CANADA

DEPARTMENT OF MINES

HON. MARTIN BURRELL, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

WILLIAM MCINNES, DIRECTING GEOLOGIST.

Summary Report, 1917, Part C

CONTENTS

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SUMMARY REPORT, 1917, PART C.

WATER SUPPLY IN SOUTHERN ALBERTA.

By D. B. Dowling.

INTRODUCTION.

An artesian water area in southern Alberta was outlined on a small map published in the Summary Report of the Survey for 1915, and was further referred to in Memoir 93; and a list of the wells in the area was given in the Summary Report for 1916, page 79. Of the two wells under contract by the department in 1916, one was finished in 1917 and gave a flow of 4,000 gallons per day; in addition a third well has been completed with a flow of 3,000 gallons per day. Wells Nos. 1 and 2 were to be cased with steel pipe 4¼ inches inside diameter. The difficulty of getting this material under war conditions and the increased cost of labour are responsible for the delay with No. 2 well. In order to demonstrate that flowing wells may be bored and the flow preserved by the use of the small pipes that are still obtainable, No. 3 well was drilled by diamond drill by Mr. J. H. Norman and a packer above the water-bearing sand was inserted carrying a 2-inch pipe to the surface. A log of the material bored through in each of these wells is given below; also logs kindly furnished by Mr. Norman of two other wells drilled by him. The cost of drilling, owing to war prices, is now abnormally high; wells 600 feet in depth, at the present scale of prices, average about $4 per foot.

Government Well No. 1, 13 Miles South of Grassy Lake, Alberta.

Bored by Geological Survey, 1917.
Location—between secs. 11 and 12, tp. 8, range 13, W. 4th mer.
Depth of well—633 feet. Flow, 4,000 gallons water per day at surface.
Driller's log, partly condensed.

Material.	Thickness. Feet.	Depth. Feet.
Surface deposits; clay, sand, and gravel	60	60
Shale and clay	7	67
Streaks of coal and clay	7	74
Sand rock	1	75
Sandy clay	39	114
Sand rock	2	116
Sandy clay	4	120
Brown shale with streak of coal	7	127
Sandy shale with some ironstone	20	147
Hard sand rock	3	150
Sandy shale	12	162
Hard, dark, sand rock	2	164
Dark shale	13	177
Coal	1	178
Shale	4	182
Shale with some coal	7	189
Sandy shale and clay	39	228
Coal and shale	2	230
Sandy shale	20	250
Coal, soft	8	258
Sand and clay; water at 270 feet rises 90 feet	30	288
Sandstone and sand	18	306
Grey shale	100	406
Sandstone and hard shale	10	416

Material.	Thickness. Feet.	Depth. Feet.
Shale with very hard layers, probably ironstone..	103	519
Sandstone..	4	523
Shale and sandy shale..	11	534
Sandstone, very hard..	3	537
Shale..	10	547
Sandstone, dark grey..	8	555
Shale, generally very hard..	26	581
Sandy shale (flow of water at 581)..	8	589
Sandstone..	12	601
Sandy shale..	4	605
Sandstone..	6	611
Shale and sandy clay..	10	621
Sandstone..	2	623
Shale..	3	626
Sandy shale (water strata at 630 feet)..	4	630
Sandstone..	3	633

This well is cased with 4½-inch steel pipe.

Government Well No. 3, Near Lake Pakowki, Alberta.

Bored by Geological Survey.
Location—between secs. 19 to 30, tp. 4, range 8, W. 4th mer.
Depth of well—643 feet. Flow, 30,000 gallons water at surface; pressure, 32 pounds.
Log from samples of drill cores furnished by J. H. Norman.

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

Flowing Well, South of Retlaw, Alberta.

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

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

Log of Well at Neidpath, Alberta.

Drilled for the Bawden Farming Company.
Location—SE. ¼ sec. 27, tp. 9, range 18, W. 4th mer.
Flow of water and gas, intermittent.
Driller's record incomplete.
The following log is furnished by J. H. Norman, the driller, as being nearly accurate.

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

POTASH IN SALINE WATERS IN SASKATCHEWAN.

By D. B. Dowling.

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 (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.

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
" " " chlorides	6·970

The brine springs of the 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.

OIL PRODUCTION, SHEEP RIVER AREA.

By S. E. Slipper.

INTRODUCTION.

