y. Williams and the writer, immediately followed the other parties. The route from Edmonton, Alberta, was by train to Peace River Crossing, and by motor boat up Peace river to Taylor flats 16 miles east of Fort St. John, B.C. Here thirteen pack horses were procured, and the party started on May 16. A wagon accompanied the pack train for 35 miles, or as far as Blueberry river, in order to save the horses for the more difficult journey beyond. This first 35 miles was partly through settled country in the vicinity of Fort St. John and for a considerable part of the distance over fine, open, rolling country, some of which has been taken up for ranching. Other parts were wooded, mostly with poplar and birch, and some spruce, but

AREA OF LIARD RIVER FROM NELSON RIVER TO SOUTH NAHANNI RIVER

At Fort Nelson the Liard is flowing through a country which at some distance back is elevated considerably above the level of the river. Steep cut banks occur along the river and in places consist of soft, Cretaceous, sandy, and dark, shales. No other exposures were found on the main river other than those described by McConnell[1] and the fossil content, although showing the age, was poor and meagre, especially the Cretaceous.

MOUNTAINS OF LIARD RIVER

North of the 60th parallel, Liard mountains begin to appear in the west. When they were about 11 miles distant, a trip was made to them across a country densely wooded with poplar, birch, and spruce. Some muskeg was encountered, but it was not as prevalent as usual in this region. The topography is rolling, with some linear ridges, one of which—in front of the mountain—is particularly marked, and is composed of fine conglomerate and coarse sandstone, presumably Cretaceous, since it is similar to a sandstone that overlies Cretaceous shale on Fort Nelson river. The strike of this sandstone ridge is much the same as the formation, namely south 7 degrees west (astronomical) and the dip of the rocks is east 38 degrees. The pebbles of the conglomerate are all well rounded. A deep valley, slightly over 2 miles wide, separates the crest of this ridge from the base of the mountain. The rock on the edge of the mountain is for the most part shale, with some sandstone fine grained in comparison with the other. *Inoceramus* was the only fossil found and suggests a Cretaceous age. The strike of these Cretaceous beds varies somewhat, but is about south 2 degrees west (astronomical); the dip varies from 30 degrees to 80 degrees to the east. A rough measurement showed not less than 800 feet exposed. Below this, forming the core of the mountain, Carboniferous rocks, much disturbed and tilted, carry a Brachiopod fauna. The contact between the two was not seen.

[1] Geol. Surv., Can., Ann. Rept., 1888-89, vol. IV, p. 53 D, etc.

with long stretches of fairly open country between. Blueberry river is very subject to flood and had to be rafted. Beyond the Blueberry the country was not so open; muskeg was more prevalent, and a bush trail through some very marshy country greatly delayed progress. A considerable part of the country has been burnt over, the resultant brûlé being most difficult to traverse.

The North Pine was the largest river encountered, but it was found to be less difficult to cross than some of the smaller, faster streams, where floating bridges had to be built. The time taken from Taylor flats to the cache on Sikanni Chief river, about 155 miles, was 15 days.

When Peace river was left on May 16 the trees were beginning to leaf. As progress was made over the trail to the west the deciduous trees were bare and the country had the appearance of very early spring. The frost was rapidly coming out of the ground and the water in the muskeg made travelling unpleasant and difficult. The only food for the horses other than what had been cached was the long, dry grass of the previous year that contained little sustenance. The young grass was already beginning to appear and on sunny slopes had even made considerable growth. The change from the upland into the valley of Sikanni Chief river about 900 feet lower was very striking. From a country of little growth, even at the end of May, spring growth in all its vigour was come upon. The trees were in leaf, green grass was plentiful, and early spring flowers were everywhere abundant. The view of Sikanni valley in all its spring beauty was really magnificent. On May 31, the day of arrival in the valley, the thermometer registered 110 degrees in the sun.

Those contemplating this journey are advised to start still earlier in the spring. The frost in the muskeg gives solid footing for the horses, and the water is less troublesome. The rivers

Age of Mountain Building—Post-Cretaceous in both Liard and Mackenzie Areas

The importance of the above section lies in the fact that it establishes the age of the mountain building as definitely later than the Cretaceous. At no other place either on the Liard or in Mackenzie mountains has any Cretaceous been found folded into the mountains, although the structure would indicate for the Mackenzie an age for mountain building the same as in the Liard area. In fact, from Nahanni butte, at the junction of South Nahanni and Liard rivers, to Lone mountain, at the junction of North Nahanni and Mackenzie rivers, there is a mountain range broken only by a few minor stream gaps.

CRETACEOUS BOUNDARY IN LIARD AREA

On McConnell's map[1] the edge of the Cretaceous is approximately in accord with the present writer's observations, the mountain to the north of the 60th parallel west of the Liard being the one in which Cretaceous beds were seen. At this point the boundary is slightly farther west than is indicated on the map and is between the Cretaceous and Carboniferous instead of between the Cretaceous and Devonian strata.

OTHER LIARD MOUNTAINS

The arrangement of Liard mountains en echelon along Liard river is apparent from McConnell's map. There are no mountains to the east of the river so that the river flows around the end of the mountains rather than across them. At Fort Liard a long, sloping mountain comes almost to the river. This is composed of very hard, cherty limestone that was formerly designated as Middle Devonian. No fossils could be found and, because rock lithologically similar is known to occur in the Carboniferous, this limestone is tentatively assigned to that age.

At outcrop 39 (McConnell's map) rock of Carboniferous age carries a Brachiopod fauna. The mountains to the west are also composed of

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[1] Geol. Surv., Can., Ann. Rept., 1888-9, vol. IV.

are not dangerous, even in flood, and the swifter streams that have to be rafted are merely troublesome. However, feed for the horses has to be considered.

Sikanni Chief river at the time of arrival was at a comparatively low water stage. Two scows had been built for the use of the parties, but the upper part of the river is much too shallow and dangerous for scow navigation. The sharp bends of the river combined with swift water undercut the banks at every bend and into these places trees had fallen from the banks and formed jams. From these logs ice strips away the limbs, leaving jagged points, that are a real danger to the scows which are forced into the jams by the strong current. Sweepers, or overhanging trees not completely dislodged from the bank, were numerous and difficult—in places impossible—to avoid. Sandbars were abundant, the river at times splitting into several shallow channels, so that the scows frequently grounded and were floated only after great trouble. Below Fontas river, navigation improved with deeper water, but was never satisfactory for scows until Fort Nelson was reached. For canoes the whole river is easily navigable and would be so even were the water lower. The trip by canoe from the cache on Sikanni Chief river to Norman on the Mackenzie is about 900 miles. The only large rapids are those of the Liard, above Simpson, and these can be easily run by keeping close to the bank on the southeast side of the river.

The advantage of this route is that it enables the traveller to reach the Mackenzie about a month before navigation through Great Slave lake is possible.

The month thus gained in the spring increased the working season by one-third and that, too, when weather conditions were more favourable than later.

Carboniferous rocks, but with a different fauna.[1] These mountains rise to an elevation of 1,300 feet above the river 2 miles from it and with strata dipping away from the river. To the north, other mountains appear in front of this range, and the dip of these is toward the Liard. Both these ranges are, really, only part of the same fold, the axis of which is now eroded to form the deep valley which separates the two mountains.

NORMAN OIL AREA—MACKENZIE RIVER DISTRICT, N.W.T.

GENERAL STATEMENT

On the east side of the Mackenzie the Norman oil area is confined to the country north of Bear Rock at the mouth of Great Bear river and south of the sharp anticlinal ridges opposite the mouth of Carcajou river. On the same side of the river, the area is bounded by the Norman or Discovery range of mountains on the east. On the west of the Mackenzie the northern and southern boundaries are not so sharply defined and the area is of considerably greater extent than on the east. It is sharply defined to the west, however, by mountains of Middle Devonian and older rocks. These mountains—called the Carcajou—are drained by various branches of Carcajou river.

PROGRESS OF DRILLING OPERATIONS

After the initial success at No. 1 well, on the east bank of the Mackenzie, 53 miles north of Norman, the Imperial Oil Company began three other wells. One of these, the Bluefish Creek well, is situated at the mouth of Bluefish creek about 8 miles down the Mackenzie from Norman. Bear Island well is on an island about 2 miles from No. 1 well and "C" camp well is a little farther up on the west bank. In none of these wells has any oil been obtained. Owing to drilling difficulties operations ceased and no further work was done until the autumn. "C" camp is the deepest well—1,704 feet—but as it is down the dip of the rocks from No. 1 well, it is not certain that it has reached the horizon from which the last supply of oil was obtained in No. 1 well.

During 1921 the Mackenzie River Oil Company drilled to the depth of about 1,510 feet, 8 miles south of No. 1 Imperial well and on the same bank of the river. Gas was obtained in this hole and used in a cabin throughout the winter for heating purposes. No attempt was made in 1922 to complete this well.

As is generally known the flow of oil from No. 1 well gradually decreased from a gusher of great promise until production almost ceased. This was attributed by some to failure of the oil supply, but, as a fact, the bottom of the hole, which was in a shale formation, had caved in and effectively prevented the entrance of oil in any quantity. During the summer of 1922 this hole was deepened to 951 feet and another flow of oil of 60 to 70 barrels a day was obtained. Although such a flow is not such as to indicate that any immense wells will be "brought in," it does demonstrate that oil is present in quantity and gives hopes that many such wells may be found.

[1] The fossils from the rocks west of the river indicate that the western part of this mountain mass is of Carboniferous age and represents a Kinderhook horizon equivalent to Château-Fern Glen time with possibly some of Lower Burlington time. An account of the correlation with fossil lists is published in the American Journal of Science.

Canada
Department of Mines

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR.

Issued 1923

LEGEND

EOCENE — T — *Coarse and fine sandstone, shale, conglomerate*

CRETACEOUS — K — *Sandstone, shale*

UPPER DEVONIAN — D3 — Bosworth formation (*sandstone and shale*)

UPPER DEVONIAN — D2 — Fort Creek formation (*shale*)

MIDDLE DEVONIAN — D1 — Beavertail *and* Ramparts formations

SILURIAN — S2 — Bear Mt. formation (*brecciated limestone*)

SILURIAN — S1 — Bear Mt. formation (*red gypsiferous shales, bedded limestone*)

ORDOVICIAN? — O — *Red shales*

CAMBRIAN — Ꞓ — *Green and red shales*

Symbols

Geological boundary (assumed)

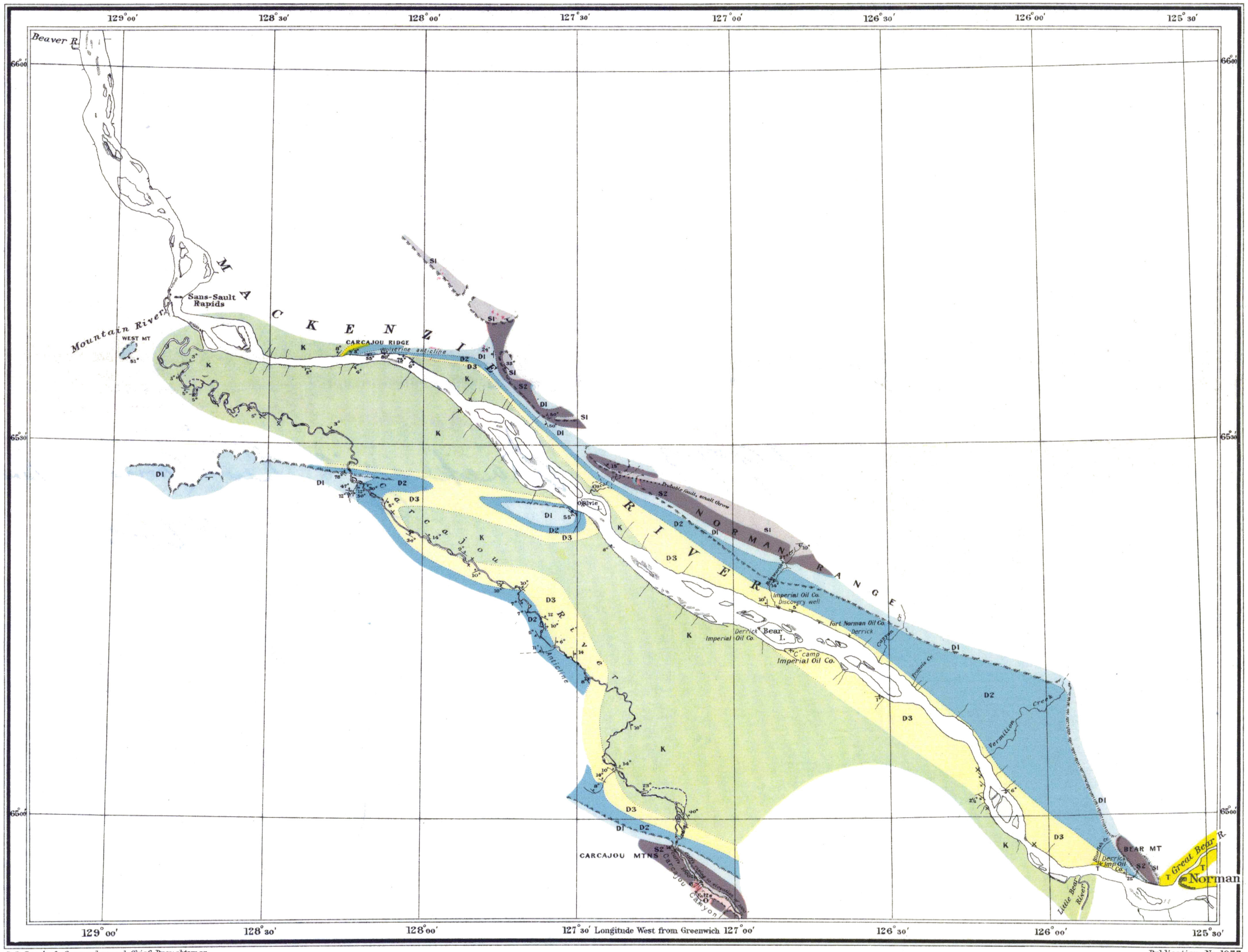
Fault (assumed)

Dip and strike

Rock outcrop

Escarpment

Approximate magnetic variation 42° East



C. O. Senécal, *Geographer and Chief Draughtsman*
J. O. Fortin, *Draughtsman*

Publication No. 1977

MACKENZIE RIVER BETWEEN NORMAN AND BEAVER RIVER, DISTRICT OF MACKENZIE.

Scale of Miles

10 5 0 10 20

SOURCES OF INFORMATION
Geology by G. S. Hume, 1922.
Base-map from surveys by G. S. Hume, 1922, and the Topographical Surveys Branch, Department of the Interior, 1921, 1922.
Map compilation by J. O. Fortin.

To accompany report by G. S. Hume, in Summary Report, Part B, 1922.

DESCRIPTION OF RIVERS AND STREAMS IN THE NORMAN OIL AREA

Carcajou River

Carcajou river has two main branches and a number of minor ones. The branch that drains farthest from the south issues from the mountains through a deep canyon with precipitous sides 1,000 feet above the bottom of the valley. For 10 miles in the mountains the river follows the strike of the rock formations and has cut down into the soft materials underlying the hard Silurian limestones. Where the river issues from the mountains it has had to cut across the harder Silurian and Devonian beds so that, within the canyon, the river has become fairly well graded. It decreases in velocity on issuing from the canyon and drops much of its load, and a broad flat has been built up through which the river flows by many intricate channels. Farther on, it again becomes one channel and has cut down 300 to 400 feet below the surrounding country. About 50 miles from its mouth it passes through a minor fold which brings hard Middle Devonian rocks to the surface in a ridge extending eastward from a point opposite Ogilvie island. For the remainder of the distance to the Mackenzie the river flows over Cretaceous rocks and has cut deep into the banks, giving high exposures of shale up to 250 feet thick in individual sections. Near the mouth the banks are all clay and the country is low.

There is only one rapid—a small one—between the mountains and the Mackenzie. Throughout long distances the current is fairly rapid, but there are long stretches where the current does not exceed 2 to 3 miles, and is even less. The country along the river banks is densely wooded and there was plenty of evidence of game, although little was seen. The Canada goose nests along the river, and tracks of wolves and foxes were abundant. Other game consisted of moose and caribou; in the mountains there are sheep.

CREEKS ENTERING THE MACKENZIE FROM THE NORMAN RANGE

Three creeks—Vermilion, Canyon, and Bosworth—were traversed. All come from the Norman range and are of about the same character. Within the mountains are falls and canyons, the latter being exceptionally well developed on Canyon creek. In the flat country west of the Norman range these creeks at low-water stage exhibit wide gravel beds with small streams flowing through.

Vermilion creek is the largest of the three, but is not navigable for a canoe. It receives its name from many exposures of brick-red shale which has resulted from an alteration of the black Fort Creek shale. A peculiarity of this stream is that in low-water stage it receives about half its water from springs about 6½ miles from the mouth. These springs are situated on the crest of a very minor anticline in the Fort Creek shale and the water issuing from them smells strongly of hydrogen sulphide.

GENERAL GEOLOGY

Table of Formations

Age	Name of formation	Sedimentation	Thickness
Eocene		Imperfectly consolidated	Sands, clays, etc.
		Erosional unconformity	
Cretaceous		Black, soft, fissile shales Greenish sandstone	Marine fossils (Ammonites), in part. Coal seams on Little Bear river
		Erosional unconformity	
Upper Devonian	Bosworth	Green sandstones and shales	1,600+
	Fort Creek	Black shales, mostly	1,500+
Middle Devonian	Beavertail and Ramparts Hare Indian River shales (not present in the Norman area)	Limestones	650 to 700 feet
		Disconformity	
Silurian	Bear Mountain[1]	Brecciated limestone Well-bedded limestone Red gypsiferous shales	400 to 450 1,000+
Ordovician?		Red shales (no fossils)	770 (Red gypsiferous shales through Cambrian)
Cambrian		Red and greenish shales and sandstone Bottom not seen	

[1] *See* Kindle, E. M., and Bosworth, T. O., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 45.

Cambrian and Ordovician?

Section in Carcajou mountains		Feet
Hard, dense limestone of Silurian age		
Thin, platy limestone with some shale		3
Heavy massive dolomitic limestone		2
Very soft, green shale that crumbles easily		3
Heavy, massive buff limestone, arenaceous in some beds		3
Soft shale deep brown in colour		6
Hard, buff limestone		10
Greenish shaly limestone		2
Soft, red shale with some gypsum—forms a talus slope, in part no exposure—mostly red beds		200±
[1]Black and grey shale with many hard limestone layers		250±
Black to greenish shale with limestone bands weathering to a yellow colour		50
Band of dark coloured hard limestone that breaks into platy layers		3
Black shale with layers of dark limestone		65
Hard, dark coloured, sandstone, almost a quartzite in hardness, with fine needles of barite		3
Shale, green on fresh exposure but weathers yellow or reddish		10
Heavy bed of limestone		2
Shaly limestone		2
Arenaceous limestone breaking into layers 3 to 4 inches thick		10
Heavy-bedded sandstone, greenish in colour		8
Green shale, 3 inches		
Limestone band, 4 inches		
Green shale, 3 feet	Fossil zone	
Limestone band, 2 inches		
Green shale, 1 foot		
Limestone band, 2 inches		12
Green shale, 1 foot	Middle or Upper	
Black shale, 1 foot	Cambrian fossils	
Green shale, 3 feet		
Green sandstone with fine quartz grains, 1 foot		
Green shale, 1 foot		
Red shale with layers of limestone		4
Platy, dark green, limy shales		3
Red shale alternating with some layers of green shale		20
Platy limestone breaking into slabs, 3 or 4 to the inch, dark green in colour		12±
Red shale with hard, oval nodules 2 to 3 inches in diameter		2
Black, platy, shaly limestone or limy shale with thin bands of limestone		12
Red shale with 2-inch bands of red limestone and nodules as above arranged, along what has probably been bedding planes. Layers of nodules break shale exposure into bands, but otherwise the bedding is indistinct. Nodules hard and limy		82
Bottom not exposed		
		769

The fossils were identified by Dr. C. D. Walcott as *Paterina* sp. and *Ptychoparia* sp., indicating Middle or Upper Cambrian age. Other than these there is nothing by which to fix the age of this section below the hard, massive Silurian beds. In fact the Silurian is very unsatisfactorily separated from the sediments below and in no place could the writer unhesitatingly draw a dividing line. In the Bear Mountain section Kindle[2] puts "red gypsiferous shale," etc., in the Bear Mountain series of Silurian age. In the Bear Mountain section there are no fossils to indicate the age of these gypsiferous beds, although a Silurian fauna is found higher in the section. Williams[3] includes possible Ordovician rocks in his section from the Wrigley area, but no Ordovician fossils have been definitely determined.

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[1] In a section east of the Mackenzie and on mount Charles, Great Bear river, the position of the 250 feet of black and grey shale is occupied by white gypsum beds and brecciated limestones. Another series of brecciated limestones occurs immediately above rocks of undoubted Silurian age.

[2]Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 44.

[3] Williams, M. Y., Geol. Surv., Can., Sum. Repts., 1921 and 1922.

The section is not all exposed at one place and several stratigraphic breaks probably occur between the Silurian and the Cambrian, but so far none has been revealed. The section thus measured may include beds from Cambrian into the Silurian and it is questionable if the Ordovician is represented at all.

Silurian

Rocks of undoubted Silurian age occur in Carcajou mountains; and in Norman range, where they form the top of the range and the cliffs, 800 feet or more in height, that face eastward. They are also prominent in the mountains to the north of Norman range but do not outcrop on the Wolverine anticline (Carcajou ridge). In the Bear Mountain formation Kindle placed some brecciated limestones in the Silurian (Plate II B). These brecciated limestones are not as thick on Bear mountain as elsewhere, and are well exposed in the Carcajou Mountain section. In a section east of the Mackenzie, on a range of mountains north of the Norman range, it was found that this brecciated limestone did not occur as such, but in the same position stratigraphically were gypsum beds. This then seems to have some connexion with the breccia, which may possibly be due to the change of anhydrite to gypsum. Wherever the limestone was found the evidences of bedding were very slight, and rounded to angular pieces of limestone in a limestone matrix were abundant. The brecciated limestone in Carcajou River area was 450 feet thick and there was a distinct break in sedimentation separating it from rocks below containing Silurian fossils. This break in sedimentation could be traced along the cliffs of the canyon made by Carcajou river and is the most pronounced break seen in the whole section below the top of the Devonian. A somewhat less pronounced disconformity is evident at the top of the brecciated limestones, separating them from fossiliferous Devonian strata (Plate II A).

The brecciated limestone was included by Kindle in the Bear Mountain formation, and overlies a series of hard, massive limestones that contain in most places a very meagre Silurian fauna. On parts of Norman range and in Carcajou mountains these limestones were nearly 1,000 feet thick, but on Bear mountain were somewhat less.

In Carcajou mountains the following fossils were found:

Halysites catenularia
Favosites sp.
Plasmopora sp.

A much larger fauna came from the same series of rocks in the Mount Charles section, Great Bear river. The list is as follows:

Halysites catenularia
Halysites catenularia var. *microporus*
Halysites catenularia cf. *nitidus*
Halysites catenularia var. In parts of this fossil the corallites are closely bunched and packed together, but in other parts of the same species there are large meshes.
Diphyphyllum sp.
Plasmopora sp.
Cyathophyllum, 2 species
Favosites with corallites about same size as in *F. niagarensis*
Syringopora, 2 species
A number of cephalopods all with mummuloid sephuncles

Some of the beds of this series are very arenaceous, especially those directly under the brecciated limestone, and in places form a sandstone very indurated and unfossiliferous. In the Norman range all the Silurian was very unfossiliferous and only fragmentary Halysites and some poorly preserved Stromatoporoids were seen.

Devonian

Beavertail and Ramparts Limestones. As originally defined by Kindle, the Ramparts limestone containing *Stringocephalus burtini* was separated from the Beavertail limestone. This fossil is of very local occurrence and where absent it is impossible to divide the Beavertail from the Ramparts limestone for mapping purposes. It is true that the top of the Beavertail is hard, dark limestone, whereas the Ramparts containing *Stringocephalus* is buff to grey, but the hard, dark limestone grades downwards without break into limestone of similar character to the Ramparts. Moreover, in the Wolverine anticline (also called Carcajou ridge), in a section that can be readily measured, *Stringocephalus* was found 60 feet below the Fort Creek-Beavertail contact. The Beavertail limestone would then have to be confined to the upper 60 feet. On the basis of fossils, however, a distinction of horizons can be made within the limestones, at least two such distinct horizons being easily recognizable but not very closely confined in vertical range. The lower is easily identified by the profusion of corals both simple and compound. From the Ramparts limestone at the head of Canyon creek the following fossils were obtained:

Cystiphyllum vesiculosum
Cystiphyllum americanum
Cyathophyllum cf. *spenceri*
Cyathophyllum sp.
Heliophyllum cf. *halli*
Phillipsastræa verneuili
Syringopora sp.
Zaphrentis sp.
Paracyclas cf. *elliptica*
Atrypa spinosa
Proetus sp.

From a small tributary of Carcajou river about 50 miles from the mouth the following were obtained:

Cystiphyllum sp.
Cystiphyllum vesiculosum
Cyathophyllum cf. *spenceri*
Cyathophyllum quadrigemum
Cyathophyllum cæspitosum
Cyathophyllum aggregatum
Heliophyllum cf. *halli*
Phillipsastræ verneuili
Phillipsastræ verrilli
Atrypa reticularis
Atrypa spinosa
Bryozoans in abundance

From a lower horizon in the limestone series, presumably in what was originally included in the Ramparts, and from the south end of the Wolverine anticline:

Cyathophyllum sp.
Palæocyclas kirbyi
Schuchertella somewhat like *chemungensis* but smaller
Paracyclas cf. *elliptica*
Atrypa reticularis

From Canyon creek on same horizon:

Palæocyclas kirbyi
Atrypa spinosa
Atrypa reticularis
Schuchertella same species as above
Productella sp.

Of these fossils *Palæocyclas kirbyi*—a flat coral—is very peculiar and has hitherto been reported only from Porcupine river, Alaska, from which place it was described by Meek.

At the north end of the Wolverine anticline, in the 60 feet between the Fort Creek shale and the beds containing *Stringocephalus burtini*, was found the following fauna:

Martinia cf. *meristoides*
Cyrtina sp.
Atrypa reticularis
Reticularia sp., a large form—abundant
Chonetes sp., very small
Leiorhynchus sp., a large form
Productella sp.
Stringocephalus burtini 60 feet below the contact with the Fort Creek shales

In this there were several beds completely filled with bryozoans.

Of the fossils found in these beds, which must be taken as the Beavertail beds at this place, *Reticularia* was especially abundant and characteristic. Excepting *Cyrtina* the other fossils occurred elsewhere at approximately the same horizon, but in much less profusion. The rocks here are well-bedded limestones and just slightly shaly. At other places the same horizon is dense, hard, black limestones that are for the most part unfossiliferous. It is these latter that were described as the Beavertail limestones and indeed they are far more typical of the area as a whole than are the fossiliferous beds occupying the same stratigraphical position at the Wolverine anticline.

Contact Beavertail and Fort Creek Shale. Along the southern end of the Wolverine anticline the contact between the Beavertail limestone and Fort Creek shale is sharp, although a few thin layers of limestone do occur in the shale towards the bottom. However, elsewhere the contact was seen in several places and not always so sharply divided. On Bosworth creek at the base of the mountains the following section occurs:

Hard brittle shale of the Fort Creek.	
Limestone band of fine texture and very persistent in character and thickness	18 inches to 2 feet
Limestone with irregular bedding 2 to 3 inches thick and with some shaly material. Abundant fossils, particularly Bryozoans. A few poor cup corals and *Atrypa reticularis* abundant in some places	8 feet
Hard, dark, bituminous limestone of the Beavertail formation.	

It is the 10 feet of intermediate beds that appear to represent a gradation, although the contact with the brittle shale above as well as with the dark limestone below is very sharp.

