FIRST ANNUAL REPORT

ON

THE MINERAL RESOURCES OF ALBERTA

BY

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CORRECTIONS

Page 14. Read "Cenozoic" for "Genozoic".

Page 15. In Table of Formations, interchange "Proterozoic" and "Paleozoic".

Page 30. Read "order given on page twenty-eight" for "order given on page one".

Page 35. Read "Quaternary" for "Quaxternary".

Page 35. Read "carbonaceous" for "barbonaceou".

Page 46. Read "eighty-seven" for "eighty".

Page 46. Read "fifteen" for "seventeen".

Page 66. Plate I referred to, has been omitted.

Page 72 Read "5.43" for "7.65" (Ferrous Bicarbonate).

Page 75. Read "12.165" for "0.069" (Chloride of Sodium).

Page 87. In foot note, read "Bulletin 325" for "Bulletin 323".

Page 102. Read "$140,760" for "$140,670" (value in bags and bbls.).

Page 102. Read "$496,048" for "$406,048" (value of salt imported from U. S., 1918).

Page 102. In Bibliography, read "p. 14 R." for "p. 15 C" Dawson).

EDMONTON, ALBERTA,

FEBRUARY 17, 1920.

HON. J. L. COTE, M. P. P.
Provincial Secretary,
Edmonton, Alberta.

SIR,—I herewith submit the First Annual Report on the Mineral Resources of Alberta.

The services of Dr. John A. Allan, of the University of Alberta, were obtained for the purpose of investigating deposits reported to exist in different parts of the province. Dr. Allan was also engaged during a portion of the year 1919, in preparing fairly comprehensive reports on the different mineral deposits in the province. These reports which are attached hereto, and will be added to each year as new information comes to hand, refer to the following minerals:

Bitumen,	Gypsum,	Petroleum,
Building Stone,	Iron,	Phosphate,
Clay,	Lead,	Potash,
Coal,	Mineral Springs,	Salt,
Copper,	Natural Gas,	Talc,
Gold,	Nickel,	Zinc.

The question of the erection of a laboratory for research work has been given consideration, but it has been decided that this work can be carried on more efficiently under the auspices of the University of Alberta, and arrangements have been made accordingly.

The question is also being considered of utilizing the different government power plants throughout the province for the purpose of showing which classes of coal are most suitable for certain purposes. A great deal of consideration is also being given to the question of obtaining a furnace suitable for Alberta coals.

The principal problems to which attention is being given are:

Utilization of tar sands,

Classification of coals,

Qualitative and quantitative determination of the mining resources of the province,

Development of clay deposits.

A library has been established in the Government Buildings of all scientific and other publications in connection with research work, and this library is being duplicated in the University.

During the month of July, 1919, a party of eight men was sent to Fort McMurray to carry on drilling operations for ascertaining the value and extent of the salt deposits reported to be in that neighborhood. This work is being done by means of a core drill, but operations have been delayed owing to the lack of transportation and the difficulty in getting repair parts for the machinery. Drilling operations were, however, commenced in September, 1919, and a depth of approximately 100 feet has been reached.

Considerable attention has also been given during the year to the development of the coal mining industry with a view to obtaining an increased market for Alberta coal in the Provinces of Manitoba and Saskatchewan.

Yours truly,

JOHN T. STIRLING.

LETTER OF TRANSMITTAL

JOHN T. STIRLING, ESQ.,
Chief Inspector of Mines,
Mines Branch,
Edmonton, Alberta.

SIR,—I have the honor to submit, herewith, a report on the Mineral Resources of Alberta. This report is made up of separate bulletins on eighteen different minerals which are known to occur in Alberta.

As this is the first report on the mineral resources of the province, it of necessity consists largely of a compilation of the information that had been published up to date, by the Geological Survey, and the Mines Branch, Ottawa, but which was scattered through numerous volumes of reports. The information in some of these reports was freely abstracted, but that containd in other reports was briefly summarized.

About four weeks were spent during the summer of 1919 in making a general field survey of some of the mineral deposits, chiefly those containing iron and salt. The results obtained from this source are also included in this report.

I have the honor to be, Sir,

Your obedient servant,

JOHN A. ALLAN.

University of Alberta,
March 1st, 1920.

Mineral Resources of Alberta

BY

JOHN A. ALLAN

INTRODUCTION

This report contains a preliminary study of most of the minerals which are known to occur in Alberta, in so far as the geological history is known. Much has yet to be done, and considerable field investigation must be carried out before the extent of the mineral resources of the Province of Alberta can be determined.

The details given in this report on each of the minerals consist essentially of a compilation of all available information, which has been abstracted from numerous reports and publications of the Geological Survey and the Mines Branch of Canada, and from various scientific journals. A field examination of some of the deposits was commenced in 1919, and the results obtained are also included in this first report on the mineral resources of the province. It is proposed to carry on detailed field surveys on various mineral deposits, commencing this summer, and these results will be published in succeeding reports. It must, therefore, be understood that the information contained in this report is preliminary in its scope, and that complete information will not be available until further field studies, and in some cases laboratory research studies, have been undertaken.

An attempt has been made in this report to summarize, and bring up to date, all available information which has been previously published on our mineral resources. This compilation entailed the perusal of hundreds of volumes, and the abstraction or summarizing of facts and details. In this work valuable assistance was rendered by Miss Grace A. Stewart, assistant in the Department of Geology at the University of Alberta.

In many cases the earlier reports have been summarized, or briefly abstracted, but in the case of some reports whole pages, sometimes several pages, have been copied. Accompanying the notes on most of the minerals mentioned, is a bibliography to which reference may be made if fuller details are required.

It will also be noted that in the case of certain mineral deposits known occurrences are mentioned, which are located beyond the northern boundary of the province in the Mackenzie Basin, or in eastern British Columbia, but in these cases the opening up of such deposits would be by way of transportation lines through Alberta.

During the season of 1919 special attention was given to occurrences of iron, in an attempt to determine if ore could be procured in or close to this province, which might be manufactured in Alberta where natural fuel as coal and natural gas is abundant. The notes on iron are therefore given in fuller detail in this report.

BITUMEN

The Alberta bituminous sands, more frequently called tar sands, cover an extensive area along the Athabaska river above and below McMurray. The outcropping beds of this immense body are exposed along the sides of the Athabaska Valley from Boiler Rapids, forty miles southwest of McMurray, to a point Pierre Au Calumet about seventy miles below McMurray. The bituminous sands also outcrop along the banks of the rivers and smaller streams which enter the Athabaska between these two points.

This bituminous formation has been examined at various times, but the most detailed study has been made by S. C. Ells, and his results were published in 1914 under the title "Preliminary Report on the Bituminous Sands of Northern Alberta," No. 281 of the Mines Branch, Ottawa. R. G. McConnell describes this unique occurrence of bitumen in the Annual Report of the Geological Survey for 1890-91.

The extent of the bituminous sands has not yet been accurately determined, but the outcrops examined show that at least sixteen hundred square miles are underlain by this formation. McConnell has estimated that these beds have a minimum distribution of one thousand square miles, whereas Ells states that an actual outcrop observed proved the extent to be not less than seven hundred and fifty square miles.

The area proven by the outcrop may be considered as triangular in shape with the apex pointing northward. The base of this triangle is forty-six miles wide between the most westerly outcrop at Boiler Rapids and the most easterly outcrop on the Clearwater and Christina rivers. The distance from this line as a base, to the most northerly outcrop on the Athabaska river, is about seventy miles.

It is known that the bituminous sands are much more extensive than the outcrops would indicate. At least ten thousand square miles are underlain by this formation and possibly more than fifteen thousand square miles. The bituminous sands form the basal member in the lower cretaceous series which occur in the Athabaska district. This formation has been called "The McMurray Formation" by McLearn.* He correlates the tar sand 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.

The tar sands are overlain by Clearwater shales and are underlain by limestone of Devonian age. Although there is a long time break represented between the Devonian and the Cretaceous, the beds in these two formations are nearly horizontal and are for the most part conformable.

The thickness of the bituminous sand varies from 125 feet to a maximum of about 225 feet. The lower limit of the formation is well defined, but the upper limit is not so pronounced. "In the majority of well exposed sections the richer material occurs in the lower part, shading off into the leaner grades in passing upward. In no instance was high grade sand found to directly underlie the superimposed shales, sandstones, and drift. It is also noticeable that the lower part of nearly all exposed sections consists of unstratified sands, and prior to impregnation by the bitumen these sands were apparently uncompact-

*McLearn, F. H., Geol. Surv., Can., Sum. Rept., Part C. 1918, Page 2.

ed. Consequently, the lower portion of the resulting bituminous sands is generally of a more or less homogeneous character. In passing upward, however, narrow bands of sandstones and occasional quartzites are found interbedded with the originally uncompacted sands. These non-bituminous strata gradually increase until, by their preponderance, they entirely replace the bituminous sand."*

This bituminous formation is the ordinary sandstone more or less saturated with bitumen. The colour of the beds varies from black to grey according to the percentage of saturation and the depth from the surface from which the sample is taken. In some cases the percentage of bitumen is so small that the sand grains are only coated with bitumen. On the whole the medium-grained sandstone is the highest grade.

The texture of the sandstone also varies considerably from a coarse grit to an extremely fine silt of which over eighty per cent. of the grains will pass through a 150 mesh screen. The following table shows the texture and richness of several samples collected by Ells and given on Page 79 of Bulletin No. 281.

Test Number	Passing Mesh									Per cent contained bitumen
	Source	200	100	80	50	40	30	20	10	
11	Athabaska river	2	11	54	16	10	5	2	.	14
12	Athabaska river	6	54	25	13	.	.	.	.	15
12	Athabaska river	7	77	14	2	.	.	.	.	16
15	Athabaska river	24	64	9	3	.	.	.	.	17
15	Athabaska river	3	38	19	40	.	.	.	.	9
16	Athabaska river	9	33	11	47	.	.	.	.	12
21	Athabaska river	3	5	1	8	7	15	33	27	15
21	Athabaska river	4	26	11	48	3	2	3	2	20
22	Athabaska river	11	70	14	5	.	.	.	.	12
47	Christina river	3	6	8	12	14	45	12	.	11
49	Christina river	3	15	11	70	1	.	.	.	14
52	Christina river	2	35	12	51	.	.	.	.	17
52	Christina river	4	34	16	46	.	.	.	.	15
39	Clearwater river	4	14	14	48	9	7	4	.	14
43	Hangingstone creek	3	22	9	51	9	4	2	.	15
31	Horse creek	5	38	8	47	2	.	.	.	16
32	Horse creek	5	47	16	32	.	.	.	.	16
33	Horse creek	5	36	14	45	.	.	.	.	15
34	Horse creek	10	33	19	37	1	.	.	.	17
35	Horse creek	4	27	11	56	2	.	.	.	9
35	Horse creek	7	77	5	11	.	.	.	.	17
36	Horse creek	4	40	5	51	.	.	.	.	16
36	Horse creek	5	39	27	29	.	.	.	.	11
27	Horse creek	3	35	15	57	.	.	.	.	13
38	Horse creek	5	42	18	35	.	.	.	.	11
38	Horse creek	4	30	18	47	1	.	.	.	16
73	McKay river	2	49	26	22	.	.	.	.	16
74	McKay river	6	25	16	40	4	9	.	.	13
64	Moose river	6	75	18	1	.	.	.	.	15
67	Moose river	8	53	19	20	.	.	.	.	16
63	Muskeg river	7	10	1	27	20	16	10	6	9
54	Steepbank river	3	8	2	25	16	20	16	9	14
55	Steepbank river	7	4	1	12	10	17	27	22	16
56	Steepbank river	2	4	1	42	22	13	9	4	17
58	Steepbank river	5	33	2	43	7	4	2	3	16
59	Steepbank river	3	4	2	72	5	5	1	.	16
61	Steepbank river	7	10	1	27	20	16	10	6	8

*Ells, S. C. Mines Branch, Ottawa, No. 281, 1914, Page 6.

The tar sands contain on an average from 15 to 18 per cent bitumen, which has a specific gravity of 1.75.

Tests made on the bitumen show that a ton of sand will produce from 15 to 25 imperial gallons of low grade oil, about 25 degrees Beaume.

The average sample of the tar sands collected by Ells, from the cliff exposed on the east side of the Athabaska river, between the town of McMurray and the mouth of Horse Creek, gave the following analysis:

Bitumen Soluble in CS_2	18.5 per cent.
Sand	80.2 per cent.
Moisture	1.3 per cent.
Specific Gravity 25° C/ 25° C = 1.75.	

Fractional distillation tests were made by Ells on a number of samples of the extracted bitumen. The results are given on page 78 of Bulletin 281, and are as follows:

"The average total percentage of oil thus distilled, including all fractions, is 69 per cent. of the original bitumen. The coke residue is equivalent to 23.7 per cent. of original bitumen. The remaining 7.3 per cent. represents uncondensed fractions, losses in apparatus, etc.

Analysis of coke—

Volatile	6.5%
Ash	2.0%
Fixed Carbon	91.5%
	100.0%

The general fractions have been grouped as follows:

Fractions	Temperature	Amount of Oil	Sp. gr.	Paraffine scale	Unsaturated (polemerized using 37 normal H2S04)
1st	0°C.-110 °C.	2.5 c.c.	0.85	...	....
2nd	110°C.-275 °C.	73.0 c.c.	0.88	0.29%	30%
	(Chiefly between 250°C. and 275°C.)				
3rd	300°C.-330 °C.	17.5 c.c.	0.91	0.09%	40.9%
4th	330°C.-360 °C.	2.5 c.c.	0.96	...	....

The sand in this formation, although the diameter of the grains varies, consists of clear or milky quartz, quite angular, irregularly rounded or well rounded. The diameter of the grains varies but the above table shows that the greater proportion ranges from 40 to 90 mesh. Ells gave the analysis of a sand taken from a sample which had been collected from six represented outcrops. This analysis may be taken as representing the sand in the bituminous formation.

SiO_2	95.50%
Al_2O_3	2.25%
CaO	0.50%
Fe_2O_3	0.35%
MgO	0.23%
Less loss on ignition	1.50%
Total	100.33%

As practically all glass manufactured in Canada at the present time utilizes imported sand, there are possibilities for utilizing all this sand in the glass industry.

In order to show the commercial possibilities of the bituminous sands of Alberta, brief quotations are given below.

McConnell in the Summary Report for 1890 estimated the quantity of bitumen in this formation.

"An analysis by Mr. Hoffman of a specimen collected some years ago by Dr. Bell gave by weight:

Bitumen	12.42
Water (mechanically mixed)	5.85
Siliceous sands	81.73

"A cubic foot of the bituminous sand rock weighs, according to Mr. Hoffman, 117.5 lbs. This figure multiplied by the percentage of bitumen 12.42 gives 14.59 lbs. as the amount of bitumen present in a cubic foot, or $\frac{14.59}{63.7}$ 22.9 per cent. in bulk. Taking the thickness at 150 feet and assuming the distribution as given above at 1,000 square miles, the bituminous sands in sight amount to 28.40 cubic miles. Of this mass, if the preceding analysis is taken as an average, although it is probably rather high, 22.9 per cent. in bulk, or 6.50 cubic miles is bitumen. The amount of petroleum which must have issued from the underlying limestones to produce 6.50 cubic miles, or by weight approximately 4,700,000,000 tons of bitumen, cannot now be estimated, as the condition of oxidation and the original composition of the oil is unknown. It must, however, have been many times greater than the present supply of bitumen."

In a public address to the members of an Industrial Congress held in Edmonton in August, 1919, Dr. T. O. Bosworth, Chief Geologist of the Imperial Oil Co., Ltd., made the following statement: "In the district of McMurray on the Athabaska river we have the largest natural exposure of oil in the world. It is interesting to consider the amount of oil in this territory. For this purpose we will suppose the area to be 15,000 square miles, the average thickness 50 feet and the average yield to be 10 gallons per ton. A simple calculation gives the result as 30,000 million barrels of oil. This is an immense quantity—it is six hundred times the world's annual production."

The commercial possibilities for the utilization of all products in the bituminous sands are very great, but much investigation work must be carried out on the method of extracting the bitumen from the sand in the field or in the laboratory, before the commercial value of this formation can be determined.

Already it has been proven that with certain treatment the sand is suitable for paving purposes. In 1915 a piece of pavement was laid down in Edmonton on Kinnaird Street, immediately south of Alberta Avenue. This experiment was conducted under the supervision of S. C. Ells of the Mines Branch, Ottawa. This pavement has been subjected to heavy traffic, but was still in excellent condition in November, 1919.

This brief report contains only preliminary notes on bituminous sands of Alberta, which may yet prove to be one of the most important mineral resources in this province. Further details will be given in a later report.

The Summary Report for 1918 published by the Department of Mines, Ottawa, on page 194, contains the results of investigations made by G. C. Parker on "Alberta Bituminous Sands For Rural Roads."

"Past experience has established two governing factors in the successful construction of asphaltic road surfaces. Not only must the bituminous binder be of the proper consistency but it must exist in the proper proportion, this proportion being dependent on the mechanical grading of the mineral aggregate. A mixture containing a fine sand can carry more asphalt than one containing coarse. Then again, the various sizes of grains must be present in relative proportions. Most consistent success has been attained with a mixture known as the standard sheet asphaltic mixture, which has the following physical composition:

Material.	Percentage by weight.
Bitumen	10.5
Passing 200-mesh	13.0
Passing 100-mesh	13.0
Passing 80-mesh	13.0
Passing 50-mesh	23.5
Passing 40-mesh	11.0
Passing 30-mesh	8.0
Passing 20-mesh	5.0
Passing 10-mesh	3.0
Total	100.0

"Analyses of samples taken from the Alberta deposits show that it will be almost impossible to secure a uniform supply of material with the above composition and that the mixture of materials of different grades will be necessary.

"That this can be accomplished has been shown in the construction of the Edmonton pavement in which two grades of bituminous sands were successfully used. One was coarse in composition and contained 12 per cent. of bitumen, while the other, containing 16 per cent. of bitumen, was very fine. These were heated and mixed in specified proportions and to them was added dry sand of the proper grading, and in sufficient quantity to modify the resultant mixture in accord with the standard. Then again the character of the impregnating bitumen was not entirely suitable, as it was too soft. It was found that by retaining the material in the heated mixing chamber for a few moments the driving off of the lighter oils resulted in a hardening of the asphalt. The materials were mixed and heated in batches; each batch was dumped on the concrete foundation and spread and rolled while hot.

"Three types of surface mixture were used. The sheet asphalt mixture contained the bituminous sands and dry sand; the asphaltic concrete contained in addition to the bituminous sand and dry sand a certain proportion of gravel; and a mixture approximating that called for by the bitulithic specifications resembled the asphaltic concrete differing from it in the grading of the mineral aggregate.

"The following analyses of the mixtures as they entered the road, as well as the analyses of samples cut from the pavement in 1918, by the writer, are shown below. When compared with the composition of the original bituminous sand, it will be seen that it is quite possible to obtain results similar to, although not identical to, those secured with manufactured imported asphalts. While the pavement has been under traffic for only three and a half years, which does not justify comparison with others laid at earlier dates, up to the present it compares favourably with similar surfaces of wholly artificial mixtures."

BITUMINOUS SAND, ANALYSES OF MIXTURES LAID IN EDMONTON IN 1915."

(Percentage by weight)

Material	Sheet Asphalt		Asphalt Concrete		Bithlithic	
	1915	1918	1915	1918	1915	1918
Bitumen	11.3	11.0	9.1	9.1	8.1	7.3
Passing 200 mesh ..	9.0	9.0	3.9	5.0	5.2	5.0
Passing 100 mesh ..	...	21.0	...	19.0	...	12.0
Passing 80 mesh ..	23.0	14.0	42.1	11.0	37.0	9.0
Passing 50 mesh ..	13.7	25.0	4.2	15.0	...	9.0
Passing 30 mesh ..	13.5	5.0	0.3	...	...	4.0
Passing 20 mesh ..	12.5	7.0	0.8	1.0	8.1	5.0
Passing 10 mesh ..	7.0	8.0	4.0	4.0	6.7	7.0
Passing ¼ inch	0.5	...	...	10.0	...	7.0
Passing ½ inch	...	...	35.3	26.0	...	12.0
Passing 1 inch	...	...	...	...	34.7	22.6
Totals	100.5	100.0	99.7	100.1	99.8	99.9

BUILDING STONE

A very small percentage of building stone used in Alberta, either in the rough or the dressed form, is quarried within this province. Rock suitable for building purposes is widely distributed throughout this province, but up to the present time only some of the more accessible sandstones or limestones have been utilized. A brief outline will be given of a few of the horizons which are accessible to present lines of transportation and which might be utilized for building purposes.

In the bibliography is given a list of references to building material, especially within the Rocky Mountains. The only report of any particular value to date on the building stones in this province is that published by Dr. W. A. Parks, of the University of Toronto, in 1916. This report on the "Building and Ornamental Stones of Canada" consists of five volumes, of which Volume 4 deals with Alberta, Saskatchewan and Manitoba. This report No. 388 was published by the Mines Branch, Department of Mines, and contains much valuable information on the building stones of this province.

As certain formations contain rock suitable for building purposes, in almost every geological age, in this province, it will be more convenient to give a brief table of formations which will show the horizons referred to. More complete details regarding the formations within the mountains will be found in Summary Report of the Geological Survey for 1912.* Fuller details regarding the formations in the plains will be found in Memoir 93, by D. B. Dowling,** and in Memoir 112 by J. S. Stewart.*** The table of formations is given on the following page.

TABLE OF FORMATIONS.

ERA	SYSTEM	GROUP	FORMATION
CENOZOIC	Quaternary	Recent Pleistocene	
	Tertiary	Pliocene Miocene Oligocene Eocene	Hand Hills conglomerate Paskapoo
MESOIOIC	Upper Cretaceous	Montana Group	Edmonton Bearpaw Belly River Pierre
		Colorado Group	Benton
		Dakota Group	Dakota (Blairmore)
	Lower Cretaceous	Kootenay	Kootenay Coal Measures
	Jurassic		Fernie shale
	Triassic		Shales
PALEOZOIC	Permian		Upper Banff shale
	Carboniferous	Mississippian	Rocky Mountain quartzite Upper Banff limestone
		Pennsylvanian	Lower Banff shale
	Devonian		Lower Banff limestone Intermediate limestone Sawback limestone (age?)

*Allan, J. A., Rocky Mountain Section between Banff, Alta., and Golden, B. C., Sum. Rept., Geol. Surv. Can. 1912, p. 168.

**Dowling, D. B., The Southern Plains of Alberta, Geol. Surv. Can., Memoir 93, 1917, p. 22.

***Stewart, J. S., Geology of the Disturbed Belt of Southwestern Alta., Geol. Surv. Can., Memoir 112, 1919, p. 23.

TABLE OF FORMATIONS—(*Continued*)

ERA	SYSTEM	GROUP	FORMATION
PROTEROZOIC	Silurian		Halysites beds
	Ordovician		Graptolite shales Goodsir shales
	Cambrian	Upper Cambrian	Ottertail limestone Chancellor shales Sherbrooke limestones Paget limestones Bosworth shales and limestone
		Middle Cambrian	Eldon limestone Stephen shale Cathedral limestone
		Lower Cambrian	Gt. White shale and sandstone St. Piran quartzite Lake Louise shale Fairview sandstone and conglomerate
PALEOZOIC	Pre-Cambrian Base not exposed.		Hector shale Corral Creek sandstone

THICKNESS OF SECTION (approximate)

Tertiary	3,500 feet
Upper Cretaceous	10,000 feet
Lower Cretaceous	4,300 feet
Jurassic	1,500 feet
Triassic	500 feet
Permian	1,400 feet
Carboniferous	4,300 feet
Devonian	4,000 feet
Silurian	1,850 feet
Ordovician	7,740 feet
Upper Cambrian	9,815 feet
Middle Cambrian	4,960 feet
Lower Cambrian	3,800 feet
Pre-Cambrian	5,910 feet
Total	63,575 feet

PRE-CAMBRIAN BUILDING STONE

The Pre-Cambrian rocks are exposed along the lower slopes of the Bow river from Castle mountain north westward beyond the pass at the head of the Bow river. About 6,000 feet of Pre-Cambrian beds have been recognized, these have been sub-divided into an upper shaly seam called the Hector formation and a lower series of quartzites and coarse grained sandstone called the Corral. Two miles east of Lake Louise station the Corral formation is exposed on the edge of the railway. Stone from this locality has been used for the bridge piers on the railway across the Porcupine creek. "The caps have been cut and show the characteristic brownish colour, but some of the rock face in less exposed position is almost as bluish in colour as when freshly quarried. The stone is undoubtedly very solid and durable, but under the influence of the weather, particularly in exposed positions, it very gradually assumes a brownish colour."

"The formation shows a slight schistosity with a northwest strike; numerous quartz stringers run with the schistosity and a set of nearly vertical joints cuts the formation in the same direction. A second set of vertical joints crosses at N. 50 degrees E. A distinct bedding quite independent of the schistosity is observed; on the face of the old quarry these beds are 4 feet, 4 feet and 12 feet, respectively, and are separated by shaly partings. Although certain parts of the exposure show excessive fracturing it would be quite possible to quarry blocks of large size."*

The Hector formation is exposed along the Bow valley east of the Kicking Horse pass. This formation consists of green, grey and purplish siliceous slate. The cleavage in this slate is indistinct and follows more than one direction, so that no material has yet been found suitable for roofing slates, although the rock is hard enough for this purpose.

There are several exposures of these slates along the railway, beginning a few hundred yards west of Lake Louise station. About six miles west of the station there is a good exposure of these slates in a quarry on the north side of the railway. These slates have been quarried and transported to Exshaw, where they are used in the manufacture of cement by the Canada Cement Company. The exposures referred to do not contain marketable slate, but valuable material might occur in the same horizon in other parts of the Rocky Mountains.

