SECOND ANNUAL REPORT

ON THE

MINERAL RESOURCES OF ALBERTA

1920

BY

JOHN A. ALLAN, M. Sc., Ph. D.
PROFESSOR OF GEOLOGY
UNIVERSITY OF ALBERTA

PRINTED BY ORDER OF THE LEGISLATIVE ASSEMBLY

CORRECTIONS AND ADDENDA

Page	
11	Natural Gas, 1920, quantity, 5,743,652 M. cu. ft. Value, $1,186,490.
51	Line 21: For "Basin" read "Basing".
67	"Coal," line 5 of table, to "Coal (clean)", line 18, should be bracketed as included in No. 1 Seam.
	"Coal," 4th last line of same table, to "Sandy shale", last line, should be bracketed as included in No. 2 Seam.
69	Interchange references at foot of page.
84	See correction slip attached to page.
85	Line 21: Oil Production in 1920 was 11,718 barrels.
87	2nd line after table: For "S. C. Slipper" read "S. E. Slipper".
89	Line 6: For "300,000" read "800,000".

HON. J. L. COTE, M. P. P.

Provincial Secretary,

Edmonton, Alberta.

Sir,—I beg to submit herewith the Second Annual Report on the Mineral Resources of Alberta.

The report contains the results of field investigation during the summer of 1920, and also additional information on certain minerals occurring in Alberta, which is not included in the first annual report.

Special consideration has been given to the occurrence of rock salt, discovered in 1920, in the well drilled by the Provincial Government at Fort McMurray for the purpose of determining the presence or absence of salt. All geological data obtained up to the present time, from the salt well core which is now at the University, are included and discussed.

Details are given on the petroleum development within the Province during the past year, and all available information on the recent discovery of oil at Fort Norman is included.

An outline map of Alberta is added to the report, on which the location of some of the mineral deposits is shown. A columnar section of the salt well is also included, as the discovery of rock salt is of great economic importance to Western Canada.

All of which is respectfully submitted.

Yours truly,

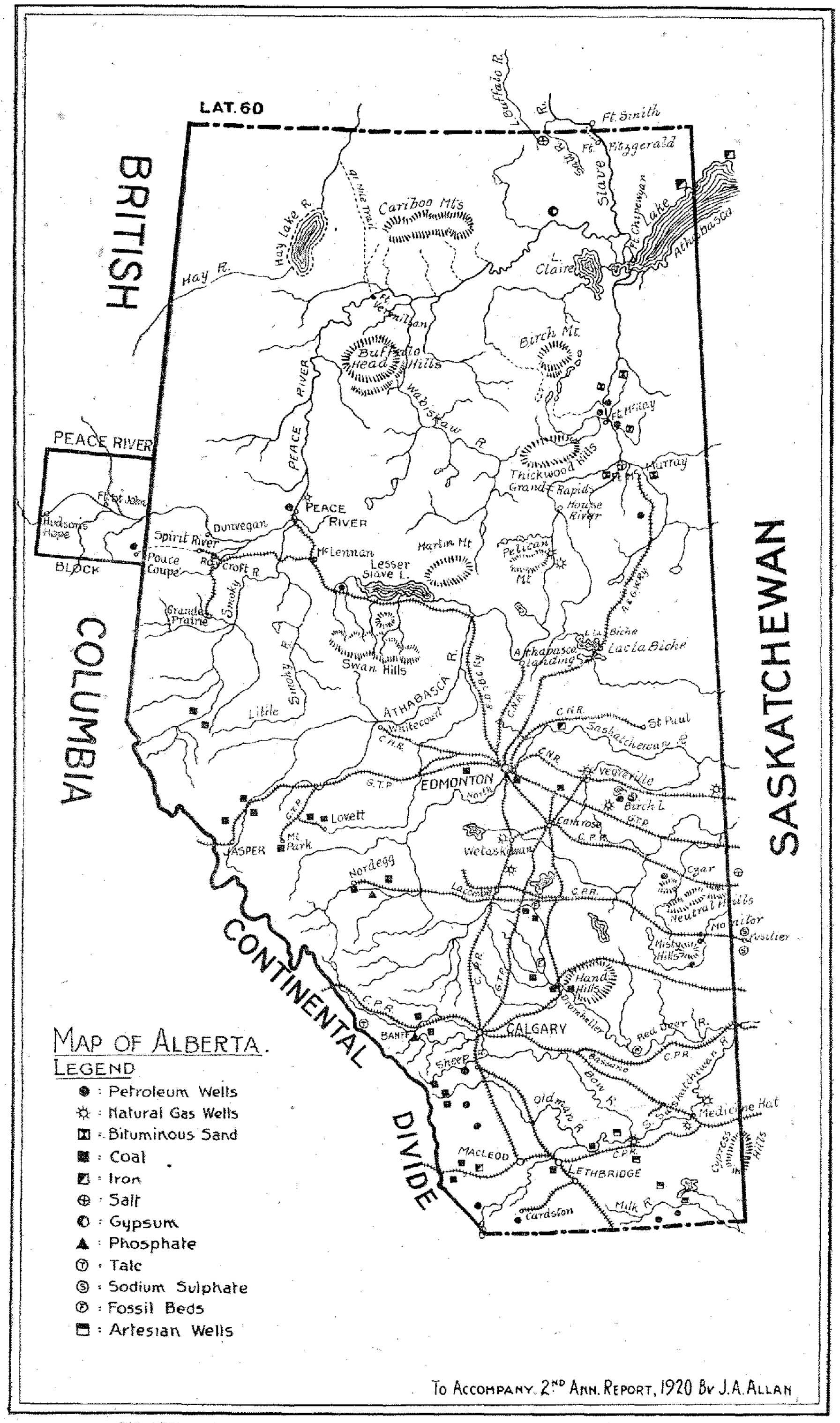
JOHN A. ALLAN.

University of Alberta,
Edmonton, February 22, 1921.

TABLE OF CONTENTS

CONTENTS

ILLUSTRATIONS



SHOWING LOCATION OF KNOWN MINERAL DEPOSITS

SECOND ANNUAL REPORT

Mineral Resources of Alberta 1920

BY

JOHN A. ALLAN

INTRODUCTION

The mineral resources of Alberta were described in a preliminary manner in the first geological report, published by the Provincial Legislative Assembly in 1919. The occurrences, determined extent, and available data already published on various minerals in the province were referred to and summarized.

In 1920 nearly five months were given to investigations in the field. Two months were spent in the northern part of the province. During this time the salt well was visited at McMurray, and the drilling records were examined and correlated. The bituminous sands formations in the McMurray district were studied, and all of the exposures of bituminous sand were mapped down the Athabasca river. The geological section was continued to the northern boundary of the province on the 60th parallel of latitude, close to Fort Smith.

A survey was made of the salt spring deposits twenty-five miles west of Fort Smith. These springs occur in both Alberta and the Northwest Territory.

A reconnaissance survey was made of the undeveloped Kootenay coal basin near the headwaters of the Highwood and Sheep rivers, where considerable prospecting has been carried out by H. A. Ford and his associates in the Highwood valley, and by P. Burns Coal Mining Company in the valley of Sheep river.

A general survey was also made of the coal measures along the Alberta Coal branch and the Brazeau, but the geology is complex, and considerable time is required to determine the structure of the measures in detail. The age of the coal seams along the coal branch has not yet been determined.

A recently discovered talc deposit west of Banff was visited.

The occurrences of other minerals visited include sodium sulphate lakes, iron shales, paint shales and ochre. No attempt was made to do detailed work on the extensive clay resources within the province, but deposits of bentonite and clay shales with excellent burning properties were located, and attention will be given to these deposits later.

Tests were made from the material collected during the field season. Seventy-two analyses have been made by J. A. Kelso, Director of the Industrial Laboratories at the University of Alberta. Although the results of these analyses are included in the body of the report, they are grouped together in an appendix.

During the past year an exhibit has been prepared of minerals and clay products representative of the resources of Alberta These are in a room at the University of Alberta set aside for this purpose, and the exhibit will be added to from time to time.

The complete core of the salt well, weighing about five tons, has been transferred to the University of Alberta. I have classified, arranged, and labelled the core in such a way that any portion of it can be examined without handling. A log has been compiled in a chart on a scale of eighty feet to one foot. Credit is due Mr. Wm. Pickles, in charge of drilling operations, for the care taken in preserving and preparing the rock core for shipment.

In the field work I was ably assisted by Ralph L. Rutherford, who was partly responsible for data collected. Miss Grace A. Stewart again acted efficiently as assistant in the office compiling data from various sources. Miss Stewart spent about two weeks in field work on glacial deposits and physiographical problems. Drafting of charts and sections of the salt well and the outline map of Alberta included in this report was creditably executed by J. O. G. Sanderson at the University. The writer was also assisted in the preparation of this report by P. S. Warren, paleontologist, and by Miss Vera Lee, both in the department of Geology at the University of Alberta.

Acknowledgments are due Mr. G. Card, Indian Agent at Fort Smith, Messrs. S. E. Slipper, H. A. Ford, and P. Burns of Calgary, the operators and mine officials on the Alberta Coal branch, and various other individuals, for assistance and information relative to the preparation of this report.

During the year 468 letters were dealt with relating to different phases of the mineral resources of Alberta.

The following table shows the mineral production for the last three years The marked increase in the production for 1920 is due to the increased production of coal. However, it is important to note that clay products show a marked increase over 1919.

MINERAL PRODUCTION OF ALBERTA, 1918 - 1920.

	1918		1919		1920	
	Quantity	Value	Quantity	Value	Quantity	Value
Gold, alluvial ....Oz.	27	$ 558	24	$ 500		
Coal ....Tons	5,972,816	20,537,287	4,964,535	18,294,495	6,908,923	$30,330,172
Natural Gas ....M. cu. ft.	6,318,389	1,358,638	8,230,838	1,365,127	5,972,816	20,537,287
Petroleum ....Brl.	13,040	100,004	16,437	97,841	11,718	75,295
Clay Products	......	381,074	......	571,949	......	821,430
Lime ....Bush.	80,408	44,141	109,067	41,276	......	......
Sand-lime Brick ....No.	600,000	6,600	729,000	10,206	......	......
Stone	......	569	......	3,189	......	......
Other Products	......	681,116	......	702,999	......	1,491,217
TOTAL	......	$23,109,987	......	$21,087,582	......	$33,904,604

BITUMINOUS SANDS

DISTRIBUTION

In the vicinity of Fort McMurray, 300 miles north of Edmonton there is an extensive deposit of bituminous sands, more popularly known as the "tar sands." The bituminous sand formation outcrops along the sides of the Athabasca valley for a distance of nearly one hundred miles north of Fort McMurray down stream, and for a distance of forty miles in a straight line up the valley of the Athabasca from Fort McMurray. There are numerous exposures of this formation along the rivers and streams which enter the Athabasca. These exposures prove the lateral distribution of the bituminous sands. As the formations rise gently towards the north the exposures of bituminous sands disappear above the sides of the Athabasca valley or have been eroded away or covered with glacial drift, between the 25th and 26th base lines, about 100 miles by river and 65 miles in a direct line north of McMurray. The areal distribution of the bituminous sands is much more extensive than the outcrops would indicate.

Wells that have been drilled for oil and gas up the Athabasca, south of McMurray, for 150 miles, and also in the Peace River valley over 200 miles west of McMurray, have proven the extent of the bituminous sand formation.

At McMurray the base of this formation is exposed about fifteen feet above the low water level in the river. At the junction of House river and the Athabasca, about sixty miles southwest from McMurray, a well was drilled by the Great Northern Asphalt and Oil Company to a depth of 295 feet, but the bituminous sand horizon was not reached, and the well was still in the Clearwater shales that overlie the bituminous sands. Above Pelican Rapids and the mouth of Pelican river, thirty miles south of House river, a well was drilled by the Geological Survey in 1897-98, in township 78, range 18, west of the 4th meridian. The bituminous sands were reached at a depth of 750 feet below the surface. Drilling ceased at a depth of 837 feet, when a strong flow of gas under terrific pressure was encountered. Natural gas has been flowing out of the well into the air since that date, and it is reported that the pressure has not been greatly decreased although the flow has continued for twenty-four years.

The well record, which is given below, indicates a thickness of eighty-seven feet of bituminous sand, but the bottom of the formation was not reached. The log of this well is as follows:*

LOG, PELICAN RAPIDS

Probable Formation	Material	Thickness in feet	Depth from Surface in feet
	Sand and Gravel	86	86
Pelican Shale	Shale, very soft, dark bluish	15	101
	Sandstone, soft	4	105
	Shale, very soft, dark bluish. At 185 feet slightly saline water	80	185
Grand Rapids Sandstones	Shale, rather hard, reddish brown	40	225
	Sandstone. At 225 feet water	9	234
	Sandstone and brown shale	11	245
	Shale, hard, grey. At 253 feet more water and gas	8	253
	Shale, light greenish-grey	27	280
	Shale, soft, greenish-grey, cement-like	10	290
	Shale, brown, with strata of grey shale	18	308
	Shale, brown	2	310
	Sandstone, hard. More gas and water	1	311
	Shale, brown, and sandstone in alternate strata	17	328
	Sandstone	12	340
	Shale, brown	13	353
	Sand rock, hard, with layers of softer rock (At 355 feet struck maltha and gas)	12	365
	Sandstone, rather hard	45	410
	Shale, brown	40	450
	Sandstone. More gas and water	15	465
Clearwater Shales	Shale, grey	61	526
	Ironstone	6	532
	Shale, grey	21	553
	Sandstone	3	556
	Very hard, probably ironstone	2	558
	Sandstone, very hard	5	563
	Shale, brown	10	573
	Shale, grey, streaks of sandstone	17	590
	Shale, grey, brown shale and sandstone in alternating strata; the cuttings show traces of maltha	30	620
	Shale, grey, strong flow of gas at 625 ft.; considerable maltha coming away with the water	5	625
	Sandstone, very hard	18	643
	Shale, soft grey	5	648

*Geol. Surv., Can., Memoir 116, 1919, p. 81.

LOG, PELICAN RAPIDS (Continued)

Probable Formation	Material	Thickness in feet	Depth from Surface in feet
Clearwater Shales (Continued)	Sandstone, hard	4	652
	Shale, soft, grey, sandy	13	665
	Ironstone	10	675
	Shale, soft, grey	9	684
	Sandstone, hard	1	685
	Shale, soft, dark grey	18	703
	Shale, soft, grey, sandy	5	713
	Sandstone, hard	10	718
	Sandstone, hard	5	723
	Sandstone	10	733
	Shale, soft grey	10	743
	Shale, soft, grey, with streaks of soft sandstone. Strong flow of gas at 750 feet. A heavy oil mixed all through the sandstone and shale	7	750
Tar Sands (McMurray Sands)	Shale, soft, dark grey, and soft sandstone. Heavy oil throughout. At 773 feet a heavier flow of gas	31	781
	Alternate strata of soft grey shale and soft sandstone. Increased quantities of heavy petroleum. Gas in volume	19	800
	Same as foregoing. At 820 feet a tremendous flow of gas of which the roar could be heard three miles or more	20	820
	Sandstone, soft. Hard streak, and light flow of gas at 830 feet	10	830
	Sandstone, soft	6	836
	Iron pyrites nodules embedded in cement-like sandstone. Very strong flow of gas	1	837

Another well was drilled by the Pelican Oil and Gas Company, four miles south of the Geological Survey well, in township 78, range 17, west of the 4th meridian This well was drilled to a depth of 2,069 feet, and the log indicates that the upper Devonian limestones were reached at 903 feet. Dowling* has classified this well record and shows the bituminous sand formation, now called the McMurray sandstone, to include the strata between 843½ and 898 feet, a thickness of 54½ feet.

In Peace River valley, 200 miles west of Fort McMurray, the records of some of the wells drilled for oil seem to indicate that the McMurray formation (bituminous sand) is reached between 900 and 1,000 feet below the surface. Dowling† shows that in the log of well

*Geol. Surv. Can., Memoir 116, 1919, p. 80.

†Geol. Surv., Can., Memoir 116, 1919, p. 84.

No. 1 drilled by the Peace River Oil Company, in township 85, range 21, west of the 5th meridian, the McMurray formation extends from 980 to 1,107 feet, which is the bottom of the well. The log of well No. 2 drilled by the same company about 1½ miles south of No. 1, to a depth of 1,057 feet, is quoted by F. H. McLearn.*

The Peace River and Athabasca sections have been studied and correlated by McLearn on paleontological evidences. He states on page 15 C that the thick sandstone near the bottom of this well may be correlated with the "tar sands of the Athabasca at the same horizon."

Oil seepages in Wabiskaw Lake district, about midway between the Athabasca south of McMurray and the Peace, are believed to be derived from the underlying bituminous sands. All of this evidence indicates the wide distribution of the sands which are so well exposed on the Athabasca.

The exact areal distribution of the bituminous sand formation can only be estimated, but from the extent of the outcrops and other indications, it is reasonable to estimate that between ten and fifteen thousand square miles are underlain by this formation.

AGE OF THE BITUMINOUS SANDS

The bituminous sands form the basal member in the lower Cretaceous series as it is known to occur in the McMurray district. McLearn has named this member the "McMurray formation," because the term bituminous sand will only apply to the formation where it outcrops and where the lighter oils have escaped at the exposures. McLearn correlates this formation with the lower part of the Loon River shales, and states that they represent the non-marine phase of the Loon River series, which is marine. His correlation of the Athabasca and Peace River sections is given in the following table:†

*Geol. Surv., Can., Sum. Rept., 1917, part C, p. 20.

†Geol. Surv., Can., Sum. Rept., 1918, Part C, p. 2.

<table>
<tr><th>System</th><th>Group</th><th colspan="2">Smoky-Peace Section</th><th>Athabasca Section</th></tr>
<tr><td rowspan="6">Upper Cretaceous</td><td rowspan="2">Montana</td><td colspan="2">Wapiti</td><td></td></tr>
<tr><td>Upper Shale</td><td rowspan="3">Smoky River</td><td rowspan="3">La Biche</td></tr>
<tr><td rowspan="4">Colorado</td><td>Bad Heart Sandstone</td></tr>
<tr><td>Lower Shale</td></tr>
<tr><td colspan="2">Dunvegan</td><td>Pelican Sandstone</td></tr>
<tr><td colspan="2">St. John</td><td>Pelican Shale</td></tr>
<tr><td rowspan="5">Lower Cretaceous</td><td rowspan="5">Lower Cretaceous</td><td>Upper Sandstone</td><td rowspan="3">Peace River</td><td rowspan="3">Grand Rapids</td></tr>
<tr><td>Middle Shale</td></tr>
<tr><td>Lower Sandstone</td></tr>
<tr><td colspan="2" rowspan="2">Loon River</td><td>Clearwater</td></tr>
<tr><td>McMurray (tar sands)</td></tr>
<tr><td colspan="5">Paleozoic Limestone Series</td></tr>
</table>

Along the Athabasca river below McMurray the bituminous sands are underlain by greyish weathering shaly limestone of Upper Devonian age. The contact between the Devonian limestone and the lowest Cretaceous sandstone saturated with bitumen appears to be a comformable one. There is, however, a broad time break between these two formations and the contact therefore represents a disconformity.

All of the outcrops of limestone and sandstone exposed along the Athabasca between McMurray and Athabasca lake were mapped during the summer of 1920 but as many of the outcrops are very small no attempt has been made to indicate them on Plate I which accompanies this report. The outcrops of limestone along the river show low folds and numerous rolls of minor importance, but the overlying bituminous sands appear to be quite regular in position.

CHARACTER AND COMPOSITION OF BITUMINOUS SANDS

In the First Annual Report for 1919 the general character and composition of the bituminous sands are given.*

*Allan, J. A., First Ann. Rept., 1919, Min. Resources of Alberta, pp. 8-13, Edmonton.

The bituminous sand formation is an ordinary light grey to white sandstone, more or less completely saturated with bitumen. The beds vary in color in the outcrops from black to light grey. The color depends upon the percentage of saturation in the sand and distance from the surface.

The thickness of the bituminous formation varies in different localities to a maximum of 225 feet. Toward the north and east from McMurray the formation has been completely denuded by glacial action.

In some beds the percentage of bitumen is so small that the sand grains are only coated with bitumen. In other beds in the same exposure the sandstone is supersaturated with bitumen, so that when heated by the sun the bitumen with the loose sand oozes down the surface of the exposed bed.

The texture of the sandstone in various strata throughout a single exposure varies considerably from a coarse grit in which thirty per cent of the sand will pass a 10-mesh screen to an extremely fine silt, of which over eighty per cent will pass through a 200-mesh screen. A table which shows the texture of several samples collected by S. C. Ells of the Mines Branch, Ottawa, is given in the First Annual Report, page 9 A wide range in texture can be seen in almost any exposure of the bituminous sand. This fact is illustrated in the following table of screening tests made on samples taken close together:

Locality of Outcrops	Percentage of Sand Passing Mesh								Bitumen in Per Cent.
	10	20	30	40	50	80	100	200	
1. Athabasca, east side 40 miles below McMurray	27	33	15	7	8	1	5	3	15
2. Same exposure	2	3	2	3	48	11	26	4	20
3. Athabasca, east side 12 miles north of McMurray	..	..	..	..	3	9	64	24	17
4 Athabasca west side, 16 miles north of McMurray	..	..	..	..	47	11	33	9	12
5. Horse Creek	..	..	..	2	56	11	27	4	9
6. Horse Creek, same exposure	..	..	..	..	11	5	77	7	17
7. Hangingstone Creek	..	2	4	9	51	9	22	3	15
8. Clearwater River	..	4	7	9	49	14	14	4	14

This marked variation in the size of sand grains is characteristic of almost every exposed section of the bituminous sand. This variation in texture must be considered in any process used for the extraction of bitumen from the sand grains.

The bitumen content in the sand also varies considerably in the different beds. In general the beds in the lower part of the formation are richer in bitumen than the higher beds, but this is not always the case. In several exposures examined on Horse creek and Hangingstone creek the richest beds exposed occur between twenty-five and fifty feet above the base of the formation.

Tests made on individual samples from various beds show that the sand contains from twelve to twenty per cent bitumen. Carefully selected specimens have tested twenty-two per cent bitumen. The average bitumen content of the sand is between fifteen and eighteen per cent. The specific gravity of the saturated sand is 1.75 to 1.80. There are, however, bands of hard nodular and ferruginous sandstone in many of the exposures, which contain little or no bitumen. Specimens collected from these bands have a specific gravity of 2.5 and 3.7. These bands are of no commercial value.

About five tons of sands were collected from an exposure on Hangingstone creek and brought to the University for experimental purposes. One cubic foot of this sand weighs 120 pounds and the bitumen content is about 17.5 per cent.

A sample from an exposure on Horse creek gave the following analysis:

Bitumen content	15.2 per cent
Sand	84.5 per cent
Moisture	0.3 per cent

Ells* gives an analysis from a sample of saturated sand collected from an exposure on the east bank of the Athabasca just north of the mouth of Horse creek:

Bitumen soluble in carbon bisulphide	18.5 per cent
Sand	80.2 per cent
Moisture	1.3 per cent

When the bitumen has been extracted the remaining sand consists almost entirely of white and colorless angular and irregularly rounded quartz grains Various analyses of the sand show that the silica content ranges from ninety-three to ninety-nine per cent. The sand has not yet been tested for glass-making, but the impurities are so low that there are possibilities of utilizing the sand when a commercial process is found for extracting the bitumen.

*Mines Branch Can., No. 281, 1914, p. 75.

EXTRACTION OF BITUMEN

The real problem in connection with the bituminous sands is one of treatment. Some process is necessary which will extract the bitumen from the sand on a commercial scale. Various laboratory processes are known which will successfully recover the bitumen, but up to the present time no process has been proven to have commercial possibilities which will extract the bitumen.

When a block of bituminous sand rock is subjected to heat the mass will soon become plastic and with further heating will flow readily, but the sand will flow with the oil, as there is no coherent material in the rock other than the bitumen.

By heating a fragment of the saturated sand in an open container, gas is liberated until all of the bitumen has been driven off and only loose white sand remains.

By heating a quantity in a closed container gas is liberated which may be condensed to a crude oil. The residue is a coke-like mass consisting of sand grains held together by a filament of bitumen residue, which remains firmly attached to the sides of the container.

Various tests of this kind have been made at the University and elsewhere. A test made by the writer while in the field gave over eight fluid ounces of oil from four pounds of the saturated sand. The oil was analyzed by J. A. Kelso in the Industrial Laboratory at the University of Alberta Kelso reports as follows:

Original Sample—	Per Cent	Specific Gravity
Water by volume	3.2	
Sediment, tarry residue	.5	
Oil by volume	96.3	19.5 Beaume

Distillation of Oil—	Degrees Cent.	Per Cent.		
First drop	70			
First fraction	80	1.0		
	90	2.0		
	100	2.6		
	110	.6		
	120	.6		
	130	1.0		
	140	.6		
	150	1.3	9.7 %	51.5 Beaume
Second fraction	160	1.3		
	170	1.0		
	180	.6		
	190	.6		
	200	1.0		
	210	1.0		
	220	1.6		
	230	2.0	9.1 %	36.5 Beaume

Third fraction	240 250 260	1.3 2.0 1.6—4.9 %	25.0 Beaume
Fourth fraction	270 280 290 300	3.0 2.0 3.0 5.3—13.3 %	24.0 Beaume
Fifth fraction	325	18.6—18.6 %	23.0 Beaume
Sixth fraction	350	14.0—14.0 %	18.5 Beaume
Seventh fraction	380	23.0—23.0 %	15.5 Beaume
Residue and loss	...	7.4 7.4	

The above analysis indicates commercially:

Commercial gasoline	9.7 per cent
Illuminating oils	27.3 per cent
Light lubricants	32.6 per cent
Medium lubricants	23.0 per cent

This sample was taken from the surface of the outcrops from which the lighter oils have escaped, but a higher percentage of the lighter products can be expected in the sands at some distance from the exposure.

Many other tests have been made on the bitumen content, which gave results ranging from fifteen to forty Imperial gallons of crude oil per ton of sand. The oil has an asphalt base only.

Considering the extent of the saturated sands, and the quantity of oil in a ton of sand, which weighs about 120 pounds per cubic foot, this deposit is worthy of extensive investigation as the possibilities are unlimited. A simple calculation based on the distribution of the exposures shows that there are at least 189 cubic miles of bituminous sands, but only an extremely small percentage of this mass could ever be utilized. The workable portion of the formation is defined by the thickness of the overburden, so that the actual area of bituminous sand which can be utilized is extremely small in comparison to the quantity in the deposit. Even if only a small acreage can ever be utilized, and a fair percentage of the bitumen content extracted, the quantity of oil in the deposit would be an important factor in maintaining the petroleum supply of the world.

Samples of this sand are being tested in several laboratories throughout Canada, the United States, and the British Isles. The chances are favorable for the discovery at an early date of a commercial process for the extraction of the oil. It is, however, the case that a successful laboratory process might not be a practicable field process. The oil can be extracted in a laboratory by heat treatment producing destructive distillation, as described on a preceding page, and also by the use of steam, hot water, or various other solvents, but none are yet known to be adaptable to the bituminous sand on a practical scale in the field.

Research on the utilization of the bituminous sands is being conducted by Dr. K. A. Clark in the Industrial Research Department at the University of Alberta This investigation is promising of results of a practical type.

Experiments were conducted in the field in 1920 by Mr. D. Diver of Calgary with an electric heater which he designed. This heater was inserted into the bituminous sand in situ and a quantity of gas was liberated and condensed. The oil obtained by this process was analyzed by J. A. Kelso with the following results:

Original Sample—	Per Cent	Specific Gravity
Water by volume	5.9	
Sediment, etc.	4.3	
Oil by volume	89.9	27.0 Beaume

Distillation of Oil—	Degrees Cent.	Per Cent.	
First drop	150		
First fraction	170	0.5	
	180	0.5	
	190	0.5	
	200	1.7	
	210	1.2	
	220	3.0	
	230	5.0—12.4 %	34 Beaume
Second fraction	240	6.2	
	250	11.7	
	260	12.0—29.9 %	30.0 Beaume
Third fraction	270	12.0	
	280	12.0	
	290	12.0	
	300	8.5—44.5 %	26.0 Beaume
Fourth fraction	325	8.5— 8.5 %	23.0 Beaume
Carbon residue and loss	...	4.7— 4.7 %	

The above analysis indicates commercially:

Illuminating oils	86.8 per cent
Light lubricants	8.5 per cent
Gasoline	0.0 per cent

The analysis shows that only a fraction of the lighter oil in the bitumen was driven off by this process. No attempt was made at determining the cost of producing the heat by the process. It was an interesting experiment, and it is the intention of those interested to try out another type of heater during the current year.

The economic problem on this deposit is one of treatment and extraction of the bitumen, and not one of transportation. During 1921 it is contemplated to extend the Alberta Great Waterways railway into McMurray. This will make the deposits quite accessible.

In July, 1920, the Federal Government by Order in Council No. 1495, "withdrew from sale, settlement or disposal for any purpose both in respect of the surface and the mining rights," all lands not already leased which contain workable deposits of bituminous sand. According to the records in the Dominion Land office in Edmonton, since this regulation was made, the Dominion Government has leased considerable acreage in small parcels to one General Wm. Lindsay and his associates, who claim to have discovered a commercial process for the extraction of the bitumen. These small parcels include many of the workable outcrops along the Athabasca and its tributaries.

BUILDING STONE

A few notes on building stone are added in this report to those given in the first annual report, page 13. This does not mean that it is not important to have the sources of building stone fully described, but during the season of 1921 time did not permit to consider these deposits. According to the statistics on the mineral production of Alberta published by the Mines Branch, Ottawa, the province in 1919 produced stone to the value of only $3,189.00. This small use of building stone is explained by the fact that building operations throughout the province were almost at a standstill for a few years. The value of this product for 1920 will be represented by a much larger figure. The table on page 11 shows a value of $1,491,217 for stone, lime and cement products for 1920.

CASTOR SANDSTONE

The area in the vicinity of Castor, from which sandstones have been quarried for building purposes, was examined and reported on by R. L. Rutherford. A few notes are here given on that district. May 23rd to 25th inclusive was spent looking over the section exposed in the vicinity of Castor, for the purpose of determining the quality of the sandstones quarried for building purposes, and the relation of this sandstone to the stratigraphic column. Exposures of sandstone occur along the banks of Beaverdam creek from its headwaters north to where it makes a sharp turn to the east in section 28, township 38, range 14, west of the fourth meridian. Beyond this point to the east there are practically no exposures along the valley for a distance of over eight miles where the survey stopped.

The first exposure of sandstone was seen near the headwaters of the stream in southeast quarter section 24, township 37, range 14, west of the fourth meridian. Towards Castor the valley deepens, a greater thickness of sandstone is exposed and a coal seam appears above the sandstone. Several prospect tunnels have been made on the coal immediately above the sandstone in sections 13 and 23, but these have been abandoned for some time. The tunnels are partially filled with surface gravel and soils. The sandstone is lying in a horizontal position and the following section is exposed in section 26, township 37, range 14, west of the 4th meridian:

10 feet surface soil and gravel.
5 feet coal and shaly sandstone.
5 feet poor dirty coal.
10 feet well jointed sandstone underlain by carbonaceous shale.