These beds seem to be more nearly related to the Beavertail formation and are, therefore, included with it rather than with the Fort Creek formation.

On the north end of Wolverine anticline the section is as follows:

	Feet	Inches
Brittle shale—*Goniatites* and *Leiorhynchus*		
Limestone band	2	
Shale	27	
Probable contact between Fort Creek formation above and Beavertail limestone below		
Massive limestone—Bryozoans and *Recticularia*	2	
Dark shaly limestone—thin bedded	1	
Dark limestone with small *Chonetes*	2	
Hard limestone		3
Dark limestone with small *Chonetes*	1	
Hard, blue limestone	1	
Hard limestone—*Productello* common	1	
Hard, blue limestone—*Recticularia, Atrypa,* and *Leiorhynchus*	3	
Hard, blue limestone	1	
Hard, blue limestone—*Productella*	5	
Thin, shaly bed—*Recticularia*		2
Bryozoan limestone	4	
Massive limestone	4	
Shale	1	
Limestone—*Atrypa* and Bryozoans	2	
Shale	1	
Limestone	2	
Shaly limestone—*Atrypa recticularis* common	6	

On the south end of the Wolverine anticline about one-half mile up river from this other exposure, in beds with a very steep dip, *Stringocephalus burtini* occurs in beds 60 feet lower stratigraphically than an exposure of the typical Fort Creek shale which is exposed only at a low-water stage of the Mackenzie.

Both of these sections indicate something of a transition from the limestones to the shales above, but elsewhere the contact was sharp. Even farther south, along the Wolverine anticline, the division is abrupt. The same may be said of the contact on Carcajou mountains and west side of Bear mountain.

Fort Creek Shales. These are about 1,500 feet in thickness in the Norman area. The best exposures are found up Vermilion and Canyon creeks and on Carcajou river. The contact with the underlying Beavertail has already been described; there is a gradual change upwards into the Bosworth sandstone and shale so that the exact division point is arbitrary. The formation is for the most part composed of black shales that contain a great deal of bituminous matter.

Above the Beavertail limestone is a zone containing a great many Leiorhynchids and an occasional *Stropheodonta*, but fossils as a rule are rare in this formation. The basal part is composed of hard, brittle shale that in places has the resistance and appearance of slate without the slaty cleavage. It breaks irregularly into thin, hard layers that show some sulphur stain. This brittle shale gradually passes into softer shale that crumbles very readily and contains more sulphur in places, giving the whole surface of an exposure a yellow colour. Within this soft shale on Canyon and Vermilion creeks a sandstone horizon 50 to 70 feet thick was found about 800 feet above the base of the formation. This sandstone weathers to a buff colour and is significant as being a possible reservoir for oil in the Fort Creek formation itself. No definite information as to the extent of this sandstone member has been obtained. It was not seen on Carcajou river or on Bosworth creek, but being in soft shale which crumbles down readily over harder layers it may easily be concealed.

The shale above the sandstone is much softer than that near the base of the formation, but no fossils were found, except in a few beds at the bottom.

A peculiarity of the shale is that in places it has turned to a bright red colour, giving Vermilion creek its name. Kindle ascribed this to slow combustion of the bituminous matter. On Carcajou river, at one point where red and yellow shale had been formed from the black shale, clinkers were observed.

On Vermilion creek several small dykes were found cutting the Fort Creek formation. This was the only place where igneous rocks were discovered in the Norman area.

Bosworth Sandstone and Shale. The most continuous section of the Bosworth sandstone was seen on a small tributary of Carcajou river. The Fort Creek shale grades upwards into the Bosworth shale, there being a gradual change from a black to a greenish colour and the introduction of sandstone layers with a minor amount of limestone layers. The thickness in this section was 1,600 feet and the top was not seen. Between the top of the exposed part and the Cretaceous beds there is an unexposed interval of 600 feet. Part of this is probably Bosworth sandstone and shale, so that the thickness may be as much as 2,000 feet.

	Feet
Cretaceous sandstone	
Interval not exposed	600
Green, sandy shale with only a little sandstone	435
Green sandstone and shale with considerable sandstone towards the top in beds never more than 1 foot thick and much more shale towards the bottom—*Spirifer* sp	295
Heavy-bedded sandstone	30
Green shale with a few small layers of sandstone	30
Green sandstone that has irregular fracture	20
Sandy, green shale	100
Green shale with some limy layers—fossils occur—mostly *Atrypa reticularis*	350
Greenish shale passing downwards into the black Fort Creek shale without break	350
Black Fort Creek shale	

On the Mackenzie about a mile west of Bluefish creek the following fossils were found:

Streptelasma cf. *rectum*
Diphyphyllum sp.
Phillipsastræa verrilli
Phillipsastræa verneuili
Acervularia davidsoni
Atrypa reticularis
Stropheodonta cf. *perplana*

About 2 miles south of Vermilion creek on the north shore of the Mackenzie the following fossils were found:

Diphyphyllum sp.
Syringopora hisingeri?
Acervularia davidsoni
Aulopora sp.
Atrypa reticularis
Stropheodonta cf. *perplana*
Atrypa spinosa
Schizophoria striatula

This outcrop is about the same stratigraphic height as the one near Bosworth creek.

On Carcajou river one outcrop deserves special mention because it contains *Spirifer disjunctus* and *Camarotoechia contracta*. This outcrop was of beds very low down in the Bosworth formation. The fauna here is similar to that found in the *Leiorhynchus* zone of the North Nahanni-Root Rivers section and is thought to represent a stratigraphical equivalent. On account of differences in the character of the sediments between the Norman and Nahanni-Root Rivers areas it is difficult at present to correlate the strata of the two areas. In the Norman area brachiopods are not abundant in the Bosworth formation and no *Athyris angelica* was found, which was so common along with various spirifers in the *Athyris angelica* zone of the Nahanni-Root Rivers area. A comparison of the thickness of the Upper Devonian from the two areas shows much thicker sediments in the Nahanni-Root Rivers area and it is the writer's opinion that there is Devonian in this section that is younger than any Devonian found in the Norman area. It is possible that the *Athyris angelica* zone and later Devonian of the Nahanni-Root sections is not represented at all in the Norman area.

Cretaceous

An erosional unconformity separates the Bosworth sandstone and shale from the overlying Cretaceous deposits. The contact is well exposed on the north bank of the Mackenzie north of the Wolverine anticline where the effect of the erosion prior to Cretaceous deposition is very marked. The basal beds of the Cretaceous are sandstones with very soft fissile shale higher up. There are large cliffs of this shale exposed along the lower part of Carcajou river, and on the Mackenzie itself south of the Wolverine anticline there are some thick exposures. On the Mackenzie, from nodules in the shale, a number of ammonites were found.

In other localities *Inoceramus* sp. was abundant.

The thickness of the Cretaceous is unknown, but is at least several hundred feet.

STRUCTURAL GEOLOGY

The mountains of the Norman oil area are for the most part gigantic folds, some of which are very sharp but with very little faulting. The Norman range rises to an elevation of 2,550 feet above the Mackenzie and is composed of a westward-dipping series of rocks of Silurian and Devonian age. The range itself east of Imperial Oil well No. 1 is the west half of a huge anticline, the axis of which has been so eroded as to leave a deep valley to the east and very abrupt eastward-facing cliffs on the range itself.

The next mountain to the north, separated from the Norman range by a gap through which drains Oscar creek, is just the reverse of the Norman range. It is the eastern half of an anticline, the western half of which has been completely eroded away. The rocks dip east, and in front of the westward-facing cliff is a country without rock exposure and covered with muskeg and almost innumerable lakes. On the northern end of the Norman range the evidence of faulting can be seen, and it seems probable a fault cuts through the gap now occupied by Oscar creek.

The mountain indicated on the map to the north of Oscar mountain is different from either Oscar mountain or the Norman range. It represents mainly the axis of an anticline of which both flanks have been partly eroded. On the north end on the west side the dip of the strata is very steep, and the highly tilted beds form in part the edge of the mountain. This is also true of part of the south end on the west face, but elsewhere erosion has removed the tilted beds leaving prominent cliffs, a feature which characterizes the eastern side of the mountain. At the south end, west of the main mountain, there is a small escarpment of Middle Devonian limestones dipping 50 degrees to the west, and with a cliff towards the main mountain from which this minor ridge is separated by a valley, the result of erosion of the brecciated beds of the top of Bear Mountain formation, which here consist mostly of gypsum. The Middle Devonian beds are in reality, therefore, only the western flank of the anticline of which the mountain forms the axis. These steeply tilted Middle Devonian rocks form a ridge slightly elevated above the muskeg flat at the base of the mountain, the ridge being easily traced to the western edge of the Wolverine anticline or Carcajou ridge where it outcrops along the Mackenzie.

The Wolverine anticline (Carcajou ridge) has been described by Kindle and Bosworth.[1] The dips along the Mackenzie are mainly steep, with the contact between the Beavertail and Fort Creek formations exposed at many places at low water. On both flanks of this anticline Cretaceous beds occur, and, at some little distance from the main line of disturbance, are almost horizontal. However, there is no reason to assume they did not originally cover the whole Devonian, for the folding dies out rapidly. As was shown for Liard mountains, the folding was later than the Cretaceous, so it is believed the mountain building in the Mackenzie is the same age. The Eocene deposits in the vicinity of Norman are only slightly tilted, and are clearly later than the mountain building. The age of the mountain building is thus fixed between the Cretaceous and the Eocene. The fossils of the Cretaceous have not yet been studied to determine the part of the Cretaceous to which these deposits belong.

Carcajou River

The rocks on the eastern face of Carcajou mountains dip to the east and although the folding on the eastern front of the mountains has been sufficient to give the rocks a steep dip, no evidence of faulting was seen at the point where the south branch of the Carcajou issues from the mountains. To the east folding on a smaller scale occurs, although 50 miles from the mouth of the river there is a well-marked fold. This fold on the east side of the river is nearly symmetrical and is a striking example of physiography conforming to structure. Middle Devonian rocks are brought to the surface and appear in the photo (Plate I) as the "rainbow arch." Farther back along the anticlinal ridge the hard Middle Devonian rocks are covered by Upper Devonian shales, so that it seems probable the fold itself plunges slightly to the east, but reappears on the Mackenzie opposite Ogilvie island.

To the west of the river the folding is much more complicated and the ridge becomes higher and—owing to the dissection by erosion—takes on a more rugged and mountain-like appearance. The intensity of the folding

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[1] Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 51.

is shown in higher dips of the strata on the north face, and by faults of minor significance and small throw within the folded area.

Between Carcajou mountains and the ridge described above there is another anticline almost at right angles to the major folds. The river has followed along the axis of this anticline for some distance and at numerous places Fort Creek shale and the Bosworth formation are exposed on cut banks of the river.

On the river north of the "Rainbow arch" ridge there are many sections of Cretaceous exposed. The strata for the most part approach the horizontal, but, at the point where the riffle is marked on the map, sandstone is exposed and is lower stratigraphically than the exposures of shale to the north. This is not shown by the dips on the map.

In the country west of Little Bear river and between Carcajou and Mackenzie rivers no attempt can be made to show structure until Little Bear river is mapped. Viewed from Carcajou mountains this country is mostly muskeg with almost innumerable lakes, and the chances of rock exposures, except on streams, are very slight. It is probably almost wholly covered by Cretaceous rocks, for these strata occur for some distance up Little Bear river.

ECONOMIC GEOLOGY

Oil Prospects

After the Imperial Oil well No. 1 had been deepened it gave a flow of 60 to 70 barrels per day. It is on the flank of the anticlinal ridge forming the Norman range. The well was originally drilled on a seepage, and at a depth of 783 feet a gusher was "brought in." As was stated under the heading "Progress of Drilling" the flow of this well gradually diminished to a negligible quantity and deepening has given a new supply. The well is now capped.

No. 1 well has now reached such a depth that the drilling has either penetrated or approached very closely to a sandstone horizon known to be 50 to 70 feet thick a few miles distant. The shape of this sandstone horizon has not been determined. The absence of outcrops along the edge of the Norman range cannot be interpreted solely as due to the absence of the sandstone, because the shale weathers very rapidly, and except under rapid stream erosion, rarely gives rock exposures. If the sandstone is in the form of a sheet it ought to be encountered in the other wells, and an oil supply being present at No. 1 well the hope for a supply elsewhere is justified. It must be remembered in this connexion that the Fort Creek shale is a marine formation, and the sandstone is on this account likely to be widespread. A sandstone horizon holding a relatively uniform thickness over a considerable area may differ widely from place to place in the amount of porosity due to a difference in the degree of cementation, and hence the oil in such an horizon might be concentrated into local pools. This would give the same effect as smaller independent lenses. From the pressure evident at No. 1 well (as high as 250 pounds) it would seem that the oil horizon is sealed, and the oil cannot escape up the dip slope, for otherwise it would long ago have been dissipated at the surface, because the dip brings this horizon to the surface between the Mackenzie and the Norman range. No water has been encountered in No. 1 well, but it cannot be said there is none below the oil horizon. On Vermilion creek there is a small anticline in the Fort Creek shale about 6½ miles from the Mackenzie. From this anticline several large springs arise, the water smelling strongly of sulphuretted hydrogen. This water is apparently surface water that has come in contact with the sulphur known to be present in considerable quantity in the shale from which the springs issue. In the vicinity of No. 1 well there appears to be no evidence from a study of the surface exposures of rock to assume a minor fold or undulation on the main fold. A part of the sandstone itself separated from the main body by differences in porosity, might give similar results as a fold. Drilling will give the only satisfactory solution to these problems. A marine sandstone widely spread over this area, but differing locally in porosity to give oil pools within the sandstone itself, affords more hope of finding a larger productive field than could otherwise be expected, for the whole field must necessarily be on the flanks of the anticlines or in the syncline, erosion having removed the possible productive formations from the major anticlinal areas.

Possible Oil Horizons. Below the Fort Creek shale there is a 10-foot section at the top of the Beavertail formation that might possibly in some places act as an oil horizon, although at best, from what has been seen, it would be considered poor. Below this the hard, dense, massive, slightly bituminous limestones of the typical Beavertail formation occur, and these are entirely unsuited to act as a reservoir.

Below the Beavertail Ramparts formations in the brecciated limestones the porosity is sufficient to form a very favourable reservoir and in certain outcrops these beds had a highly bituminous odour. No seepages were found in them, and since they are nowhere in contact with the shales from which the oil is presumed to have been derived, it would be only under exceptional conditions that oil could reach them.

Above the Fort Creek shales in the Bosworth sandstones and shales oil does occur, in fact the main seepages, including that on which No. 1 well was drilled, come from this formation. It is by far the most favourable formation in which accumulations could occur, having more sandstone members than any other formation. So far, all the wells drilled have begun in this formation with the exception of Bluefish well where the Bosworth is overlain by Eocene deposits, and in no case is there a suitable cover that would retain the oil. In other words, in no well now drilling can production of any account be expected from this horizon. The geological map prepared in connexion with this report shows large stretches of country to the southwest of the Mackenzie where the Bosworth formation is covered by Cretaceous rocks. The Cretaceous rocks have been already described. There is a considerable thickness of sandstone at the base overlain by fine, impervious shales, a condition very favourable for the retention of oil in the Bosworth sandstone, and possibly in the Cretaceous sandstones as well. Drilling through the Cretaceous deposits into the Fort Creek formation at well-chosen locations would, it appears to the writer, greatly enhance the chances of oil discovery. It must not be forgotten in this connexion that the Cretaceous is separated from the Devonian by an erosional unconformity, and not in every locality does the Bosworth formation occur under the Cretaceous sediments.

Summary of Conclusions, Norman Oil Area

The rocks range in age from Cambrian to Eocene.

The potential oil area is greater on the west side of the Mackenzie than on the east side.

The mountains are anticlinal in origin.

No. 1 well is on the flank of the major anticline which forms the Norman range of mountains.

The top of the Norman range of mountains east of No. 1 well is composed of Silurian rocks.

No. 1 well is situated on the outcrop of the Bosworth formation of Upper Devonian age.

The present oil-producing horizon in No. 1 well is from the Fort Creek formation underlying the Bosworth formation, and also of Upper Devonian age.

The present oil production of No. 1 well is probably from a sandstone 50 to 75 feet thick in the Fort Creek formation.

The top of the Beavertail formation of Middle Devonian age is a hard, dense limestone unsuitable for an oil reservoir.

The sedimentation most favourable for oil accumulation occurs in the Bosworth formation of alternating sandstones and shales.

The Bosworth formation on the east side of Mackenzie river provides most of the oil seepages.

The Bosworth formation on the west side of Mackenzie river is overlain by Cretaceous sandstones and shales, the latter of which are suitable as a cover for an oil field.

COPPER ORE FROM THE NORTH SHORE OF GREAT BEAR LAKE

Two specimens of copper ore were given to the writer at Norman by Mr. C. E. Sloan who had brought them from the outcrop on the north shore of Great Bear lake. A report on these, made by V. Dolmage of the Geological Survey, is as follows:

"These specimens consist chiefly of bornite and quartz, but small amounts of chalcopyrite, malachite, and chalcocite can also be seen in the hand specimens.

Microscopically they are seen to consist of the following minerals named in their order of abundance: bornite, quartz, chalcocite, calcite, covellite, pyrite, chalcopyrite, malachite, a light grey mineral in too small amounts to determine.

Pyrite and quartz were the first minerals deposited. Following these came the bornite, some of the chalcopyrite, chalcocite, and the undetermined grey mineral. Later than these were deposited the remainder of the chalcopyrite, the remainder of the chalcocite, and still later the covellite, calcite, and malachite.

The late chalcopyrite occurs as minute, almost submicroscopic, blades occupying cleavage cracks in the bornite and forming a reticulate pattern.

This is very high-grade copper ore and has been to some extent enriched by surface solutions. The extent of this enrichment is difficult to determine, but it is probable that all the bornite and much of the chalcocite and chalcopyrite are primary and, therefore, that the primary ore was itself fairly high grade."

RECONNAISSANCE ACROSS NORTHEASTERN BRITISH COLUMBIA AND THE GEOLOGY OF THE NORTHERN EXTENSION OF FRANKLIN MOUNTAINS, NORTHWEST TERRITORIES

By M. Y. Williams

CONTENTS

	PAGE
Introduction	65
General geology	67
Economic geology	86

INTRODUCTION

In 1922 the writer entered Mackenzie River valley in company with George S. Hume and party via Fort St. John and Sikanni Chief river.[1]

The field work consisted of a geological traverse from Fort St. John to the junction of Fort Nelson and Liard rivers, and a study of Franklin Mountain area in Mackenzie district between Wrigley and Great Bear river.

The writer was ably assisted by C. H. Crickmay of Vancouver, who made extensive collections of plants and insects in addition to his geological work. The writer wishes to express appreciation of the assistance so cordially given by Messrs. H. Philip, of Taylor Flats, and Birley of Fort St. John; by the Hudson's Bay, Alberta and Arctic, and Northern Trading Companies' officials at the various posts; and by Mr. J. A. Macdougall, Mining Recorder, who kindly furnished housing accommodation for the writer's party at Norman.

The region from Fort St. John to Sikanni Chief river was traversed by pack train, which for about 150 miles follows an old trail used in part during the Yukon gold rush of 1898. The last 20 miles of the trail is new, having been cut during the winter by the Topographical Survey's party.

The country is gently rolling and semi-prairie, with swampy lowlands and spruce and jackpine ridges. The lowlands are commonly covered with willow and alder, but many southern slopes are well carpeted with grass. For about 30 miles from Fort St. John, or to Blueberry creek, the land is leased by ranchers, who raise horses and cattle and put up hay for winter feed.

The country is drained by tributaries of North Pine river, the main streams crossed being Blueberry river, Nig creek, Pine river, and Barker creek. These have developed wide valleys, 200 or 300 feet below the uplands, with clay banks that are here and there 100 feet high. The stream beds are well graded and the current is moderate during average water conditions. The height of land is probably 1,200 feet above Peace river at Fort St. John, or about 3,600 feet above the sea. The descent to the Sikanni Chief is quite abrupt, the valley being about 1,000 feet below the height of land, and 700 to 800 feet below the top of the flat-lying

[1] See footnote, p. 47.

Cretaceous sandstone, which rises as precipitous cliffs about half a mile back from the stream bed. The spruce and black poplar of Sikanni valley are large, thrifty trees up to 2 feet in diameter. South of the height of land much of the country has been burned to clear it for pasture, but north the country is rougher and less desirable for ranching, and is mostly covered with thrifty white spruce and balsam poplar, with isolated stands of white poplar, white birch, and jackpine on the ridges.

The cache on Sikanni Chief river was located at the mouth of a stream, appropriately named Whipsaw. From Whipsaw creek down to the mouth of Conroy creek, a distance of 66 miles, the river averages 500 feet in width and flows swiftly through a crooked channel at the bottom of a valley less than one mile in average width. The current averages about 4 miles an hour, and is remarkably uniform, being interrupted only by riffles over bars and one insignificant rapid. The shores are, however, in many places piled with logs, and submerged and anchored logs make travelling somewhat perilous. At bends in the river erosion exposes buried log jams over which mature trees are growing. Much of the drift timber from Sikanni Chief and Fort Nelson rivers reaches the Mackenzie by way of the Liard, and with the upper Liard timber forms the largest supply of driftwood to the lower Mackenzie valley. One spruce drift log on Fort Nelson river measured 7·9 feet in circumference at the butt and 130 feet in length.

At Conroy creek the survey of the river was discontinued, but the geology was investigated to the confluence of Fort Nelson and Liard rivers. The last 20 miles of Fort Nelson river were surveyed with compass and Rochon micrometer by G. S. Hume.

Above Conroy creek, few signs of Indians appear and the weathered condition of the lean-to camp frames and the overgrown blazes along the river indicate that they have nearly abandoned this part of the Fort Nelson system. At the mouth of Conroy creek a large camping ground is marked out by paths, fresh tepee frames, and cached kettles and other utensils. Fontas river is about 200 feet wide at the mouth and appears to be navigable for some distance upstream. On its banks, a camp site is indicated by tepee frames.

The main tributary of Fort Nelson river is Mosqua river, which empties into the Nelson about ½ mile above the post. The Mosqua is about two-thirds as large as the Fort Nelson above the confluence, and has as its main branch Prophet river which joins it about 5 miles above its mouth. The Indians are reported to go 70 miles or more up Prophet river to fish at a large lake west of the river. They go up on foot and come down in flimsy spruce-bark canoes.

From the Fontas down, sand-bars are somewhat numerous between quiet stretches of water. Below Fort Nelson the water is slower and sand-bars occur, especially for some miles above the confluence with the Liard.

GENERAL GEOLOGY

Table of Rock Formations

—	Description	Tentative correlations
Cretaceous	500 feet of sandstone containing thin lignite seams and plant fragments near base	With Dunvegan sandstone (fresh water) of both east and west Peace sections
	Contact appears conformable	
	650 feet or more of dark, pyritiferous shales containing fish scales near base, and including several thin sandstone beds	With Fort St. John shale (marine) of east and, in the west, the St. John (or possibly the St. John, Gates, and Moosebar formations)
	Contact not seen	
	100 feet crossbedded, torrential sandstones and grits, containing plant remains in upper beds	With Peace River sandstone of east, with Gates formation of west; or with Dunvegan formation of west?

Between Fort St. John and the divide, separating the Peace and Mackenzie basins, bedrock was seen at only three localities. Near where the trail crosses Montagneuse creek, about 20 miles north of Fort St. John, crossbedded grit outcrops in a stream bank. On the trail just north of the divide between Nig creek and the main branch of North Pine river, flat-lying sandstone outcrops. This is crossbedded and fine grained, containing quartz and mica, and some ironstone concretions. It weathers brownish yellow. Where the trail leaves the upper water of Barker creek, crossbedded arkosic grit outcrops. One bed is 3 feet thick and the pebbles—which are one-half inch or less in diameter—consist of polished black chert, rounded quartz, and fragments of ferromagnesian minerals.

North of the divide the trail crosses several rock-rimmed gullies and finally follows Whipsaw valley between sandstone walls to Sikanni Chief river. The geological section at this locality is described below.

	Description of Sediments	Thickness Feet
Forming cliffs	Shaly, friable sandstone to top of cliff	100
	Massive sandstone, gritty near top and containing plant remains	120
	Sandy shale and thin, fissile lignite	25
	Sandstone	30
Outcrops obscured by swamp or talus		460
Crossbedded sandstone in thin beds		30
Dark grey, fissile shale, containing ironstone lenses 1 inch thick and 10 inches across. Fish scales occur in lower 20 feet, similar in general characters to those found in the shales at Taylor flats below Fort St. John. Astringent waters ooze from the shales leaving a white residue on the surface which otherwise weathers black		75

Shale exposures are common along the river to the vicinity of Etleh creek. All the exposures are the same kind of shale, bearing fish scales and exuding water charged with products of the oxidation of pyrite. Yellow residues suggesting sulphur remain in places on the erosion faces, and the river water tastes acrid and the shale banks have a strong smell. The mud along the river, and especially along the shale exposures, is exceedingly soft and sticky. Even where extensive exposures of shale occur, a water-line indicates no departure from an horizontal attitude. The thickest exposure of shale noted was about 160 feet, in a cut bank below Dehacho creek. The sandstone bed resting upon the shale at Whipsaw creek occurs at successively higher elevations downstream, the fall of the river exposing lower and lower beds. The following section was measured east of Sikanni Chief river about 4 miles north of Whipsaw camp:

Description of Beds	Thickness Feet
Soft weathering sandstone and grit at edge of dissected plain	80
Massive sandstone and grit	30
Grey shale	20
Covered interval	80
Massive sandstone	40
Covered interval	180
Massive, grey, crossbedded sandstone forming a small cliff. Fragments of pelecypods in talus	40
Covered interval	25
Soft shale, containing thin sandstone beds near top and nodules with plant remains near base	30
Thin, fissile shale	30
Micaceous sandstone, shaly in part	10
Grey shale	20
Covered interval above river	550

About 6 miles below Etleh creek the following section is exposed in the west bank of the river:

Description of Beds	Thickness Feet
Argillaceous sandstone	25
Nodular sandstone, interbedded with friable, shaly sandstone containing some ironstone concretions	20
Micaceous sandstone, in thin beds with shaly partings and containing small, imperfect remains of plants	8

Although no exact contact with the black shales of the upper river was observed, the above section appears to represent a formation lower than the shales. Similar exposures continue downstream as far as Klewie creek, where, in a 200-foot exposure, lower beds consist of: 50 feet of dark shale, with thin sandstone beds containing ironstone concretions, overlain by 50 feet of sandstone similar to that described just above. Similar beds outcrop to within about 10 miles of Fort Nelson, below which the country bordering the river is low.

About 20 miles above the Liard, Fort Nelson river in its northward curve approaches the bordering upland, which is over 700 feet above the river. Three miles farther down river the rock escarpment is close to the northeast bank, a condition which is general for 9 miles. The lower cliffs commonly form a perpendicular wall dropping sheer below water level, and known as "Roche-qui-trempe-a-l'eau." These rocks are sandstones and grits and commonly exhibit remarkable crossbedding suggestive of strong current action.

The highest exposures occur in the cliff front between 560 and 700 feet above the river. The lower beds of these consist of fine conglomerate and grit, the pebbles consisting of black polished argillite, rounded white quartz, and a little rounded calcite. Concretions also occur with radial structure. Lower beds seen along the water consist of greenish sandstone containing plant remains. Lower down, cliffs composed of 75 feet of sandstone and grit drop sheer below the water level.

The lower 50 feet is composed of 1-foot beds, crossbedded within themselves; the upper 25 feet is tumultuously crossbedded. These grits appear to be still lower in the section than the exposures above Fort Nelson, their lower beds probably being continuous with some of the grits that occur high up in the sections along Liard river below the mouth of the Fort Nelson.