Notwithstanding many handicaps, the development of the Black Diamond Oil field has made steady progress. At the present time (February 4, 1918) there are five wells producing oil, three small stills in operation, six drilling outfits active or recently active, and a gasoline absorption plant in the course of erection.

The development of the field is retarded at the present time by the difficulty of obtaining well casing and drilling machinery, and the bad condition of the main road from the oil wells to the railway at Okotoks, a distance of less than 20 miles, which makes heavy freighting over it an expensive undertaking.

Producing Wells.

Southern Alberta Oil Company, Well No. 1. This is still the most important producing well in the field. It is stated that about 30 barrels a day is allowed to flow, which is the limit of the capacity of the tanking and distilling equipment.

Alberta Southern Oil and Refining Company, Well No. 1. This well is pumping some 10 to 15 barrels per day. It is located on sec. 13, tp. 20, range 3, W. 5th mer.

Prudential Oil Company. This company has been pumping a small quantity, about six barrels a day, from the well on sec. 1, tp. 20, range 3, W. 5th mer.

Alberta Petroleum Consolidated Oil Company, Well No. 2. This well, on sec. 1, tp. 20, range 3, W. 5th mer., has been idle since 1916 with a lost string of pump-rods in the hole, but was recently cleaned out and has been pumping steadily an output of 25 to 30 barrels a 10-hour working day. It produces the heaviest oil in the field, the specific gravity being 0·831038 degrees Beaume scale. All the other crude oils produced in the field are much lighter, ranging around 50 degrees to 60 degrees Be.

Calgary Petroleum Products Company, Well No. 1. This well still produces an almost pure gasoline at irregular intervals, roughly estimated at some hundred barrels per month. Wells No. 1 and No. 2 of this company supply gas for power to other outfits in the field.

Distilling Plants.

The Alberta Southern Refining Company. This company has a one-unit still which handles the crude oil from the Southern Alberta well No. 1 and the Alberta Southern No. 2.

The Canadian Southern Refining Company. This company has a one-unit still and is supplied from the Prudential well and the Alberta Petroleum Consolidated well No. 2.

The Calgary Petroleum Products Company. This company has a still which is supplied with oil from well No. 1.

These "refineries" extract only the gasoline and lighter distillate fractions. No attempts have yet been made to treat the heavier products of the crude oil.

Drilling Operations.

Mount Stephen Oil Company. The well begun about a year ago by this company had to be abandoned owing to drilling difficulties, at a depth of 2,000 feet more or less. A new hole has been started not far from the old one, and is down some 400 feet.

Southern Alberta No. 2. This well is down about 3,500 feet and drilling is still in progress.

Alberta Southern No. 2. A drilling derrick is in course of erection.

Record Oil Company. This well, which has been drilled by a portable drilling machine, has reached a depth of 4,325 feet. Work has been stopped pending the erection of standard drilling equipment.

Midwest Oil Company. Under this title a company has taken over the Western Pacific well in sec. 31, tp. 19, range 2, W. 5 mer., and expects to continue drilling to the oil sand.

A plant for the extraction of gasoline from the gas produced from wells No. 1 and No. 2 of the Calgary Petroleum Products Company is in course of erection.

VIKING-ATHABASKA GAS FIELD.

By D. B. Dowling.

The introduction of oil-burning tractors in farming operations has caused a great increase in importation of the light oils. As these imports are mostly from Wyoming the fear of a possible embargo owing to home needs has made the subject of a home supply of oil one of national interest. The possibilities of the great plains as an oil-field has induced a renewal in prospecting, but most of this has been very conservative. The testing this year has been largely confined to the area near the Battle river and northwestward toward the Athabaska and Peace rivers. The delineation of the possible field, which depends on the underground structure, was begun this season with S. E. Slipper and Professor J. A. Allan as assistants. The area within which a possible oil-field and a probable gas field may be found can be outlined as a belt extending from Saskatchewan by way of the Viking field, northwest to the Athabaska river near Athabaska, and thence in a broad curve to the Peace river below Peace River Landing. A broadening of the belt northward from this line is evident in the Athabaska valley as the oil in the McMurray sands seems to be genetically connected with the possibilities of the whole area.

The beds underlying this triangular area slope to the southwest at a very low angle with probably many small local inflexions and they are considerably flattened near their southwestern edge to form a terrace or level zone which in places may be considered anticlinical in structure. The beds south of this flattened area dip at higher angles into the great Alberta syncline.