The sandstone quarries are situated about 200 yards north of the Canadian Pacific bridge across Beaverdam creek in a small tributary ravine. The sandstone is light yellowish in color, massive bedded, well jointed, but soft in texture and with considerable clay in the cement In several sections examined north of Castor the beds belong to the lower part of the Edmonton formation, as the underlying marine shale of the Bearpaw occur a few miles east of Castor.

The sandstone from the quarries at Castor has been used in several of the local buildings, two of which are Castor Public School, erected in 1910, and the Merchants Bank building. Of these two the stone in the latter presents a much better appearance. In the public school building the corners are left with an unfinished surface, that is, the jointing plane of the rocks is the face. These jointing planes have become rusty or iron-stained so that the surface of the stone has a dirty dark appearance. These iron-stains are present even on the stone with smoothed surface, so that the exterior has a smeared appearance. The stones used as supports across the windows seem to have been too weak to hold the weight, as many have cracked Another difficulty with this stone for building purposes seems to present itself in the setting, as the mortar does not grip the stone, and after drying falls out readily. This fault is due to the fact that the rock is so porous that it extracts moisture from the mortar before it has time to set, thus leaving a powder between the blocks instead of a gripping cement.

In the Merchants Bank building there seems to have been greater selection in using this building stone, and also more cutting and polishing of the blocks before they were placed in the building. This gives a much better appearance, although the true nature of this stone for building purpose is best seen in the public school.

CLAYS AND CLAY PRODUCTS

No attempt will be made in this report to describe systematically occurrences or uses to which Alberta clays are adapted. The origin and occurrence of clays were described in a general way in the First Annual Report,* and a few notes are here added on certain districts.

In the First Annual Report, page 44, mention was made of certain companies producing clay products which are situated within the town of Medicine Hat. At Redcliff, nine miles west of Medicine Hat, there are several brick plants, two of which will be mentioned briefly.

The plant of the Redcliff Brick and Coal Company is situated about half a mile southwest of the Canadian Pacific Railway station at Redcliff. Mr. A. Sellhorn is in charge of this plant. The product manufactured at the present time is almost entirely brick, ordinary red brick and pressed brick. Formerly hollow tile was made but this was discontinued. During the past year the company has commenced to manufacture a dark reddish-brown rough-cut brick which is placed on the market as a tapestry brick. Brick from this source has been used in the construction of the mining engineering and medical buildings at the University of Alberta.

The Belly River shales exposed along the bank of the river are used in the plant and are mined by tunnel from the side of the valley. The principal shale bed lies sixty-one feet below the surface and the material is hoisted by inclined tramway up to the plant. Gas is used under the boilers and an automatic feed regulates the flow of gas. The clay is treated by the stiff-mud process. Common bricks are burned in scove kilns; the pressed brick and face brick are burned in three beehive kilns and twelve Koch Patent kilns. This kiln is rectangular in outline with arched roof. The flue is situated at the end and is used for two kilns which therefore form a unit. The burn in the Koch kiln requires about four weeks and the bricks are first subjected to from twelve to fourteen days' preheating. A type of fire-proof flue lining, used by the Canadian Western Steel Company at Redcliff for moulding ingots, is manufactured by this company from No. 2 refractory fire clay from a deposit south of Moose Jaw.

*Allan, J. A., First Ann. Rept., Min. Resources Alta., Edmonton, 1919, p. 28.

Ries and Keele describe the tests made on the shales used for brick-making at Redcliff and their report is as follows:*

"**Tests of Redcliff Shales**—Run of bank used for wirecut brick (1688). This shale shows good plasticity, but a full-sized brick would not stand rapid drying, and considerable trouble has been experienced at the works on this account. It would, therefore, be well to try adding 1 per cent of salt to the shale. It worked up with 19 per cent of water to a mass whose air shrinkage was 7.2 per cent and average tensile strength of 378 pounds per square inch.

"The wet-moulded bricklets behaved as follows:

Cone	Fire Shrinkage %	Absorption %	Color
010	0	11.59	Red
03	0.4	8.87	Red
1	3.0	3.44	Red
3	Vitrified		
5	Fused		

"The shale burned to a good red color, and became steel hard at cone 010. It is not adapted to paving brick or sewer-pipe because of the tendency to crack, and also because it does not make a good vitrified body. We were shown some samples of drain tile and fireproofing said to have been made from this shale, but the Company at Redcliff has not yet attempted the production of this.

"A test was also run of the shale bed (1686) occurring near the top of bank, and used alone for making dry-press brick. In the laboratory both wet-moulded and dry-press tests were made. It was found to be a very plastic sticky material, which worked up with 30 per cent of water. Its average air shrinkage was 11 per cent, and the average tensile strength 305 pounds per square inch.

"The shale alone cracked badly in air-drying, but the addition of salt prevented this. The use of the latter also reduced the air shrinkage to 7.3 per cent.

"The following tests represent the results obtained with wet-moulded bricklets made of the shale without salt, and dried very slowly:

Cone	Fire Shrinkage %	Absorption %	Color
010	Slightly swelled	10.77	Light red
03	2.3	4.18	Dark red
1	5.0	1.34	Dark red
3	4.6	0	Dark red
5	Nearly fused		

*Ries, H., and Keele, J., Geol. Surv., Can., Memoir 24-E, 1912, p. 65.

"The shale burned to a good red color, and hard body at cone 010, but was not steel hard until cone 03. Its color deepened very considerably at this cone. Were it not for the trouble caused in drying, it might be useful for sewer-pipe.

"A dry-press bricklet at cone 05 had a good body, was steel hard, of dark red color, and had an absorption of only 6.2 per cent.

"The best results obtained in the laboratory in treating this clay were obtained by calcining a portion of it, and using the calcined part as 'grog' in the raw clay, taking equal parts of each. This mixture worked well when wet. It could be dried moderately fast with safety and when burned to cone appeared to give a good sewer-pipe body.

"This clay could probably be calcined at the works by the method in use now for burning lime. This is done by building up limestone blocks in hollow, bechive shaped heaps, and burning with natural gas. The calcined clay 'grog' would have to be charged in a dry pan with the raw clay.

"The dark shale (1687) from the base of pit is exceedingly sticky and plastic, and worked up with difficulty. It took 43 per cent of water for mixing, and the shale also checked badly in air drying.

"This mass was thoroughly dried, re-ground, and mixed with water, and 2 per cent its weight of hydrochloric acid added. It then took only 33 per cent of water. This acidified clay had a high air shrinkage of 11.6 per cent, and dried in the warm room without cracking. Salt could be used instead of the acid.

"The tensile strength is probably high, but the briquettes shrunk so much that they would not hold in the clips of the testing machine.

"Wet-moulded bricklets behaved as follows:

Cone	Fire Shrinkage %	Absorption %	Color
010	0.65	10.82	Light red
03	2.00	6.07	Red
1	0	3.41	Brown
5	Fused		(Cracked)

"The clay burned steel hard at cone 010. The most serious objections to this clay are its high air shrinkage, and cracking in drying. On account of the latter, it is not mixed in with the other layers of the bank.

"Underlying the upper five-foot lignite seam in the coulee below shale bank is a four-foot bed of light-buff sandy shale (1685), which was tested because it was claimed to be of buff-burning character.

"When mixed with 28 per cent of water this formed a plastic, springy mass, which seemed rather short in the working. The average air shrinkage was 4.4 per cent, and the average tensile strength 297 pounds per square inch. The clay did not stand fast drying.

"In burning the wet-moulded bricklets behaved as follows:

Cone	Fire Shrinkage %	Absorption %	Color
010	Slightly swelled	22.36	Salmon
03	0	22.27	Pale red
1	1.3	14.00	
2	Vitrified		
3	Well fused		

"This clay behaved similar to a silty surface clay. Its high porosity up to cone 03, and sudden softening below cone 1, would lead one to believe that it is calcareous, but this is not the case. It is called a buff-burning clay, but the fire tests show that it is not. The clay did not make a good dry-press.

"The material can hardly be used for anything but common brick, and is not sufficiently plastic for fireproofing. Moreover, it would have to be worked by underground methods and in connection with the overlying lignite."

The plant of the Redcliff Pressed Brick Company is situated about half a mile east of that of the Redcliff Brick and Coal Company. In this plant approximately the same kind of shale is used and a red pressed brick is manufactured. A slightly different type of Koch kiln is used at this plant. The chambers are nearly twice as large as those used at the Redcliff Brick and Coal Company, and the kilns are placed side by side with the chimney between instead of at the end.

In the Crowsnest Pass there are many occurrences of Fernie, Kootenay and Benton shales which are suitable for various clay products. J. D. Mackenzie describes an occurrence on the south fork of Oldman river between Pincher creek and the Crowsnest Pass. His report follows:*

"The Benton beds are nearly wholly a fine clay shale, and are of prospective value as a source of material for common brick manufacture. A bed of light grey plastic shale outcrops in the Benton measures exposed on Jackson creek, about one-fourth mile from its junction with the South Fork river. This bed, although not well exposed at this outcrop, appears to be about four feet thick, and dips 35 degrees southwest. Less than one-fourth mile upstream the plastic shale is repeated by folding, and dips 65 degrees southwest, the strata forming a syncline overturned to the northeast. At this exposure is a well-defined 4- to 5-foot seam of white to light grey, slightly yellowish stained, fine plastic shale between walls of dark grey fine fissile clay shale.

"These two outcrops have been sampled by Mr. D. Diver of Calgary, and his samples have been subjected to tests by Prof. Edward Orton, Jr., of Ohio State University. Mr. Diver kindly furnished the writer with a copy of Prof. Orton's report, wherein he sums up his conclusions by saying: 'It is my judgment that with competent management a mixture of these two clays can be made the basis of a successful face brick industry, and a successful industry for stoneware and similar heavy pottery.' "

Samples from this deposit were tested by Ries, who describes the result as follows:†

"The tests made on the shales from Passburg are interesting. They are all plastic. Four of them soften at a comparatively low cone, while the other two stand a much higher heat. It seems that the best plan to adopt would be to make a mixture of the two classes, as the shales of higher heat resistance would serve to hold the mixture up in burning.

"I believe that the shales contain good possibilities. Most of the shales are sufficiently plastic to flow through a die. They burn to a good red dense body, with low shrinkage and low absorption. Those of lower fusibility could be used for common or pressed brick, drain tile, or, I believe, for fireproofing. A mixture of the two classes of material could probably be used for paving brick, and possibly sewer-pipe. In the latter case, the more refractory of the shales should form two-thirds of the mixture."

There are certain shale beds outcropping close to the railway between Lundbreck and Burmis at Passburg, east of the mountains along Crowsnest Pass. One of these deposits is situated on section

*Geol. Surv., Can. Sum. Rept., 1912, p. 245.

†Ries, Geol. Surv., Can., Memoir 65, 1915, p. 54.

11, township 7, range 3, west of the 5th meridian. Samples taken from this deposit about 200 feet from the Oldman river, one-half mile south of the Canadian Pacific railway, and about two miles west of Burmis station, have been tested by Ries.

The results of these tests are described as follows:*

"Among the deposits that have been prospected is one located near Passburg, in section 11 township 7, range 3, west of the 5th meridian. The claim which is controlled by J. Kerr of Passburg and others, is about 200 feet from the Oldman river, about one-half mile south of the Canadian Pacific railway track and two miles west of Burmis station. The deposit is covered somewhat by the river terrace deposits, but the beds which are somewhat folded are of Blairmore (Dakota?) age, according to Leach's map of 1912.

"Six samples were supplied from different beds by Mr. Kerr as follows:

"Lab. sample 1936, Kerr's No. 4, said to represent a five-foot bed, the highest of the section.

"Lab. sample 1939, Kerr's No. 3, from a four-foot bed.

"Lab. sample 1921, Kerr's No. 1, from a four-foot bed.

"Lab. sample 1920, from eight-foot bed about same level as 1921.

"Lab. sample 1938, Kerr's No. 5, said to be four feet thick, and to lie twenty feet below 1921.

"Lab. sample 1937, Kerr's No. 6, said to lie fifteen feet below No. 5, and to be 10 to 12 feet thick.

"The deposit was more extensively opened up after the writer's visit to the region, and four of the samples were sent in later.

"The following are the laboratory tests made on the samples and conclusions drawn from them:

"One sample (Lab. No. 1936) was a soft grey shale, that works up well to a plastic mass and could be made to flow through an annular die. The average air shrinkage was 8.7 per cent, which was a little high. It burns to a red color, and is thoroughly vitrified at cone 1; in fact, the bricklets deformed under the weight of a few courses of test bricklets resting on them. Fired at several cones the following results were obtained:

LABORATORY SAMPLE NO. 1936

Cone	Fire Shrinkage %	Absorption %
010	1	10.00
05	3	7.43
1	5.4	0.09

*Ries, H., Geol. Surv. Can., Memoir 65, 1915, p. 45.

The shale shows a low fire shrinkage, and the bricklets had a good ring even when burned only to cone 010. It will not stand burning above cone 1, or even that high, but at cone 03 should give a good dense brick. The absorption is not high, even at the lowest cone at which it was tested. The material would probably make a vitrified product at a low cone. Figure 13 gives the graph of the burning tests.

"A second sample (Lab. No. 1939) was silty clay shale, which, however, has good plasticity, and worked up well to a plastic mass whose air shrinkage was 7 per cent. The shale burned pink at cone 010, red at cone 05, and brown at cone 1. It became steel hard at cone 05, but the bricklets had a good ring even at cone 010. The clay was vitrified and even somewhat softened at cone 1. It fused about cone 3.

"Below are the burning tests:

LABORATORY SAMPLE NO. 1939

Cone	Fire Shrinkage %	Absorption %
010	0	11.00
05	1.8	8.50
1	5.0	1.59
3	Fused	

"From the tests on the wet-moulded bricklets the clay gives evidence of making a vitrified ware at a low cone.

"Dry-pressed bricklets burned at cone 010 were too soft, but those fired at cone 05 had a good ring and 10.88 per cent absorption.

"A third sample (Lab. No. 1921) was a light grey shale, which when ground up and mixed with water gave a body of excellent plasticity whose average air shrinkage was 6.6 per cent, and average tensile strength when air-dried was 30 pounds per square inch. No difficulty was experienced in forming wet-moulded bricklets of the clay, nor in making it flow through an annular die. The bricklets had a good ring even at as low a cone as 010.

"The burning tests were as follows:

LABORATORY SAMPLE NO. 1921

Cone	Fire Shrinkage %	Absorption %	Color
010	1.6	11.46	Salmon
05	4.2	6.18	Red
1	5.4	2.00	Dark red
3	Fused		

"The shale softened somewhat even at cone 1, and it would hardly be safe to burn it as high as this, if used alone. The fire shrinkage is not high, and neither is the absorption.

"The clay could probably be moulded dry-press.

"Several possible uses suggest themselves. The shale could be employed for making red brick, and possibly vitrified brick. It could also be moulded and burned at a low heat for drain tile. If the shale will take a salt glaze it should be tried for sewer-pipe. Fire-proofing is another product that I believe could be made from this shale.

"A fourth sample (Lab No. 1920) is also a light grey shale of good plasticity, which worked up readily with 21 per cent of water. The average air shrinkage was 6.6 per cent, and the average tensile strength when air dried was 25 pounds per square inch. It has enough plasticity to flow through a tile die. The shale burns to a red color, which increases in depth with the intensity of the firing. The bricklets are steel hard at cone 05, and practically vitrified at cone 1. The burning tests were as follows:

LABORATORY SAMPLE NO. 1920

Cone	Fire Shrinkage %	Absorption %
010	1.0	9.02
05	2.7	7.75
1	4.7	2.30
3	Fused	

"The shale would probably work for paving brick, as well as building brick.

"A fifth sample (Lab. No. 1938) is another shale of good plasticity, whose air shrinkage was 8.5 per cent. The shale burns to a brownish red color and is steel hard at cone 05. The burning tests were as follows:

LABORATORY SAMPLE NO. 1938

Cone	Fire Shrinkage %	Absorption %
010	1.0	11.98
05	1.7	9.24
1	3.6	4.16
3	5.0	3.40
7	Nearly viscous	

"This is one of the most refractory of the Passburg shales tested, and in this respect resembles the next one. The bricklets had a good ring and color even at cone 010.

"The dry-press bricklets at cone 010 showed 12.58 per cent absorption, and 2.6 per cent fire shrinkage. They were a little soft for use. Those burned at cone 05 were nearly steel hard, with 11.07 per cent absorption.

"A sixth sample (Lab. No. 1937) is of a clay shale which is sandy and of a low plasticity. It does not work as well as 1936, for example, and yet no trouble was experienced in wet-moulding it, nor in forming it into dry-press bricklets. The average air shrinkage of the wet-moulded shale was 7 per cent. It burns to a red body, which is steel hard at cone 05. The absorption is moderate, and the fire shrinkage is low up to cone 05. These facts were borne out by the following tests of the wet-moulded bricklets:

LABORATORY SAMPLE NO. 1937

Cone	Fire Shrinkage %	Absorption %
010	1.3	15.91
05	2.0	14.20
1	6.0	2.93
3	8.0	1.50
7	Viscous	

"The dry-press bricklets were too soft for use at cones 010 and even 05, but at cone 1 they were hard with a fire shrinkage of 7.6 per cent and an absorption of 3.3 per cent."

CRANDELL PRESSED BRICK AND SANDSTONE PLANT

The plant of the E. H. Crandell Pressed Brick and Sandstone Company is situated at Mile Five on the main line of the Canadian Pacific railway, west of Calgary. This plant was closed during the period of the war, but operations were resumed in 1920.

The raw material is derived from an escarpment about 125 feet high which forms the south side of the Bow valley close to the railway. The clay beds consist of shales and shaly argillaceous sandstones of Paskapoo age. The section of the beds below the soil in the pit from which the raw material is derived is as follows:

5 feet light grey massive sandstone.
10 feet sandy shale with bands of ferruginous sandstone.
10 feet massive sandstone (not used).
3 feet dark sandy shale (not used).
3 feet bluish grey shale.
7 feet light yellow sandy shale.
7 feet ferruginous sandstone.
10 feet thin-bedded grey sandstone.
8 feet massive grey sandstone (not used).
35 feet shales and shaly sandstones irregularly bedded, jointed and broken. Ironstone along the breaks.
25 feet covered to level of railway.

It is the lower thirty-five feet in the pit that is utilized chiefly, although no particular care is taken in sorting out the material. The beds are broken down by blasting and the material is taken direct to the crushers. The massive sandstone is used for building purposes.

The process used in the manufacture of brick is the dry press. The plant has a full capacity of one and one-half million bricks per month. Up-draft kilns are used for burning, with forced drafts, and slack bituminous coal is used for fuel.

The products manufactured are red pressed brick, clinker brick, encaustic brick with enamel and porcelain finish, also plain and enamelled wall and floor tiles in various colors and designs.

The appearance and quality of both the brick and tile are excellent. The demand for tile is yet very limited because architects do not seem to be cognisant of the fact that floor and wall tile of good quality can be made from Alberta clays.

TREGILLUS BRICK PLANT

One mile west of the Crandell Clay plant, the same series of beds were worked by the Tregillus Brick Company, but this plant has been closed down for some time and is almost entirely dismantled. This plant when in operation produced a good quality of brick and especially a rough-cut brick which was placed on the market under the trade name of "tapestry brick." This class of brick has been used in the construction of the Arts building at the University of Alberta.

A somewhat similar type of rough-cut brick is now being manufactured by the Redcliff Brick and Coal Company at Redcliff, Alberta. This brick has been used in the mining engineering and medical buildings at the University of Alberta.

This type of brick has a dark reddish brown color and has an attractive appearance, but on account of its rough and hackly surface is a bad dust collector.

ZUCHKA BRICK PLANT

A plant was installed in the spring of 1920 by the Zuchka Brick Company, about three-quarters of a mile north of the town of Smoky Lake, on the St. Paul des Metis branch of the Canadian National railway, in section 27, township 59, range 17, west of the 4th meridian.

When the plant was visited the average daily output was twenty-seven to twenty-eight thousand bricks per day, and thirteen to eighteen men were employed.

The stiff-mud process is used, the bricks are wirecut and are burned in scove-kilns using wood for fuel.

The clay is taken from the gentle sloping side of the valley of White Earth river, about half a mile from the creek and thirty-five feet above water level.

The clay appears to be of residual origin derived from the disintegration of the shale beds in the Pakan formation (middle Belly River series). Further to the east the surface soil becomes sandy, where the Victoria sandstone is exposed or comes close to the suface.

The following section is exposed in the clay pit:

1	foot	surface soil.
2½	feet	soil and clay mixed.
2	feet	clay sand.
4	feet	yellowish clay (being used).

The clay dries and burns without excessive cracking. The brick has a buff color and is somewhat soft, but is suitable for common building purposes. The first kilns of brick burned were not of good quality as the clay used was taken from close to the surface and contained some sandy gravel. A much better quality of brick is produced from the clay and shale beds when the pit was opened up further from the surface.

BENTONITE

Bentonite is a variety of clay which is very fine in texture and shaly-like when dry, but extremely soapy when wet. This clay will absorb three times its weight in water, so that on account of its absorption properties it forms a soft, soapy, jelly-like mass when thoroughly mixed with water. When thoroughly saturated with water this material is colloidal in form and as such has been found to be of use in the manufacture of various products.

Bentonite is seldom found pure, but usually contains various impurities which give the material a creamy yellow to dark greenish color. Bentonite clays are widely distributed throughout the Edmonton and Belly River formations. Surface clays have been formed from the breaking down of shales containing bentonitic clay. This type of clay is better known by the name of gumbo. On account of its extreme soap-like character when wet, it enters as an important factor in the study of road-making throughout Alberta.

Bentonite is used in the paper industry and in textile industry for the sizing of the yarn. It is also useful as a cleanser of cloth and is a clarifier of oils. A satisfactory shaving soap can be manufactured from this clay, and it also forms a basis for various salves and other medicinal products.

A thin bed of pure bentonite was examined in the Edmonton formation in the vicinity of Drumheller and Rosedale, in the Red Deer valley. Beds of clay with true bentonite properties were found in this formation at a number of places. The thickest bed of pure bentonite occurs in the coal mine at Rosedale, where the clay forms a parting four inches to about fourteen inches in thickness. The quality of this bentonite is such that this material can be regarded as of commercial value. Irregular beds were found at other places in the Edmonton formation

Further investigations are being carried out on bentonite clay in the laboratory of the research department at the University of Alberta, and the results may prove that the purer grades of bentonite in Alberta are commercially valuable. An analysis representative of the pure bentonite in this formation was made at the University of Alberta and gave the following result:

Silica	69.46 per cent
Iron Oxide	3.35 per cent
Alumina	16.25 per cent
Lime	2.06 per cent
Magnesia	2.76 per cent
Ignition Loss	5.04 per cent
Alkalis, etc.	1.08 per cent

COAL

INTRODUCTION

Coal is the most important of the mineral resources in Alberta which have been developed up to the present time, in that coal mining operations have been carried on continuously since 1881. Probably the earliest record of the occurrence of coal in Alberta was that made by Sir Alexander Mackenzie in 1789. He found a coal seam on Great Bear river, and refers to a seam of coal which he discovered on the Red Deer river near the mouth of Rosebud creek. This occurrence is on the margin of the Drumheller coal basin. Both of these occurrences are recorded on a map published in 1801.

In 1800 David Thompson made a trip from Rocky Mountain House down the North Saskatchewan river and recorded all the coal seams, but unfortunately his manuscript was not published until about two years ago by J. B. Tyrrell.

In 1841 Sir George Simpson discusses the occurrences of coal at Fort Edmonton. He notes that it was being used in the blacksmith shops and was found to be as good as any other blacksmith coal.

Coal was discovered in the foothills in 1845, possibly in the Bankhead-Canmore district in the Cascade coal basin. Sir James Hector, geologist on the Palliser expeditions, records coal seams on Athabasca river and Pembina river in 1860, near the site of the present mines.

The coal resources of Alberta have played an important role in the early opening up and settlement of the prairies. The surveys for the proposed Canadian Pacific railway across the prairies were beginning about 1878, but no thought was then given to the mining possibilities in Alberta. The prairies were not looked upon favorably by the pioneer settlers, who chose the more wooded districts first. It was in 1875 that Dr. George M. Dawson was sent west to make the first exploration along the international boundary line. His report that there were great seams in the treeless areas, and his accompanying map did much to bring about a change in sentiment towards the prairies. Mr. J. B. Tyrrell in '85 and '86 explored what was then called "Northern Alberta," including the Edmonton district. He mapped all the coal seams along the rivers. This report and map, which is now a classic, greatly assisted in opening up the country, by showing the settlers where coal for fuel could be obtained.

When the first transcontinental line reached the mountains the coal used was being hauled from Ohio. About 1881 the first coal seam was opened at Lethbridge and the first coal was hauled to Medicine Hat, and when used on the locomotives was found to burn, so a narrow-gauge railway was built to Lethbridge and the mine was opened up. In '82 and '83 the first mine was opened at Anthracite and Canmore in the Cascade and Bow valleys. This coal was used in the heavy construction work of the railway in the mountains. It is a fact that had the plains and the foothills not contained coal suitable for locomotive purposes, that much of the railway construction work within the mountains would have had to have been postponed until a later date.

This brief historical sketch is added to show that the presence of extensive seams of coal, and the pioneer development of the coal resources, have assisted materially in opening up and in settling part of Western Canada.

In making an estimate of the coal resources in any area it is necessary to determine the areal distribution of the coal-bearing formations, and to estimate the approximate thickness of the coal seams throughout that area. As a result of the importance of coal in Alberta much detailed work has been carried on through the Federal Geological Survey. Stratigraphical information has been obtained throughout Alberta and the distribution of the coal-bearing formations mapped as accurately as the geological knowledge to date would warrant.

Information on the coal resources of Alberta has been published from time to time by Mr. D. B. Dowling. In many districts the information which he has published is all that is yet known on the coal measures.

The coal resources in Alberta, eastern British Columbia, and western Saskatchewan have been defined largely through the excellent work carried on by D. B. Dowling, and in part, by the earlier field investigations carried on by G. M. Dawson, R. G. McConnell, and J. B. Tyrrell. These men are responsible for the earliest detailed examination of the geological structure and distribution of the coal measures in western Canada. Of these Dowling has covered the coal fields most extensively, and his numerous publications relating to coal measures in Alberta will be found in the annotated catalogue recently published by the Geological Survey.*

HORIZONS

In Alberta there are three important coal horizons in the Cretaceous. These horizons are in most localities separated by shale formations of marine origin. All grades of coal are found in Alberta ranging from lignite of medium grade to high grade semi-anthracite coal bordering on anthracite This wide variety of coal being produced by the mines in Alberta is too frequently overlooked in discussions relating to the quality of coal in this province. Alberta does not contain any large deposits of anthracite coal, but small irregular lenses of anthracite occur within the mountains where portions of the coal seams have been affected by the most intense diastrophic movements.

The two most important factors to be considered in discussing coal deposits are Age and Pressure. Both of these factors must be considered in a study of the coal resources of this province.

The quality of the coal in the various districts and different seams can be shown to be largely dependent upon these two factors.

The three coal-bearing horizons in Alberta are:

1. Edmonton formation, Upper Cretaceous.
2. Belly River formation, middle of the Upper Cretaceous.
3. Kootenay formation, Lower Cretaceous.

These horizons are separated from each other by formations from 700 to 3,000 feet in thickness. The coal seams in the lower formations are of higher quality than those which occur in the younger formations. This is due to the age and to the fact that they have been subjected to pressure from the overlying load for a greater period. On the other hand it is important also to remember that the Rocky Mountains form the western side of the province, and the mountain-building movements, which have been the cause of the upbuilding of the mountains, have exerted a greater pressure on the coal seams to the west. The quality of a coal, therefore, increases when a seam is traced towards the west and into the foothills or within the front ranges of the Rocky Mountains. The highest grades of coal are, therefore, found near the foothills, or within the front ranges. At the same time the seams of coal belonging to the Belly River and Kootenay formations are exposed close to the mountains or within the mountains, due to the fact that the beds have been tilted upwards in the process of mountain building.

*Ferrier, W. F., Geol. Surv., Can., No. 1723, 1920, pp. 446-448.

There are several coal basins in Alberta, widely distributed. The grade and quality of the coal in these individual basins vary, but in general it may be said that the higher grades are found towards the west. There are other coal basins containing high grade semi-bituminous or anthracite coals which have not yet been developed but which are known to possess large reserves for future use. Those undeveloped areas include those at the head of the Highwood and Sheep rivers described in this report, and those towards the head of the Smoky river between Athabasca and Peace rivers.

The importance of the coal resources of Alberta is evident when the amount of this mineral in reserve is considered. It is estimated that Alberta contains about fifteen per cent of the coal reserves of the world or about 87 per cent of the coal reserves of Canada. Upwards of 96 per cent of the coal reserves of Canada lie west of the Great Lakes. Mining operations began in Alberta in 1881, when 1,500 tons were produced. In 1920 the output was 6,908,923 tons. Since the beginning of mining operations in this province, the total output has been only a little over 60,000,000 tons. In the 1919 Annual Report of the Alberta Mines Branch, Mr. J. T. Stirling, Chief Inspector of Mines, states that during the last fifteen years, "100,484,038 tons of coal have been affected by mining operations," of which 47,227,498 tons have been extracted, and 26,628,770 tons have been "lost beyond any chance of recovery." This is a deplorable fact and one which calls for immediate consideration and investigation.

There is still a large scope for further field investigations on the coal resources of Alberta. These problems include the correlation of the seams, the extent of the seams, uniform quality, range in quality in any particular seam and many other phases of direct economical importance.

The following pages contain notes on some of the coal basins along the foothills or behind the front ranges of the mountains, but none of these basins have been worked up in detail.

HIGHWOOD COAL BASIN

Less than a week was spent on a reconnaissance survey of a coal area within the front ranges of the Rocky Mountains on the Highwood and Sheep rivers. This basin lies on the southwest slope of the Highwood range. In Highwood valley coal seams have been prospected by Harry A. Ford of Calgary and his associates, in townships 16 and 17, ranges 4 and 6, west of the 5th meridian. In the valley of the south fork of Sheep river, the northern extension of the Highwood coal area has been developed by P. Burns Coal Mining Company, of Calgary, in township 19, range 7, west of the 5th meridian. Sheep river area lies northwest of the Highwood area because the strike of the Highwood range is about north forty degrees west. This corresponds to the structural trend of all the ranges in the Rocky Mountains in this latitude.

The Highwood river begins at the junction of Mist and Storm creeks in township 18, range 7, west of the 5th meridian. Both of these creeks rise from the limestone range which forms the continental divide. They are separated by the Misty range which begins in Mount Rae 10,160 feet in elevation, and terminates in Mist Mountain at the junction of the creeks. The Highwood follows the less resistant rocks in the lower Cretaceous and in the lower series of the upper Cretaceous. The coal seams occur in the Kootenay measures between the Highwood range of limestone on the northeast, and the continental divide of limestone on the southwest. In township 16, range 5, the valley turns sharply to the east, leaving the Lower Cretaceous coal basin. It cuts transversely across Devonian and possibly Carboniferous limestone ridges which form the front range of the Rocky Mountains. In township 17, range 4, the valley widens on leaving the limestone escarpment in Mount Head, and follows a northeasterly trend across the inner foothills underlain by Cretaceous formations On section 36, township 17, range 4, Trap or Flat creek enters from the northwest. Five miles farther down its course Sullivan creek enters from the same direction, and about three miles farther down Ings creek enters also from the northwest.