The only fossils found in these formations are the fish scales already noted, and plant remains. About 18 miles above the mouth of Fort Nelson river, plant remains were collected from sandstone blocks which had evidently come from the upper sandstone formation. These are reported on by W. A. Bell as follows: "Micaceous, coarse sandstone, grey, weathering to a light buff yellow. All material too fragmentary for specific identification. The genera *Protophyllum*, *Menispermites*?, and *Aspidiophyllum* identified."

Although diagnostic fossils are lacking, a comparison with the Peace River sections leads to the following tentative conclusions: the crossbedded sandstones of lower Fort Nelson river may be equivalent to the Bullhead Mountain sandstone; the thick shale series, with fish scales in at least one member, may be a continuation of the marine Fort St. John shale; and the upper sandstones, containing lignite and plant remains, may be a northern equivalent of the Dunvegan sandstone.

Following this correlation the lower sandstones would be of Lower Cretaceous age, and the shales and overlying sandstones would belong to the Colorado group of Upper Cretaceous age.

FRANKLIN MOUNTAINS NORTH OF WRIGLEY

General Features

The western border of Franklin mountains, from the vicinity of Wrigley to Saline river, is from 6 to 8 miles east of Mackenzie river. Exceptions occur in the case of Roche-qui-trempe-a-l'eau; a small mountain ridge bordering the Mackenzie 1½ miles below Wrigley; and of low mountains situated 3 miles east of the Mackenzie in the vicinity of Blackwater river. For 40 miles south of Great Bear river, Franklin mountains are represented by a chain of about six isolated knobs, none of which appears to rise more than 1,000 feet above Mackenzie river. Mount Charles, situated on the north bank of Great Bear river, is a continuation of this chain, and rises about 1,440 feet above Great Bear river and probably 1,500 feet above Mackenzie river. Mount Charles and its extensions to the north are about 10 miles in length, beyond which subdued knobs could be seen extending probably 20 miles farther.

Cap mountain, east of Wrigley, was mentioned in the writer's last year's report,[1] Further investigation has shown it to be a westerly-

[1] Geol. Surv., Can., Sum. Rept., 1921, pt. B.

dipping fault block, bounded on the east and northeast by a curving fault scarp. It consists of a long, curved ridge of quartzite, with its maximum elevation near the centre of curvature. It rises here about 4,700 feet above the river or 5,000 feet above the sea. For 6 miles to the westward, successively higher formations have been eroded into successively lower mountain masses, and 6 miles farther west, beyond a nearly level plain, the Roche-qui-trempe-à-l'eau and its extension northeastward to mount Gaudet[1] exhibit another eastward-facing scarp.

The northeasterly scarp of Cap mountain is probably 1,000 feet high, and the descent is steep below for perhaps another 1,000 feet. To the northward the mountains are composed of soft, light grey limestones, which are eroded into rounded forms, or in many places into flat-topped buttes. These general conditions hold beyond Blackwater river, excepting that mountains on the eastern side of the range have westerly dips, and are probably bounded on the east by fault scarps. About 4 miles north of Blackwater river, at the eastern front of the range, is situated the southernmost of three conspicuous, pyramidal peaks, the middle one of which is probably the mount Bompas of McConnell.

Ochre river has cut through the low mountains north of Cap Mountain fault scarp and, below the rock outcrops, has excavated a somewhat deep channel through glacial and outwash materials. Blackwater river, 25 miles farther north, rises in Blackwater lake east of the mountains, flows through what appears to be a somewhat wide canyon in the front ranges, and westward through a wider, mountain-flanked valley to the rolling muskeg and wooded country bordering Mackenzie river.

North of the high peaks of the Mount Bompas group the mountains become lower, and flatten out toward the valley of Saline river which occupies a low pass and is eroded for the most part through gravel and till. Three miles east of the mouth of Blackwater river, a small mountain range has offset the river to the south, and extends northward as a ridge of decreasing elevation to within a short distance of the mouth of Saline river. North of Saline river the mountains are confined to a single ridge, which culminates at a distance of about 4 miles in mount Clark, second only to Cap mountain, in Franklin range. This mountain rises about 4,500 feet above sea-level. Northward the Mount Clark ridge extends for 4 or 5 miles as low mountains, beyond which are the isolated knobs extending to Great Bear river.

Mount Clark is faulted from near its northern end past its southwest escarpment; the movement appears to have been that of an upthrust from the east, or an underthrust from the west. The faults were observed near Wrigley, on Blackwater river, and in mount Clark, and the probable fault bounding the eastern side of mount Charles is believed by the writer to exemplify a general block-faulted structure of Franklin mountains (compare with that of the southern Rocky mountains).

Physiography

The main divide of Franklin range is situated near the eastern border, where the uplift has been greatest and the oldest rocks are exposed. Only

[1] For the unnamed northern knob of the ridge known in its southern extension as "Roche-qui-trempe-à-l'eau", the writer proposes the name of the old Hudson's Bay family Gaudet, Mr. T. C. Gaudet being the present Hudson's Bay Company's post manager at Wrigley.

small streams, however, originate in the mountains themselves. The River-between-two-Mountains, Blackwater, and Great Bear rivers cross Franklin range, and Saline river probably rises east of the range, but this has not been determined. The channels through the range are filled in part by glacial till, outwash sand and gravel, and clearly belong to the same age of erosion as the valley of Mackenzie river. This system was developed before and during mountain building, and was completed before Eocene time as represented by the flat-lying deposits above Norman on both Mackenzie and Bear rivers. The Cretaceous sediments of Mackenzie and Bear rivers are only slightly tilted, and rest upon Devonian and possibly upon an older Palæozoic. Uplift and erosion preceded Cretaceous sedimentation.

Glaciation has rounded and subdued the topography and widened the rock-rimmed valleys into typical glacial forms. Glacial erratics lie on the very top of Cap mountain and within 400 feet of the top of mount Clark. The boulders are Precambrian and are evidently from the east. Glacial grooves on Cap mountain point 12 degrees to 17 degrees north of west, but were probably controlled by the local topography. On the west side of mount Clark, glacial striæ run 20 degrees north of west.

Post-Glacial erosion has incised stream channels in glacial till and outwash deposits, to the extent of 100 feet, or much more in the case of Mackenzie river. Frost and weathering have formed stacks and steep faces on some of the mountains and have produced very moderate amounts of talus material along the precipitous fault scarps. In a few cases streams have undercut their banks, causing rock slides, as for example along the north branch of Blackwater river; and elsewhere narrow channels are being eroded in solid limestone as described in last year's report. Generally speaking, post-Glacial erosion has left only a minor record compared with either pre-Glacial or Glacial erosion.

The terraces of Mackenzie river, and the deepening of its channel, have already been noted by Kindle and the writer.

Geology

Table of Formations

Pleistocene			Till, outwash sands, and gravels about 200 feet
Eocene			Erosion surface Silts and semi-consolidated sands and gravels containing lignite beds About 200 feet
No erosion contact recognized			
Cretaceous			Shales and sandstone containing marine molluscs 100 feet or more

Table of Formations (Continued)

	No erosion contact recognized		
Devonian	Upper	Simpson shale	Dark grey shale containing thin limestone beds about 1,000 feet
	Conformable contact		
	Middle		Grey limestones, containing fairly rich and varied fauna about 2,000 feet
	Disconformity		
Silurian	Upper	Lone Mountain formation	Brecciated, massive dolomite, containing interbedded gypsum and chert 530 + feet to 1,600 feet
	Conformable contact		
	Middle	Mount Kindle formation	Waterlime and grey magnesian limestone, with coral fauna 580 feet
	Disconformable contact		
	Lower	Franklin Mountain formation	Buff limestones, buff and red shales 500 feet to 1,000 feet
	Disconformable contact		
Cambrian	Middle	Saline River formation	Buff and green shale, red shale, salt and gypsum, about 500 feet
		Covered interval of several hundreds of feet	
		Mount Cap formation	Green shales, rusty shales, and sandstones about 200 feet
	Conformable contact		
	Lower	Mount Clark formation	Pink quartzite, ferruginous grit, and conglomerate 600 feet or more
	Disconformity		
Precambrian (?)	(Beltian?)		Dark shales, grey and drab shales 375 feet

The best and most comprehensive section seen in Franklin range is that from Wrigley through Cap mountain, described in last year's report. Further work, however, has made it possible to separate new formations and to add considerable detail in regard to the thickness and characters of the formations already recognized. Another Cambrian-Precambrian (?) section is to be seen at mount Clark and a fine Silurian section is seen at mount Charles.

The Wrigley-Cap Mountain section is summarized in the following table:

Devonian	Upper			Shale probably covered by drift below Roche-qui-trempe-à-l'eau
	Middle			Dark grey limestone characterized by *Phillipsastræa verneuili, Syringopora perelegans, Productella spinulicosta, Paracyclas elliptica,* and *Callonema clarki* Lower beds, fine-grained grey limestone containing *Schuchertella* sp.
Disconformity				
Silurian	Upper	Lone Mountain formation Thickness 1,600 feet		Massive, light, grey, cavernous, gypsifercus limestone, commonly brecciated on large scale. No fossils
	Middle	Mount Kindle formation 560 feet		Grey, magnesian limestone, Niagara corals
	Lower	Franklin Mountain formation about 500 feet		Buff dolomite, pea-green shale and sandy red shale containing in upper 20 feet of beds, *Rhipidomella hybrida, Rhipidomella circulus*
Disconformity				
Cambrian	Middle	Saline River formation	Upper division about 300 feet	Banded, calcareous shales (containing *Lingulella* sp.) with interbeds of red and green shale
			Lower division about 200 feet	Red and grey shale containing salt and gypsum and selenite
		Covered interval		
		Mount Cap formation	About 200 feet	Grey and green fissile shales containing *Lingulella?* and *Tetradium*-like forms. Red sandstone and shale containing seaweeds, *Lingulella, Bathyuriscus, Ptychoparia, Saratogia*
	Lower	Mount Clark formation	About 620 feet	Pink and red quartzite containing *Scolithus* 500 feet or more Red shale and ferruginous sandstone 50 feet Hematite, red conglomerate, and sandstone 70 feet or more
Precambrian (?)			375 feet or more	Dark shales, 150 feet Grey and drab shales, 225 feet

The section here consists of westerly-dipping beds west of the fault scarp that forms the eastern side of Cap mountain, in which is exposed the Cambrian-Precambrian (?) section. To the eastward, formations as high up as the Middle Silurian occur as easterly-dipping beds.

The section from Mackenzie river at the mouth of Saline river, across mount Clark, includes only Precambrian (?) and Cambrian formations. The outcrops are disconnected and will be described under the formations.

Mount Charles Section Taken Close to Great Bear River

Silurian	Upper	Lone Mountain formation	Thin-bedded, brown-weathering dolomite, 190 feet
			Brown, coarse-grained, sandy dolomite in 2 to 3-foot beds. Brecciated in part, 340 feet
	Conformable contact		
	Middle	Mount Kindle formation	Hard, light grey dolomite, thin bedded, cherty in lower 70 feet, 180 feet
			Chert, probably silicified dolomite, 60 feet
			Unfossiliferous beds, 30 feet
			Grey magnesian limestone containing Niagara corals, 210 feet
	Conformable contact		
	Lower	Franklin Mountain formation	Grey magnesian limestone, 470 feet
			Limestone and chert, pebbles and grit in limestone matrix, 75 feet
			Grey limestone, 120 feet
			Cavernous limestone, 200 feet
Cambrian (?)		Saline River formation	Grey gypsum, 150 feet or more

Farther north the main peak of mount Charles consists of Middle Silurian limestone, full of Niagara corals. The section to the northwest is given below:

Devonian	Middle		Dark grey limestone containing *Schuchertellas*, about 30 feet
	Contact covered		
Silurian	Upper	Lone Mountain formation	Grey gypsum, about 500 feet
	Middle	Mount Kindle formation	Chert beds, probably replacement of dolomite, about 300 feet
			Grey limestone with Niagara corals, about 200 feet

Mount Cap formation, as described in the Summary Report for last year, consists of a lower member of 375 feet of grey and dark shales, seen in the fault scarp on the northeast of Cap mountain; a second member of 120 feet of ferruginous conglomerate and sandstone approaching low-grade iron ore near the centre; a third member of more than 500 feet of pink quartzite which forms the crest of Cap mountain; and a fifth or upper member of grey and rusty phyllites, seen in gullies and on the flank of the southern extension of Cap Mountain ridge. The thickness of the phyllites is not known. Thin-bedded sandstone forms a transition from the quartzite to the phyllite above, and contains trilobite remains, *Saratogia* being identified by Dr. Walcott in material collected from these beds in 1921 as already noted.[1]

In this year's collection, Dr. Walcott[2] recognizes seaweeds, *Lingulella* sp., *Bathyuriscus* (*Poliella*) cf. *sylla* Walcott, *B.* n.sp., "*Ptychoparia*" sp. In the phyllite the following were found: *Lingulella*?, *Tetradium*-like form.

Mount Clark consists of a faulted anticline of quartzite, with phyllites flanking the western side. The section starts in the red quartzite, with ferruginous beds, and this division with the overlying pink and white quartzite is 800 feet thick. On the western flank the section is about as follows:

	Thickness Feet
Arkose, eroded at top	2
Fissile green shale containing *Olenellus canadensis*	15
Green arkosic grit .... about	10
Pink quartzite containing *Salterella* near top	500
Green, sandy, fissile, micaceous shale	?
Probably pink quartzite	?

On the eastern slope of mount Clark, ridges of quartzite have an aggregate measurement of about 2,900 feet. It is possible, however, that faulting or concealed structure has caused repetition of the beds.

To the north of mount Clark, two small mountains, extending about 3 miles, have the appearance of quartzite.

In the banks of Saline river, at the mouth of a tributary stream about 8 miles above Mackenzie river, about 25 feet of phyllites occur. These contain *Bathyuriscus* n. sp.

The above evidence shows that the sediments of Cap mountain described last year as the Mount Cap formation should be subdivided into three formations, the oldest of which may be Precambrian; the middle may be Lower Cambrian, and the upper Middle Cambrian in age. It is proposed to retain the name Mount Cap for the upper thin sandstones and the overlying phyllites, for it was from fossils in the sandstones that the age of the beds was determined as Cambrian. The subdivisions are described below.

Precambrian (?)

The lower beds exposed in the eastern side of Cap mountain consist of shales which, according to Kindle, may be divided into a lower division of greyish to drab shale 225 feet thick, and an upper division of dark shales

[1] Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 59.

[2] All the Cambrian fossils referred to in this report were identified by Dr. C. D. Walcott and Dr. Resser.

150 feet thick. Above these shales are grits, conglomerates, and sandstones, highly impregnated with hematite. These beds resemble the basal beds of the Cambrian of the Cranbrook area as described by Schofield.[1] Although no unconformity has been demonstrated, the conglomerates and grits resting upon the shales clearly indicate a period of renewed uplift and erosion, and on this ground the underlying shales are provisionally classed as Precambrian (Beltian?) in age, and the overlying formation is Lower Cambrian, as described above.

In the western-facing escarpment of the southern end of mount Clark, ferruginous beds occur about 800 feet below the top of the mountain. It is probable that the underlying beds, here mostly covered by talus, are to be correlated in age with these shales.

Mount Clark Formation

In the Cap Mountain section, ferruginous grits and conglomerates overlie the dark shales here regarded as Precambrian. These and the overlying quartzite and sandstone make up the Mount Clark formation as here defined. The section, taking Kindle's figures, is as follows:

	Feet
Red quartzite and sandstone	500 or more
Red shale and ferruginous sandstone	50
Low-grade hematite	20
Red ferruginous sandstone	50

From the upper beds of the quartzite, Crickmay collected *Scolithus*, as reported on by Dr. Walcott.

In the Mount Clark section, ferruginous beds and green micaceous shale are overlain by pink and white quartzite 500 feet or more in thickness, above which is arkosic grit 10 feet thick, and 15 feet of fissile green shale, upon which rest eroded remnants of arkose. Near the top of the quartzite *Salterella* and *Olenellus canadensis* Walcott were found in the shale. On the evidence of these fossils, the age of the beds is fixed by Dr. C. D. Walcott as Lower Cambrian and consequently the Mount Clark formation, as exposed in mounts Cap and Clark, is considered to be Lower Cambrian.

Mount Cap Formation (Re-defined)

In rusty, thin-bedded sandstone near the top of the beds exposed in Cap mountain, fragments of trilobites were found in 1921, which were identified by Walcott as *Saratogia*. On this evidence all the Cap Mountain beds were classed as Cambrian in age, with a suggestion of Upper Cambrian affinities. This year *Lingulella* sp., *Bathyuriscus* (*Poliella*) cf. *sylla* Walcott, *Bathyuriscus* n. sp., "*Ptychoparia*" sp., and seaweeds were found in the same sandstones. In addition to the 100 feet or more of green and rusty, thin-bedded sandstones, and overlying grey and rusty shales or phyllites, there were discovered, about one-half mile to the north, fissile green phyllites, probably belonging still higher in the section. The phyllites are down-faulted against quartzite and their real position is, therefore, in doubt. In these, as already stated, *Lingulella*? and *Tetradium*-like forms were found.

[1] Schofield, S. J., Geol. Surv., Can., Bull. No. 35, p. 7.
Specimens of these beds have been examined by Schofield who first recognized their resemblance to the conglomerate at the base of his Burton formation.

The thin sandstones, shales, and phyllites are included in the Mount Cap formation, the age of which is Middle Cambrian, according to Walcott's determination of the fossils found this year.

Green phyllites of similar character occur at the forks of Saline river, about 8 miles above its mouth, and in these Walcott has recognized *Bathyuriscus* n. sp. of Middle Cambrian age. About 25 feet of beds are exposed at this locality, but, as at Cap mountain, the thickness of the formation cannot be determined.

Saline River Formation

In the banks of Saline river, from 1½ to 2 miles above its mouth, 100 feet of beds are exposed as follows:

	Feet
Soft, red, earthy shale, with interbeds of gypsum one inch thick, at base..	15
Green shale, with large salt hoppers, and running brine, from which salt forms in the creek bed during midsummer by evaporation............	10
Green shale, with occasional thin red beds..............................	30
Shale beds, firm, dark and light alternating..............................	45

In the talus from the upper shales *Lingulella* sp. and *Micromitra* were found.

A distance of about 6 miles intervenes between the Middle Cambrian phyllites of Saline river and the red shales, but between these phyllites and mount Clark there are exposures of fine-grained, unfossiliferous limestones extending up the sides of a hill for about 400 feet. They are, probably, interbedded with shales. At various places on the hill are sink-holes that owe their origin to the solution of underlying gypsum or salt beds. Fine-grained, buff-weathering limestones, similar to those near the sink-holes, form a ridge of hills east of mount Clark, and are separated from the Mount Clark quartzite by a fault. These limestones are thought to be included in the upper beds of the Saline River formation.

West of Cap mountain, as described in last year's report, soft, red shales with interbeds of gypsum and selenite outcrop at the base of mount Kindle, and apparently are in sequence with the Mount Cap phyllite beds, although several hundred feet of covered interval intervenes. The red colour of the shales appears to be largely a result of weathering, for the centres of most red nodules are green. The red gypsiferous horizon also outcrops east of Cap Mountain fault in the easterly-dipping section. Although no complete section is visible, the soft shales probably are 200 feet thick. Upwards the shales grade into green shales, with alternating soft and hard beds. Much of the section on mount Kindle is obscured by talus, but the formation probably extends upward from the red beds for 300 feet, or to the base of firm calcareous shale which forms a cliff. This subdivision is arbitrary and the actual relationships with the overlying beds are unknown, although the strike and dip do not change noticeably. In the talus from some of the upper beds *Obolus mcconnelli* Walcott was found.

In the eastern face of mount Charles, as already outlined above, some 150 feet of grey gypsum is overlain by 200 feet of brecciated, porous, massive limestone in which Kindle probably found his fossils. The writer knows of no such gypsum beds elsewhere in the Lower Silurian formations, and they would appear to belong to the Saline River formation which is essentially gypsum bearing. The age of the Saline River formation is based upon the meagre fossil collections noted above. Dr. Walcott considers the fossils as Middle Cambrian. On this basis the Saline River formation is an upper division of the Middle Cambrian, the Mount Cap formation being the lower division. The contact and intervening beds are obscured.

Evidently Upper Cambrian and all of Ordovician time are indicated by the contact between the Saline river and the Franklin Mountain formations. This contact was not observed, being generally talus covered.

The gypsum and overlying 320 feet of limestone correspond in position with the Saline River formation, and the gypsum content increases the similarity. Kindle states, however, that he collected Lower Silurian fossils from the lowest beds of the section (presumably above the gypsum) and on this ground the writer includes all the beds above the gypsum, provisionally, in the Franklin Mountain formation. The conglomerate bed with limestone matrix may necessitate a separation out of the beds below it under a new formational name.

Franklin Mountain Formation

Above the talus-covered beds on mount Kindle assigned to the upper part of Saline River formation there are nearly 500 feet of grey, buff-weathering, calcareous shales, with red interbeds, grading upward into buff limestones upon which rest the Mount Kindle coral-bearing limestones. The upper contact is well exposed in the second mountain south of mount Kindle, where yellow, thin-bedded, fine-grained limestone is overlain by grey limestone bearing Niagara corals. No angular unconformity is observable, but the change is abrupt, and although no fossils were found in the beds immediately below the contact, *Rhipidomella circulus* and *R. hybrida* were found about 15 feet lower down. These suggest affinities with the Medina Cataract formation of Ontario, of Lower Silurian age. The contact is thus shown to represent a lost interval of sedimentation, and so is disconformable. The upper limestones of the formation are in part fine grained, and grey or pink, and elsewhere are nodular and buff coloured. It is thought that the buff limestones east of mount Clark, and on the hill between Saline river and mount Clark, belong to this formation.

The Mount Charles section, as already given, consists, from the base upward, of 150 feet ± of grey gypsum, 200 feet of cavernous limestone, 120 feet of grey limestone, 75 feet of limestone containing pebbles and grains of quartzite or chert, and some worn fossils, and some 470 feet of grey limestone, apparently without fossils, which is overlain without apparent break by limestone bearing Niagara corals. In position in the section and in scarcity of fossils, the upper 520 feet of beds correspond with the Franklin Mountain formation of mount Kindle and vicinity.

MOUNT KINDLE FORMATION

As already described, the barren, or nearly barren limestone beds at the top of the Franklin Mountain formation, are overlain (apparently disconformably) throughout the Franklin mountains by grey limestones carrying a coral reef fauna, very similar to that of the Niagara limestone of the Great Lakes region. The Mount Kindle section was described by the writer last year. On the second mountain south of Kindle this formation is about 560 feet thick and consists of the following units:

	Thickness Feet
Thin-bedded waterlime, no fossils	300
Grey limestone, containing near top *Palæofavosites aspera* and *Trematonotis?* Near middle, *Palæofavosites aspira* (d'Orbigny) and *Rhynchonella* sp. About 20 feet above base, *Zaphrentis* sp., *Favosites* sp., *Halysites catenularia* var. *microporus* (Whitfield). About 5 feet above base, *Zaphrentis* sp., *Palæofavosites aspera* (d'Orbigny), *Platystrophia biforata* Schlotheim, *Rhipidomella circulus* Hall? *Homoeospira apriniformis* Hall? Total	260

This is overlain by limestone breccia of the next higher formation. The coral limestone forms the peak of mount Kindle and several mountains in the vicinity.

On the flank of Lookout mountain, about 16 miles north of Cap mountain, the coral beds outcrop, but are mainly obscured by the overlying and unfossiliferous limestone.

On mount Charles, as already described by Kindle, the coral beds form the top of the peaks, and the west flank of the mountain at Bear river. Near the river, the section consists of 240 feet of coral-bearing, grey, magnesian limestone, 60 feet of chert (probably silicified limestone), and an upper member of 180 feet of light grey dolomite with thin, hard, even beds at the top. These are overlain by coarse dolomites of the next higher formation. About 3 miles to the north, the coral limestone that forms the main peak of mount Charles is over 200 feet thick and is overlain to the westward by 300 feet of fine-grained, white chert, which appears to be a replacement of dolomite. The chert is overlain by gypsum of the next higher formation.

The coral beds contain:

[1]*Acervularia gracilis* (Billings), *Diphyphyllum multicaule* Hall, *Palæofavosites aspera* d'Orbigny, *Halysites catenularia microporus* (Whitfield), *Halysites compacta* Rominger, *Plasmopora follis* Edwards and Haime, *Orthoceras* sp.

These fossils are closely related in age to the corals of the Niagara limestone of lake Huron and lake Timiskaming, and indicate a Middle Silurian age for the formation. The upper unfossiliferous water-limes, cherts, etc., may, with good reason, be considered as a separate formation; on the other hand, they may represent a shallowing condition of the seas at the close of Niagara time, as is the case with the Eramosa water-limes of Ontario. In part the upper beds may represent Guelph time. It seems simpler at present to consider these beds as the upper division of the Mount Kindle formation.

LONE MOUNTAIN FORMATION

Kindle[2] has described the Lone Mountain formation from Lone mountain at the mouth of North Nahanni river, and includes in it the beds below the fossiliferous Devonian limestone, as follows:

	Feet
(b) Light grey to dark, almost black dolomite and magnesian limestone mostly fine grained but with some beds of saccharoidal texture, about	1,500
(a) Massive, dark grey limestone, some beds mottled with dark-coloured dolomite. Corals present	50

[1]The coral from mount Kindle identified in Geol. Surv., Can., Sum. Rept., 1921, p. 60 B, as *Columnaria alveolata* proves to be a specimen of *Acervularia gracilis* with small, regular corallites.

[2] Kindle, E. M., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 44.

Throughout the southern 50 miles of Franklin mountains, the Middle Devonian limestone rests upon massive, dolomitic limestone cut and impregnated by veins and stringers of calcite. No fossils were found in it, and the underlying fossiliferous beds have been placed by the writer in the Mount Kindle formation. With this slight modification of definition, that is, excluding such beds as Kindle's lower 50 feet of fossiliferous limestones, the formations described below will fit into the Lone Mountain formation already established by Kindle on North Nahanni river, and on Discovery range north of Norman. As will be seen below, brecciation, gypsum content, and in general, variable characters, mark this formation in Franklin mountains.

Kindle[1] has described the formation on Bear mountain underlying the fossiliferous, Devonian limestone, as the Bear Mountain formation, and has included in it near the base the Red gypsiferous shale with bands of selenite, locally known as the "Beavers." He concludes: "It is not impossible that the Bear Mountain formation may represent a special facies of the Lone Mountain formation." Kindle fails to bring out in his section the brecciated character of much of the formation, which impressed the writer while studying it. Having seen a series of sections of limestones and dolomites, occupying stratigraphically the place of the Lone Mountain formation, and extending from Lone mountain to mount Charles, the writer is satisfied that all but the lower red gypsiferous beds of the Bear Mountain formation are to be correlated with the Lone Mountain formation.

The red gypsiferous shales are identical in lithological characters with the gypsiferous beds of the Saline River formation, and as the outcrops in Bear mountain have been clearly faulted, to form the three exposures known as the Beavers, the writer is not convinced that the red beds properly belong with the Bear Mountain formation. In case the sequence is undisturbed, the red beds are to be correlated with the grey gypsiferous beds of the Lone Mountain formation as developed at mount Charles.

On mount Kindle and in the vicinity, massive, brecciated, light grey dolomite containing gypsum overlies the Mount Kindle formation, and is overlain by Middle Devonian grey limestone. The thickness is about 1,600 feet, which may be due in part to the thickening of this soft, incompetent formation near the crests of the anticlines by the action of mountain-building forces. The general characters clearly suggest an original gypsum member, as is the case in the Mount Charles section. Brecciation also involved the lower beds of the Middle Devonian limestone, fossiliferous fragments of which are included in the upper brecciated beds. Light coloured dolomite of the Lone Mountain formation forms the crests of low, rounded mountains over an area north of Cap mountain, which probably extends beyond Blackwater river.