The structure of the Rocky Mountains is such that corresponding formations of the same age are known to occur in irregular bands from the International Boundary to the northwest. Pre-Cambrian formations of a similar character are found along the Athabaska valley west of Edmonton between Jasper and Yellowhead Pass. No material has yet been found in this area suitable for roofing slates or other building purposes.

CAMBRIAN BUILDING STONE

The Cambrian system of rocks is extensively distributed in the central portion of the Rocky Mountains, and has the enormous thickness of over 18,000 feet. This represents one of the thickest Cambrian sections which

*Parks, W. A., Bull. 388, Mines Branch 1916, p. 261.

has yet been measured in the world. It consists essentially of 3,800 feet of siliceous rock, principally quartzitic, sandstone and siliceous shale; 10,275 feet of calcareous and dolomitic limestones and 4,500 feet of shale, much of which is calcareous.

The most important siliceous member which may be used as a building stone is the St. Piran which consists of massive quartzites with a measured thickness of 2,735 feet. It is well exposed at the southwestern corner of Lake Louise where the formation has vertical cliffs; the beds vary in thickness from a few inches to five feet or more. There is a pronounced system of vertical joints running north 50 degrees east, and an irregular system cutting across.

This quartzite is extremely hard, and has a brown colour due to smoky quartz and small particles of mica in the cement.

It was the intention of the railway company to construct the Lake Louise chalet of this quartzite, and a quarry was opened up at the southwest end of the lake in which blocks of stone were taken for the central portion of the original chalet. It was found that the stone was much too hard to be chiselled and could not be cleaved into blocks with any regular shape, so that the use of the stone for building was abandoned.

This quartzite would make most durable stone if it could be found jointed more regularly so that the cost of producing a stone could be greatly reduced.

At the base of the Cambrian which is exposed on the Grand Trunk Pacific, between a point two miles east of Jasper station and Yellowhead Pass, there is a conglomerate schist which varies from a coarse-grained stone into a much finer pebbly quartzite. The prevailing colour of this rock is greenish grey but on account of secondary mica and some iron it weathers into a yellowish or greyish brown. The finer textured stone is suitable for use in rough large blocks but the coarser types are of no value.

The middle and upper portions of the Cambrian system consist of massive thin-bedded limestones associated with shales most of which are calcareous. The lowest member of the Cambrian in the Bow valley is called the Cathedral formation, which is about 1,600 feet thick, this is the only formation which may prove to be of value as a building stone in the limestone horizons of the Cambrian. This formation forms a cliff over 1,000 feet in height at the base of Castle mountain at Castle station on the Canadian Pacific railway. Parks describes this formation as follows:*

"Immediately north of Castle Mountain station is an exposure of limestone which has been opened in a small quarry for lime burning. The strata are disposed at high angles, and the stone is excessively checked, hard, and splintery; in places it shows blebs and lines of whitish calcite which weathers brown. The whole mass weathers to a light brown colour with characteristic etched lines. The stone is easy of access and could readily be quarried, but it gives little promise from the present point of view. (1322)

*Parks, W. A., Mines Branch, No. 388, 1916, p. 34.

"East of Castle Mountain station (one mile east of Johnson creek), and about a half mile north of the railway, is an exposure of limestone forming a cliff of 50 to 75 feet in height at the base of Castle mountain. The formation extends for a considerable distance and rises towards the west. The face of the escarpment seems to be a joint plane, and the formation is crossed by other joints at right angles. These latter partings are widely spaced as a rule, but in places they are close together forming shattered zones. As the bedding is unusually heavy, and the amount of fracturing much less than usual it is possible to quarry blocks of any reasonable dimensions. The stone itself is more desirable than most of the Cambrian limestones, and is described below as No. 1333. The formation overlies a hard black brittle limestone. The accessiblity of the location, the formational features of the strata, and the quality of the stone are more favorable here than in any other outcrop of Cambrian limestones with which I am familiar.

"*The stone*: No. 1322.—A very hard, fine-grained, semi-crystalline limestone of dark grey colour. The stone is not pitted or cavernous, but it is rather badly checked; it weathers to a dirty grey surface with a minutely pitted appearance.

"No. 1333.—A coarsely crystalline, light greyish limestone; it closely resembles No. 1315 from the Upper Banff limestone. The present stone is softer, darker, less 'clean' on freshly-fractured surfaces, and without the slightly bluish cast of No. 1315; it would probably be of less strength and greater porosity. The stone is decidedly softer than No. 1315, and has a distinct grain indicating a certain degree of schistosity; it has a tendency to crumble under repeated blows of the hammer."

These notes on the Cambrian limestone can be taken as descriptive of the same formations, where exposed in other parts of the province such as the Athabaska valley and the Crows Nest.

The Ordovician and Silurian rocks are not extensively developed on the eastern slope of the Rocky Mountains, and in this report need not be discussed.

DEVONIAN BUILDING STONE

The Devonian consists almost entirely of limestone which has been subdivided into the Lower Banff limestone at the top, underlain by the intermediate limestone. The Sawback thin-bedded limestone which underlies the intermediate was temporarily placed in the Devonian by the writer, but its true stratagraphic position is still in doubt.

The upper two formations in the Devonian will be the only ones referred to in this report.

The eastern part of the Rocky Mountains consists of a series of blocks which have been thrust over each other from the west so that the eastern face forms a steep escarpment, while the western slope is more gradual. These blocks or ranges expose the Devonian limestones at the base of the escarpments. The Devonian blocks are overlain by the Lower Banff shale and the Upper Banff limestone, which are Carboniferous in age. Many of the characteristics in the limestone of the Devonian and Carboniferous system are alike, but brief notes will be made on the building possibilities of each.

The intermediate limestone has a measured thickness of over 1,800 feet, and the overlying Lower Banff limestone is over 1,500 feet in thickness. Parks gives a concise description of the possible usefulness of these limestones for block purposes.* "It is of course obvious that the limestones of these formations can easily be obtained in enormous quantities at innumerable places throughout the whole length of the eastern ranges. They are accessible along all the lines of railway that penetrate the mountains, and each of the divisions could be quarried without difficulty at points convenient for shipment. Nevertheless, I know of no place where any of these stones have been quarried for building purposes, but they have been exploited to some extent for lime burning and for use in the cement industry. As far as I can learn, a small block in Blairmore is the only building constructed of these stones, if we except a few rough structures on the properties of the companies operating for lime, etc. In the Canadian Pacific hotel in Banff a few blocks of Upper Banff limestone have been used for keystones in arches.

"The reason for the failure to utilize this abundant material lies in peculiarities of composition and structure and in formational features which may be enumerated as follows:

(1) Hardness.—The great bulk of the formations is much too hard to be chiselled at a cost which would permit of successful competition with other stones.

(2) Nodules.—Much of the Upper Banff and some of the Lower Banff limestone is filled with nodules and thin bands of silica which absolutely prohibit its use as a fine building stone.

(3) Bedding.—Throughout the formations, the original bedding of the constituent strata is obscured, with the result that the stone comes out in great irregular masses unsuitable for coursing stone. The additional cost of cutting bedding places is a strong deterrent factor. Much variation is observed in this respect.

(4) Diversity.—The various layers differ considerably in quality and structure. This objection, taken by itself, is not very serious, as it applies to nearly all limestone localities, but taken together with No. 5 below it becomes of great moment.

(5) Tilting.—The strata are nearly everywhere inclined at high angles, and in consequence it is seldom possible to quarry an individual layer without removing contiguous less desirable material. It is to be noted in this connection that quarrying on the eastern scarped faces of the mountains is impossible, and that the back slope is covered with debris or with the Rocky Mountain quartzite and later formations. It follows, therefore, that quarrying can be carried on only in the crosswise valleys where the successive strata are accessible; here the difficulties due to the inclination of the strata are ever present.

(6) Fracturing.—The whole mass of the mountains is greatly shattered and broken. This fact alone would not prevent and might even assist quarrying operations if the divisional planes were even and disposed in definite directions. Throughout the mountains, however, it is seldom that distinct systems of joints occur, the whole mass being traversed by irregular, ill-defined, and in places excessive partings.

*Parks, W. A., Mines Branch No. 388, 1916, p. 111.

"In connection with this subject it must be remembered also that the local demand for building stone is slight, and that a very high grade of stone could alone stand the additional cost of freight charges to the larger centres of consumption.

"In view of the enormous extent of these limestones and their variations throughout the great thicknesses exposed, and in the absence of any definite location where they are quarried for building purposes, it is impossible to present the reader with an adequate economic description. A general idea of the character of the stone in the different formations may be obtained from the quotations given below, and from the description of the stone obtained from a few type localities. While the statement is doubtless based on insufficient information, I am inclined to believe that the only layers likely to prove of real economic value from the present point of view are situated in the Upper Banff series. The stone of these beds is more suitable for carving than the average, its colour is pleasing, and it presents a well-defined crystalline structure. This type of stone was seen in the rock-slide at Frank, in the talus of Mount Rundle, and near the quarries of the Summit Lime and Cooperage Works, on the Crows Nest line; doubtless it is present in greater or less amount throughout the formation."

The thermal sulphur springs at Banff occurring in the intermediate limestone rock is high in sulphur and is a rather coarsely crystalline limestone.* Specimens of Lower Banff limestone from the vicinity of Pocohontas and also from the vicinity of Banff have been polished, and prove the rock will take a good polish and resembles closely the black marble. The Lower Banff limestone is being quarried a few miles east of Jasper and utilized for the manufacturing of cement by the Edmonton Portland Cement Company at Marlboro.

ROCKY MOUNTAIN QUARTZITE

This formation occurs as the uppermost member of the Carboniferous period. It is exposed on the westward slopes of several ranges in the Rocky Mountain system. Along the Bow valley this formation has a varying thickness up to about 800 feet. It consists largely of grey to pure white quartzite; the stone is extremely hard, breaks with an irregular fracture, and frequently weathers yellowish.

A few blocks of this quartzite have been used in the constructions of the Canadian Pacific Railway hotel at Banff. In general this stone cannot be regarded as a suitable building stone.

UPPER BANFF SHALE

Along the sides of the Bow valley at various points west of Kananaskis, there is exposed a series of dark brown shales which have a thickness of about 1,400 feet. In some places the shales are highly calcareous and might better be called thin bedded limestones.

The bedding planes are very even and jointing planes regular. These structural properties permit of the quarrying of blocks suitable for coarse masonry. The individual beds vary in thickness up to about 18 inches.

*Allan, J. A., Sum. Report., Geol. Surv., Can., 1912, p. 167.

On the west slope of Mount Rundle at Banff this formation dips at a steep angle of 70 degrees to the west. The uniform bedding forms a smooth exposure on the dip of the beds along the side of Spray river about three-quarters of a mile from the point where the Spray joins the Bow river. Well defined joints run parallel to the dip, roughly at right angles to the bedding and three to six feet apart.

A quarry has been opened on the Spray river where this structure is well developed. The stone is dark grey to black when fresh but assumes a lighter colour after it has been exposed for a time.

This stone has been used extensively in the construction of the Banff Springs hotel, and also in the buildings at the government swimming pool, better known as "Cave and Basin." This stone has also been used in small quantities in various other buildings in Banff, and has been found to be very satisfactory, although it is by no means an attractive stone.

KOOTENAY FORMATION

This formation represents a lower part of the Cretaceous, and consists largely of interbedded sandstones and shales and coal seams. Although the sandstone of this age is widely distributed throughout the whole length of this province, within the front ranges of the Rocky Mountains, it has not yet been proven to be of any value as a building stone.

DAKOTA FORMATION

This formation is widely distributed throughout the western part of the province of Alberta. It consists chiefly of greyish to greenish sandstones frequently speckled with grains of mica or other dark mineral fragments. "These stones are hard and tough with poor weathering qualities, but they are useful for rough construction. The probability of their use for such purposes, rather than the prevailing limestones of the mountains, lies in the fact that they may be quarried in thicknesses suitable for coursing, whereas the limestones usually require bedding. The stones examined show a paucity of quartz grains, but a large amount of feldspar and dark ferromagnesian minerals in an altered condition. The stones are compact with a low porosity. The cementing matter is argillaceous rather than calcareous, and in some cases it is rather scanty. The four stones tested are alike in their physical properties, i.e., they are all hard, tough, fairly strong and of low porosity. Nevertheless, there is considerable difference in the specimnes when compared with one another. They all agree in possessing a low power of resistance to frost action."*

EDMONTON FORMATION

The Edmonton formation has a very wide distribution in Alberta. It extends from the International Boundary line northward at least as far as Lesser Slave Lake, and is roughly triangular in outline with the apex of the triangle to the south. In the latitude of Edmonton this formation has about its maximum width, and extends from Fort Saskatchewan to the foothills, a distance of about 200 miles. This

*Parks, W. A., Mines Branch Ottawa, No. 388, 1916, p. 170.

fromation is overlain in central Alberta by the Paskapoo, which also has in general a triangular distribution. The Edmonton formation outcrops about the edges of the Paskapoo, and also along valleys which have cut through the younger formation.

The beds in the Edmonton formation are of brackish or fresh water origin and consist essentially of sandstones, sandy clays, and clay shales. There are workable seams of coal towards the base of this formation and other seams near the top of the formation. The lower coal seams are worked by mines in the Edmonton, Clover Bar and Drumheller districts. The upper seams are exposed along the north Saskatchewan river, west of Edmonton, and along the Pembina river, where it is being mined.

There are many sandstone beds in this formation, some of which are more suitable for building stone than others, but thus far no extensive use has been made of these sandstones. In the Macleod district a quarry has been opened up at Monarch in this formation, and considerable stone has been used in various buildings throughout the province.

In the discussion of the building stones of Alberta, Dr. Parks grouped stones from the Edmonton and the Paskapoo formations, so that in this preliminary report no further discussion will be made of the Edmonton formation.

PASKAPOO FORMATION

The Paskapoo formation is of Tertiary age and represents the youngest formation in Alberta which has a wide distribution. This formation overlies the Edmonton, and consists of sandstones and clays deposited under fresh water conditions. In general the sandstones in this formation are softer than those in the Edmonton, but this stone has been used extensively for building purposes throughout Alberta.

Up to the present time the Paskapoo and Edmonton sandstones are the most important building stones within this province.

The qualities of the stone have been fully described and discussed by Dr. Parks, so that his description will be given in full.*

"Before proceeding to a general discussion of the stone it is advisable to indicate the location of the more important quarries. Following the practice adopted throughout these reports, the quarrying regions may be arranged from south to north, in the following, more or less defined, geographical 'areas.'

"The areas are as follows:

"*Monarch area* on the Old Man river west of Monarch station on the Crows Nest line of the Canadian Pacific railway.

"*Macleod-Brocket area* embracing quarries in the Porcupine hills west of Macleod, at Brocket on the Crows Nest line to the westward, and on Pincher Creek still farther west.

"*High River area* including abandoned quarries on Highwood river west of the town and a few scattered quarries to the east.

*Mines Branch Ottawa, No. 388, 1916, p. 189.

"*Sandstone area* comprising a few unimportant quarries near the village of Sandstone on the Calgary-Macleod line of the Canadian Pacific railway.

"*Calgary area* embracing the immediate vicinity of Calgary and the country northward to Beddington.

"*Glenbow-Cochrane area* including quarries at Keith, Glenbow and Cochrane on the main line of the Canadian Pacific railway west of Calgary.

"*Red Deer area* with small and unimportant quarries at Red Deer, Didsbury and Innisfail.

"*Entwistle area* on the main line of the Grand Trunk Pacific railway west of Edmonton.

"The marketable stone from the different quarries varies in grain and colour and in the degree to which reediness or a marked laminated structure is developed.

"On the basis of colour we may classify the product of the principal areas as follows:

"Blue Stone—Monarch, Entwistle, Sandstone.

"Very Yellow Stone—Entwistle.

"Yellow Stone—Calgary.

"Buff Stone—Monarch.

"Greyish Yellow Stone—Glenbow-Cochrane, Red Deer, High River, Sandstone.

"Grey Stone with a slightly brown cast—Macleod, Brocket.

"In grain the stone varies so much in a single area or even in a single quarry that no general observations can be made. The coarsest type is the grey variety at Entwistle and the finest stone from the Macleod and Arnold quarries in the Monarch area. Observations on buildings bring out the following points of a general character:

"(1) The stone should not be used for the lower courses of buildings where the injury from wetting and freezing is excessive. Striking instances of the deterioration the stone suffers under such conditions may be observed in the City Hall, the Cathedral of the Redeemer, and the buildings of the Young Men's Christian Association in Calgary.

"(2) The stone should never be laid up on edge, as it is prone to exfoliation. A striking example may be observed in the Natural Resources building of the Canadian Pacific railway in Calgary.

"(3) The stone is bibulous and rapidly absorbs dirt. On this account, sand-rubbed surfaces preserve the original colour better than rock face. The rock face work in the Alberta hotel, Calgary, has become grey through the imbibition of dirt rather than by a change in the colour of the stone. The McDougall block, Calgary, was built in 1905 of local stone. The lower courses became so grey that they were cleaned at a later date. The upper courses, however, and particularly the rubbed work, have retained the yellow colour to a better degree.

"(4) Mud spots or clay inclusions are of frequent occurrence; these are not conspicuous in rock face work, but they constitute a serious objection to the use of certain stones for smooth finish.

"(5) The average stone is not suitable for very exposed positions. Small pillars, copings, etc., are generally found to be seriously disintegrated after a few years. An extreme example is seen in the building of the Young Men's Christian Association in Calgary.

"The stratigraphic peculiarities of the Paskapoo sandstones are expressive of their origin as off-shore deposites as irregular bedding, pinching out of layers, variation in grain, and cross bedding are to be observed in all the quarries.

"An important feature from the present point of view is the fact that only the superficial part of the exposure is workable. The original stone is too hard to satisfy the demands of the trade, and it is not possessed of good wearing properties. The workable zone depends on the depth to which oxidation has penetrated. This depth varies in different localities, but it is never very great, and in consequence neither deep or extended quarries can be expected. This failure of the quarries to supply unlimited material is an important factor bearing on the success of the industry. An exception to the above principle is seen in the case of the blue stone at Monarch which, although primary, is even softer than the buff stone which is the result of oxidation.

"Speaking generally, the original Paskapoo sandstone consists, as to mineral grains, of about one-third quartz, one-third semi-decomposed feldspar, and one-third dark coloured indeterminable grains of a ferromagnesian character. These components vary somewhat, and in consequence there is a more or less defined 'pepper and salt' effect according to the amount and clearness of definition of the darker grains. The original stone has a high content of lime carbonate in the cement; it is to this substance that the stone owes its hardness, and it is to its solution and removal that the altered stone shows its softness and greater porosity.

"Besides the normal unaltered stone and the softened secondary derivative, many quarries present a still harder type which occurs in limited layers or in the centres of natural blocks of the altered stone. This material is known as 'hardhead,' but the term is also applied to the normal unaltered stone, particularly in those quarries where 'hardhead' proper is not conspicuous. I am of the opinion that this very hard material is the result of secondary concentration of carbonate of lime.

"As already stated, the quarry at Monarch differs from all the others in that the original stone is softer than the secondary oxidized type. The quarries at Entwistle also differ from the majority in that the original stone is very soft although harder than the altered yellow variety.

"It may be said, therefore, that we have three different types of alteration to consider:

"(1) A soft blue stone altering to a harder buff stone—Monarch.

"(2) A soft blue stone altering to a still softer yellow stone—Entwistle.

"(3) A hard bluish to grey stone altering to a soft stone of grey brownish-grey or yellow colour—All the remaining quarry areas of the Paskapoo sandstone.

"A preliminary examination has been made in order to determine the process of alteration in these different cases. As a more detailed description is given under the various stones it will suffice to state here the general conclusions in each instance as follows:

"(1) Monarch.—The amount of cement increases with a consequent reduction of pore space. The original content of carbonate of lime is only slightly reduced, and the loss is more than made up by the addition of argillaceous matter derived from the decay of the original mineral grains of the blue stone. It is quite to be expected that the altered stone would be harder than the original.

"(2) Entwistle.—The alteration in this instance consists of a large removal of carbonate of lime by solution, a decomposition of some of the original mineral grains, and a further removal of some of the results of this decomposition in the form of carbonates. There is little or no addition of argillaceous matter to the cement, but there is a pronounced oxidizing effect with a consequent bright yellow colour owing to the presence of a considerable percentage of iron. This type of alteration is evidently one of excessive leaching and oxidation.

"(3) Calgary, as indicative of the general type.—In this case there has been a partial removal of carbonate of lime in solution, also a conversion into carbonate of certain constituents of the original grains. Oxidizing effects are not pronounced. This type of alteration is evidently due to carbonation; it is to be expected that the Entwistle type would ensue were the flow of water through the stone more abundant.

"A review of the general physical characteristics of the Paskapoo sandstones is best presented by a comparative table in which the averages of the different types of stone are placed side by side. In compiling the following statement of averages, only the better known stones of recognized commercial importance have been included as representative of the different types. In some cases the average is not very expressive as the variation is too great, e.g., the two Cochrane stones in respect to hardness.

"The types recognized and the stones used are as follows:

" I. The blue Monarch stone.
" II. The buff Monarch stone.
"III. The Calgary type, represented by the best stone from Oliver's quarry and the stone from Beddington.
"IV. The Glenbow stone.
" V. The Cochrane stone, represented by two examples from the Shelley Quarry Company.
"VI. The Macleod-Brocket type represented by stone from the Porcupine hills and from the quarry of the Crowsnest Stone Company near Brocket.

"An average of these nine best known commercial stones is given in column VII.

	I.	II.	III.	IV.	V.	VI.	VII
Specific gravity	2.691	2.688	2.687	2.665	2.672	2.677	2.679
Weight per cubic foot, lbs.	138.64	140.02	131.48	134.19	136.24	144.66	137.54
Pore space per cent.	17.47	16.56	21.72	19.34	18.26	12.83	17.66
Coefficient of saturation	.71	.79	.69	.68	.72	.76	.72
Dry crushing strength, lbs. per sq. in.	7,092	6,796	5,985	7,631	9,617	11,119	8,306
Wet crushing strength, lbs. per sq. in.	3,963	4,708	3,874	5,640	7,007	7,224	5,613
Frozen crushing strength, lbs. per sq. in. ..	2,976	3,679	2,782	3,896	4,212	6,524	4,065
Transverse strength, lbs. per sq. in.	308	556	398	554	658	582	521
Shearing strength, lbs. per sq. in.	459	512	431	497	642	586	531
Loss on corrosion, grams per sq. in.	.0223	.0255	.06746	.04301	.05031	.04194	.04558
Drilling factor, mm	21.4	....	25.2	21.0	26.6	17.8	22.7
Chiselling factor, grams	27.40 II	8.55 II	9.44 II	6.87 II	14.66 II	4.72 II	11.16 II

"The general averages in column VII may be taken without comment as expressing the physical characteristics of the commercial Paskapoo sandstones.

"The other columns indicate that the Glenbow, Cochrane, and Calgary stones are the most porous, that the Cochrane and Macleod-Brocket stones are the strongest, and that the blue Monarch stone is the most easily chiselled. The Macleod-Brocket stone suffers the least and the blue Monarch stone the most under the freezing test.

"At the time of my examination of the Paskapoo sandstones, in the summer of 1915, no quarries were in actual operation; in consequence, most of the specimens were obtained from old dumps or from the exposed face. There can be no doubt that some departures from the figures herein given would be obtained by conducting the experiments on uniformly seasoned stone. Nearly all the Paskapoo sandstones harden somewhat on exposure, due to the conversion into carbonates of the lime and magnesia of the cement; this factor alone renders necessary the procuring of equally seasoned samples if closely comparative results are to be obtained.

"The present state of inactivity in the industry is to be ascribed to various causes, among which the most important are:—

"1. The failure of the quarries with depth.

"2. The variable nature of the stone and the presence of hardhead and mud holes.

"3. The lack of confidence on the part of contractors in the ability of the operators to supply stone to order.

"4. The competition of other stone, particularly Tyndall and Indiana limestone.

"5. The high cost of quarrying due to the large amount of waste for which there is no market either as rubble or for use in macadam. The only stone a quarryman can dispose of is his best quality of soft building blocks.

"6. The high wages demanded by stonecutters ($6 per day). Stone can be dressed in the big mills of Indiana at a cost which makes this figure almost prohibitive.

"7. The refusal of contractors to accept any but the softest stone. This attitude is doubtless due to the high cost of stone-cuting. It is to be remembered that few commercially successful sandstones in other centres are as soft as the average Paskapoo stone.

"8. The average stone, however optimistic we may desire to be, is not really a first class sandstone for monumental structures."

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CLAY

The clay resources of Alberta may be classed among the most important mineral resources, but up to the present time the extent and commercial value of these resources have not been investigated in detail. It is known that deposits suitable for the manufacture of various kinds of ceramic products are widely distributed throughout the province east of the Rocky Mountains escarpment. The raw material used in the manufacture of brick, tile, pottery and other ceramic products is obtained from one of two sources:

(1) Surface clays and unconsolidated clays.

(2) Shales of greater age.

Geological examinations show that both of these types of deposits are known to be extensively distributed throughout the prairie provinces. Certain clays and shales have been and are being manufactured into various kinds of ceramic products.

The value of the production of clay products manufactured in Alberta increased annually until 1912 when the annual production had a value of nearly one and a half million dollars. The output decreased rapidly after that year due to the fact that construction for the most part ceased during the period of the war. In 1917 the value of the clay products in Alberta had decreased to a little over a quarter of a million dollars. The accompanying table shows the value of the annual production of clay products in Alberta since the year 1906, compared with that is the value of common and pressed brick manufactured each year.