Near Ings creek the Highwood again swings to the southeast to get round the harder Dakota rocks in the outer foothills. At the mouth of Pekisko creek in township 17, range 1, west of the fifth meridian, the Highwood again turns to the northeast and continues through the western plains to the town of High River.

The Highwood west of the plains is distinctly terraced all the way for some distance west of Cat creek, where the Ford property has been prospected. In some places seven distinct terraces are present. The terraces have been formed during the lowering and disappearance of a post-glacial lake. One of these terraces is continuous for about fifteen miles. The terraced character of the Highwood valley eliminates any problem in railroad construction. In this respect it is a most remarkable and unique valley. A railroad could be constructed into the Highwood coal basin without requiring a single rock cut.

The Highwood coal area has been examined in detail by Dr.

Bruce Rose in 1919.* who has traced and mapped the coal formations from the Crowsnest field north to Sheep river. Rose recognies three bands of Kootenay coal-bearing formations in this field, the foothills area, the mountain area, and the Mist and Storm Creek area.

The foothills area lies east of the limestone ridges in the Highwood range. It contains coal seams which are exposed in Trap or Flat creek and along other small creeks tributary to Highwood and Sheep river. Although I have examined samples of coal from Trap creek I was unable to investigate the occurrence and the prospects which have been opened up. This belt is badly faulted, but the samples examined indicate a good quality of coal.

The mountain area lies between the Highwood range and the continental divide. Rose noted three coal-bearing bands at the Oldman-Highwood divide, but on page 18C he states that "the middle band plays out by faulting and folding about three miles north of the divide."

The western band of the Kootenay rocks in the Highwood follows the west side of the valley. This band was not examined at close range, but the character of the rocks is such that they could be seen following close to the base of the limestone escarpment in the continental divide, toward the junction of Storm and Mist Creek valleys. Two arms of this band pass on either side of Mist mountain at the east end of Misty range and form the Mist and Storm Creek area.

Rose describes the structure on page 20C as follows:

"The western band of the coal formation in the mountain area bifurcates, one branch passing along Mist Creek valley and the other along Storm Creek valley. To the south these bands join in an anticlinal fold, but northward the centre of the anticline is broken by an overthrust fault that passes east of Misty range so that the band which follows Mist Creek valley lies to the east of this overthrust fault with the Devono-Carboniferous limestone of Misty Range thrust against it, and the band which follows Storm Creek valley lies in its natural succession on the west slope of Misty range.

"In Mist Creek valley the band running east of Misty range lies to the west of the creek course, crosses a number of ridges running from the range, and finally crosses the head of Mist creek to Sheep River divide, beyond which it was not followed. East of the creek course and lying on the west slope of Highwood range, is another

*"Highwood Coal Area, Alberta," Geological Survey of Canada, Summary Report, Part C. 1919, p. 14.

band of the coal formation. This is the northward extension of what was called the eastern band in the mountain area. It crosses the divide at the head of Mist creek and connects with the coal at the Burns mine on Sheep river. Other outcrops of the coal formation were seen in the broken area between these two bands at the head of Mist creek, but are probably of small extent. No prospecting has been done in this valley and the formation was not traced in detail, but it is likely that much of it will yield good coal. This likelihood applies particularly to the eastern band which is continuous from the Ford mine on Cat creek to the Burns mine on Sheep river.

"In Storm Creek valley the band west of the Misty range crosses the creek twice and at its head lies on the west side of the pass to Pocaterra creek, which flows north to Kananaskis river. No prospecting has been done along Storm creek, but on the same band along Pocaterra creek a number of good coal seams were opened a few years ago and it is reported that analyses of picked samples gave a carbon content of 80 per cent. This band was not followed northward, but seems to pinch out a few miles farther on, for a view from the pass at the head of Pocaterra creek shows that the limestones of the ranges to the east and west come together in a distance of approximately ten miles."

The eastern band of the mountain area crosses the Highwood river in section 28, township 16, range 5, west of the fifth meridian. On the north side of the Highwood there appear to be three distinct parts to the eastern band which may have resulted from repeated faulting. These were traced in a northwesterly direction along the east side of the Highwood valley, and over the divide about due north of Mist mountain into Sheep River valley, where the measures follow the south side of the valley.

The Ford property, which is referred to as the Ford mine, covers the southeasterly end of this band from Highwood river, while the P. Burns property includes the continuation of this band to the northwest, and in the valley of Sheep river in township 19, range 7, west of the fifth meridian.

The H. A. Ford property has been opened up by numerous prospect tunnels along Cat creek. When I visited this area in September the seams were being uncovered and opened up for more permanent development on the slope close to the Highwood, in township 16, range 5, where the seams pass under the valley. Sufficient work had not been done to prove up the structure or quality of the coal at this point. On Cat creek fourteen seams of coal are exposed and have been prospected in a distance of less than a mile across the strike of the formations. The numbering of the seams have been given in the order in which they have been opened up. Beginning at the most easterly prospect the seams may be described as follows:

No. 000. About four feet of badly crushed coal containing considerable bone, but with many lensy fragments of solid coal with high lustre. The limestone outcrops a few yards east of this prospect.

No. 00. About eight feet of solid coal and four feet of badly crushed coal. An analysis of this coal is given by Rose and quoted in the table below

No. 0. Seven feet six inches of good-looking coal.

No. 1. Five feet glossy compact coal and about four feet badly crushed coal.

No. 2. Twelve feet glossy and blocky coal, fourteen inches of bone, three feet six inches fair coal.

This seam, which is eight feet from No. 1, dips at 53 degrees west and strikes north 39 degrees west. Two analyses were made from this seam and are given in the table.

Very little work has been done on numbers 3 and 4, so that the exact width of these could not be determined, but Rose gives a thickness of four and five feet respectively.

No. 5. Thirty-three feet made up as follows: 11 feet coal, 4 feet shale and coaly shale, 18 feet coal. Analyses are given below of samples taken from different parts of this seam. This is one of the best seams on the property and contains much coal of good marketable quality. The strike of the seam is north 39 degrees west, and the dip 85 degrees southwest.

No. 6 seam. Ten feet wide has been opened up about fifty feet below No. 5. This seam appears to represent the upper part of No. 5, whereas the lower part of No. 5 at this level appears to have pinched out considerably. Two analyses have been made from this seam from representative samples taken from the total width of the seam.

No. 7. Twelve feet of very good coal has been opened up seventy feet below the level of No. 6. The strike here is north 42 degrees west and the dip 88 degrees west to 88 degrees east.

No. 8. A five-foot seam of badly crushed coal opened up five feet below No. 7. No blocks could be obtained from this seam but the prospect does not extend beyond the weathered portion of the coal. The strike of this seam is north 62 degrees west and the dip 65 degrees northeast. There is a fault between 7 and 8.

No. 9 has been opened up half way down the canyon of Cat creek. The prospect exposes four feet six inches of fine textured but clean coal. The strike is north 38 degrees west, and the dip about 80 degrees west.

Between the camp and the mouth of the canyon there are two seams. The upper one, No. 10, is about seven feet wide, and the coal is mined for camp use in small but angular blocks. An analysis is given below from a representative sample taken from this seam.

No. 11 is within a few feet of No. 10, but on account of the crushed character of the seam only twelve feet can be readily measured.

The samples of coal which I collected and which are included in the table below were taken from points at or close to the surface during a wet period. The moisture content appears high, but this must not be taken as representative of the coal which occurs farther in where it is not affected to the same extent by atmospheric conditions. The ash content is also high because no attempt was made to discard chippings from shale lenses when taking the samples. A considerable percentage of the shale bands could readily be eliminated during mining. The heating value of each sample taken is reasonably high. The coal, particularly that in seams 2, 7 and 8, is of excellent marketable quality and can be classed as a high grade semi-bituminous or semi-anthracite. Tests do not prove it to be a coking coal. Analyses Nos. 7 and 8 were made from single piece specimens. These results are more representative of the coal as it could be mined. There does not appear to be any reason why certain seams in this area could not be mined economically, and with transportation difficulties negligible. This coal area can be regarded as important undeveloped deposit.

ANALYSES OF COAL FROM PROSPECTS ON CAT CREEK

	No. 1.		No. 2	
Loss on air drying	3.4 %		1.8 %	
	As Received	Air Dried	As Received	Air Dried
Moisture	4.3	0.9	3.3	1.5
Volatile Matter	15.4	16.0	17.2	17.5
Fixed Carbon	60.3	62.4	63.2	64.4
Ash	20.0	20.7	16.3	16.6
B. T. U.	11,630	12,040	12,290	12,510
	No. 3.		No. 4.	
Loss on air drying	2.8 %		1.8 %	
	As Received	Air Dried	As Received	Air Dried
Moisture	3.5	0.7	2.4	0.6
Volatile Matter	16.2	16.7	15.2	15.5
Fixed Carbon	59.5	61.2	59.7	60.8
Ash	20.8	21.3	22.7	23.1
B. T. U.	11,630	11,965	11,430	11,640

ANALYSES OF COAL FROM PROSPECTS ON CAT CREEK (Continued)

	No. 5.		No. 6.	
Loss on air drying..........	2.6 %		2.2 %	
	As Received	Air Dried	As Received	Air Dried
Moisture	3.0	0.4	2.7	0.5
Volatile Matter	15.4	15.7	14.0	14.3
Fixed Carbon	57.9	59.5	58.1	59.4
Ash	23.7	24.4	25.2	25.8
B. T. U.	11,390	11,690	11,180	11,430

	No. 7.		No. 8.	
Loss on air drying..........	0.0 %		0.0 %	
	As Received	Air Dried	As Received	Air Dried
Moisture	0.2	0.2	0.3	0.3
Volatile Matter	15.2	15.2	17.4	17.4
Fixed Carbon	79.1	79.1	72.8	72.8
Ash	5.5	5.5	9.5	9.5
Sulphur	0.2	0.2	0.2	0.2
B. T. U.	14,620	14,620	13,890	13,890

	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
Proximate analysis						
Moisture	0.6	0.9	0.5	0.6	0.6	0.7
Ash	23.6	8.1	8.7	7.6	23.9	6.8
Volatile Matter	14.3	16.0	15.1	16.0	16.2	18.8
Fixed Carbon	61.5	75.0	75.7	75.8	59.3	73.7
Ultimate analysis						
Sulphur	0.6	0.6	0.5	0.5	0.3	0.7
Calorific value in B. T. U.	11,620	14,110	14,150	14,300	11,370	14,370

1. Representative sample from Seam Number 6.
2. Average sample from Number 10 Seam.
3. Average sample from Seam Number 5, upper eleven feet.
4. Seam Number 5, average of the upper and lower parts of the seam which are separated by two feet of shale.
5. Average sample from Seam Number 5, lower eighteen feet.
6. Seam Number 2, average of the whole seam. The high ash content in this analysis is due to a band of bone which might easily be eliminated when mined.
7. Single piece sample from Number 2 Seam.
8. Single piece sample from No. 5 Seam.

9 to 14 inclusive are given by Rose on page 19C in the Summary Report for 1919. The samples were collected by him and analyzed in the laboratory of the Fuel Testing Station, Mines Branch, Ottawa.

9. Seam 00 sample across seven feet forms poor coke.
10. Seam 00 single piece sample agglomerate.
11. Seam Number 2, single piece sample forms poor coke.
12. Seam No. 5, single piece sample from bottom—agglomerate.
13. Seam No. 6, sample across seam, forms poor coke.
14. Seam No. 9, single piece sample, forms good coke not much swollen.

SHEEP RIVER COAL BASIN

The south fork of Sheep river rises from the north slope of Mount Rae in township 19, range 7, west of the 5th meridian. The head of this valley, which is broadly rounded by glacial action, terminates in a low divide drained on the north slope by the Elbow river. This river extends to the southwest and terminates in a low divide which is drained on the opposite side by Pocaterra creek, a branch of Kananaskis river

From the Sheep-Elbow divide the valley of the former follows a southwest trend for six miles between a limestone ridge on the northeast, and a Cretaceous and Jurassic ridge on the southwest. After passing the location of the Burns mine in the southwest quarter section 14, township 19, range 7, the valley turns slowly to the east and at the same time narrows considerably. The river has cut a comparatively narrow gorge through the limestone ridge of the front range. From Gorge creek eastward the sides of the valley are distinctly terraced, but the terraces are not as continuous nor as level as those on the Highwood. The terracing disappears behind the front escarpment of the mountains.

A good automobile road extends from Okotoks westward past Black Diamond and the Turner valley oil field. West of this point the grades are very irregular and sometimes steep. The road follows up Maccabee creek, and near the entrance to the forest reserve, crosses over a ridge to the river a short distance above the mouth of Dyson creek, which enters from the south. The road follows the north side of the river, and the most difficult part of it is the crossing at Gorge creek, the bottom of which is about 200 feet below the terraces on either side. A good wagon road extends to the P. Burns coal mine, although some very difficult grades are encountered due to the gorge-like nature of the valley. A considerable portion of the road west of Gorge creek has been constructed and maintained by the company operating the mine.

Just west of the front range of the Rocky mountains the valley of Sheep river has been formed in a Cretaceous trough which contains many seams of coal of Kootenay age. This coal basin, which is the continuation of the measures in the mountain area on the Highwood, terminates to the northwest about three miles beyond the Highwood-Elbow divide Most of the area containing the Kootenay coal measures is owned by the P. Burns Coal Mining Company of Calgary. These measures have been opened up in sections 14 and 15, township 19, range 7, west of the 5th meridian.

The P. Burns coal mine is situated on the south slope of the valley between a small creek known as Sharp creek, to the west, and Rickert creek to the east, down which an old Indian trail passes from Highwood river. The prospect work on this coal basin is represented by numerous pits and small tunnels along Sharp creek and other small creeks which cut across the coal measures. The present development work consists of a tunnel about 1,800 feet long, which has been driven to the southwest, so that it intersects the various formations The section exposed in the tunnel is approximately as follows:

950 feet sandstone and shale strike north 27 degrees west dip 70 degrees west.
35 feet coal, Burns seam.
375 feet sandstone and shale.
38 feet coal, Sharp seam.
140 feet shale and sandstone.
18 feet coal
133 feet sandstone.
7 feet coal.
60 feet sandy shale
3½ feet coal.

The tunnel terminates just beyond this seam. At the time of my visit a drift 160 feet long was being extended along the seven-foot seam, with the intention of connecting up with the surface in Rickert creek to the east for the purpose of ventilation.

Along Sharp creek a few hundred yards west of the tunnel six seams were examined. Others are reported to occur farther up the creek but these were not visited. The following seams were examined in prospect tunnels beginning at the mouth of the valley:

No. 1. Burns seam passes west of the outlet of the valley.
No. 2. Sharp seam, 32 feet of coal.
No. 3. Seven feet six inches This one is 18 feet in tunnel.
No. 4. Eight feet coal.
No. 5. Five feet coal.
No. 6. Seven feet coal.
No. 7. Corlet seam; 2 feet solid coal; 4 feet 9 inches rock; 12 feet solid coal; 14 feet rock; 13 feet soft coal; no foot wall in sight.

In Rickert creek the following seams are exposed:

No. 1. Burns seam 20 feet coal in the foot wall, 5 feet soft rock, 9 feet 11 inches coal in the hanging wall.
No. 2. Seam coal 21 feet.
No. 3. Seam coal 12 feet 6 inches.
No. 4. Seam coal 7 feet
No. 5. Seam coal 9 feet 6 inches.

As this examination was only of a reconnaissance character no attempt was made to work out in detail the structure of the coal measures. The information obtained was sufficient to warrant the opinion that a large and valuable coal basin has been proven to exist, and that the coal is of high grade semi-bituminous or semi-anthracite quality.

The geology and structure of the coal basin towards the head of Sheep river has been described as follows by D. D. Cairns.*

"This Cretaceous basin terminates to the north about two and a half miles north of the Elbow river; the southern end was not explored as it extends far to the south of the area covered by this report.

"The Cretaceous measures in some places, especially to the south, appear to be faulted along their western edge. Towards the north, however, a secondary fold is developed as the Elbow river is approached, that causes the trough to become somewhat narrower. Here it appears quite certain that the Paleozoic rocks to the west have been pushed over themselves and now overlie the Cretaceous.

"Immediately on top of the limestones are some very hard, fine-grained, almost white quartzites, from 200 to 300 feet thick, and varying in color from pure white to a light grey. The shales and sandstones which overlie these are much thicker than to the east around the Moose Mountains, although they are otherwise very similar. The conglomerate which overlies the coal measures to the east was not seen here in place, but considerable of the float was found on the hill sides, so that it very probably outcrops on some of the higher points or ridges; but as our work was done late in the autumn, with considerable snow on the ground, we did not find it.

"The formation here consists chiefly of sandstones, characteristically brown in appearance. In fact from the river up to the tops of the high rugged Cretaceous ridge here the whole series is strikingly brown in color. The sandstones are, for the greater part, quite uniform in texture as well as in color, being rather fine-grained and not very hard. About halfway up the hill a few coarser and greyer beds were seen and also some darker ones. Above this again are a number of black shale beds, generally only a few feet in thickness and often carbonaceous, being at times composed almost wholly of the remains of ferns, etc. Near the top of the hills are a few coarser grey and greenish sandstones. Quite a number of plant remains were collected from this series, all being very characteristic Kootenay types.

*"Moose Mountain in District, Southern Alberta," Geol. Surv., Can., Memoir 61, 1915, p. 50.

"The lowest beds of this series were only seen in a few places, but there they correspond very closely with the rocks underlying the coal measures just outside the mountains and even very noticeably have the same peculiar yellowish weathering which so much resembles limestone weathering, although these shales and sandstones in most places contain very little lime.

"The high hills of this Cretaceous trough extend in a northwesterly direction along the west side of Sheep river to within about three miles of the Elbow river. From here they rapidly disappear and the Cretaceous and Jurassic instead of being a high rugged ridge become a narrow valley in between the limestone hills on each side. The formation, as it were, goes up in the air; so that about three miles north of the Elbow river it has tapered out entirely. The coal also disappears with the high hills, having been all eroded away in the northern part of the basin.

"At the northern end of this trough the same quartzites appear as were seen farther south and they outcrop similarly on both sides, proving that this part of the trough is in the form of a synclinal fold. Along the river the folding of the limestones, also, gives ample evidence of this.

"The western contact is high up on the face of the escarpment at the Elbow river, but as the trough is traced northward it descends, and finally, at the point of thinning out entirely, reaches nearly the level of the valley.

"Some hundreds of feet of dark shales were seen next to the Paleozoic quartzites here, resembling very closely those around the Moose Mountains, and they are undoubtedly of the same horizon. Intercalated in these dark Fernie shales are thin beds of yellowish brown weathering sandstones of medium hardness and texture and reddish grey in color. The shales present in their bedding planes quite a soot-like appearance."

COALSPUR-LOVETT AREA

An extensive and important coal area, about which little is known structurally, lies between Coalspur and Lovett on the Alberta Coal Branch in the outer foothills west of Edmonton. The extent of this coal area has not yet been defined, and the age and the relation between the various coal seams now being worked has not yet been determined. A general survey was made of this area in 1920, but no detailed work was done. This coal area has been briefly referred to by Dowling* and Stewart.†

*Dowling, D. B., Geol., Surv., Can. Sum. Report, 1909, p. 147.
†Stewart, J. S., Geol. Surv., Can. Sum. Report, 1916, p. 100.

This basin is reached by a branch of the Grand Trunk Pacific Railway which leaves the main line at Bickerdike, ten miles west of Edson. It follows up the Embarras river to Coalspur, thirty-seven miles from the main line. At Coalspur the railway branch follows up a valley, tributary to the Embarras, in a southeasterly direction to a low divide, and then down the Little Pembina river as far as Lovett, at Mile 56, nineteen miles from Coalspur. There are a number of sidings along this branch of the railway, but the position of the workings is determined by the mile posts which represent the distances from Bickerdike

The main trough in which the coal measures lie is reached at Coalspur, but a seam rather badly crushed has been opened up at Minehead, three miles down the Embarras from Coalspur.

The extent and quality of the coal in these measures has been determined by the following mines and prospects:

Mile 37—Coalspur-Yellowhead Pass Coal and Coke Company, present output about 200 tons per day.

Mile 40—Development started by Oliphant-Munson Collieries, but abandoned when visited.

Mile 44—Near Diss siding—abandoned.

Mile 47—Basin siding—Oliphant-Munson Collieries, present output about 1,000 tons per day.

Mile 48—Prospect—Proposed development work planned.

Mile 50—Mudge siding—Foothills Collieries, output about 200 tons per day.

Mile 51½—Prospect—operations proposed.

Mile 52¼ and 52½—Blackstone Collieries, mining and stripping, output about 180 tons per day.

Mile 53—Blackstone Collieries extension No. 6, stripping overburden when visited.

Mile 54—Brookdale Collieries, mining operations started.

Mile 55½—Pacific Collieries, capacity output about 90 tons per day.

Mile 56—Lovett Pacific Pass Collieries, now abandoned.

Beyond this point another prospect was being opened up, but this locality was not visited.

Brief notes were made along this coal basin beginning at Lovett. The depression followed by the Little Pembina represents a fracture or possibly a series of small fractures along the western limb of an anticlinal fold, the crest of which lies at most points less than one mile to the northeast. The trend of the structure is about north 45 degrees west, and the dip where observed varies from a few degrees to the southwest to a maximum of about 60 degrees southwest. There are local structures where the beds are intensely buckled and crumpled, but these do not appear to be general. There are two well-defined coal seams along this belt, which at Lovett are known as the Mynheer seam below, and the Silkstone seam 191 feet higher up. The limited field work to date has not correlated the seams in the various mines nor has it determined that these are the only two workable seams in this belt. At various points local buckling has thickened the seams, while at others the seams are undisturbed. The maximum amount of buckling observed is at Mile 47, where the working face in the open cut exposes about seventy-five feet of coal. Test holes have determined about 130 feet of coal. The mines at Lovett now abandoned were worked by the Pacific Pass Collieries, subsidiary to the North American Collieries. It is reported that operations ceased here because the seams where worked became so broken and dirty that the coal could no longer be mined economically. The colliery is being dismantled and several of the cottages are being moved to Coalspur.

Two seams were mined at Lovett. The lower or Mynheer is fourteen feet thick, but less than eight feet was worked. The upper or Silkstone seam runs from twelve to fourteen feet in thickness.

The structure in this vicinity strikes about north thirty to forty degrees west, and the dip is about twelve degrees to the southwest. The workings at Lovett lie on the westward slope of an anticlinal ridge, the crest of which is about three quarters of a mile northeast of the railway.

Stewart, on page 101, 1916 Summary Report, gives the following columnar section compiled from bore holes put down by the company in the vicinity of the mine. The log record is given as the details would be of use in future development, at least in the southern part of the area.

LOG OF DRILL HOLE AT LOVETT

Strata	Thickness Feet	Thickness Inches
Sand and gravel	4	0
Grey shale	3	0
Grey sandstone	25	6
Grey shale	13	5
Dirty coal	1	0
Coaly shale	4	0
Coal "Silkstone seam"	14	0
Clay shale	19	0
Coal	1	0
Carbonaceous shale	2	0

Coal	4	0
Clay shale	27	6
Sandstone	20	0
Dark shale	27	0
Grey sandstone	11	6
Clay shale	3	6
Coarse sandstone	4	0
Soft grey sandstone	9	6
Coarse sandstone	11	6
Dark shale	4	6
Grey shale	26	6
Coal	1	0
Fine grey sandstone	11	0
Coarse sandstone	5	6
Sandstone	6	0
Mynheer Seam—		
Coal	6	6
Shale	1	0
Coal	6	6
Grey sandstone	9	6
Brown shale	9	0
Sandstone	1	8
Dark shale	5	0
Clay shale	6	6
Hard shale	5	6
Soft sandstone	16	6
Clay shale	1	6
Sandstone	3	0
Shale	3	0
Soft sandstone	20	0
Hard sandstone	3	0
Clay shale	4	0
Shale	13	0
Black shale	0	6
Clay shale	12	6

At Mile 55½ Mr. O. L. Puckett and associates are working a lease of the North American Collieries under the name of Pacific Collieries, but when visited little development had been done and operations had temporarily ceased. The seam being mined was the lower, or Mynheer, seam, which here dips at 12 degrees to the southwest. The roof is a massive ferruginous sandstone which disintegrates easily and contains many plant fragments. The footwall is a thin-bedded grey sandstone. An average sample gave the following analysis, made by J. A. Kelso at the University of Alberta:

Loss on Air Drying .... 3 per cent

	Sample as Received	Air Dried
Moisture	9.9	7.1
Volatile matter	31.1	32.0
Fixed carbon	39.8	41.0
Ash	19.2	19.9
Heating value in B.T.U. per pound	9,715	9,810

At Mile 54, Brookdale Colliery is being opened up with Mr. J. Crawford in charge, on legal subdivision 6, section 16, township 47, range 19, west of the 5th meridian. A sixteen-foot seam has been opened up in a tunnel, but only twelve feet are being mined, two feet being left on the roof and the floor respectively. There appears to be a local bend in the measures at this point as the dip ranges from five to nine degrees.

At Mile 53½, the Blackstone Collieries extension No. 6 were removing the overburden, which is here about twelve feet thick, for the purpose of opening a portion of a seam that has been thickened by local buckling. On the surface the coal is very dirty, but this does not determine the quality at greater depths.

The same company is carrying on extensive mining and stripping development at Mile 52¼ and 52½. The operations were in charge of Mr. J. S. MacDonald, Manager; Mr. Wm. Hunter, Mine Superintendent; and Mr. A. E. Ockley, Surveyor.

From a small draw east of the railway two tunnels have been driven. "Drift A" extends about 300 feet at north 72 degrees west, and "Drift B" about 300 feet at south 65 degrees east. The seam is considerably crushed, but where exposed in the draw the thickness is about 30 feet, and the dip is eighteen degrees southwest. At the southeast face the seam is about ten feet thick and the coal is dirty. The creep is so great that this working was being abandoned. At the northwest face about sixteen feet of the seam is being worked. In one of the raises examined in "Drift A" is a sharp bend in the seam, and at the surface the seam is nearly horizontal.

At Mile 52½ the crushed coal seam has been uncovered by stripping and the coal is being quarried. At the highest point above the railway from sixteen to twenty feet of coal is exposed, the upper part of which is quite rusty. The dip is fourteen degrees southwest on top, but on the face of the hill the seam bends downwards, and the dip is 75 degrees southwest. This structure is local but ought to be considered in planning future development.

Between Mile 49 and Mile 52 the depression followed by the railway swings to the southwest so that at Mile 50, Mudge siding, the strike of the coal measures lies nearly one mile west of the strike at Mile 56. This sudden bend in the topography is due to local twisting and displacement in the measures, but the exact amount of displacement does not appear to be sufficiently great to prevent the development of the measures.

Between Mile 51½ and 52 on the south side of the Little Pembina there are a number of prospects, but sufficient work has not been carried out on any one of them to determine the character of the coal or the structure of the measures. The Bituminous Collieries own the leases west of the Blackstone Collieries, and it is the intention of the company to commence development work on these leases at an early date. A tunnel less than twenty feet in length exposes eleven feet of good-looking coal. The roof consists of soft yellowish sandstone underlain by two feet of carbonaceous shale. This exposure is only about one thousand feet west of the excavation at the Blackstone Collieries.

The following analysis was made from a representative sample taken across the face of the coal in the prospect tunnel; the analysis was made by J. A. Kelso at the University of Alberta:

Loss on air drying .... 1.0 per cent

	As Received	Air Dried
Moisture	8.2	7.3
Volatile matter	33.4	33.7
Fixed carbon	49.0	49.5
Ash	9.4	9.5
B.T.U. per lb.	11,335	11,450

The Foothill Collieries are situated at Mile 50, near the centre of section 24, township 47, range 20, west of the 5th meridian. Mr. Wm. Onions is mine manager, and he has given particular attention to the housing and comfort of his employees. The tipple is situated close to the rails on the sidings, excavations having been made in the side of the valley to make room for the tipple. It was being renovated and partly rebuilt at the time of my visit. This lack of space between the railway and the valley escarpment makes it difficult to plan any further enlargement to the tipple.

The following section was made along the railway close to the colliery:

1 foot	8 inches	Yellowish sandstone N. 4 degrees W. dip 19 degrees W.	
6 "	0 "	Coaly shale and dark shale.	
1 "	0 "	Thin-bedded sandstone.	
1 "	6 "	Coal.	
0 "	10 "	Clay	
1 "	0 "	Coaly shale.	
6 "	0 "	Coal.	
1 "	0 "	Clay shale.	
3 "	0 "	Coal.	

Mining is being carried on down the dip which ranges from twelve to fifteen degrees. There is an increase in the dip towards the bottom of the workings which is about 600 feet on the pitch. There are also small rolls in the floor. From the incline shaft drifts and rooms have been opened up connected by chutes, and mining up the pitch is being extended. The working face consists of six feet of clean coal and one foot of clay underlaid by three feet of coal. The clay band is very irregular, and in one of the rooms widens to two feet. This irregularity is due to a certain extent to buckling. The mine is comparatively dry and like all others in this district, free from gas. The following analysis of a sample taken from the working face, represents the average grade of coal being mined at this point:

Loss on air drying .... 1.0 per cent

	As Received	Air Dried
Moisture	6.4	5.5
Volatile matter	36.3	36.7
Fixed carbon	48.8	49.2
Ash	8.5	8.6
Heating value in B.T.U. per lb.	11,525	11,640

At Mile 49½ on the east side of the railway there is a small prospect, which shows ten feet of coal with a yellowish sandstone roof and a shaly bed on the floor. The dip varies from fifty-five to seventy-five degrees to the east and the strike is north five degrees west. The seam looks similar to the one in the mine at the Foothills Collieries, and if so there is a distinct fold passing between this prospect and the railway. The following analysis was made from a representative sample from this seam:

Loss on air drying .... 7.2 per cent

	As Received	Air Dried
Moisture	17.8	11.5
Volatile matter	31.9	34.3
Fixed carbon	40.1	43.2
Ash	10.2	11.0
Heating value in B.T.U. per lb.	9,735	10,490

The moisture is high in this analysis because the sample was taken from a point almost on the outcrop and should not be regarded as representative of the seam farther in.

The Oliphant-Munson Collieries are in operation at Mile 47. Here the coal seam has been buckled up to such an extent that there appears to be an unbroken seam of immense thickness. The coal so buckled has been stripped of the overburden, and the excavation when visited showed about seventy-five feet of solid coal. Test holes which have been put down show that the thickness at this point is about 130 feet. On closely examining the face of the quarry distinct evidence of crumbling and buckling can be seen, so that this deposit only represents a thickening caused by mountain building movements. The seam so thickened was not observed, but there is no reason to believe that any seam occurs here of exceptional thickness. Preparations were being made to load the cars with a steam shovel.

The coal is much broken but the quantity is attractive, and with the exception of certain dirt bands particularly towards the surface the whole mass can be utilized for railroad purposes. When I visited this point the output was about 1,000 tons per day. The entire output is used for steam purposes.