On the north branch of Blackwater river faulted brecciated dolomite is well exposed. Toward the top it exhibits complicated crossbedding in unbrecciated beds. The contact with the overlying Middle Devonian limestone is clear and apparently disconformable.

On mount Charles, near Great Bear river, 340 feet of saccharoidal, coarse-grained, brown dolomites overlie the firm beds of Mount Kindle formation, and are overlain by more than 100 feet of thin-bedded, brown

[1]Ibid, p. 45 B.

dolomites, in part brecciated. The top of the section was not seen. Three miles farther north, the chert beds of the Mount Kindle formation are overlain by about 500 feet of grey gypsum, which in turn is overlain by Middle Devonian limestone. The sudden lateral change in gypsiferous formations is in accordance with occurrences elsewhere. Thickening and thinning due to mountain movements are altogether likely.

The age of the Lone Mountain formation has been given as Silurian by Kindle and this is substantiated by its position in the section, and its characters, which are analagous to those of the Salina formation of Ontario, and New York, and the Upper Silurian gypsiferous and saline formations of Manitoba and northern Alberta. The contact with the Mount Kindle formation appears to be conformable, and that with the overlying Middle Devonian limestones disconformable. The age of the formation is consequently thought to be Upper Silurian.

MIDDLE DEVONIAN LIMESTONE

The Middle Devonian limestone of Franklin mountains was described in last year's summary report, and but little new information has been gathered regarding it other than its areal extent. The formation consists of dark grey, semi-crystalline, and, in part, argillaceous limestones, estimated to be 2,000 feet or more in thickness. The lower 600 to 700 feet are most commonly exposed in Franklin mountains, where they form the western slopes. On the north branch of Blackwater river the Middle Devonian limestone overlies brecciated dolomite of the Lone Mountain formation. Brecciation ceases at the contact, the massive grey Devonian limestone being entirely unaffected. Black chert nodules occur in the brecciated beds.

The following fossils were found to be the best guides to the Middle Devonian limestone: near the base—*Schuchertella* sp. nr. and higher up *Phillipsastræa verneuilli* Edwards and Haime, *Cladopora dispansa* Davis; and *Productella spinulicosta* Hall.

SIMPSON AND HIGHER SHALE FORMATIONS

Shale of Simpson age probably lies buried beneath the drift a short distance below Roche-que-trempe-à-l'eau as exposures of dark grey shale belonging higher in the section occur in the west bank of Mackenzie river about 9 miles below Wrigley. This section is about 160 feet thick and contains fossils in a 2-inch bed of limestone about 70 feet up. The lower beds contain discoid ironstone concretions from 2 inches to 1 foot in diameter and cone-in-cone concretions of calcite, formed around ironstone centres. These peculiar concretions are generally discoid and vary from 9 inches to 2 feet in diameter.

Nearly opposite Ochre river, 5 or 6 feet of limestone with interbeds of shale overlie soft green shale. The beds dip to the south, but the fossils which they contain are thought by Hume who studied these exposures west of Mackenzie river to represent beds higher than Simpson shale.

From 9½ to 11½ miles above Johnson river, jointed, fine-grained sandstone, and soft green and grey shales outcrop along both banks of the Mackenzie. About 30 feet of beds are exposed in the east bank just below the upper trail to Blackwater lake. The beds dip gently to the west and consist of olive-green fissile shale, with interbeds of thin, sericitic, schistose sandstone. Worm castings and concretions similar to those of the first exposure below Wrigley also occur in the sandstones. These shales and sandstones are probably higher than the Simpson shale division of the Upper Devonian.

CRETACEOUS SANDSTONES AND SHALES

Outcrops of shales and interbedded sandstones occur in the west bank of the Mackenzie about 2 miles below the mouth of Dahadinni river, and continue downstream for about 3 miles.[1] Another outcrop occurs about 3 miles farther down. The beds dip down river about 2 feet in 100 feet. The upper section consists of soft, hackly, green shale, with 6 inches to 1 foot of grey sandstone 3 feet up, and a 2-foot bed of hard sandstone 15 feet up. The lower sandstone contains trail markings, and current ripples about 2 inches across. Fossils were found in the lower sandstone and shale beds and in concretions contained in the lower beds: but F. H. McLearn recognizes only *Pecten* sp. and states that "Until faunas of Mackenzie River Cretaceous are studied systematically, only preliminary identifications can be made."

The beds may be classed as Cretaceous in age.

On Great Bear river, on both sides of the rapids, about 2 to 3½ miles above mount Charles, brown sandstones outcrop, dipping southeast about 3 degrees[2]. These beds contain the following fossils as identified by F. H. McLearn: *Inoceramus* sp., large indeterminate starfish trails in sandstone and impression of soft-bodied coelenterate, a Medusæ? These beds are classed as Cretaceous.

The Cretaceous beds of Great Bear river are separated from the east-facing escarpment of mount Charles by a covered interval of nearly 2 miles. The Silurian rocks of mount Charles appear to be terminated to the east by a fault, but the throw would, in all probability, not be great enough to bring higher beds than those of Silurian age beneath the Cretaceous deposits. This conclusion is supported by observations made throughout the Franklin mountains. On Mackenzie river the subjacent strata are not exposed, but it is probable that either Middle Devonian limestones, or Upper Devonian shales underlie the Cretaceous deposits. A decided unconformity is suggested although not proved.

EOCENE DEPOSITS

As reported by McConnell[3] semi-consolidated sandstones and shale of Eocene age outcrop at Norman and vicinity. These deposits outcrop on the west bank of Mackenzie river, 18 to 22 miles above Norman, on the north bank from 2 to 7 miles above Norman, and at Norman extending around on to Great Bear river and along the southeast bank, upstream to the small point opposite the mouth of Brackett river.

The beds 20 miles above Norman dip to the south at about 10 to 15 feet per thousand feet and are estimated to be about 300 feet thick. The

[1] McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. IV, p. 21 D.
[2] Bell, J. M., Geol. Surv., Can., Ann. Rept., vol. XII, p. 25 C.
[3] Geol. Surv., Can., Ann. Rept., vol. IV, p. 22 D.

outcrops are partly obscured by glacial till and gravel, but the lower outcrops are well exposed and represent a section as follows:

	Thickness Feet	Inches
Glacial silt	—	
Grey and brown sandstone, crossbedded	10	
Gravel mixed with shale; pebbles of limestone, quartzite, and dark chert		6
Grey, friable, crossbedded sandstone	50	
Brown concretionary sandstone, containing silicified wood and leaves of deciduous trees	10	

The section upstream, belonging just above, is as follows:

	Feet
Lignite in places	4
Covered interval	12
Pea-green shale	8
Lignite at water's edge	-

Still higher in the section is another upstream exposure as follows:

	Feet
Silt	10
Lignite and shale, the upper 20 feet containing fair lignite beds	30
Grey, silty shale	25

In the upper exposures much of the shale is burned brick red by the combustion of the lignite. Charcoal occurs in some of the thin upper lignite beds in the vicinity of upright tree stumps.

The section 2 to 6 miles above Norman consists of 80 feet of light grey, semi-consolidated sandstone, with lignite near the base, as seen in up-river exposures. Near the middle of the section is a 15-foot massive bed, with a thin lignite bed just above it. Another thin lignite seam occurs near the top of the section. As the lignite, where best developed, is now on fire, or has been burned out, its actual thickness is problematical. Leaves from this locality and the exposures described above were collected by G. S. Hume in 1921 and referred to W. A. Bell[1] who reported on them as follows:

"Two miles above Norman, *Sequoia langsdorfi* (Brongniert) Heer; *Corylus maquarri* (Forbes) Heer; *Pterospermites dentatus* Heer; *P. spectabilis* Heer; *Populus arctica* Heer; *P. hookeri*? Heer; *Quercus* cf. *olafseni* Heer."

"From west bank of Mackenzie 20 miles above Norman—*Acer* cf. *arcticum* Heer." Bell assigns these beds to the Eocene and concludes that the climate of the time was temperate.

The deposits along the southeast side of Great Bear river may be illustrated by the section 1½ miles above the Mackenzie, which is as follows:

	Thickness Feet
Crossbedded sand with some firm beds	28
Fine, loose conglomerate, composed mostly of polished pebbles of black, cherty argillite, about 1 inch in diameter	40
Low-grade lignite	1
Unconsolidated sand with thin conglomerate beds	30
Talus covered from river level up	20

The argillite pebbles litter the beach at Norman and are similar to pebbles in the Cretaceous on Liard and Fort Nelson rivers. Keele[2] describes

[1] Geol. Surv., Can., Sum. Rept., 1921, p. 76 B.

[2] Keele, J., "A Reconnaissance Across the Mackenzie Mountains in the Pelly, Ross, and Gravel Rivers, Yukon and North West Territories." Geol. Surv., Can., p. 40.

similar pebbles as occurring in conglomerates referred to the Cretaceous, found by him on the north bank of Gravel river about 25 miles above its mouth. Black shale interbedded with cherty argillites, and cherts are mentioned by Keele (page 38) as occurring in beds of Upper Ordovician age; on the upper waters of Ross river. The Carboniferous formations of Yukon also contain chert, and Hume reports chert in Carboniferous rocks in Mackenzie mountains north of Liard river. As no Carboniferous formations are known immediately west of Gravel River–Fort Norman area, it seems probable that uplifted Ordovician strata were eroded to supply the gravels of Cretaceous time, although Carboniferous formations, since eroded away, may have been the source of the pebbles. The erosion of the Laramide mountains may have released these pebbles to be included in the Eocene conglomerates.

PLEISTOCENE AND RECENT DEPOSITS

As already stated, glacial erratics of Precambrian origin are found scattered over Franklin mountains right to the top of Cap mountain, and to within 200 feet of the top of mount Clark. Glaciated valleys are common, but glacial striæ were seen only on the quartzite of Cap Mountain ridge where the direction of ice movement is indicated as 12 degrees and 17 degrees north of west and on mount Clark where the direction is 20 degrees north of west. These rather abnormal directions were probably due to the deflexions caused by local topographic features. The valleys of Mackenzie river and its tributaries are in general cut into till and outwash glacial material. At Ochre river the section of till is 150 feet deep. Limestone boulders here are mixed with Precambrian boulders, but are less worn. From Blackwater river down, the top of the glacial deposits is 150 to 200 feet above the bed of the Mackenzie. At the mouth of rivers flowing from the west, much gravel and sand occur, as in the banks of Dahadinni river, where 30 feet of coarse gravel is overlain by 100 feet of evenly bedded clay, sand, and yellow silt. Saline river flows through rolling country, where the soil is well drained and gravelly. Evidently an unusual amount of glacial morainic material was dropped on the lee side of mount Clark. Farther north, and especially along Great Bear river, the glacial debris is rather evenly and thinly spread out, and innumerable lakes occur, with muskeg intervening.

STRUCTURE

With steep escarpments to the east and gentle slopes to the west Franklin mountains as a range consist of westerly tilted fault blocks. Actual faults were observed at a number of localities and best of all in the vicinity of Wrigley. There Roche-qui-trempe-à-l'eau and mount Gaudet at the northern end of the ridge consist of a closely folded anticline with eastern face terminated by a strike fault. Branch faults occur at the southern end of the ridge and much calcite and selenite have penetrated crevices and fissures and some beds of limestone have been changed almost entirely to chert. The fault line appears to pass to the north along the steep east face of a small mountain which was not visited. As no rock is visible against the eastern side of the fault plane the throw of the fault cannot be determined. The nearest rock outcrops to the east are 4 miles away and consist of Upper Devonian limestone, but it would appear that the formation underlying the intervening flat land is probably Upper Devonian shale as is the case elsewhere in the vicinity.

The fault scarp along the eastern face of Cap mountain is even more interesting in that it has been traced into a normal anticline at its southern extension and in that it curves like a drawn bow away to the northwest. The maximum downthrow was to the northeast and has not been measured. The escarpment is, however, about 1,000 feet high and the fault is probably not less than 2,000 feet.

Between Ochre river and Blackwater river the formations dip gently to the west, but the topography along the eastern extension of the mountains gives even at a distance the suggestion of steeper dip. On lower Blackwater river gentle folds and minor faulting occur.

In the vicinity of Saline river the folding is gentle, except in the case of mount Clark where the Precambrian-Cambrian? quartzite has been folded into a closed anticline which has faulted along its southeastern extension with upthrust from the eastward estimated at 2,000 feet. Another fault nearly parallel with this one passes east of the base of mount Clark, separating the Lower Cambrian quartzite from Upper Middle Cambrian limestone and thus having a probable downthrow of about 1,500 feet to the east.

The eastern face of mount Charles, which is in strike with a similar escarpment on the east side of a small mountain 2 miles south of Great Bear river, is best explained as a fault scarp. The nearest rock outcrops to the east are of Cretaceous age and are about 2 miles away. The mountain stands, however, about 1,400 feet above the bed of the stream which flows along its eastern side, and the downfaulting on the east is probably of this amount.

MOUNTAIN BUILDING AND EARLIER UPLIFT

Franklin mountains and the adjacent parts of Mackenzie and Bear rivers have not furnished complete evidence of the age of mountain building. The absence of Carboniferous, Triassic, and Jurassic sediments suggests that the region was above sea-level in Upper Palæozoic and early and middle Mesozoic time. The calcite and selenite veins, and the crystallization, silicification, and dynamic metamorphism of the Silurian and Devonian sediments indicate disturbances which did not affect the Cretaceous unmetamorphosed beds. Most conclusive of all is the evidence of the chert pebbles in the Cretaceous conglomerates. These pebbles evidently came from Palæozoics exposed by erosion in the Mackenzie-Yukon mountains. The combined evidence points to uplift and deep erosion before Cretaceous time, at least in the region of the Yukon-Mackenzie watershed which Keele[1] recognized as of earlier origin than Mackenzie mountains.

A second uplift and the building of fault-block mountains occurred, however, after the Cretaceous sediments of the Mackenzie basin were deposited, as already stated by Kindle and others. The Cretaceous sediments are somewhat tilted in the vicinity of Franklin mountains and the drainage system, major and minor, was well established before the Eocene deposits were laid down. Not only are these deposits undisturbed, but

[1] Keele, J., Ibid, p. 17.

they contain, in conglomerate beds, large quantities of chert pebbles which were probably derived by destruction of the Cretaceous conglomerates. It may be argued that these pebbles and those of the Cretaceous have come from the same source, and this is possible. However, the finer polish and excessive wear of the pebbles, along with the finer character of the Eocene deposits as compared with the Cretaceous sediments, suggest that they have undergone two periods of erosion and deposition. The present mountains are doubtless a product of the Laramide revolution during which the Rocky mountains were built; there is good evidence, however, for believing that the Palæozoics were at least uplifted and differentially eroded in post-Devonian, pre-Cretaceous time. Other workers in the region may be expected to add conclusive evidence in this regard.

ECONOMIC GEOLOGY

PLACERS

Small traces of placer gold were found in the gravel at the mouth of the River-between-Two-Mountains by Messrs. Adams and Malley early in the summer of 1922, and as a result the river was staked for about 8 miles, or through the mountains, by local traders and trappers. There is a story that men on their way to Yukon in 1898 or 1899 discovered gold here. The writer, in 1921, studied the mountain on the south side of the canyon and also the river valley for about 1½ miles up, and one of his party panned at the river mouth, but owing to high water did not find the gold-bearing beds. This year the writer panned again and found fine flake gold on the discovery claim. Similar gold is said to have been found through the mountain canyon, which is walled by dolomite of Upper Silurian age, capped by Middle Devonian limestone. The river flows along its lower course through a valley cut about 100 feet into glacial till and outwash gravel, and considerable material of the same kind occurs as far up as the mountains. The gold is clearly derived from the unconsolidated glacial deposits, and large placers are not to be expected.

GYPSUM

Gypsum beds occur in the Saline River formation at the foot of mount Kindle and in adjoining mountains on Saline river about 1½ miles above its mouth, and on mount Charles. In the Franklin Mountain formation in the eastern face of the mountain and near Great Bear river about 150 feet of grey gypsum outcrops. In the Lone Mountain formation about 2 miles north of Great Bear river, on the western slope of the mountain, white to grey gypsum outcrops with an estimated thickness of 500 feet. These Mount Charles deposits are within reach of water transportation on Great Bear river, should sufficient demand arise for gypsum in the lower Mackenzie valley. Specially constructed, shallow draft boats would be required, however, and the season of transportation would be limited to a few weeks in the latter part of the open season.

SALT

Brines oozing from the salt beds of the Saline River formation, about 1½ miles up Saline river, evaporate sufficiently during the low water of summer to form encrustations of salt on the gravel of the river bed. This salt has been long known to the Hudson's Bay Company, and has been used locally for table and preserving purposes. The quantity of salt produced is very small.

LIGNITE

Until stripping and sampling have been undertaken, the value of the Tertiary lignites above Norman will not be known. The best-looking beds occur in the west bank of the river about 21 miles above Norman, and near the survey station P.M. 14 north. Here 20 feet of beds near the top of the section appear to be composed principally of lignite beds. Samples of coal burned in the camp fire and in a camp stove proved to be very high in ash; and silicified wood is commonly found in the lignite beds or in close association.

PETROLEUM

The region occupied by Franklin mountains is unfavourable for the occurrence of petroleum. From the vicinity of Wrigley to the mouth of Dahadinni river only a narrow belt of Upper Devonian shales borders the east bank of Mackenzie river, and the Middle Devonian limestones forming the west flank of the mountains are without protective covering and are deeply eroded. These limestones are the hope of the oil prospector, and it will be seen that they are not suitably protected to contain oil in this vicinity. North of Dahadinni river the Devonian formations cross to the west side of the Mackenzie, leaving only Silurian and older formations on the east as far north as Great Bear river, and much farther in the hilly region extending northerly from mount Charles.

Independent of the occurrence of formations, the sharp folds and extensive faults of the Franklins, together with metamorphism, silicification, etc., are very unfavourable for oil accumulation.

The Cretaceous and Eocene beds are much too isolated and eroded to offer any hope of oil deposits.

MACKENZIE RIVER DISTRICT BETWEEN PROVIDENCE AND SIMPSON, N.W.T.

By E. J. Whittaker

CONTENTS

	PAGE
Introduction	88
General description of district	88
General geology	97

Illustrations

Plate III.	A.	Joint-plane developed in Hay River limestone, 110 feet high by 175 feet long. Redknife river just above lower entrance to gorge	129
	B.	Small tributary entering Redknife river from above canyon, 1 mile above lower entrance to gorge. Fall 33 feet	129
IV.	A.	Boulder in ancient channel of Redknife river at the falls	130
	B.	Falls on small stream near head of Jean-Marie river	130
Figure	4.	Redknife and Bouvier rivers (Mackenzie river), district of Mackenzie	91
	5.	Jean-Marie river (Mackenzie river), district of Mackenzie	92

INTRODUCTION

During the season of 1922 the writer completed the geological reconnaissance, commenced in 1921, of the country along Mackenzie river between Providence and Simpson. The ordinary route into the field was followed, starting from Edmonton June 12, and arriving at Providence June 24. The Hudson's Bay Company has a fast new boat on the upper part of the route between Waterways and Fitzgerald. The journey from Fort Smith to Providence was made in schooners bound for the Arctic, and Great Slave lake was crossed while a certain amount of ice was still present. On the return trip Edmonton was reached on September 29.

Micrometer surveys were carried up Bouvier river for 17 miles, Redknife river for 45 miles, Jean-Marie river for 110 miles, and Rabbitskin river for 25 miles, and in the case of the Redknife and Jean-Marie, were carried to their headwaters. Geological traverses were made back from the river, and one long traverse of 20 miles was made from Rabbitskin river to the north into Horn mountains. All the navigable streams in this area have now been examined. Trout, Horn, and Kakisa rivers were traversed in 1921. A. K. McGill acted again very efficiently as assistant.

The writer wishes to acknowledge many kindnesses accorded him by people in the district, and more particularly the officers of the trading companies at Providence and Simpson, and especially Sergeant Thorne of the Royal Canadian Mounted Police, with whom the whole party stayed in Simpson while waiting for transportation to Edmonton.

GENERAL DESCRIPTION OF DISTRICT[1]

As regards the streams entering the Mackenzie it must be remembered that dead water is at the mouth of every tributary, so that an accurate estimate of their volume cannot be made unless they are explored for some distance.

[1] Geol. Surv., Can., Sum. Rept., 1921, pt. B, pp. 45-55, and Map 1956.

BOUVIER RIVER

Bouvier river joins the Mackenzie from the south, about 25 miles below Mills lake. It is 100 to 200 feet wide for a distance of 3 miles above its mouth, but then becomes a rushing, turbulent brook, 15 to 25 feet wide, full of boulder rapids, obstructed by log jams, and almost impassable for canoes.

For 6 miles the river flows over gravel and shingle bars between low banks of boulder clay. Going upstream, the banks rise and the river cuts down to bedrock, and flows in a low, wide gorge flanking shales with sandstone partings which belong to the Hay River formation. The lowest exposures occur 12 miles above the mouth. The valley maintains its southerly direction and widens to about 500 feet, with a depth of 75 feet. In this part of the river, rock exposures occur mostly just at the top of the banks, and only sections of a few feet are exposed. The river flows between grassy banks in the valley bottom. Back from the river on either side the country is an almost level plain and recently has been so thoroughly burned that one may walk for miles unhindered by bush. About 15 miles above its mouth the river abruptly turns to the west, for a quarter of a mile, leaving its former wide valley, and flows for about half a mile through a narrow gorge, 80 feet deep and only 40 feet wide, in which is exposed a continuous section of Hay River limestones. At the bottom of this gorge the river flows for over 400 yards along joint-planes. This gorge is post-Glacial in age and is due to damming of the old channel. The river soon rejoins the old channel just above the gorge (Plate III A).

For 3 miles above the gorge the river flows in a shallow, narrow valley, with low ramparts of limestone outcropping at frequent intervals. Above these exposures the general level of the country becomes less, resulting in the formation of a great muskeg extending east and west. It is at least 5 miles wide and of unknown length. To the south, higher land could be seen, no doubt the continuation of the escarpment so prominent farther down the Mackenzie. This broad muskeg occupies the same flat plain in which lake Kakisa lies, 30 miles farther to the east. Bouvier river, which below this point runs in a generally north-south direction, traverses this muskeg in a general direction of north 60 degrees east for a short distance; but as its channel is not depressed at all, it wanders at will through the muskeg, and only a small part of the water is confined to one channel. The muskeg could not be traversed on foot and the survey was stopped at this point.

A light canoe at high water might be brought down Bouvier river, but for practical purposes it is entirely unnavigable. A poorly defined Indian trap-line which parallels the lower, better wooded, part of the river at a distance of from 100 to 400 yards to the east is of some assistance to anyone exploring this valley.

REDKNIFE RIVER

Redknife river heads in Alberta plateau, in latitude 60° 55′ and longitude 119° 45′ and flows for about 50 miles in a general northeasterly direction until about 6 miles from the Mackenzie. Then it rather abruptly changes its course to slightly west of north, entering the Mackenzie 63 miles below Providence and 19 miles above the mouth of Trout river. For about a mile upstream from its mouth the river is 600 feet wide, but then rapidly contracts to 50 feet and meanders among gravel bars in a valley about 2,000 feet wide. As in the case of the other streams crossing the escarpment bordering Alberta plateau, Redknife river is swift and full of shallow rapids and for long stretches spreads out over gravel bars to several times its normal width, in which places even a canoe channel is difficult to discover. The valley walls become higher and closer together as the escarpment is approached. About 10 miles from the mouth, measured by the river, the banks of boulder clay are abruptly replaced by sheer, vertical cliffs, and the river flows in a gorge 125 feet deep, whose scenic beauty is not surpassed by any of the canyons in this area. One quarter of a mile above the entrance to the gorge a small stream plunges precipitately over the eastern wall in a vertical cataract 70 feet high; and half a mile farther up, another stream enters the main river by a falls 33 feet high (Plate III B). The rock walls can be ascended at a few points only. Most of the rapids are too shallow to run, and seven portages altogether are required to pass various obstacles in the gorge.

Immediately above the upper cataract mentioned above a short portage of 30 yards is required to pass a chute 4 feet high. Three-quarters of a mile farther up stream the whole volume of the river boils through a narrow gap 15 feet high—the Big chute—formed by enlargement along a joint-plane. The cliffs rise vertically for 100 feet on either side. Breakneck portage, as this is called, is on the west side of the river. It ascends a vertical cliff 35 feet high, where all equipment must be hauled up by a windlass; it then climbs to the top of the steep cliff above the river; follows the cliff for 200 yards; and then descends 80 feet abruptly to the river. This portage leads past three chutes, is 400 yards long, and is by far the greatest obstacle to travel on this river. Above it in quick succession come four chutes, each passed by a short portage, and finally, just at the upper end of the gorge, a portage of 40 yards leads past a vertical fall 15 feet high. The total length of the gorge is 3½ miles. The falls are of very recent origin. Originally the river ran in a great oxbow one-third of a mile long, but recently the narrow neck of till has been pierced and the stream now falls over the old cut bank of the former channel. Since their inception the falls have retreated 20 feet. The old channel is readily recognizable by its boulders, cut banks, and sparse vegetation. One of these boulders showing the scouring action of the current is shown in Plate IV A. A small stream now occupies parts of this former channel.

Above the falls the river turns to the southwest, and for 17 miles meanders in a shallow valley with grassy banks, and averages 75 feet in width. The cover of boulder clay is very thin, for limestone shows almost continuously in the bed of the stream but seldom rises more than 3 feet above the water. Short rapids occur with intervening stretches of quiet water, but become less common going up stream, and finally cease entirely. The river narrows to 30 feet and meanders in an exasperating manner through an almost level plain, 14 miles by river representing only 6 miles in a straight line. This is the most monotonous section of the whole river. The banks seldom rise more than 5 feet above the water and are covered with fallen timber. The country was burnt over a few years ago and the dead trees along the river now form many log jams that within a few years will, probably, render this part of the river almost unnavigable.

Above this level plain the country rises and the river once more becomes swift and broken by rapids which continue until lower Redknife lake is reached 40 miles above its mouth. This part of the river has not been burnt over and is a pleasant contrast to the previous section. Four miles below the lower lake an Indian camp site is located. The river enters lower Redknife lake near its northern end. Just northwest of this point the outlet of the lake is very effectively masked by the thick growth of marsh grasses through which the canoe must be pushed. Two small tributaries, neither of them navigable, enter this lake. One mile above the lower lake a broad channel 100 yards long leads to the upper lake. For 4 miles above the upper lake, Redknife river remains about 40 feet wide with very little current; then it suddenly turns to the south, contracts to less than 10 feet wide, becomes very crooked, shallow, and swift, and is no longer navigable. In fact, this point may be considered its headwaters.

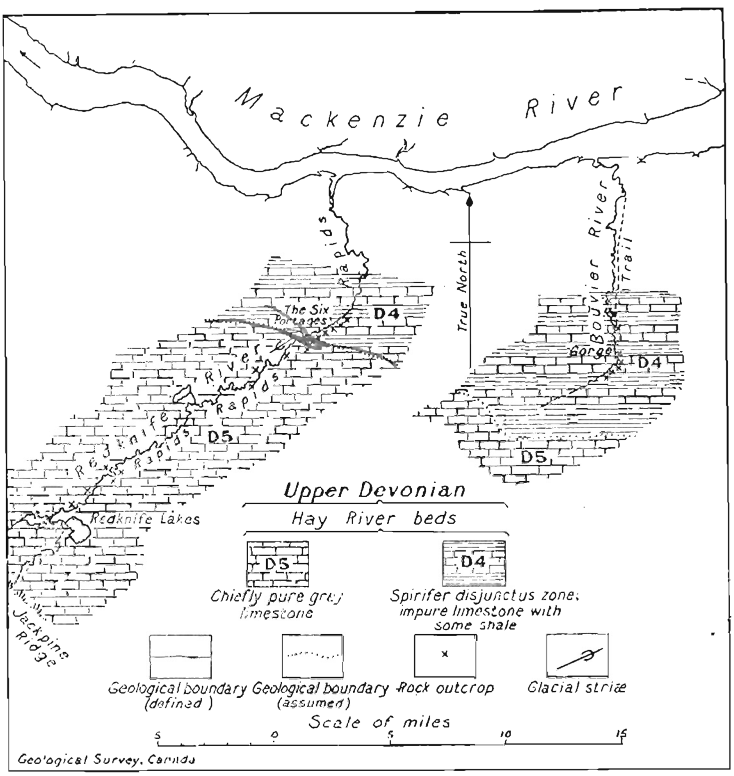


Figure 4. Redknife and Bouvier rivers, Mackenzie river, district of Mackenzie.