Along this terrace which rises to the northwest, the sandy beds at the base of the Colorado shales have been found to contain considerable gas where they are elevated above the level of the line of salt water saturation, which is here slightly above sea-level. Heavy oil in varying amounts has been found in the lower sands in two of the Viking wells and in two wells at Peace River Landing. In the Athabaska valley on the northeastward extension of the structure plane the lower sands have also appreciable amounts of heavy oil and gas. At the outcrop these sands are represented by the McMurray tar sands. The prospecting so far done has shown the presence of natural gas in fair amount, but the production of oil is not yet well assured. Tests of the gas show the inclusion in it of gasoline vapour, and it is expected that the extraction of this vapour and the discovery of many uses for the methane gas, besides its use as fuel, will some day make this immense field a great manufacturing area.

VIKING GAS FIELD. STRUCTURE OF AREA.

By S. E. Slipper.

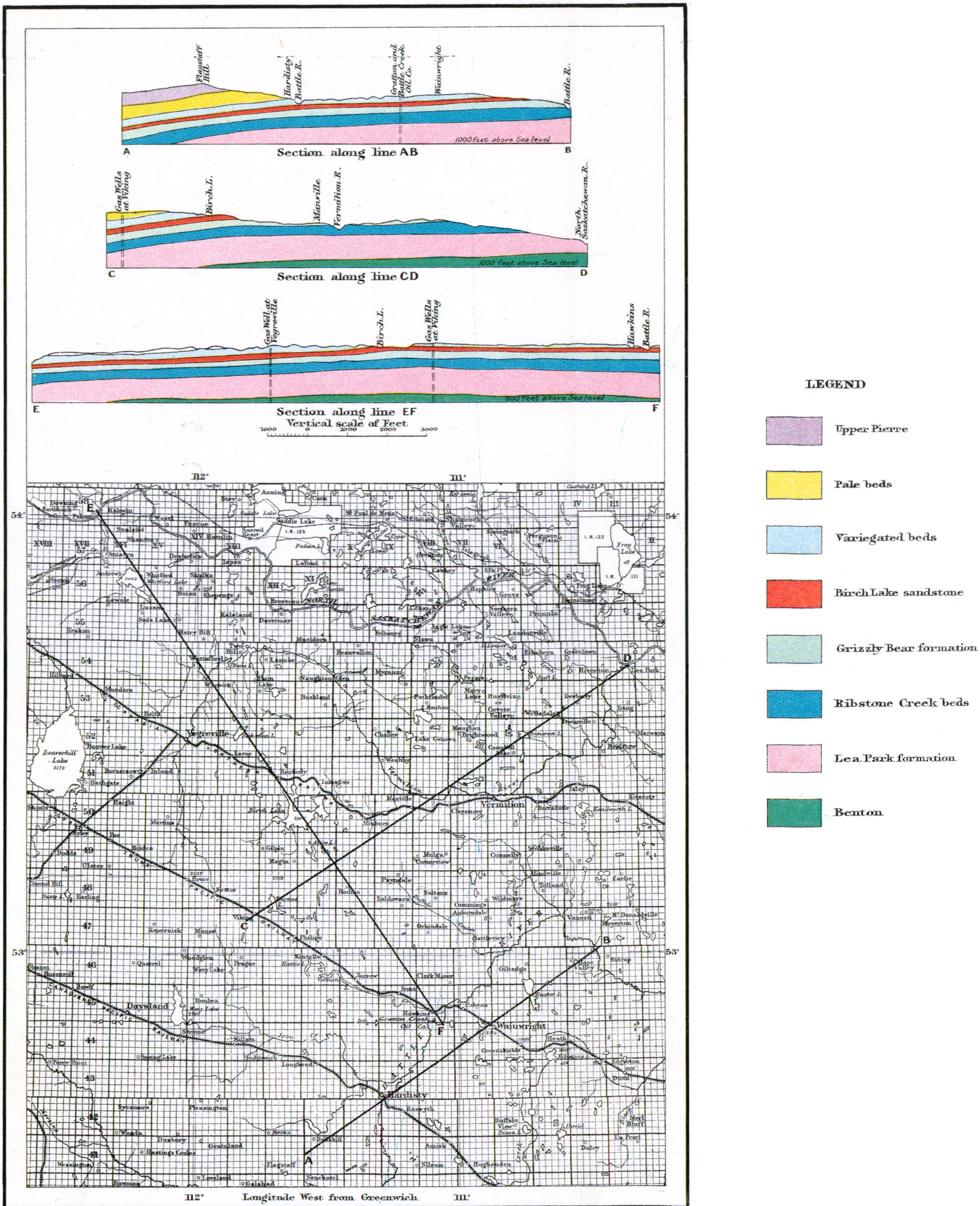
CONTENTS.