The anticlinal fold which was noted northeast of Lovett was observed within a mile of the working at Mile 47. At Coalspur the Yellowhead Pass Coal and Coke Company are mining on the same measures, but no details were obtained regarding the structure at this point as the time was limited for field observation. This mine is under the charge of Mr. George Eaton, and the output in 1920 was about 200 tons per day.

These notes are of necessity fragmental, because the problem in connection with the structure of the coal measures in this district is one which will require considerable time. It is nevertheless important that the geological structure in this basin should be definitely determined, in view of the immense reserve of coal that has been proven by the mines in operation, and also because large sums of money have been and are being expended for the development of this field. In general it may be said that the coal is of a non-coking bituminous type. Much of the coal is best suited for steam purposes as very little attempt is made to extract the foreign material in the various mines now operating. This district underlain by the coal measures is also being considered for petroleum, and numerous leases have been taken for oil since November, 1920.

MOUNTAIN PARK BASIN

At the head of the east fork of the McLeod river there is a Kootenay coal area, and in it Mountain Park Collieries are operating. The Mountain Park coal branch has been constructed and maintained by the company from Coalspur to the property, a distance of about thirty miles to the southwest. This basin lies just west of the front range of the Rocky Mountains, and the mines are located at an elevation of 5,800 feet above sea level, between ridges which rise about 2,000 feet higher. I was unable to visit this colliery, but on account of the recent interest being taken in the area a short distance to the east, as containing a possible oil field, the following notes are included from the Summary Report for 1916 by J. S. Stewart. page 102.

"The structure, though simple in its large features, is complicated in detail. The coal measures here form part of one of those large fault blocks so characteristic of the Rocky Mountains. The only exception to the dominant southwestward dip are local folds in shales and drag folds on the northeast side of thrust faults. In this region, the northeastern faces of both the first and second mountain ranges are the *loci* of major thrust falts. The trend of the mountain ranges is very irregular and the strike of the coal measures between the mountain ranges shows considerable irregularity. At the townsite, the strike is about 60 degrees west of north and the dip 30 degrees southwest. As we proceed northwest the whole basin is seen to pitch toward the southeast and a tight syncline causes the uppermost part of the coal measures to be repeated at the southwestern side of the basin. The western limb of this syncline is overturned and a coal seam outcropping at the edge of the second range of mountains, and dipping southwest, has the appearance of being overlain by the thick limestone series which forms the mountains. East of the townsite, several small folds which plunge steeply toward the east, cause the strike to change greatly within very short distances.

"The basin shows a continuous section from the Palaeozoic limestones and quartzites to the Upper Cretaceous. The Jurassic represented by the Fernie formation, is composed of dark, brownish weathering shales, limestones, and black shales of marine origin. The shales of the Fernie formation holding marine fossils, grade upward into similar black shales with arenaceous and calcareous bands. In these upper shales no marine fossils were found, and, after a stratigraphic interval of about 200 feet has been passed, the shales show numerous and well preserved ripplemarks and plant remains make their first appearance. If the uppermost bed which contains marble fossils is the top of the Fernie formation, this formation has a thickness of about 1,000 feet, but some of the brown shales at the base may be Triassic. Overlying the Fernie is the Kootenay formation composed of shales, sandstones, conglomerates, and coal beds. The true thickness of the formation is hard to obtain on account of the disturbed condition of the rocks. Making allowance for duplication, however, the total thickness must be about 3,000 feet. The lower half consists mainly of shales; the upper half consists of conglomerates, sandstones, shales, and coal seams. The productive coal measures are confined to the upper 1,000 feet of the formation. The contained fossils are wholly of continental origin, consisting of plant remains and a few freshwater molluscs.

"Overlying the Kootenay formation is a series of grey sandstones, and thick-bedded sandy shales, with a conglomerate bed at the base. This series is about 400 feet in thickness and is generally assigned to the Dakota formation; fossils observed consisted of two or three tree trunks, twelve to eighteen inches in diameter, and a few obscure impression of leaves and rootlets.

"The Dakota series grades upwards into dark grey fissile shales very similar in appearance to the Benton shales of southwestern Alberta. These shales contain marine fossils, Inocerami and Prinocyculus types being the most common. This series is about 1,150 feet in thickness and is probably to be correlated with the Blackstone shales of the Bighorn coal basin.* These Blackstone shales are overlain by about seventy-five feet of sandstone and conglomerate in which no fossils were observed. The stratigraphic horizon and the lithologic character of these rocks suggest their provisional correlation with the Bighorn formation described by Malloch.

"Overlying this Bighorn series is another series of shales very similar to the shales beneath. A complete section of this upper shale formation is not present. They are poorly exposed, much disturbed, and faulted. A few marine fossils were collected from these beds but have not yet been determined.

"The Kootenay formation contains many coal seams in this basin. Two of these are worked by the Mountain Park Coal Company. No. 1 seam, the uppermost, is seven feet thick; the other seam, known as No. 3, lies about 300 feet below No. 1 and is over 20 feet thick in places, but of this only twelve feet is mined. These seams have been opened up by slopes and tunnels on both sides of the valley. The workings on the east side have already penetrated over 3,000 feet, and on the west about 2,000 feet. The average daily output in August this year was about 400 tons."

The coal is coking bituminous. Official representative samples collected by the District Inspector of Mines were analyzed by Mr. J. A. Kelso at the University of Alberta. The following results were obtained.

Moisture	0.8		0.9
Volatile matter	25.5	to	29.9
Fixed carbon	62.8	to	67.7
Ash	6.0	to	6.4
B. T. U.	14,190	to	14,330

Two seams are being worked. No. 1 is seven feet thick, of which four feet are mined; No. 3 seam 300 feet below No. 1 is twelve feet thick where mined, but the seam in places is over 20 feet thick. Both seams are gaseous. The coal is used largely for railroad work.

About eight miles north of Mountain Park is the Cadomin mine. No details regarding the structure were obtained on this area. The output of the two mines in this branch for 1919 amounted to about 274,300 tons.

*Malloch, G. S., "Bighorn Coal Basin, Alberta," Geol. Surv. Can., Mem. 9., pp. 35-36.

A new property, known as the Mary Greig mine, is being opened up west of the Cadomin.

The structure close to and behind the front range of the Rocky Mountains is decidedly complex and requires detailed field investigation to determine the character of the measures along the strike of the structure. The Mountain Park area corresponds to the Pocahontas and Bedson coal area on Athabasca river, whereas Cadomin and Mary Greig areas appear to correspond to the Brulé Lake and Folding Mountain areas.

BRAZEAU COAL AREA

The Brazeau coal basin lies north of the North Saskatchewan river, west of the Brazeau range, which here forms the front range of the Rocky Mountains, and almost due west of the town of Red Deer. A branch of the Canadian National Railway extends west from Stettler a distance of about 180 miles. Nordegg, at the end of this branch line, is situated within the Brazeau coal basin. The coal measures in this basin are of Kootenay age, but rock exposures are rare, as there is a thick covering of glacial drift. The Brazeau Collieries located at Nordegg are working these measures. There are five coal seams known, but at present two seams of coal are being mined known as No. 2 and No. 3. These occur in southwest dipping Kootenay beds which overlie the beds in first limestone range of the mountains, known as the Brazeau range.

No. 2 seam is the lower seam stratigraphically and has a thickness of seven feet. No. 3, the upper seam, is over fourteen feet in thickness. The two seams are about 500 feet apart horizontally at the mine and the stratigraphic difference is 100 feet. The general dip of the measures is about 12 degrees toward the southwest, although some of the shale members show local variations in dip. This structure does not affect the more resistant beds which overlie the first limestone range of the mountains, known as the Brazeau range.

The mine entry is about 160 feet above railway level, and the workings extend about two and a half miles from the entry. At present the seams are being mined up the dip, the coal is lowered by gravity to the main tunnels, where it is hauled by electric trolleys to the tipple. The output is from 14,000 to 15,000 tons per day and approximately 500 men are employed. Mr. J. Shanks is mine manager and Mr Stewart is mine superintendent.

The coal is bituminous coking variety and is used almost entirely for railroad consumption. On account of the heavy overburden and the position of the seams between limestone ranges, the coal is in a finely divided condition, but is well suited for the purpose to which it is put.

A representative analysis of this coal made by J. A. Kelso at the University of Alberta is as follows:*

Moisture	0.8
Volatile matter	16.0
Fixed carbon	68.2
Ash	15.0
B. T. U.	13,000

On account of the recent attention which has been given to the inner foothills between the North Saskatchewan and the Athabasca as a possible field for petroleum development, a few additional notes are here given from the 1916 Summary Report of the Geological Survey by J. S. Stewart. To these notes are added the log of drill hole No. 2 Brazeau Collieries which was worked out by Stewart from the cores carefully preserved by the company. His report follows:†

"The rocks which compose the Brazeau range are mainly limestones. The cross section through the anticline along the railway reveals a thickness of about 1,750 feet of Paleozoic limestones with less amounts of quartzite and calcareous shales. These beds include both Devonian and Carboniferous strata. Overlying this, there are about 900 feet of shale with several limestone beds which, on the basis of a few belemnite fossils, are referred to the Fernie formation (Upper Jurassic); some of the lower shale beds, however, may be Triassic, as shales of this age are believed to occur to the west and also south of this section.

"The Fernie formation is overlain by the Kootenay, which here consists of shales, sandstones, and coal beds with a few lenticular beds of limestones The deposits are of continental origin, the fossils being mainly fern-like plants; but a few horizons carry a fresh-water molluscan fauna. Near the base of the formation there is a thick bed of conglomerate, the base of which is not exposed; the contact with the Fernie formation lies somewhere between the conglomerate and a belemnite-bearing limestone about 400 feet below the surface.

"The coal-bearing strata belong to the Kootenay formation, but the rocks of the Kootenay and formations immediately overlying are rarely exposed, being concealed by thick deposits of glacial drift."

*Allan, J.A., First Ann. Rept., Mineral Resources of Alberta, 1919, p. 49.
†Stewart, J. S., Geol. Surv., Can., 1916, p. 94.

LOG OF DRILL HOLE No. 2 BRAZEAU COLLIERIES*

Depth in Feet	Strata
0 — 6	Soil.
6 — 12	Shale.
12 — 21	Shale, soft grey.
21 — 29	Sandstone.
29 — 36	Grey shales.
36 — 53	Sandy shales, greenish grey, extremely friable.
53 — 64½	Mostly shale, friable, greenish grey in color. The lower two feet is more solid and better cemented.
64½— 83	Sandy shale, dark greenish grey.
83 — 92	Sandy shale, greenish grey, friable.
92 — 94	Sandy shale, greenish grey, friable.
94 —108	Shaly sandstone, fine-grained, dark grey with a little carbonaceous material.
108 —111	Carbonaceous shale followed by three inches of coal.
111.6—118.6	Carbonaceous shale followed by another three inches of coal.
118.6—123	Carbonaceous shale: from 114 to 118 feet these shales yielded several well-preserved fossil plants.
123 —132	Shaly sandstone, dark grey carbonaceous, with plant material.
132 —135	Sandy shale, black carbonaceous.
135 —140	Sandstone, grey, fine-grained, comparatively light in color.
140 —144	Sandy shale, firmly cemented, yields a solid core, dark grey in color.
144 —149	Sandstone, grey, with small amount of carbonaceous material.
149 —153½	Sandstone, grey, very fine-grained.
153½—161½	Shale, dark grey, very friable, contains considerable carbonaceous material.
161½—173½	Shale, black and carbonaceous, contains much black shiny vegetable remains.
173½—180½	Shale becomes more massive, harder, and contains less carbonaceous material.
180½—194	Shaly sandstone, fine-grained, slightly carbonaceous.
194 —206	Shale, dark grey.
206 —213	Sandstone, grey, fine-grained.
213 —224	Sandstone, grey, with numerous carbonized plant fragments.
224 —232	Sandstone, comparatively light grey, fine-grained, contains a small amount of carbonaceous matter.
232 —235	Shale, dark grey, friable, carbonaceous.
235 —238	Sandstone, grey, fine-grained, dark in color with numerous small specks of coaly matter; the rock is firm and hard, yielding a solid core.
238 —240	Sandy shale, carbonaceous.
240 —242	Sandstone, grey, medium-grained.
242 —251	Sandstone, grey, fine-grained, somewhat shaly at about 246 feet.
251 —256	Grey shale.
256 —257½	Sandstone, fine-grained, one-quarter inch coal.
258 —261	Shale, dark grey, friable.
261 —263	Shale, dark grey, coaly and friable.
263 —268	Sandstone, black, fine-grained and shaly, and carbonaceous.
268 —283	Shale, carbonaceous, hard and massive in many places, with many small plant impressions throughout, becomes sandy at about 280 feet.
283 —284	Coaly shale.
284 —285	Coal.
285 —289½	Black coaly shale, very friable.
289½—294½	Coal.
294½—303	Shale, dark grey, friable, quite sandy, almost sandstone in places.
303 —318	Sandstone, shaly, dark grey, very fine-grained.
318 —332	Sandstone, dark grey, fine-grained, hard and massive, yielding a long solid core, shaly toward top and bottom.
332 —335	Sandstone, dark grey, fine-grained.
335 —346	Sandstone, grey, medium-grained.

*Stewart, J. S., Geol. Surv., Can., Sum. Rept., 1916, p. 96.

Depth in Feet	Strata
346 —363	Sandstone, grey, with numerous small specks of carbonaceous matter, medium to fine-grained, yields long solid cores.
363 —377	Sandstone, hard grey with considerable carbonaceous matter and a few coaly streaks, fine-grained.
377 —383	Sandstone, fairly coarse, well cemented and hard. Carbonaceous with coaly matter, otherwise the sandstone is pretty clean.
383 —398	Coal. (Seam No. 3.)
398 —402	Shale, sandy, black and carbonaceous.
402 —403	Shale, carbonaceous, containing plant remains.
403 —404	Shale, black, carbonaceous and friable.
404 —408	Sandstone with plant remains, fine-grained, dark grey.
408 —415	Shale, sandy, black, carbonaceous, friable.
415 —418	Shale, black, carbonaceous with plant remains somewhat fissile.
418 —431	Black shales, very friable, carbonaceous and coaly for about two feet (418 to 420).
431 —448	Shale, dark grey, extremely friable, with much carbonaceous, coaly matter at about 446 feet.
448 —451	Sandstone, fine-grained, dark grey, carbonaceous.
451 —455	Shale, sandy highly carbonaceous and black, containing many plant fragments.
455 —462	Sandstone, fine-grained, carbonaceous, dark grey.
462 —481	Sandstone, grey, carbonaceous with numerous coaly plant impressions, fine-grained.
481 —491	Sandstone, fine-grained, carbonaceous, becomes shaly toward 490 feet passing into coaly shale and coal.
491 —499	Shale, black to dark grey.
499 —506	Coal. (Seam No. 2.)
506 —515	Sandy shale, dark grey with considerable carbonized plant remains.
515 —533	Shale, black and extremely friable, sandy, and carbonaceous.
536 —548	Shale, sandy, dark grey, somewhat greenish in places, rather friable.
548 —551	Black shale, friable, carbonaceous.
551 —555	Sandy shale, hard, dark grey.
555 —563	Sandstone, fine-grained, with numerous small fragments of carbonized plant material.
563 —568	Shale, dark grey carbonaceous and firm, two small specimens of plants were collected.
568 —572	Sandy shale, grey, fine.
572 —576	Shale, carbonaceous and extremely friable.
576 —578	Shale, sandy, dark grey, fairly massive, and hard, also somewhat carbonaceous.
578 —581	Shale.
581 —584	Black shale.
584 —585	Coal.
585 —589	Sandstone, dark grey, carbonaceous.
589 —592	Carbonaceous shaly sandstone.
592 —593	Coal.
593 —595	Carbonaceous shale.
595 —596	Coal.
596 —597	Shale, dark grey.
597 —604	Sandstone, grey, medium to fine-grained.
604 —608	Shale, dark grey, rather friable with a small amount of carbonaceous matter.
608 —617	Grey sandstone.
617 —631½	Mainly dark grey sandy shales, fairly fissile and becoming more sandy near 631 feet
631½—643	Shale, firm, calcareous, yielding a solid hard core.
643 —660	A rapid alternation of dark grey sandy shales and shaly sandstones, all fine-grained.
660 —670	Sandstone, grey, hard, and yielded a long firm core.
670 —681	Carbonaceous shales, sandy.
681 —699	Sandy shale, black and grey, highly carbonaceous, apparently due to plant material (no fossil noted).
699 —717	Black carbonaceous shales, coaly about near 699 feet.

Depth in Feet	Strata
717 —723	Black carbonaceous shales, very friable, become calcareous near 723 feet and contain a few molluscs.
723 —729½	Carbonaceous shales with bands highly calcareous, in places almost limestone; the fracture along the bedding is commonly black and glistening.
729½—739	Shale, calcareous, carbonaceous, somewhat fissile; contains plant and molluscan fossils.
739 —757	Shales, carbonaceous, fairly fissile, contains a considerable number of bivalves at about 746 to 750 feet.
757 —777	Black shales, contain small bivalves about 760 to 763 feet.
777 —782	Black sandy shale.
782 —789	Shaly sandstone, fine-grained, black and carbonaceous.
789 —807	Mainly black friable shales with a little sandstone near the base. The shales contain numerous small fragments of shells and small pieces of pyrite.
807 —811	Black siliceous shale, rich in fossil molluscs from 809 to 811 feet, bivalves gastropods.
811 —813	Sandstone.
813 —817	Shale, grey and carbonaceous.
817 —820	Sandstone.
820 —827	Shale, carbonaceous containing numerous small bivalves.
827 —833	Carbonaceous limestone, also containing numerous small bivalves.
833 —843	Calcareous sandy shales, carbonaceous, yields a fairly solid core, many fragments of shells.
843 —846	Sandstone, dark grey, carbonaceous, fine-grained.
846 —849	Shale, calcareous, hard, and massive; fossil plants and casts of molluscs.
849 —851	Coaly shale.
851 —856	Sandstone, fine, hard, becomes shaly and carbonaceous toward 856 feet.
856 —860	Grey shale.
860 —863	Sandstone.
863 —874	Dark grey shale.
874 —876	Carbonaceous shale, contains a few molluscs.
876 —891	Mainly fine-grained sandstone, carbonaceous, with both plant and animal remains.
891 —892½	Black shale with molluscan remains.
892½—902½	Black shale, well cemented and fissile, almost the entire thickness of ten feet is highly fossiliferous, containing numerous gastropods and small bivalves which show concentric striae.
902½—906	Black shale with a few bivalves.
906 —925	Shale, calcareous, and limestone, mainly the latter, color of rock mostly dark grey
925 —933	Shale, black, carbonaceous and somewhat fissile.
933 —945	Sandstone, shaly, fine-grained, dark grey.
945 —946	Carbonaceous shale, sandy, black, plant remains.
946 —960	Mainly sandstone, dark grey, fine-grained, carbonaceous in the more shaly beds.
960 —970	Shale, extremely friable and crumbly, carbonaceous.
970 —972	Ashy grey, friable, clay shale.
972 —974	Black shale with coaly matter.
974 —982	Sandy shale, becoming practically a fine sandstone near 982 feet, dark grey in color.
982 —988	Sandy shale, carbonaceous.
988 —990	Arenaceous limestone.
990 —1001	Arenaceous limestone.
1001 —1010	Sandstone, grey, fine-grained, firmly cemented, dark in color.
1010 —1012	Shale, black and carbonaceous.
1012 —1015	Sandstone, fine-grained, shaly, dark grey.
1015 —1018	Sandstone, fine-grained, calcareous, and carbonaceous.
1018 —1025	Sandstone, fine-grained, black and highly carbonaceous, hard and well cemented.
1025 —1026	Sandstone, very fine, carbonaceous.
1026 —1034	Sandstone, medium-grained, fairly light grey, very hard, and contains much pyrite.

Depth in Feet	Strata
1034—1040	Sandstone, hard, dark, grey, contains much pyrite, also is inclined to be more friable, finer and shaly.
1040—1049	Limestone, firm, hard, shaly, beginning and ending with rather friable calcareous shale.
1049—1054	Carbonaceous shale, black, contains numerous plant remains, small parallel veined leaves.
1054—1059	Dark grey shale
1059—1060	Calcareous shale.
1060—1065	Carbonaceous shale, fairly massive, calcareous near top.
1065—1069	Shale, black carbonaceous, becomes practically a limestone at about 1067 to 1068 feet.
1069—1077	Mainly a fine-grained sandstone, dark grey, contains numerous plant fragments.
1077—1090	Hard, fine-grained sandstone with a small amount of carbonaceous matter.
1090—1096	Sandy shale, dark grey, yields a solid core.
1096—1100	Shale, dark grey, extremely friable.
1100—1117	Mainly sandy shale, extremely friable, the core being in crumbs, small amount of carbonaceous material, color dark grey.
1117—1120	Shale, carbonaceous. very friable and crumbly.
1120—1131	Sandstone, dark grey, fine-grained, shaly but yields a fairly solid core.
1131—1141	Sandstone, grey very fine-grained, contains a few fragments of fern fronds at about 1134.
1141—1158	Sandstone, dark grey, carbonaceous, fine-grained.
1158—1170	Sandy shale, dark greenish grey, extremely friable.
1170—1183	Shale, dark grey to black, slightly carbonaceous.
1183—1190	Sandstone, fine-grained, becoming medium to coarse-grained near 1190 feet.
1190—1200	Shaly sandstone, hard, fine-grained carbonaceous, but without preserved remains.

"The general dip of the beds is about 12 degrees toward the southwest. The dip of the massive competent beds is quite regular. The shales show local variations in places.

"The log, however, does not show the true thickness of the coal seam, as the coal is extremely friable and does not yield a core. In the course of prospecting the company has found five coal seams, only two of these, however, are worked. These seams are known respectively as No. 2 and No. 3. No. 2 seam is the lower and is about seven feet thick on the average. No. 3 seam is about fifteen thick.

"Development work on No. 2 seam has penetrated over 4,000 feet from the tunnel mouth and on No. 3 seam it has reached 3,500 feet from the entry. At the time visited, this colliery was shipping 1,200 to 1,500 tons of coal a day."

PEMBINA COLLIERY

The Pembina mine is situated on the west side of Pembina river, at Evansburg, on the Canadian National railway about seventy miles west of Edmonton. Sections of the surface formations are well exposed along the banks of Pembina and Lobstick rivers, which flow in deep valleys about 200 feet below the general level of the country.

Between the two railway bridges over Pembina river there is exposed below the surface soil, approximately twenty-five feet of light yellowish sandstone, twenty-five feet of soft massive grey sandstone, and nearly a hundred feet of shales and shaly sandstone.

The strata are nearly horizontal except for occasional small local rolls. The mine is operated by the North American Collieries and Mr. J. McLeod is mine manager. The output when the mine was visited was about 700 tons a day, and the seam is mined by a vertical shaft about 305 feet deep. The mining development at the present time is towards the north.

There are two distinct coal seams, the upper seam, No. 1, is 22 feet 6 inches in thickness, but has been abandoned on account of the many clay partings and sulphur bands which it contains. No. 2 seam, which is the one that is being worked, is 7 feet 6 inches in thickness, of which the lower six feet is extracted and eighteen inches of the top coal left for a roof. This makes an exceptionally good roof and requires very little timbering. The mine is comparatively dry and gas is found in very small quantities. Only electric lamps are used. The coal is machine-mined by electrical coal cutters. All haulage is done by storage battery and trolley locomotives.

The coal seams occur near the top of the Edmonton formation which belongs to the uppermost Cretaceous period. The sandstones and possibly the shales which are exposed on the surface belong to the Paskapoo formation. The coal is of domestic quality and is used principally for this purpose, but the small sizes give very good results under power house boilers.

The quality of the coal is best represented by the following range of analyses from three representative samples collected under the direction of the Mines Branch, and analyzed by J. A. Kelso in the Industrial Laboratory at the University of Alberta. These were given in the First Annual Report, 1919, p. 49.

Moisture	15.8	to	18.0
Volatile matter	28.6	to	30.7
Fixed carbon	42.3	to	43.6
Ash	8.5	to	11.3
B. T. U.	9,030	to	9,480

The shaft is in the southeast quarter section 30, township 53, range 7, west of the 5th meridian. The elevation of the top of the shaft is 2,526 feet above sea level. The following section in the shaft was obtained from the records of the company:

SECTION IN SHAFT AT PEMBINA MINE

Thickness Feet	Inches		Strata
1	0	....	Surface loam
18	6	....	Yellow clay
29	6	....	Light grey sandstone
198	5	....	Blue and grey shale
3	6	....	Coal
3	2	....	Carbonaceous shale
1	2	....	Coal
0	2	....	Clay shale
0	8	....	Coal
0	2	....	Shale
2	6	....	Bony coal
0	10	No. 1 Seam..............	Coal
0	6	....	Bony coal
6	0	....	Coal
0	2	....	Shale
3	10	....	Coal
0	1	....	Shale
2	4	....	Coal (clean)
3	2	....	Clay shale
26	0	....	Sandstone
3	0	....	Clay shale
1	6	....	Coal
0	1	....	Clay shale
5	11	No. 2 Seam..............	Coal
0	10	....	Sandy shale

CARBON COAL AREA

A new area of domestic coal is under development on Kneehill creek, about twenty miles west of Drumheller, in township 29, range 23, west of the fourth meridian. The coal seams are exposed on the surface, lying nearly horizontal, and belong to the uppermost members in the Edmonton formations. A single specimen was analyzed at the University of Alberta and gave the following results:

Loss on air drying .... 5.6 per cent

	As Received	Air Dried
Moisture	17.33	12.42
Volatile matter	30.92	32.75
Fixed carbon	45.02	47.69
Ash	6.73	7.14
B.T.U. per lb.	9,620	10,190

IRON

LOWER MACKENZIE BASIN

Occurrences of iron ore in the Lower Mackenzie River valley have been noted by Dr. E. M. Kindle in 1919.*

The most northerly occurrence which Dr. Kindle observed is represented by thin bands of limonite, less than ten inches thick, in shales of Cretaceous age which outcrop along a large stream entering the Mackenzie five miles above the ramparts and thirty miles south of the Arctic Circle.

A one-foot band of limonite near the top of Silurian reddish gypsum-bearing shale is also noted as occurring on the southern slope of Bear mountain near Fort Norman. A bed of lignite coal of fair quality occurs within three miles of Bear mountain. A five-foot bed of lignite coal is exposed in the bank of the Mackenzie at Fort Norman.

Kindle states that the most promising bed of iron ore known in the Mackenzie valley is a twenty-foot band of hematite which outcrops twenty miles east of the river, on the eastern escarpment of a mountain range that represents the eastern face of the Franklin mountains. "The thickness of the ore and its relations to the beds in which it occurs are shown in the following section, measured in descending order, on the eastern slope of Cap mountain near the eastern end of an Indian trail that leaves the Mackenzie at the mouth of a ravine about one mile north of Wrigley. The total thickness of this section is in the neighborhood of 5,000 feet, but only the part exposed in the eastern face of the mountain is given here.

Red quartzite and sandstone (summit of mountain) Dip 10 to 15 degrees to west	500
Red shale and ferruginous sandstone	50
Hematite	20
Red sandstone with high percentage of iron	50
Dark shales	150
Greyish to drab shale	225

"Average samples collected from each of four different levels in the bed indicate a rather siliceous ore too low in iron to be commercially valuable at the present time. A composite sample made from

*Geol. Surv., Can., Sum. Report, Part C, 1919, p. 2.

equal weights of these four samples was found on analysis* to contain metallic iron, 12 per cent. A selected sample collected by Mr. Joseph Hodgson of Fort Wrigley gave the following analysis:

Iron metallic	56.01	per cent
Silica	15.42	per cent
Sulphur	0.014	per cent
Phosphorus	0.031	per cent

"Five or six hundred feet of horizontal exposure of this ore was examined and showed no noticeable variation in thickness. Though this bed of ore has not been seen in any other sections, its considerable thickness apparently justifies the expectation of a rather extended distribution in a north and south direction, which is the direction of its line of probable outcrop."

The hematite ore on Mount Cap is placed in the Upper Silurian series.

A sample of shaly hematite analyzed by J. A. Kelso at the University of Alberta gave:

Insoluble siliceous residue	66.42	per cent
Oxide of iron	26.44	per cent
Oxide of aluminum	4.38	per cent
Lime	.00	per cent
Magnesia	.00	per cent
Loss on ignition	2.08	per cent
Equivalent of oxide of iron as metallic iron	18.49	per cent

If this sample is representative of the body of the deposit the high silica content and low iron would not make this deposit a commercial ore. Keele* in 1910 reports an occurrence of hematite 50 to 100 feet thick coarsely laminated with red siliceous slates about 100 miles west of the Mackenzie on the Gravel river which enters the Mackenzie four miles above Fort Norman. "An assay of an average sample of this ore was made at the assay office of the Mines Branch, and gave only 25 per cent of iron."

SHEEP RIVER DEPOSITS

The occurrence of iron along the Sheep river outside the mountain was discussed in detail in the "First Annual Report on the Mineral Resources of Alberta," page 65. In that report I stated in referring to the deposits on the south fork of Sheep river near the junction of Maccabee creek, that although a report had been circulated that this deposit contained 2,400,000 tons of iron ore analyzing 29.9 per cent metallic iron, I had not found up to that time "a single ton of rock exposed in that section that could

*These analyses were made by the Mines Branch, Dept. of Mines, Ottawa.

*Keele, J., "A Reconnaisance Across the Mackenzie Mountains, etc.," Geol. Surv. of Canada, 1910, p. 50.

be classed as iron ore.* This report has been criticized severely, and it has been stated that the real deposit of iron was not examined. In order to verify my statement interested parties forwarded two samples from this deposit for analysis. One sample contained less than 1.05 per cent oxide of iron, which represents about 1 per cent metallic iron. The other sample of ironstone nodule gave 4.75 per cent iron oxide, which represents about 3 per cent metallic iron. Analyses of samples which I collected and which are included on page 66, First Annual Report, 1919, showed 4.55 per cent metallic iron in one and 4.03 per cent in the other. These analyses are considerably lower in iron content than those made from samples which I collected in 1919. These results emphasize my statement that the iron content in this formation is low and the deposit is of no economic importance. It is unfortunate that even yet attempts are being made to interest the public in this unimportant occurrence of iron oxide.

During the past summer further field investigations were made of the Benton shales, in which the iron is supposed to occur along Sheep river and Highwood river. Benton shales are exposed at a number of points where the river cuts transversely through the formation. Particularly good exposures are to be seen along Sullivan creek between the bridge and the point where it enters the Highwood. These shales are slightly ferruginous and contain clay ironstone bands similar to those on Sheep river, but even in this section there can be no beds which can be considered as economic deposits.

OCHRE

Spring deposits of ochre are very common throughout the province, particularly along the banks of rivers where the surface water which is circulated through superficial deposits comes to the surface again. The waters in these springs are highly charged with iron oxide, a few with manganese oxide, and these minerals are deposited about the springs. The quality of the ochre in many of the deposits is of high grade, but the quantity in most cases is small, so that the deposits are generally regarded as of little commercial value.

During the summer of 1920, a field examination was made of a deposit of ochre which occurs north of the Saskatchewan river below Pakan, and which has been frequently spoken of as a very large deposit of bog iron. This deposit is situated towards the headwaters of Red Clay creek, a tributary to the North Saskatchewan river, ten miles east of Pakan, in section 36, township 58, range 15, west of the 4th meridian. The deposit lies about ten miles from the nearest railway, which is at Smoky lake.