	VALUE OF Annual Production of Clay products	VALUE OF Annual Production of common and pressed Brick
1906	$ 108,217	....
1907	353,672	$ 353,672
1908	240,384	240,336
1909	442,486	441,606
1910	757,232	750,982
1911	1,052,751	779,001
1912	1,356,184	1,105,912
1913	893,408	732,408
1914	462,199	(183,696)
		(93,358)
1915	115,696	45,649
1916	225,140	92,782
1917	309,991	180,815
1918	381,074	182,061
1919		

This table shows that the annual production increased steadily from the year 1908, reaching a maximum in 1912; it also shows that the production since 1915 is again on the increase.

It is important to note that in the year 1917 Canada produced clays and clay products to the value of $4,779,038.00. In the same year Canada imported raw material and manufactured clay products to the value of $6,610,837.00, of this amount 55.6 per cent. came from the United States.

This important fact points to the future possibilities in the clay industry provided raw material is available for the manufacture of different classes of ceramic products.

Within the three prairie provinces clays are known to be extensively distributed, but much detail work yet remains to be done both in the field and in the laboratory before the economic value of these clays can be determined.

A brief outline of the origin of the clays and shales in this province will enable one to apprehend the possible extent of these deposits and to realize what possibilities there are for the development of the ceramic industries.

During the early part of the Cretaceous period a sea varying in depth and in width flowed from the Gulf of Mexico to the Arctic ocean, in this sea were deposited muds which later became consolidated into shales.

Movements in the sub-structure occurred which indicated the introduction of a period of revolution when the Rocky Mountains at the west were about to be built. These movements caused a shallowing of the sea and brackish water or even fresh water conditions existed for a time. This continental sea was ultimately disconnected by a land barrier which was caused by uplift, but into the embayments north and south of the land barrier, clays and sands were deposited which later became consolidated into shales and sandstones. At times the sea extended almost as far east as Manitoba and during other periods the eastern shore-line occurred much further west.

The shales resulting from these muds are therefore widely distributed throughout Alberta and Saskatchewan and to a lesser degree in southwestern Manitoba.

The next important period in the geological history of these provinces is represented by the Glacial period which extended into comparatively recent times. During the Glacial period various ice sheets formed a continuous mantle of ice of unknown thickness over the entire width of the Dominion. Enclosed in this ice, as in all glaciers of today, was a large amount of gravel, fragments of rock, sands and clays. When the ice melted this debris was deposited along the floor of the land. In many places lakes irregular in size and shape were formed in this debris along the front of the retreating ice sheet. Into some of these larger lakes much mud and sand was washed from the melting ice, and was in turn distributed over the floors of these lakes, in some cases the entire lake basin ultimately became filled up with the clays, in other cases the extent of the lake was greatly reduced.

All of the many lakes east of the Rocky Mountains in this province have been formed in this way and a study of the material around many of them shows that the extent of this basin was much greater at one time.

As a large area of the surface of this province is veneered with glacial debris and unconsolidated clays of Pleistocene age, the extent and thickness of clay beds of commercial value vary in different parts of the province. It is only by careful field observations and by carrying out numerous physical tests on the clay that the quantity, quality and commercial value of the clay resources in this province can be determined.

Added to this class of surface clay are those deposits which occur as terraces and flood plains along the sides of the larger valleys. In these deposits the clays are frequently better sorted than in those deposits of lake origin, and they are therefore more likely to be uniform in character. As a rule these deposits are readily accessible on various river terraces, so that many of the brick plants throughout this country have been utilizing this grade of clay for the manufacturing of brick and tile.

The clay resources of Canada have been under the consideration of the Department of Mines, Ottawa, for a number of years. In 1909, the Geological Survey Branch engaged Dr. Heinrich Ries, Professor of Geology at Cornell University, to make a general investigation of the clays throughout Canada. In this work Dr. Ries was associated with Joseph Keele, who was then with the Geological Survey Branch, but who is now chief engineer of the Ceramic Division, Mines Branch. A number of Memoirs prepared by Ries and Keele have been published by the Geological Survey, on the clays of western Canada and portions of these are given in this report.

The occurrence of available raw material in the Great Plains for the manufacture of clay products will be briefly described in the order given on page one.

SURFACE CLAYS*

"By far the greater number of clay deposits worked in the Great Plains region are surface clays of unconsolidated character, and recent geological age.

"They consist of a heterogeneous mantel of silts and clays, mixed with gravel and sand deposits, which usually conceal and level up the inequalities of the bed-rock. So thick are they in some cases, that the bed-rock lies several hundred feet below the surface.

"Whatever their character, these materials were in most cases deposited by water; the latter having often been derived from the melting ice of the continental or mountain glaciers."

**"The fact should be borne in mind, however, that these surface deposits may vary in their character from place to place, the phases seem including silts, clays, gravel, and sand. Of these the silty type is perhaps the most abundant."

MODE OF OCCURRENCE.***

"The surface clays of the Great Plains region used for brickmaking purposes may belong to any of the following groups: (1) lake clays; (2) river-terrace or flood-plain deposits; (3) delta deposits.

"*Lake Clays.*—As the front of the great continental glacier receded towards the north, lakes of various dimensions filled the depressions in the uneven surface of the country; and into these lakes the drainage of

*Ries, H., and Keele, J.—Clay and Shale Deposits of the Western Provinces, Memoir 24E, Geol. Survey, Canada, 1912.
**Ries, H. and Keele, J., Geol. Surv., Can. Memoir 25, p. 11, 1913.
***Geol. Surv., Can., Memoir 24E, 1912, p. 13.

the surrounding land was carried, the sediment thus transported settling to the bottom, and forming beds of fine stratified clay silt and sand. Some of the clay in these lakes was contributed by streams flowing from glaciers at or near their margins. The dark grey clay underlying the brick clay in the Red River valley is probably derived from this source. It is a massive clay, containing vertical joints, faintly stratified in the upper part and carrying scattered boulders and streaks of gravel below. In time the supply of water from the melting ice diminished and the lakes became partially, or totally, drained by the cutting down of their outlets.

"One of the most extensive clay deposits as yet known occurs in the former bed of glacial 'Lake Agassiz,'* the sediments of which constitute the best brick clays of Manitoba. Raised beaches at various levels are still preserved for long distances on the eastern slopes of Pembina, Riding, and Duck mountains, and these mark what were once the western shores of this great body of water.

"Large areas of surface clays occur in the Saskatchewan valley from Prince Albert to Edmonton, and on the South Saskatchewan as far as Saskatoon. These clays often occur in thick beds, showing a vertical jointing which is sometimes more pronounced than the lines of stratification. Their plasticity is generally good and the beds are free from layers of sand or gravel. These clays were probably deposited in bodies of water lying in the wide basin like depressions of the river valleys and impounded behind temporary dams formed by terminal moraines.

"Evidences of similar conditions are found in clays which occur near the Red Deer river at Red Deer, in the expansion of the valley of the Bow river at Cochrane, and in the valley of the Old Man river in the vicinity of Pincher. The lake clays that occur in the latter localities, however, are more distinctly stratified, and are often interlaminated with sandy layers, a feature due, probably, to the greater velocity of the entering streams.

"The overburden of these clays usually consists of loam of no great thickness, but for some distance below the loam the clay is liable to be silty. This silty portion, however, is mixed in with the underclay when mining.

"*River-Terrace or Flood-Plain Deposits.*—Rivers which cut through drift deposits carry a certain amount of sand, clay and gravel, according to their velocity and volume. Whenever the slope of the stream bed is lessened, the water loses velocity, and consequently carrying power, and is then compelled to deposit the larger particles in its load, and these accumulate to form beds of gravel or sand; but the finer particles are carried on until a further reduction of the velocity compels the stream to drop them also. If the clays are deposited where the current is very slow, and remains fairly constant, a thick bed may be built up; but owing to fluctuations due to changing seasons, the kind of deposit usually accumulated consists of alternating layers of sand, silt, and gravel.

*Upham, W.:—Glacial Lake Agassiz in Manitoba, Geol. Survey, Canada, Vol. IV, Part E., 1888-89.

"The greater portion of these deposits is eventually removed by the stream as it cuts down its bed, but often wide areas bordering the stream remain as terraces at one or more levels above the water. The clay on the surface of the flood-plain terrace may be added to by the deposition of sediment during periods of high water.

"Some extensive terraces containing brick-clays exist along the valley bottom of the North and South Saskatchewan river, and to a lesser extent in many of the smaller stream valleys throughout the region.

"Clay beds in river terraces are usually irregular in extent, and can rarely be mined alone, as the interbedded sand and silt must be taken out with the clay; consequently, the bricks made from many deposits of this class are porous, and low in crushing strength.

"*Delta Deposits.*—These occur at points where streams discharge into lakes, and vary in extent with the volume of material carried in by the river. One of the most extensive deposits of this class occurs in Manitoba, and, known as the Assiniboine delta,* was formed during the maximum development of glacial 'Lake Agassiz.' The remains of this delta show a roughly triangular area of about 700 square miles lying between Neepawa, Brandon, and Cypress River. The materials composing the deltas are more or less stratified beds of gravel, sand, and clay, which slope towards the lake bottom. There is generally, however, an absence of definite arrangement of material. The clays occur in lenses or pockets, and often contain streaks of pebbles and sand which cannot be separated from the clay in mining.

PROPERTIES AND USES

"Nearly every part of the western provinces has beds of brick-clay which are utilized in proportion to the demands of settlement. The bricks, however, that are made from them vary considerably in quality, according to the kind of clay used, or the care and skill exercised by the brick-maker.

"In some cases the quality of the bricks could be improved by better methods of handling the clay, and harder burning; but, sometimes, the only remedy is to move the brick plant to a better clay deposit.

"As the amount paid for bricks is not a large item in the cost of a structure, it is better to pay transportation charges on good brick, than to use a poor quality material, because it happens to be close at hand.

"During late years increase in population and consequent demand for building material has been so great, that builders were compelled to use a quantity of inferior brick which would otherwise be rejected.

"Generally speaking, the surface clays of the region possess certain characteristics in common, being all more or less calcareous, often silty, and showing a tendency to check in air drying.

"Their calcareous content is due to the erosion of extensive areas of limestones, which lay directly in the path of the general movement of

*Upham, W.:—Glacial Lake Agassiz in Manitoba, Geol. Sur., Canada, Vol. IV, Part E, 1888-89.

the ice sheet, while their silty character was contributed largely by the amount of rock flour in the boulder clay or till, from which many of the beds were derived.

"These clays for the most part are easily fusible; melting at the fusing point of cone 1 (1150°C.); but in certain localities they are more refractory, due no doubt to the large percentage of magnesia present, and these do not melt until cone 3 (1190°C.) or even cone 6 (1250°C.) is reached.

"The following chemical analyses of some Manitoba clays, made by Mr. M. F. Connor, of the Mines Branch, show the large amount of lime and magnesia in their composition. These samples were collected in 1903 by J. Walter Wells.*

	1	2	3
Silica (SiO_2)	54.00	50.66	45.15
Alumina (Al_2O_3)	9.25	10.00	9.05
Iron oxide (Fe_2O_3)	2.77	3.43	3.75
Lime (CaO)	9.77	10.00	14.00
Magnesia (MgO)	3.51	3.10	7.11
Alkalies (Na_2O, K_2O)	2.34	2.31	2.52
Sulphur trioxide (SO_3)	0.05	1.80	0.10
Moisture	8.66	4.00	1.50
By difference	9.95	15.04	16.82

(1) Yellowish-grey unstratified clay free from sand. Stephens Brick Company, Portage la Prairie.

(2) Yellowish clay free from sand. Virden Brick Company, Virden.

(3) Yellowish clay. Eastman's Brickyard, Gilbert Plains.

"The melting of calcareous clays occurs rather suddenly after the point of incipient fusion is reached in the kiln, so that it is unsafe to attempt the manufacture of vitrified wares from them.

"These clays burn to a buff colour when the percentage of lime is high; but the majority of them burn red, owing to the iron content being proportionately high. When underburned the strongly calcareous clays are red or salmon coloured.

"The greater part of the bricks produced in the country are common bricks made by the soft-mud or sand-moulded method; a small quantity of these are re-pressed for facing bricks. Only a few works make stiff-mud bricks. There is an ever-increasing demand for dry-press bricks, and some firms produce no other kind; but these are mostly made from shales; the silty surface clays or those containing an excess of sand not being suitable for this process. Some of the more plastic surface clays, however, when burned to cone 03 (1090°C.) will produce a good hard dry-press brick.

"The silty and sandy clays, when tempered with water, work up into a body which is 'short,' or lacking in cohesion when wet, and if used in a stiff-mud machine is liable to tear at the corners when coming from the die.

*Wells, J. Walter:—Industrial value of the Clays and Shales of Manitoba, Mines Branch, Dept. of the Interior, Ottawa, 1905.

"The plastic clays will generally come through the die intact, but the chief objection to working them by this method is, that the green bricks are too difficult to dry.

"There is no doubt that taking these clays from the bank in the autumn, and weathering in stock piles over winter, improves their working qualities. This precaution is especially desirable if the bank contains some highly plastic beds or layers, as the frost seems to open the body and reduce the stickiness and lessen the tendency to checking in the green bricks when air drying. A few of the brickmakers have adopted this method with good results, as it does not cost much more for labour, and the clay is available for use earlier in the spring; because the frost goes out of the piles quicker than it does from the bank. Pebbles of limestone are a source of weakness if allowed to pass into the bricks without being crushed. These pebbles burn to lime oxide in the kiln, and afterwards absorb moisture from the air which causes them to swell and burst the bricks.

"Clays containing pebbles should be passed through rolls before entering the pug-mill; the rolls will throw out the larger pebbles and crush the small ones. The finer the pebbles are crushed and the better the particles are distributed through the clay, the greater the improvement in the brick.

"The bricks made from these surface clays are usually burned in scove kilns, the fuel used being wood, lignite, or natural gas, according to the locality."

*"For common brick many of these surface silts, or silty clays work well, provided they are properly handled.

"Knowing that the deposits may vary from point to point, within a short distance, the ground should be carefully looked over before the location of a plant is decided on, and then the deposit selected should be tested before a plant is erected, for nothing is more costly than experimenting with a fully built and completely equipped plant.

"Surface clays will usually be chosen in preference to shale for common-brick manufacture because they are easier to dig and work. They do not always give the better results, however, when a comparison of these two classes of material is made.

"But around some of the larger cities of the Plains the surface clays must be drawn upon for a local source of supply."

SHALES

The formations from which shales may be obtained for the manufacture of clay products are shown in the following table, and include the Benton (Niobrara), Pierre, Belly river, Bearpaw, Edmonton of Cretaceous age and the Paskapoo of Tertiary age:—

*Ries, H. and Keele, J., Geol. Surv., Can. Memoir 25, 1913, p. 11.

Quaxternary		Glacial clays and other surface deposits Pleistocene clays
Tertiary		Paskapoo (Willow creek, St. Mary river upper part)
Upper Cretaceous	Montana group	Edmonton (St. Mary river lower part) Bearpaw chiefly shales Belly river chiefly brackish water deposits. Pierre marine shales. (A phase of Belly river series)
	Colorado group	Benton (Niobrara) marine.
	Dakota group.	Dakota (Blairmore in part)
Lower Cretaceous.		Kootenay.

Shales of a lower age than the Edmonton are not worked in the province of Alberta at the present time.

The Benton shales are exposed along the foot hills and a few points elsewhere throughout the province along the sides of certain valleys, but have not yet been tested for the manufacturing of clay products.

The Niobrara shale is best developed in Manitoba and Southern Saskatchewan. This formation apparently comfortably overlies the Benton and consists largely of a grey calcareous shale with a band of greyish chalky limestone near the top. In southern Manitoba near Leary this shale has been used successfully for dry pressed brick, in many places the shale contains too much barbonaceous material to be of value. Tests made in the laboratory by Ries and Keele show that a mixture of the Niobrara and the Pierre shales can be employed for the manufacture of sewer-pipe.

The Pierre formations consist essentially of marine shales in Manitoba and Saskatchewan, but in Alberta it proves to be a marine pnase near the base of the Belly river series. The laboratory tests showed that there is a marked difference between the shales of the Niobrara and the Pierre formations.

"The Pierre shales weather but slowly, the main change being a disintegration of the shale deposit into a number of scaly fragments. Even these when ground up and mixed with water do not yield high plasticity, nor do they burn readily to a dense body. They are, however, sometimes more refractory than most of the shales of the Great Plains area, showing a fusing point of as much as cone 15.

The Niobrara shales on the other hand are decidedly more plastic, denser burning, and with a much higher shrinkage, and tensile strength. They also burn to a better colour, but are sometimes gypsiferous, so that after burning the gypsum unless well broken up may show itself as white specks. On the other hand the Niobrara shales do not stand as much heat as the Pierre shales, and may at times develop black coring if not burned slowly.

"As a result of some tests which were made, the suggestion is advanced that it would be desirable to use a mixture of Pierre and Niobrara shales at some of the localities where these could be found close together."*

The Belly river series consists chiefly of brackish water deposits which include several beds of shale. This series has a widespread distribution throughout Alberta and the Great Plains in general, but on account of the heavy mantle of Pleistocene and younger material, outcrops are scarce. The formations in this series are best exposed along the cutbanks of the large rivers, such as the Northern and Southern Saskatchewan, Red Deer and Belly rivers, but in these sections the beds may not be continuous owing to the irregular surface of the formation. It has been proven that the Belly river shale deposits are more or less lenticular in shape so that adjoining or overlapping lenses are not necessarily alike. This fact points to the necessity of very careful field examination in the search for suitable raw material.

"Taking the case of two beds, lying one above the other, we find that one may fuse at cone 1, while the upper may stand cone 18; or one may dry without cracking while the other gives much trouble from this cause; or again one may burn buff, while the other burns red.

"These statements should not be interpreted to mean that the lenses are small, for many of them are of considerable size.

"We feel it necessary, however, to caution investors to test the clay properly before constructing a clay plant, for we know of instances where much money has been expended in setting up machinery to work some of these clays into products for which the raw material was unsuited. It seems to us possible to determine this beforehand, and indeed we have been able to do so in our laboratory tests.

"Lying as the Belly River formation does, in central and southern Alberta, it should be seriously considered by the manufacturers of clay products, and yet up to the present time it has been utilized only in the vicinity of Medicine Hat."**

The Bearpaw formation consists of a series of marine shales to the southeast of Edmonton, which are similar in character to the Pierre marine shales underlying the Belly river series. The Bearpaw shales are particularly well exposed along the Red Deer river below Drumheller, and in many streams which enter the Red Deer and south Saskatchewan river. Towards the northwest this formation apparently changes into one having brackish water characters not unlike the overlying Edmonton formation. The shales in this formation have not been utilized for clay working in any part of the province.

The Edmonton formation was formerly regarded as the lower member of the Laramie series, whereas the upper member included what is known as Paskapoo. The Edmonton formation represents the closing

*Ries, H., and Keele J., Memoir 25, 1913, p. 19.
**Ries, H., and Keele J., Memoir 25, 1913, p. 28.

phase of the upper Cretaceous period and consists of brackish and fresh water, soft sandstones, shales and indurated clays. This formation is widely distributed throughout central Alberta; it forms a roughly triangular area which extends from Fort Saskatchewan westward to the foothills, and from the vicinity of the Lesser Slave lake on the north to the International Boundary. The structure in the area occupied by the Edmonton formation is roughly troughlike. The trough has its narrowest portion at the south and widens rapidly towards the north; along the center of this troughlike depression occurs the Paskapoo fresh water formation. Coal seams are found towards the top and bottom of the Edmonton formation, and with these seams are frequently associated the best quality of shales.

Shales from the Edmonton are used for the manufacture of common brick, but the tests made by Ries and Keele on samples from various parts of the formation, show that there is a wide range in the quality of these shales. Those occurring around Edmonton were found to give considerable trouble in moulding and drying, and are therefore not of satisfactory quality unless by mixing other material of a different quality, when a good grade of clay product might be obtained.

The tests made on various samples taken from points west of Edmonton show that there occurs raw material that could be used for common, pressed and paving brick, drain tile, fire proofing and probably in some cases sewer pipe.

The results of these tests accompany those from other localities taken from the same formation, and are found in another portion of this report.

The Paskapoo formation which is of Tertiary age and which overlies the Edmonton formation consists largely of shales and sandstones usually soft and frequently ferruginous. Outcrops are scarce and the formation is covered by a thick and extensive deposit of Pleistocene and post-Glacial sands and clays. Tests on samples of shales from this formation by Ries and Keele show that there are a number of good shale deposits in the formation; that different beds of shale vary in their refractoriness, the fusion point of the different shales ranging from Cone 3 (2,174°F.) to Cone 15 (2,606°F.); that the shales are usually red burning; that there is frequently a rapid alternative from shale to sandstone; that the formation contains material suitable for making common or pressed brick, fire proofing and in some cases even sewer pipe, but that care should be taken in examining the deposit and in having the material properly tested before any clay plant is located.

In southern Saskatchewan there are high grade stoneware and earthenware clays occurring in the Teritary formation. Fireclays which are classed as No. 2 grade refractory clays also occur at a number of localities in the same district. These clays are found to be suitable for the manufacture of architectural terra-cotta, paving brick and several other burned clay products for structural purposes.

These clays have been examined and tested by N. B. Davis, Assistant Engineer of the Ceramic Division in the Mines Branch, Ottawa. Mr. Davis classifies the clays from this district as follows:

"In a general way clays may be classified according to their geological occurrence and the uses to which they are adapted. From a geological standpoint clays are either residual or transported. Residual clays are formed by the weathering of rock in place, while, on the other hand, transported clays are those that have been transported from their source by water and deposited elsewhere.

"Considering the uses to which clays may be adapted, they may be classified as refractory, semi-refractory and non-refractory. Refractory transported clays constitute the majority of the fireclays and ball clays of commerce, and to this group belong many of the Whitemud beds of the Dirt hills and Lake-of-the-Rivers districts, as well as the top bed in the vicinity of Eastend.

"Fireclays are used most commonly in the industrial furnaces of the ceramic and metallurgical industries, such as blast, open-hearth, and crucible melting furnaces, Bessemer converters, glass furnaces, lime and cement kilns, for flues, boiler settings, stove linings, etc.

"Clays in the refractory group do not deform, in the standard cone deformation test, until the temperature of 26 is reached. Those that deform at temperature between cones 26 and 30 inclusive are classed as No. 3 grade; those that deform at temperatures between 30 and 33 inclusive are of No. 2 grade; while those that deform above cone 33 are considered No. 1 grade.

"Many of the fireclay deposits of the world occur underlying coal seams, but such is not the case in Saskatchewan. The clays under the thickest seams of coal, such as in the Estevan district, are non-refractory. The fireclays of the Whitemud beds are not directly associated with any well defined coal seams.

"Clays that are very plastic, refractory, and white burning are called ball clays. They find a use as a plastic ingredient of white ware bodies to give working strength. The clays of the upper part of the Whitemud beds at Willows are good enough to be classed as ball clays. An analysis of a sample collected in the pit of the Alberta Clay Products Company at Willows is given in the following table, in comparison with standard ball clays:

	I.	II.	III.	IV.
SiO_2	58.28	48.99	45.57	46.11
Al_2O_3	26.07	32.11	38.87	39.55
Fe_2O_3 / FeO	1.79	2.34	1.14	0.35
CaO	0.68	0.43	....	....
MgO	0.34	0.22	0.11	0.13
K_2O / Na_2O	1.46	3.31	0.16	....
TiO_2	....	....	1.30	1.20
H_2O	12.02	9.68	14.10	13.78
Total shrinkage at cone 9	17.0	....	20.0	15.0

I. Willows clay.
II. English ball clay.
III. New Jersey ball clay.
IV. Florida ball clay.

"The clays from the following localities were found to be sufficiently refractory to be classed as fireclays:

Sample No.	Locality	Refractory value.	Thickness.
436	Sec. 36, tp. 6, r. 22, 3rd.	Cone 26	6 ft. bed.
474	Willows	Cone 30	15 ft. bed.
476	Willows	Cone 28	19½ ft. Same section.
477	Willows	Cone 27	
478W	Willows	Cone 30	
469	Willows	Cone 30	24 ft. Same section.
467	Willows	Cone 31	
470	Willows	Cone 29	
471	Willows	Cone 30	
481	Sec. 14, tp. 11, r. 28, 2nd.	Cone 28	12 ft.
1648	Claybank	Cone 32	15 ft. Same section.
1649	Claybank	Cone 31	
1650	Claybank	Cone 32	
486	Sec. 11, tp. 13, r. 26, 2nd	Cone 28	4 ft. bed.
565	Yellow Grass	Cone 28	10 ft. bed.
556	Halbrite	Cone 27	6 ft. bed.
551	Sec. 17, tp. 21, r. 10, w. of 3rd	Cone 26	20 ft. bed.

"The Saskatchewan fireclays are all distinctly soft and usually very plastic. They differ from the hard gritty fireclays or shales such as those occurring in Sumas mountain, B. C., inasmuch as they require the addition of a non-plastic ingredient in order to reduce the shrinkage and assist in the drying of wares made by the plastic processes. The absence of a suitable non-plastic material has led to the adoption of the dry pressed process in the manufacture of firebrick from these clays.

"Clays that deform below cone 26 to as low as cone 10 are classed as semi-refractory. Some of the more refractory grades are good enough for certain moderate fire resisting purposes such as stove brick and ladle linings, but the majority are used for making sewerpipe, stoneware, art pottery, paving brick, architectural terra-cotta and face brick.

"Stoneware and sewerpipe clays must have good plastic and drying qualities, and must burn to vitrified bodies between the temperatures of cone 3 to 9. They must also take a good salt glaze. Most stoneware is made from a mixture of clays to produce a body having the required properties in the raw and burned state.

"The clays of the Whitemud beds of the Frenchman River valley, near Eastend, are mainly of stoneware grade. They are being mined and shipped to Medicine Hat for use in the manufacture of sewerpipe in the plant of the Alberta Clay Products Company, and for stoneware pottery in the plant of the Medalta Stoneware, Ltd.