Illustrations.

INTRODUCTION.

The field work of the 1917 season consisted in the mapping of the areal geology of a portion of the central Alberta and Saskatchewan plains extending south from the North Saskatchewan river to the Saskatoon-Calgary branch of the Canadian Northern railway, and westward from range 27, W. 3rd mer., in Saskatchewan, to an irregular western boundary (determined by geological conditions) in Alberta. This boundary may be roughly indicated by a line drawn from Pakan on the North Saskatchewan to Youngstown on the Saskatoon-Calgary branch of the Canadian Northern.

The work was wholly economic, attention being devoted to the natural gas and petroleum possibilities of the area.



Geological Survey, Canada.

Figure 1. Diagrammatic structure sections, Central Alberta.

Scale of Miles

10 0 10 20 30 40

To accompany Summary Report by S.E. Slipper, 1917.

SUMMARY OF CONCLUSIONS OF ECONOMIC IMPORTANCE.

It has been determined that the broad anticlinal fold or uplift which is shown on the current geological maps of the area, as extending in a northwesterly direction across Battle river and almost to the North Saskatchewan, does not exist. On the other hand it has been found that the strata rise continuously eastward across Alberta and as far into Saskatchewan as the mapping was carried. That is, the structure is a monocline and not an anticline.

From Birch lake northwestward, along the general strike, there is a "plunging" of the strata; the sandstone on the shore of Birch lake has an elevation of 2,140 feet, whereas the same sandstone on the North Saskatchewan near Pakan [1] has an approximate elevation of 1,850 feet, indicating a depression of 290 feet in somewhat over 50 miles.

These facts, namely, that the major structure is a monocline and that there is an uplift or upwarp along the strike culminating in the vicinity of Birch lake, are of the first importance when considering the natural gas and petroleum possibilities of the district. This upwarp may explain the occurrence of natural gas in the important field north of Viking and points to the possibility of the field having a larger and more productive extension to the northeast. In any event development should not be controlled by a belief in a major anticlinal structure extending northwest through the area.

In the Neutral hills and Tit hills north of Coronation and in the Mud buttes and Misty hills south of Monitor, many minor folds were observed and mapped. These minor folds may contain oil and gas, but no drilling has been done to test them. The lowest surface exposures are the Pale beds of the Belly River formation and hence depths to the gas and petrolific horizons would be considerable. It should be pointed out that nowhere else on the Canadian prairies have such sharp upwarps been observed; but south of the boundary, in Wyoming, all the productive oil fields are located on minor uplifts of the Cretaceous basin.

STRATIGRAPHY.

A revised stratigraphic table is given on page 8. Short descriptive notes are included with the table as it is impossible to give a more detailed description in this summary.

The beds are all included in the Montana group of the Cretaceous system.

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[1] Allan, J. A., Geol. Surv., Can., Sum. Rept., 1917, pt. C.

Table of Formations.

System.	Group.	Series.	Local formations.	Thickness feet.	Descriptive notes.
Cretaceous.	Montana.	Edmonton			
		Upper Pierre.	Pierre shale. Bulwark sandstone. Pierre shale.	600 to 700	Marine. Dark grey, clay shale containing large quantities of selenite and ironstone nodules. The Bulwark beds are hard, massive and bedded, brown sandstones. The lower part of the Pierre weathers white and contains incoherent sandstone strata.
		Belly River.	Pale beds.	About 500	Pale, incoherent, cross-bedded sandstone, green clays, and sandstones. Indigo-coloured nodules, thin coal seams. Freshwater fossils.
			Variegated beds.	200†	Interlayered sandstone and shale showing various tints of greens, and browns and yellows, also coal seams; brackish water deposits.
			Birch Lake sandstone.	60 to 100	Massive, cross-bedded sandstone, buff-coloured, containing lenses of harder sandstone. Brackish water deposits.
			[1]Grizzly Bear formation.	100 to 40	Dark, blue grey, marine shale, contains ironstone and sandstone nodules. Some beds of yellow, incoherent sandstone.
			[2]Ribstone Creek formation.	225	Greenish-yellow, massive, soft sandstone at top, green and carbonaceous shale and coal, light grey sandstone at base. Brackish water deposits.
		Lower Pierre.	[3]Lea Park formation.	700	Marine. Typical blue-grey shale, selenite and nodules.