Redknife lakes are less than 10 feet deep. On the southeastern side of both lakes a small beach has been developed. Elsewhere the shores are very low and marshy. A similar small, almost oval, lake occurs half a mile from the river about 8 miles farther north. The relationship of these rivers and lakes may be seen in Figure 4. Compared with the Mackenzie lowlands on the opposite side of the river the Alberta plateau is surprisingly free from lakes, these three being the only ones seen.

Fifteen to 20 miles south of, and easily visible from, Redknife lakes a group of gently sloping hills, known locally as Round mountain, reach an apparent elevation of 1,500 feet above the plain and are wooded to the top.

The volume of water in Redknife river is less than one-quarter that of Trout river and although the Redknife may be, for canoes with light loads, a passable route into the area about its headwaters it cannot owing to shallowness and swiftness, be recommended.

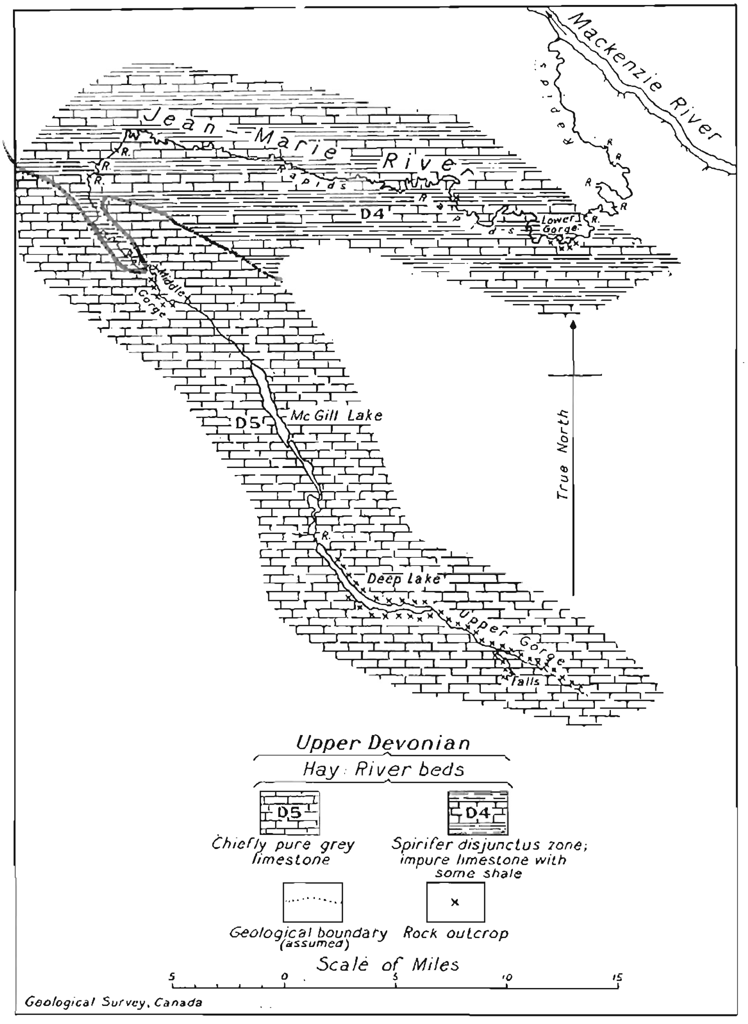


Figure 5. Jean-Marie river, Mackenzie river, district of Mackenzie.

JEAN-MARIE RIVER

Jean-Marie river rises within 15 miles of Trout river (Figure 5) and flows northwesterly for 45 miles, approaching within 12 miles of Liard river at the foot of the rapids. It then swings around rapidly and pursues a course slightly south of east until within 22 miles of the Mackenzie, where it turns once more to the left in a course of north 15 degrees west, roughly paralleling the Mackenzie for many miles and joining it 41 miles above Simpson. From headwater to mouth the distance is 110 miles, but in a straight line is only about 30 miles. The volume of water outranks that of Redknife river and travelling was much easier than on either the Redknife or the Bouvier.

Dead water is present for about half a mile up from its mouth, after which the river narrows to 50 feet and becomes swift and shallow. At one point there is a line of boulders lengthwise of the stream, to pass which a portage of 30 yards is necessary. However, about 3 miles above its mouth the river widens out, becomes broad and deep and nearly currentless, broken by occasional boulder rapids. Such boulder rapids apparently act as dams holding back and deepening the water above. The river winds in a shallow valley about 600 yards wide. Twenty-one miles above its mouth the river passes through low exposures of grey shales and shaly limestones and sandstones. There the river widens to over 100 feet and is so swift and shallow—though without rapids—that canoes must be tracked up the middle of the stream. Above this point rapids once more commence at intervals. The river flows in a shallow ill-defined valley and meanders through a plain characterized by an abundance of sandy drumlins which are much more pronounced here than in the areas hitherto described.

The abrupt escarpment so prominent along the Mackenzie farther to the east is here represented by a very gradual rise in the level of the country. Within this area of higher land the course of the river gradually swings from nearly east and west around to the southeast; and flows in a valley over 1,000 yards wide and about 100 feet deep. Within this valley the river is readily navigable, being wide, deep, and without current except rarely where blockaded by a boulder rapid. About 75 miles above its mouth the stream has cut down to bedrock and for 2 miles flows in the bottom of a shallow gorge with a maximum depth of 40 feet. In this gorge the stream is split by shingle bars into many channels and is very shallow. For 50 miles below this gorge and 20 miles above no rock exposures occur.

Above the gorge easy water prevails for 8 miles up to a small lake, McGill lake,[1] 5 miles long and $\frac{1}{3}$ to $\frac{1}{2}$ mile wide. A barrier of boulder clay, represented in the river itself by a series of heavy boulder rapids just at the outlet, has dammed back the waters and flooded the entire valley floor. This lake is very shallow, and its shores are badly burned over. For 5 miles above the lake, similar flooded conditions occur; the river alternately dilates and contracts, and the valley floor is largely marsh. Most of this area of motionless water is thickly covered with pond lilies at its upper end. Jean-Marie river enters as a stream only 10 feet wide, very shallow and swift. This section is only three-quarters of a mile long and flows out of Deep lake, which is 5 miles long and one-quarter of a

[1] Named for the writers's student assistant during the seasons of 1921 and 1922.

mile wide. Deep lake is very picturesque and a great contrast to McGill lake. Its shores are high and rugged and the valley banks, which now approach each other closely, are more rugged, and sharply truncate the level plain on either side. Rock exposures along their crests are almost continuous. A surprising feature of the lake is its depth—115 feet was obtained in the middle. About half of the lake only can be seen at once as its course turns more and more to the east. For about three-quarters of a mile above the upper end of the lake the river is wide and without perceptible current. At this point, which marks the limit of navigation, a ruined cabin and five old spruce and birch-bark canoes were observed. No Indians had camped here for some time past. This upper body of water is also known locally as Fish lake.

Above this navigable part the valley walls approach each other rapidly and increase in elevation; the river runs in a much divided shingle channel. Ten miles above Deep lake the stream commences its wild dash through this gorge, dropping 225 feet in 6 miles. No falls are developed in this section, but the river drops rapidly from one ledge to another. At its upper end, it is completely above the plateau level. At ordinary stages of water in this upper gorge the river often disappears for hundreds of yards beneath great masses of shingle fallen from the overhanging cliffs. Four miles above Deep lake the river is dammed back for half a mile. This stretch of dead water is in violent contrast with the swift points above and below. At the lower end of this dead water a small tributary comes in from the south. On this tributary there is a beautiful little fall 45 feet high (Plate IV B).

From the above description, therefore, it is seen that Jean-Marie river may be roughly divided into lower, middle, and upper gorge sections, with intervening stretches of dead water or at any rate dead water with rapids. The origin and distribution of these rapids, and the somewhat peculiar phases of the river valley, will be discussed later. Although some of the rapids are shallow, the long stretches of dead water make better canoeing than is usual in this part of the country.

RABBITSKIN RIVER

Rabbitskin river enters the Mackenzie from the north 22 miles above Simpson and through most of its course traverses the Mackenzie lowlands. Its headwaters are unknown, and questioning of the native inhabitants elicited no very satisfactory information. It is said to rise in Horn mountains. It was examined by the writer for 25 miles only, but its general course could be observed from tall trees for 5 miles farther. For 16 miles above its mouth it is navigable with difficulty, flowing in rapids between steep, high banks of till, but above this point and as far as the traverse was carried, the river was wide and deep. Its general course is east 10 degrees south and thus it almost parallels the Mackenzie. Between the two rivers, however, is a ridge of boulder clay nearly 200 feet high and it is in this ridge that the greatest rapids occur. Between the ridge and Horn mountains the land is lower and extremely flat, but it is not as swampy as the area traversed by the writer in 1921 from Horn river to the south-eastern end of Horn mountains. The whole area has been burnt within the last twenty-five years and now is largely covered with a second growth of scrub poplar. Along the watercourses only does any of the original timber remain.

From Rabbitskin river, at what seemed the most suitable point, a traverse of 20 miles was made into Horn mountains. This work was left until the beginning of September, and anyone contemplating a trip across muskeg country is strongly advised to wait as long as possible, until the ground gets a chance to dry. In fact, on the ingoing trip the party suffered because of lack of water, many hours' travel frequently elapsing between pools. But that the groundwater table is very close to the surface was shown by the fact that a slight rain filled all the pools and marshes. The greatest obstacle in such a traverse is brûlé. Horn mountains in this area rise rather abruptly from this level plain to a height of about 1,500 feet. The ascent is made in a gentle slope of about 300 feet in half a mile and an abrupt rise of 1,200 feet in about 300 yards. From the crest the land rises very slowly for about a mile, then merges into the plateau which forms the top of the mountain. The plateau at this point is covered with stunted spruce and, more rarely, poplar.

From the summit a wonderful view is obtained if the weather be clear, as fortunately was the case at the time of the writer's visit. On the great level plain between the mountains and the Mackenzie only five small bodies of water were observed, a great contrast with the country seen from Horn mountains at their southeast end. Nahanni butte, and the range of mountains extending north from it, were plainly visible, though over 100 miles away, and the detailed configuration of the escarpment to the south of the Mackenzie could be observed. Looking along the crest as far as the eye can reach, Horn mountain is seen descending to the plain with the same uniform, rather abrupt, slope as described above.

Rabbitskin river is 50 to 75 feet wide and has a larger volume than any of the other rivers traversed in 1922, but is smaller than either the Horn or the Beaver, and is less than half the volume of the Trout. Its waters, fed from a muskeg country, are much browner than those of the streams leading from Alberta plateau. Rock exposures were not encountered in the river, but were observed in Horn mountains.

TIMBER

The area examined is most discouraging from a forester's point of view. Along Bouvier and Redknife rivers the whole country has been swept by fire within the last three years. Such fires, on account of the resulting brûlé, render exploration of the country almost impossible, and the smaller streams become jammed with logs. Below Redknife lakes this was especially unfortunate, for some of the best timber of the country was located there. Spruce stubs were measured up to $2\frac{1}{2}$ feet in diameter. Locally, small areas of timber about the headwaters of Jean-Marie river have escaped and are covered with a fair growth of spruce up to 8 inches in diameter. Elsewhere along this river repeated burnings have laid the country bare. As noted above, in Horn Mountain area a fire, about twenty years ago, swept the country, which now is covered by scattered growths of poplar that have lately suffered again. These conflagrations are largely due to the Indians, partly through carelessness and partly through certain superstitions to which they give credence.

FISH AND GAME[1]

Marten is the most common fur-bearing animal in the area. The upper reaches of Jean-Marie and Trout rivers appear the best for trapping, but as a whole, and as the result of the fires, game is very scarce.

Jackfish are abundant in Bouvier and Rabbitskin rivers, and in the Redknife as far as Big chute. Peculiarly, this species has never established itself in the upper part of the river, a fact to which the thousands of minnows present bear witness. Small bluefish, also, were observed in this part of the river. Indians state that whitefish and lake trout are present in Deep lake on Jean-Marie river, but none was observed by the writer.

TABLE OF DISTANCES ALONG RIVERS

Mackenzie River

	Miles
Providence to Mills lake	16
" Bouvier river	53
" Redknife river	63
" Trout river	82
" Head-of-the-Line	89
" Jean-Marie river	115
" Rabbitskin river	134
" Simpson	156

Bouvier River

From outlet to head of dead water	3
" lowest rock exposure	12
" lower end of gorge	15
" point where river emerges from muskeg	17

Redknife River

From outlet to lower end of gorge	10
" Big chute	11½
" falls	13½
" lower Redknife lake	40
" upper Redknife lake	41
" end of traverse	45

Jean-Marie River

From outlet to lower gorge	21
" lower Big Bend	22
" upper Big Bend	63
" lower end of middle gorge	75
" upper end of middle gorge	77
" McGill lake	82
" Deep lake	92
" upper end of Deep lake	97
" end of navigable river	98
" end of traverse	108

Rabbitskin River

Outlet to upper end of bad rapids	16
" end of traverse	25

[1] For general account *see* Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 50.

GENERAL GEOLOGY

Pleistocene, Cretaceous, and Upper Devonian formations were encountered in the area explored. No Middle Devonian beds were observed east of the Mackenzie, but they might be revealed on further exploration at the headwaters of Rabbitskin river. The general section is as follows:[1]

Table of Formations

—	—	Thickness
		Feet
Pleistocene and Recent	Boulder clay, alluvial and lacustrine deposits.	10 to 100
Cretaceous	Rabbitskin sandstones	50 to 100
	Mountain shales	100 to 500
Upper Devonian	Hay River beds	700
	Simpson shales	150

SIMPSON SHALES

No additional information was obtained this summer in regard to the more exact mapping of the boundaries of this formation. Both Jean-Marie and Rabbitskin rivers were favourably situated for such exposures, but none was found. The drift is very thick in the lower parts of both rivers, especially the Rabbitskin, and as the shale weathers so very easily this may account for the lack of exposures.

HAY RIVER BEDS

Sections exposing Hay River beds were encountered and measured along the Bouvier, Redknife, and Jean-Marie. The most complete section occurs along the Redknife, but the highest beds were observed at the head of Jean-Marie river. The sections correspond in general, though differing in detail, to the section described last year.[2]

In Redknife River section about 125 feet of limestone is exposed above the falls, and about 225 feet of limestones in the gorge below the falls. Above the falls, the river has cut little below the level of the surrounding country and only small sections of a few feet are exposed in any one spot, but exposures in the bed of the river are very common. The most conspicuous elements in the fauna are the large numbers of corals, which form reefs of great thickness, more especially in the vicinity of the falls. One specimen of *Phillipsastræa* 26 inches in diameter was observed. The bed, which forms the top of the falls, is characterized by an unusual pelecypod fauna. This may be especially well observed on the west bank of the river immediately above the falls. Immediately below this pelecypod horizon is a bed of impure, buff-weathering limestone, 9 feet thick, which contains many well-preserved crinoids. This horizon can be correlated

[1] For more complete section *see* Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 51.
[2] Geol. Surv., Can., Sum. Rept., pt. B, 1921, pp. 52–53.

with bed *K* of the Trout River section, just below the top of the third falls. It may be said that this whole section contains a well-preserved crinoid fauna in which the genus *Melocrinus* is dominant. *Spirifer disjunctus* is the characteristic fossil of the section below the falls.

Jean-Marie River section consists of three parts separated by long stretches of quiet river without rock exposures. These sections are known respectively as the lower, middle, and upper gorges. The lower gorge, however, is rather a wide, shallow canyon ½ mile wide and less than 100 feet deep. Flanking the valley at intervals are sections of bluish grey, calcareous and sandy shales with thin parting of calcareous sandstone. These beds resemble very much the beds exposed at the rapids of Liard river and are characterized by many *Stropheodontas* and *Goniatites.* The middle gorge exposes a section 60 feet thick of fairly pure, grey limestones weathering buff. This contains an abundant and characteristic fauna with *Hypothyris cuboides*, *Conocardium*, several species of *Spirifer*, *Schizophoria striatula*, *Cryptonella*, and several specimens of a trilobite probably *Bronteus.* This fauna is exactly the same as that observed at the top of the escarpment south of Kakisa lake. The specimens of *Conocardium* are unusually well preserved and many show a great flare on the umbonal ridge. The upper part of this section is correlated with the beds exposed at the top of the falls on Redknife river.

Between the bottom of this section and the top of the section in the lower gorge there is a vertical difference in level of at least 200 feet. Though the middle and upper gorges are 21 miles apart the vertical sections may be less than 100 feet. In this upper gorge there is a section of 165 feet of grey limestones with thin, shaly partings underlain by a bed which varies in thickness considerably from place to place, but averages 20 feet of very fine-grained, nearly unfossiliferous, pure grey limestone. The former beds are sparingly fossiliferous and the characteristic fossil is a large, undescribed *Rhynchotrema.* The highest beds of this section outcrop just at the general level of the surrounding country.

On Bouvier river a fairly complete section of the lower part of the Hay River beds is shown. These lie entirely within the *Spirifer disjunctus* zone. In the gorge, and above, are exposed 95 feet of buff-weathering grey limestones which contain an abundant coral fauna in which *Phillipsastræa* predominates. In the section extending below the gorge for 5 miles along the river are beds 85 feet thick, which grade from impure, grey limestone, with thin shale partings at the top, down into bluish green shales with thin sandstone or limestone partings at the bottom. These lower beds have very few corals, but a large *Atrypa*, *Goniatites*, and many gastropods are common, and fish plates occur in the sandy layers.

The Hay River beds are all characterized by well-developed joint-planes usually nearly vertical and this feature is responsible for the rugged and vertical canyon walls so common on all these rivers (*See* Plate III A). The major joint-planes run in two directions, as shown in the list of a few representative sets given below.

Bouvier river—head of gorge	S. 59° W.	S. 31° E.
Redknife river, 4 miles below lower Redknife lakes	S. 53° W.	
Redknife river at falls (poorly developed)	S. 6° W.	S. 30° E.
Trout river at second falls	S. 59° W.	S. 58° E.
Jean-Marie river, head of upper gorge	S. 83° W.	S. 32° E.
Jean-Marie river, head of middle gorge	S. 68° W.	

MOUNTAIN SHALES

This formation was not observed in 1922. The streams flowing down from the Horn Mountain escarpment are so very small that none of them has succeeded in cutting down below the mantle of drift. However, judging from its position as determined last year, it seems entirely probable that the Mountain shales are present in this area and underlie the Rabbitskin sandstone.

RABBITSKIN SANDSTONE

This formation caps Horn mountains. The bottom of the formation was not observed. It consists of a rather coarse, white to rusty yellow, friable sandstone. The beds are 6 inches to 10 inches thick, and partings of soft, black shale are common. The sandstone beds frequently contain ironstone concretions up to 1 foot in diameter and 4 feet long. Fossils were not observed in this formation. Exposures are infrequent. Those observed by the writer had been exposed by a series of landslides which were located from Rabbitskin river with the aid of field glasses.

Round mountain, observed from the upper part of Redknife river, in all probability is composed of rocks of Cretaceous age, but direct observation was not possible.

PLEISTOCENE AND RECENT

Everywhere a mantle of till covers the bedrock, with the result that rock exposures in this area of flat-lying rocks are practically confined to the river valleys. Rabbitskin river has not yet succeeded in cutting down to the bedrock in the area explored. It is improbable, owing to the lack of streams of any size, that rock exposures occur at all in the large area bounded by Horn mountains and Horn, Mackenzie, and Rabbitskin rivers. In this area the land surface undulates gently with many lakes and ponds occupying the depressions, but toward the northwestern part, i.e., between Rabbitskin river and Horn mountains, these ponds are much less common. On the west side of the Mackenzie the surface of the drift is much more irregular and numerous drumlins occur. One such drumlin, which is cut by Jean-Marie river about 50 miles above its mouth, is 125 feet high and affords a fine view of the surrounding country even to the Rocky mountains at Nahanni butte on Liard river.

Glacial striæ were observed at one point only—on Redknife river, 5 miles above the falls. Two sets were observed running south 55 degrees west and south 45 degrees east. The latter appeared to be the older.

Glaciation is apparently responsible for the broad, deep valley of the upper part of Jean-Marie river, which is much too large for the present insignificant stream. McGill lake is probably also caused by a dam of morainal material. Deep lake, however, seems to have been deepened by ice action. Its depth, 115 feet, is unique for this area, where most bodies of water such as Redknife lakes occupy only shallow depressions in the drift.

Modern river ice action seems largely responsible for the many boulder rapids which are separated by stretches of quiet water. Such rapids nearly always occur at a sharp bend in the stream, where an ice jam would occur and produce a blockade of boulders. Many of these walls of boulders have a difference of elevation on the two sides of the river of as much as 3 feet.

STRUCTURE

The rock formations, where exposed, are nearly flat lying and fold structures are almost absent. A low dome on Jean-Marie river produces the middle gorge. Small, local dips of 2 degrees to 3 degrees occur in many localities, but they are never persistent or uniform and usually die out within a hundred yards. Oil possibilities are practically negligible, except perhaps at the dome at the middle gorge. This is, however, commercially inaccessible.

INVESTIGATION OF ARTESIAN WATER, COAL, PETROLEUM, AND NATURAL GAS IN ALBERTA

By D. B. Dowling

CONTENTS

	Page
Introduction	101
Red Deer River placer deposits	101
Foothills coal area	101
Artesian area of southern Alberta	104
Prospecting for gas and oil in southern Alberta	123

Illustrations

Map 1979.	Artesian area, southern Alberta	104
Plate V.	A. Showing water drawn by wagon before artesian wells were drilled	131
	B. Government test well No. 1 connecting pipe and water tank for cattle	131
VI.	Apparatus used for saving the gas which comes with the water. Farm of John Ell	132
Figure 6.	Part of southern Alberta showing underground contours of top of Milk River sandstone in relation to sea-level. Bored wells shown by heavy black dots	108

INTRODUCTION

Field work by the writer in 1922 included investigations into the development of the mineral resources of Alberta, principally coal mining in the foothills of Rocky mountains, placer mining on Red Deer river, drilling for artesian water in southern Alberta, and, incidently, prospecting for gas and oil.

RED DEER RIVER PLACER DEPOSITS

The examination made of the placer mining operations on Red Deer river, townships 38 and 39, ranges 22, 23, and 24, west of the fourth meridian, gave no indication of platinum in the gravels and rather small returns in gold. Gold values less than the cost of extraction were obtained from the gravels of the present stream bed and from bench gravels that represent river levels during earlier stages of the cutting of the channels, but no trace of platinum was detected in any of the samples taken. The rush for claims on Red Deer river was based evidently upon an exaggerated expectation of values in the gravels.

FOOTHILLS COAL AREA

In the eastern part of the Alberta syncline the Upper Cretaceous coal horizons are in the Edmonton and Belly River formations. These subdivisions merge together westward and determination of the exact age of the coal beds will depend largely on the plant remains. The syncline continues west of the Canadian National Railway crossing of Pembina river and the longitude of Rocky Mountains house on the Saskatchewan, but farther in this direction lower rocks reach the surface and then bend downward again. A long anticline is thus formed which is in evidence at Coalspur and on the Saskatchewan, west of Saunders creek. A coal-bearing horizon is brought to the surface on this anticline and prospecting commenced there before the railway was completed to the mountains.[1]

[1] Geol. Surv., Can., Sum. Repts., 1909 and 1916.
Min. Resources of Alberta, Ann. Rept., 1920.

Observations from the train in 1922, while on a brief trip up each of the railway branches, confirm previous accounts of the structure. From Edson for 30 miles southwest there appears to be little disturbance, but no doubt the approach to the anticline is accompanied by an increase in the eastern dip of the beds. This is evident at mile 32, where the dip is apparently 30 degrees. A coal seam appears in the valley of the Embarras, at mile 33, and although somewhat crushed, is mined there. The thickness is given variously as between 9 and 12 feet. The shipping point for this coal is called Mine Head station. Farther west the crown of the anticline is passed, and a coal seam– presumably the one mined at Mine Head— is mined at Coalspur, by the Yellowhead Pass Coal Company. This seam is reported to be about 8 feet thick. About 3 miles nearer the mountains in direct line, a seam—presumably a repetition of the same seam— is mined by the McLeod Coal Company. Here it dips northeast at from 35 to 40 degrees. Following the railway to the valley of McLeod river the dip steepens. There may be some faults along this stream since there are rather abrupt changes from high dips to stretches where the rocks appear horizontal or with low dips. As the outer range of the Rockies is approached the strata appear to be of a lower horizon, and dark shales are in evidence. Between the mouth of Lusker creek and the first limestone is a deep syncline pitching to the southeast. In the valley of McLeod river the strata in the west limb of the syncline are Kootenay and contain the coal seams mined at Cadomin. These are almost vertical and in places may be repeated by sharp folds. The eastern limb of the syncline does not expose the Kootenay rocks in this valley, but they are found up Lusker creek, where a mine is now being established. The seam, apparently the same as at Cadomin, is 35 feet thick and there is another, not yet mined, 22 feet thick. These coals belong to the steam coal class as mined in the mountains and are older than the foothills coals near Coalspur.

From Coalspur southeastward a separate line of railway has been built to Lovett. Several mines have been opened on the coal seams outcropping along this spur, which runs just west of the crown of the anticline.[1] Other small mines or prospects were opened at intervals along the railway, but many of them were closed on account of the cheaply mined deposits at Basing now worked by the Sterling Collieries Company.

Apparently a rather thick coal seam situated on the western side of the anticline has been buckled and has probably acted as a sliding plane for the upper measures under the pressure from the west that caused the anticline. Several slips of this nature are observable in the vicinity of the mountains, and, where slaty partings occur in the coal seams, the result is generally detrimental to the coal moved. In the case of the seam at Basing very little earthy matter seems to have been included between the sandstones composing the roof and those composing the floor; and the material filling the enlarged space appears to be mainly coal. The total dimensions of the deposit have not been proved, but the part that is known seems to indicate a very large reserve of coal. It appears to be several miles long, tapering in both directions from the mass shown in the pits at Basing. The upper part has been denuded by natural processes and afterwards covered by a mantle of boulder clay which is now being removed by steam shovel, exposing the mass of coal. The mass appears to be

[1] Geol. Surv., Can., Sum. Rept., 1916, pp. 100–102.

about 150 feet wide at the surface. On the east side the foot-wall is seen at one place, dipping west 80 degrees. Borings across the floor show that this steep dip continues for about 30 feet and then flattens to the general dip of the rest of the western part of the anticline. The roof, a small exposure of which appears on the edge of the pit and near the valley in which the railway runs, has also been found by drilling to have a moderate westward dip and its approach to its normal relation to the floor is, probably, continued westward of the above-mentioned valley. A thickness of 90 feet of coal was found by drilling near the railway, showing a large reserve beneath the level of the tracks.