"Certain of the Eastend clays, particularly those described as Nos. 438, 439, 440, are well adapted to be used for modelling clays in the schools of the Province and of the adjoining provinces of Alberta and Manitoba.

"All of these clays are suitable for making face brick by either the dry-press or stiff-mud process, and certain of them have possibilities for paving brick."*

The temperatures at which clays will fuse are determined by comparison with standard Seger cones. These are slender triangular pyramids about two and a half to three inches high and about half an inch on the side of the base. They are made of a series of mixtures of clay and fluxes, so graded as to give a series of fusion points. The fusion point of each cone differs by 20°C. or 36°F. from the next one to it. There are 61 of these standard cones now on the market numbered 022 to 39, which give a fusion temperature ranging from 590°C. (1,094°F.) to 1940°C. (3,470°F.)

The following table gives the fusion range of a few of these cones:—

Case No.	Fusion	Temperatures
015	1,472°F.	800°C.
010	1,742°F.	950°C.
05	1,922°F.	1,050°C.
1	2,102°F.	1,150°C.
3	2,174°F.	1,190°C.
6	2,282°F.	1,250°C.
9	2,390°F.	1,310°C.
12	2,498°F.	1,370°C.
15	2,606°F.	1,430°C.
18	2,714°F.	1,490°C.
20	2,786°F.	1,530°C.
22	2,858°F.	1,570°C.
24	2,930°F.	1,610°C.
26	3,002°F.	1,650°C.
28	3,074°F.	1,690°C.
30	3,146°F.	1,730°C.
32	3,218°F.	1,770°C.
34	3,290°F.	1,810°C.
36	3,362°F.	1,850°C.

For the purpose of reference the following table gives the approximate temperatures to which the various types of ware are burnt:—**

	No. of Cone
Building brick	012 - 01
Paving brick	01 - 5
Sewer pipe	3 - 7
Buff face brick	3 - 9
Hollow blocks and fireproofing	07 - 1
Terra-cotta	02 - 7
Conduits	5 - 8
Firebricks	5 - 14
White earthenware	8 - 9
Red earthenware	010 - 05
Stoneware	6 - 8
Porcelain	11 - 13
Electrical porcelain	8 - 12

*Davis, N. B.—Report on the Clay Resources of Southern Saskatchewan, No. 468, Mines Branch, Dept. of Mines, Ottawa, 1918, p. 14.

**Davis, N. B.—Mines Branch, Report No. 468, 1918, p. 22.

BENTONITE

One variety of clay which is common in this district is known as Bentonite or Soap-clay. It varies in colour according to the impurities which it contains, from a dirty white to a creamy yellow. It is exceedingly smooth and fine textured, and when soaked in water forms a soft soapy jellylike mass. In the early days it was used by the employees of the Hudson's Bay Company and by the Indians as a substitute for soap. The main characteristic of this clay is that it absorbs an excessive amount of moisture; this clay will absorb about three times its weight in water.

Bentonite with varying degrees of purity is common in the Edmonton and Belly river formations. As some of the surface clays have resulted from the breaking down of these older rocks, it is not uncommon to find streaks of Bentonite in these clays. When such clays occur on the surface they are better known by the name of gumbo.

Bentonite was previously regarded as unfit for burnt clay products, but experiments carried on by Keele on some of the Alberta bentonitic clays, show that most of them can be made workable by some process of pre-heating, if the commercial conditions in the locality in question allow the use of such a process.

A new use for bentonite has been recently found in the textile industry for the sizing of yarn. If a bed of bentonite of sufficient thickness and purity can be found, the same may be of commercial value if situated conveniently to transportation. Only pure material can be made use of. The quality of the clay can be tested by anyone by dropping a lump in a cup of water, if the clay changes to a jellylike mass it is bentonite, and if there is no sediment or dirt in the bottom of the container, the quality is good. A workable bed of bentonite should be at least two feet in thickness.

DRYING OF CLAYS

One of the greatest drawbacks in the utilization of the clays from the great Plains region, during the process of manufacturing of clay products has been encountered in the drying stage. Of the many samples of clays and shales which were collected during the investigations by Keele & Ries about 25 per cent. cracked during air-drying, after being moulded. Such defective clays were found to occur principally in the Edmonton and Belly river formations. As these clays are extensively distributed and would be of considerable economic value if they could be utilized in the manufacturing of clay wares, a series of experiments were carried on by Keele on the drying and pre-heating of clays.

Regarding this class of raw material Keele writes as follows:*

"Several beds of these clays and shales could be manufactured into facing bricks by the dry-press method, but it is impossible to use them for the many important structural wares which involve the use of the wet-moulded processes.

*Ries, H., and Keele, J.—Memoir No. 25, Chapter VII, p. 83.

"During the progress of the laboratory work on the samples of these clays collected in the field, the writer was confronted with the difficulty of preparing test pieces from them for the purpose of observing their behaviour under fire. The clays absorbed a great deal of water in tempering, afterwards forming a stiff pasty mass which was tough and sticky and hard to work. Shortly after being set to dry the moulded shapes cracked, even small test pieces splitting badly in the ordinary laboratory temperature. The surface of a full-sized brick readily became dry, and developed a perfect network of cracks, which deepened and widened as drying progressed, while the inside remained moist for several days. The use of substances which would coagulate the clay was tried to cure this cracking, being careful to use materials which were cheap and readily available, so that if the remedy were successful it could be used on a commercial scale. Of the various acids and alkalis tried, common salt to the amount of 1 per cent. added to the clay seemed to give the best results. The salt kept the surface of the bricklets moist while the water was working its way out of the body.

"Full-sized bricks made from some clays thus treated would dry safely in the ordinary room temperature, but many clays would not, and few of the salted clays would stand even moderately fast drying.

"Furthermore the thickness and soap-like qualities of the clays were not ameliorated to any appreciable extent by the mixture.

"The next method which suggested itself was the use of non-plastic materials like sand or grog. River sand, ground quartz, and calcined clay were successively used. These were added to the clays in varying amounts up to 50 per cent.

"The mixtures with sand failed in every respect, and although the grogged clay could be safely dried in some instances, and burned to a good body, the bad-working qualities of the raw clay were still in evidence.

"Preheating experiments were done on several of our clays, and the results arrived at seem to prove that this is the best method so far, for dealing with the difficulty.

"The preheating causes marked changes in the character of the clay, the most important for practical purposes being the change from a tough sticky mass, having undue shrinkage and abnormal cracking in drying, to an open granular body which can be easily worked and rapidly dried.

"The preheated clays require considerably less water for mixing than the raw clays, consequently the air shrinkage in the clays thus treated is greatly reduced."

Since the defective drying quality of certain clays is a hindrance to the development of the clay industry, Mr. Keele continued his experiments on the drying of clays. Some of the results of this further investigation were published in 1915 in Memoir 66.

It was found that the preheating method gave good results. This method consists in heating the raw clay in a suitable type of rotary kiln to a temperature ranging from 400 to 600 degrees C. This preheating destroys the adhesive qualities of the clay and causes it to assume a somewhat granular texture.

The chief obstacle in the use of this preliminary treatment was found to be the expense of operating this process.

Another experiment tested out to prevent cracking in drying was the addition of some non-plastic constituent such as sand. It was found that the clay required more than 50 per cent. of sand to overcome this cracking, and therefore when burnt the product was found to be too weak to be of any practical value.

Highly plastic clays were treated with various chemicals which coagulate and thus render the clays of denser texture. These coagulants include carbonate of soda, barium hydrate, hydrochloric acid, and sodium chloride; but satisfactory results were not obtained.

Another experiment tested was the effect of the addition of various percentages of lime to the clays that showed this marked defect while drying. It was found that only caustic lime had any effect in this treatment.

Many of the clays treated are very plastic and pasty when wet so that difficulty is encountered when the clay is passed through the machinery.

*"The addition of 1 to 3 per cent of quicklime to these clays gives immediate relief, by destroying the stickiness, and causing an extraordinary difference in the ease with which they can be worked up. An excess of quicklime will make the wet body actually short and crumbling so that it would be liable to tear in moulding. The quantity of water required for tempering the clay is increased by the use of quicklime.

"The effect of caustic lime on drying is even more pronounced than on working qualities of the clay. Small test pieces that cracked badly when drying in a room, could be dried intact when exposed to warm sun and wind, when a small percentage of it was added. The quicklime should be finely ground and thoroughly mixed with the clay at least 24 hours before using for moulding.

"The effect of caustic lime on the burned body is the weak point of the mixture. It causes a white scum on the surface of the burned ware, and weakens the body unless burned to a high temperature.

"The experiments with this ingredient have not been carried far enough yet to make a full report on its effect on the various clays.

"Clayworkers as a rule avoid lime if possible, as it is a detriment, especially when present in coarse particles. Its use in connection with these troublesome clays is only advocated as a last resort, when other remedies have failed."

CONCLUSIONS

The shale and clay resources of this province are extensively distributed. Field investigation on these resources has been very limited and more extensive surveys are necessary before the location and extent of commercial deposits can be determined.

*Keele, J., Memoir 66, 1915, p. 47.

Although certain clays have been utilized successfully for the manufacturing of clayware, yet certain difficulties have been encountered in many clays, which are detrimental to the manufactured products.

Further investigation and experimentation on the physical properties of the raw material are urgently required before the manufacturer can be induced to operate on these resources.

The variety of quality in the shales and clays is known by the laboratory tests which have already been made, and if a proper mixture of the raw material from different sources or localities can be obtained, many classes of ceramic products can be manufactured.

This is only a preliminary report on some of the details which are known regarding the field occurrences of clays and shales, and certain tests which have been made on the quality of the clay resources found in different geological formations.

During the summer of 1919 several of the clay working plants in the province were visited. Preliminary notes are here given on the two largest plants, which are manufacturing various kinds of pottery, sewer pipe, tile, etc., as well as common brick.

THE MED-ALTA-STONEWARE COMPANY, LIMITED

In the autumn of 1912 this company under the name of the Medicine Hat Potteries established a new industry to the clay working industry of the province. This pottery is situated on the east side of the town of Medicine Hat. The fuel used for burning the product is natural gas.

The products of this plant include flower pots, which are moulded by hand on a potter's wheel from the alluvial clays that cover the terrace on which a portion of the town is situated. Other products include dyson pickle jars, stone jars, crocks, demijohns, bean pots, water coolers, milk pans, spittoons, open stoneware jars with a maximum capacity of 60 gallons, utilized in photographic trades, jardiniers, and other ornamental flower pots.

Originally much of the clay used was imported from Spokane and mixed with Redcliffe clay, but now the raw material for all the products, except the common flower pots, is obtained from quarries on the Whitemud river at Eastend, Saskatchewan. Two varieties of clay are used; a plastic white clay and a grey sandy clay. The brown "slip" used on pickle jars and certain other jars is obtained from Michigan and Albany, New York. The feldspar "slip" is imported from Ontario, and with it is added a small quantity of zinc oxide. In the summer of 1919 the plant was utilizing about four thousand tons of clay per year or about ten tons of clay per day.

When the plant was visited, Mr. Flint was manager and Mr. Grant superintendent.

THE ALBERTA CLAY PRODUCTS COMPANY

The plant of this company is situated within the town of Medicine Hat. It is one of the largest plants in Western Canada and is equipped with sewer pipe machinery, tile and dry-press brick machinery. The fuel used is natural gas. The products manufactured consist of tile of various kinds including brick tile, drain tile, building tile, also well curbing, flue lining and sewer pipe. A certain quantity of pressed brick and a small quantity of fire brick are also manufactured. The plant is exceptionally dusty and unhealthy for the workmen. There seems to be an unnecessary amount of dust which comes from the ball mills and the pug mills.

The drying-room is kept at a temperature between 90 and 95 degrees. The floor of the room consists of wooden strips about half an inch apart, so that the heat travels from the lower floor through the products stacked on the upper floor.

When the plant was visited there were ten 30 foot kilns of the round-down-draft type and four 40 foot kilns of the same type. The glaze used for the sewer-pipe and tile is salt. The brick machines when in operation turn out about 2,000 brick per hour. The plant is utilizing approximately 10 tons of clay per hour.

The raw material for brick and building tile is obtained from the Edmonton shales which are being excavated at Coleridge about six miles northeast of Medicine Hat. There is a thin mantle of drift and recent clays, but these are not utilized. Brick and building tile from 2 to 12 inches are manufactured from the Coleridge clay, which stands a temperature of 2,000 degrees F.

The clay for the other products is obtained from Eastend and Willows, Saskatchewan, and are reported to stand a temperature ranging from 2,600 to 3,100 degrees F.

When the plant was visited there were about 80 men employed.

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COAL

The Province of Alberta contains seventeen per cent. of the coal reserves of the world, and about eighty per cent. of the coal reserves in Canada. Nearly the whole of the south half of the Province is underlain by one or more coal bearing formations. D. B. Dowling in "The Coal Resources of the World" has estimated that Alberta contains an actual reserve of over 386,360 million tons, and a probable reserve of about 673,550 million tons of coal. This makes a total reserve of 1,059,910 million tons of coal within the Province; this is an excellent argument in favor of increased coal production to supply the entire demands of the eastern Prairie Provinces.

When discussing the quality of the different coals in Alberta, it is important to note that there are three coal bearing horizons within this Province, each belonging to a different geological age, and separated from each other by formations from 700 to 3000 feet in thickness.

The coals from these various horizons differ in grade and quality. Those from the lower and therefore older formations on account of their age, and of the greater weight to which they are subjected by the overlying formations, are of a harder and better quality and more suitable for steam and coking purposes. The older coals are lower in moisture, higher in fixed carbon content, and as a rule, higher in volatile constituents. On the other hand the grade of coal in a single horizon improves towards the foothills and mountains. This is due to the fact that towards the west the coal seams have been more intensely compressed and otherwise carbonized by the stresses from the mountain building forces, which were uplifting the present Rocky Mountain system. These stresses and the formation of the coal in Alberta were in no way connected with volcanic forces, as is so commonly believed to be the case. The dynamic forces which assisted in compressing and metamorphosing the coal seams in Alberta, have been those connected with orogenic or mountain-building movements, or with much broader continent-wide uplift. This latter movement has been the cause of raising the coal seams and the associated beds from approximately sea level where they were formed, to their present elevation of over 2200 feet above sea level.

The variation in the age of the coal and also the distance from the mountains has produced all grades of coal in Alberta, from a medium quality of lignite under the plains, to an anthracite within the front ranges of the Rocky Mountains.

Three coal horizons which are worked in Alberta occur in the following formations, from the youngest to the oldest:—

1. Edmonton Formation (Uppermost Cretaceous).
2. Belly River Formation (Middle Part of Upper Cretaceous).
3. Kootenay Formation (Lower Cretaceous).

In certain localities in Alberta and in Saskatchewan there are workable seams in the beds of lower Tertiary age. This coal is all lignite in character.

The Kootenay coal measures are exposed and worked principally within the front range of the Rocky Mountains, or in the foothills close to the front escarpment of the mountains. The coal varies from bituminous to anthracite. The most important bituminous coal basins in these measures are Crow's Nest; Livingstone and Moose Mountain, which include deposits on the upper part of Sheep river; Bow Valley at Bankhead and Canmore; Brazeau, Big Horn, Mountain Park, Brule Lake and Pocahontas, and Smoky River.

The coal seams in the Belly River formation are worked in the Lethbridge basin.

Other exposures occur in the vicinity of Medicine Hat; the lower part of the Red Deer river; South Saskatchewan and North Saskatchewan rivers, where these streams cut through the Belly River formation. The area in Alberta underlain by the Belly River coal horizon is very much larger than the actual outcrops would indicate. At Edmonton the Belly River coal seam has been located by drilling at 1400 feet, and at Tofield the corresponding seam occurs at 1050 feet.

In the vicinity of Calgary where there is a considerable thickness of Tertiary rocks capping the Cretaceous formation, three coal seams have been drilled through in what is believed to be the Belly River formation. The depths given for these seams are as follows:—

A 5-foot seam at 2562 feet;

A 7-foot seam at 2655 feet; and

A 4-foot seam at 2875 feet;

below the surface. For the time being these seams are too deep to be worked profitably so long as equally suitable coal can be obtained at or close to the surface.

The coal from the Belly River measures ranges from bituminous to sub-bituminous. Dowling estimates that these coal measures are distributed over 25,974 square miles, and contain an actual and probable reserve of 189,450 million tons of coal.

The Edmonton formation contains two coal horizons. The uppermost coal seam occurs near the top of the formation and varies in thickness from about 5 feet, south of the Bow river to a maximum of 25 feet on the North Saskatchewan west of Edmonton. This upper seam is worked at a number of localities towards the foothills of the mountains.

About 500 to 600 feet below this upper seam a number of seams occur near the base of the formation. These seams are known to extend from near the International Boundary line northward to the vicinity of Morinville, north of Edmonton. These seams are worked at a number of localities which include Drumheller, Tofield, Edmonton, Clover Bar, Sturgeon Valley and Morinville.

It has been estimated by Dowling that the actual total area containing available coal in the whole Edmonton formation is 25,235 square miles, which will produce 383,697 million metric tons. To this amount may be added a probable reserve in this formation covering 27,170 square miles which would produce 417,261 million metric tons.

The quality of the coal in this formation ranges from bituminous down to lignite. Much of the coal of this age may be classed as sub-bituminous. The term "Domestic coal" has been applied to the grade of material mined from this horizon.

The chief value of Alberta coal at the present time lies in its use as a fuel. Fuel is a substance which when ignited, combines with oxygen or burns, and during this process evolves a quantity of heat. This heat may be used for domestic, industrial or power purposes.

Investigations have shown that coal can be utilized more profitably in many other forms than as a fuel. It is of the greatest importance that research be carried out on the various grades of coal in this Province, to determine what by-products may be obtained from them, which might make the coal more valuable than by utilizing it in its natural state as a fuel.

The calorific value of coal as a fuel depends largely on the amount of heat which can be obtained from a given quantity of coal. This measure of heat is called the calorific value of the coal, and is the number of heat units available in one pound of coal. In this country the heating value of coal is usually expressed in terms of the British Thermal Unit (B. T. U.), which is the amount of heat required to raise the temperature of one pound of water through one degree Fahrenheit. Sometimes the heat value is expressed in terms of calories when one calorie equals 3968 B. T. U.

A few representative analyses are here given of samples of coal, which have recently been collected under the direction of The Mines Branch, from various mining districts throughout this Province. These analyses have been made in the Industrial Laboratory at the University of Alberta. Accompanying the analyses are given the heating values of each sample. These analyses do not represent all the mining districts, but several will be added in a later report on the coal resources of the Province.

District	Moisture	Volatile Matter	Fixed Carbon	Ash	B. T. U.
Crow's Nest Pass (13)	0.6 to 3.2	24.1 to 28.9	52.9 to 68.5	6.1 to 17.4	11,940 to 14,140
Pincher Creek					
Lethbridge (9)	8.7 to 11.8	30.7 to 39.8	39.3 to 50.6	5.7 to 18.2	9,330 to 10,880
Magrath					
Milk River (2)	14.8 to 16.4	33.2 to 34.8	41.2 to 41.4	8.8	10,000 to 10,200
Taber (4)	10.7 to 15.1	31.3 to 34.4	41.0 to 47.4	7.3 to 11.5	9,510 to 10,690
Bow Island (1)	20.7	33.2	39.6	6.5	8,990
Medicine Hat (4)	21.9 to 26.3	29.0 to 32.6	35.8 to 39.0	5.5 to 10.8	8,030 to 8,760
Aldersyde (4)	10.9 to 14.0	31.8 to 34.1	43.0 to 48.6	7.8 to 9.2	9,980 to 10,330
High River (1)	10.2	31.7	50.1	8.0	10,870
Canmore (Burns) (1)	1.0	15.6	68.2	15.2	12,830
*Banff	0.6	8.6	80.0	10.8	13,600
Drumheller (21)	14.3 to 19.8	30.6 to 34.2	35.6 to 46.5	4.5 to 9.7	9,020 to 10,225
Big Valley					
*Brazeau	0.8	16.0	68.2	15.0	13,000
Brooks (1)	15.9	24.4	41.7	8.0	9,910
Hanna					
Lacombe					
Trochu (1)	19.1	28.8	43.9	8.2	9,350
Three Hills (1)	18.3	29.1	44.4	8.2	9,540
Carbon					
Battle River					
Camrose (3)	23.9 to 26.0	29.2 to 35.2	32.6 to 38.7	6.1 to 8.3	8,475 to 8,540
Tofield (1)	26.9	31.1	39.1	2.9	8,885
Clover Bar (13)	20.2 to 24.6	28.6 to 30.7	38.2 to 43.3	5.6 to 9.3	8,570 to 8,880
*Edmonton	22.6	28.9	40.7	7.8	8,726
Namao (1)	23.0	32.0	36.2	8.7	8,450
Cardiff (1)	22.6	27.7	42.6	7.1	8,630
Wabamun (1)	19.6	30.48	41.57	8.35	9,101
Pembina (3)	15.8 to 18.0	28.6 to 30.7	42.3 to 43.6	8.5 to 11.3	9,030 to 9,480
*Jasper Park	0.30	21.6	65.2	12.9	13,190
Yellowhead Pass (2)	6.1 to 6.5	32.6 to 34.5	52.7 to 53.3	6.7 to 7.6	11,390 to 11,400
Mountain Park (2)	0.8 to 0.9	25.5 to 29.9	62.8 to 67.7	6.0 to 6.4	14,190 to 14,330
Peace River					
**Smoky River	0.3 to 2.9	12.5 to 22.6	63.4 to 82.5	1.0 to 16.5	12,000 to 14,500

*Representative analysis.
**Geol. Surv., Can., Sum. Rept., 1916. p. 92.
NOTE—The numbers after the district refer to the number of analyses taken. With the exception of the Smoky River District, all samples were collected by Government officials.

COPPER

Small pockets and irregular lenses of chalcopyrite are known to occur within the Rocky Mountains along the Bow Valley west of Banff in the vicinity of Castle Mountain and Copper Mountain, but such occurrences are not commercially important.

Chalcopyrite occurs in the district considerably north of Hudson Hope on the Peace river, but the extent of this deposit has not yet been determined.

Specimens of bornite, chalcocite and cuprite have been obtained from certain districts in the pre-Cambrian area north of Athabaska and Slave Lakes, but the details are not yet known regarding these occurrences.

Natural copper occurs in the pre-Cambrian rocks in the lower part of the Coppermine river which is a tributary to Coronation Gulf. J. J. O'Neill, of the Geological Survey, examined this deposit while on the Canadian Arctic Expedition and states that "There are in Bathurst Inlet area, more than 6,000,000,000 tons of rock carrying 1-100 to 1-4 of 1 per cent. of disseminated native copper, and an unestimated amount of amygdaloidal copper running over .1 per cent.; besides this there are veins cutting through the above rocks, some containing thin sheets of native copper 1-64 to 1-8 inch in thickness and others carrying over 4 1-2 per cent. of flake copper."*

GOLD

Gold occurs in the gravels along most of the rivers which drain the east slope of the Rocky Mountains. The information up to date points to the fact that the North Saskatchewan, Peace and possibly the Liard rivers contain most important placer gold.

During the last few years certain streams tributary to the Athabaska have been found to contain placer gold and some platinum. Although gold colours may be obtained from the gravels in the rivers and streams south of the North Saskatchewan river, yet no important deposits of placer gold are known.

The most prominent gold bearing gravels at the present day are those along the North Saskatchewan river west of Fort Saskatchewan, and along the Peace river, particularly west of Fort St. John.

The gold is irregularly distributed throughout the gravels of the present streams, and also under bench gravels, and along old river channels. Concentration has taken place in the most protected portion of the stream channels. The gold is extremely fine in texture and flakey. It is frequently called flour gold, but under a microscope the flakes are

*O'Neill, J. J., Geol. Surv., Can., Sum. Rept., 1916, page 333.

usually well rounded. Platinum and iridium are frequently present as minute silvery grey, flattened grains. Information to date would seem to indicate that certain Peace river placers are richer in platinum than those of the North Saskatchewan.

The origin of the placer gold has been a subject of discussion. At least part of the gold is derived from the glacial and glacio-lacustrine deposits which cover much of the surface of the province, and have been transported from the interior of the mountains on the west, or from the pre-Cambrian areas, to the northeast.

J. B. Tyrrell believes that the placer gold has been derived chiefly from the disintegration of the sandstone in the Edmonton formation. "In Western Alberta, in a great series of conformable Mesozoic and Tertiary sediments, gold occurs in a finely divided state in the Edmonton sandstones at the top of the Cretaceous. These beds were laid down near an old short line, and the fossils contained in them prove that they were deposited in brackish water. No beds containing a sufficient quantity of gold to pay for mining have yet been discovered in these sandstones, but the streams which now drain the country east of the Rocky Mountains cut down into them in many places, and concentrate the gold derived from their sandstone banks into the gravel bars in the river, whence it is collected by simple methods of alluvial washing. The gold so obtained is in very minute particles which, under the microscope, may be seen to be well rounded like most other particles of placer gold. I believe that it is also in the form of such minute rounded particles in the Edmonton sandstone, from which it is derived, for no matter how near the gravel bars which now contain it, may be to its probable source in the sandstone itself, the gold always presents the same rounded appearance.*

Tyrell also considers that the Edmonton beds "in their turn were the old and very low grade placer deposits which have come from the mountains west of the Upper Columbia Valley."**

Practically all the placer gold produced in Alberta has been recovered from the North Saskatchewan river. Up to the commencement of the war, gravel dredging companies operating for the production of gravel for construction purposes, passed the taling over a blanket or riffles and recovered a certain amount of the gold as a by-product, but most of the gold has been recovered by such simple methods as panning, rocker and grizzlies.