[1]Equivalent to *Shandro shale* of Mr. Allan's North Saskatchewan section.
[2] " *Brosseau* formation of Mr. Allan's North " "
[3]Name applied to these shales by Mr. Allan.
NOTE. The base of the Ribstone formation is, roughly, 1,600 feet above upper gas horizon of the Colorado group, i. e. the Viking gas sand.

Battle River Section from Beaverdam Creek to Ribstone Creek.

Many exposures of the Pierre shale and Bulwark beds occur near the mouths of Beaverdam and Young creeks at Lorraine. These beds rise downstream and expose the underlying Pale beds.

Near Hardisty the Variegated beds are first observed, but the best sections of them are on the railway cuttings at the mouth of Gratton creek.

Above the mouth of Gratton creek, at the Gratton and Battle Creek Oil Company's well, the yellow sandstone of the Birch Lake formation is exposed. This rises to the level of the railway bridge at Fabyan and then continues nearly horizontally, forming a "rim rock" to the valley as far as Grizzly Bear coulee, where the Grizzly Bear marine shale formation occurs and, a short distance downstream, the upper part of the Ribstone Creek formation is exposed at water-level. These two formations make up the section to Ribstone creek.

NATURAL GAS DEVELOPMENT.

The Northern Natural Gas and Development Company have completed their eighth well in the field which they have developed north of Viking. The wells have an average open flow capacity of 3,000,000 cubic feet a day.[1]

[1] Information on the depth of drilling and well records is given in the Sum. Rept., 1916.

Mr. H. L. Williams and associates are drilling a prospective gas well at a location 5 miles north of Court, Saskatchewan. At the time of writing (February 4, 1918) the well was 2,736 feet deep and in a sandstone formation. At a depth of 2,628 feet, a gas flow was struck which lasted only a short time and was followed by water which filled the hole 2,000 feet. Drilling is being continued.

The Gratton and Battle Creek Oil Company are resuming work on their well located on Battle river near the mouth of Gratton creek.

SECTIONS ALONG NORTH SASKATCHEWAN RIVER AND RED DEER AND SOUTH SASKATCHEWAN RIVERS, BETWEEN THE THIRD AND FIFTH MERIDIANS.

By J. A. Allan.

CONTENTS.

Illustrations.

INTRODUCTION.

In order to get further information regarding the substructure of the plains to the southeast of Edmonton, the writer was instructed to examine the section along the North Saskatchewan river between the 5th meridian, just west of Edmonton, and Battleford, in Saskatchewan.

Another section was examined between Red Deer and Saskatoon, along Red Deer and South Saskatchewan rivers, in order to correlate the stratigraphy of central Alberta with that of the southern portion of the province.

The chief object in examining this field was to determine the geological structure in the Upper Cretaceous formations that are exposed along these rivers.

The geological map of Alberta and Saskatchewan shows a prominent up-arching of the formations with a northerly trend to the axis of folding. The Belly River formations are exposed along the crest of this fold from the International Boundary northwards, through central Alberta to township 52, in the vicinity of Vegreville.

As considerable attention is being given to the northerly end of this area, and a number of holes have been and are being drilled with the expectation of finding petroleum in commercial quantities, it was considered important to ascertain the stratigraphical relation between the various formations.

The following problems had to be considered in the field: The possibility of the northerly continuation of this anticlinal structure across the valley of the North Saskatchewan. The occurrence and character (whether marine or brackish) of the Bearpaw formation below the Edmonton formation. The thickness and subdivisions of the Belly River series. The occurrence of a thin marine member in the lower portion of the Belly River series, which would correspond to a marine member which has been found in well drillings farther south. The relation of the Belly River series to the strata occurring farther east. The age of the marine shales which were known to occur at the mouth of Vermilion river, whether younger or older than the Belly River series. The structure of the beds between the 4th meridian and Battleford. The relation of the rocks to the east and to the west of the Belly River series on the South Saskatchewan river.