At present the mining is all above grade, stripping and mining being done by steam shovel. Coal is mined by steam shovel and screened and hand-picked before loading on cars for shipment.[1]

SAUNDERS CREEK

Coal mining on the anticline that crosses North Saskatchewan river east of the first or outer range is centred in three or four mines situated along the Canadian National railway between Saunders and Harlech, 37 to 47 miles from the crossing at Rocky Mountain House. During the building of the railway a coal seam was discovered in the gorge cut by Saunders creek, and shortly after the completion of the road coal was mined from this locality.[2] J. S. Stewart[3] states that the seam dips about 5 degrees to the northeast, and that two seams had been discovered, an upper one of 12 feet with clay partings and a 5-foot lower one of bright coal which had earned a good reputation as a domestic coal. The lower seam has since been traced over the anticline and mined at two other places. The Alexo mine, near the summit of the anticline, works the lower seam 5 miles west of Saunders and the Harlech mine 5 miles farther away is situated on the western limb of the anticline, where the dip is 22 to 26 degrees to the southwest. The increased dip at Harlech brings a greater thickness of beds containing coal seams to the surface. A few notes relative to this section are given here.

HARLECH

At the mouth of a small creek at mile 165½ a coal seam was discovered dipping to the southwest. Farther up this creek three other seams are now known, all dipping in the same direction toward the railway. These are numbered, in order from the railway:

Seam No. 1

	Ft.	In.
Section near the tipple—		
Top coal	3	6
Shale		4
Bottom coal	2	3
	6	1
Section on first creek west—		
Top coal	3	3
Lower bench not seen		

[1] A review of several papers by Roland H. Briggs, Canadian Mining Journal, September 30, 1921, includes one of a paper by George Sheppard on "Coal Mining by Steam Shovel in Alberta" in which the operations at Basing are described. Additional details are given in the issue of the same periodical, September 15, 1922, and a general history of the operations and details of equipment appears in the Western Canada Coal Review of November, 1921.

[2] Geol. Surv., Can., Sum. Rept., 1913, p. 152.

[3] Geol. Surv., Can., Sum. Rept., 1916, p. 100.

Seam No. 2

About 600 feet along tramway from No. 1, giving a distance across measures below No. 1 of about 260 feet.

Section at tramway—	Ft.	In.
Sandstone roof		
Mining	0	6
Coal	4	0
Clay, contorted	3	0
Coal	1	0
Parting	0	2
Coal	2	0
Section on first creek west—		
Sandstone roof		
Mining	0	6
Coal	4	0
Clay	1	6
Coal	1	0
Parting	0	2
Coal	2	0
Shale and sandy shale foot-wall		

Section on third creek west. On this creek a large opening on No. 2 seam shows no clay parting and about 6 feet of coal with small parting in lower coal.

Section on fourth creek west. Along the strike of No. 2 seam several openings have been made on what appears to be a bulge in No. 2 seam. In this the top bench is seen with a contorted and folded lower part. In some of the cuts there appears to be 5 feet of coal in the folded part, that is, the seam looks as if it contains 9 feet of coal.

In the slope at the tramway it is clearly seen that a movement between the beds has been localized in the clay parting of the middle of this seam and that to the northwestward the movement has also affected the lower bench.

Seam No. 3

A short distance below No. 2 seam, a 2-foot seam has been uncovered overlying about 2 feet of sandstone and shale, with a little coal beneath. A small outcrop on one of the creeks west is taken as representing this seam.

Seam No. 4

It was considered that the seam mined near the top of the anticline should be about 50 feet from No. 3 across the measures. This position was located on the ground and when visited an excavation was made disclosing the seam beneath a sandstone roof:

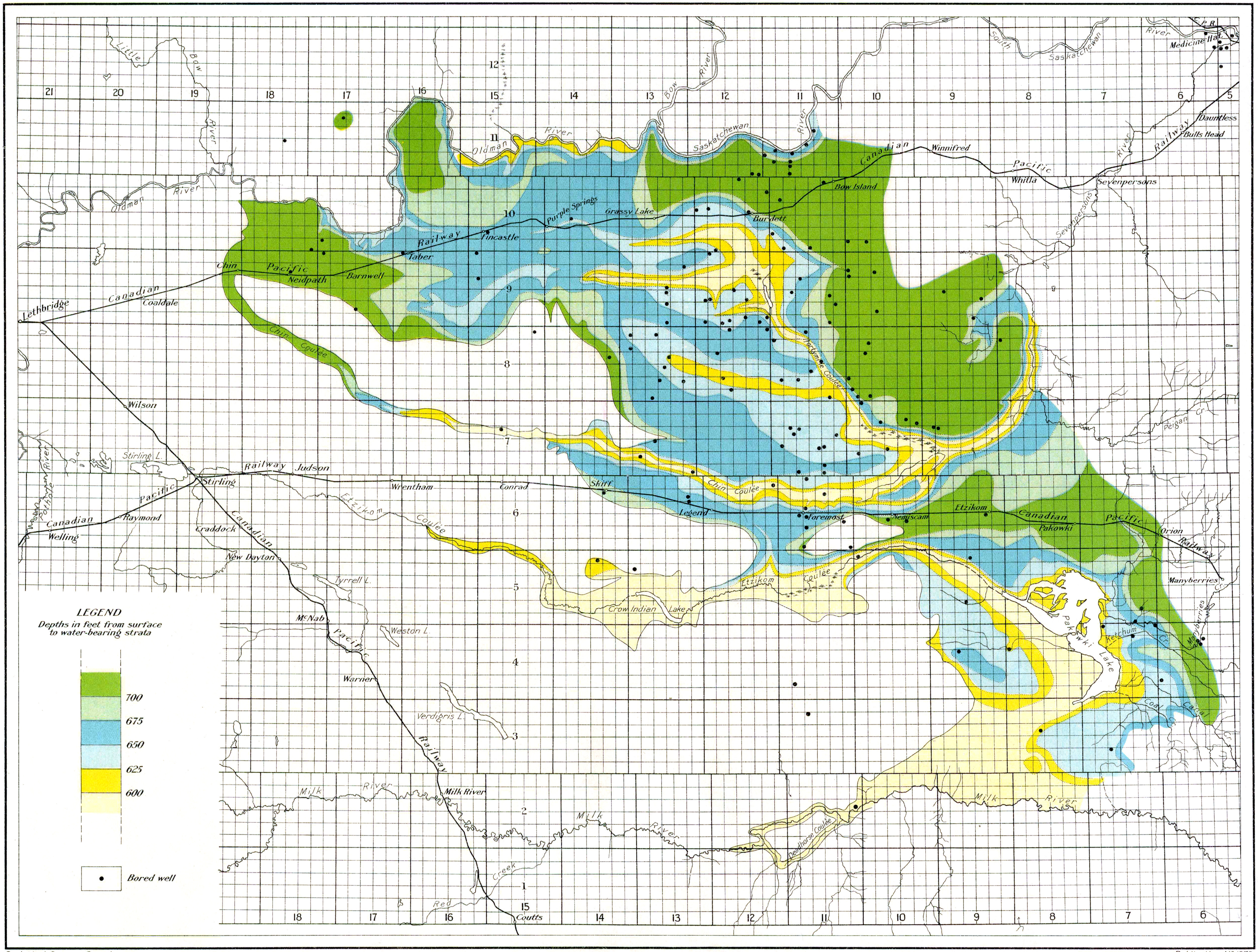
	Ft.	In.
Mining	1	0
Coal with ½-inch parting in middle	5	6

As this coal appears to be in an unbroken state it promises to furnish a greater percentage of lump coal than those being mined, an advantage in the domestic market. Mining of this seam was contemplated at once, so that the coal marketed from the group of mines in this locality will be largely from the same seam, which underlies an area about 10 miles wide.

The coal from these mines bears the trade name "Saunders Creek" and is a bituminous variety of the non-coking type, a little lower in fixed carbon and still classed with the smokeless coals. The fuel value is over 11,000 British thermal units.

ARTESIAN AREA OF SOUTHERN ALBERTA

The plains in Alberta south of Saskatchewan river slope gently from an elevated region near the International Boundary to the wide depression occupied by Oldman and South Saskatchewan rivers. To the southwest of this plain rises Milk River ridge, part of an outlying series of hills in front of the foothills of the Rockies. To the south, and just across the boundary line, in Montana, rise the three intrusive masses known as the



Geological Survey, Canada.

Publication No 1979

Artesian Area, Southern Alberta.

Scale of Miles

5 4 3 2 1 0 5 10

To accompany Report by D.B.Dowling, in Summary Report, Part B, 1922.

Geology by D.B.Dowling, 1922.

Sweet Grass hills. To the east lies the remnant of a former elevated plateau, the Cypress hills.

This plain, surrounded on three sides by higher country, is scored by valleys that at one time formed part of a drainage system that would be at variance with the present surface slope. These valleys are assumed to have been formed during the recession of the Glacial ice-sheet. They are now dry, whereas others flowing more nearly in conformity with the present slope, such as Milk River valley and the trench cut for Oldman and South Saskatchewan rivers, are still occupied by streams. There are evidences that northern streams were forced to flow to Milk river, although its valley is cut through land which is generally higher than that near the northern streams. This drainage could be accomplished only by a damming of the former tributary streams. Presumably the ice front caused this diversion of the waters and its retreat northeastward by melting seems to afford explanation for the features found. All the channels except parts of Milk River valley bear evidences of youth, and some of them were occupied only a short period before being abandoned.

The diversion in some cases appears to have been uphill, as in the case of Fortymile coulée to join Chin coulée, or of Milk River valley where it is carved along the face of the north slope of Sweet Grass hills to a point at which drainage to the Missouri was obtained. As the underlying rocks were soft, a permanent channel was established by the scouring action of Milk river augmented for a period by the diversion from the St. Mary and Oldman. Milk river may thus be likened to an irrigation ditch from which water might be piped over a rise of ground to a lower level, although on a scale too great for the action of the syphon. An examination of the rock through which the channel is cut shows that for a certain distance—roughly from near Milk River station to Dead Horse coulée through ranges 15, 14, 13, and 12, west of the 4th meridian—this rock is a porous sandstone capable of carrying the water underground. If it came to the surface at a lower place, a series of very strong springs would result. This actually happens farther up the valley, where the water follows a sandstone bed northward through the Milk River ridge to the vicinity of Spring coulée, west of Magrath. In the area under discussion the porous sandstone does not reach the surface, but dips gently to the north, only a little more than the slope of the surface. Being covered by dark shales that are not porous, the contained water does not escape naturally, but remains under a slight pressure. If there were no retardation by the sandstone the pressure would be great enough to bring the water to the surface in all the area level with the water in Milk river from which it was derived. Friction and loss of head occasioned by many leaks near together lower the level of the artesian area, and the outer edge of the artesian area also lowers slightly with the distance from the source.

A study of the surface as mapped by the Irrigation Branch of the Department of the Interior was used to outline approximately the probable artesian area on a small map published in the Summary Report for 1915. A study of the beds exposed in the district gave also an indication of the general even surface of the underlying water-bearing sandstone and thus an estimate of the average amount of boring required to reach the sand.

Publication of this map and report brought an appeal from the Board of Trade at Lethbridge to the Federal Government to have test wells bored by the department responsible for the survey. A small appropriation was granted the Geological Survey for the purpose of drilling three test wells to be located within the designated artesian area so as fairly to test the geological conclusions. The decision to bore test wells was reached about August 1, 1916, and on August 6 a contract was arranged with the Youngren Drilling Company for two wells. "Of the two wells under contract by the Department in 1916, one was finished in 1917 and gave a flow of 4,000 gallons a day; in addition a third well has been completed with a flow of 3,000 gallons a day (*typographical error for* 30,000). Wells Nos. 1 and 2 were to be cased with steel pipe $4\frac{1}{4}$ inches inside diameter. The difficulty of getting this material under war conditions and the increased cost of labour are responsible for the delay with No. 2 well. In order to demonstrate that flowing wells may be bored and the flow preserved by the use of small pipes that were still obtainable, No. 3 well was drilled by diamond drill by Mr. J. H. Norman and a packer above the water-bearing sand was inserted carrying a 2-inch pipe to the surface." [1]

No. 2 well on which the delay occurred was reported finished July 22, 1918, with a flow of 11,000 gallons per day. Private enterprise resulted in the drilling of several other wells, but climatic conditions in the years following the good crop of 1915 were not favourable, and financial stringency retarded the private development of the area. The report of the Lethbridge Board of Trade for 1918 refers to the general improvement in the irrigated areas and notes that the obtaining of water for domestic and stock purposes in outside areas showed some improvement. The great expense of boring and casing a 4-inch well was lessened by using jetting machines that bored a vertical hole from 2 to 3 inches in diameter, and by using a small pipe for casing. The above report contains the following statement under the heading "Well Water Supplies for Farms."

"Very satisfactory progress has been made during the year in developing the underground sources of water supply that were discovered by the officers of the Geological Survey in 1915. These discoveries were followed up by the drilling of three test holes, all of which gave practical evidence of the presence of the water; these wells were put down by the Dominion Government upon the pressing request of this Board; and we have every reason to congratulate ourselves on the outcome of our efforts in helping our farmers to secure water supplies. While the first wells put down by the Government cost about $5,000 each, a cheaper process which is quite effective has since been developed; and the wells that are now being made produce supplies of water that are ample for farm use and indeed for village and town use, at a cost of about $1,500 per well."

Then follows a list of about thirty wells developed in the area.

Attention was again drawn to the area by the Lethbridge Herald in its issue of March 12, 1920, in which additional wells were noted. Chemical analyses of the water issuing from several of the wells were made by Dr. F. T. Shutt, chemist of the Department of Agriculture, and it was found that the proportion of soluble salts increased in proportion to the distance from the source of supply, Milk river. This increase appears largely in the sodium chloride and to a lesser extent in the sodium carbonate, the two salts present. These proportions, however, are not large and make a very soft water with a taste of baking soda and common salt so slight that

[1] Geol. Surv., Can., Sum. Rept., 1917, p. 1 C.

it is seldom detected. In the wells at the northern limit of the field, where these salts are greatest, the water is still usable for stock and domestic purposes.

Use of the Water. Visits to the field in 1920 and 1922 showed that many of the farmers were irrigating gardens, notwithstanding the carbonate of soda in the water, which is deleterious to growing crops. The first experimental use south of Bow Island of a large flow of water produced good crops for the first year, but the land was rendered very hard and almost useless for the next crop. Since the first visit the farmers have been using less water and in some cases leaving parts of their gardens fallow. The climate during the summer is so equable and generally warm that the addition of water causes an abundant growth. In some of the gardens melons, cucumbers, and pumpkins were noted.

Notwithstanding that the gardens irrigated show an abundant growth, there remains a danger of overloading the soil with carbonate of soda. In the studies of alkali soils carried out by Dr. Shutt, near Strathmore,[1] bare spots were found on which growth was prevented by impregnation of sodium carbonate, 0·2 per cent of this salt causing toxicity.

Underdraining is recommended and it may here be mentioned that in a large part of the area included in the artesian district the underlying rocks are quite porous and may, by underdraining, absorb the soda from the surface soils to an appreciable extent. The following is the report from the Dominion Chemist, Dr. F. T. Shutt, on the examinations of the water from several of the wells:

Report on Waters from Artesian Wells in Southern Alberta

"Six samples of water from artesian wells in southern Alberta, collected and forwarded to Ottawa in September, 1919, in accordance with instructions from the Director of the Reclamation Service, have been submitted to analysis, the examination being specially conducted with a view to ascertaining the suitability of the waters for irrigation purposes.

The samples were received at the laboratories of the Experimental Farm in good order. The waters were all clear, bright, practically free from sediment or deposit, and possessed a marked though not strong saline (alkaline?) taste.

The analytical data have been tabulated for convenience of comparison and the hypothetical combination of the salts present, given, as per attached sheet of results.

Discussion of Results. All the waters are more or less saline in character. Those from the Beaver well, Government well No. 3, and the Foremost well fall into one group, possessing a saline content in the neighbourhood of 1,000 parts per million, the essential mineral constituent of which being sodium carbonate, amounting to approximately 860 p.p.m. or 60 grains per gallon. A small percentage of sodium sulphate is present in the water from the Beaver well; sodium chloride is present in only negligible amounts. Compounds of calcium and magnesium are practically absent.

The water from Government well No. 2 is slightly more saline than the waters just discussed, the total saline content being 1,500 p.p.m., the

[1] "Alkali Content of Soils", Shutt and Smith, Trans. Roy. Soc. Can., vol. XII, sec. III, p. 83.

sodium carbonate being somewhat higher, and the sodium chloride distinctly higher, though perhaps not excessive for a "deep-seated" water.

The water of the Taber well is more strongly saline than those discussed, with a total saline content of approximately 2,700 p.p.m. It has practically the same sodium carbonate content as the Government well No. 2, but contains much more sodium chloride.

The water of the well "south of Retlaw" is markedly the most saline of the series, with a saline content of approximately 6,000 p.p.m. In sodium carbonate, however, it is very similar to the waters of the three wells first considered, the additional salinity being due to a much larger sodium chloride content.

The outstanding characteristics of these waters considered as a series are their practical freedom from calcium and magnesium compounds and their essential uniformity as regards sodium carbonate. It is the latter constituent which marks the element of danger in considering these supplies as water for irrigation purposes.

Though in limited quantities, and occasionally applied, the first three waters might be used for a time on soils with good drainage without marked injurious results, we are of the opinion that they are not safe or suitable waters for irrigation purposes. Nos. 47008, 47009, and especially No. 47010, are undoubtedly too saline for use as irrigation waters."

Analysis of Waters from Artesian Wells in Southern Alberta

No. 1	Laboratory No. 47005	Name: Beaver well	Location: Sec. 24	tp. 2	range 11
2	47006	Govt. well No. 3	19	4	8
3	47007	Town of Foremost	20	6	11
4	47008	Govt. well No. 2	19	9	10
5	47009	Taber well	32	9	16
6	47010	South of Retlaw	28	11	17

—	No. 47005	No. 47006	No. 47007	No. 47008	No. 47009	No. 47010
	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
Total solids at 105° C	1140·0	960·0	1040·0	1520·0	2692·0	6080·0
Loss on ignition	200·0	210·0	160·0	240·0	130·0	400·0
Solids after ignition	940·0	750·0	880·0	1280·0	2560·0	5680·0
Lime (CaO)	free or tr.	free or tr.	free or tr.	free or tr.	free or tr.	traces
Magnesia (MgO)	"	"	"	"	"	"
Soda (Na_2O)	570·0	400·0	400·0	600·0	1400·0	2400·0
Sulphuric acid (SO_3)	120·0	50·0	free	10·0	10·0	20·0
Chlorine (Cl)	20·0	40·0	80·0	250·0	760·0	3160·0
Carbonic acid (CO_2)	340·0	360·0	400·0	470·0	480·0	390·0
Reaction	alkaline	alkaline	alkaline	alkaline	alkaline	alkaline
Hypothetical combination	grains per gallon	grains per gallon	grains per gallon	grains per gallon	grains per gallon	grains per gallon
Sodium sulphate (Na_2SO_4)	14·7	?	?	?	?	?
" carbonate (Na_2CO_3)	56·4	69·9	63·7	78·4	80·5	63·0
" chloride (NaCl)	2·8	4·0	8·4	28·0	88·2	317·8

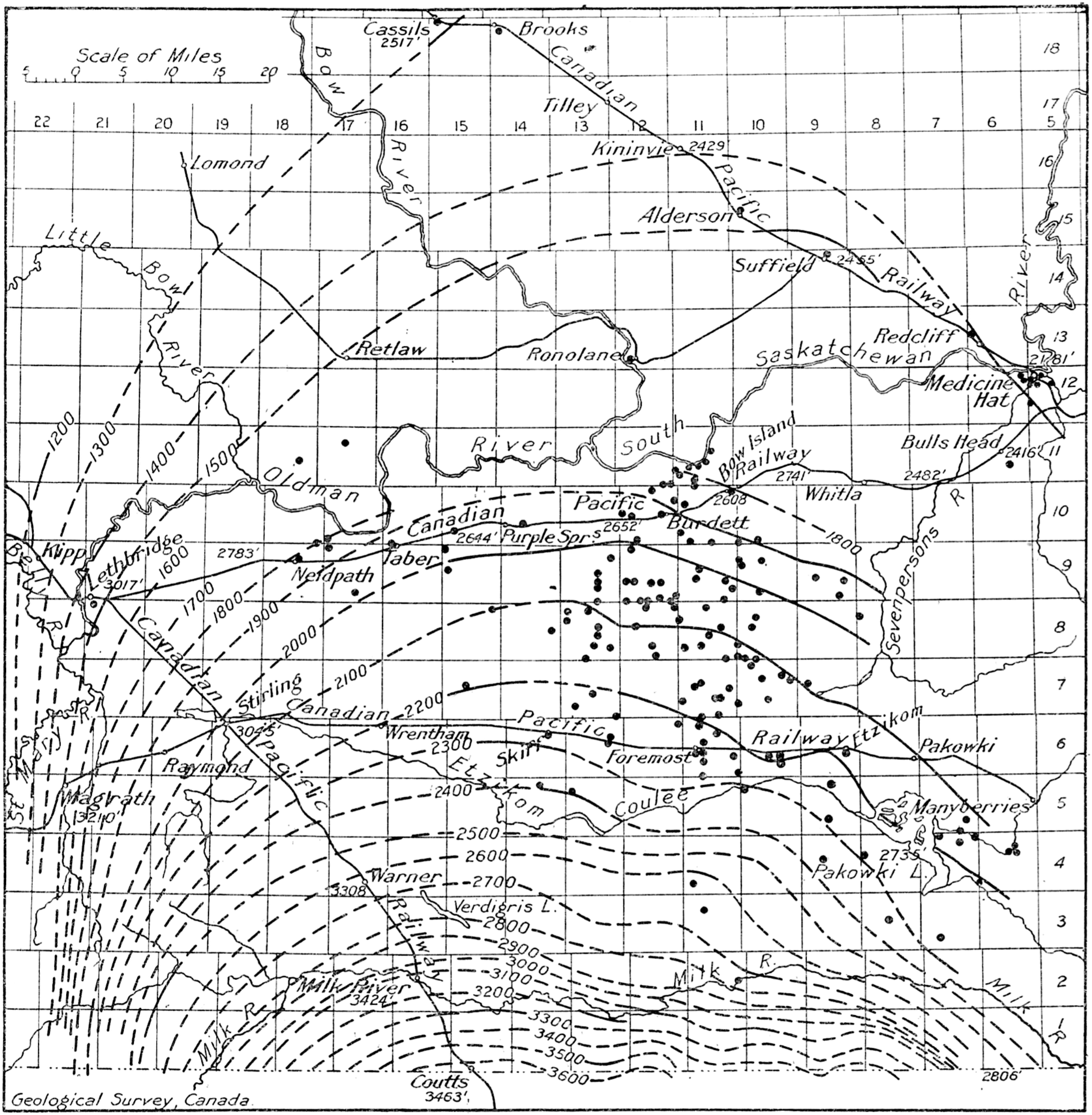


Figure 6. Part of southern Alberta showing underground contours of top of Milk River sandstone in relation to sea-level. Bored wells shown by heavy black dots.

During the examination of the geological structure it was determined that the sandstone series into which some of the water of Milk river is absorbed continues northeastward and forms the storage reservoir from which was obtained the gas used in the city of Medicine Hat. Loss of gas by seepage through the sandstone to the outlet in Milk River valley is stopped by the water. The pressure in the gas wells is thus equalized by the weight of water in the beds on the upward slope. As the measures are in places quite thick there can be no exact dividing line between the part containing gas only, and that saturated with water. Certain of the lower beds may convey water into the gas area and gas may invade the water area through the upper part of the sands.

In many of the water wells a small flow of gas is obtained before the water-bearing stratum is reached. In others a flow of gas sufficient for use for cooking comes to the surface with the water. As it is a methane gas and is odourless it leaves no taste in the water and both gas and water are utilized. The method is primitive. Gas and water are collected in a tank, often a gasoline drum, the gas is drawn by a small pipe from the top and the water from near the bottom. The gas pressure is maintained by control of the water outlet. Several examples of this combined use of water and gas were observed and will be found noted in the appended list of wells.

The general lack of rain during the summer months resulted in poor crops of wheat, except in 1915 and a fair crop in 1922. The dry weather caused gradual drying of the soil after the spring rains and a lack of moisture to the wheat plant during the filling stage of the grain's growth. Experiments in growing rye seem to be more successful, the ripening stage being reached before the moisture in the soil has evaporated. Many of the farmers declare that with artesian wells giving gas for the kitchen stove, water for stock, water for gardens and shade trees, and a fairly sure crop of rye, there is little fear of the settlers migrating, since many of them have passed through more than one long period of scarcity of rain.

DEPTH OF DRILLING

Several logs of wells were obtained from the drilling operator, but most of the records given below are statements from the farmers or others and in some cases at least are only estimates. An attempt was made to determine in all cases the depth to the water-bearing sand and, by comparison of barometer readings with the bench-marks on many of the township corners, to ascertain the elevation above sea-level of the top of the water-bearing formation in order to check the conformation of the underlying beds. The following table summarizes the results of these readings and from it has been compiled two charts (Figure 6 and Map 1979): Figure 6 showing a series of contours on the top of the Milk River sands (the artesian water-bearing strata) and thus showing the general subsurface structure; Map 1979 showing the limits of the artesian area and the depth to which boring should be conducted in the search for water.