Gold was discovered in workable quantities on the North Saskatchewan river in 1861 but no record is available of the amount of gold recovered between 1861 and 1886. The following statistics have been compiled by the Department of Mines, Ottawa, from the reports of the local bank managers as a basis. This table shows the production of gold from the North Saskatchewan field since 1887.

*Tyrrell, J. B., Can. Min. Jl., Vol. 39, No. 7, 1918.
**Can. Min. Inst., Bull., No. 34, 1915, page 80.

Year	Fine ounces	Value	Year	Fine ounces	Value
1887	102	$2,100	1903	48	$1,000
1888	58	1,200	1904	24	500
1889	967	20,000	1905	121	2,500
1890	193	4,000	1906	39	800
1891	266	5,500	1907	33	675
1892	508	10,506	1908	50	1,037
1893	466	9,640	1909	25	525
1894	726	15,000	1910	89	1,850
1895	2,419	50,000	1911	10	207
1896	2,661	55,000	1912	73	1,503
1897	2,419	50,000	1913	..	...
1898	1,209	25,000	1914	48	992
1899	726	15,000	1915	195	4,026
1900	242	5,000	1916	82	1,695
1901	726	15,000	1917	No returns received	
1902	484	10,000	1918	27	558
			Total	15,036	$310,814

Calculated from the value: One dollar=0.048375 oz.

McConnell described the gold placers on the Peace river in 1890, "Gold was found in many of the bars along Peace river, and in several places in sufficient quantities to deserve attention. Three miles above the mouth of Battle River, a large bar of nearly a mile long, on the left bank, was examined, from which we obtained fifteen to twenty colors of fine gold, by washing a few handsful of mixed gravel and sand in an ordinary frying pan. We tried the bar at several points and always with the same result. A small stream descends from the plateau on the opposite side of the river and by leading its waters across the river, which is here about 1,000 feet wide, the bar might be easily and inexpensively worked on a large scale. Twelve miles further up the river another bar was examined which yielded from twenty to forty colours, when washed in the same way. Numerous other bars occur in this portion of the river, which would probably give as good results as those examined.

"The presence of fine gold in some quantity in the bars above the mouth of Battle River is probably due to the diminution in the strength of the Peace River current which takes place here, and its consequent loss of transporting power. The same fact is shown in the gradual substitution of sandbars for gravel bars which occur at the same point."*

During the past few years more attention has been given to placer mining on the upper stretches of the Peace, Parsnip and Finlay rivers. The results have been quite encouraging and more extensive operations may be expected in the near future.

The commercial importance of certain gravels on the Peace river below Hudson Hope has been proven during the past summer by ordinary sluicing methods, under the direction of Mr. R. D. Featherstonehaugh. Gold of an excellent quality has been obtained, and also a magnificent

*McConnell, R. G., Geol. Surv., Can., Vol. 5, 1890-91, Page 62 D.

sample of platinum weighing about two pennyweights, was recovered with a gold pan. Platinum has also been recovered in 1917-18 from the gravels on the North Saskatchewan between Clover Bar and Fort Saskatchewan.

Various devices for separating the finest gold are being tried out on the gravels along the North Saskatchewan and Peace rivers. If these are successful, the production of gold will be greatly increased in the future.

Gold has also been reported in small quantities from various points on the Liard river,* and also on the Peel river.**

Reef gold is known to occur from samples in the pre-Cambrian rocks north of Lake Athabaska and also north of Great Slave Lake. No important deposits have yet been discovered but this dstrict is considered as favourable for prospecting.

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GYPSUM

Gypsum is a hydrous sulphate of calcium, better known by the trade name, Plaster of Paris. Transparent gypsum is called selenite, and the white, massive, fine-textured variety, is called alabaster. Gypsum is softer than the blade of a knife, and can be easily crushed to a white powder. This mineral frequently occurs with rock salt, and it is also widely distributed through certain sedimentary rocks, more especially shales and limestones. It is also found mixed with clay as a surface deposit, and is called gypsite.

Gypsum is widely distributed throughout the plains of Alberta and the Mackenzie basin north of the province. Crystals of selenite, and sometimes thin beds of gypsum are common in the marine shales and certain brackish water deposits of Upper Cretaceous age, which underlie wide regions throughout the province. This occurrence of gypsum has no commercial value because the quantities in any one locality are relatively small.

Calcium sulphate is also a common constituent in several of the mineral springs, and also in the water rising from the strata pierced in boring operations, but the amount is always relatively small.

*McConnell, R. G., Geol. Surv., Can., Ann. Rept., Vol. 4, 1889, Page 29 D.
**Camsell, C., Geol. Surv., Can., Ann. Rept., Vol. 16, 1904, Page 46 C.C.

Gypsum interbedded with clay or limestone has been found in a number of wells drilled for oil along the banks of the Athabaska.

Deposits of pure gypsum outcrop along the Peace river for a distance of 15 miles from Little rapids down to a point 5 miles below Peace point, and also in the escarpment which lies to the west of Slave river. These deposits may yet prove to be of commercial value.

The gypsum deposits on the Peace and Slave rivers were examined by Charles Camsell in 1916 and fully described in the following notes.*

"At almost all the outcrops of the Palaeozoic rocks in the area an important deposit of gypsum occurs. In other places where no outcrops occur, the presence of gypsum was suspected by the pitted and broken nature of the surface, which is so characteristic of a region underlain by gypsum. How much of the region is actually underlain by gypsum, it is difficult to say, but the area must be very great and can probably be measured in hundreds of square miles.

"The thickness of the beds is variable and it is very likely in certain portions of the region they may be absent altogether. Nowhere is a complete section of the beds exposed, and although in most outcrops the top is visible, the base is never seen. A maximum thickness of 50 feet is exposed at two points, namely, Peace river at Little rapid, and in the escarpment at the brine springs of Salt river. In other localities thicknesses of 10 or 20 feet are exposed.

"No attempts have been made to work any of the gypsum deposits because of their remoteness from settled districts where gypsum products could be used, and indeed no claims have as yet been taken up on them. Some of the outcrops could not be worked economically because of the depth of overlying material, but others have not this disadvantage. The exposures on Peace river are the most favourably situated in this respect, while those in the escarpment at the brine springs could also be easily developed.

"On Peace river gypsum is exposed on both banks of the river almost continuously for a distance of 15 miles or from Little rapids to a point five miles below Peace point. The exposed thickness varies from a few feet up to a maximum of 50 feet, the latter occurring on the south side of the river at the foot of the rapids. The gypsum is usually white and massive. In places it is earthy and thin bedded or holds narrow bands of dolomitic limestone. Selenite is rare, but thin veins and beds of satin spar are common. Anhydrite is occasionally present in rounded nodules or in thin beds. Overlying the gypsum is a fractured and broken bed of limestone, but since the structure of the beds is undulatory the gypsum is frequently brought up to the top of the cliffs and has no cover except the drift, the limestone having been removed by erosion. The drift varies in thickness from 5 to 15 feet and when the gypsum is covered only by the drift the conditions are most favourable for the economical mining of the beds. Such conditions occur in a number of localities in the section, particularly on the north side of the river.

*Camsell, Charles, Geol. Surv., Can., Sum. Rept., 1916, p. 139.

"Judging by the character of the surface back from the face of the cliff, gypsum must extend back from the river for a considerable distance. Taking an exposed length of 15 miles along the river and an average thickness of 15 feet of gypsum and assuming that the beds extend back from the river for at least a distance of a quarter of a mile on either side of the river, the quantity of gypsum in the Peace River section is at least 217,000,000 tons. A considerable proportion of this is very favourably situated for mining on account both of its location and the thin overburden of drift.

"On Slave river," 40 miles above Smith landing, "gypsum outcrops on the west side of the river a few miles below La Butte. The section shows about 10 feet of somewhat earthy, thin-bedded gypsum of white, grey, or bluish colour. The beds are traversed by thin seams of selenite and satin spar. They are, however, overlaid by about 20 feet of brecciated limestone. This, together wtih the fact that the beds would be below the river-level at the high water stage, would make the economical working of them somewhat difficult.

"Gypsum outcrops again on Slave river immediately below point Ennuyeux, where a thickness of about 4 feet of thin-bedded, impure gypsum is exposed near the water-level at a medium stage of water. The same disadvantages as hold in the last-mentioned outcrop would prevent the easy mining of the beds at this locality.

"Gypsum is also said to occur at Bell rock 7 miles below Fort Smith beneath the brecciated limestone of which the rock is built. The escarpment west and south of the brine springs of Salt river shows sections of gypsum beds at several points.

"About 4 miles south of the brine springs at the forks of Salt river, cliffs of gypsum are exposed in the face of the escarpment. The escarpment here forms a deep bay and is 150 to 200 feet in height. It is heavily wooded and as a rule rises out of Salt plain with an easy slope to the upper plain. Several streams cut through the face of the escarpment and a number of springs rise from its base. These springs are not briny though they are milky white in colour from suspended calcium sulphate. This soon settles and the water becomes pale bluish in colour. At the locality mentioned cliffs of gypsum half a mile in length appear and are visible by their whiteness from some distance out in Salt plain. The cliffs are in a ruinous state and are deeply fissured and broken down, and the base strewn with freshly detached masses of gypsum and a tangle of fallen trees. The top of the escarpment also shows many recent cracks and deep sink holes. The cliffs show 40 to 50 feet of thin-bedded gypsum with occasional narrow layers of anhydrite or beds of dolomite. The gypsum is white or greyish and is disposed in horizontal beds. On the surface it crumbles to the powder gypsite and this is carried away by the streams and secondarily deposited farther down.

"North of this locality the gypsum appears to decrease in thickness and is there seen to be overlaid by beds of grey crystalline dolomite. Gypsum was again observed in the face of the same escarpment at a point about 8 miles southwest of Fitzgerald where Salt river flows along its base. The section here shows about 20 feet of thin-bedded white gypsum overlaid by about 10 feet of dolomitic limestone.

"The escarpment is known to extend more or less continuously from the last mentioned locality in a sinuous line northwestward for about 40 miles or beyond Little Buffalo river." About 8 miles southwest of Fitzgerald there is a section in the same escarpment which exposes 10 feet of dolomitic limestone underlain by 20 feet of thin-bedded, white, rock gypsum. "Since the escarpment is probably caused by erosion where hard resistant beds overlie softer and more soluble strata, it is reasonable to suspect that, as the strata of the escarpment are horizontal, gypsum will be found to occupy the base of the escarpment throughout the greater part of its length. This suspicion is borne out by the character of the surface on the top of the escarpment, which is broken and pitted with sink holes in a way characteristic of a gypsum region."

Gypsum also occurs further down the Mackenzie basin. On the north shore of Great Slave lake, Cameron describes another occurrence of gypsum.*

"At Gypsum point and along the southwest shore of the north arm, red coloured thin-bedded calcareous sandstones and arenaceous limestones, ripple-marked and cross bedded, outcrop in various places and hold, between the bedding planes, thin seams of flesh-coloured gypsum. Some of the gypsum is well crystallized into long satinspar crystals and shows distinct evidence of deposition from solution." Beds of flesh-coloured gypsum, 2 to 5 inches in thickness were found at this locality.

At Bear Rock mountain, situated at the junction of Great Bear river and Mackenzie river a couple of miles west of Fort Norman, an extensive deposit of gypsum is described by McConnell.**

"Bear Rock is separated from the main range, and is built of limestones, quartzites and shales, bent into the form of an anticlinal. A small stream cuts deeply into the heart of the mountain and exposes a very good section. The lowest beds seen consist of reddish and greenish shales, alternating with layers of pink colored gypsum, and cut by numerous veins and seams of a white fibrous variety of the same mineral. The gypsum in parts of the section replaces the shales almost altogether, and the layers are separated by mere films of greenish and reddish argiliaceous material. The base of the gypsiferous shales was not seen, but they are at least several hundred feet in thickness. They are overlain by a series of dolomites, quartzites and limestones six to seven hundred feet thick, and then by the bluish coral bearing limestones of the Devonian. Some of the limestone is bituminous, and omits a fetid odor when struck, and Franklin states that he saw "sulphurous springs and streams of mineral pitch issuing from the lower parts of the limestone strata." These were not seen by Richardson when he descended the river in 1826, on account of the height of the water, and they were also hidden at the time of my visit."

Dawson states*** "The 'Rock by the River's Side' on the east bank of the Mackenzie, about half-way from the Liard to Bear Lake River, is

*Cameron, A. E., Geol. Surv., Can., Sum. Rept., 1916, p. 74.
**McConnell, R. G., Geol. Surv., Can. Ann. Rept., Vol. IV, 1888-89, p. 101 D.
***Dawson, G. M., Geol. Surv., Can., Ann. Rept., Vol. II, 1886, p. 18 R.

the only solid rock observed by Richardson in this part of the course of the river. It consists of limestone dipping at high angles and is cut by veins of gypsum. The rocks are said to be like those of the limestone ridge at the rapid on Bear Lake River. Shale beds are said to 'abut' against the lower side of the rock rendering it probable that there is here an unconformable contact of the Cretaceous rocks with the limestones."

Thin layers of gypsum inter-stratified with dark grey, shaly dolomite, occur on Mount Charles near "The Rapid" on Great Bear river.**

According to the record of well No. 1 drilled by the Athabaska Oils, Limited, on the east bank of the Athabaska about 10 miles below Fort MacKay, a bed of gypsum 130 feet thick is recorded at a depth of 577 feet below the surface.

Beds of gypsum undoubtedly occur along the Athabaska river, but the purity of the material has not yet been determined. The wells drilled through this horizon would seem to show that the gypsum is closely associated with rock salt, as a strong flow of salt water has been encountered in certain wells below the gypsum horizon.

In Manitoba the gypsum industry though still young is increasing each year in importance. The deposits are extensive and the gypsum lies within a few feet of the surface. With transportation facilities these deposits are proving to be commercially valuable. From this gypsum all grades of wall plaster are produced. Plaster board and asbestos plaster are also being manufactured in small quantities from the deposits located at Gypsumville.

It is reasonable to expect that with better transportation facilities the gypsum deposits along the Peace river at least, will become a commercial asset to this province. There is already a growing market for gypsum products throughout central Canada, which would undoubtedly increase if the manufactured products could be supplied locally at a lower price than the same imported material.

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IRON

INTRODUCTION.

The object of this report was to determine the possible occurrences of iron ore in Alberta which might be mined economically and manufactured within the province where there is an adequate supply of coal and natural gas for fuel. Another object was to investigate various newspaper and individual reports regarding the occurrences of extensive deposits of iron ore which were awaiting development in this province.

In making this investigation all obtainable information was procured from publications issued by the Geological Survey, the Mines Branch and the British Columbia Bureau of Mines; geologists and mining engineers who were acquainted with specific regions were consulted in person or by correspondence; the more accessible localities were visited, the geological structures examined and average samples taken for analysis.

All available information from other sources was carefully considered, such as from interested individuals, newspaper items, and reports written for companies or interested parties.

Iron occurs in Alberta in several forms, and at many localities, but up to the present time, no deposits have been found of such a size and quality as to warrant development. There are, however, very large unprospected areas north of Alberta and Saskatchewan in which iron ores of commercial value may yet be discovered. Since Alberta has an unlimited supply of coal, the presence of iron ore of even moderate grade, if in sufficient quantity to be mined economically, would prove to be an important asset with the growth and development of the industrial market in the western prairie provinces. Even if commercial deposits of iron ore were found in eastern British Columbia these would prove valuable to this province.

TYPES OF OCCURRENCES

1. Ironstone nodules in bands or as scattered nodules.
2. Ferruginous shales.
3. "Iron formation" (hematite) in pre-Cambrian areas north of Lake Athabaska.
4. Limonite and bog iron spring deposits of local distribution.
5. Magnetite shales.
6. Sheep river deposits.
7. Hematite deposits in eastern British Columbia.

IRONSTONE NODULES.

Ironstone nodules and clay nodules saturated with iron are widely distributed, and are abundant in the fresh-water and brackish-water sandstones of upper Cretaceous age throughout the province. These formations are exposed along the sides of valleys, and are particularly numerous at certain localities along the Red Deer, Battle, South Saskatchewan, Belly and Bow rivers. At many points, especially along the Red Deer river, an accumulation of the ironstone nodules has resulted from the disintegration and weathering of the soft Edmonton and Belly river sandstones. In the vicinity of Drumheller and also in the vicinity of Sand creek north of Brooks, such accumulations can be seen. In no locality are these deposits of economic importance.

Specimens of these ironstone nodules can be obtained which are high in metallic iron, but the quantity of such material is decidedly limited. The following analysis of clay ironstone from the river, 20 miles north of Brooks, was made by F. G. Wait of the Mines Branch*, "A light, clove brown, compact, massive ironstone." It yielded on analysis:

Metallic iron	57.22
Insoluble mineral matter	7.36
Titanic dioxide	None

Another sample of clay ironstone was analysed by F. G. Wait "from a short distance east of Bellevue, on the line of the Crows Nest Pass railway."

"A brownish-grey, reddish-brown weathering, compact, massive ironstone, with which is associated a small quantity of limonite."

"It was found to contain:

Metallic iron	36.63
Insoluble mineral matter	12.20
Titanium dioxide	None."

A more representative sample is referred to by J. B. Tyrrell in his description of the ironstone on the Red Deer.** "In some places along the outcrop of the beds of the Edmonton series, and notably on Red Deer River west of the Hand Hills, a large quantity of clay ironstone is scattered over the face of the clay and sandstone banks, and over the surface of the alluvial flats, which stretch between them and the river. Samples of ironstone similar to that which is here seen, have been analyzed by Mr. Hoffman, and found to contain from 22 to 34.90 per cent. of metallic iron. It occurs, however, in the rocks in very irregular lenticular bands and nodules, so that after what is lying on the surface had been collected, the work of digging it from the banks would give irregular and uncertain results."

Clay ironstone nodules also occur along the Peace river in the corresponding formations and the occurrence is described by R. G. McConnell.*** "Clay ironstone in nodules and thin beds, is of universal occurrence in the Cretaceous shales of the region, but is especially abundant in some of the outcrops of the Fort St. John shales on Peace River, between Battle River and the mouth of Smoky River. The ironstone here, owing to the rapid erosion of the soft shales has been silted out, and in many places forms thick accumulations at the foot of the cliffs lining the valley, some of which may prove to be of economic value. The Pelican sandstone on the Athabaska is usually capped with a bed of hemitiferous sandstone varying in thickness from a few inches to four or five feet. A specimen of this rock was examined in the laboratory of the Geological Survey, and found to contain 12.4 per cent. of metallic iron."

*Wait, F. G., Mines Branch, Can., No. 59, 1909, p. 69.
**Tyrrell, J. B., Geol. Surv., Can., Ann. Rept., 1886, p. 150 E.
***McConnell, R. G., Geol. Surv., Can., Ann. Rept. 1890-91, Vol. V, p. 63 D.

Along the Athabaska valley below Fort McMurray, Ells notes the occurrence of iron ore float, but this deposit had no commercial value.* "During the course of the season's work, fragments of iron ore float—up to 15 pounds in weight—were found at a number of points on Steepbank and Moose rivers. At a point on Steepbank river, 4.9 miles from the mouth, two small excavations, 40 feet apart, were made in the northeast bank. In each instance a thin capping of bituminous sand overlies a compacted bed, one to two feet in thickness, and made up of fragments of siderite up to 20 pounds in weight. These fragments are not water-worn nor pitted as would be the case with float that had been carried any distance. A bed of clay, one to four feet in thickness, underlies the iron ore, and itself rests upon well bedded Devonian limestones."

"A representative sample of the iron ore analysed by Mr. H. A. Leverin gave: Iron, 35 per cent; insoluble, 18 per cent."

FERRUGINOUS SHALES

Another occurrence of iron is found in a certain brown shale formation which outcrops along the inner foothills, and within the front ranges of the Rocky Mountains. This ferruginous formation has been traced from the International Boundary northward beyond the Athabaska river, but at no place has the quantity or the quality been found to be of economic importance. D. B. Dowling describes the character of these beds where they outcrop along the Athabaska river in Jasper Park.** "Some of the shale bands which separate the heavy bedded limestone formation contain a certain amount of iron oxide. In some cases these beds have a distinctly brownish colour, and samples, showing enrichment of the lower beds by infiltration from higher levels, are found, which could be called ores. These, if found in sufficiently large bodies, may be mined, but exploration sufficient to establish their presence in such quantity has not been undertaken. Claims for iron have been staked on the face of Fiddle mountain (between Fiddle and Drystone creeks) on a band of iron-bearing black shale which lies between the heavy limestone formations. The greatest impregnation of iron oxide is to be found in a series of siliceous shales between the limestone and the coal-bearing rocks above. As red bands, these rocks have been traced northward from the Kananaskis river, and their greater thickness, compared with the lower shales, should increase the possibility of finding in them mineable portions, though, as a rule, they would be of low grade. The smelting of these ores might be made possible by the reduction of the siliceous material by concentration."

IRON FORMATION

On the north shore of Lake Athabaska near Black bay, there occurs a series of rocks which Camsell has called the Tazin series. The upper member of this series has been called the iron formation by Alcock, who described it as follows:*** "The upper member of the group consists of an iron-bearing series, made up of white quartzite, banded, cherty, ferruginous quartzite and cherty quartzite, interbanded with hard, blue

*Ells, S. C., Mines Branch, Dept. of Mines, Can., Sum. Rept., 1914, p. 63.
**Dowling, D. B., Geol. Surv., Can., Sum. Rept., 1910, p. 158.
***Alcock, F. J., Geol. Surv., Can., Sum. Rept., 1916, pp. 154 and 155.

hematite. The quartzite is dense and hard and has been much fractured; concentration of the iron has been limited to small, local, well-leached patches."

"At several places the Tazin series contains considerable quantities of hematite and a number of claims have been staked on these deposits. Two types are represented: (1) shear-zones in hematite-bearing quartzite; (2) concentrations by the leaching of silica from the iron formation.

"An example of the former type is found northeast of Black bay. In a highly sheared zone the regional quartzite has gone over into a sericite schist. The zone contains considerable quantities of red hematite but the concentration has been insufficient to produce any valuable ore and the deposit itself is very limited.

"The second type of deposit is seen in the Beaverlodge syncline. The upper portion of the series, as already described, consists of interbedded hematite and quartzite. The structure consists of a syncline with dips on the limbs up to 70 degrees, and pitching to the southwest at an angle of 30 degrees, disappearing under the lake. The total area of the iron-bearing portion exposed covers only 250 acres. The hematite varies from a hard blue variety to a soft red variety and is highly siliceous, except in local well-leached patches. Evidence of the leaching of silica is seen in the transition of the quartzite into hematite with porous rock adjacent to the latter and in the fact that the hematite is found in cavities and along facture planes where circulation would favour leaching. The high grade variety is in too small quantities to be of economic importance in that region. An analysis of a specimen of hematite from this locality gave the following percentages: Iron, 66.70; silicon, 2.12; phosphorus, 0.014; sulphur, 0.013."

At Tsu lake Camsell found the same formation in the Tazin series.* "The Tsu lake area is situated northeast of lake Athabaska. The rocks have been grouped into the Tazin series which is pre-Cambrian in age and is the oldest known series in the region. They are intruded by granites and gneisses.

"This series contains lenses of iron formation. These lenses of iron ore are unimportant, but their presence affects the compass appreciably, so that the magnetic declination varies several degrees in different parts of the lake.

"The district is worthy of further investigation by the careful prospector, as larger bodies of iron ore might be found in the iron formation in the Tazin series of rocks."

LIMONITE, ETC.

Small deposits of limonite, bog iron, and yellow ochre are common, but no deposit has yet been described as workable in size or quality.

There are numerous iron springs along the sides of valleys and also on the plains, which have deposited yellow ochre, and in some the vegeta-

*Camsell, Charles, Geol. Surv., Can., 1916, Memoir No. 84.

tion has been replaced by limonite, but those deposits on record are relatively small and of no important value. Oxide of manganese (wad) is also associated with many of the spring deposits.

Samples of ochre have been sent in to the department, having fair qualities, from the vicinity of Athabaska landing, from the foothills region and from various points in the valleys of the North Saskatchewan, Red Deer and Battle river.

A sample of limonite from Red Deer river, east of Knee hill, was analysed by F. G. Wait of the Mines Branch and found to contain:*

Metallic iron	49.45
Insoluble mineral matter	7.20
Titanium dioxide	None.

There is a deposit of limonite known to occur on the north side of the North Saskatchewan river under the muskeg at the head of Redclay creek, about 15 miles northeast of Pakan. Samples which I have examined are of the loose earthy bog iron type and of good quality. This deposit is reported to be extensive, but no detailed examination has yet been made, and the depth of the deposit is not known.

Within the Rocky Mountains small deposits of limonite have been reported from several localities. I have examined ochre deposits on the slopes of the Bow Valley, south of Castle station, between Storm mountain and Copper mountain, and deposits of ochre from Chalybeate springs on the Vermilion river in British Columbia west of the pass by the same name; but these occurrences are small and are not valuable.

MAGNETITE SHALES

In the vicinity of Burmis station in Crows Nest Pass, 9 miles east of Blairmore, Alberta, iron bearing beds occur interbanded with a series of soft, coarse sandstones. These beds have been traced over 8 miles to the northwest. There are at least three iron bearing beds made up of hardened, black, magnetic sands. Considerable development work has been done on the deposits principally on the Gardiner group of claims. The thickest bed is shown to be 10½ feet and another band has a thickness of 8½ feet. The southern end of this deposit lies about one mile north of Burmis station. This is the only portion of the deposit that I was able to visit this season. In the small, open cuts two beds of iron ore are exposed. The larger bed is about five feet in width and the smaller one somewhat thinner. On the surface there appears to be a considerable thickness of ore because the beds are dipping at approximately the same angle as the slope of the hill so that the outcrop of the ore is very much wider than the natural width of the iron bearing bed.