Only brief mention will be made in this summary report of the section along South Saskatchewan river, as the more important structure has been determined along North Saskatchewan river.

SUMMARY OF RESULTS.

The results of the examination of these two river sections show that the geological structure in the Upper Cretaceous is somewhat different from that shown on the geological maps of Alberta and Saskatchewan.

There is no prominent anticlinal fold in central Alberta. The older formations from the Paskapoo to the lower Pierre (Lea Park formation) are exposed in regular succession from west to east, the dip in the strata being towards the west.

On the North Saskatchewan, between the 5th and 4th meridians, the structure is homoclinal, that is to say the formations are all dipping in one direction, which is towards the west. The angle of dip is greatest towards the west and decreases towards the east. For a considerable distance along the river in the vicinity of Lea Park the strata are lying nearly horizontal. Between the 4th meridian and Battleford there is a slight dip in an easterly direction, corresponding approximately to the slope of the plains level, which is from 2 to 7 feet to the mile. There seems to be indications of downward warping towards the south, thus giving a flexure across the strike, which would probably connect up with the transverse up-arching at Birch lake.

Between Edmonton and the mouth of Sturgeon river the river section exposes the lower beds in the Edmonton formation. The character of the beds in the Bearpaw formation cannot be determined on North Saskatchewan river on account of lack of exposures. However, there is sufficient distance along the river between the bottom of the Edmonton and the top of the Belly River formations to allow for the occurrence of the Bearpaw beds below the drift and alluvium in the valley.

The Belly River series includes four formations of freshwater origin and a thin formation of marine shales. These marine shales correspond to the lower Pierre, and represent an incursion of the sea from the southeast during the Belly River stage.

The beds of the lower Pierre, called the Lea Park formation, rise from below the Belly River series, near Fort island, and continue beyond Battleford. The river follows closely along the strike of the formation. The lowest beds in the section are exposed in the vicinity of Lea Park at the mouth of Vermilion river. The beds exposed along the river at Battleford are stratigraphically about 250 feet higher in the Lea Park formation than those exposed at the mouth of Vermilion river. This indicates that there is a dip towards the east and possibly a slight flexure towards the south.

In the South Saskatchewan section the strata at Red Deer lie about 150 to 200 feet above the base of the Paskapoo. This formation is underlain in turn by the Edmonton brackish-water series, and the Bearpaw formation which consists essentially of marine shales. The corresponding Bearpaw beds are not exposed on North Saskatchewan river.

The beds of the Belly River series first appear near the mouth of Hanalta creek in township 24, about 35 miles southeast of Drumheller. These brackish and freshwater beds are exposed beyond the mouth of the Red Deer river to a point about 18 miles above Saskatchewan Landing near the mouth of Antelope creek.

At this point the lower Pierre marine shales are exposed below the Belly River series, which again shows that the structure is still homoclinal rather than anticlinal.

The lower Pierre beds are exposed at various points down the river as far as township 32, where the valley becomes very broad and is covered with a thick mantle of Quaternary deposits.

The lowest beds in the South Saskatchewan section are exposed in the vicinity of tps. 21 and 22, W. 3rd mer., about 25 miles west of Elbow. Between Elbow and Outlook the exposures of shales belong to the upper part of the lower Pierre formation. This would indicate that in this section, as well as in the northern one, the beds have a slight easterly dip.

From the information obtained in these two river sections it is apparent that the structure shows a broad, flat-topped arch with a gradual dip towards the east and northeast and more pronounced dips on the western flank.

NORTH SASKATCHEWAN RIVER.

The distance from Edmonton to Battleford by river route is 328 miles. The elevation of the low water plane at Edmonton is 2,000 feet above sea-level, and at Battleford under the traffic bridge the elevation is 1,515 feet. This difference of 485 feet between these two points represents an average gradient on the river of 1·14 feet to the mile. The grade is steepest between Edmonton and the mouth of Vermilion river.

The following table has been compiled from data obtained from the Public Works Department at Prince Albert. This table indicates the plane of the low water line on the North Saskatchewan.

Low Water Elevations on North Saskatchewan River.