*Allan, J. A., Mineral Resources of Alberta, 1919, p. 66.

The extent and quantity of ochre available was proven by sinking test holes with a six-inch auger. R. L. Rutherford, who, as field assistant, carried on these tests, describes the deposit as follows:

"After making a general survey of the country for two or three miles around the deposit, test holes were sunk with a six-inch auger. Six test holes were sunk along the valley bottom 150 feet apart and sixteen in all were put down. The test holes averaged about five feet in depth and in every case where bog iron showed in the boring the hole extended completely through the deposit. In no instance was it possible to find a thickness of bog iron greater than twelve inches and even in such cases the entire twelve inches were not of uniform composition.

"In several cases the bottom of the test hole was in a grey sand not even stained with iron. Mr. Ed. McAdam of Pakan, who is one of the owners of the claims staked in this locality, stated that the deposit had been carefully prospected seventeen to twenty years ago and that approximately $10,000 had been spent on the same. This prospecting consisted of sinking holes down to various depths with a churn drill. He reported that in places bog iron deposits twenty-two feet in depth had been drilled through. However, in drilling holes at the present time eight to ten feet away in the most concentrated portion of the deposit no bog iron was struck in these holes. There are remaining evidences of twenty test holes that were sunk a number of years ago and these extend up the valley in section 36, township 58, range 15, west of the 4th meridian.

"The valley in which this deposit lies is very much drier than it was when the earlier prospecting was done. There is evidence that at that time water was held in the valley by beaver dams, but since the removal of these dams a large amount of the bog iron that had accumulated has been washed out of this basin into the valley below and then down Red Clay creek to where it empties into the North Saskatchewan river. Today these deposits cover not more than an acre and have an average depth of about eight inches. Small bands of ochre two to three inches in thickness can be found outside of this area, but owing to the fact that they are mixed up with sand and decayed vegetable matter they are of no importance. In the area where the thickest bed of ochre occurs there is a spring of quite a strong flow of water, but it is quite apparent that this water does not carry much iron in solution.

"In all cases our test holes brought us down to a grey sand without an iron stain. All the bog iron today lies within the creek bed proper, which ranges in width from eight to twenty feet, but widens out to 150 feet where the water from the spring enters. Away from this creek the beds are sand and gravel, but show no indications of beds of bog iron.

"It appears to me that this deposit is lying in an area where the country rock and soil has been formed from the breaking down of the Victoria sandstone of the Belly River series. These sandstone beds are exposed along the *North Saskatchewan river a few miles* west of this locality. The beds there are dipping slightly to the west and would outcrop on the surface in the vicinity of the area where the deposit of ochre occurs. The surface soil is mostly sand and it appears to me that the iron has leached out from these decomposed sandstones and has been concentrated in the valley which in earlier times was blocked up. At present the deposit does not seem to be increasing in size and it is so covered with vegetation that were it not for the trampling by range cattle the bog iron might not be noticed. Even at its thickest point it is mixed up to a considerable extent with plant roots and vegetable decay."

A sample of ochre collected contains numerous rootlets and other fragments of vegetable materials, but the color is of dark reddish brown. Analyses made by J. A. Kelso at the University of Alberta are as follows:

Insoluble residue	4.22	3.02
Oxide of iron	58.14	58.48
Oxide of aluminum	4.88	6.12
Lime	.12	.13
Magnesia	.00	.00
Loss on ignition	37.16	31.06
Equivalent of oxide of iron as metallic iron	40.69	40.93

The quality of this material is satisfactory as shown by the analyses, and the powder produced on burning is of excellent quality and would be valuable in making mineral paints. Tests made on some of this burnt powder showed that it could be used to good advantage as a paint and that it retained its body after being applied to wood surfaces.

Although this deposit is relatively unimportant on account of its size and impurities which it contained, yet the ochre might be used locally for paint purposes such as are required around farm buildings.

PAINT SHALES

From time to time samples of ferruginous shale are sent in to the laboratory to be tested for paint properties. Some are satisfactory, but many are unsuited for this purpose. Some of the Benton shales, shaly bands in the Belly River series, and especially in the

Edmonton series, have sufficient iron in them to burn to a reddish powder.

No systematic study has yet been made to determine the economic value, if any, in such shale beds.

Between the Battle river and Halkirk, on the Lacombe branch of the Canadian Pacific railway east of Stettler, there is a wide distribution of reddish burnt clays.

These shaly bands occur towards the base of the Edmonton formation. The color is due to the fact that the shales have been baked by the heat from a coal seam which has been burned. The character of the burnt shale is most irregular and the economic value of this material is very doubtful.

This district was examined by Rutherford and the following notes were prepared by him, all of which I have verified personally.

The creek in which these beds are exposed is a tributary of Battle river, and for the most part flows in an east-west direction, with the exception of the headwaters, which flow north. The map name for this creek is Okwanim but the local name is Paintearth, due to the fact that in one particular area several buttes and domes in the river valley are covered with bright red material. Exposures of these deposits are best shown at various places along the valley from section 35, township 39, range 16, west of the fourth meridian, down to section 29, township 39, range 15. These beds form the top layer of various buttes in the creek valley. The valley itself is quite wide, ranging from two to three miles, and has gentle sloping, grass-covered sides. The buttes within the valley stand out quite prominently in the nature of bad lands, varying in height from twenty-five to fifty feet and in some cases less.

The red debris weathered from an upper layer has been washed down the sides of the buttes, making them look bright red in the distance, but on digging in a short distance it can be seen that this red material comes from a layer which is not very thick. The beds under the red layer are soft, light grey sandstones, and sandy clays. The surface is grass covered and in every case where red layers occur, lumps of cinders can be found scattered about the top. Small coal seams occur adjacent to or not far removed from the red layers.

There are many side coulees along Paintearth creek which produce typical badlands; almost the entire area of section 36, township 39, range 16, and sections 30, 31 and 19, in range 15, is badlands. A section taken from one of the buttes is as follows:

1 - 2 feet surface soil.
1 - 2 feet red earth and coal.
15 - 20 feet light grey sandstone (soft).
10 - 15 feet sandy clay, varying in color, dark green, reddish, brownish.

The dip of these beds is for the most part horizontal, although by tracing a stratum through several buttes there seems to be a slight dip of about three degrees to the east.

There are buttes of two general elevations, one series having approximately the same elevation as the surrounding country, the other series are considerably lower than the surrounding country. It is a noticeable feature that where the high buttes occur no section shows the red bands. The majority of the red-top buttes occur in the deeper valley. It would seem that the origin of these is due to the fact that the coal seam, which is well exposed further south, has been burned out in this locality and has changed the clays and soils above to red beds. Then the beds have fallen in, giving a depression where the drainage has naturally followed and cut the land into mesas, buttes and steep-faced escarpments.

In some places the clays have been burned to a yellowish color. This would probably indicate one of two things, (a) a different kind of clay from the former red beds, or (b) less burning. I think the latter is most probable because the yellow bands are frequently found close to and in some cases right against unburned coal seams. Moreover, it is to be noted that the red coloring within these clays is not very permanent. Samples taken from the red layers, which were quite red when collected, after being exposed to the inside atmosphere for about three months, have practically lost all the red color and have changed to a light creamy yellow. Only those pieces which are more or less of cinder-like nature have retained their color. Thus the only thing that keeps the tops of these buttes red in color is the constant action of erosion and the washing down of fresh layers from time to time.

Approaching Halkirk from the area of the buttes, the coloration dies out, the valleys of tributary creeks become steeper and a coal seam is well exposed in places. In a branch creek known as Spruce creek the valley is about 100 feet deep with steep sides exposing soft grey sandstone, some sandy clay, as well as a good coal seam. This coal seam has been opened up in two places. One prospect is in the southeast quarter of section 18, township 39, range 15, but was not being operated during the summer. A second small prospect is situated in the northeast quarter section 8, township 37, range 15, operated by Mr. R. Ruscee, and known as the Halkirk mine.

The main tunnel has been driven south by west and at the present time is approximately 700 feet in length. The coal seam lies horizontal and is from five to six feet in thickness. A section of the seam is as follows:

1 foot coal.
6 - 8 inches bone.
3 feet coal.
1 - 2 inches sandstone.
1 foot coal.

The mine is exceptionally dry and has a light grey sandstone hanging wall and a hard sandstone foot wall. In this locality the surface material above the coal seam is eighty-five feet thick.

MICA

Mica is one of the most common minerals in igneous and crystalline rocks, but deposits of economic value are rare, because the plates are either too small or too scattered through the rock to be extracted on a commercial scale.

There are three important varieties of mica, but only two are used extensively in industries These are muscovite or white mica, which is a hydrous potassium aluminum silicate, and phlogopite, or amber mica, which is a hydrous potassium, magnesium, aluminum silicate. A third variety, biotite or black mica, is the most common but on account of its opaque or semi-opaque character and high iron content it is least valuable.

The best deposits of mica occur in coarsely crystalline rocks, known as pegmatites. These pegmatites consist chiefly of quartz, feldspar and mica, and usually occur as dikes cutting older rocks. A pegmatite may also occur as irregular masses, lenses or veins which vary in width and length. Mica mining presents many difficulties because of the irregular character of the deposits. Those carrying on mica operations must be experienced in the proper methods of extraction of this mineral.

About fifty per cent of the world's supply of mica comes from Bengal, India. This is the chief producer of muscovite. Canada produces nearly 25 per cent of the world's supply. The muscovite deposits which have been opened up are commercially unimportant, but valuable deposits of amber or phlogopite mica are mined in both Ontario and Quebec. In 1919 Canada produced mica to the value of $273,305.

The value of mica depends upon the size of blocks, the clearness, color, perfection of cleavage and freedom from flaws. The New York quotations on sheet mica in January, 1921, were as follows:

Inches	Per pound
1½ x 2½	$ .75
2 x 2	1.15
2 x 3	1.65
3 x 3	2.10
3 x 4	2.50
3 x 5	2.75
3 x 6	3.75
6 x 6	4.00
6 x 8	4.75
Clear block A1	10.00
Extra large	25.00

The uses of mica are too numerous to mention in detail. The uses of mica depend upon the form in which it is marketed, as powder or in sheets. Sheet mica is used largely in the electrical industry for insulation, and to some extent for glazing purposes.

No economic deposit of mica occurs in Alberta, but the recent discovery of muscovite of good quality towards the head of Peace river in British Columbia, which is tributary to Alberta, is sufficient reason for including a description of the occurrence of this mineral in this report.

What appears to be an economic deposit of muscovite mica occurs on the west side of Finlay river, which with Parsnip river forms the head of Peace river west of the Rocky mountains. The deposit occurs on the slopes of a mountain, locally known as "Mica Mountain." It is situated nine to twelve miles southwest of Fort Grahame and sixty-five miles up the Finlay river above Finlay forks. This deposit may be reached by two routes. One route is up Peace river from the town of Peace River at the terminal of the Edmonton Dunvegan and British Columbia railway, 375 miles north of Edmonton. The other route is from Prince George over Giscombe portage to Summit lake, down Crooked river to Fort McLeod, the Pack and Parsnip rivers to Finlay forks, and then up the Finlay to Fort Grahame. There is a good pack trail from the west side of the Finlay opposite Fort Grahame to the deposit, a distance of less than twelve miles.

Eight full-sized mica mineral claims have already been staked on the deposit by Mr. William MacIntosh, who has had considerable experience in developing mica deposits in Quebec and Ontario. Several samples from the deposit were given to me and these I have examined microscopically and have had analyses made.

The mica is associated with quartz and feldspar and occurs in pegmatite dikes which appear to have a northeast and southwest trend. The country rock is micaceous schists. Blocks or "books" of mica are strewn about the surface due to the disintegration of the pegmatites. Blocks of mica roughly defined by crystal faces were obtained from a fraction of an inch up to a maximum of eleven inches in diameter. Both the optical properties and the chemical analysis show that the variety is muscovite of high quality. The mica has an eminent cleavage, high degree of transparency and is highly flexible. Microscopically, the muscovite is free from all flaws, stains and internal structures that affect the market value of the mineral, such as the "ruled," "herring-bone," or "A" structures. The yellowish stain on the blocks is entirely superficial and due to a coating of iron oxide about the margins of the blocks resulting from exposure on the surface of the ground. This color is not present in the centre of the blocks or in the unweathered blocks in the pegmatite. There would be considerable waste in trimming the blocks which are now weathered on the surface.

An analysis of the muscovite was made by Mr. J. A. Kelso, in the Industrial Laboratories at the University of Alberta. Magnesia is almost absent and the iron content is due to a superficial coating of oxide as determined under the microscope. The composition corresponds most closely to muscovite from Bengal, India. The following analysis was made by Mr. Kelso, and for comparison the analysis of muscovite from India is given:

	British Columbia	Bengal, India
Silica	50.52 per cent	45.57 per cent
Alumina	37.20 per cent	36.72 per cent
Iron oxide	1.20 per cent	2.23 per cent
Lime	0.06 per cent	0.21 per cent
Magnesia	0.04 per cent	0.38 per cent
Potash	7.14 per cent	8.81 per cent
Water	3.94 per cent	5.05 per cent

The quality of this mica is such that there should be a ready market if it can be produced at a reasonable cost. Mr. MacIntosh estimates that the cost of transportation from this deposit to the railroad at Peace River should be about eight cents per pound. This would include down stream transportation on the Finlay and Peace rivers to Rocky Mountain canyon, a fourteen-mile portage, and then down the Peace to the railway at Peace River.

Plans are now under way to develop this deposit at an early date. A party has left Edmonton to open the deposit.

Another deposit of mica known for several years occurs not far from the western boundary of Alberta, on the south side of the Fraser valley at Tête Jaune Cache, on the Grand Trunk Pacific railway. The mica occurs in pegmatites cutting mica schists, and is a phlogopite variety. Flaws, stains and imperfections are so common that the deposit is not considered to be commercially important.

PETROLEUM

INTRODUCTION

At possibly no time in the history of the world has such a persistent search ever been made for natural reservoirs of petroleum, in many countries throughout the world, as during the year 1920. With the ever increasing uses for petroleum as liquid fuel for motive power on the land, the sea and in the air, for illuminating purposes, for power and lubrication in industry, for chemical manufactories, for preservatives and for road-making, the demand is fast exceeding the production, and what is more serious, the known supply of petroleum in reserve. These cold facts are causing governments and especially large oil corporations, to give serious attention, and to spend large sums of money in the search, on scientific lines, for possible new petroleum fields in almost every country throughout the world. J. D. Northrop, a well-known American geologist, has made the startling statement that although the United States has produced in 1919 over 330,000,000 barrels of petroleum, yet "the petroleum production in the United States is expected to reach its maximum this year and to decline steadily hereafter,"* unless new sources of petroleum are discovered.

About 62 per cent of the world's known supply of petroleum in reserve is in the United States, and about 20 per cent in Mexico and Russia. Canada is today one of the most promising unproven and largely unprospected countries in the world for petroleum. The possibilities of finding extensive reservoirs of petroleum are greater in western Canada, and especially in Alberta, than in any other field in Canada where the known geological structure is suitable for petroliferous accumulations.

The possible petroleum resources of Alberta are today receiving the attention of many of those interested in the petroleum industry throughout the greater part of this continent and also the British Isles.

*"Petroleum Resources of the World," Eng. and Min. Jl., Vol. 108, Dec. 27, 1919, p. 954.

STRATIGRAPHY

Between the Rocky mountains on the west and the pre-Cambrian shield on the east, there is a broad belt of comparative low relief, which, physiographically, is known as the Great Plains region. Corresponding topography extends north..ards to the mouth of the Mackenzie river and southwards to the Gulf of Mexico. The northern part from about the 54th parallel of latitude is drained by the great Mackenzie River system, while most of the area south of the 49th parallel is drained by the Mississippi River system. The intervening area between these two great watersheds is drained eastward by the Saskatchewan River system. This belt in Canada has a width of over 800 miles at the international boundary line and includes most of Alberta, Saskatchewan, and part of Manitoba, but narrows rapidly towards the north. At the 60th parallel of latitude, which is the northern boundary of the province of Alberta, this belt lies well within the width of this province, and is about 150 miles wide between the pre-Cambrian rocks on the east and the Rocky mountains on the west. This low upland continues down the Mackenzie valley, narrowing to a minimum width in the vicinity of Fort Norman, and then widening towards the north at the delta of the Mackenzie river about latitude 70 degrees. Substructure over this broad upland in central Canada can in general be described as trough-like, with the older formations outcropping along the inner foothills and the front ranges of the Rocky mountains on the west, and also bordering the oldest pre-Cambrian rocks on the east.

This broad belt, trough-like in outline, is capped by sedimentary rocks of the upper Cretaceous age chiefly, and in certain limited areas with younger Tertiary rocks. The underlying formations on top of the pre-Cambrian granites consist essentially of shales, limestones and some sandstones, chiefly of Devonian or Silurian age. The extent of the formations belonging to the different ages has not yet been defined, because the surface is in the main veneered with glacial deposits. Outcrops are few and indications of the presence or absence of the formations at depths are lacking.

Definite information as to the occurrence of any particular stratum in any particular locality can only be ascertained by drilling. However, the present geological knowledge of this vast area indicates with some certainty that upwards of 300,000 square miles are underlain by formations suitable for the accumulations of petroleum in Alberta, the lower Mackenzie basin, and parts of Saskatchewan and Manitoba. When one realizes the vast area in this part of Canada which may contain many oil reservoirs, one must assume an optimistic attitude regarding the future development of the country insofar as petroleum is concerned.

The stratigraphy of this belt in Alberta and the northland is not unlike that south of the international boundary line. Similar structure prevails southward to the Gulf of Mexico. Many productive oil fields have been discovered and developed along the western plains of the United States in Texas, Oklahoma, Colorado, Wyoming and Montana. A recent oil field has been developed in Montana within a few miles of the Canadian border. The northward continuation of the formations in Montana into Alberta has stimulated field investigations for petroleum. The formations within Alberta are just as suitable for the accumulations of petroleum, and the natural occurrence of minerals of any kind is not confined to political boundaries.

The problem of working out the most suitable structure in Alberta and the Mackenzie basin is extremely difficult on account of the scarcity of outcrops, the thick veneer of glacial debris, and expansive muskegs, so that development must of necessity proceed more slowly than it would if the structure could be more readily determined. The early work of the Geological Survey of Canada has assisted greatly in directing the attention of field geologists to certain areas in Alberta and the Mackenzie basin, where structural indications are favorable, at least to a certain extent.

Petroleum was first discovered in Alberta in 1898 southwest of Pincher Creek within the front range of the Rocky mountains, and a small quantity of oil was obtained. Gas and oil seepages are common throughout Alberta and the lower Mackenzie, but little interest was taken in the oil possibilities of the province until 1914. In May of that year a light oil of gasoline grade was discovered in the Dingman well, situated in the Turner valley, sixteen miles west of Okotoks and thirty-five miles southwest of Calgary. This discovery precipitated a boom during which about 500 companies were formed. Less than two dozen of these companies ever began drilling operations before the "boom" broke early in August when the war began. Most of these oil companies soon disappeared and in 1919 less than a dozen were active.

POSSIBLE FIELDS

Although field investigation was carried on in a small way during the period of the war, it was not until the spring of 1919 that a systematic field search was started to outline the most likely areas in which petroleum might be found. These field investigations were carried out by geologists under the direction of large petroleum operators, corporations and government departments.

Systematic field work continued during the field season of 1920 and geological field parties were working from the international boundary line to the lower Mackenzie below Fort Norman, which is situated on the 65th parallel of latitude. With the data now available it is possible to say where the most promising fields are. The geological structure is such that it is known that there are certain areas where the oil-bearing horizons are too deep to warrant drilling, and, at the same time, that there are certain fields in which the chances are greater for finding petroleum, if this mineral occurs in the underlying formations within these areas. The presence of petroleum in commercial quantities under these areas can only be determined by drilling. The principal possible petroleum areas are as follows:

1. Southwestern Alberta, including Cardston, Pincher Creek and Waterton Lakes districts.

2. Southeastern Alberta, along the margin of Sweet Grass hills.

3. Okotoks field, including Sheep river, the Highwood and Willow Creek areas in the outer foothills. This field includes the Turner valley, where in 1919 the Calgary Petroleum Products company and the Southern Alberta company produced 16,457 barrels of light and crude oil.

4. Central eastern field, including the Monitor, Czar, Viking, and Birch Lake areas.

5. Central western field, within the foothills between the North Saskatchewan and Athabasca rivers.

6. Peace River field, in the vicinity of the town of Peace River and about twenty miles downstream within the limits of the valley.

7. Upper Peace river field, south of the river in the Peace river block about Pouce Coupé and in the adjoining territory in Alberta.

8. Athabasca field, north and south of McMurray, within a radius of about seventy-five miles.

9. Great Slave Lake field, the western end of the lake, including Windy Point area on the north and Pine Point area on the south.

10. Fort Norman field, on the lower Mackenzie west of Great Bear lake.

During 1920 about twenty drilling outfits were at work more or less intermittently during the year. These were distributed from the 49th parallel northward to Fort Norman on the 65th parallel of latitude. Most of the drilling operations were carried on by the Imperial Oil company.

DESCRIPTION OF FIELDS

In the southwestern field drilling was continued on two wells north of Cardston in the vicinity of Twin Buttes, but these have not yet been completed.

Twin Butte No. 1 well is situated in legal subdivision 15, section 14, township 4, range 30, west 4th meridian.

Twin Butte No. 2 well is in legal subdivision 1, section 23, township 4, range 29, west 4th meridian. Both wells were drilled by the Northwest Company, which represents the drilling company in the Imperial Oil Company.

The structure in this area has been described by Stewart.*

The first well for petroleum in the province was drilled on Oil creek, north of Waterton lakes, in township 1, range 29, west 4th meridian. The surface rocks here are of Cambrian age folded into a well-pronounced anticline. It is reported that the drill passed through the lower Paleozoic rocks into the Benton shales of upper Cretaceous age which here contain a small quantity of oil. This structure has resulted from the overthrusting of the older rocks on to the younger Cretaceous rocks during the period of mountain building. No commercial quantity of oil has been obtained from this area, although in Oil creek oil is dripping from the limestones exposed along the sides of the canyon.

In southeastern Alberta several wells have been drilled both south and north of Milk river. The Grand Trunk Pacific Development Company drilled a well in section 1, township 1, range 12, west 4th meridian, near the west butte of Sweet Grass Hills, and a few hundred feet north of the international boundary. In the upper strata of limestone a thick oily substance, vaseline-like in appearance, was found, but the well yielded no oil. The log of this well is given in Memoir 116 published by the Geological Survey.†

A well drilled by the Beaver Oil company on the north bank of Milk river yielded a strong oil seepage at 2,690 feet, but the quantity was insignificant. This horizon is underlain by salt water-bearing sandstone which prevented further drilling.

The United Oil company well No. 3 is situated twenty miles due north of the Beaver well in southwest quarter section 31, township

*Stewart, J. S., Geol. Surv., Can., Memoir 112, 1919.

†Dowling, D. B., Slipper, S. C., McLearn, F. H., "Investigations in the Gas and Oil Fields of Alberta Saskatchewan and Manitoba," Geol., Surv. Can., Memoir 116, 1919, p. 49.

5, range 10, west 4th meridian, in Etzikom Coulee. In this well a thick petroleum or maltha occurred in the strata overlying the Paleozoic rocks at a depth of 2,690 feet in the Beaver well. This would indicate that the strata are dipping decidedly towards the north. A complete log of this well to a depth of 3,705 feet is given in Memoir 116, p. 51. Operations at these wells have stopped at least temporarily.

At the present time (February) the Boundary Location well is the only one in operation, according to S. E. Slipper, Petroleum Engineer for the Department of the Interior in Alberta and the northland. This well is being drilled by the Northwest Company in legal subdivision 4, section 9, township 1, range 22, west 3rd meridian.

In the Okotoks field oil was discovered in the Dingman well in May, 1914, on the north bank of the south branch of Sheep river, in section 6, township 20, range 2, west 5th meridian. Much attention was given to the Turner valley, in which this discovery well is situated, on account of the anticlinal structure which follows the trend of the valley.

The principal wells in this valley at the present time are:

PRINCIPAL OIL AND GAS WELLS IN TURNER VALLEY

1. Calgary Petroleum Products (three wells, Nos. 1, 2 and 3), Section 6, Township 20, Range 2, West of the 5th.
2. Alberta Petroleum Consolidated (No. 1 and No. 2 wells), Section 1, Township 20, Range 3, West of the 5th.
3. Canada Southern Co. (Prudential Oil and Gas Co.), Section 1, Township 20, Range 3, West of the 5th.
4. Mt. Stephen Oil and Gas Co., Section 7, Township 20, Range 2, West of the 5th.
5. Southern Alberta (No. 1 and No. 2 wells), Section 18, Township 20, Range 2, West of the 5th.
6. Alberta Southern Oil Co., Section 13, Township 20, Range 3, West of the 5th.
7. Mid-west No. 1 (Western Pacific Oil Co.), Legal Subdivision 8, Section 31, Township 19, Range 2, West of the 5th.
8. Mid-west No. 2 (North Western Pacific Oil Co.), Section 24, Township 20, Range 3, West of the 5th.
9. Alberta Pacific Oil Co. (Acme Well), Section 20, Township 19, Range 2, West of the 5th.
10. Record Oil Co., Section 4, Township 19, Range 2, West of the 5th.

A number of other wells have been drilled but are now abandoned.

The Record well has been drilled to a depth of 4,325 feet. Difficulties have been encountered from caving-in in the uncased hole, so that it has been impossible to get the tools out. There is considerable oil in the bottom of this well and the indications are favorable if the well was properly cased and cleaned out. An analysis of this oil made at the University of Alberta gave the following results:

Specific Gravity of Oil, 54 degrees Beaume

Distillation Tests—

Commences to distil at 60 degrees Centigrade

From 60 to 210 C.	79.3 per cent
210 to 300 C.	14.0 per cent
300 to 325 C.	3.3 per cent
325 to 350 C.	2.0 per cent
Residue and loss	1.4 per cent

Commercial Indication—

Commercial gasoline	79.3 per cent
Burning oil	14.0 per cent
Light lubricants	5.3 per cent

In 1919 Alberta produced 16,437 barrels of petroleum and the production in 1920, although not yet published, will be slightly larger. All of this oil was produced in the Turner valley by the Calgary Petroleum Products Limited, the Alberta Southern, and the Alberta Petroleum Consolidated. A brief description of each of these is given in the First Annual Report, page 81.

The oil produced by the Calgary Petroleum Products Limited, Well No. 1, was of natural gasoline grade. Well No. 2 produces a gas rich in gasoline. The gas is treated by the absorption process and the product has a gravity of from 65 degrees to 69 degrees Beaume. A second grade of gasoline with a gravity of from 93 degrees to 95 degrees Beaume is obtained as a compressor product. The plant has been temporarily closed as a result of a fire. The wells of this company are now reported to be under the direction of the Imperial Oil Company. The product produced by the Alberta Southern is of considerably heavier grade. The A. P. Con. wells produced an oil which has a gravity of about 38 degrees Beaume.

South of the Highwood river and west of Nanton the Imperial Oil company is now drilling two wells. Willow Creek well No. 1 is located in the northeast quarter section 29, township 14, range 2, west 5th meridian, and is known as the Christie well. The other well, No. 2, on section 7, township 16, range 2, west 5th meridian, was started by the Associated Alberta Oil Company. Promising indications are reported from these wells.

In the eastern field the following wells were started in 1920:

Misty Hill well on northeast quarter section 24, township 32, range 4, west 4th meridian, south of Mud Buttes. This well is being drilled by the Northwest Company.

West Regent Oil well on northeast quarter section 19, township 34, range 4, west 4th meridian.

Union Oil well No. 2, close to the railway at Monitor in northeast quarter section 5, township 35, range 4, west 4th meridian.

Tit Hill well by the Northwest Company, nine miles southwest of Czar, legal subdivision 10, section 17, township 40, range 7, west 4th meridian.

Grattan well on section 4, township 45, range 8, west 4th meridian.

Union Oil well No. 1, Birch Lake well in section 14, township 50, range 12, west 4th meridian.

The Czar and Grattan wells have reached the greatest depth according to most recent reports and have favorable oil indications.

Drilling operations were started in the Irma district in 1915. Three wells have been started but not completed. The present Grattan well at the end of 1920 was reported to have reached a depth of about 3,000 feet but no quantity of oil has yet been obtained.

In the Viking district ten wells have been drilled by the Northern Alberta Natural Gas company. This district has been proven to be a gas field. These wells were drilled for the purpose of supplying natural gas to the city of Edmonton, but no satisfactory arrangements have yet been made to supply the capital city with this much needed product

The western central field has not yet been proven by drilling. During the past few months considerable interest has been taken, especially, in the northern end of this field between Athabasca and Brazeau rivers. Many leases have been taken out along the Alberta Coal branch, and drilling is anticipated during 1921. The stratigraphy has not yet been worked out in this belt, and there is still some doubt as to whether the younger formation belongs to the Edmonton or to the Belly River series. At the south end of the Alberta Coal Branch there is anticlinal structure, but it is known that the formations are more or less faulted within a few miles to the west.

PEACE RIVER FIELDS

In the Peace River field, which extends from the town of Peace River downstream to approximately Tar island, a distance of about twenty miles, drilling operations have been carried on more or less continuously for the past five years. The valley of the Peace river is about 750 feet deep, and the bottom of the valley is comparatively narrow, so that the area on which the oldest rocks are exposed is decidedly limited. At many points along the valley terraces are comparatively narrow but it is on these terraces that wells have been drilled. Oil has been struck in a number of wells which have been drilled, but commercial quantities have not yet been obtained. The gravity of the oil from No. 2 drilled by the Peace River Oil Company is 12.5 degrees Beaume. The following wells have been located north of the town of Peace River; all are west of the 5th meridian:

	Legal Sub.	Sec.	Township	Range
1. Victory Well, now being drilled.......	11	37	83	21
2. Peace River Petroleum Well, No. 1, on River Lot 9				
3. Peace River Oil Well, No. 3	10	4	85	21
4. San Joaquin Oil Well, No. 1	1	11	85	21
5. San Joaquin Oil Well, No. 2	1	11	85	21
6. Northern Pacific Well	6	11	85	21
7. Tar Island Oil Well, No. 1	14	24	85	21
8. Tar Island Oil Well, No. 2	14	24	85	21
9. Tar Island Well, No. 3	14	24	85	21
10. Peace River Oil Well, No. 1	4	31	85	21
11. Albersas Oil Well	10	11	85	21
12. Community Oil Well	1	23	85	21
13. Peace River Petroleum Well, No. 2	12	28	87	20

Drilling is being continued in only five of these, according to S. C. Slipper. These are Nos. 1, 4, 5, 7 and 13.

The greatest difficulty encountered in this field has been a strong flow of salt water and gas. Well No. 2 drilled by the Peace River Oil Company struck a flow so strong that to date it has not yet been capped, but according to the regulations now in force the company is compelled to have this flow stopped. It is the intention of the Department of the Interior to have its engineers seal off this well in the spring of 1921.

It would seem from the drilling carried out to date that a strong flow of water may be anticipated at almost any level below 900 feet.