List of Artesian and Other Deep Wells In Southern Alberta Passing through Milk River Sands[1]

Sec..	Tp.	R.	Mer.	Owner	Elev.	Depth to sands	Elev. top of sands	Obtained from the sands	Remarks
19	14	1	4	Community Oil Co.	2,500	1,530	970	G.	
NW. ¼ 18	12	5	4	City of Medicine Hat	2,347	1,098	1,249	G.	South Industrial gas well
SW. ¼ 30	12	5	4	" "	2,151·6	911	1,240	G.	Marlborough gas well
NW. ¼ 30	12	5	4	" "	2,262·8	1,017	1,245	G.	Central Park "
SE. ¼ 30	12	5	4	" "	2,139·5	904	1,235	G.	Powell "
SW. ¼ 32	12	5	4	" "	2,128·9	898	1,230	G.	Balmoral "
SW. ¼ 28	12	5	4	" "	2,147·6	942	1,205	G.	Stella "
27	4	6	4	Yeast and Higdon	....	809	....	A.	Flow 25 gals. water per m., bored by O. J. Morrison
27	4	6	4	" "	....	725	....	A.	Flow 18 gals. per m., Morrison
27	4	6	4	" "	....	755	....	A.	Flow 24 gals. per m., "
SW. ¼ 7	4	6	4	Green & Co.	2,853	637	2,216	A.	Flow 17 gals. per m., "
SW. ¼ 14	11	6	4	Medicine Hat Oil Co.	2,527	....	....	....	Drilling
NE. ¼ 25	12	6	4	City of Medicine Hat	2,269·4	1,029	1,240	G.	Cousins and Sissons gas well
SW. ¼ 36	12	6	4	" "	2,148	914	1,234	G.	Craft gas well
SE. ¼ 19	13	6	4	J. F. Bending	2,431	967	1,464	G.	Gas well bored by O. J. Morrison
NW. ¼ 9	3	7	4	Wm. Krenzke	2,891	654	2,237	A.	Flow 25 gal. per m., "
NE. ¼ 32	4	7	4	T. H. Retherath	2,811	616	2,195	A.G.	Gas tank in house, 37 gals. water per m., Morrison
35	4	7	4	E. L. Roberts	2,836	640	2,196	A.	25 gals. per m., "
36	4	7	4	John B. Fuller	2,846	694	2,152	A.	Flow 24 gals. per m., Morrison
E. ½ 11	5	7	4	Henry Beisterfeldt	2,830	717	2,113	A.	" 16 " "
2	5	7	4	E. F. Harm	2,836	665	2,171	A.	" 35 " " piped to house and barn
21	3	8	4	M. S. Thompson	....	....	....	A.	Artesian well reported
19-30	4	8	4	Government well No. 3	2,919	620	2,299	A.	*See* log No. 1
NW. ¼ 30	8	8	4	Geo. Roan	2,711	740	1,971	A.	7 gals. per m., little gas
NW. ¼ 21	4	9	4	Jos. Maddaugh	2,998	680	2,318	A.	Head 24 ft., flow 3 to 4 gals. per m.
NE. ¼ 9	5	9	4	— Ashley	....	....	....	A.	Well reported flowing
W. ½ 34	5	9	4	W. Goundrey	....	....	....	A.	" "
14	6	9	4	Town of Etzikom	2,893	718	2,175	A.	5·5 gals. per m.
NE. ¼ 19	7	9	4	Whelan Land Co.	2,803	714	2,089	A.	
W. ½ 20	7	9	4	Richard Iverson	2,803	736	2,067	A.	
NW. ¼ 2	9	9	4	J. Schan	2,657	670	1,987	A.G.	3 gals. per m., use gas in house
SE. ¼ 14	9	9	4	C. C. Johnson	2,717	740	1,977	A.	3 gals. per m.
NE. ¼ 17	9	9	4	O'Neil estate	2,772	785	1,987	A.	3½ gals. per m.
33	14	9	4	Suffield, C.P.R.	2,463	885	1,578	G.	Gas well. Sands at 885 and 960. *See* Sum. Rept. 1916, p. 129

SW. ¼	31	5	10	4	United Oil Co. No. 3	2,859	532	2,327	A.	Log No. 2 and Mem. 93, p. 79, and Mem. 116, p. 50, flow 16,000 gal.
	14	6	10	4	Mrs. Thompson					Well reported
	16	6	10	4	J. Stewart	2,900	762	2,138	A.	Near Nemiskan
NE. ¼	7	7	10	4	J. Johnson	2,833	677	2,156	A.	7 gals. per m.
SW. ¼	15	7	10	4	Tom. Barrows	2,843	665	2,178	A.	7 gals. per m.
S. ½	25	7	10	4	Ed. Woodsky	2,813	714	2,106	A.	
	26	7	10	4	Geo. Molloy	2,858	712	2,146	A.	
S. ½	28	7	10	4	S. A. D. Jordan	2,813	685	2,128	A.	
W. ½	32	7	10	4	A. Burger	2,823	650	2,173	A.	Large flow, irrigates garden and trees
	5	8	10	4	Chas. Reynar	2,823	700	2,123	A.	Drilled by O. J. Morrison
S. ½	6	8	10	4	G. R. Howden	2,833	684	2,149	A.	10 gals. per m.
W. ½	6	8	10	4	J. G. Murray	2,833	707	2,126	A.	
NW. ¼	7	8	10	4	Jas. Stevens	2,806	726	2,080	A.	Irrigates garden
N. ½	20	8	10	4	M. O. Brustad	2,811	780	2,031	A.	2 gals. per m.
E. ½	29	8	10	4	F. W. Tweedle	2,796	765	2,031	A.	
SE.	9	9	10	4	Harry Jenkins	2,830	750	2,080	A.	Bored by O. J. Morrison
	28	9	10	4	Geo. Flamme	2,810	946	1,864	A.G.	Small flow. L. H. Wright
	19-30	9	10	4	Government well No. 2	2,710	758	1,952	A.G.	Large flow. Log No. 3
SW. ¼	30	9	10	4	Fred Thurston	2,715	760	1,955	A.	Bored by L. H. Wright
NE. ¼	5	10	10	4	Ed. Nicola	2,752	869	1,883	A.	" "
NW. ¼	6	10	10	4	Chauncey Morey	2,740	827	1,913	A.G.	" "
	30	15	10	4	Alderson, C.P.R.	2,503	1,040	1,463	G.	Gas well, gas at 1,040 and 1,150, for log *see* Mem. 116, p. 54
	24	2	11	4	Beaver Oil Co.	2,903	167	2,736	A.	Deep well, for note on, *see* Mem. 116, p. 23
	28	3	11	4	Dreamfields Oil Co.	3,167	510	2,657	W.	Water does not reach surface. Log No. 4
SW. ¼	8	4	11	4	Yerkes	3,159	508	2,651	W.	Water does not reach surface. Log No. 5
	1	6	11	4	West Can. Nat. Gas Co.	3,004				Rig erected
SW. ¼	4	6	11	4	T. H. Frankish	2,967	708	2,259	A.	Water comes to surface, drilled by Gardner
NW. ¼	9	6	11	4	Mrs. Jas. Thompson	2,940	690	2,250	A.	Small flow
SW. ¼	13	6	11	4	Jas. Lang	2,997			W.	Water rises to 2,982 feet. elev., pumped by windmill
	16	6	11	4	Town of Foremost	2,922	650	2,272	A.	3 wells drilled by C.P.R. and 1 by town corporation, flow is now very small. Log No. 6. Log, Mem. 93, p. 82
	17	6	11	4	W. M. Wheatley				A.	Well reported
	27	6	11	4	Alex. Linton				A.	Well reported, large flow
NW. ¼	33	6	11	4	H. Pilkingrude	2,853	625	2,228	A.	
SW. ¼	2	7	11	4	Albert B. Taylor	2,853	650	2,203	A.	
NW. ¼	2	7	11	4	Arthur Taylor	2,843	640	2,203	A.	
SW. ¼	4	7	11	4	John Hopple	2,833			A.	Well noted, no information
SW. ¼	14	7	11	4	A. Miller	2,800	646	2,154	A.	
S. ½	15	7	11	4	C. de Bry	2,800	646	2,154	A.	Elevation approximate only

[1] A, Artesian G, Gas W, Water not flowing

List of Artesian and Other Deep Wells in Southern Alberta Passing through Milk River Sands—Continued

Sec.	Tp.	R.	Mer.	Owner	Elev.	Depth to sands	Elev. at top of sands	Obtained from the sands	Remarks
SE. ¼ 18	7	11	4	Geo. Goetz	2,816	......	......	......	No information obtained, flowing well at house
SE. ¼ 20	7	11	4	W. Thompson	2,776	650	2,126	A.	
N. ½ 20	7	11	4	W. A. Starner	2,731	......	......	A.	Flowing well. Depth not obtained
21	7	11	4	J. D. M[illegible]dill	2,776	640	2,136	A.	Good flow
SW. ¼ 24	7	11	4	Mrs. Doherty	2,803	625	2,178	A.	Very large flow, 30 gals. per m.
E. ½ 2	8	11	4	S. Hoffert	2,775	......	......	A.	Well flowing. No information
NE. ¼ 7	8	11	4	F. R. Elford	2,730	600	2,130	A.	Drilled by Eugene Emard
NW. ¼ 9	8	11	4	J. G. Kimmett	2,740	630	2,110	A.	" J. G. Kimmett
W. ½ 15	8	11	4	J. J. "	2,760	650	2,110	A.	" "
LSD 4 23	8	11	4	West Can. Nat. Gas. Co.	2,6[illegible]1	490	2,131	A.	In Fortymile coulée, big flow of water
30	8	11	4	Martin Johnson	2,714	637	2,077	A.	
33	8	11	4	Geo. Schultz	2,705	665	2,040	A.	Depth reported
SE. ¼ 2	9	11	4	Max Geldrich	2,732	712	2,022	A.	
N. ½ 12	9	11	4	John Palm	2,770	746	2,024	A.	Bored by O. J. Morrison
14	9	11	4	Thos. Roberts	2,723	700	2,023	A.	Reported depth not checked
17	9	11	4	— Arbuthnot	2,680	650	2,030	A.	Depth given by Mr. Allen
W. ½ 21	9	11	4	E. E. and W. W. Allen	2,670	654	2,016	A.	Bored by O. J. Morrison
SW. ¼ 2	10	11	4	Ole Nordin	2,683	735	1,948	A.G.	Gas used in house
SW. ¼ 5	10	11	4	J. Collins	2,633	640	1,993	A.	
7	10	11	4	Wm. Reber	2,621	640	1,981	A.	Well in pasture field
SE. ¼ 30	10	11	4	John Fairbairn	2,564	670	1,894	A.	Pipes water from gas well
35	10	11	4	Town of Bow Island	2,622	822	1,800	A.	Flow 6 gals. per m., Morrison
4	11	11	4	West Can. Nat. Gas Co.	2,554	825	1,729	A.	Gas well No. 16. Water from lower part of sands
NW. ¼ 4	11	11	4	Town of Bow Island	2,526	740	1,786	A.	Log of gas well. *See* Mem. 116, p. 52
7	11	11	4	West Can. Nat. Gas Co.	2,533·7	800	1,733·7	A.	Water from lower part of sands, gas well No. 11
7	11	11	4	" "	2,467·4	860	1,607·4	A.	Gas well No. 12. Water from lower part of sands
9	11	11	4	" "	2,273·3	625	1,648·3	A.	Gas well No. 3, water at 625 and 980 feet
9	11	11	4	" "	2,520·6	825	1,695·6	A.	Gas well No. 13
15	11	11	4	" "	2,300	410	1,890	A.	Gas well No. 1. Water also from 600 feet
17	11	11	4	" "	2,273	670	1,603	A.	Gas well No. 4. Lower sands
22	11	11	4	" "	2,269·9	615	1,654·9	A.	Gas well No. 5
36	6	12	4	M. MacKenzie	2,656	......	......	A.	Well in Chin coulée, large flow
NE. ¼ 3	8	12	4	Albert Schultz	2,770	640	2,130	A.	Elevation approximate
N. ½ 10	8	12	4	S. Hazel	2,753	620	2,133	A.	Total depth of well 640 feet
NE. ¼ 20	8	12	4	Tom. Burke	2,743	650	2,093	A.	Drilled by E. Emard

NE. ¼ 33	8	12	4	Arie De Beeld	2,703	640	2,063	A.	Moderate flow
36	8	12	4	Larse Johnson	2,693	650	2,043	A.	
SW. ¼ 1	9	12	4	Carl Linwald	2,685	650	2,035	A.	
NE. ¼ 1	9	12	4	W. H. Strom	2,680	670	2,010	A.	
NW. ¼ 2	9	12	4	Martin Hoel	2,682	660	2,022	A.	
SE. ¼ 4	9	12	4	Ernie Beers	2,708	644	2,064	A.	Drilled by E. Emard. Good flow
SW. ¼ 4	9	12	4	Royal Linwald	2,708	620	2,088	A.	" "
SE. ¼ 6	9	12	4	Conrad Young	2,708	653	2,055	A.	5 gals. per m.
SW. ¼ 14	9	12	4	Andrew Volk	2,675	650	2,025	A.	
SE. ¼ 18	9	12	4	John Ell	2,683	620	2,063	A.G.	Total depth of well 640 feet, 10½ gals. per m. Uses gas from well in house
NW. ¼ 15	9	12	4	Theodore Hammill	2,675	645	2,030	A.	
SW. ¼ 17	9	12	4	Gus Schnedt	2,683	640	2,043	A.	5½ gals. per m.
NW. ¼ 32	9	12	4	Jean Galvin	2,659	650	2,009	A.	Depth of well 670 feet. Good flow
SE. ¼ 5	10	12	4	Ray Galvin	2,629	620	2,009	A.	Small flow
W. ½ 19	10	12	4	— Ledgerwood	2,636	630	2,006	A.	Small flow. Total depth of well 660 feet
W. ½ 20	10	12	4	R. Poole	2,641	635	2,006	A.	Depth of well 668 feet
23	10	12	4	Burdette Sta., C.P.R.	2,578	740	1,838	A.	Large flow
25	10	12	4	West Can. Nat. Gas Co.	2,531	680	1,851	A.	Gas well No. 19. Water reported also at 715 feet
N. ½ 34	10	12	4	John Clark	2,592	715	1,880	A.	
1	11	12	4	West Can. Nat. Gas Co.	2,548	585	1,963	A.	Gas well No. 14. Water reported at 815 feet
1	11	12	4	" "	2,563	627	1,936	A.	Gas well No. 18. Water reported at 730 feet
8	13	12	4	Ronolane Sta., C.P.R.	2,424	775	1,649	A.	*See* Sum. Rept. 1916, p. 134
									Note, elevation is probably below that assumed
30	5	13	4	Kentucky ranch	3,035	630	2,405	W.	Water rises to 72 feet of surface and then pumped
NE. ¼ 23	6	13	4	John Kotkas	....	....	....	A.	Well reported as now silted up
SE. ¼ 26	6	13	4	N. T. Anderson	....	....	....	A.	" " "
1	7	13	4	R. Neil	2,660	350	2,310	A.	Good flow, elev. approximate
8	7	13	4	Wm. Warburn	....	....	....	A.	Flowing well reported
NW. ¼ 15	7	13	4	Gritman ranch	2,906	680	2,226	A.	Small flow
4	8	13	4	Martin Carr	2,831	650	2,181	A.	Good flow
10	8	13	4	J. M. Carey	2,800	655	2,145	A.	Drilled by Emard
11-12	8	13	4	Government well No. 1	2,781	630	2,151	A.	Log No. 7, Sum. Rept., 1917, p. 1 C.
15	8	13	4	Wm. Gilbert	2,771	640	2,131	A.	Good flow
22	8	13	4	H. Crude	2,751	602	2,149	A.	
SE. ¼ 30	8	13	4	D. B. Kunsman	2,791	652	2,139	A.	1½ gals. per m.
SE. ¼ 31	8	13	4	M. M. Ladd	2,765	642	2,123	A.	1½ gals. per m.
SE. ¼ 33	8	13	4	Jas. Leaky	2,720	630	2,090	A.	2 gals. per m.
3	9	13	4	— Klein	2,758	720	2,038	A.	Piped to house and garden
NE. ¼ 10	9	13	4	John Fettig	2,739	650	2,089	A.	Total depth of well 670 feet
NE. ¼ 15	9	13	4	Anton Fettig	2,744	690	2,054	A.	Good flow used in garden
SE. ¼ 22	9	13	4	Felix Gross	2,700	640	2,060	A.	Good flow

List of Artesian and Other Deep Wells in Southern Alberta Passing through Milk River Sands—Concluded

Sec.	Tp.	R.	Mer.	Owner	Elev.	Depth to sands	Elev. at top of sands	Obtained from the sands	Remarks
NW. ¼ 25	9	13	4	B. E. and R. N. Berlin	2,680	681	1,999	A.	Total depth 696 feet. Good flow, 2 gals. per m.
34	5	14	4	M. E. Graham	3,027	610	2,417	A.	Flow 25 gals. per m.
26	6	14	4	School at Skiff	2,957	683	2,274	A.	Flow 6 gals. per m. Rises to 2,969 feet
SW. ¼ 24	8	14	4	Art. Noble	2,841	735	2,106	A.	Small flow, depth given by E. Emard
16	10	14	4	Farm near Purple Springs	2,580	660	1,920	A.	Silting up last visit
SE. ¼ 33	18	14	4	Town of Brooks, C.P.R.	2,487	1,120	1,367	G.	Log, Mem. 116, p. 57
21	7	15	4	Albert Green	2,713	503	2,210	A.	Large flow
36	8	15	4	Daze Bros.	2,833	895	1,938	A.G.	Intermittent small flow, mostly gas
19	9	15	4	Robt. McGibbon	2,697	680	2,017	A.	Very small flow
31	9	15	4	Sam Ayres	2,657	666	1,991	A.G.	Fair flow. Gas tank for house
8	10	15	4	— Cook	2,640	....	....	A.	Bored for coal before 1915. No record
5	19	15	4	Cassils Sta., C.P.R.	2,523	820	1,703	G.	Gas struck at 820 feet. *See* Ann. Rept., vol. IV, 75 G.S.
32	9	16	4	City of Taber	2,667	608–670	2,059–1,997	A.	This is from the Foremost beds. Flowing water at 670 feet. Mem. 93, p. 102, and Mem. 116, p. 56. Log No. 8
—10	9	17	4	M. Lillibridge	2,827	826	2,001	A.	Small, intermittent flow
LSD 14, 31	9	17	4	West. Can. Nat. Gas Co.	2,707	785	1,923	W.	Gas well No. 1, water at 785 and 880 feet. Chin coulée
LSD 14, 6	10	17	4	" "	2,709·3	830	1,879·3	W.	Gas well. Chin coulée No. 3
26	11	17	4	Bowes Bros.	2,785·7	870	1,915	A.	Small flow. Bored by J. H. Norman. Log, Sum. Rept., 1917, p. 2 C. Analysis of water; Rep. Rec. Service 1919-1920, p. 18. *See also* Log No. 9
SE. ¼ 27	9	18	4	Bawden Farming Co., at Neidpath Sta., C.P.R.	2,738	704	2,034	A.	Flowing water comes from 784 feet. Log, Sum. Rept., 1917, p. 3 C. *See also* Log No. 10
LSD 3, 1	10	18	4	West. Can. Nat. Gas Co.	2,699·9	770	1,930	W.	Gas well. Chin coulée No. 2, flowing water also from 855 feet
NW. ¼ 14	11	18	4	Cameron ranch	....	....	....	W.	Well bored by Hodgson to 1,003. Sands at 765 feet to 828 feet, probably does not flow
36	8	21	4	City of Lethbridge	2,990	1,515	1,475	W.	Water-bearing sands at 1,603. Log, Mem. 93, p. 96, and Mem. 116, p. 65, *See also* Log No. 11

LOGS OF PRINCIPAL WELLS IN DISTRICT

Log No. 1

Government Well No. 3, Near Lake Pakowki

Bored by Geological Survey

Location: between secs. 19 to 30, tp. 4, range 8, W. 4th mer.

Depth of well: 643 feet. Flow 30,000 gallons water at surface; pressure, 32 pounds

Log from samples of drill cores furnished by J. H. Norman

Material	Thickness	Depth
	Feet	Feet
Surface material and shales	60	60
Sandstone with oyster shells	7	67
Calcareous sandstone	4	71
Dark grey shale	4	75
Sandstone	25	100
Shale, slightly sandy	20	120
Sandy shale	5	125
Grey shale	5	130
Grey shale with lighter streaks	10	140
Dark shale	48	188
Sandy shale	12	200
Shale	35	235
Gritty shale	35	270
Shale	5	275
Shale, slightly gritty	26	301
Sandstone	9	310
Gritty shale	15	325
Fine, grey sandstone	30	355
Shale, gritty	25	380
Sandy shale	25	405
Shale	72	477
Colloidal clay, grey	1	478
Shale	7	485
Light-coloured mixture clay and mica scales	1	486
Shale	12	498
Gritty shale	31	529
Calcareous shale	1	530
Soft sand (small flow water)	25	555
Soft shale	2	557
Coal	3	560
Clay	7	567
Sandstone	11	578
Shale, very thin leaved	14	592
Sand and sandstone	51	643

Log No. 2

United Oils Well No. 3

Etzikom, SW. ¼ sec. 31, tp. 5, range 10, W. 4th mer.

—	Material	Thickness	Depth from surface
		Feet	Feet
	Surface deposits, brown clay	130	130
Foremost beds, 120 feet	Sand, fine, greenish grey	50	180
	Shale, dark greenish	20	200
	Sand, dark green	50	250
Pakowki shales, 265 feet	Shale, greenish black	265	515
Milk River sandstone, 170 feet	Coal	5	520
	Shale, soft	6	526
	Coal and black shale	6	532
	Sand with streaks of coal	11	543
	Sand, fine, top of water-bearing beds	7	550
	Sand, fine, bottom of water-bearing beds	75	625
	Sand, fine, light grey	60	685
Colorado shales, 1,776 feet	Shales, blue black	1,330	2,015
	Sand, gas flow 10,000,000 c.f	5	2,020
	Shale, and shaly sand at 2,250 feet, salt water 7,000 bbls. per day	280	2,300
	Shales	161	2,461
Dakota and Kootenay	Sand and shale	24	2,485
	Shale and sand, green and red	50	2,535
	Sand and shale, grey	135	2,750
	Shale, pink	150	2,900
	Slate, sand, shale, and sand	85	2,985
	Sand saturated with heavy oil	65	3,050
	Sand, generally grey	145	3,195
	Shale, blue grey	15	3,210
Palæozoic	Limestone, grey, cream, and buff	410	3,620
	Shale, greenish grey	85	3,705

Log No. 3

Government Well No. 2

Between secs. 19-30, tp. 9, range 10, W. 4th mer.

Drilled by Youngren Drilling Company

Material	Thickness	Depth from surface
	Feet	Feet
Sandy clay	20	20
Gravel	50	70
Gravel, sand, and boulders	5	75
Clay, blue	15	90
Sandy clay, water at 95 feet	10	100
Gravel	20	120
Quicksand	30	150
Sandy shale, brown	32	182
Shell rock, hard	1	183
Coal	1	184
Clay and shale	10	194
Ironstone, thin shells	6	200
Shale, brown	7	207
Ironstone	2	209
Sandy shale, soft	13	222
Sand rock, hard	2	224
Shale, soft	9	233
Sandstone	3	236
Shale, soft	4	240
Streaks of hard sandstone	2	242
Shale, soft	2	244
Shale, brown and grey	5	249
Ironstone and sandy shale	4	253
Sandstone	17	270
Shale, dark, soft	10	280
Shells, reddish	2	282
Shale	8	290
Sand, blue, hard	3	293
Hard layers	4	297
Red rock, hard	2	299
Shale	5	304
Shale with hard streaks	37	340
Sand, grey, hard	10	350
Shale, generally brown	100	450
Getting rig used from 450 feet to 750 feet, no samples		
Sand and water struck at	....	734
Total depth of well: 750 feet		
Measured flow: 11,000 gals. per day		

Log No. 4

Dreamfield No. 2

Log of well drilled on L.S.D. 12, sec. 28, tp. 3, range 11, W. 4th mer. By Thomas J. Jamieson, Medicine Hat, Alberta

Formation	Thickness	Depth
	Feet	Feet
Red clay	15	15
Sand	1	16
Grey clay	10	26
Light shale	24	50
Dark shale	40	90
Soft shale with fossils	20	110
Dark, fossil shale	30	140
Sandstone with shale streaks	40	180
Pale, sticky shale	89	269
Bastard lime, very hard	1	270
Streaky shale, full of slips	55	325
Dark shale, lots of colours	45	370
Lighter shale	40	410
Oil-shale, fossils	42	452
Blue shales	44	496
Rock, hard	14	510
Milk River sandstone	180	690
Soft rock	7	697
Sticky shale, sandy streaks, gas	6	703
Oil-bearing shales and rotten rock	14	717
Grey shale	83	800
Dark shale	40	840
Harder shale	29	869
Blue shale, very hard	23	892
Sand	9	901
Dark shale	99	1,000

Log No. 5

Well Drilled on Yerkes Farm

SW. ¼ sec. 8, tp. 4, range 11, W. 4th mer.
Drilled by H. H. Conzet

Material	Thickness	Depth
	Feet	Feet
Surface material, gravel, sand, and clay about	2	2
Shale, gravel, sand, clay, soapstone	173	175
Coal		
Shales and sandstone	178	357
Black shale	40	397
Coarse sandstone	10	407
Black shale	10	417
Coarse sandstone	28	445
Black shales and some sandstone	63	508
Sandstone and water	3	511
Brown shale	2	513
Coarse sandstone, water-bearing	4	517
Sandstone	42	559
Shales	87	646
Coarse sandstone	2	648
Hard, black shales	22	670
Fine sand	37	707
Yellow sand and clay	2	709
Grey washed sand with water	9	718

Log No. 6

Artesian Well at Foremost

Sec. 16, tp. 6, range 11, W. 4th mer.

Driller's record, A. N. Duff, North Star Drilling Co., Regina, 612 feet, 6⅔ casing in well, from records Chief Engineer, C.P.R., Winnipeg

Formation	Material	Thickness	Depth
		Feet	Feet
Foremost beds	Clay and boulders	90	90
A coal seam at top has been	Shale	8	98
denuded	Sandstone	13	111
	Rock	2	113
	Clay and stones	4	117
	Rock	1	118
	Shale, blue sand, and *coal*	24	132
	Coal and hard shale	12	144
	Shale, *coal*, and blue sand	2	146
359 feet	Shale and coal	14	160
	Shale and sandstone	19	179
	Shale, sandstone, and *coal*	17	196
	Shale	66	262
	Shale, sandy	97	359
Pakowki shales	Hardpan	2	361
	Shale, sandy	80	441
266 feet	Hardpan	1	442
	Shale	183	625
Milk River sandstone	Sand (water at 625 feet)	99	724

Log No. 7

Government Well No. 1, 13 Miles South of Grassy Lak

Bored by the Geological Survey, 1917

Location: between secs. 11 and 12, tp. 8, range 13, W. 4th mer.

Depth of well: 633 feet, flow 4,000 gals. water per day at the surface

Driller's log partly condensed

Material	Thickness	Depth
	Feet	Feet
Surface deposits; clay, sand, and gravel	60	60
Shale and clay	7	67
Streaks of coal and clay	7	74
Sand rock	1	75
Sandy clay	39	114
Sand rock	2	116
Sandy clay	4	120
Brown shale with streaks of coal	7	127
Sandy shale with some ironstone	20	147
Hard, sand rock	3	150
Sandy shale	12	162
Hard, dark, sand rock	2	164
Dark shale	13	177
Coal	1	178
Shale	4	182
Shale with some coal	7	189
Sandy shale and clay	39	228
Coal and shale	2	230
Sandy shale	20	250
Coal, soft	8	258
Sand and clay, water at 270 feet rises 90 feet	30	288
Sandstone and sand	18	306
Grey shale	100	406
Sandstone and hard shale	10	416
Shale with very hard layers, probably ironstone	103	519
Sandstone	4	523
Shale and sandy shale	11	534
Sandstone, very hard	3	537
Shale	10	547
Sandstone, dark grey	8	555
Shale, generally very hard	26	581
Sandy shale (flow of water at 581 feet)	8	589
Sandstone	12	601
Sandy shale	4	605
Sandstone	6	611
Shale and sandy clay	10	621
Sandstone	2	623
Shale	3	626
Sandy shale (water strata at 630 feet)	4	630
Sandstone	3	633
This well is cased with 4½-inch steel pipe		

Log No. 8

Flowing Well at Taber

Condensed record from Mem. 116, p. 56

Probable formation	Material	Thickness Feet	Thickness Inches	Depth from surface Feet	Depth from surface Inches
Surface deposits 51 feet	Clay and gravel	51		51	
Pale beds 20 feet	Shale and sandstone	20		71	
	Taber coal seam				
Foremost beds 325 feet 10 inches	Sandstone and shale in beds 2 to 20 feet thick	200		271	
	Shale and some sandstone	102	6	373	6
	Shaly coal	0	6	374	
	Shale	2	4	374	4
	Coal	0	8	377	
	Shale and sandstone	19	10	396	10
Pakowki shale 211 feet 2 inches	Shale, becoming sandy at base	211	2	608	
Milk River sandstone	Light coloured shales and sands of Verdigris coulée	50		658	
	Sands (artesian water)	12		670	
	Fire-clay	3		673	
	Coal	0	3	673	3
	Sandstone	136	9	810	
Colorado shale	Sandstones in thin beds in shale	120		930	
	No record	530		1,460	
	Shale	620		2,080	
	Sandstone, white	10		2,090	
	Shales and sandstones	150		2,240	
	Sandstone	110		2,350	

Log No. 9

Flowing Well, South of Retlaw

Bored by J. H. Norman
Location: sec. 28, tp. 11, range 17, W. 4th mer.
Depth of well: 923 feet. Flow, 4,000 to 6,000 gallons per day
Driller's record

Material	Thickness	Depth
	Feet	Feet
Surface material	60	60
Sandstone	78	138
Shale with hard streaks	122	260
Three small coal seams between 233 and 260 feet		
Shale	20	280
Sandstone	20	300
Shale	4	304
Coal	2	306
Shale	6	312
Soft, sticky, sandy shale	49	361
Sandstone	29	390
Shale: 8 inches *coal* at 434 feet	70	460
Sandy shale	13	473
Layer of shells (probably oysters)	2	475
Shale	41	516
Sandstone	4	520
Shale	40	560
Green shale	14	574
Sandy shale	3	577
Shale (3 small seams of coal between 609–622 feet)	55	632
Sandstone	15	647
Sandy shale	40	687
Shale (some gas at 813 feet)	126	813
Shale with some grit (some gas at 840 feet)	30	843
Shale	27	870
Sandstone with water	53	923

Log No. 10

Well at Neidpath Station, C.P.R.