—	Elevation, feet.	Mileage.	Grade.
Edmonton	2,000	0	
Fort Saskatchewan	1,950	25	2 feet per mile.
Redwater creek	1,920	43	1·6 " "
Myrtle creek	1,900	55	1·5 " "
Pakan	1,845	75	2·7 " "
White Mud creek	1,825	85	2·0 " "
Shandro ferry	1,818	94	0·8 " "
Desjarlais ferry	1,807	103	1·2 " "
Saddlelake creek	1,777	114	2·7 " "
Brosseau	1,755	125	2·0 " "
Hopkins ferry	1,715	160	1·1 " "
Mooswa	1,692	176	1·4 " "
Lea Park	1,650	197	2·0 " "
Fourth meridian	1,635	212	1·0 " "
Battleford	1,515	328	1·0 " "

North Saskatchewan river is not navigable below the 4th meridian on account of the numerous sand-bars which are constantly changing their position. During the spring and early summer a river boat, the *City of Edmonton,* plies between Edmonton and Shandro ferry. Were it not for Crooked rapids the river would be navigable down at least as far as Brosseau during the months of May, June, and the early part of July.

Table of Formations.

Quaternary	Recent	Alluvium, beach, and sand-bar deposits.
	Pleistocene	Fluviatile and glacial deposits.
Tertiary	Paskapoo	(Exposed only along Red Deer river.)
	Edmonton	(Brackish-water.)
	Bearpaw	(Not definitely determined on North Saskatchewan, but marine on Red Deer.)
Upper Cretaceous.	Belly River series.	Myrtle Creek formation (fresh). 425 feet. Pakan formation (freshwater). 225 " Victoria sandstone (freshwater). 95 " Shandro shales (marine). 70 " Brosseau formation (freshwater). 325 "
	Lower Pierre	Lea Park formation (marine). 375 "