San Joaquim Well No. 1 was drilled by Mr. H. L. Williams near the Three Creeks on the east side of the Peace River.

Drilling was stopped at a depth of 1,265 feet on account of gas pressure and the loss of tools. Well No. 2 was started close to No. 1. Drilling has reached a depth of about 900 feet and care has been taken to prevent a sudden flow of water or gas which might also ruin this well.

An analysis of the oil from No. 1 well was supplied by Mr. Williams. This analysis was made at the University of Saskatchewan:

Specific Gravity at 60 degrees F. 0.982

		First Test	Second Test
Naphtha	90-150 degrees C.	1.7%	1.8%
Kerosene	150-300 degrees C.	18.1%	18.1%
Lubricating Oil	300-375 degrees C.	64.5%	65.0%
Residue loss		15.7%	15.1%

The following report on a sample of oil was made by E. Stansfield in 1916 in the laboratory of the Mines Branch, Department Mines, Ottawa:*

"Sample No. 823. Crude petroleum. Collected by Charles Camsell of the Geological Survey on September 18, 1916, from McArthur well, Peace river, seventeen miles below Peace River Crossing.

"The sample was a dark viscous oil, with an odour resembling kerosene, from which a considerable amount of water had separated out at the bottom of the bottle This water was neglected.

"It was found to be impossible to make a satisfactory fractional distillation of the crude oil on account of trouble with bumping and frothing. A preliminary distillation was ultimately carried out under reduced pressure as far as was possible in a glass flask, a sticky black pitch remaining in the flask. The oil obtained by this preliminary distillation was fractionated in an Engler apparatus.

"The results obtained follow:

Solubility of crude oil in benzine, practically completely dissolved.
Solubility of crude oil in gasoline, 5 per cent by weight insoluble (soft asphalt, dirt and tarry matter).
Solubility of crude oil in alcohol-ether, considerable insoluble matter.
Specific gravity of crude oil, 0.984 at 15.5 degrees C.
Flash point, Pensky-Martens close test 59 degrees C.
Fire point, about 127 degrees C.

Preliminary distillation of 201 grams of crude oil gave:
136 grams of oil distillate of 0.902 sp. gr. or 67.7 per cent by weight and 73.9 per cent by volume.
46.3 grams of pitch residue or 23.0 per cent by weight.
18.7 grams of water and loss, or 9.3 per cent by weight.

Fractional distillation in an Engler apparatus of 100 c.c. of oil distillate gave:
140 degrees C. first drop.
140 to 150 degrees C. gasoline and kerosene fraction, 2 per cent by volume, 0.642 sp. gr., or 24.0 per cent crude oil.
Residue, lubricating oils, etc., 64.5 per cent, or 48.4 per cent crude oil.

On a large scale the preliminary distillation could be carried further than in the small scale laboratory experiments, and larger yields obtained.

Calorific value of crude oil, 9.730 calories per gram, or 17,520 B.T.U. per lb.
Sulphur in crude oil, 4.9 per cent."

*Geol. Surv. Can., Sum. Report, 1916, p. 144.

The upper Peace River field includes in part the Peace River Block, particularly that area south of Peace River and adjoining territory in Alberta. Since November, 1920, considerable interest and excitement has arisen in the district about Pouce Coupé in ranges 12 to 14, townships 77 to 82, along the Pouce Coupé river which flows northward into the Peace. Up to February, 1921, about 300,000 acres have been leased in this district. The rush into this district has been stimulated chiefly by the fact that large acreage has been leased by the Imperial Oil company. It is reported that arrangements are being made to commence drilling operations in the spring of 1921. Most of the leases acquired lie within townships 77 to 82, ranges 12 to 14, west 6th meridian. Very little geological information has yet been made public on this area and no detailed work has yet been carried out by the Geological Survey in the district that has been leased. In the summer of 1919, J. S. Stewart made a geological reconnaissance of the region southeast from Hudson Hope. The area examined lies entirely on the west side of the Kiskatinaw river. The stratigraphic succession of formations as worked out by Stewart is as follows:*

TABLE OF FORMATIONS

Period	Group	Formation	Character of the Strata
Upper Cretaceous	Montana	Smoky River	Two shale series divided by a sandstone series. Total estimated thickness 550 feet.
	Colorado	Dunvegan	Mainly thick-bedded sandstone with lesser amounts of shale and thin sandstone; thickness about 530 feet.
		St. John	Upper member 1,300 feet dark shale; middle member 50 to 80 feet sandstone; lower member 800 feet dark shale.
Lower Cretaceous		Bullhead Mountains	Sandstone, shale, and coal above; massive sandstone below; total thickness 2,000 feet.
Jurassic			
Triassic			Limestone, sandstone, and shale.

*Stewart, J. S., "Oil and Gas Possibilities in Northeastern British Columbia," Geol. Surv., Can., Sum. Report, 1919, part C, p. 4.

The structure of this area is described as follows by Stewart, on page 6:

"The width of the area examined was determined largely by the width of a narrow belt where the folding was diversified and the dips were comparatively gentle. In other words was confined to a strip of country where the structure is most favorable for the accumulation of oil or gas. In this belt at least two, and perhaps three, anticlinal folds appear to be persistent for considerable distances along the strike of the rocks. The maximum dip of the limbs of these folds is about 15 degrees. The rocks to the west of this gently folded belt are much more intensely folded and faulted, but to the east of it dip very gently northeast in monoclinal fashion, and the dip must be measured in feet per mile rather than in degrees."

The conclusions reached by Stewart are as follows:

"Generally speaking, four factors are essential in an oil field. These are:

"1. A porous bed or sand by which oil may be absorbed.

"2. A suitable structural condition to permit concentration at a particular locality.

"3. Presence at one time or another of water as an accumulating agent.

"4. Petroleum originally diffused through the rocks of a reasonably large area surrounding the favorable structural centre.

"Putting the area under discussion to these tests, it is found that there are places along the anticlinal folds where the structural conditions are probably fulfilled.

"There are plenty of porous sands in the Bullhead Mountain formation and it may be assumed that there has always been plenty of water to act as an accumulating agent.

"The anticlinals are for the most part eroded well down into the lower part of the St. John shales, yet there is a possibility that porous absorbent sandy lenses occur in places. The underlying Bullhead Mountain formation is composed largely of coarse sandstone but this formation is mainly of fresh-water origin, and excepting coal deposits, contains very little organic matter likely to produce petroleum. There is, however, a possibility in places of interfingering of marine shales from the east with the Bullhead series of the west. Below the Bullhead Mountain formation is a series of dark calcareous shales, sandstones, and limestone of Triassic age. These beds contain numerous fossils which indicate that they are probably all of marine origin.

"If the first three conditions are fulfilled in this region and it is quite reasonable to presume that in places they are, then number 4 is the only unknown factor. The St. John shales are a source from which organic matter might have been derived to produce petroleum and the next promising series of strata are those of the underlying Triassic. Hence in projected boring operations preparations should be made to penetrate at least the entire thickness of the Bullhead Mountain formation if the region is to be fairly tested, The depth necessary to reach the Triassic shales will, of course, be governed by the location, but in the most favorable places in the region examined these shales are probably at least 3,000 feet below the surface."

Although it is not yet known that the stratigraphy and structure described above can be applied to the Pouce Coupé district, yet the facts may assist those contemplating development in that district until the geology has been thoroughly examined.

The Athabasca field is referred to under the heading of bituminous sands.

GREAT SLAVE LAKE FIELD

The Great Slave Lake area which may prove to be, at least in part, an oil field, lies toward the west end of the lake, and includes Windy Point on the north shore of the lake, and Pine Point south of the lake and east of Hay River post. During 1919 and 1920 many oil leases were staked on both sides of the lake. Late in the summer of 1920 the Imperial Oil Company began drilling operations on Windy Point. On account of the late date when the drilling party reached the well site a depth of only 325 feet was drilled before the close of the season. No positive indications of oil have been reported from this well. This outfit was under the charge of Professor A. E. Cameron.

The geology along the shores of Great Slave lake has been fully described by Cameron in 1916* and 1917† in the summary reports of the Geological Survey.

*Cameron, A. E., "Reconnaissance on Great Slave Lake, Northwest Territories" Geol. Surv., Can., Sum. Rept., 1916, pages 66-76.

†Cameron, A. E., "Exploration in the Vicinity of Great Slave Lake," Geol. Surv., Can., Sum. Rept., 1917, part C, p. 22.

Cameron describes the geology about Pine Point and also Windy Point in the summary report for 1916, on pages 71 and 73 respectively. His report follows:

"In the vicinity of Pine Point there is definite anticlinal structure, and it was found possible to compile a geological section of the rocks exposed. *Blue-grey weathering, hard, calcareous shales* and thin-bedded limestones predominate. All are highly bituminous and fossiliferous.

"On the islands to the east of the point similar sediments outcrop at various places. These islands seem to have been formed by the doming up of the underlying rocks and the beds exposed are apparently lower than those found in Pine Point, though probably of the same series. A tentative correlation was made between the lowest beds exposed in the anticline and the uppermost beds exposed on the islands. The rocks are thin-bedded bituminous limestones, highly fossiliferous, and in some cases in the more massive beds a porous cavernous structure was found, the cavities being filled with bitumen. The following section exposed on Pine Point and the islands to the east were measured.

Section at Pine Point

	Thickness Feet	Inches
Thin-bedded limestone	0	8
Fossiliferous and bituminous shale	0	8
Dark brown, oily shale	1	0
Thin-bedded limestone	0	4
Concretionary bituminous, calcareous shale	6	0
White weathering limestone, nodules in dark shales, all bituminous	2	0

Section on the Islands East of Pine Point

	Feet	Inches
White weathering limestone, nodules in dark shale, all bituminous	4	0
Dark hard shale, limestone bands	1	2
Limestone breccia in shale	0	4
Thin-bedded bituminous limestone	1	6
Dark bituminous shale	0	10
Argillaceous limestone, bituminous	1	2
Interbedded bituminous shales and limestones	1	6
Massive limestone, hard bituminous	1	8
Dark bituminous shale	0	4
Massive limestone, fine textured, hard, cavities with bitumen	6	6
Dark bituminous hard shales	1	0

Windy Point—"The southeastern shore of Windy Point is characterized by wide limestone shingle barrier beaches. At the southeastern extremity of the point a wave-cut cliff fifteen feet high begins and extends north in a straight line for some three miles. Just opposite the easternmost portion of the point the cliff is about one half mile inland and between it and the lake shore are the remnants of numerous old lake beaches of limestone shingle. Above the cliff the ground rises in a uniform slope to a height of about 100 feet and extends as a flat tableland into the interior. This slope also shows many old lake beaches; from the top of the hill to the shore forty-one were counted.

"The sediments exposed in the cliff are medium to thin-bedded, cream weathering limestones and calcareous shales. Fresh fracture shows red to brown colors and a medium grain. Practically all the beds are highly fossiliferous and bituminous. A vein of calcite averaging two inches in width contained appreciable quantities of coarsely crystallized galena.

"The northeast portion of the point is composed of a porous and cavernous dolomite or magnesium limestone. The dolomites are badly fractured and fissured and along the fissures and between the bedding planes numerous seepages of petroleum occur, accompanied by large sulphur springs. Fresh fracture shows a dark brown, crystalline, bituminous, magnesian limestone changing to a white coarsely crystallized dolomite. Cavities are common and are invariably lined with curved rhombohedral crystals of dolomite. The cavities are usually filled with heavy petroleum. Fossils are rare but the lower beds contain a few tightly coiled gastropods. The petroleum seepages occur most abundantly in the vicinity of this fossil horizon."

A sample of oil from Windy Point, collected by Mr. Camsell and analyzed by E. Stansfield of the Mines Branch, gave the following results:

Specific gravity crude oil at 15.5 degrees C. 0.957

Preliminary distillation of 203.7 grams crude gave 122.2 grams oil distillate of 0.888 sp. gravity. This is 60 per cent by weight or 64.5 per cent by volume of the crude oil.

Fractional distillation, Engler apparatus of 100 c.c. oil distillate taken gave first drop at 178 degrees C. at 178 degrees to 300 degrees C. gave illuminating oil, etc., 23 per cent by vol., 0.855 sp. gr., equivalent to 14.9 per cent by vol. crude oil.

Residue, lubricating oils, etc., 77.0 per cent by vol., equivalent to 49.6 per cent by vol. crude oil.

Calorific value crude oil 10,040 gram calories, 18,070 B.T.U. per pound.
Sulphur in crude oil, 1.0 per cent.

The geology in the vicinity of Great Slave lake was studied in detail by Cameron in 1917 and his report appears in the Summary for that year.

The stratigraphic succession as worked out by Cameron is as follows:*

*Geol. Surv., Can., Sum. Rept., Part C, 1917, p. 25.

Great Slave Lake Section

Quaternary

Lake and river deposits.
Glacial deposits.

Unconformity

Cretaceous

Meander shales.

Unconformity

Upper Devonian

Hay River limestones
Hay River shales
Simpson shales.

Middle Devonian

Slave Point limestones
Presqu'ile dolomites
Pine Point limestones.

Unconformity

Upper Silurian

Fitzgerald dolomitic limestones
Redrock arenaceous limestone.

Unconformity

Pre-Cambrian

Granites, gneisses, and metamorphics.

Description of Formations

"**Pre-Cambrian.**—Pre-Cambrian rocks are exposed on Great Slake lake east of the north arm and at several places on Slave river above Fort Smith. On the shores of the lake they show as coarse granites and gneisses intruding greenstone schists and metamorphics. On Les Iles du Large a massive bed of coarse, clear white quartzite is found overlying the granites, but whether the contact is intrusive or not was not apparent. On Slave river the granites underlie Paleozoic sediments and the sections frequently show five to ten feet of a coarse arkose lying between the granites and the Paleozoic sediments.

"**Upper Silurian.**—The massive bedded gypsum exposed on Peace river and at points on Slave river is referable, on paleontological evidence, to the upper Silurian. Near Fitzgerald coarse porous, dolomitic limestone carrying an upper Silurian fauna is exposed and similar sediments are found in the escarpment at the Salt Springs west of Fort Smith.

"At Gypsum Point on Great Slave lake coarse, porous, dolomitic limestones carrying fossils similar to those found in the dolomitic limestones near Fitzgerald overlie bedded, brick-red, arenaceous limestones carrying gypsum beds.

"**Lower Devonian.**—No distinctly lower Devonian sediments were observed in the vicinity of the lake shores or on Peace river. Kindle reports shales carrying middle Devonian fossils suggestive of the Ithaca formation, a local facies of the Portage in New York, directly overlying the Gypsum series on Peace river. An erosional unconformity exists here between the Gypsum series and the overlying shales. On Great Slave lake, however, a thick series of middle Devonian sediments are found lying between the Simpson shales and the upper Silurian dolomitic limestones. Fossil evidence shows that the Simpson shales are equivalent to the Portage formation of New York.

"**Middle Devonian.**—Middle Devonian sediments exposed on the shores of the lake are divided on lithological and paleontological evidence into three formations: Slave Point limestones, Presqu'ile dolomites, and Pine Point limestones. These may be correlated with the Manitoban limestones, Winnepegosan dolomites, and Elm Point limestones of the Manitoba section.

"The Pine Point limestones, the lowest member of the series, are exposed in the vicinity of Resolution, at Pine Point on the south shore of the lake, and on Ketsicta Point on the north shore. They are thin-bedded, bituminous, dark-colored, fine grained limestones and limy shales.

"The thickness of the Pine Point series is not directly observable, but from structural evidence appears to be about 100 feet.

"The Presqu'ile dolomites, overlying the Pine Point series, are exposed at Presqu'ile Point and on the Burnt islands east of Pine Point on the south shore. On the north shore they show as the oil-bearing dolomites at the Tar springs on Nintsi (Windy) Point and on the shores of Sulphur bay. Although not exposed elsewhere on the north shore of the lake, structural conditions suggest their presence in the region between Tagkatea and Ketsicta points.

"Exposures show this formation to consist of two members: an upper, thin-bedded, dolomitic limestone highly fossiliferous and carrying the diagnostic fossil *Stringocephalus burtoni*, and a lower member composed of a coarsely crystalline porous and cavernous dolomite. This latter is the oil-bearing horizon at the tar springs on Nintsi Point. The formation is estimated to have a thickness of about 200 feet.

"The Slave Point limestones, composing the upper formation of the middle Devonian, are exposed on the south shore, from Presqu'ile Point to High Point, on Buffalo river, and on the north shore at Slave Point and along the lake shore between House and Moraine points.

"This formation is composed of thin-bedded, medium-grained dark grey, and slightly bituminous limestones and has an estimated thickness of about 160 feet.

"**Upper Devonian.**—Upper Devonian sediments in the region are divided into three formations: Hay River limestones, Hay River shales, and Simpson shales. The Hay River limestones and shales carry an abundant *Spirifera disjuncta* fauna and may be correlated with the Chemung formation of New York, and the Simpson shales carry some of the fossils characteristic of the Portage formation of New York.

"The Simpson shales are not exposed in the vicinity of Great Slave lake, but on Mackenzie river near Simpson are found underlying the Hay River shales. A thickness of 150 feet is exposed and shows soft, greenish grey clay shales. Limestone and sandstone bands, so common to the Hay River shales, are absent here and the fossil evidence does not show the Spirifera disjuncta fauna which is so abundant in the Hay River series. It is probable that these soft Simpson shales underlie the western end of the lake and a considerable portion of the valley of Buffalo river.

"The Hay River shales are exposed in the valley of Hay river below the falls and are also probably present underlying the basin of Buffalo lake and in the valley of Beaver river. Where exposed on Hay river they show as soft, bluish-green, clay shales and carry thin bands of highly fossiliferous limestone and ripple-marked sandstones. A measured thickness of 400 feet of these shales is exposed in the river valley.

"The Hay River limestones directly overlie the soft Hay river shales and the section as exposed in the gorge on Hay river shows a gradation between the two formations.

"The section in the gorge on Hay river shows 221 feet of thick and thin-bedded, hard, fine-grained, light-colored limestones and at least another 75 feet is exposed in the river valley above the falls. About forty feet from the base of the limestones occurs a bed of soft fossil clay shales forty-seven feet thick. The presence of this shaly member in the limestone series has been the cause of the formation of the two falls on the Hay river. At the falls on Beaver river the limestones are similar to those at Louise falls on Hay river. The shaly member is here absent and in place of an upper fall there is a long series of low cascades from five to fifteen feet high.

"**Cretaceous.**—Soft, fissile, dark shales of Cretaceous age are exposed in the valley of Hay river at intervals throughout the distance between the 6th meridian and Grumbler rapids. The contact between these and the underlying Devonian limestones is not exposed, but would probably show, as elsewhere in Western Canada, an unconformity. The shales show numerous large concretions and occasional ironstone bands and closely resemble the Loon river of the Peace River Section. A few miles below the 6th meridian a sandstone layer twenty-five feet thick shows in the valley and this very probably represents the Peace River sandstones of the Peace River section, which are known to thin out to the east and north.

"**Recent.**—The entire region is overlain by a heavy deposit of glacial drift. Cut banks on the river valleys frequently show sections twenty to a hundred feet thick of boulder clays and gravels of glacial origin.

"The meandering character of all the rivers has developed extensive flood-plains of alluvial material on the inside of the curves and the large rivers have formed widespread deltas at their point of discharge into the lake.

Structural and Economic Geology

"Stratigraphic studies have revealed the presence of a gentle anticline stretching across the lake from Pine Point on the south shore to Nintsi (Windy) Point on the north shore. On the south shore the apex of the anticline is shown on the east side of Pine Point and the lowest beds exposed show the Pine Point series of bituminous limestones and limy shales.

"The presence of higher strata, the overlying Presqu'ile dolomites, both to the east on Burnt islands and to the west at Presqu'ile Point, clearly demonstrates the anticlinal structure. On the north shore the crest appears to lie in the erosion basin of Sulphur bay. The Presqu'ile dolomites are exposed on the east shore of Nintsi

Point, at various points on the shores of the bay, and eastward to Jones Point; whereas the overlying Slave Point limestones are shown on Slave Point west of Nintsi Point and again near House and Moraine Points northwest of Jones Point.

"Structural conditions suggestive of gentle anticlinal folding are noticeable in the limestone outcrops on Buffalo river and those exposed on Hay river above the falls. Exposures are confined to the valley floors where the rivers have cut down into the Devonian sediments and on account of the overburden of glacial drift the extent of the folding was not observable.

"As shown by the oil seepages and tar pools on Nintsi Point, the Presqu'ile dolomites appear as the most probable oil horizon of the district, and as these sediments are exposed on the limits of the anticline, the possibilities of an oil-producing field existing on the shores of the lake are not very great.

"A thick series of soft clay shales is exposed on Hay river, which from the stratigraphical relation would appear to overlie the dolomites. If the dolomite horizon can be found elsewhere in the district under suitable structural conditions and overlain by these impervious shales, it may be worth investigating with a drill.

"On Hay river, above the falls, limestone outcrops in the valley show gentle undulations forming anticlines and synclines of a low order. The limestones here exposed represent upper members of the Hay River limestones which overlie the thick series of shales above mentioned.

"It is to be noted that the section exposed on Peace River shows members of the Simpson shale series unconformably overlying the gypsum series of upper Silurian age, and thus the middle Devonian section as exposed on Great Slave lake is here absent. It is, therefore, possible that the dolomites would not be found underlying the shale series in the folded area above the falls on Hay river, or, if present, they would probably be somewhat thinner in their development than is shown on the shores of the lake. If drilling operations were conducted on Hay river, a thickness of about 1,000 feet of sediments would have to be pierced before the Presqu'ile dolomites would be reached."

FORT NORMAN FIELD

Since the first news reached the public in October, 1920, that oil had been discovered in the Fort Norman district, few oil fields in the world have received so much attention and comment. This is partly due to the fact that it is the furthest north that oil has ever been discovered.

Fort Norman is a Hudson's Bay post situated on the east side of Mackenzie river, at the mouth of Bear river, which is the outlet of Great Bear lake. Fort Norman lies just outside the Arctic circle close to the 65th parallel of latitude, on longitude 126 degrees west. This point lies on a latitude which passes several miles west of the city of Victoria, on Vancouver Island. In a direct line it is about 1,000 miles north-northwest from Edmonton, and about 1,600 miles by river route from the northern terminus of the railroad. North of Fort Norman the Mackenzie continues for over 300 miles before it enters the Arctic ocean close to the 65th parallel of latitude. The width of the low upland at Norman between the broken structure to the east of the Mackenzie valley and that to the west in the Mackenzie mountains is less than 100 miles.

The geology of this district has not recently been examined by the Geological Survey, but field investigations have been carried on by geologists for private corporations intermittently since 1914. The geological data thus obtained are not available for public use.

In the spring of 1914 Dr. T. O. Bosworth investigated the geology in the Mackenzie basin for oil indications. A detailed report of this work has never been made public, except in an article written by Dr. Bosworth which appeared in "The Petroleum World" in February, 1915, page 91.

A number of oil claims were staked in 1914 by Dr. Bosworth and the members of his party about forty miles north of Fort Norman.

Interest in this district lapsed until the summer of 1919, when a systematic field survey was commenced by the Imperial Oil Company under the direction of Dr. Bosworth.

The geological activities of 1919 extended from the international boundary line northward to the Arctic circle. The claims staked under the direction of Dr. Bosworth in the Fort Norman district were transferred to the Imperial Oil Company in 1919. A drilling outfit was sent into the Mackenzie river field by the Imperial Oil Company in 1919 with Geologist T. A. Link in charge. The first well was located in the far north close to the Bosworth lease which had been staked by Dr. Bosworth in 1914. This well site is situated forty-five miles below Fort Norman on the east side of Mackenzie river, a few yards from the high water level. This site is close to the Arctic circle.

The drilling party remained in the north throughout the winter of 1919-20. Drilling operations were commenced early in the spring of 1920, and Mr. Link continued a geological survey. The first indication of oil in the well was found within 200 feet of the surface, but it was not until the end of August when the drill had reached the depth of 800 feet that a strong flow of oil and gas was struck. *This discovery has attracted world-wide attention.*

The first intimation of the discovery which reached the outside world came through the press under the caption, "Oil Struck at Fort Norman, a Barrel a Minute Flow." The facts, however, are somewhat different from the first report, which was not official. Mr. Link, who was in charge of the drilling and was present when the discovery was made, has stated publicly that the pressure was sufficient to throw the oil some distance above the top of the derrick. The flow, however, was intermittent.

Between the gushes a two-inch pipe was attached to the top of the casing and the well was capped. No accurate measurements were made of the quantity of oil which flowed from the top of the casing.

The oil taken from the well has an olive-green color and a gravity between 36 and 39 degrees Beaume. The oil has a paraffin base and there appears to be no asphalt base present.

A sample of the oil collected by a member of the party in charge after the well had been capped, and given to the writer, has been analyzed in the Industrial Laboratories at the University of Alberta. The following are the results of this analysis:

Original Sample, 36 Degrees Beaume.

Distillation of Oil—	
70 to 150 degrees C.	21.5 per cent
150 to 300 degrees C.	37.5 per cent
300 to 350 degrees C.	34.0 per cent
350 to 375 degrees C.	6.0 per cent
Loss	1.0 per cent
Commercial Indication—	
Commercial gasoline	21.5 per cent
Illuminating oils	37.5 per cent
Light lubricants	34.0 per cent
Medium lubricants	6.0 per cent

A copy of the government report of analysis of Fort Norman oil made by J. H. H. Nicolls at the Mines Branch, Department of Mines, Ottawa, has been given to the writer. This report, No. B574, is as follows:

No. 1719.—Sample of crude oil from 872-foot well drilled at Oil creek, 53 miles below Fort Norman, N.W.T., by the Imperial Oil Company, sent in for analysis by Deputy Minister of Mines.

The oil is opaque, dark olive green, with an odor between those of kerosene and gasolene. It is completely soluble in petroleum ether, indicating that there is no asphalt base present.

Distillation	Continuous Method	Engler Intermittent Method	Specific Gravity	Color
First drop	60 degrees C.	59 degrees C.		
Up to 100 C.	6.5 c.c.	7 c.c.	0.687	Colorless
100 to 160 (?)	12.0 c.c.	14 c.c.	0.735	Colorless
150	12.5 c.c.	12 c.c.	0.783	Colorless
200 250	10.5 c.c.	11 c.c.	0.816	Colorless, opalescent
250 300	10.5 c.c.	10 c.c.	0.837	Very faint yellow, opalescent
300 350	10.0 c.c.	12 c.c.	0.861	Straw yellow, opalescent
Residue (by difference)	38.0 c.c.	34 c.c.	0.929	Dark brown with olive green tinge

Probably some cracking here

Specific gravity of original oil calculated from the above figures, 0.837. There was insufficient residual oil from distillation to determine its viscosity, but at 100 degrees F. it flowed very slowly, and at 210 degrees F. comparatively rapidly, from a Redwood viscosimeter.

Calorific value—

Calories per gram, gross 10,320
B. Th. U. per lb., gross 18,582
Sulphur .... 0.02 per cent

Signed: J. H. NICOLLS,
Acting Chief Engineering Chemist.

It is reported that the bottom of the well is in dark colored shales which are overlying a sandstone stratum, and therefore a larger flow of oil is believed to exist in the more porous formation below.

The discovery of oil indicates the occurrence of an undefined oil field. The extent of this field and the quantity of oil which it contains cannot be estimated, but must be proven by drilling operations. There are great difficulties which will hinder the development of this field into an oil-producing centre. The prime difficulties are the inaccessibility to transportation, the rather severe winter season, and the short summer season, which is about four months in length. In spite of these difficulties a rush is already under way, and lease-staking parties are already on the road to the new far north oil fields. The new oil regulations which came into effect in January, 1921, have abated the interest and excitement temporarily, but increased activity is anticipated in the spring. An aerial service is being established from Edmonton or Peace River to the Fort Norman field, which, if successful, will assure a longer season for field activities.* This discovery does not yet assure a large reserve for future consumption, but the indications are sufficiently favorable to instil optimism as to the future oil possibilities in Western Canada.

*On March 12, 1921, the two aeroplanes owned by the Imperial Oil company made their first trip from Peace River to Hay River Post of Great Slave lake. The trip was made successfully when the temperature ranged from 20 to 25 below zero. The planes returned on the 14th.

SALT

INTRODUCTION

In the First Annual Report on the Mineral Resources of Alberta, pages 87 to 102 are devoted to the subject of salt.* The consumption of salt in Canada, uses, composition and types of occurrences of sodium chloride in the form of rock salt, natural brines or artificial brine are briefly outlined. All of the occurrences of saline springs in Alberta and in the Mackenzie basin were briefly described, and all references to salt in any form in this area were briefly summarized from government publications and other sources. The various occurrences will not be further referred to at this time.

For some years there has been an impression that enormous deposits of rock salt occurred in Northern Alberta, particularly in the vicinity of Fort McMurray. This idea resulted from the fact that two wells had been sunk at the mouth of Horse creek, about a mile south of McMurray townsite. In the records of these borings two immense beds of rock salt were reported. The record of No. 1 well is so incomplete that it was regarded as of little importance, but in well No. 2 there was reported to be two beds of salt, 100 feet and 90 feet in thickness respectively, separated by 75 feet of limestone. These wells were drilled with the ordinary standard of churn drill and no samples were kept of the mud from the different beds.

After having examined all available data and having considered field indications of the occurrences of rock salt, I recommended that the presence or absence of rock salt in commercial quantities would be easily proven by drilling a test well with a core drill in the vicinity of Fort McMurray. As a result of this recommendation, the provincial government obtained control of the salt rights in an area along the Clearwater valley from the Athabasca river at McMurray, eastward up the valley of the Clearwater along the proposed line of railway. A rotary Davis Calyx drill manufactured by the Ingersoll Rand Company, Limited, was secured, and a well was started in October, 1919. The well is situated within the townsite of McMurray, on river lot 8, block 4, lot 7, on section 21, township 89,

*Allan, J. A., Mineral Resources of Alberta, Edmonton, 1920, p. 87.

range 9, west of the 4th meridian. The drilling operations were managed by Mr. Wm. Pickles, and he was assisted by three men. Considerable difficulty was encountered close to the surface deposits, which are of river origin, as the well is located over an old channel of the Clearwater river.

Operations were continued intermittently during the winter 1919-20, which was exceptionally long and severe, but resumed activity commenced in the early spring. The progress of the whole was very slow, due to the fact that the character of the formations encountered were such that it was necessary to make various changes in the equipment. Repairs and new equipment had to be procured in Edmonton or in several cases in eastern Canada. The transportation difficulties between Fort McMurray and Edmonton were so great that frequently a week or more elapsed before the necessary material could be obtained. Drilling was continued until November, 1920, and the plant was shut down when the drill had reached a depth of 685½ feet, and when the required results had been obtained.

LOCATION OF THE SALT WELL

Fort McMurray is situated on the east bank of the Athabasca river in township 89, range 9, west of the 4th meridian, at the mouth of the Clearwater river. Horse creek enters the Athabasca about one mile south of the mouth of the Clearwater, which flows on the north side of the townsite. Between McMurray and Horse creek lies a ridge 250 feet high made up largely of bituminous sands, commonly known as "tar sands," which represent the "McMurray formation" of middle-upper Cretaceous age. The town of McMurray is located on a series of flat terraces which rise like steps above Clearwater river. The uppermost terrace stands thirty-five feet above the normal level of Athabasca river. These terraces consist of gravel, sand and clay, which have been deposited by the Clearwater river at various stages in the post-glacial development of that valley. The terraces when followed eastward along the Clearwater disappear when respective levels correspond to those in the present stream, or where the river has washed away all evidence of the terrace due to the widening of its present course.