Drilled for the Bawden Farming Company
Location: SE. ¼ sec. 27, tp. 9, range 18, W. 4th mer.
Flow of water and gas, intermittent
Driller's record incomplete

The following log is furnished by J. H. Norman, the driller, as being nearly accurate.

Material	Thickness	Depth
	Feet	Feet
Surface soil and clay	60	60
Soft sandstone	20	80
Shale (small seam of coal at 126 feet)	46	126
Shale and sandstone (18 inches coal at 406 feet)	280	406
Shale and sandstone (some gas at 704 feet)	298	704
Sandstone	46	750
Shale	34	784
Water, sand	6	790
Sandstone, very close grained	154	944

Log No. 11

Well at Lethbridge

Condensed from Mem. 116, p. 65

Probable formation	Material	Thickness	Depth from surface
		Feet	Feet
Surface deposits, 299 feet.....	Sand, gravel, clay.........................	299	299
Pale beds of Belly River formation, 651 feet	*Lethbridge coal seam* eroded east of this Shales and sandstones generally light coloured.............................	661	960
Foremost beds, 350 feet......	Sandstones and shales generally yellowish.	350	1,310
Pakowki shale, 215 feet......	Shale, dark...............................	215	1,525
Milk River sandstone, 88 feet	Sandstone and shale .... Sandstone (water-bearing).................	41 47	1,613
Colorado formation..........	Shale, generally dark to bottom of well....	617	2,230

PROSPECTING FOR GAS AND OIL IN SOUTHERN ALBERTA

The pressure in both the Bow Island and Medicine Hat gas fields is diminishing owing to the great demand made upon the reserve. The closing of the leaking well of the Canada Cement Company in the Medicine Hat field by the engineers of the Department of the Interior seems to have checked the rapid fall of pressure there. In the Bow Island field there appear to be indications of the approach of water on all sides of the small dome in which the wells are situated, an intimation that other structures holding gas must be found to supplement the supply. Interest is thus renewed in the subject of natural gas and a few notes are given here relating to the structure of the area, the probable occurrence of other fields, and the position of the gas-bearing beds in the section.

These two gas fields draw their supplies from two different sand beds in the Cretaceous formations underlying the plains. These sands are separated by close-textured shales from 1,200 to 1,400 feet thick. The upper one, from which Medicine Hat derives its gas, is to the westward, and is exposed in the valley of Milk river. It is also the reservoir for the artesian water. The gas sand of the Bow Island field lies deeper and does not reach the surface in the plains area of the south except, possibly, in the immediate vicinity of the Sweet Grass hills of Montana. The exact underground position of these sands is determinable only from the records of drilling. As few drillings outside the gas fields have penetrated the lower sand, study is necessarily confined to the records of drillings into the upper sand to determine its general shape, slope, and thickness. From this, however, some general predictions may be made of the slope or general structure of the lower sand. The oil in the Montana fields comes from beds lying beneath both of these gas sands. Indications of this horizon are found in three borings, which, although not successful in finding oil, show the presence of tarry matter at 2,500 feet below the upper or Medicine Hat gas sand (Milk River formation). Drillers in search of gas, may, therefore, when they locate the upper sand, look for another gas sand at a further depth of 1,200 to 1,400 feet. If intending to drill deep wells they may look for sands impregnated with tarry matter, and possibly oil, at a depth of 2,500 feet below the upper sands.

A survey of this upper sand horizon from which to predict the underlying strata seemed desirable, and a preliminary attempt to do so was made this season as set forth below. In the chapter on artesian water supply a considerable number of well logs are described and their elevations given. The elevation of the top of the Milk River sand in each well is also computed. These, when plotted on the map and combined with other data from field exposures and other wells, enables a preliminary subsurface contouring on these sands to be made which shows the structure. This contouring, which is shown on the accompanying Map No. 1979, may be taken as indicative of the general structure of the lower strata as well. Variations in the thickness of beds will change details, but for purposes of description the structure contours are indicative of the general structure of the lower gas sands.

The sandstone from which the artesian supply of water is obtained forms a flat, conical structure truncated in its highest part so that it surrounds the Sweet Grass hills of Montana, and slopes away from them to the north, east, and south. The northern slope is mainly in Canada, and the sandstone decreases gradually in thickness toward the east, showing that it was a shore deposit facing a sea to the east. As noted in the chapter on the artesian area a large part of the western section is saturated with water. A small flow of gas is found in the artesian wells, generally from the upper beds of the sand. Eastward, this gas increases in abundance; between Bow Island and Medicine Hat the sands containing water become thinner, whereas the gas increases. The gas supply at Medicine Hat is drawn from these same sands, which are also reached at Redcliff, Suffield, and points to the northeast. The gas field is on the rim of the structure above alluded to, and the gas pressure is, very probably, maintained by the weight of the water in the sands of the artesian area. It is to be expected that failure in the supply at Medicine Hat will not be heralded by a fall in pressure to the same extent as at Bow Island, but by the appearance of water in the wells to the west.

The sands from which the Bow Island supply is derived, lie, as mentioned above, from 1,200 to 1,400 feet below the Milk River sandstone.

Attempts have been made at Medicine Hat to tap this source of supply, but the drilling has demonstrated that in that vicinity the lower sand contains salt water under pressure. The reports of the Bow Island field show that at one time the upper limit of this water was on the slope between the two places. Reduction of the gas pressure has raised this limit, and water is encroaching on the Bow Island field. The edge of the water is probably parallel to the contour of the upper sand given on accompanying Map No. 1979, and if new gas fields are to be found they should be looked for in the area embraced by the higher contours, that is, up the slope. The attempts to find gas near Barnwell show that almost the same contour as at Bow Island has been followed with less success.

Advice as to where other gas fields are to be found cannot be given without more detailed knowledge of the underground structure than is now available, but it seems certain that the same measures lower down the slope, that is, northward, will be found to contain more water than gas. In general the chances of finding gas in the Bow Island gas sands seem to be greater in a southerly direction. The highest point attained by the strata underlying this part of the plains is in the vicinity of the Sweet Grass hills, in Montana, where they are exposed in rings about each hill. Westward of Sweet Grass hills the rocks form a small dome or enclosed structure in which gas and oil have been obtained. Drilling has shown that this dome is not symmetrical, being steeper on the east and south and elongated in a northwesterly direction. This northwesterly slope is quite irregular, corrugations, lumps, and small domes being indicated by the drilling. It is found also that the accumulation of oil is confined to a band between certain levels and also between two ridges running one toward the north and the other to the northwest. Although the oil has not been discovered on this slope nearer than 10 miles to the Canadian line it is not improbable that other structures on the long slope into Canadian territory may yield either oil or gas, though there is insufficient information to locate these structures at the present time.

The drillings in the Montana field show a similarity of strata to those exposed in the one deep well at Etzikom coulée, the log of which is given in the preceding tables. The red shales in this log below 2,485 feet, repeated at 2,900 feet, are the horizon-markers in the oil field. Oil is sometimes found in sands about 200 feet below the pink shales which seem to be equivalent to some of the sands in the Etzikom well at the 3,000-foot mark. In this well the deposits below 3,000 feet do not appear to correspond with many of the formations recognized in Wyoming overlying the Carboniferous limestones. And in considering the section in the vicinity of the Montana line, comparisons must be made with the sections obtained in the borings nearby.

GEOLOGICAL SECTION NEAR COUTTS

The section compiled from several of these records can be summed up as below. The sandstones which surround the Montana field in an escarpment and are estimated at 380 feet in thickness, are partly eroded at the boundary so that there the section would be:

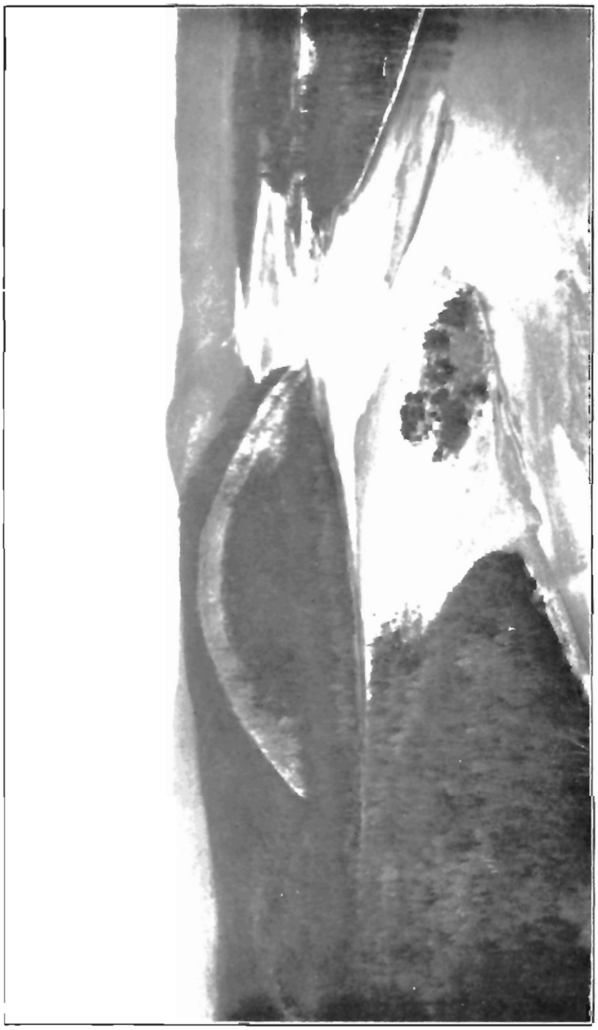
			Feet
Cretaceous	Milk River sands.........	Eagle sandstone.........................	175
	Colorado shales...........	Shale with concretionary bed at base....	1,000
		Shale with two sands near base..........	700
	Kootenay of Montana.....	Lakota of Wyoming..................... } Morrison............................... }	350
		Sunburst sand...........................	10 to 60
Jurassic.........	Ellis formation............	Sundance of Wyoming....................	250
	Ellis sand............	....	10–20
Carboniferous?..	Madison limestone........	....	1,200
	Sand..................	....	100

The Colorado shales contain a concretionary layer which is useful as an horizon marker. This is sometimes spoken of as the Mowry sands and outcrops at the crown of the dome near the Troy-Sweet Grass boring. In the lower part of the Colorado two gas sands occur which are probably near the same horizon as the gas sands of Bow Island. In Montana they carry a small amount of gas and water.

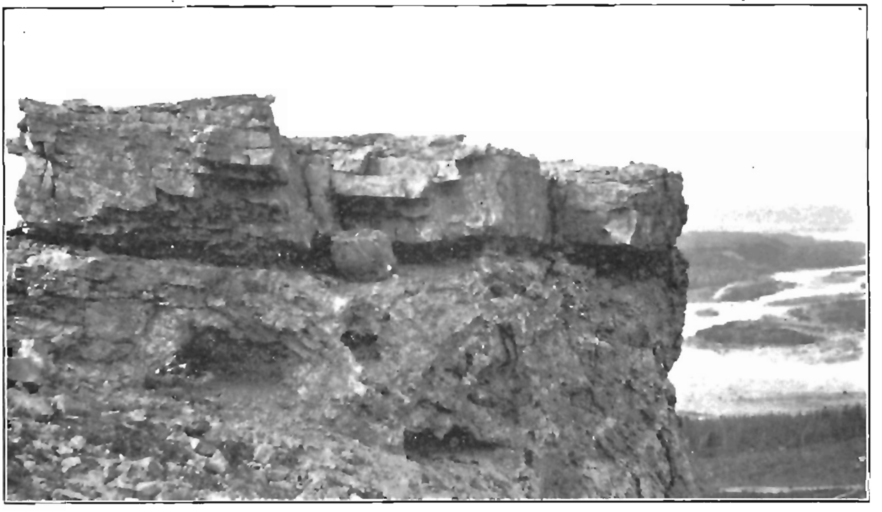
Beneath the Colorado is the horizon which in Canada is subdivided into the Blairmore and Kootenay. This is not subdivided in Montana and is supposed to be the same as the Dakota and Morrison formations of Wyoming. The section contains pink, maroon, yellow, and greenish shales similar to those in the Etzikom record. At the base is a sandstone member from which the oil in the Sunburst well, the first productive well of the district, was obtained. Locally it is referred to as the Sunburst sand.

Several members found in Wyoming beneath the Kootenay are absent, and a formation correlated with the Ellis, a lower part of the Jurassic, seems to fill the section between the Carboniferous and the Cretaceous. It consists of about 250 feet of variegated shales and a few thin limestone bands. At the base is a sandy lime varying in thickness from 10 to 20 feet. The larger production of oil comes from this horizon. The Madison limestone, a lower member of the Carboniferous formation, is the credited horizon forming the solid limestone mass beneath the softer beds through which the drill passes. Whether this correlation is definite is not certain, since one drilling was continued through 1,200 feet of beds and reached a sandy shale supposed to be Middle Devonian, as it is reported to have signs of petroleum in it. As this member was dry at the summit of the dome it is predicted that on the flank at lower elevations oil may yet be found in it.

PLATE I



"Rainbow arch" of Carcajou river. A good example of topography conforming to structure. (Page 60.)



A. Carcajou Canyon section. The disconformity separates the brecciated beds below from the fossiliferous Devonian limestone above. (Page 54.)

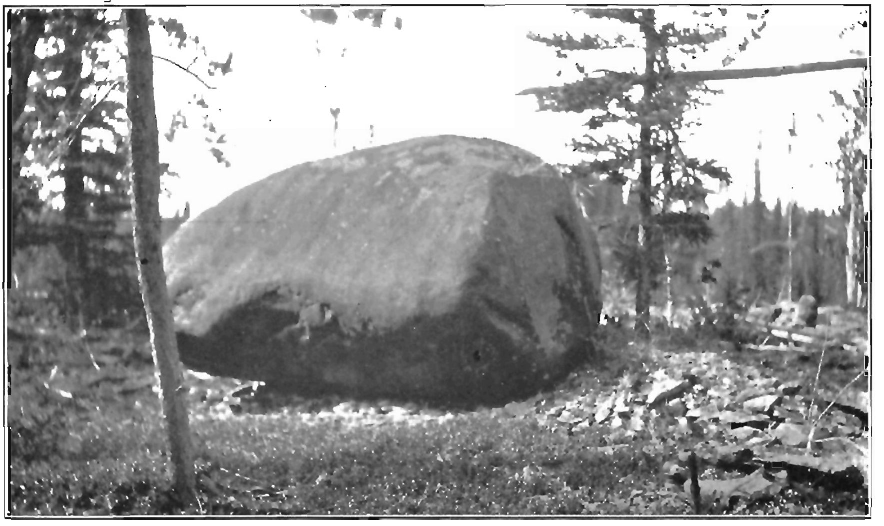
B. Brecciated beds on Bear Rock showing the character of the breccia fragments. (Page 54.)

PLATE III

A. Joint-plane developed in Hay River limestone, 110 feet high by 175 feet long. Redknife river just above lower entrance to gorge. (Page 89.)

B. Small tributary entering Redknife river from above canyon, 1 mile above lower entrance to gorge. Fall 33 feet. (Page 90.)

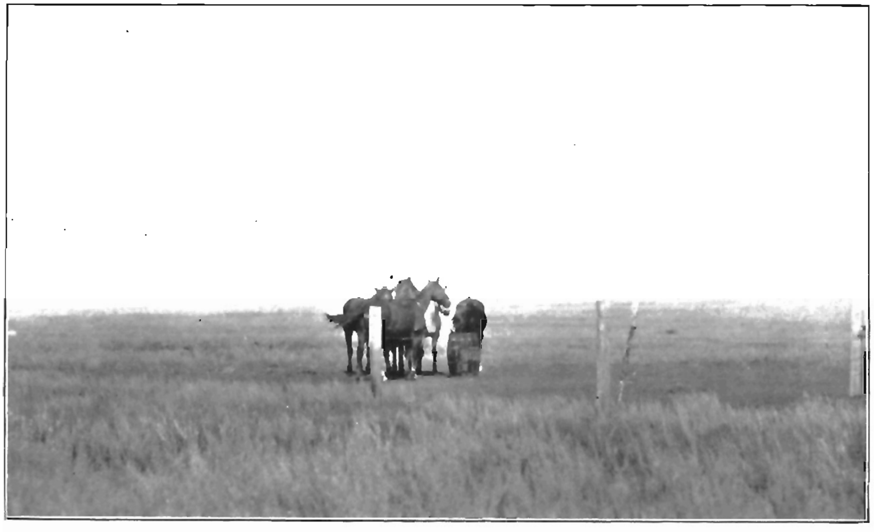
PLATE IV



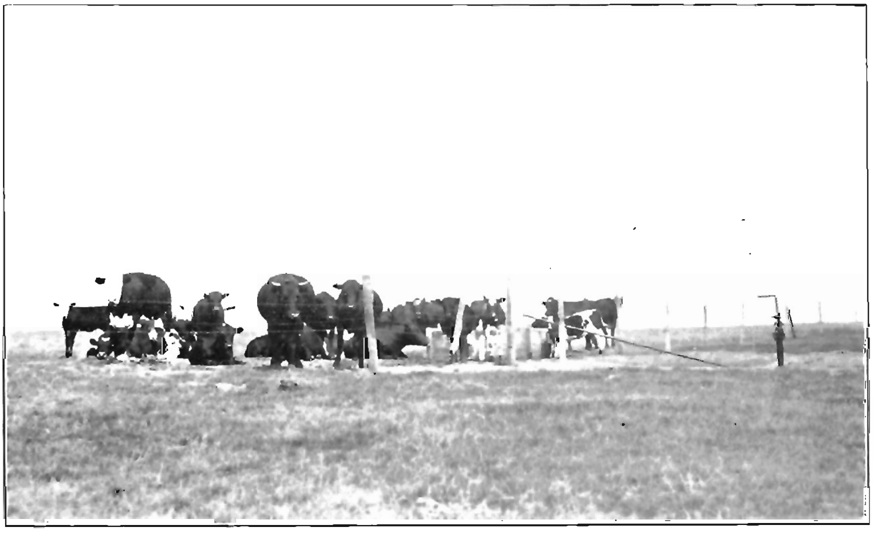
A. Boulder in ancient channel of Redknife river at the falls. Current travelled from left to right undercutting boulder at upstream end and depositing material in eddy at downstream end. (Page 90.)

B. Falls on small stream near head of Jean-Marie river. About one-quarter of volume of water comes through joints in Hay River limestones. (Page 94.)

PLATE V



A. Showing water drawn by wagon before artesian wells were drilled.



B. Government test well No. 1, connecting pipe and water tank for cattle. (Page 106.)

Apparatus used for saving the gas which comes with the water. Farm of John Ell. (Page 109.)

INDEX

PAGE
Adams, Mr. 86
Alberta
 See also Red Deer r.
 Prospecting for gas and oil. 123-126
 Rocks, correlation with those of Peace River canyon. 6, 7
Albian formation. 7
Alluvial gold—
 Red Deer r. 101
 River-between-Two-Mountains. 86
Analyses—
 Coal, Peace River canyon. 13, 16-25
 Water, artesian, southern Alta. 108
Aptian formation. 7
Argovian formation. 7
Artesian water—
 Southern Alta., notes, analyses, and borings. 104-123
Aylard, C. L. 3
Aylard ck.—
 Character. 3
 Coal. 10-12, 14-20, 28, 29
 Columnar section. . . . . . *Facing* 8, 36-40
Bain, G. W. 47
Barker ck. 65, 67
Barremian formation. 7
Basing, Alta. 102, 103
Bear Island well. 50
Bear Mountain formation. 52, 54
Bear Mountain section. 53
Bear Rock. 128
Beaver well. 108
Beavertail formation. 52, 55, 56, 62, 63
Bell, W. A. 69, 83
Belly River formation. 101
Big bend, Jean-Marie r. 96
Big chute, Redknife r. 90
Birley, Mr. 65
Blackwater l. 70
Blackwater r. 70, 71, 80, 84, 85
Blairmore area. 6
Blairmore formation—
 Correlation with Gates and Moosebar formations. 6, 7
Blueberry r. 48, 65
Bluefish Creek well. 50
Board of Trade, Lethbridge, Alta. 105
Bompas, mount. 70
Boring records. *See* Log records.
Bosworth ck. 51
Bosworth formation. 52, 58, 63
Bouvier r. 89, 91, 96-98
Bow Island, Alta. 107, 123-126
Briggs, R. H. 103
Brines. 87
Bullhead mt. 3
Bullhead Mountain formation. 3, 4, 7
 Correlation with Kootenay. 6, 7
Cadomin, Alta. 102
Callovian formation. 7
Cambrian, Franklin range. 72, 73
Campbell, M. R. 9
Canada Cement Co. 123
Canneloid coals. 10, 14, 16, 24, 25, 27, 28
Canyon ck. 51, 55, 56
Canyon of The Mountain of Rocks. *See* Peace River canyon

PAGE
Cap mt. 69, 70, 71, 75, 76, 80, 84, 85
Carcajou canyon. 128
Carcajou mt. 53, 54, 61
Carcajou r. 51, 59, 60, 127
Castle Point coal seam—
 Description. 18, 19
 Section showing. . . . . . *Facing* 8
Cenomanian formation. 7
Charles, mount. 69, 77, 79, 80, 85, 86
Clark, mount. 70, 71, 75, 78, 84, 85
Coal—
 Foothills area. 101-104
 Peace River Canyon area, B.C., rept. by McLearn. 1-46
Coal ck.—
 Coal. 10, 12-14, 25, 26, 28
 Columnar section. . . . . . *Facing* 8
Coalspur, Alta. 101, 102
Colorado shale. 126
Columnar sections—
 Peace River Canyon coal seams. . . . *Facing* 8, 30-46
Conroy ck. 66
Contact pt.—
 Coal. 12-15, 25, 26, 30, 45, 46
 Columnar section. . . . . . *Facing* 8, 45, 46
 Rocks. 5, 6
Conzet, H. H. 119
Copper, Great Bear l. 63
Coutts, Alta. 125
Cretaceous—
 Europe, correlated with Alta. and B.C. 6, 7
 Franklin range. 71-73
 Liard area. 48, 49
 Mackenzie basin. 59, 82, 97
 Montana oil fields. 126
 Sikanni Chief valley. 67
Crickmay, C. H. 65
Dead Horse coulée. 105
Deep l. 93, 94, 96, 99
Dehacho ck. 68
Devonian—
 Franklin range. 72, 73
 Mackenzie basin. 55, 97
Divesian formation. 7
Dolmage, V. 63
Dolomites. 80
Dowling, D. B. 3
 Rept. by, on artesian water, coal, petroleum, and natural gas in Alta. . 104-126
Dreamfield well. 118
Drumlin. 99
Duff, A. N. 119
Eagle sandstone. 126
Earle narrows—
 Coal. 14-20
  Thickness, section showing. . . . . . *Facing* 8
Edmonton formation. 101
Ellis formation. 126
Eocene deposits, Mackenzie basin. 82, 83
Etleh ck. 68
Etzikom, Alta. 116
Etzikom coulée. 125
Europe—
 Cretaceous, correlation with Alta. and B.C. rocks. 6, 7

PAGE
Falls coal seam—
Description........ 15–17
Section showing........ *Facing* 8
Ferro pt........ 8
Ferro Point coal seam—
Section showing........ *Facing* 8
Fish, Mackenzie R. dist........ 96
Fish l........ 94
Foothills coal area........ 101–104
Foremost, Alta........ 108, 119
Fort Creek formation........ 51, 52, 56, 57, 61–63
Fort Liard, N.W.T........ 49
Fort Nelson, B.C........ 48
Fort Nelson r........ 68
Fort St. John, B.C........ 47, 65
Fossils—
Blairmore area........ 6
Franklin range........ 75–83
Liard r........ 48
Mackenzie basin........ 97, 98
Norman area........ 52–58
Sikanni Chief r........ 68
Fossil-tree pt.—
Coal........ 10, 14, 18, 21, 30–36
Sections from, to Milligan pt. and Grant flat........ *Facing* 8, 30–36
Structure........ 8
Franklin mt., rept. by M.Y. Williams........ 65–87
Franklin Mountain formation........ 72–74, 78
Galloway, C.F.J........ 1, 24
Galloway coal seam—
Description and anal........ 24
Section showing........ *Facing* 8
Galloway falls........ 8, 24, 26
Game—
Mackenzie R. dist........ 96
Gas, natural—
Alta., prospecting for........ 123
From water, photo of apparatus for saving........ 132
Mackenzie basin........ 50
Gates formation........ 3, 6
Correlation with Upper Blairmore formation........ 6, 7
Gaudet, mt........ 70, 84
Gething, Neil........ 3
Gething coal seam—
Description and anal........ 23, 24
Gething ck.—
Character........ 3
Coal........ 10–14, 17, 23–26, 29
anal........ 16, 24
Columnar section........ *Facing* 8
Rocks........ 4, 5
Gething formation........ 4, 8, 9
Gilmore, R. E........ 9
Glaciation—
Mackenzie basin........ 99
Franklin mt........ 71, 84
Gold. *See* Alluvial gold
Grant coal seam........ 29
Description and anal........ 20–22
Section showing........ *Facing* 8
Grant flat—
Coal........ 8, 26, 29, 32–36
Section from to Fossil-tree pt. *Facing* 8, 32–36
Tunnel W. of, plan........ 20
Grant mt........ 3, 4, 8, 21
Gravel r........ 84
Great Bear l., copper........ 63
Great Bear r........ 84, 86
Gypsum........ 77, 78, 86

PAGE
Hare Indian River shales........ 52
Harlech, Alta........ 103
Hay River formation........ 89, 91, 92, 97, 98, 129, 130
Head-of-the-Line........ 96
High falls, Moosebar ck........ 17
Horn mt........ 95, 99
Hudson Hope, B.C........ 3
Hume, G. S., rept. by, on Norman Oil fields and part of Liard r........ 47–63
Imperial Oil Co........ 50
Index coal seam, section showing........ *Facing* 8
Island ck........ 10, 15
Jamieson, T. J........ 118
Jean-Marie r........ 92, 93, 95–100, 130
Johnson ck.—
Character........ 3
Coal........ 10, 14, 15, 23–26, 28, 29
Columnar section........ *Facing* 8
Johnson mt........ 8
Kakisa l........ 89, 98
Keele, J........ 83, 84
Kimmeridgian formation........ 7
Kindle, E. M........ 75, 76, 79, 80
Kindle mt........ 80
Klewie ck........ 68
Kohl, Harold........ 9
Kootenay formation........ 126
Coal, character........ 27
Correlation with Bullhead Mountain formation........ 6, 7
Lethbridge, artesian water........ 105, 106, 123
Liard mts........ 48, 49
Liard r., rept. by Hume on part of........ 48–50
Lignite, Mackenzie r........ 83, 87
Little Mogul coal seam—
Description and anal........ 17
Section showing........ *Facing* 8
Log records, artesian water, Alta........ 110–123
Lone mt........ 79
Lone Mountain formation........ 72–74, 79–81
Lookout mt........ 79
Lovett, Alta........ 102
Lusker ck........ 102
Lynx ck........ 5
McConnell, R. G........ 48
Macdougall, J. A........ 65
McGill, A. K........ 88
McGill l........ 93, 94, 96, 99
Mackenzie r.—
See also Norman
Glaciation........ 84
Sandstone and shales........ 82
Mackenzie River basin—
See Franklin mts.
Norman oil field
Whittaker, E. J.
Mackenzie River Oil Co........ 50
McLearn, F. H., rept. by, on Peace River Canyon area, B.C........ 1–46
McLeod r........ 102
McLeod Coal Co........ 102
Madison limestone........ 126
Malley, Mr........ 86
Maps—
Alberta, southern, showing bore-holes for artesian water........ *Facing* 108
Jean-Marie r........ 92
Mackenzie r. from Norman to Beaver r. 50
Peace River Canyon coal area........ 2
Redknife and Bouvier rivers........ 91
Medicine Hat, Alta........ 109, 123, 124
Milk r........ 105, 106, 109