The ore is magnetite, but all the analyses made from samples collected from various portions of the deposit show that there is a very high percentage of titanium in the ore. An analysis of an average sample gave about 40 per cent. of metallic iron and 5.5 per cent of titanic acid, so that this ore is not suitable in its natural condition. The presence of

*Mines Branch, Dept. of Mines, Can., No. 59, 1909, p. 69.

titanium in the ore raises the fusion point of the charge in the furnace so that it has the effect of freezing the charge. It is possible that the titanium shown in the analysis may be due, at least in part, to the presence of rutile or sphene or some other titanium mineral; if this is the case, a product might be obtained by some method of magnetite concentration, sufficiently free from titanium to be of commercial value. On the other hand, if the titanium is present as an impurity in the magnetite, no metallurgical process has yet been found which would concentrate the ore from such an impurity.

A number of samples of this ore were collected and a detailed examination will be made on them in order to ascertain the nature of the titaniferous material in the ore, and the possibility of concentrating this ore so that it can be smelted.

The following analysis were made from representative samples of iron ore from this deposit. No. 1 was made from samples which I collected from the southern end of the deposit one mile north of Burmis. This analysis was made by J. A. Kelso in the industrial laboratory in the University of Alberta. No. 2 is a sample taken from the richest looking material in the same locality as No. 1. No. 3 was made from a sample taken across the ten and a half foot bed towards the north end of the deposit. The samples Nos. 2 and 3 were collected by W. W. Leach of the Geological Survey and the analysis was made by the Mines Branch, Ottawa, in 1911.

	I	II	III
Metallic Iron	59.08 per cent.	55.50 per cent.	39.80 per cent.
Silica	4.03 per cent.	12.53 per cent.	18.33 per cent.
Alumina	2.30 per cent.	....	....
Ferric oxide	84.40 per cent.	....	....
Lime	0.09 per cent.	2.78 per cent.	2.21 per cent.
Magnesia	....	0.52 per cent.	2.25 per cent.
Titanium Dioxide	3.42 per cent.	5.74 per cent.	5.56 per cent.
Phosphorous	none	0.10 per cent.	0.073 per cent.
Sulphur	0.09 per cent.	trace	trace

This deposit seems to have considerable extent, and, if the percentage of titanium in the ore can be reduced by concentration, the ore might become commercially valuable. In the present state of the ore it is of little value and yet this is one of the most important deposits known at the present time in Alberta.

W. W. Leach, of the Geological Survey, examined this deposit in 1911 and reports as follows:* "At the end of the season a hurried visit was made to a number of iron claims in the vicinity of Burmis station, about 9 miles east of Blairmore. These claims have been prospected by means of open-cuts and a short tunnel along a line extending for about 8 miles northwards from a point near Burmis station; most of the prospecting, however, having been done near the northern extremity of this line on the headwaters of Cow creek.

*Leach, W. W., Geol. Surv., Can., Sum. Rept., 1911, p. 199.

"The iron-bearing beds occur interbedded with a series of soft, rather coarse, light-coloured sandstones which outcrop along the foothills two or three miles east of the Livingstone range. This range is composed of Palalozoic limestone with a narrow belt of the coal-bearing Kootenay formation, evidently with a faulted contact, lying along its eastern flanks. The sandstone series containing the iron-bearing beds apparently forms part of the upper Cretaceous group which extends eastward towards the prairie, but as no fossils were found and its stratigraphical relations not seen, its proper horizon is not known. It is evident, however, that the great fault noticed in the Crows Nest valley near Burmis must extend northward, a short distance east of the Livingstone range, and with its eastern downthrow brings together the Kootenay rocks and the upper Cretaceous.

"On the most northerly claims, where most work has been done, there are at least three iron-bearing beds contained in a thickness of not more than 250 feet of strata; the rocks here, however, are rather severely folded, causing difficulty in identifying the beds on which the various openings have been made.

"In the valley of a small creek, rising in the Livingstone range, three distinct beds were seen, on the middle one of which a tunnel about 100 feet in length has been driven with a cross-cut 34 feet long, driven to the west, at the end. The tunnel and the first 20 feet of the cross-cut are in ore, but unfortunately this work was done on the axis of a synclinal fold with gentle dip on its easterly limb and slightly overturned to the west, the result being that at the tunnel entrance the ore is lying almost flat while at the end of the cross-cut it is standing vertical. The ore is also somewhat fractured, is much slickensided, and shows considerable calcite developed along fracture planes. It is impossible at this point to gain a fair idea of the size or quality of the deposit. About 200 yards to the south of the tunnel an open-cut on the same bed also near the axis of the syncline shows it to be 8½ feet thick and fairly uniform in character.

"Another open-cut about one-half mile south of the tunnel exposes a second bed which is probably below the first and is here 10½ feet thick. The strata at this point are nearly horizontal, dipping from 5 to 8 degrees to the west; and the ore appears to be of a very uniform nature. A sample taken across the bed in this cut was analyzed by the Mines Branch with the following results:

Fe (metallic)	39.80	per cent.
SiO_2	18.33	per cent.
CaO	2.21	per cent.
MgO	2.25	per cent.
TiO_2	5.56	per cent.
P	0.073	per cent.
S	trace.	

"The writer was informed that there are a number of other openings both to the north and south of this point, but none of these were examined with the exception of a couple of small cuts, about one mile north of

Burmis, where two beds of iron ore were seen. The ore, where stripped, was found to be dipping with practically the same angle as the slope of the hill so that it was difficult to measure the thickness of the beds, the larger bed showing about five feet and the smaller three feet of ore with the top in neither case clearly defined.

"A sample of the smaller and richer-looking bed was taken and analysed by the Mines Branch, the results being as follows:

Fe (metallic)	55.50 per cent.
SiO_2	12.53 per cent.
CaO	2.78 per cent.
MgO	0.52 per cent.
TiO_2	5.74 per cent.
P	0.10 per cent.
S	trace.

"It would appear that this deposit consists of a number of beds of indurated black magnetic sand, probably in the form of an ancient shore concentration. Under the microscope the ore was seen to be composed of more or less rounded particles of magnetite, quartz, and augite with a little secondary calcite, apparently derived from plagioclase, the whole being cemented with iron oxide. It is possible that the titanium dioxide shown in the above analysis may be due, at least in part, to the presence of sphene or rutile; if this is the case a product might be obtained by some method of magnetic concentration, sufficiently free from titanium to be of commercial value. Experiments are now being conducted in order to ascertain the nature of the titaniferous minerals present in the ore."

SHEEP RIVER DEPOSITS

During the past year considerable interest and excitement has arisen over the reports which occasionally appeared in newspapers, sometimes the remarks of individuals, and sometimes as news items from sources unknown, that there were enormous deposits of iron situated southwest of Calgary from which unlimited supplies of iron ore could be obtained for smelting purposes. These reports were to a certain extent responsible for the request that this investigation be made on the possible iron supply within the province.

The district referred to lies southwest of Okotoks, along the south fork of Sheep river, in the foothills and also within the front ranges of the Rocky Mountains.

I have gone over the section from the Turner valley west to range 6, and have examined and sampled what was supposed to be the richest beds, and yet it is with regret that I have to report that the grade of ore is most unsatisfactory, as is shown by the accompanying analyses, and also the quantity is quite insignificant, so that the reports which have been current were entirely unfounded on facts.

There are two localities along the Sheep river to be discussed, where scores of claims have been staked for iron, and some prospecting has been carried out, a number of years ago.

The one locality extends west for about four miles from the junction of Macabee creek and the south fork of Sheep river, about twenty-five miles west southwest of Okotoks.

I was given a report which was not signed, but which had been made for a syndicate controlling thirty mining claims in this locality. This report describes the location of the property, and the geology, which is decidedly erroneous. The report states "This property possesses two veins of clay ironstone, one of which measures approximately 400 feet across, aggregating a width of 1100 feet of vein." An estimate of the ore available is given as 2,400,000,000 tons. It is also stated that if the ore were mined at the rate of 10,000 tons per day, mining operations could continue for 766 years on this property. An analysis is also given from "Samples taken from the surface," and analysed by the Kingston School of Mines at Kingston. This analysis gives 29.9 per cent. metallic iron in the sample as submitted.

I visited this property in company with Mr. D. B. Dowling of the Geological Survey, who was also interested that such a deposit of iron had been overlooked by various geologists who had previously examined this district. I examined the section, which is well exposed along the Sheep river, also a short tunnel and several open cut prospects. The formation is the Benton shales, the character of which is known throughout the whole of Alberta. There are a few clay ironstone bands, but the widest exposed in the section is shown in Plate 1 and measured about eight inches. Samples were taken from a tunnel on the north bank of Sheep river, which, when analysed show that the sandy shales cannot even be classed as ferruginous, so low is the content of iron. The following analyses were made by J. A. Kelso, in the Industrial Laboratory at the University of Alberta:

	I.	II.
Metallic Iron	4.55 per cent.	4.03 per cent.
Silica	67.86 per cent.	70.40 per cent.
Alumnia	13.96 per cent.	15.16 per cent.
Ferric oxide	6.50 per cent.	5.76 per cent.
Lime	0.12 per cent.	0.12 per cent.
Phosphorous	0.01 per cent.	0.04 per cent.
Sulphur	0.12 per cent.	0.18 per cent.

Instead of there being billions of tons of iron ore in this locality, there is not a single ton of rock exposed in this section which would be classed as iron ore.

I wish to emphasize this point, that steps should be taken at once to prevent the circulation of such an erroneous report as mentioned above, which is most detrimental to the industrial welfare of the country when the facts are known.

The other district to which I will refer is situated along Sheep river about 25 miles west of Macabee creek. A blue print which was given me shows the position of forty-six mining claims which were staked for iron. These claims lie west of the mouth of Gorge creek. There is a well-exposed section along Sheep river above the mouth of Gorge creek. I examined the section at a number of points and was accompanied by an interested party, who took me to what were supposed to be the best showings. More time would have been spent on the section if the character of the rock and the indications of iron had been more favorable.

The rock consists of sandy shales and sandstones interbedded with highly siliceous ferruginous bands. Three of these iron bands are shown in one exposure, lying between steeply dipping sandstone. The widest iron band observed measured forty inches. Samples were taken from a number of the iron bands and three of the best were analysed by J. A. Kelso at the University of Alberta. The results of these analyses are:—

	I	II	III
Metallic Iron	7.61 per cent.	6.19 per cent.	7.01 per cent.
Silica	69.20 per cent.	70.04 per cent.	68.08 per cent.
Alumnia	16.34 per cent.	18.18 per cent.	13.70 per cent.
Ferric Oxide	10.88 per cent.	8.84 per cent.	10.02 per cent.
Lime	0.22 per cent.	0.32 per cent.	0.08 per cent.
Phosphorous	0.02 per cent.	0.10 per cent.	0.03 per cent.
Sulphur	0.08 per cent.	0.18 per cent.	0.08 per cent.

The quantity of ore in these iron bands is commercially unimportant, and the analyses show that the quality of the ore is also of no commercial value. Aside from these factors the analyses show that the ore is extremely high in silica and practically free from lime, so that even though the iron content were many times greater, the highly silicious character of the ore would make it almost impossible of treatment in the ordinary blast furnace without concentration. The concentration of such an iron rock is not an economic possibility.

HEMATITE DEPOSITS IN EASTERN B. C.

The nearest known deposits of iron outside of the province of Alberta are those known as the Bull river and the Kitchener deposits in southern British Columbia.

The Bull river deposits occur in the Fort Steele Mining Division, East Kootenay, B. C., about six miles from the Bull River station on the Kootenay Central railway, between Elko and Fort Steele, twenty miles from Cranbrook, and about ten miles north of Jaffray station on the Crow's Nest line of the Canadian Pacific rialway. The deposits are situated on the southeast side of Bull river at an elevation of 3,000 feet above the valley.

Leach examined this deposit in 1902 and describes the occurrence as follows:* "The base of the mountain consists of Cambrian quartzites and altered argillites dipping at low angles to the east. Towards the top these are succeeded by dolomites, interbedded with highly altered argillites, apparently conformable with the lower beds and probably also of Cambrian age. In a number of these upper beds the original constituents

*Leach, W. W., Geol. Surv., Can., Ann. Rept., Vol. XV, 1902-3, p. 181 A.

have been replaced in varying degrees by hematite ore. The work done consists entirely of surface stripping and open cuts, more or less disconnected, so that until further work is done it is impossible to form an opinion as to the continuity of the ore in the several beds, nor was the source of the ore made clear, though it is certain that mineralization has taken place over a considerable area. The ore appears to be of good quality, though in places somewhat silicious. The maximum thickness of clear ore seen was about five feet."

More recent information has been received from Mr. James L. Laidlaw, Mining Engineer at Cranbrook. The property of the Bull River Iron Mines, on which considerable development work has been done, is situated at an elevation of 6,500 feet above sea level, and 3,000 feet above the railway at Bull River station. A wagon road leads from the railway to the foot of the mountain, a distance of six miles.

The property in this group consists of eight claims and fractions, about three hundred and seventy-five acres, and crown granted. Development work consists of several open cuts and short tunnels.

The ore is hematite, and it occurs in bands interbedded with limestone and dolomite which is reported to be Devono-Carboniferous in age. The greatest width of iron band recorded is eight feet, but there are numerous one to four foot bands reported.

Five zones of parallel veins have been noted and can be traced across the entire length of the claims, a distance of 3,500 feet. A typical section of one of these zones is given as follows:—

Ore, 4 feet, containing 55 per cent. iron.
Rock, 1 foot.
Ore, 3 feet, containing 35 per cent. iron.
Rock, 6 inches.
Ore, 1 foot, containing 60 per cent. iron
Rock 1 foot.

An average analysis of the hematite, supplied by Mr. Laidlaw is:—

Metallic iron	58.99 per cent.
Sulphur	0.062 per cent.
Phosphorus	0.029 per cent.
Insoluble residue	10.14 per cent.

At the foot of the mountain on which the deposits occur in Bull River there are falls capable of developing 12,000 H.P. The nearest coke supply is Fernie, a distance of fifty miles. Limestone for flux occurs close to the deposits.

The Kitchener iron deposits are situated near Cadorna station on the British Columbia Southern railway. A blue print map and a few notes on the deposits were kindly supplied by the Natural Resources Department of the Canadian Pacific railway at Calgary. This map shows over sixty claims and ten fractions. These claims are situated along a narrow zone about eight miles long, which follows a northwest and southeast trend between Goat river, just west of Cadorna, and Arrow creek to the west.

The ore consists of hematite and is found in steep-dipping veins. The widest vein is reported to be about sixteen feet. The country rock is quartzite with intruded bysills of greenstone. Numerous assays have been made on this ore, which are recorded to contain on an average of from fifty-seven to sixty-four per cent. iron.

No detailed maps or geological examination have yet been made of these districts, which would indicate the persistence of the ore, although geologists and mining engineers have stated that the quantity of ore and the inaccessibility of the deposits would not warrant development at the present time. Further information is required on these deposits of hematite ore.

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LEAD

Stringers of galena have been noticed in the Rocky Mountains in the vicinity of Castle Mountain west of Banff, the Yellowhead Pass west of Edmonton and at a few other localities, but the quantity of this metal is insignificant.

MINERAL SPRINGS

This preliminary report on the mineral springs of Alberta deals briefly with some of the characteristics, which have been noticed in the variation of composition of samples of water analyzed from several of the numerous mineral springs. A detailed study has been made of the waters from the more important mineral springs of Canada by R. T. Elworthy, and published in 1918 as Bulletin 20, Part 2, by the Mines Branch, Ottawa. Only a brief summary of the analyses made from Alberta springs is included in this report, and a few additional analyses are given of mineral waters not included in the bulletin referred to above.

The composition of the waters in the springs recorded varies in the character of the salts present in solution, and also in the quantity of each salt in the water. Many known springs throughout this province have not been tested for their mineral content. Considerable chemical investigations must yet be made on mineral waters from springs and from numerous lakes throughout Alberta, before the economic value for medicinal purposes or for the extraction of some salt can be determined.

The analyses of springs Nos. 1 to 13 are given in detail in the bulletin referred to above, prepared by Mr. Elworthy.

No. 1. Hudson's Bay Springs, situated at the forks of Salt river, a tributary of Slave river.

No. 2. Mission Springs, about 6 miles south of the forks of Salt River.

No. 3. Snake Mountain Springs, about 2 miles east of Mission springs.

No. 4. Sulphur Point Springs, situated on the south shore of Great Slave lake.

No. 5. Vermilion Chutes Spring, from a borehole 268 feet deep at Vermilion Chute on Peace river.

No. 6. Sulphur Spring, Jasper Park, south of Pocahontas, Alberta.

Springs 7 to 13 inclusive occur in the vicinity of Banff, Alberta, on the east slope of Sulphur Mountain ridge—

No. 7. The Upper Hot Spring.

No. 8. The Kidney Spring, about 600 feet below No. 7.

No. 9. The Middle Hot Springs.

No. 10. The Cave Spring.

No. 11. The Basin Spring.

No. 12. The Lukewarm Spring, close to the automobile road, three miles west of Banff.

No. 13. The Alpine Club Spring.

Constituents.	Parts Per Million					
	1	2	3	4	5	6
Potassium Chloride	900	800	800	Trace	22	....
Sodium Chloride	258,000	256,300	256,000	351	12,100	82.4
Magnesium Chloride	800	800	800	191	739	...
Calcium Chloride	...	...	...	...	688	...
Sodium Sulphate	400	200	200	...	...	54.4
Magnesium Sulphate	...	...	...	644	...	100.0
Calcium Sulphate	4,100	4,200	4,200	1,220	143	...
Sodium Bicarbonate	...	...	...	...	...	...
Magnesium Bicarbonate	...	...	...	...	...	13.3
Calcium Bicarbonate	...	...	...	486	...	348.0
Ferric Oxide	...	...	...	...	...	} 7.3
Alumina	...	...	...	...	...	
Silica	...	...	...	...	...	8.9
TOTALS	264,200	262,300	262,000	2,892	13,692	614.3

Constituents.	Parts Per Million.						
	7	8	9	10	11	12	13
Ammonium Chloride	0.27	0.59	0.27	0.27	1.18	0.86	0.26
Lithium Chloride	0.59	0.59	1.19	1.19	0.59	0.30	...
Potassium Chloride	7.08	3.80	6.26	8.57	6.26	2.09	...
Sodium Chloride	9.82	10.17	6.37	7.83	7.83	5.09	3.80
Magnesium Chloride	...	1.52	...	...	...	49.76	...
Calcium Chloride	...	...	...	...	...	...	...
Sodium Sulphate	4.40	...	6.46	9.02	9.94	...	42.00
Magnesium Sulphate	196.50	191.00	192.51	194.11	351.63	50.98	143.50
Calcium Sulphate	672.20	615.87	640.78	593.84	1180.10	151.73	14.56
Calcium Bicarbonate	165.80	196.42	158.66	170.57	212.22	203.79	286.20
Strontium Bicarbonate	7.65	8.28	2.41	14.46	19.18	...	...
Ferrous Bicarbonate	7.65	2.22	10.50	4.80	8.10	2.23	3.47
Silica	31.0	31.0	27.6	23.40	31.0	12.4	12.6
TOTALS	1100.74	1061.46	1053.01	1028.06	1828.01	479.23	506.39

The following analyses are not recorded in Bulletin No. 20 of the Mines Branch, Ottawa.

14. La Saline spring, Athabaska river.

Twenty-seven miles north of McMurray on the east side of the Athabaska valley there are a number of small saline springs. The largest one has a basin 12 feet in diameter, and two feet in depth. The water from this spring is extremely clear and is depositing tufa on the lower slopes of the valley over which it runs.

A sample of this water which I collected on May 15th, 1919, was analysed by J. A. Kelso in the Industrial Laboratory at the University of Alberta.

Sample Collected	May 15th, 1919.
Temperature..................	40° F.
Flow.........................	Irregular
Taste.........................	Distinctly bitter.
Specific gravity at 15°C.........	1.052

ANALYSIS.

Constituents	Grains in one Imperial Gallon.	Parts per 1,000
Potassium Chloride	50.3	6.11
Sodium Chloride	3903.5	55.75
Magnesium Chloride	488.5	6.97
Lime Sulphate	413.3	5.90
Magnesium Sulphate	36.6	.52
Ignition Loss	207.0	2.95
Total Solids	5097.2	78.20

Specific gravity at 60° F. 1,052.

15. La Saline spring, Athabaska River.

Sample collected by R. G. McConnell, 1890.

ANALYSIS.

Constituents.	Parts per 1000
Potassium	0.868
Sodium	23.937
Calcium	1.574
Magnesium	0.496
Sulphuric acid (SO_4)	4.702
Chlorine	38.461
	70.038
Chlorine required, in addition to that found to satisfy bases	0.056
	70.094
Hypothetical combination—	
Chloride of potassium	1.655
Chloride of sodium	60.883
Chloride of magnesium	1.049
Sulphate of lime	5.352
Sulphate of magnesia	1.155
	70.094
Total dissolves solid matter, by direct experiment, dried at 180° C.	69.616
Specific gravity, at 15.5°C.	1.052

16. Saline springs on Red Clay creek, Athabaska valley.

Sample collected by R. G. McConnell in 1890.

ANALYSIS

Constituents.	Parts per 1000
Potassium	0.036
Sodium	4.783
Calcium	0.947
Magnesium	0.122
Sulphuric Acid (SO_4)	2.759
Chloride	7.394
	16.041
Chlorine required in addition to that found to satisfy bases	0.021
	16.062
Hypothetical combination—	
Chloride of potassium	0.069
Chloride of sodium	0.069
Sulphate of lime	3.220
Sulphate of magnesia	0.608
	16.062
Total dissolved solid matter by direct experiment dried at 180° C.	16.263

Specific gravity at 15.5°C. 1.012.

17, 18, 19. Overflow From Wells on Athabaska River.

In a number of wells which have been drilled for oil along the banks of the Athabaska river below McMurray, strong flows of saline water were encountered from three of these wells. The highly saline sulphurous waters are still flowing at a very rapid rate, and are depositing their salts on the rocks over which they flow. These analyses are taken from summary report for 1914, page 64, published by the Mines Branch, Ottawa.

17. Overflow from casing-head of number one well, Athabaska Oils, Ltd., ten miles below Fort McKay on Athabaska river.

18. Overflow from casing-head of "Salt of the Earth" well, west bank Athabaska river, one mile north of McKay.

19. Overflow from casing-head of well drilled by Fort McKay Oil and Asphalt Co., at La Saline, August, 1914. These samples were collected by S. C. Ells in 1914.

ANALYSIS

Constituents.	Parts per million.		
	17	18	19
Calcium	1,638	1,347	3,354
Magnesium	385	585	1,021
Potassium	296	336	192
Sodium	22,988	76,268	84,076
Chlorine	36,188	118,636	127,960
Bycarbonic acid (HCO_3)	469	372	36
Carbonic acid (CO_3)	none	none	none
Sulphuric acid (SO_4)	4,144	4,920	2,956
Specific gravity at 15.5° C.	1.047	1.133	1.150

NATURAL GAS

Natural gas is found to be widely distributed throughout the Cretaceous rocks which form the sub-structure of Alberta. The gas horizon in most cases occurs in strata over-lying oil bearing formations, and the gas may have been derived from the volatilization of the oil from the underlying beds. On the other hand there are gas horizons which are not believed to be underlain with oil bearing beds; in such cases the gas is believed to have been derived from carbonaceous material present in certain underlying strata. Gas horizons in Alberta occur in several of the members of the Cretaceous series, particularly the Upper Cretaceous, but small quantities of gas have been located in the younger formation, which is Tertiary in age.

In the southeast part of the province there is an extensive productive area in which Medicine Hat and Bow Island are the centres.

In the Medicine Hat field there are upwards of 70 wells. Gas is obtained from a sandstone about 1000 feet below the river level at Medicine Hat. This gas bearing sandstone belongs to the Milk River formation, which lies at the base of the Belly River series. In most of the wells, except the older ones, the gas is under a rock pressure of over 500 pounds. The gas is used for industrial and domestic purposes. Fuller details on this field are given in the summary report published by the Geological Survey for 1916, page 124.

The Bow Island gas field lies about 40 miles west of Medicine Hat. The gas sand in this field is reached at approximately 2000 feet. This gas horizon is considerably lower than the Medicine Hat gas sand, and occurs in two beds of sand about 30 feet apart, in the lower portion of the Colorado marine series, in what is known as the Benton shales. These sands lie about 400 feet above the base of this formation. The rock pressure in 1919 was about 700 pounds and the production per well varies from five million to 29 million cubic feet per day.*

The gas from this field is piped nearly 200 miles to supply Lethbridge, Macleod, Calgary and other smaller towns in Southern Alberta.

In both of these fields the gas is dry. This means that the gas contains a very low percentage of lighter oils.

In 1918 Alberta produced 6,318,389 thousand cubic feet from 74 wells, with a value of $1,358,638.00. This represents about 32 per cent. of the total production of natural gas throughout Canada. Almost all of this gas was produced from the Bow Island and Medicine Hat fields.

The Turner Valley gas field is situated 35 miles southwest of Calgary in the vicinity of Sheep river. The operations in this district are briefly described under the notes on petroleum. The gas and oil horizons in the Turner Valley are believed to occur in the Blairmore formation which underlies the Colorado shales. The lower part of this formation is of Dakota age.

*Slipper, S. E., Geol. Surv., Can., Memoir 116, 1919, p. 23.

It has been determined that gasoline can be extracted economically from natural gas by the absorption process. The Calgary Petroleum Products Company are now operating a plant and recovering gasoline from the natural gas. A series of absorption tests have been made on the gas with the recovery of as high as 1.7 and 1.9 pints of gasoline per 1,000 cubic feet of gas. The gasoline product had a specific gravity of about 0.837.*

An attempt is now being made to treat the gasoline extracted by some deodorizing process. If this is successful the value of the product obtained will be considerably increased.