GENERAL GEOLOGY

The terrace deposits at McMurray are lying directly on top of a limestone series which is upper Devonian in age. The top of these Devonian limestones are exposed on an island which lies in the mouth of the Clearwater, and also along the banks of the Athabasca north and south of McMurray. The limestones are overlain by bituminous sands (McMurray formation) that are of middle-upper Cretaceous age. There is therefore an erosion contact, which represents a long period of time, between the Devonian limestone and the bituminous sandstone.

The succession of formations up Athabasca river between McMurray and Athabasca Landing as described by McConnell is as follows:*

La Biche shales	900 feet
Pelican sandstone	40 feet
Pelican shales	90 feet
Grand Rapid sandstone	300 feet
Clearwater shale	275 feet
Bituminous sands	0 to 200 feet
Devonian limestones	30 feet

The difference in elevation between the Clearwater and the plateau to the south is about 300 feet. At various points along the valley of the Clearwater the bituminous sands and the Clearwater shales are exposed, overlying the Devonian limestone. By locating the salt well at Fort McMurray the minimum depth to the salt-bearing horizon was obtained.

CORE OF SALT WELL

By using the Calyx core drill and by preserving the core, a complete record of the various beds encountered in the well has been obtained. The diameter of the well at the surface is ten inches. The bore hole was reduced to eight inches at ninety-five feet from the surface, to six inches at 113 feet, and again to five inches at 512 feet. This diameter extends to the bottom of the hole, which is at 685½ feet. The upper ninety-five feet is protected with 9⅝-inch casing and 7⅝-inch casing extends to 112 feet. It was not the intention to case the hole, but when the drill had reached 512 feet certain shale beds were caving so badly that it was necessary to case the hole to this depth. The diameter of the hole was then reduced to five inches but as no serious difficulty arose from caving in the strata passed through below this depth no casing has been used.

The rock core is not complete throughout, as many portions of it were soft and were washed away during drilling. All of the core fragments obtained were carefully labelled and properly boxed. The entire core as obtained was brought out during the winter to Edmonton, and is now permanently preserved in a room for this

*McConnell, R.G., Geol. Surv., Can. Ann. Rept., Vol. V. Part D, 1890-91, pp. 27-62 purpose at the University of Alberta. After making a detailed examination of every part of the core I have arranged the entire core in trays properly labelled and placed on shelves in consecutive order, so that it is possible to examine any portion of the core without having to remove a single fragment. The complete core of the salt well may be seen by any one interested in the rock formations in Northern Alberta, by informing the writer, or any other person at the University of Alberta who may be acquainted with this core material.

The value of this core cannot be estimated as it contains a complete record of the formations below the surface at McMurray for a depth of nearly 700 feet. As it is reasonable to expect that the formations are related lithologically throughout all Northern Alberta and even in the lower Mackenzie basin, the data obtained from this well will prove of value to any one carrying on drilling operations in the north. The record would of course be more complete if a hole were drilled down to the pre-Cambrian granites at the bottom of the sedimentary series. One well drilled by the Athabasca Oils Limited, fifty-six miles below McMurray, extends into the pre-Cambrian rocks. The log record of this well is given on page 97 of the First Annual Report, and is repeated in another part of this report. By correlating the data from the McMurray salt well with all available data in Northern Alberta, more valuable information is obtained regarding the geological structure in the north.

Further detailed study is being made of the rock core, as all of the fossil types have not yet been determined. The information which is now on hand regarding the rock core is given below. A columnar section of the well is given in Plate 2, but the information is of necessity generalized on account of the scale. This columnar section is made from a log drawn to a scale in which one foot represents eighty feet, but as this section is nearly nine feet long, it could not be conveniently included in this report. The section prepared from the rock core is as follows:

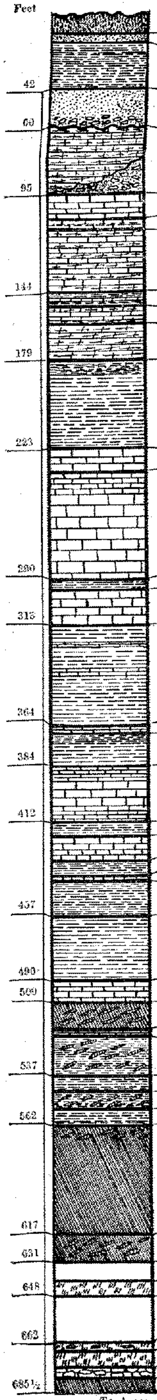
LOG OF SALT WELL, FORT McMURRAY

Strata	Depth from Surface	Thickness in Feet
Loose soil and sandy loam	0 — 15	15
Quicksand	15 — 18	3
Blue alluvial mud	18 — 41.5	13.5
Hard sand	41.5— 42	0.5
Heavy white silica sand	42 — 55	13
Boulders and granite sand, base of river deposits	55 — 60	5
Shaly limestone; core fragmental	60 — 78	18
Crevice in limestone filled with sand and granite boulders	78 — 95	17

CORE RECORD OF SALT WELL NO. 1.

Compiled by J. A. Allan.

Drilled by Alberta Government at Fort McMurray



Feet	Feet	
	15	Soil.
	3	Quicksand.
42	24	Blue alluvial mud.
60	13	White sand and boulders.
95	35	Shaly limestone with crevices filled with sand and boulders.
	12	Grey fossiliferous limestone.
	5	Shale and limestone interbedded.
144	32	Massive and shaly limestone interbedded.
	7	Calcareous shale and shaly limestone.
	9	Shaly fossiliferous limestone.
179	19	Shaly limestone.
223	44	Calcareous shale including 7 ft. soapy shale near top.
	13	Mottled limestone.
290	54	Massive fossiliferous limestone.
	5	Fragile shale.
315	18	Fossiliferous limestone.
364	51	Soft blue and grey shale.
	3	Mottled limestone.
384	17	Calcareous shale with 5 ft. talcose shale at top.
412	28	Dark grey limestone.
	6	Talcose shale.
	12	Grey limestone.
	7	Soft shale.
	3	Fossiliferous limestone.
457	17	Green shale.
490	33	Grey Calcareous shale.
509	10	Grey massive limestone.
	14	Hard anhydrite and gypsum.
	2	Limestone.
537	21	Shale and gypsum.
	8	Blue shale.
	9	Gypsum and shale.
562	8	Green and brown shale.
617	55	White and bluish anhydrite with gypsum near top.
631	14	Anhydrite and gypsum.
	10	Rock Salt and saline Mud.
648	7	Salt and anhydrite, part missing.
662	14	Transparent Rock Salt.
	4	Anhydrite and gypsum.
	8	Rock Salt and anhydrite.
	5	Limestone and Rock Salt.
685½	6½	Compact, hard anhydrite.

To Accompany Second Annual Report, 1920, by J. A. Allan.

Strata	Depth from Surface	Thickness in Feet
Massive grey fossiliferous limestone, beginning of eight-inch hole	95 — 107	12
Thin bedded grey calcareous limestone with thin shale layers	107 — 111	4
Massive grey limestone	111 — 124	13
Fine textured soft grey limestone with pyrite nodules	124 — 126	2
Coarsely crystalline grey limestone	126 — 133	7
Mottled grey limestone	133 — 139	6
Thin bedded limestone and calcareous shale with 3 inches hard fragmental limestone with fossils	139 — 144	5
Greenish grey calcareous shale with many thin limestone layers less than half an inch in thickness	144 — 150	6
Shaly fossiliferous limestone	150 — 152	2
Limestone with calcareous shale bands	152 — 155	3
Thin bedded grey limestone	155 — 159	4
Greenish grey calcareous shale 8 inches mottled limestone	159 — 163	4
Massive mottled limestone	163 — 164	1
Shaly fragmental limestone	164 — 174	10
Massive beds of shaly limestone with shale bands (9 inches of limestone with pyrite)	174 — 178	4
Bluish grey talcose shale	178 — 185	7
Grey calcareous shale	185 — 190	5
Dark grey compact calcareous shale	190 — 222	32
Massive compact mottled limestone, complete core	222 — 235	13
Massive fossiliferous limestone, core complete	235 — 242	7
Fragile fossiliferous limestone	242 — 243	1
Massive mottled fossiliferous limestone	243 — 279	36
Greenish grey compact fossiliferous argillaceous limestone, an imperfect fossil specimen, probably a Stropheodont	279 — 282	3
Massive mottled fossiliferous limestone (the core between 222 and 290 is almost complete)	282 — 290	8
Very fragile shale (Eatonia variabilis)	290 — 295	5
Massive limestone made up largely of fossils	295 — 313	18
Dark grey calcareous shale	313 — 316	3
Fragile talcose shale, very plastic	316 — 327	11
Hard grey fossiliferous limestone	327 — 328	1
Bluish talcose shale, pyritized fossils	328 — 340	12
Soft bluish shale with 4 inches hard limestone at top	340 — 355	15
Massive fossiliferous limestone almost entirely fossils (Cyrtina curvilineata)	355 — 357	2
Bluish shale with calcareous band at the top	357 — 364.5	7.5
Mottled limestone, few fossils	364.5— 367	2.5
Talcose shale	367 — 372	5
Grey limestone	372 — 373	1
Fragile calcareous shale; struck small gas pocket at 377, very little smell (Atrypa reticularis and Cyrtina curvilineata)	373 — 383	10
Soft talcose shale, core reduced in size by water	383 — 384	1
Bluish grey argillaceous limestone	384 — 386	12
Thin bedded dark grey limestone	386 — 402	6
Soft thin bedded grey limestone, much trouble from caving between 384 and 412; this bed might be called massive calcareous	402 — 412	10
Talcose shale, much of the core washed away	412 — 418	6
Massive grey limestone	418 — 425	7
Argillaceous limestone	425 — 428	3
Soft greenish fossiliferous shale, small pocket of gas with strong odor	428 — 435	7
Thin bedded grey fossiliferous limestone	435 — 438	3
Soft talcose shale with shaly limestone	438 — 442	4

Strata	Depth from Surface	Thickness in Feet
Greenish calcareous shale (Atrypa reticularis, Schizophoria striatula, Cyrtina curvilineata Crinoid stem)	442 — 455	13
Argillaceous limestone	455 — 457	2
Grey compact calcareous shale	457 — 490	33
Massive mottled limestone; at 500 there is a sharp change to gypsum and anhydrite	490 — 500	10
Grey and white gypsum	500 — 502	2
Anhydrite with irregular lenses of selenite (gypsum)	502 — 510	8
Gypsum	510 — 512	2
Siliceous shale and gypsum	512 — 514	2
Limestone and anhydrite	514 — 516	2
Shale with gypsum bands and lenses	516 — 524	8
Anhydrite gypsum and shale interbedded	524 — 537	13
Bluish grey shale	537 — 545	8
Thin bedded gypsum and shale	545 — 554	9
Brown shale	554 — 558	4
Dark green shale	558 — 562	4
White anhydrite	562 — 570	8
Brown shale	570 — 571	1
Bluish gypsum and anhydrite	571 — 572	1
Anhydrite	572 — 617	45
Anhydrite and gypsum	617 — 625	8
Brown dolomite limestone	625 — 626	1
No core, washings saline	626 — 627	1
Anhydrite and gypsum, the salt crystals	627 — 631	4
Porous granular core, largely rock salt	631 — 635	4
Hard anhydrite	635 — 636	1
No core but washings saline, specific gravity of brine 1.09	636 — 641	5
Granular porous mass, salt and anhydrite	641 — 645	4
No core but the saturated brine, specific gravity 1.23 (4¾ pounds of salt evaporated from 2 imperial gallons of brine)	645 — 648	3
Rock salt, transparent and colorless	648 — 662	14
Anhydrite	662 — 663	1
Salt and anhydrite	663 — 666	3
Impure anhydrite	666 — 667	1
No core, many salt fragments	667 — 670	3
Salt, most of core dissolved	670 — 674	4
Anhydrite and rock salt	674 — 675	1
Dolomite and salt	675 — 679	4
Coarse granular anhydrite	679 — 683	4
Compact finely crystalline anhydrite, the bottom of the hole is still in the anhydrite	683 — 685.5	2.5

This core shows that the strata in the lower 165 feet, that is below the 500-foot level, consists largely of anhydrite, gypsum and rock salt. As the bottom of the well remains in anhydrite, and as there is no indication of a change in the character of the rock, it is reasonable to expect that there may be even a greater thickness of rock salt below the depth reached in the well. However, at least fourteen feet of transparent commercial rock salt occurs between 648 and 662 feet in a single bed. The fragmentary character of the core, and the small amount of solid rock in the core below 631 feet, seem to indicate that in the last fifty-five feet of strata there are possibly twenty-five to forty feet of comparatively pure rock salt, interbedded with anhydrite and shale, but, nevertheless, of commercial value.

The quality of the salt is satisfactory, as is shown in the following analyses, all of which were made in the Industrial Laboratories at the University of Alberta:

ANALYSES OF ROCK SALT FROM DRILL CORE

	1	2	3
Water soluble	53.78		
Insoluble matter	46.32	0.24	0.46
Analysis of water soluble—			
Calcium sulphate ($CaSO_4$)	1.94	4.74	0.90
Sodium chloride (NaCl)	97.28	94.78	98.46
Ignition loss	0.40	....	....
Magnesia	0.00	0.00	0.00
Potash	0.00	0.00	0.00

	4	5	6
Insoluble	.....	0.30	.....
Calcium sulphate	2.48	2.78	1.84
Sodium chloride	97.01	96.53	97.64
Ignition loss	0.21	0.18	0.28
Magnesia	0.00	0.00	0.00
Potash	0.00	0.00	0.00

1. Transparent rock salt from 660 feet.
2. Rock salt from 14-foot bed.
3. Transparent rock salt 650 feet.
4. Brine taken from the well at 660 feet.
5. Rock salt with anhydrite lenses from 645 feet.
6. Brine from the bottom of the well at 685 feet when drilling ceased.

These analyses show that the chief impurity present is calcium sulphate, which is not present in sufficient quantity to be detrimental to the salt for market purposes. The salt capping at 647½ feet is almost a pure anhydrite with a small quantity of gypsum. The analysis of the rock is as follows:

Residue	0.62
Lime	39.29
Magnesia	0.28
Sulphuric anhydrite	55.80
Ignition loss	3.91

There are many beds of anhydrite and gypsum of commercial quality which would prove valuable if there was a market for this mineral, and if at any time the rock salt should be recovered by mining. Several analyses were made from the core at various depths below 500 feet, where the gypsum and anhydrite first occur. These analyses show that there is considerable thickness of anhydrite and gypsum in the strata pierced by this well. These minerals are of commercial quality if a market could be found for the product. All of these analyses were made by J. A. Kelso and the results are as follows:

ANALYSES OF GYPSUM AND ANHYDRITE FROM SALT WELL

	No. 1	No. 2	No. 3	No. 4
Depth in feet	534	546	564	662
Residue	1.02	.....	2.02	4.22
Lime	32.81	17.36	33.88	37.42
Magnesia	5.14	6.66	0.98	1.25
Sulphuric anhydride	58.11	0.63	48.62	54.05
Ignition loss	2.72	25.62	14.01	0.72
Silica	.....	34.20	.....	.....
Iron oxide	.....	2.00	.....	.....
Alumina	.....	9.20	.....	.....
Alkalis, etc.	.....	4.33	.....	.....
Sodium chloride	.....	.....	.....	1.99

	No. 5	No. 6	No. 7	No. 8	No. 9
Depth in feet	664½	665	666	671	676
Residue	5.62	5.20	1.02	4.72	2.01
Oxide of iron and alumina	5.98	.....	4.02	.....	.....
Lime	34.58	35.27	29.46	35.84	35.56
Magnesia	0.00	0.24	0.00	0.46	6.66
Sulphuric anhydride	49.07	49.16	41.88	52.46	50.67
Sodium chloride	0.38	0.58	20.90	5.02	0.32
Ignition loss	4.01	9.02	2.78	1.24	4.52

	No. 10	No. 11	No. 12	No. 13
Depth in feet	681	684	670—673	685½
Residue	4.02	.....	7.72	1.38
Lime	37.04	40.78	33.00	40.00
Magnesia	0.12	0.37	0.09	0.09
Sulphuric anhydride	54.62	58.34	47.09	57.44
Sodium chloride	1.02	.....	4.72	.....
Ignition loss	3.01	0.42	7.30	1.07

The strata penetrated by the drill are remarkably free from water as no appreciable flow of water could at any time be detected in the well. This is an important factor if mining operations should be contemplated for the recovery of salt.

The information obtained from the rock core makes it apparent that the extraction of the rock salt by mining would be the most feasible one. There are at least fourteen feet of sufficiently pure rock salt which could be mined and marketed without further treatment, at the same time possibly a considerable thickness of less pure rock salt could be mined from other beds, which would require additional treatment. If a shaft were sunk to the rock salt horizon, certain gypsum and anhydrite beds could also be mined when any market demand should arise for calcium sulphate.

For the purpose of comparison with the records from this well, the logs from three other wells in the vicinity are given:

NO. 1 WELL, MOUTH HORSE CREEK

Loose surface material	0 — 17 feet
Limestone	17 — 117 feet
Soapstone and limestone	117 — 520 feet
Salt	520 — 620 feet
Limestone	620 — 635 feet
Salt	635 — 740 feet
Limestone	740 — 770 feet
Sandstone	770 —1475 feet

NO. 2 WELL, MOUTH HORSE CREEK

	Top Bottom Feet	Thickness Feet
Loose surface material	17	17
Limestone	17 — 77	60
Shale	77 — 92	15
Limestone	92 — 152	60
Shale	152 — 192	40
Soft shale	192 — 197	5
Limestone	197 — 237	40
Shale	237 — 242	5
Limestone	242 — 362	120
Shale	362 — 382	20
Limestone	382 — 462	80
Shale	462 — 502	40
Limestone	502 — 562	60
Shale	562 — 592	30
Limestone	592 — 604	12
Salt and water	604 — 704	100
Limestone	704 — 779	75
Salt	779 — 869	90
Limestone	869 — 999	130
Shale	999 — 1059	60
Brown sandstone	1059 — 1119	60
Brown Medina rock	1119 — 1139	20
Hard red rock (streaked)	1139 — 1405	266

No. 3 ATHABASCA OILS LIMITED WELL

Surface deposits	13	feet
Bituminous sand	65	feet
Shale	20	feet
Bituminous sand	57	feet
Shale	175	feet
Limestone	65	feet
Shale	20	feet
Limestone	175	feet
Gypsum	*130*	*feet*
Limestone (containing a salt water stratum)	192	feet
Red rock	63	feet
Hard reddish flinty sand (second salt water stratum)	130	feet
Reddish granite (containing gold)	25	feet

Numbers 1 and 2 are from well No. 1 and well No. 2 sunk on the property of the Northern Alberta Exploration Company, between 1907 and 1912, near the mouth of Horse creek, about one mile south of the site of the Alberta Government salt well. The log record of well No. 1 is of no value, while that of No. 2 has but a slight resemblance to the accurate log obtained from the salt well on McMurray townsite.

Number 3 is the log of well No. 1, owned by the Athabasca Oils Limited, and situated on the east bank of the Athabasca river about twenty miles below McMurray. This log shows 130 feet of gypsum beginning at a depth of 195 feet, and is interesting for comparative purposes only, as the details are not sufficient to make it of practical importance.

In conclusion it may be said that the record of the Alberta government salt well at Fort McMurray shows that there is a commercial quantity of rock salt available for extraction, and the market in Alberta and the other western provinces is sufficient to warrant the further exploitation and development of this mineral resource.

The rock core also seems to prove a stratigraphic problem of vast importance to mineral development in northern Alberta. It would seem that all of the rocks to the gypsum horizon at a depth of 500 feet in the salt well are of upper Devonian age, and that there are no middle or lower Devonian beds present which would correspond to the formations of those ages found in the lower Mackenzie basin. It is generally supposed that the gypsum and rock salt in central Canada belongs to the upper Silurian. If this is the case, it would seem that the middle and lower Devonian rocks are missing at Fort McMurray. The fossils that have been determined seem to indicate that all of the strata to a depth of 500 feet belongs to the upper Devonian. This information is of great importance to anyone contemplating drilling for oil or any other mineral in that part of Alberta.

LIST OF FOSSILS FROM SALT WELL CORE

The fossils from the core of the Salt Well have been determined by Mr. P. S. Warren of the University of Alberta.* His report on the fossils determined follows:

REPORT ON THE FOSSILS DETERMINED FROM THE CORE OF SALT WELL NO. 1, McMURRAY, ALBERTA

Depths are given from the surface in feet.

95 to 133	Fossils very difficult to extract. Fragments of Atrypa reticularis, a small Spirifer and a Gastropod
133 to 139	A species of Leptodesma very common.
139 to 144	Fossils plentiful. Schizophoria striatula. Atrypa spinosa. Atrypa reticularis. Productella sp. Spirifer sp. Eatonia cf. variabilis. Cyrtina sp. Crinoid stems. Spirorbis omphalodes. Bryozoa sp.
144 to 164	No fossils observed.
164 to 174	A species of Spirifer very abundant, also a species of Cyrtina Atrypa spinosa. Atrypa reticularis.
174 to 222	No fossils observed.
222 to 235	Schizophoria striatula. Atrypa reticularis. Atrypa spinosa. Productella sp. Crinoid stems.
235 to 290	A species of Productella very common, also Atrypa reticularis. Atrypa spinosa. Schizophoria striatula. Stropheodonta demissa. Cyrtina sp. Gastropod sp. Crinoid stems.
290 to 295	No fossils observed.
295 to 313	Atrypa reticularis. Stropheodonta demissa. Schizophoria striatula. Euomphalus sp. Spirifer sp. Crinoid stems.
313 to 360	Fossils mostly in thin limestone beds. Atrypa reticularis. Schizophoria striatula. Cyrtina sp. Spirifer sp. Aviculopecten sp. Crinoid stems.

*Department of Geology, University of Alberta.

360 to 426	Fossils scarce. Atrypa reticularis. Cyrtina sp. Spirifer sp.
426 to 442	Spirifer sp. Schizophoria striatula. Atrypa reticularis. Leptodesma sp. Lingula spatulata. Eatonia sp.
442 to 490	Lingula spatulata very common and also Leptodesma sp., besides which— Reticularia Schizophoria striatula.
490 to 500	Atrypa reticularis.

"There were no fossils observed below this point.

"It is difficult to determine the age of this fauna on account of some of the species being new and the lack of good horizon markers. I would place it in the upper Devonian for the following reasons:

"1. The presence of Lingula spatulata.

"2. The resemblance of this fauna to that obtained in the upper Devonian as developed on Hay river,* some of the fossiliferous bands being absolutely identical.

"The entire absence of the typical middle Devonian fauna as developed on Great Slake lake."

SALT SPRING DEPOSITS ON SALT RIVER

In the First Annual Report on page 90 a description is given of the occurrence of numerous saline springs including those on Salt river. During the past summer I visited these springs when making a survey of the extreme northern portion of this province. Salt river is situated about twenty-five miles west of Fort Fitzgerald and Fort Smith, as shown on Plate 1, which is a key to various important mineral deposits within and close to the boundaries of the province. The river rises a few miles south of the 60th parallel of latitude, which is the northern boundary of the province. It flows in a northerly direction into the lower Slave river, which it enters about twenty miles below Fort Smith. The saline springs are situated along the base of an escarpment made up largely of gypsum and shale which fringes a broad flat prairie on the west side of Salt river, known as the "Salt Prairie." This prairie for a distance of from two to five miles from the escarpment in the vicinity of the springs is almost perfectly level. Over a large area it is void of all vegetation except a salt plant, Salicornia rubra, as determined by Professor F. J. Lewis. Occasional islands and peninsulas sparsely

*Geol. Surv., Can., Ann. Rept. (New Series) Vol. IV, 1888-89, Part D, pp. 70-71.
†Recent collections made by Mr. A. E. Cameron in that region.

covered with spruce and poplar rise from two to fifteen feet above the level of the prairie. A small creek tributary to Salt river drains the prairie, and the water in the creek is strongly saline.

Only five of the numerous saline springs were visited and these occur as bubbling springs, small streamlets, and as mere threads of saline water rising to the surface close to the escarpment, or coming directly from the base of the escarpment.

At the time of our visit to these springs on July 4 the flow was very small. From one of the principal springs there were about 150 tons of salt accumulated on the surface, but the flow had practically ceased. Considering the quantity of salt present the flow from these springs must have been considerably greater in the earlier part of the season.

The brine from these springs precipitates the sodium chloride as soon as it comes in contact with the atmosphere; in this way a deposit of salt accumulates. At the time of our visit a quantity of salt available about the springs which were observed was estimated to be about 400 tons. At the Mission spring, situated about six miles south of the forks of Salt river, the deposit of sodium chloride had a depth of three feet and measured less than 100 feet in diameter.

At the "New Salt Spring," about a mile south of the Mission spring, the brine at one point observed was rising in a small basin so fully saturated that salt crystals were being formed on the surface of the pool, and were floating down the streamlets to add to the deposit.

Analysis 1 was made from brine taken from one of the "New Salt Springs." The specific gravity of the brine was 1.203.

Analysis 2 represents the composition of the water from the Mission spring. The specific gravity of this brine was 1.198.

Analysis 3 represents the composition of the salt deposited at the "New Salt Spring." These analyses were made by J. A. Kelso in the Industrial Laboratory at the University of Alberta.

	1	2	3
Sodium chloride	98.65	98.51	95.50
Calcium carbonate	0.07	0.08	....
Calcium sulphate	1.14	1.09	....
Magnesium chloride	0.14	....	....
Magnesium sulphate	....	0.32	....
Sodium sulphate	....	....	3.96
Lime	....	....	0.00
Magnesia	....	....	0.00
Insoluble	....	....	0.14
Ignition loss	....	....	0.20

About five tons of the salt from these springs and from those owned by the Hudson's Bay at the forks of Salt river are collected annually. The salt is used at Fort Smith and at trading posts and missions in the lower Mackenzie district.

Arrangements have been made by the Mackenzie Fisheries Ltd. to make use of this salt next season at their fishing plant, which was constructed in 1920 on the north shore of Lake Athabasca, near the head of Black bay. Salt from these springs was purchased last season by our party at Fort Smith for ten cents per pound.

SENLAC SALT LAKE

Senlac salt lake is situated in the southeast half of section 30, township 39, range 25, west of the third meridian, and in the northeast half of section 19 in the same township and range. This lake lies about eighteen miles east of the inter-provincial boundary in Saskatchewan, but since an attempt is being made to recover salt from these sources a few notes might here be added on the occurrence.

The area of the lake is about 185 acres and lies in a depression in an area of rolling topography. The lake is close to the old Sounding Lake-Battleford trail, and about ten miles southeast of Senlac on the Canadian Pacific railway. In the dry season the bottom of the lake is exposed and consists of a mud containing numerous salt crystals. Around the margin of the lake the only vegetation which grows is a salt plant, Salicornia rubra. This plant is abundant and it seems to indicate that the mud contains a high percentage of sodium chloride.

A company has been formed for the purpose of recovering sodium chloride from the brine by evaporation. A plant, forty-eight by eighty-four feet, has been erected with evaporation pans, and the company expects to produce salt early in 1921.

Eight wells have been put down at different points about the centre of the lake. These wells range in depth from twenty-five to 102 feet. Into these wells the brine rises and an attempt has been made to evaporate the brine by solar process. The following analyses represent the composition of the product obtained by solar evaporation:

	1	2
Insoluble	0.28	0.82
Calcium sulphate	1.35	1.51
Magnesium chloride	0.08	0.04
Sodium chloride	98.08	97.41

(1) Represents product obtained from solar evaporation pans.

(2) Salt taken from the lake during dry season.

The brines in the wells are quite concentrated and many tests have been made on the same with the salimeter. Tests as high as 98 salimeter degrees have been obtained; this represents 25.6 per cent sodium chloride. Saturated brine contains 26.5 per cent salt.

The following analysis was made from brine collected in September from well No. 1:

Calcium carbonate	0.35
Calcium sulphate	4.55
Magnesium chloride	3.70
Sodium chloride	91.40

SODIUM SULPHATE

During the past year considerable interest has arisen over the occurrence of deposits of pure sodium sulphate in various lakes in the vicinity of the Alberta-Saskatchewan boundary.

Sodium Sulphate is a hydrous sulphate of sodium better known as Glauber salt, and is also known under mineralogy as Mirabilite. It is a white saline material which is readily soluble in water and occurs in lake deposits and also as an incrustation on the surface of soils, particularly in regions where the annual rainfall is small. In some localities it is known as "white alkali" in contrast to "black alkali," which is sodium carbonate.

In Western Saskatchewan and in Eastern Alberta there are a number of lakes or lake basins which contain deposits, in some cases very extensive, of quite pure glauber salt. Only one of any importance has yet been found in Alberta, although there are many lakes in which the waters, though saline, contain mixed salts. Commonly associated with sodium sulphate are magnesium sulphate and calcium chloride.

DESCRIPTION OF DEPOSITS

There is a deposit of pure sodium sulphate situated in the south half of section 12, township 50, range 11, west of the fourth meridian, about six miles southwest of the town of Minburn on the main line of the Canadian National railway, about 100 miles east of Edmonton. This deposit forms the bed of a lake which covers about thirty acres. The deposit consists of clear crystalline glauber salt and is reported to have a depth of from ten to fourteen inches. It is reported that a conservative estimate of the deposit available has been given as over 100,000 tons of remarkably pure sodium sulphate.

This lake is usually covered with a few inches of water in the spring time but this water soon becomes more or less saturated with the dissolved sodium sulphate. It is believed that springs on the north shore of the lake are responsible for this deposit and are still depositing salt in the lake. An analysis made at the University of Alberta gave the following results:

Insoluble	0.78
Calcium sulphate	0.36
Magnesium sulphate	0.84
Potassium sulphate	0.20
Sodium chloride	0.32
Sodium sulphate and water of crystallization	97.50

It is the intention of those who are interested in this deposit, which is only three and three-quarters miles from the railway, to produce this mineral for the market. Already a small quantity has been sold locally for agricultural purposes and some has been shipped to Winnipeg for commercial use.

FUSILIER DEPOSIT

Another deposit of sodium sulphate occurs in the east half of section 17, township 34, range 27, west of the third meridian, about five miles north of the railway at Fusilier, Saskatchewan, and eight miles east of the Alberta boundary. The deposit forms the bed of a lake which covers an area of about fifty-five acres. In the springtime the surface of the lake is covered with water which has more or less sodium sulphate dissolved in it, but throughout the summer the lake bed is exposed. This deposit consists of pure crystalline sodium sulphate which varies in depth from a few inches along the edges of the deposit to a maximum of over ten feet as proven by test pits which have been put down. The deposit is renewed by brine which rises from some source yet undetermined. From observation made of this deposit a conservative estimate of the quantity available would seem to be about one million tons. The deposit is owned by the "Soda Deposits Limited," with Mr. J. O. Williams of Calgary as managing director. A spur will be constructed from the railway to the deposit, but to date a quantity of the sodium sulphate has been brought to the railway by motor trucks and shipped eastward to be used in the pulp industry.