The Viking gas field is situated 80 miles southeast of Edmonton. Nine wells have been drilled north of Viking by the Northern Alberta Natural Gas Development Company, for the purpose of providing a natural gas supply for the City of Edmonton. These wells have proven the presence of gas in two sands separated by a stratum of shale over 100 feet thick, and overlain by a thick series of shales. "The upper sand has been pierced in eight wells and gas has been obtained in varying amounts in each. The depths of this gas range from 2146 to 2200 feet from the surface. In four of the wells the flow seemed to be insignificant and the wells were drilled to the lower sand lying from 139 to 155 feet below the top of the upper sand. In three of these a large flow was obtained from the lower sand and the upper sand was cased off. In one, the gas is supposed to be derived from both sands."**

The gas in the Viking field is "wet", but contains a much lower percentage of gasoline than the gas in the Turner Valley field.

Absorption tests showed that 1,000 cubic feet of gas contained only from 0.01 to 0.06 pints (American measure) of gasoline, with a specific gravity ranging from 0.834 to 0.838.

Tests were carried out on the calorific value of the natural gases in the above mentioned fields. The abbreviated results of these tests are as follows:***

Source of Gas.	B.T.U. per Cubic Foot.
Bow Island Pipe Line	893.8
Bow Island Town Well	817.0
Medicine Hat City Hall	745.3
Medicine Hat Old Power Station	677.4
Calgary Petroleum Products, Ltd.	
Well No. 1 from inner casing	876.5
Well No. 2 from inner casing	1008.0 to 1146.3
No. 2. Upper gas well	873.6
No. 2. Upper gas well	1015.0
No. 2. Lower gas well	1104.0

Along the Athabaska river below Athabaska Landing there are numerous gas seepages. Flows of gas have also been encountered in almost every well drilled in this field.

*Geol. Surv., Can., Sum. Rept., 1918, page 21C.
**Dowling, D. B., Geol. Surv., Can., Sum. Rept., 1918, page 39C.
***Geol. Surv., Can., Sum. Rept., 1918, page 20C.

In the summer of 1897 the Federal Government commenced drilling at the mouth of Pelican river. The following summer work was resumed, and, at a depth of 837 feet a strong flow of gas under terrific pressure was struck which caused operations to cease. This natural gas has been flowing out of this well into the air since that date, and it is reported that the pressure has not been greatly decreased during the past twenty-four years. This well alone proves that the quantity of gas in the Athabaska field is very great.

Gas has been struck in wells drilled for oil at various points along the Peace river from the town of Peace River down stream.

The horizon from which much of the gas on the Athabaska and Peace rivers is derived, occurs at or near the base of the Lower Cretaceous series. Small quantities of gas have been struck in the La Biche shales which occur about the centre of the Upper Cretaceous.

At scores of localities in Alberta, and in the district north of the province, the presence of gas has been proven. These occurrences show that the natural gas in reserve is very widely distributed throughout the province both horizontally and vertically. Nevertheless, it is important that steps should be taken to conserve the natural gas, and where possible, to extract from it any gasoline or other lighter oils which it may contain.

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NICKEL

Nickel deposits of economic importance do not occur in Alberta, but in the Pre-Cambrian rocks, at the east end of lake Athabaska in the neighborhood of the trading post of Fond du Lac, nickel-bearing rocks were discovered in 1912 by prospectors sent out by the Northern Exploration Co. of Edmonton. Prospectors rushed into the field in 1913 and 1914, and especially in 1915 after it had been reported that very rich silver ore had been discovered. One assay was reported to give $11,000 to the ton in silver.

In the summer of 1915 Mr. Charles Camsell was sent in by the Geological Survey to examine the reported deposits. In his report Camsell states "There is undoubted evidence of nickel and copper occurring in the norite, but from the showings on the surface the ore-bodies appear to be too small and of too low grade to be economically important at present, in a region so remote from railway transportation. There is, however, sufficient evidence of sulphide mineralization throughout the region embracing the north shore of lake Athakaska to justify a hope that deposits of nickel, copper, silver, or gold ores may yet be found that would be sufficiently valuable to work."*

Regarding the silver discovery Camsell writes: "No evidence could be obtained that silver ore assaying $11,000 to the ton occurs anywhere in the region examined, and in my opinion the sample that gave that assay result must have come from elsewhere and possibly from outside the district altogether."

Several samples were collected by Mr. C. Camsell and Mr. F. J. Alcock from localities where some development work had been done, the analyses of these samples from the Fond du Lac ores, are given by Camsell as follows:**

	1	2	3	4	5	6
Copper	0.09	Nil	...	Trace	Trace	6.65
Nickel	Nil	Nil	0.10	Trace	0.20	0.07
Gold	...	Nil	Nil	Nil	Nil	Nil
Silver	...	Nil	Nil	Nil	Nil	Nil

Samples of Cobalt bloom have been brought from the north and are reported to have been found north of Athabaska lake.

PETROLEUM

A few brief notes will be given in this report on the occurrence of petroleum in Alberta, but this must be regarded as preliminary to a more detailed study of this mineral which is one of the most important occurrences in Alberta.

Although at the present time the principal oil fields in Canada are situated in the peninsula of southwest Ontario, yet widespread attention is being given to Alberta as a possible source for a supply of petroleum for future use.

Prospecting for oil has been carried on in Alberta most vigorously and energetically during the past two seasons. Scientific investigations are being carried on by large and small corporations in the search for reservoirs of petroleum.

*Geol. Surv., Can., Sum. Report., 1915, p. 122.
**Geol. Surv., Can., Sum. Rept., 1915, p. 125.

That petroleum occurs within this Province is an undisputed point from the facts which are now known, but the location of large reservoirs of oil is yet a matter of conjecture. If geological structures could be found suitable for the accumulation of oil, then the possibility of a commercial supply of petroleum occurring in these structures could only be proven by drilling operations.

The approximate production of petroleum in Alberta in 1918 was 13,040 barrels valued at $100,004.00. During the past five years there has been a small but increased production of petroleum in this Province. The total production in Canada in 1918 was 304,741 barrels. The production in Alberta was obtained from four or five wells situated in the Okotoks field in the Turner Valley southwest of Calgary. It was to this field that much attention was given in 1914 when a light oil about 90 per cent. gasoline was obtained, which without refinement was used in automobiles. A few notes on this field are here given.

The Okotoks field is situated 16 miles west of Okotoks in the Turner Valley. Okotoks, which is the shipping centre, is 27 miles south of Calgary.

Petroleum was struck on May 16, 1914. This "strike" was followed by a "boom," when about five hundred companies were formed. Most of these companies have since ceased to operate. The companies now operating include the following:—

Calgary Petroleum Products, Ltd.
Southern Alberta Company.
Alberta Petroleum Consolidated.
Alberta Southern Oil Company.
The Midwest Oil Company.
Record Oil Company.
Mount Stephen Oil and Gas Company.

The Calgary Petroleum Products Ltd. (originally the Dingman Company), have two wells operating, known as Dingman No. 1 and Dingman No. 2. A third well is now being drilled. Dingman No. 1 was completed in May, 1914, and it produced daily a few barrels of natural gasoline product. Dingman No. 2 is primarily a gas well. These two wells are reported to produce between three million and four million cubic feet of gas per day. The gas is rich in gasoline and is treated in a gasoline absorption plant which produces two grades. The first product is a gasoline about 10 degrees lighter than ordinary commercial gasoline. It has a gravity of 65° or 69° Beaume and is obtained by the absorption process. The second grade of gasoline is a compressor product with a gravity of 93° to 95° Beaume. The gas after passing through the plant is used to operate the absorption plant, and has a higher heating value than the ordinary natural gas.

No. 1 well of the Southern Alberta Company has a reported output of 30 to 50 barrels per day. The oil is treated in a "topping plant" operated by the Southern Alberta Refineries, Ltd. The products obtained are gasoline, kerosene and distillate. An additional plant is being installed to manufacture lubricating oils and wax from the residue. The

Refinery Company has paid at least three dividends each of 10 per cent., whereas the Southern Alberta Company has paid two dividends of 12 and 15 per cent. respectively.

The Alberta Petroleum Consolidated, better known as the "A. P. Con." has a well drilled to 2950 feet which produces a small quantity of heavier oil which has a gravity of 38° Beaume.

The Alberta Southern Company has one well producing 10 barrels per day.

The well of the Midwest Oil Company is now being drilled and is believed to be nearly completed.

The Record Oil Company has obtained a showing of oil in a well which is 4325 feet deep. This is the deepest well yet drilled in this district, and present indications appear to be quite favourable.

The Mount Stephen Oil and Gas Company is now drilling a well within a few hundred feet of No. 1 of the Southern Alberta Company.

During the past three years considerable development work has been done along the Peace river. Small quantities of oil have been found having a gravity of 12.5° Beaume, but commercial quantities have not yet been obtained.

In the vicinity of Great Slave lake there are seepages and petroleum springs from which samples of crude oil collected by A. E. Cameron of the Geological Survey in 1916, show a gravity of 16° Beaume. This is the highest grade of crude oil which has yet been obtained from Northern Alberta. Drilling operations have been started in this district and will be continued this coming summer by the Imperial Oil Co., Ltd.

There are numerous oil seepages distributed throughout the whole length of the province. The oil horizons are not yet definitely proven but more than one horizon seems to occur.

Certain porous sandstone series in the Upper Cretaceous form a suitable container of petroleum. One of these porous sandstone beds is saturated with petroliferous material and forms the bituminous sands or tar sands exposed along the Athabaska river. These have been described under the heading of Bitumen.

The source of the petroleum is in a deeper horizon of the Devonian bituminous shales, and possibly even in certain Silurian shales.

PHOSPHATE

One of the chief uses of phosphate is as a fertilizer. This use alone makes the discovery of phosphate beds, in or close to Alberta, very important on account of the agricultural resources in this province.

For a number of years beds of shale, carrying a sufficiently high percentage of phosphate of lime to make them of economic value have been mined in Idaho. The same formation extends northward within the

Rocky Mountains in Alberta and southeastern British Columbia. These phosphate beds have been examined at various points in the mountains as far north as the Athabaska river, and, although high grade fragments have been found with the drift, and in certain localities very thin layers of phosphate shale are known to occur in the Upper Carboniferous rocks, yet the beds are never thick enough nor sufficiently high in phosphates to be considered at present of commercial value. The highest phosphoric acid content obtained from analyses which were taken across the best strata was 27.63 per cent.

Adams and Dick in a paper on the "Discovery of Phosphate of Lime in the Rocky Mountains," published by the Conservation Commission of Canada, briefly describe the occurrence of phosphate beds from Idaho northward as far as the Banff district. A more detailed investigation on the possible occurrence of phosphate beds was carried out by the Department of Mines at Ottawa, with the result that a rather extensive report has been prepared on the economic value of phosphate rock at Banff, Alberta.*

The following quotations from this report sum up briefly the possibilities of economic deposits of phosphate rock in Alberta, in so far as field investigations have been carried.

"The writer's examination showed that a well defined phosphate series exists in the Rocky Mountains in rocks of Upper Carboniferous Age; but that, in the Banff area at least, the beds are neither thick nor sufficiently high in phosphoric acid to be considered of a present economic importance. The average content of tricalcic phosphate in the principal bed found was 43.7 per cent. The highest phosphoric acid content obtained from samples taken across the entire bed was 27.63 per cent. The rock though unsuited to the manufacture of acid phosphate by the sulphuric acid method, owing to the low percentage of tricalcic phosphate, and to the large amount of silica present, would possibly prove suitable for treatment by one of the thermic processes that have lately been proposed to supplant the sulphuric acid method. Mining would be difficult owing to the steep dip of the beds (55°) and would necessitate underground working."

On further examination of the phosphate beds at Banff during the summer of 1916, and of the area south to the Montana boundary, for the possibilities of further beds, de Schmid states: "The phosphate bed as represented in the Banff district, Alberta, becomes thinner and poorer in phosphoric acid the farther south it is followed. The most southerly outcrop found at Tent mountain, about 8 miles south of Crow's Nest, showed a three inch bed of such nodular phosphate, of which the purest material ran only 47 per cent. tricalcic phosphate."

It is the intention to carry on further investigations on the phosphatic beds within the mountains during the coming summer.

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*de Schmid, H. S.—"Investigation of a Reported Discovery of Phosphate in Alberta," Bulletin No. 12, Mines Branch, Ottawa, 1916.

POTASH

Potash may be obtained from a variety of sources. The main source of the world's supply of potash is obtained from brines or saline springs, or from deposits from certain springs, the water of which carries potassium salts in solution. Potash is an abundant constituent of certain igneous rocks in such minerals as orthoclase and leucite. But a process for the extraction of potash on a commercial scale from these minerals has not yet been obtained.

Previous to 1914 much of the potash consumed in this continent was obtained from Germany. The output in the United States is increasing each year, but up to the present time potash has not been found in commercial quantities in Canada.

There has been considerable interest taken in the possible occurrence of potash in commercial quantities in Alberta, Saskatchewan, and the territory to the north.

In 1916 Charles Camsell of the Geological Survey examined the region between Peace and Slave rivers in northern Alberta. The prime object of this investigation was to determine the possibility of finding salts of potassium associated with the gypsum beds which were known to outcrop in this region. Camsell's report is as follows:*

"Rumors had been circulated last spring that specimens of a mineral containing a high percentage of potash had been found somewhere in this region; and, since the only extensive deposits of potash in Europe are associated with beds of gypsum, anhydrite, and rock salt, it seemed not improbable that similar potassium salts might be found to be associated with the rocks of that character in this region. Potassium salts are very soluble indeed and it was recognized that natural outcrops of either potassium chlorides or sulphates would not be likely to occur in a region of such humidity as that of northern Alberta; and since it was not advisable for the Geological Survey to conduct any deep drilling operations on the gypsum beds, the investigation of possible sources of potash was necessarily confined to the collection and analyses of the underground waters which reach the surface at a number of points throughout the region.

"The locality in which potassium salts were most likely to be found was at the brine springs of Salt river. Three samples were collected from this locality, the analyses of which are given on a previous page. Recalculating the hypothetical combinations out to percentages of total solids we find that No. 1 contains 0.34 per cent. of potassium chloride; No. 2, 0.31 per cent.; and No. 3, 0.30 per cent. of the same mineral.

"Two other samples of water were taken, the analyses of which were made in the laboratory of the Department of Mines and are given below. No. 4 is from a depth of 268 feet in the bore-hole put down at Vermilion chutes on Peace river, and No. 5 is water from a natural spring at Sulphur point on the south shore of Great Slave lake.

"The analyses are as follows:

*Camsell, Charles, Geol. Surv., Can., Sum. Rept., 1916, p. 142.

ANALYSES OF WATERS FROM VERMILION CHUTES AND SULPHUR POINT

Ions	Parts per Million	
	No. 4	No. 5
Chlorine	8,340	213
Sulphuric acid (SO_4)	100	1,500
Bicarbonic acid (HCO_3)	...	370
Calcium	289	480
Magnesium	189	130
Sodium	4,760	200
Potassium	12	Trace
Total	13,690	2,892
Hydrogen sulphide	400	42

Hypothetical combination	Parts per Million		Percentage	
	No. 4	No. 5	No. 4	No. 5
Potassium chloride	22	...	0.16	...
Sodium chloride	12,100	351	88.37	12.14
Magnesium chloride	739	191	5.39	6.60
Calcium chloride	688	...	5.04	...
Magnesium sulphate	...	644	...	22.27
Calcium sulphate	143	1,220	1.04	42.18
Calcium bicarbonate	...	486	...	16.80
	13,692	2,892	100.00	100.00

Specific gravity at 18°C. No. 4, 1.011; No. 5, 1.002.
Flow of No. 4 on July 13, 1916, 42 gallons per minute; temperature 42°F.
Flow of No. 5, on Aug. 4, 1916, about 2 gallons per minute.

"In all these analyses the proportion of potasium is low, and certainly not high enough to make it possible to extract the potassium in a commercial way even if the volume of water from each of these localities were very much greater; nor is there anything to indicate that the waters of these springs flow through rocks containing an unusual proportion of potash. There is no evidence, therefore, of the presence of potash in commercial quantities in the vicinty of the points where these samples were collected."

Small quantities of potash are found in the analysis of samples taken from brine springs, and from water issuing from wells which have been drilled into the water bearing horizons in various localities throughout

Alberta. The percentage of potassium salts is, however, too small to make them of commercial importance, or to indicate that these saline waters are associated with beds of potassium minerals.

Throughout the plains there are numerous alkaline lakes, especially in the drier areas. The composition of the water in these lakes varies between wide limits, so that many salts are represented in the deposits associated with these lakes. The principal salts contain magnesium soda, potash, calcium, but there is still a very large field for investigation on the contents of these waters, and the amounts of mineral salts present. In 1917 Mr. D. B. Dowling of the Geological Survey investigated the presence of potash in the saline waters of certain lakes in Saskatchewan. In this report he states:*

"The presence of alkaline lakes in many districts, especially in the dry belt, has drawn attention to the possibility of there being potash salts in the rocks underlying the plains. Many analyses have been made of these waters and slight traces of potash have been found. The most hopeful indications are from samples of the waters from the northeastern part of Saskatchewan which is underlain by beds similar to the Odanah shales of the Riding Mountain section of Manitoba. Analyses of the shales of Pembina Mountain section and of the gumbo derived from the washing down of the shales into the Red River valley indicate that both contain a small amount of potash salts. The boulder clay of the Regina district, also, which is derived from the shales of the north, has appreciable amounts of potash minerals, so that although commercial deposits may be hard to find, yet, owing to the natural potash content of the soil, the agricultural necessity for this alkali is very remote in the Red River valley and throughout a large part of the plains.

"The water of Quill lake at Wynward contains an appreciable amount of potassium chloride, and it is possible that some contributing springs may be found that may be of value. The following analysis of this water has been furnished by the Canadian Pacific railway:

ANALYSIS OF WATER FROM QUILL LAKE

	Parts per 100,000.
Cal. carb.	20.55
Cal. sulph.	0.40
Mag. carb.	1.86
Mag. sulph.	562.46
Soda carb.	22.55
Soda sulph.	680.27
Soda chl.	178.43
Pot. chl.	16.33
Fe. and Al.	0.85
Silica	2.2

"Boring for potash is in progress near Weyburn. Surface indications in this district are derived possibly from the leaching of the boulder clay, but the boring will probably penetrate to the Odanah shale beneath and the question of whether the salt is disseminated through the shale as in the outcrops in Manitoba, or is found in commercial deposits, will be decided.

*Dowling, D. B., Geol. Surv., Can., Sum. Rept., 1917, Part C, p. 3.

"An analysis of the water found at Talmage on the Grand Trunk Pacific railway near Weyburn shows a high alkaline content, but the soda and potassium salts are not separated. The following analysis was made for the railway company by the Dearborn Chemical Company of Canada, Toronto.

ANALYSIS OF WATER FROM TALMAGE, SASK.

	Parts per gallon.
Silica	4.847
Oxides, iron and alumina	0.175
Carbonate of lime	trace
Sulphate of lime	62.665
Carbonate of magnesia	21.669
Sulphate of magnesia	86.243
Soda and potassium sulphates	117.992
Soda and potassium chlorides	6.970

"The brine springs of Lake Winnipegosis district in Manitoba have been found to contain a larger per cent. of the potassium salts than is found in the brines of western Ontario, but this percentage is apparently not sufficient to indicate that the water could be used as a source of potash."

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SALT

INTRODUCTION.

The Salt deposits of Canada and the salt industry have been fully described by L. H. Cole,* whereas the earlier development of the salt industry in Canada has been described in various reports of the Geological Survey. These and other shorter descriptions have been used freely in the compilation of this report, which deals specifically with the province of Alberta. The bibliography gives the names of those who have described or referred in detail to the occurrence of salt and brines in Canada.

Salt is one of the necessities of life and is universally in demand. With increased population and increased number of stock throughout Canada, the demand for this mineral will also increase. To these facts must be added the industrial growth of the country which will require an increase in the commercial supply of salt.

The salt industry in Canada is quite limited in extent. In 1918 Canada produced only 44 per cent. of the salt consumed by its population. The production of salt in Canada was 131,727 tons valued at $1,285,034,

*Cole, L. H.—"The Salt Deposits of Canada and the Salt Industry," Bulletin 323, Mines Branch, Dep't of Mines, 1915, p. 152.

which represents a decrease of 5 per cent. in the amount produced the previous year. On the other hand the value of the salt produced in 1918 was 22.6 per cent. higher than that of 1917. The United States in 1917 produced 6,978,177 short tons which represents more than 99 per cent. of all the salt used in that country for that year.

The total sales of salt in Canada in 1918 were 131,727 short tons valued at $1,285,039. The imports of salt were 168,417 tons valued at $1,119,170; the exports were 5,141 tons, valued at $75,807. The consumption of salt in Canada in 1918 was approximately 295,000 tons. Taking the population of Canada at 8,075,000, the per capita consumption of salt was 73 pounds.

The total consumption includes 100,103 tons of salt imported from Great Britain for the use of fisheries. When this quantity is deducted the per capita consumption amounts to 48 pounds.

Alberta has a population of 580,000. If the average consumption per capita corresponds to that of the whole Dominion of Canada, the annual requirements of salt in the province of Alberta would amount to 13,920 tons.

The Canadian production in 1918 was obtained entirely from the salt fields in south western Ontario, where are situated the only salt deposits which have yet been commercially developed in Canada. A few years ago there was a small production from brines in Manitoba and New Brunswick. A deposit of rock salt, in one place about 50 feet in thickness, has been recently opened up in the neighborhood of Malagash, Cumberland county, Nova Scotia.* This is the first known occurrence of rock salt in Canada to be discovered at a depth sufficiently shallow to enable it to be worked economically by actual mining operations.

The occurrence of numerous saline springs, some of them nearly saturated with common salt, and the reported occurrence of thick beds of rock salt at moderate depths in Alberta, make it most important that the possibilities of developing economical deposits of salt in this province should be thoroughly investigated.

USES OF SALT

The uses of salt are many and varied and the number is being increased from time to time. Salt is used largely for domestic purposes. A very white and fine grade and one free from or low in impurities is required for table and culinary purposes. For salting cattle both in the stable and in the field, a very coarse grade of rock salt is desired. Salt is used to prevent deterioration in dairying, both in butter and cheese manufacturing, meat packing, fish-curing, and other related industries. It is also used extensively for refrigerating purposes, such as in the manufacturing of ice cream.

In the metallurgical industry salt is used extensively in the treatment of gold, silver, copper and lead ores by chloridizing, roasting and leaching processes, and also in the refining of copper-nickel material such as is produced at Sudbury, Ontario.

*Cole, L. H.—"Notes on the Discovery of Rock Salt in Nova Scotia," Can. Min. Jl., Vol. 40, No. 1, 1919, p. 8.

In the form of brine, salt is used extensively in the chemical industries in the preparation of various salts of sodium for the market. Among the salts produced from this mineral might be mentioned, caustic soda (sodium hydrate), soda ash (sodium carbonate), salt cake (sodium sulphate), bleaching powder (chloride of lime), and various other chemicals containing a sodium base.

There are many other miscellaneous uses such as curing hides, making pickles, the salt glaze on pottery, in enamelling and pipe works, to prevent cracking of bricks in drying and firing, and in the manufacture of carborundum. Salt is also of value in recovering potash salts as a by-product in the Portland cement industry.

Within the last few years the demand for industrial products has increased within the Dominion along with the rapid commercial and industrial growth. This demand has in many cases caused an importation of the finished or raw material required. This increased demand will undoubtedly result in research as to the possibility of obtaining the raw material, and in producing the finished products within the confines of the Dominion.

COMPOSITION OF SALT

Common salt or rock salt is known to mineralogists as halite. It is the chloride of sodium ($NaCl$) and is composed of 60.6% sodium and 39.4% of chlorine. Rock salt has a vitreous lustre and is transparent and colorless when pure. Sometimes various shades of color are present; these are due to impurities which give blue, brown, red, yellow or purple hues. Salt has a characteristic taste known to all, and is readily soluble in water.

When rock salt is found crystallized the crystals usually have the form of a cube; frequently these crystals are distorted and cavernous on the smooth face. The crystals break very readily along faces parallel to the sides of the cube. These features are all readily noted in any coarse variety of table salt, when examined under a magnifying lens.

Rock salt also occurs massive in the form of beds which may vary in thickness, and which frequently are interstratified with other rock material. Rock salt is an important source of commercial salt, and it is only the massive form of loosely crystallized salt.

TYPES OF OCCURRENCE

Common salt is a widely distributed mineral and occurs in the following types of deposits:—

(1) As beds of sufficient thickness to constitute solid masses termed rock salt.

(2) As natural brine in pores and cavities in the rocks, from which it may flow as salt springs, or be tapped by wells drilled or dug through the overlying rock formations.

(3) In solution in the water of the ocean, and in inland salt lakes or seas, as in the case of Great Salt lake in Utah, or the Dead Sea in Palestine.

(4) As minute crystals disseminated through the soil, or in marshes and swamps.

The first three are of economic importance as any of these types may serve as a commercial source of salt.

Salt is present in all ocean water. Normal sea water contains about 3.5 per cent solid material, largely common salt. Most inland lakes or seas which have no outlet contain varying percentages of common salt. In these cases the percentage of salt has resulted from the concentration of the water by evaporation. This process, the concentration of salt water, has been going on in nature from the earliest geological time to the present epoch, so that salt is obtained from rocks of all ages from the Cambrian to the present. In Canada rock salt and brines are associated with the Silurian, Devonian, and Carboniferous rocks.

The actual operation of the deposition of salt can be observed in many accessible localities. When a salt lake dries up, or when a body of ocean water becomes partly cut off by a barrier, evaporation in the enclosed area exceeds the supply of water carried into that basin, with the result that a bed of salt is formed. It is important to note that such beds of salt are lenticular in shape, thick at the centre where the water was deepest, and thinning out towards the edges.

There are several other explanations for the origin of beds of rock salt, but in every case the salt has been deposited through the concentration of saline water.

Pure rock salt is seldom found in beds of any great thickness. There is frequently an alternation of material, usually, gypsum, salt, clay, and other more soluble salts which may be present in the concentrated saline waters.

In cases where rock salt is formed from the evaporation of sea water, it is invariably associated with gypsum, but it does not follow that gypsum and salt must always be found together because gypsum is sometimes derived from other sources, whereas rock salt might be formed by the leaching of salt from older formations. In such cases salt would be found independent of gypsum.

OCCURRENCES OF SALINE SPRINGS.

There are numerous saline springs known to occur in various localities within the Mackenzie basin. There is an outcrop of rock salt on the northeast end of Bear Rock, near the mouth of Great Bear river. This is the only occurrence reported where rock salt outcrops at the surface.

The salinity of the waters from various springs differ from adjoining regions and sometimes in the same region. The salinity ranges from a mere trace of sodium chloride to about 26 per cent., which represents almost total saturation.

The most important saline springs at the present time are those situated on the Salt river which lies at the extreme northern limit of the Province of Alberta and enters the Slave river about half way between Athabasca and Great Slave lakes. There are four important groups of springs, from each of which salt is deposited on the surface, in two of these springs salt is collected and used by the Hudson's Bay Company and also by the Roman Catholic Mission, upwards of four tons are collected annually from these springs. The occurrence of these springs has been known for many years, descriptions of the salt springs were given by Sir John Richardson, by Captain Back, McConnell and C. Camsell.

Richardson who visited the springs in 1820 writes as follows:

*"The Salt River flows in from the westward, a short way below the portages. We ascended it for twenty-two miles, including its windings, but not above half that distance in a straight line, for the purpose of visiting the salt springs from which it derives its taste and name. Seven or eight copious saline springs issue from the base of a long, even ridge about six hundred feet high, and spreading their waters over an extensive clayey plain, deposit a considerable quantity of very pure common salt in large cubical crystals. The mother water flowing into the Salt River gives it a very bitter taste, which it retains until near its junction with the Slave River, when the addition of some fresh water streams, renders it only slightly brackish. A few patches of greyish compact gypsum were exposed on the side of the ridge from whence the springs issue."

In 1833 the springs were again visited by Richardson, accompanied by Captain Back, the latter describes them as follows:

**"There were no mounds like those seen in 1820; but just at the foot of the hill which bounds the prairie in that quarter, there were three springs, varying in diameter from four to twelve feet, and producing hillocks of salt, from fourteen to thirty inches in height. The streams were dry, but the surface of the clayey soil was covered, to the extent of a few hundred yards toward the plain, with a white crust of saline particles."

Mr. R. G. McConnell in the summer of 1887 ascended the Salt river as far as the brine springs and gives a description of the occurrence in his report for that year.***

As these brine springs are of economic importance the description given by Camsell, who visited this district in 1902, and again in 1916, is as follows:

****"In each of the springs the water rises among an accumulation of boulders near the base of the escarpment and flows thence into shallow circular basins, after which the water trickles away through barren salt-encrusted clay flats to the river. On evaporation, salt is precipitated from the brine in the basins and is gathered at these points. The basins are usually about 15 to 30 feet in diameter and are in many cases surrounded by a natural dyke of clay or gravel 1 to 3 feet high. The bottoms of the basins are floored with a deposit of salt of varying thickness. In other cases hillocks of salt 12 or 15 feet in diamteer and up to 2 feet in height are formed at the springs.

At the time of our visit to these springs on August 26 and 27, the flow was very small, being rarely as much as four gallons per minute at any one spring. The flow, however, is said to be considerably greater in

*Dawson, G. M., Geol. Surv. Can., Annual Report, Vol. 2, 1886, p. 14 R.
**Narrative of the Arctic Land Expedition, p. 80.
***Geol. Surv., Can., Vol. 4, p. 62 D. 1887.
****Camsell, C., Summary Report, Geol. Surv., Can., 1916, p. 141.

the spring-time when the surface water is melting and running off from the region. The temperature of the brines on emission varied from 35 to 40 degrees Fahrenheit, with the atmosphere at 60 to 70 degrees, and many of them were saturated solutions of sodium chloride.

Altogether about 4 tons of salt are collected annually from these springs for the use of the trading posts and missions of the Mackenzie River district.

Samples of brine were taken from three localities and analysed in the laboratory of the Department of Mines, Ottawa. The data on the samples are as follows:

No. 1 locality, Hudson's Bay springs at the forks of Salt river; taken August 21, 1916. Contains in 1,000 parts by weight:

ANALYSIS OF WATER FROM HUDSON'S BAY SPRINGS

Ions		Hypothetical combination	
Potassium	0.5	Potassium chloride	0.9
Sodium	101.5	Sodium chloride	258.0
Calcium	1.2	Calcium sulphate	4.1
Magnesium	0.2	Sodium sulphate	0.4
Chlorine	157.7	Magnesium chloride	0.8
Sulphuric acid (SO_4)	3.1		
	264.2		264.2

Temperature of air on collection .... 62°F.
Temperature of brine .... 40°F.
Specific gravity at 65°F. 1.204
Flow about 1½ gallons per minute from each of eight springs.

No. 2 locality, Mission springs, about 6 miles south of the forks of Salt river; taken August 26, 1916. Contains in 1,000 parts by weight:

ANALYSIS OF WATER FROM MISSION SPRINGS

Ions		Hypothetical combination	
Potassium	0.4	Potassium chloride	0.8
Sodium	100.8	Sodium chloride	256.3
Calcium	1.2	Calcium sulphate	4.2
Magnesium	0.2	Sodium sulphate	0.2
Chlorine	156.6	Magnesium chloride	0.8
Sulphuric acid (SO_4)	3.1		
	262.3		262.3

Temperature of air on collection .... 70°F.
Temperature of brine .... 35°F.
Specific gravity at 65°F. 1.204
Flow about 3 gallons per minute.

No. 3 locality, Snake Mountain springs, about 2 miles east of Mission springs; taken August 29, 1916. Contains in 1,000 parts by weight:

ANALYSIS OF WATER FROM SNAKE MOUNTAIN SPRINGS

Ions		Hypothetical combination	
Potassium	0.4	Potassium chloride	0.8
Sodium	100.7	Sodium chloride	256.0
Calcium	1.2	Calcium sulphate	4.2
Magnesium	0.2	Sodium sulphate	0.2
Chlorine	156.4	Magnesium chloride	0.8
Sulphuric acid (SO_4)	3.1		
	262.0		262.0

Temperature of air on collection .... 58°F.
Temperature of brine .... 40°F.
Specific gravity at 65°F. 1.202
Flow about 4 to 5 gallons per minute.

In recalculating these analyses we find that sodium chloride constitutes in each sample over 97.6 per cent. of the total solids. The percentage of dissolved matter in the brine, namely over 26 per cent, indicates practically a saturated solution of salt at that temperature.

Camsell is of the opinion that the salt in these brines is probably derived from crystals of salt disseminated through the gypsum rock which is abundant in the outcrops of this locality. Salt bearing gypsum occurs in the springs at Snake Mountains.

In Section 25, Township 106, 5th Meridian, about thirty miles south of Peace River, there occurs a long saline slough 60 feet wide, and two miles north of this slough in Section 1, Township 107, there occurs a saline river 125 feet wide.*

Sir J. Richardson was informed by Mr. McPherson that on the Liard river, at the junction of the Nahanni river, there occurs a salt deposit of Nahanni butte. The basin of this spring is 50 feet in diameter and is never dry. Mr. McConnell ascended the Liard river in 1887 but did not succeed in finding the deposit on the top of this butte, but writes: "A neighboring mountain, however, showed a white patch on its steep side which is plainly due to the deposits of a mineral deposit of some kind, and may be the one referred to."**

Along the Athabaska river below Fort McMurray, there are a number of saline springs which vary in the percentage of sodium chloride which they contain. There have been a number of holes drilled along the banks of the Athabaska, below McMurray, for the purpose of finding petroleum, and in a number of these wells strong flows of saline water were encountered. Analyses have been made on the brines from several springs and wells and these are given below.

*Ponton, A. W., Dep't of the Interior, Top. Surv. Branch, Can., Ann. Rept., 1908-09, p. 171.

**Geol. Surv., Can., Ann. Rept., 1888-89, p. 57 D.

One of the most important springs occurs at La Saline, twenty-seven miles north of McMurray, on the east side of the Athabasca valley. Opposite Willow island the rocky escarpment swings eastward from the river. In the area between the escarpment and the river there is a broad flat several hundred acres in extent, a portion of this flat is occupied by a La Saline lake, which in the period of high water is a mile and a half in length.

From the river and about 75 feet above the mud flats there occurs several small springs, the largest one has a basin 12 feet in diameter and two feet in depth, the water is extremely clean and when visited had a temperature of 40 degrees. At the point from which the mineral water issues the water from the deposits is extremely bitter, but not particularly saline.

The salts from these springs form a cone-shaped deposit of tufa 12 feet high and 200 to 250 feet wide over the top of the limestone which forms the escarpment. These deposits also form a white coating down the face of the escarpment to the edge of the mud flats below.

The tufa is chiefly calcareous but is intermixed more or less with gypsum, considerable sulphur and a smaller percentage of common salt. A sample of this tufa which I collected on May 15th, 1919, and which was analysed in the Industrial Laboratory at the University of Alberta gave the following results:

Calcium Sulphate	23.62%
Magnesium Sulphate	43.01%
Magnesium Chloride	0.84%
Magnesium Carbonate	0.80%
Sulphur	26.55%
Organic matter, etc.	5.18%

Other samples of the salts of the tufa deposit were collected by S. C. Ells, of the Mines Branch, Ottawa, while examining the tar sands of the McMurray district in 1913. Three of these samples were analysed by Dr. J. T. Donald and in part were found to contain:

	I.	II.	III.
Sodium Chloride	1.78%	1.07%	traces
Calcium Sulphate	7.43%	73.07%	78.88%

A sample of water collected from the largest spring and analysed by J. A. Kelso, Industrial Laboratory, University of Alberta, gave the following results:

	Grains in one Imperial Gallon.	Parts per 1000.
Potassium Chloride	50.3	6.11
Sodium Chloride	3903.5	55.75
Magnesium Chloride	488.5	6.97
Lime Sulphate	413.3	5.90
Magnesium Sulphate	36.6	.52
Ignition Loss	207.0	2.95
Total Solids	5097.2	78.20

Special Gravity:—60°F. 1.052.

This analysis shows that the water contains only about 5½ per cent. sodium chloride, whereas tufa deposited by the water does not contain more than a trace of sodium chloride.

A sample of water collected by McConnell and analysed by F. G. Wait of the Mines Branch, Ottawa, gave the following results in 1,000 parts by weight:*

Potassium	0.868
Sodium	23.937
Calcium	1.574
Magnesium	0.496
Sulphuric acid (SO_4)	4.702
Chlorine	38.461
	70.038
Chlorine required, in addition to that found to satisfy bases	0.056
	70.094
"Hypothetical combination:	
Chloride of potassium	1.655
Chloride of sodium	60.883
Chloride of magnesium	1.049
Sulphate of lime	5.352
Sulphate of magnesia	1.155
	70.094
Total dissolves solid matter, by direct experiment, dried at 180°C.	69.616
"Specific gravity at 15.5° C.	1.052

"There was not enough of the water at the disposal of the operator to admit of his examining it for any of the more rarely occurring constituents."

Two miles above the mouth of Red Clay creek there is a copious bubbling saline spring on the west bank of the Athabaska river 100 feet above the water line. From this spring large quantities of hydrogen gas are given off, which can be detected by its odor for a distance of a half a mile. An analysis of the water collected by McConnell in 1890 and analysed by Mr. Wait of the Mines Branch, gave the following results in 1,000 parts by weight:**

Potassium	0.036
Sodium	4.783
Calcium	0.947
Magnesium	0.122
Sulphuric acid (SO_4)	2.759
Chlorine	7.3994
	16.041

*Hoffman, G. C., Geol. Surv., Can., Ann. Rept., Vol. VI, 1892-93, p. 79 R.
**Hoffman, G. C., Geol. Surv., Can., Ann. Rept., Vol. VI, p. 80 R.

Chlorine required, in addition to that found, to satisfy bases	0.021
	16.062
"Hypothetical combination:	
Chloride of potassium	0.069
Chloride sodium	12.165
Sulphate of lime	3.220
Sulphate of magnesia	0.608
	16.062
Total dissolved solid matter, by direct experiment, dried at 180°C.	16.263
"Specific gravity at 15.5°C.	1.012

"The quantity of water at the disposal of the operator was too limited to allow of his examining it for any of the more rarely occurring constituents."

In a number of wells which have been drilled along the banks of the Athabaska river, for oil, strong flows of saline water were struck. From three of these wells the highly saline and sulphurous waters are still flowing at a very rapid rate depositing their contents on the rocks over which they pass. Samples of these brines were collected by S. C. Ells, and the following are the results:

No. 1. Overflow from casing-head of No. 1 well, Athabaska Oils, Ltd., Athabaska river.

No. 2. Overflow from casing-head of "Salt of the Earth" well, sunk by A. von Hammerstein, on west bank Athabaska river, 1 mile north of McKay.

No. 3. From largest spring at La Saline lake.

No. 4. Overflow from casing of well drilled by Fort McKay Oil and Asphalt Company, at La Saline (August, 1914).

RESULTS OF ANALYSES OF BRINES

	No. 1	No. 2	No. 3	No. 4
	Parts per Million	Parts per Million	Parts per Million	Parts per *Million
Ca	1638	1347	1821	3354
Mg	385	585	571	1021
K	296	336	496	192
Na	22988	76268	21184	84076
HCO_3	469	372	530	36
CO_3	none	none	none	none
Cl	36188	118636	39792	127960
SO_4	4144	4920	4688	2956
Sp. gr. at 15.5°C.	1.047	1.133	1.052	1.150

*Mines Branch, Dept. of Mines, Ottawa, Can., Sum. Rept., 1914, p. 61.

Well No. 1, owned by the Athabaska Oils, Limited, is situated on the east bank of the river about 20 miles below Fort McKay, or 56 miles below Fort McMurray. This well, which was commenced in 1911 and finished in 1912, is 1130 feet deep. The last 25 feet is in Laurentian granite, which was reported to contain about $13.00 to the ton in gold. The log of this well is as follows:

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

It is important to note that this well, which was drilled through the sedimentary rock into the pre-Cambrian granite, did not show any rock salt, but the log shows a stratum of gypsum 130 feet thick at a depth of about 580 feet.

A well drilled one mile north of Fort McKay on the west side of the river is reported to extend below the sedimentary formations, but no rock salt was encountered. There is a strong flow of sulphurous brine from this well casing and the analysis is given in No. 2 in the table above.

Two wells have been sunk by the Northern Alberta Exploration Company, between 1907 and August 1912, on the south of the town of McMurray. Well No. 1 is 50 feet from the edge of the Athabaska river, and Well No. 2 is 155 feet east of No. 1. It is reported that two beds of rock salt, or salt bearing formations, were encountered in both wells, the upper bed is shown to be 100 feet and the lower one 95 feet, making a total thickness of 195 feet of rock salt. Although the two wells are only 155 feet apart there is a marked lack of agreement in the formations as recorded in the following logs:

WELL NO. 1.

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—1,475 feet

WELL NO. 2.

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

The log of well No. 2 was taken from the records of the Northern Alberta Exploration Company, while that of No. 1, which was not on the files of the company, was taken from Bulletin No. 325, Mines Branch, Ottawa, page 84.

No samples of the reported salt have been preserved so that to date there is no direct evidence that thick salt beds actually occur in that district.

Three possible explanations may be offered for the presence of salt in the formations in the horizon shown in the log records. The reported salt bearing formations may consist of:

1. Rock salt with little or no impurities.
2. Mixture of salt and gypsum rock.
3. A mixture of clay, gypsum and rock salt.

The first is not probable. The springs and brine in the McKenzie basin, with the exception of those on Salt river, contain very little sodium chloride. If the brine were associated with rock salt a much higher percentage of sodium chloride would be found in the analysis. Rock salt has not been reported in any of the other wells drilled along the Athabaska river, but a gypsum bed 130 feet thick is recorded in well No. 1 of the Athabaska Oils Limited, 20 miles below Fort McKay.

After having examined all available data and conditions in the field, I recommended that the presence or absence of salt in commercial quantities would be most quickly proven by drilling a test hole in the vicinity of Fort McMurray. As a result of this recommendation the Provincial Government have obtained control of a certain area and a test well is being drilled on the south bank of the Clearwater, within the townsite of McMurray. It is expected that the reported salt bearing formations will be reached early in 1920. The well is being drilled with a Calyx drill, and the core will be carefully collected and examined. The drilling operations are in charge of Mr. William Pickles.

Other occurrences of saline springs are known on the Clearwater and Christina rivers. A well known group of saline springs occur on the north side of the Clearwater river about four miles below Cascade rapid. Bell describes these as follows:* "Here the springs are very copious, issuing from the bank in a number of places, for a space of 300 yards in length. The largest single spring forms a small brook itself, and the addition of these and all the other mineral springs which flow in further down, must increase considerably the soluble salts in the water of the whole river."

In the same report page 18 MM is given the analysis of a sample from these springs. "Five and a half quarts of water was taken from one spring and evaporated. A residue of 1.36 ounces (avoirdupois) of crude salt was obtained and from one-fifth to one-fourth more adhered to the kettle used in evaporating. The salt consisted of very large quantities of soda, chlorine, and sulphuric acid, large quantities of lime, magnesia, and carbonic acid, a small quantity of insoluble residue, and very small quantities of potash, alumina, and ferric oxide."**

On the left bank of the Christina river, about 12 miles from its mouth, where it enters the Clearwater there are several bubbling springs of saline water containing a certain sulphuretted hydrogen.

There are numerous saline springs irregularly distributed through the prairie provinces. The water in some of these is more saline than in others, and many are known as "Alkali" lakes. In very few of these is sodium chloride being dsitributed, but magnesium sulphate, sodium sulphate, sodium carbonate and also potash are common precipitates from these lakes.

There is a saline lake near the eastern border of the province which covers about 640 acres. It is reported that brine springs occur at a number of points on the bottom of the lake and that these keep up the supply of saline water. During the past summer an attempt was made to evaporate the brine and manufacture salt on a commercial scale. The results of this experiment have not yet been made known, but a supply of salt which was given me proves to be of very pure and very high grade quality.

On the broken plains lying to the north of Cypress hills there are many lakes, some of them quite small, others covering a large area. "The lakes vary through every degree of salinity, from those covered with a thick crust of crystallized salts down to others in which the water is perfectly fresh, and the two extremes are not infrequently met with side by side. At one point, near the west end of Bitter Lake, one of the most saline lakes in the district, a spring of fresh water was found bubbling

*Bell, R., Geol. Surv., Can. Report of Progress, 1882-83-84, p. 26 CC.
**Geol. Surv., Can., Memoir 108, 1919, p. 32.

up on the beach, and the same thing was noticed at several other places. As a rule, however, saline lakes occur more frequently in the low-lying areas, and fresh water lakes on the higher grounds."*

For the purpose of reference the following conversion tables for salt solution, are added, which are taken from a more complete table published by F. E. Englehardt.**

CONVERSION TABLES FOR SALT SOLUTIONS

Salimeter degrees	Baume degrees.	Specific Gravity	Per cent. of salt	Pounds of salt in a gallon of brine of 231 cubic inches.	Gallons of brine required for a bushel of salt.
1	0.26	1.002	0.265	0.022	2,531.40
2	.52	1.003	.530	.044	1,264.40
4	1.04	1.007	1.060	.088	629.72
8	2.08	1.014	2.120	.179	312.68
12	3.12	1.021	3.180	.270	207.02
16	4.16	1.028	4.240	.363	154.21
20	5.20	1.035	5.300	.457	122.53
24	6.24	1.043	6.360	.552	101.33
27	7.02	1.048	7.155	.624	89.64
29	7.54	1.052	7.685	.673	83.14
30	7.80	1.054	7.950	.698	80.21
32	8.32	1.058	8.480	.747	74.92
36	9.36	1.065	9.540	.846	66.15
40	10.40	1.073	10.600	.947	59.09
44	11.44	1.081	11.660	1.050	53.32
48	12.48	1.089	12.720	1.154	48.52
52	13.52	1.097	13.780	1.259	44.46
56	14.56	1.106	14.840	1.367	40.95
60	15.60	1.114	15.900	1.475	37.94
64	16.64	1.123	16.960	1.586	35.29
68	17.68	1.131	18.020	1.697	32.98
72	18.72	1.140	19.080	1.812	30.90
76	19.76	1.149	20.140	1.927	29.04
80	20.80	1.158	21.200	2.045	27.38
84	21.84	1.167	22.260	2.164	25.87
88	22.88	1.177	23.320	2.286	24.48
92	23.92	1.186	24.380	2.408	23.24
96	24.96	1.196	25.440	2.534	22.00
100	26.00	1.205	26.500	2.660	21.04

"Pure water at ordinary temperature dissolves somewhat more than one-third its weight of salt, or from thirty-five to thirty-six hundredths. As results of experiments it appears that 100 parts by weight of pure saturated brine at temperatures of from 32° to 70° Fahrenheit contain from 26.3 to 26.7 parts of salt, the specific gravity of the brine being 1.205 at 60° Fahrenheit. The salometer or instrument used to fix the value of the brines is an aerometer with an arbitrary scale on which 0° represents the density of pure water and 100° the density of saturated brine, both

*McConnell, R. G., Geol. Surv., Can., Vol. I, 1885, p. 15 C.

**Englehardt, F. E., The Manufacture of Salt in the State of New York; Bull. 11 N. Y. State Museum, 1893.

at a temperature of 60°F. The following table gives, in the first column, the degree of salometer; in the second the degree of Baume aerometer, which is a hydrometer with an arbitrary scale; the third column the true specific gravity; the fourth, the parts of salt in 100 of the brine; the fifth, the number of gallons of brine required for one bushel of salt. As may be seen these two last columns are based on the supposition that a saturated brine contains 26.5% of salt, which is the quantity arrived at through the further experiments on salt solutions."*

DATA ON FREIGHT CHARGES ON SALT FROM ONTARIO

As most of the salt used in Alberta is imported from south western Ontario the following freight rates have been supplied by the district freight agent of the Canadian National Railway, Edmonton, and may be of use in determining the market for salt produced within the province. These are the rates from all of the salt fields in south western Ontario except Clinton.

Carload lots Sarnia to Edmonton, Minimum (bulk) ..... 60,000 lbs.
(packed) ..... 45,000 lbs.

RATES FROM SARNIA TO CONSUMING POINTS

	Bulk.	Packed.
Prince Albert	68½c per 100 lbs.	73½c per 100 lbs.
Regina	59½c per 100 lbs.	64½c per 100 lbs.
Saskatoon	64½c per 100 lbs.	69½c per 100 lbs.
Medicine Hat	72 c per 100 lbs.	77c per 100 lbs.
Calgary	79½c per 100 lbs.	84½c per 100 lbs.
Camrose	77 c per 100 lbs.	82c per 100 lbs.

The following tables compiled from the Annual Report of the Department of Trade and Commerce, show the exports and imports of salt in the Dominion of Canada.

SALT EXPORTED FROM CANADA

Salt exported to		1917 Quantity	1917 Value	1918 Quantity	1918 Value
		Cwt.	$	Cwt.	$
British Empire		3,199	2,384	76,882	57,526
Foreign	United States	2,850	1,698	15,953	18,281
	France			10,000	
Total salt exported		6,049	4,082	102,835	75,807

*Annual Rept., Geol. Surv., Can., Vol. XV, 1902-3, p. 215 S.

SALT IMPORTED INTO CANADA

	1917		1918			
	Quantity	Value	Quantity		Value	
Salt.	Cwt.	$	Cwt.	Cwt.	$	$
Brit. Emp.	2,285,632	556,136	1,642,523	2,366,263	667,343	857,360
Foreign			723,740		190,017	
In Bulk.						
Brit. Emp.	717,242	121,196	906,734	906,734		201,050
Foreign						
In Bags & Bbls.						
Brit. Emp.	166,841	68,277	51	274,013	63	140,670
Foreign			273,962		140,697	
Total Salt.						
Brit. Emp.	1,371,874	385,913	1,642,574	3,547,010	667,406	1,199,170
Foreign	1,797,842	359,696	1,904,436		531,764	

Salt imported from the United States in 1917, 1,264,031 cwt. Value $298,853
Salt imported from the United States in 1918, 1,561,552 cwt. Value $406,048.

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TALC.

Talc is known to occur in the vicinity of Banff, but the extent of the deposit has not yet been determined. The mineral is rather high in lime to be of first class quality. Talc is a hydrous magnesium silicate, is soft and has a soapy feel.

It is marketed as rough talc, sawed slabs or ground talc, and has many uses, such as table tops, sinks, mantels, switchboards, fireproof paints, filling for paper, a base for lubricants, toilet powders, shaving creams and many other uses. The price of rough talc varies from a dollar up to $6.00 or $7.00 per ton.

ZINC.

Pockets, irregular lenses and narrow veins of zinc sulphide (sphalerite) occur at a few points within the Rocky Mountains. One occurrence has been opened up by the Eldon Mining Co., Ltd., near Eldon Station on the Canadian Pacific Railway about fifteen miles west of Banff. The quality of this ore is satisfactory but the extent of this deposit has not yet been proven.

Other small occurrences are known in the Rocky Mountains to the northwest.

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