The quality of this sodium sulphate is remarkably pure as is shown in the following analyses made in the Industrial Laboratories, University of Alberta:

	1	2	3	4
Magnesium sulphate	0.15	0.12	....	....
Sodium chloride	0.08	0.08	....	0.09
Calcium sulphate	....	0.14	....	....
Potash	....	....	....	....
Insoluble residue	1.10	....	....	....
Sodium sulphate and water of crystallization	98.57	99.63	99.78	99.82

These analyses were all made from samples taken within three feet of the surface of the deposit.

COURT DEPOSIT

Another deposit of sodium sulphate which was examined is situated in the northwest quarter of section 10, township 33, range 28, west of the third meridian. This lake lies two miles south of Court, Saskatchewan, on the Lacombe-Kerrobert branch of the Canadian Pacific railway, and five miles east of the Alberta boundary. The area of this lake is about twenty acres and the lake lies in a long depression between rolling hills of glacial origin. When this lake was visited in May the sodium sulphate deposit could be observed only about the margin of the lake, but later in the season it was stated that very little water would remain on the surface of the deposit.

Mr. John Nelson, who owns the Victoria claim on this deposit, stated that the occurrence of three feet of sodium sulphate below six to eight inches of mud mixed with sulphate crystals had been proven at the claim post, which can be seen near the centre of the lake. Springs are reported to be visible during the dry season, but these were not observed on account of the high stage of water in this basin. Some of the sodium sulphate collected along the shore was cloudy with dust particles and silt, but other material is remarkably pure.

Analysis No. 1 was made from the purer material, while analysis No. 2 represents the composition of the brine taken from the shore of the lake.

	1	2
Magnesium sulphate	0.09	1.29
Sodium chloride	0.09	0.32
Calcium sulphate	....	0.97
Potash	....	....
Insoluble residue	....	....
Sodium sulphate and water of crystallization	99.72	97.31

There is reported to occur a very large deposit of sodium sulphate about twenty miles north of Maple Creek, Saskatchewan, on the main line of the Canadian Pacific railway. No details have been obtained of this deposit other than that it is believed to contain several million tons of sodium sulphate sufficiently pure to be of commercial value.

Large deposits of Astrakanite have been reported to occur in Mustiki lake, which is situated near Kaskakee springs, in Saskatchewan. Estimates as high as nine million tons are reported to occur in these deposits and some of the mineral has been shipped into Ontario for the manufacture of Glauber and Epsom salts.

Natural sodium sulphate is not common in deposits sufficiently large to be of economic value. The deposits in Saskatchewan and Alberta are somewhat unique on account of the purity of the salt which they contain.

Sodium sulphate has many uses, as Glauber for medicinal purposes and especially in the manufacture of paper pulp by sulphate process. Sodium sulphate is also used in the manufacture of plate glass, window glass and in dyeing and coloring. In North America most of the sodium sulphate has been obtained in the manufacture of hydrochloric acid from sodium chloride. This product is known commercially as "salt cake." As there is an apparent demand, especially in the pulp industry in Canada, for sodium sulphate, development of pure deposits of this mineral in Alberta and Saskatchewan is contemplated.

TALC

Canada in 1919 produced 18,842 tons of talc. Most of this came from altered magnesium limestones at Madoc, Hastings County, Ontario.

Talc has such a variety of uses that although the product may not be absolutely pure, some use can be found for it. The pure grades of talc are used for toilet powders, shaving cream, filler for paper, a base for heavy lubricants, soap adulterants, sizing cloth, for dressing leather, and it has even been known to be used for adulterating food. Talc is also used as a furnace lining for fireless cookers, fire resistant paint, and for the tips of gas burners. When talc can be sawn in larger slabs it is used for table tops, sinks, laundry tubs, mantels, switch boards, sanitary appliances, and foot warmers. These and other uses make it important that consideration should be given to any known occurrence of talc.

A deposit of talc occurs twenty-five miles west of Banff on the west side of Vermilion Pass, close to the continental divide, which is also the inter-provincial boundary line. This point is reached from Banff by an automobile road, which follows up the north side of the Bow river to Castle mountain station, then crosses the Bow and follows up Vermilion creek over the pass by the same name. This is the inter-provincial automobile road to the Pacific coast, and it is now open for some distance west of Vermilion pass. The deposit is situated about 750 feet above the automobile road on the east slope of Mount Whymper, so this deposit, although it occurs a few miles west of the inter-provincial boundary line, would be developed from the Alberta side.

This occurrence indicates that other deposits may be found on the Alberta side of the continental divide. The talc occurs as irregular pockets and lenses in middle Cambrian magnesium limestones. The talc has a greenish-grey color and is massive, although pockets of fibrous talc also occur. The masses of talc are extremely irregular in their extent, but four of these have already been opened up by prospect and the indications are favorable for the development of an economic deposit. The widest mass opened up is about eight feet and the quality is remarkably uniform throughout. The masses of talc are considerably fractured, so that it would be impossible to produce sawn slabs of more than a foot or two feet in diameter. In some of these masses associated with the talc are well-defined crystals of quartz and crystals of calcite and dolomite.

The formation in this locality has not yet been thoroughly prospected and the chances are favorable for the discovery of even larger pockets than those already opened up.

The magnesium limestones which contain the talc at Mount Whymper continue to the southeast along the continental divide and also to the northwest, but no important lenses of talc have been found outside of this locality. This talc when ground forms a white powder, which is free from grit, so that the mineral can be used for almost any product in which talc is an essential.

ANALYSES OF TALC

	1	2	3	4
Silica	64.06	62.91	61.52	61.35
Alumina	2.10	....	....	....
Iron oxide	....	1.68	0.84	4.42
Lime	....	....	....	0.82
Magnesia	30.13	31.12	31.38	26.03
Soda	1.78	1.17	....	0.62
Water	1.41	1.53	5.42	5.10

Analysis No. 1 was made in the Industrial Laboratory at the University of Alberta.

Analysis No. 2 was made for Mr. O. Boucher, one of the owners of the property.

Analysis No. 3 is a high grade Indian talc which is used largely for the gas burner manufacture.

Analysis No. 4 is a high grade talc from North Caroline which has been found suitable for the manufacture of gas burners.*

There recently appeared a small pamphlet on talc in fire-resistant paint, published by Mr. R. D. Ladoo, Mineral Technologist, U.S. Bureau of Mines.†

This pamphlet points out the erroneaus opinion held by many as to the constituents in fire-resistant paints. In the formula of certain paints used for this purpose, "asbestine," which is magnesium silicate, forms 33 per cent by weight of the total liquid pigment. It has frequently been noted that asbestine was in some way related to "asbestos." Regarding this point Mr. Ladoo says,

*Diller, J. S., Fairchild, J. G., and Larsen, E. S., Econ. Geol., Vol. 15. No. 8, 1920, 665.

†Reports of Investigations, No. 2150, U.S. Bureau of Mines, Washington, D.C., August, 1920.

"that asbestine is not asbestos, but is a trade name for a fibrous variety of talc mined in the Gouvernour district in Lawrence County, New York." He, however, states that this research "should afford talc producers a new market of importance, but it can only be won by removing the erroneous opinion held in some quarters in the paint industry that 'asbestine' is ground 'asbestos.'"

J. S. Diller, discussing the uses of talc and soapstone, states that "some of the large producers have one or more trade names, such as 'Verdolite,' 'Asbestine,' 'Agalite,' and 'Talclay,' by which their special products are known in the market, but all these products are included under 'commercial talc.' Much of the material included under commercial talc does not belong to that mineral species."*

As most talcs are more or less fire-resistant, it is quite possible that the talc from the Vermilion pass deposit can also be used in the manufacture of this new paint. In any case the deposit is worth developing as it is certain that some commercial use can be made of this mineral as it occurs in the deposit described above. The extent of the deposit can not be ascertained until further development has been carried on. Steps are being taken by those interested to have this deposit developed, in which case the talc would have to be hauled down to the railway as Castle Mountain station. It is the intention to construct a road for this purpose from the automobile road at Vermilion pass up to the property, but no difficulties should be encountered in building suitable roads for this purpose.

*Mineral Resources U.S., 1912, p. 1142.

APPENDIX

The following analyses have been made from samples collected during the field operations in 1920. These samples have been analyzed in the Industrial Laboratories at the University of Alberta under the directorship of Mr. J. A. Kelso. Most of these analyses are given throughout the report under the minerals contained in each, but for convenience they are listed here collectively.

Nos. 1, 2, 3, 4. Sodium Sulphate from lake covering about 55 acres, nine miles north of Fusilier.

	No. 1	No. 2	No. 3	No. 4
Magnesium sulphate	0.15	0.12	....	....
Sodium chloride	0.08	0.08	....	0.09
Calcium sulphate	....	0.14	....	....
Potash	....	....	....	....
Insoluble residue	1.10	....	....	....
Sodium sulphate and water of crystallization	98.57	99.63	99.73	99.82

No. 5. Sodium Sulphate from a small lake about two miles south of Court.

Magnesium sulphate	0.09
Sodium chloride	0.09
Calcium sulphate	....
Potash	....
Insoluble residue	....
Sodium sulphate and water of crystallization	99.72

No. 6. Brine from Sodium Sulphate lake two miles south of Court.

Total solids .... 1.582 pounds per gallon

Analysis of solids—

Magnesium sulphate	1.29
Sodium chloride	0.32
Calcium sulphate	0.97
Sodium sulphate	97.31

No. 7. Sodium Sulphate (Glauber Salt) from a small lake east of Birch lake and southwest from Minburn.

Insoluble	0.78
Calcium sulphate	0.36
Magnesium sulphate	0.84
Potassium sulphate	0.20
Sodium chloride	0 32
Sodium sulphate and water of crystallization	97.50

ANALYSES (Continued)

	No. 8	No. 9
Insoluble in water	4.75	3.02
Analysis of water soluble—		
Sulphuric anhydride (SO_3)	67.18	73.56
Alumina (Al_2O_3)	16.21	10.04
Iron oxide (Fe_2O_3)	6.19	4.16
Lime	....	....
Magnesia (MgO)	8.24	9.74
Potash (K_2O)	2.06	2.32

	No. 10	No. 11	No. 12	No. 13	No. 14
Silica	66.42	4.22	3.02	76.46	58.72
Iron oxide	26.14	58.14	58.48	2.48	4.62
Alumina	4.38	4.88	6.12	15.02	9.31
Lime	.00	.12	.13	0.18	8.12
Magnesia	.00	.00	.00	0.14	0.98
Loss on ignition	2.08	32.16	31.06	4.02	15.46
Alkalis, etc.	.00	.00	.00	1.70	2.78
Equivalent of oxide of iron as metallic iron	18.49	40.69	40.93	....	....

No. 15

Metallic iron	59.08
Silica	4.03
Alumina	2.30
Ferric oxide	84.40
Lime	0.09
Titanium dioxide	3.42
Phosphorus	....
Sulphur	0.09
Vanadium	trace

No. 8. Alum Rock in greyish-yellow irregular fragments from upper Peace River district in the vicinity of Spirit river—exact locality not given.

No. 9. Alum Rock from same locality.
No. 10. Hematite Iron Shale from the lower MacKenzie valley, near Fort Norman.
No. 11. Bog Iron (ochre) from the upper part of Red Clay creek, north of Shandro on the North Saskatcheewan river (36, 58, 15, west of 4th).
No. 12. Bog Iron from bed of stream Red Clay creek, in section 36, township 58, range 15, west of the 4th meridian.
No. 13. Clay Iron Shale from Benton shales exposed along Sheep river.
No. 14. Ironstone nodule from Benton shale, Sheep River, Alberta.
No. 15. Magnetite Shale from Burmis, Alberta.

	No. 16		No. 17		No. 18	
Loss on air drying	3.4 per cent		1.8 per cent		2.8 per cent	
	As Received	Air Dried	As Received	Air Dried	As Received	Air Dried
Moisture	4.3	0.9	3.3	1.5	3.5	0.7
Volatile matter	15.4	16.0	17.2	17.5	16.2	16.7
Fixed carbon	60.3	62.4	63.2	64.4	59.5	61.3
Ash	20.0	20.7	16.3	16.6	20.8	21.3
B.T.U.	11,630	12,040	12,290	12,510	11,630	11,965

	No. 19		No. 20		No. 21	
Loss on air drying	1.8 per cent		2.6 per cent		2.2 per cent	
	As Received	Air Dried	As Received	Air Dried	As Received	Air Dried
Moisture	2.4	0.6	3.0	0.4	2.7	0.5
Volatile matter	15.2	15.5	15.4	15.7	14.0	14.3
Fixed carbon	59.7	60.8	57.9	59.7	58.1	59.4
Ash	22.7	23.1	23.7	24.4	25.2	25.8
B.T.U.	11,430	11,640	11,390	11,690	11,180	11,430

ANALYSES (Continued)

No. 16. Coal from Seam No. 6, Ford Coal Claims, township 17, range 6, west of the 5th meridian, on the Highwood river.

No. 17. Coal from No. 10, Ford Coal Claims, Highwood river.

No. 18. Coal from Seam No. 5, upper eleven feet, Ford Coal Claims, Highwood river.

No. 19. Coal from Seam No. 5, average of the upper and lower parts of the seam which are separated by two feet of shale, Ford Coal Claims.

No. 20. Coal from Seam No. 5, lower eighteen feet, Ford Coal Claims.

No. 21. Coal from Seam No. 2, Ford Coal Claims.

	No. 22		No. 23		No. 24	
Loss on air drying	3.0 per cent		7.2 per cent		1.0 per cent	
	As Received	Air Dried	As Received	Air Dried	As Received	Air Dried
Moisture	9.9	7.1	17.8	11.5	8.2	7.3
Volatile matter	31.1	32.0	31.9	34.3	33.4	33.7
Fixed carbon	39.8	41.0	40.1	43.2	49.0	49.5
Ash	19.2	19.9	10.2	11.0	9.4	9.5
B.T.U.	9,715	9,810	9,735	10,490	11,335	11,450

No. 22. Average sample of coal from Mynher Seam at Mile 56 (Lovett) on Alberta Coal Branch.

No. 23. Average sample of coal from ten-foot seam being prospected at Mile 49½, near the Foothills Collieries, Alberta Coal Branch.

No. 24. Average sample from Tunnel Prospect, at Mile 51½, on the Alberta Coal Branch.

ANALYSES (Continued)

	No. 25		No. 26		No. 27	
Loss on air drying	1.0 per cent		5.6 per cent		0.0 per cent	
	As Received	Air Dried	As Received	Air Dried	As Received	Air Dried
Moisture	6.4	5.5	17.33	12.42	0.2	0.2
Volatile matter	36.3	36.7	30.92	32.75	15.2	15.2
Fixed carbon	48.8	49.2	45.02	47.69	79.1	79.1
Ash	8.5	8.6	6.73	7.14	5.5	5.5
B.T.U.	11,525	11,640	9,620	10,190	14,620	14,620

	No. 28		
Loss on air drying	0.0 per cent		
	As Received	Air Dried	
Moisture	0.3	0.3	Sulphur content in Nos. 31 and 32, 0.2 per cent
Volatile matter	17.4	17.4	
Fixed carbon	72.8	72.8	
Ash	9.5	9.5	
B.T.U.	13,890	13,890	

No. 25. Average sample from the seam being worked at Mile 50, Foothills Collieries, Alberta Coal Branch.

No. 26. Specimen of coal from new prospect at Carbon, Alberta.

No. 27. Sample specimen, Coal Seam No. 2, Ford Coal Claims, Highwood river.

No. 28. Sample specimen, Coal Seam No. 5, Ford Coal Claims, Highwood river.

ANALYSES (Continued)

No. 29. Crude Oil extracted from Bituminous Sands at Fort McMurray by destructive distillation treatment.

	Degrees Cent.	Per Cent	Specific Gravity
Original Sample—			
Water by volume		3.2	
Sediment, tarry residue		.5	
Oil by volume		96.3	19.5 Be.
Distillation of Oil—			
1st drop	70		
1st fraction	80	1.0	
	90	2.0	
	100	2.6	
	110	.6	
	120	.6	
	130	1.0	
	140	.6	
	150	1.3 — 9.7%	51.5 Be.
2nd fraction	160	1.3	
	170	1.0	
	180	.6	
	190	.6	
	200	1.0	
	210	1.0	
	220	1.6	
	230	2.0 — 9.1%	36.5 Be
3rd fraction	240	1.3	
	250	2.0	
	260	1.6 — 4.9%	25.0 Be.
4th fraction	270	3.0	
	280	2.0	
	290	3.0	
	300	5.3 — 13.3%	24.0 Be.
5th fraction	325	18.6 — 18.6%	23.0 Be.
6th fraction	350	14.0 — 14.0%	18.5 Be.
7th fraction	380	23.0 — 23.0%	15.5 Be.
Residue and loss		7.4 — 7.4%	

The above analysis indicates commercially—

Commercial gasoline	9.7 per cent
Illuminating oils	27.3 per cent
Light lubricants	32.6 per cent
Medium lubricants	23.0 per cent

ANALYSES (Continued)

No. 30. Light oil product obtained by heating Bituminous Sands in place with electric heater designed by Mr. D. Diver.

Original Sample—	Degrees Cent.	Per Cent	Specific Gravity
Water by volume		5.9	
Sediment		.8	
Oil by volume		93.3	29.5 Be.
Distillation of Oil—			
1st drop	150		
1st fraction	160	0.5	
	170	1.5	
	180	1.5	
	190	2.0	
	200	2.0	
	210	5.0	
	220	9.5	
	230	8.5 — 30.5%	34.5 Be.
2nd fraction	240	12.2	
	250	12.2	
	260	16.0 — 40.4%	30.0 Be.
3rd fraction	270	8.0	
	280	9.0	
	290	3.5	
	300	6.0 — 26.5%	25.5 Be.
Carbon residue and loss		2.6	

ANALYSES (Continued)

No. 31. Product obtained in the same way as No. 34.

		Degrees Cent.	Per Cent	Specific Gravity
Original Sample—				
Water by volume			5.9	
Sediment, etc.			4.3	
Oil by volume			89.8	27.0 Be.
Distillation of Oil—				
1st drop		150		
1st fraction		170	0.5	
		180	0.5	
		190	0.5	
		200	1.7	
		210	1.2	
		220	3.0	
		230	5.0 — 12.4%	34.0 Be.
2nd fraction		240	6.2	
		250	11.7	
		260	12.0 — 29.9%	30.0 Be.
3rd fraction		270	12.0	
		280	12.0	
		290	12.0	
		300	8.5 — 44.5%	26.0 Be.
4th fraction		325	8.5 — 8.8%	23.0 Be.
Carbon residue and loss			4.7 — 4.7%	

The above analysis indicates commercially—

Illuminating oils	86.8 per cent
Light lubricants	8.5 per cent
Gasoline	0.0 per cent

No. 32. Crude Oil obtained from the well now down to 4,235 feet drilled by the Record Oil Company in section 4, township 19, range 2, west of the 5th meridian.

Specific gravity of oil, 54 Be.

Distillation tests—

Commences to distil at 60 degrees Cent.

From 60 to 210 Cent.	79.3 per cent
210 to 300 Cent.	14.0 per cent
300 to 325 Cent.	3.3 per cent
325 to 350 Cent.	2.0 per cent
Residue and loss	1.4 per cent

Commercial indication—

Commercial gasoline	79.3 per cent
Burning oil	14.0 per cent
Light lubricants	5.3 per cent

ANALYSES (Continued)

No. 33. Crude Oil collected from the Fort Norman well immediately after the discovery and during the blow-out of oil and gas.

Original Sample, 36 degrees Be.

	Per cent
Distillation of oil—	
70 to 150 degrees C.	21.5
150 to 300 degrees C.	37.5
300 to 350 degrees C.	34.0
350 to 375 degrees C.	6.0
Loss	1.0
Commercial indication—	
Commercial gasoline	21.5
Illuminating oils	37.5
Light lubricants	34.0
Medium lubricants	6.0

No. 34. Talc from Mount Whymper, two miles from the Vermilion Pass, west of Banff, Alberta.

Silica	64.06
Oxide of aluminum	2.10
Iron oxide	64.06
Lime	.00
Magnesia	30.13
Ignition loss	1.41
Soda, etc.	1.78

No. 35. Mica (Muscovite) from the west side of the Finlay river, nine miles southwest of Fort Grahame.

Silica	50.42
Alumina	37.20
Oxide of iron	1.20
Lime	0.06
Magnesia	0.04
Potash	7.14
Water	3.94

No. 36. Common Salt, coarsely granulated, taken from the solar evaporation vats near Senlac, Saskatchewan.

Insoluble	0.28
Calcium sulphate	1.35
Magnesium chloride	0.08
Sodium chloride	98.08

No. 37. Coarse dark grey salt taken from the lake bottom during dry season, Senlac, Saskatchewan.

Insoluble	0.82
Calcium sulphate	1.51
Magnesium chloride	0.04
Sodium chloride	97.41

ANALYSES (Continued)

No. 38. Brine from Well No. 1, Senlac, Saskatchewan.

Total solids—

Grams per litre	148.776
Pounds per gallon	1.4877

Analysis of solids—

Calcium carbonate	0.35
Calcium sulphate	4.55
Magnesium chloride	3.70
Sodium chloride	91.40

No. 39. Sulphurous saline water, very clear, from the mouth of Cut Bank creek, Clearwater river, in township 89, range west of the 4th meridian.

Total solids—

Grams per litre	2.16
Pounds per gallon	.0216
Specific gravity	1.001

Analysis of solids—

Sodium chloride	81.71
Calcium carbonate	0.60
Calcium sulphate	0.00
Magnesium sulphate	0.00
Sodium sulphate	0.00
Magnesium chloride	0.00
Magnesium carbonate	3.61
Sodium carbonate	14.08

Sulphuretted hydrogen—heavy.

No. 40. Brine from the Mission Salt spring on the Salt river, close to the northern boundary of Alberta.

Total solids—

Grams per litre	313.3
Pounds per gallon	3.133
Specific gravity	1.198

Analysis of solids—

Sodium chloride	98.51
Calcium carbonate	0.08
Calcium sulphate	1.09
Magnesium sulphate	0.32
Sulphuretted hydrogen	0.00

ANALYSES (Continued)

No. 41. Brine from the new salt spring, Salt river, close to northern boundary of Alberta.

Total solids—	
Grams per litre	323.7
Pounds per gallon	3.237
Specific gravity	1.203
Analysis of solids—	
Sodium chloride	98.65
Calcium carbonate	0.07
Calcium sulphate	1.14
Magnesium chloride	0.14

No. 42. Salt deposited by the spring near the Salt river at the northern boundary of Alberta.

Sodium sulphate	3.96
Lime	0.00
Magnesia	0.00
Insoluble	0.14
Sodium chloride	95.50
Ignition loss	0.20

No. 43. Saline water from the well drilled for oil one mile below Fort McKay on the west bank of the Athabasca river

Total solids—	
Grams per litre	217.2
Pounds per gallon	2.172
Specific gravity	1.124
Analysis of solids—	
Sodium chloride	96.19
Calcium carbonate	0.55
Calcium sulphate	0.34
Magnesium sulphate	2.09
Sodium sulphate	0.83
Sulphuretted hydrogen—slight.	

No. 44. Bentonite clay from the vicinity of the Battle river east of Camrose. Sample submitted by Mr. J. O. Williams of Calgary.

Silica	69.46
Iron oxide	3.35
Alumina	16.25
Lime	2.06
Magnesia	2.76
Ignition Loss	5.04
Alkalis, etc.	1.08

The remaining analyses were made from samples from the core of salt well drilled at Fort McMurray by the Provincial Government in order to prove up the occurrence of rock salt.

ANALYSES (Continued)

	No. 45	No. 46	No. 47	No. 48	No. 49	No. 50	No. 51
Siliceous residue	25.16	1.02	2.02	0.34	2.22	0.32	0.62
Lime (CaO)	28.39	32.81	33.88	40.56	38.70	39.79	39.29
Magnesia (MgO)	2.98	5.14	0.98	0.16	0.85	0.61	0.28
Sulphuric anhydride (SO_3)	35.38	58.11	48.62	57.94	54.00	58.01	55.80
Ignition loss	7.62	2.72	14.01	0.92	4.22	0.76	3.91

	No. 52	No. 53	No. 54
Water soluble	53.78	Solid matter, 2.718 lbs. per gallon	1.8242 lbs. per gallon
Insoluble matter	46.32		
Analysis of water soluble		Analysis of solids	
Calcium sulphate ($CaSO_4$)	1.94	2.48	1.84
Magnesia	0.00	0.00	0.00
Sodium chloride (NaCl)	97.28	97.01	97.64
Ignition loss	0.40	0.21	0.28
Potash	0.00	0.00	0.00

No. 45. Salt Well Core, McMurray, depth 516 feet.
No. 46. Salt Well Core, McMurray, depth 534 feet.
No. 47. Salt Well Core, McMurray, depth 564 feet
No. 48. Salt Well Core, McMurray, depth 582 feet.
No. 49. Salt Well Core, McMurray, depth 596 feet.
No. 50. Salt Well Core, McMurray, depth 601 feet.
No. 51. Salt Well Core, McMurray, depth 647½ feet. Salt capping.
No. 52. Salt Well Core, McMurray, depth 660 feet.
No. 53. Salt Well Core, McMurray, depth 660 feet, brine.
No. 54. Salt Well Core, McMurray, depth 685 feet, brine.

ANALYSES (Continued)

	No. 55	No. 56	No. 57	No. 58	No. 59	No. 60	No. 61
Insoluble in water	34.20	0.24	0.30	0.46	4.22	5.62	5.20
Calcium sulphate	0.00	4.74	2.78	0.90	0.00	0.00	0.00
Sodium chloride	0.00	94.78	96.53	98.46	1.99	0.38	0.58
Magnesia	6.66	0.00	0.00	0.00	1.25	0.00	0.24
Alkalis, etc.	4.33	0.00	0.00	0.00	0.00	0.00	0.00
Lime	17.36	0.00	0.00	0.00	37.42	34.58	35.27
Iron oxide	2.00	0.00	0.00	0.00	0.00	5.98	0.00
Alumina	9.20	0.00	0.00	0.00	0.00		0.00
Sulphuric anhydride	0.63	0.00	0.00	0.00	54.05	49.07	49.16
Ignition loss	25.62	0.00	0.18	0.00	0.72	4.01	9.02

	No. 62	No. 63	No. 64	No. 65	No. 66	No. 67	No. 68
Residue	1.02	4.72	7.72	2.01	4.02	0.00	1.38
Lime	29.46	35.84	33.00	35.56	37.04	40.78	40.00
Magnesia	0.00	0.46	0.09	6.66	0.12	0.37	0.09
Iron oxide and alumina	4.02	0.00	0.00	0.00	0.00	0.00	0.00
Sulphuric anhydride	41.88	52.46	47.09	50.67	54.62	58.34	57.44
Sodium chloride	20.90	5.02	4.72	0.32	1.02	0.00	0.00
Ignition loss	2.78	1.24	7.30	4.52	3.01	0.42	1.07

No. 55. Salt Well Core, McMurray, depth 546 feet.
No. 56. Salt Well Core, McMurray, rock salt.
No. 57. Salt Well Core, McMurray, depth 645 feet.
No. 58. Salt Well Core, McMurray, depth 650 feet.

ANALYSES (Continued)

No. 59. Salt Well Core, McMurray, depth 662 feet.

No. 60. Salt Well Core, McMurray, washings 664½ ft.

No. 61. Salt Well Core, McMurray, depth 665 feet.

No. 62. Salt Well Core, McMurray, depth 666 feet.

No. 63. Salt Well Core, McMurray, depth 671 feet.

No. 64. Salt Well Core, McMurray, depth 670-673 feet.

No. 65. Salt Well Core, McMurray, depth 676 feet.

No. 66. Salt Well Core, McMurray, depth 681 feet.

No. 67. Salt Well Core, McMurray, depth 684 feet.

No. 68. Salt Well Core, McMurray, depth 685½ feet.

INDEX

A

C

E

F

M

T

U

V

W

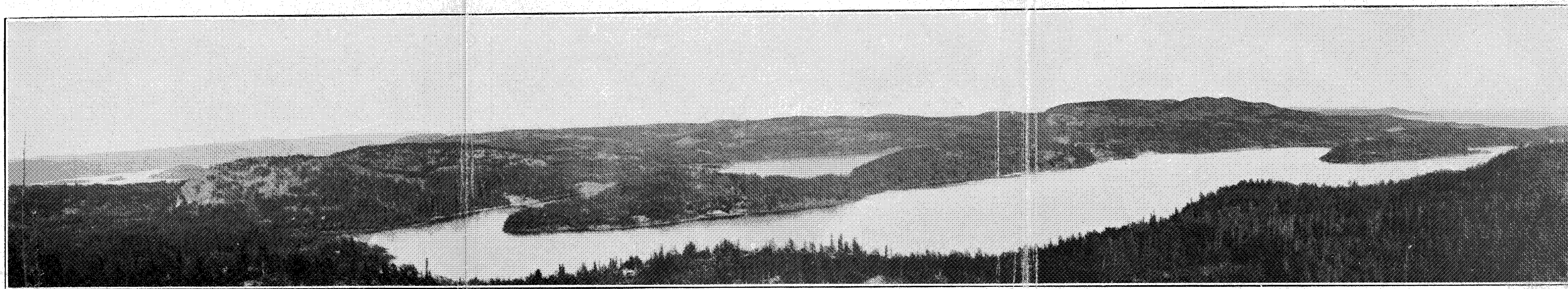


PLATE I.—Panoramic View of Fishhook Bay from west side, looking over Besmer and Valley Mineral Claims.

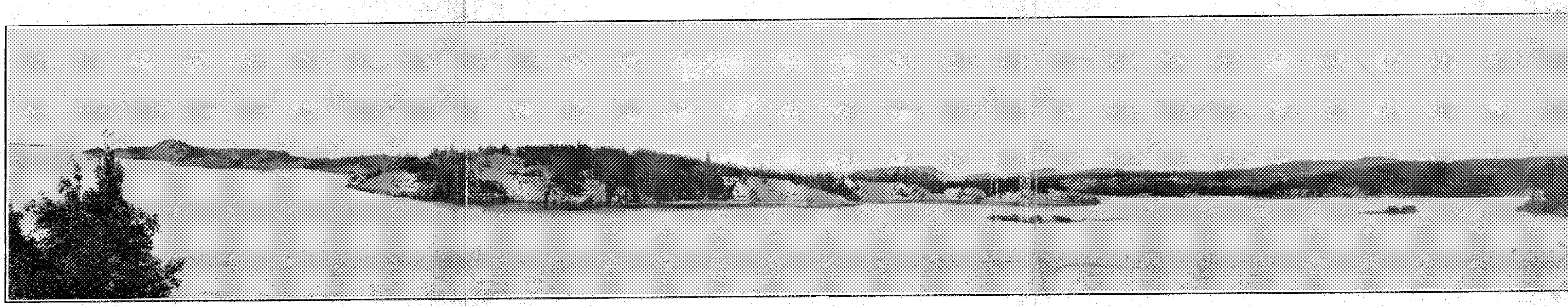


PLATE II.—Panoramic View of Outlet of Fishhook Bay from east side, looking over Jay Mineral Claim. Shows typical character of country.