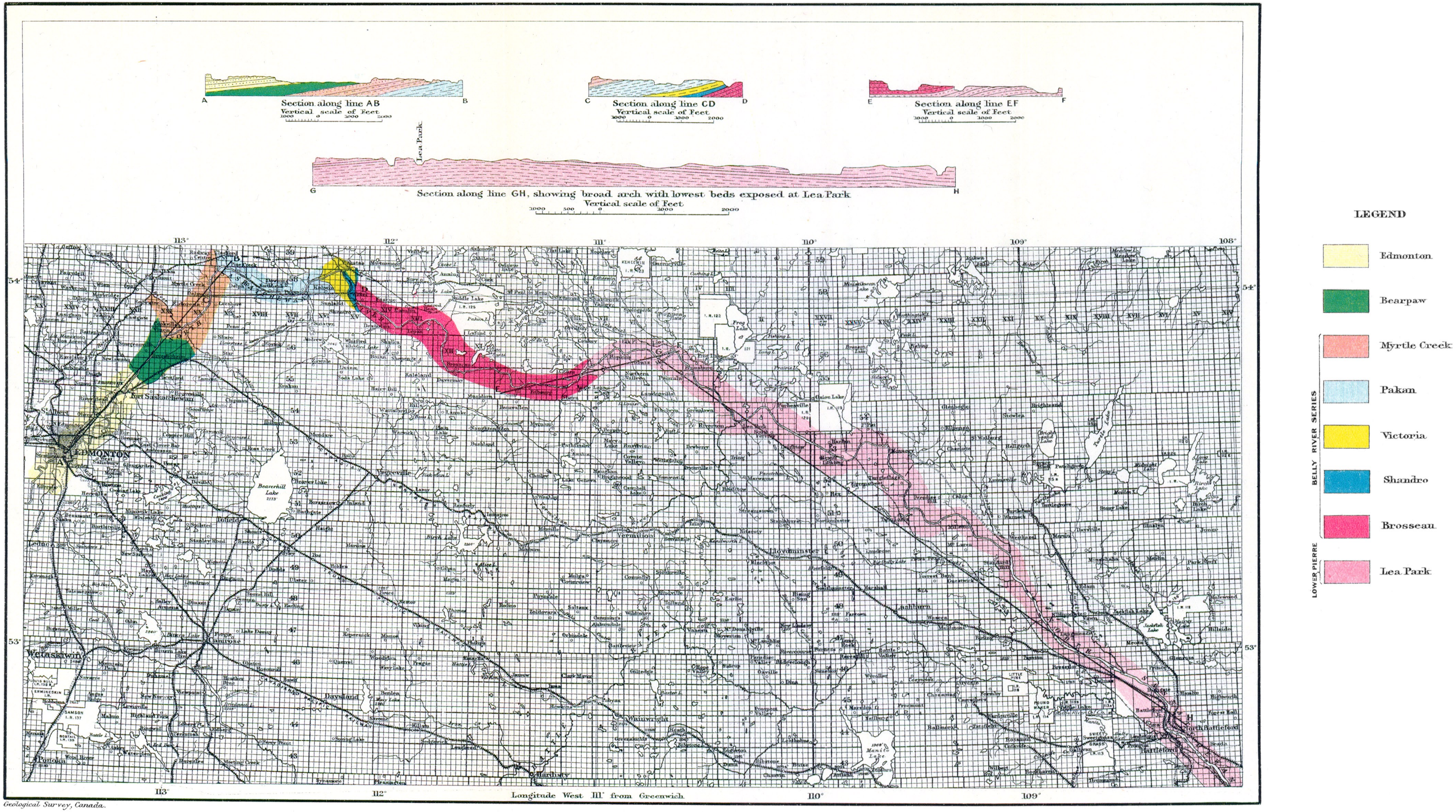

Figure 2. Diagrammatic structure sections, North Saskatchewan River, Edmonton to North Battleford.

Scale of Miles

10 0 10 20 30 40

To accompany Summary Report by J.A. Allan, 1917.

Description of Formations.

Edmonton Formation. This formation consists of greyish and light yellowish sandstones, frequently clayey in composition, shales, several coal seams, and clays of brackish-water origin. These beds are exposed at various points along the river from Edmonton down to near the mouth of Sturgeon river, a distance of approximately 20 miles. The thickness represented below Edmonton is about 300 feet. Coal seams that are mined about 100 feet below the river level at Edmonton outcrop in the vicinity of Clover Bar, a distance of 6 miles. This represents a westerly dip of the beds of 17 feet to the mile.

Bearpaw Formation. This formation is represented farther south by a series of marine shales and shaly sandstones, which on the Red Deer river have a thickness of about 600 feet.

No marine beds belonging to this formation were observed along the North Saskatchewan river, but for a distance of 8 miles below the last exposure of the Edmonton formation the valley sides are low and rock exposures are extremely rare. A few exposures were observed of greenish-grey shales and clayey ferruginous sandstone. Some of the beds enclose plant and coaly fragments which suggest brackish-water origin. If the beds of the Bearpaw formation cross the valley under this lowland they may be of brackish-water rather than of marine origin.

Further information on this horizon will have to be obtained from drill-holes or from outcrops on the level of the plains.

Belly River Series. The Belly River formations are exposed along the North Saskatchewan from near Vinca ferry, 5 miles west of the mouth of Redwater river, down to Fort island, about 25 miles below Brosseau, in tp. 55, range 8, W. 4th mer.

This series can be divided into five formations, as shown in the accompanying table of formations. Each of these can be correlated with the formations exposed on the plains to the south, which have been determined by S. E. Slipper and are described by him in another part of this summary report.

The Myrtle Creek formation is well exposed at the mouth of Myrtle creek and corresponds to the Pale beds in Mr. Slipper's classification. This formation includes clayey sandstones irregularly hardened, arenaceous shales, shales, bluish and brownish ironstone nodules, and thin coal seams and coaly shales near the top. The thickness of the formation is at least 425 feet.

Pakan formation includes a thin-bedded, variegated series of arenaceous shales, thin coal seams, thin grey sandstones, and sandy clays. The lower part of the formation is exposed on Egg creek, about a mile from the mouth, and also at the north end of Pakan ferry.

Three miles below Pakan a massive bed of yellowish sandstone rises from below the Pakan formation and forms Victoria rapids. This formation has been called the Victoria sandstone and does not exceed 95 feet in thickness. It corresponds to the Birch Lake sandstone in Slipper's table.

Below the Victoria sandstone there is a thin series of dark grey marine shales containing calcareous and arenaceous concretions. These shales are exposed along the water level below the mouth of White Mud creek. Fragments of *Inoceramus, Scaphites,* and possibly *Placenticeras* were found in the calcareous concretions. In the vicinity of Shandro ferry these shales disappear and it is probable that they rise above the level of the valley under the thick mantle of drift. The Shandro shales do not exceed 70 feet in thickness in the various exposures along the river. Slipper has called the corresponding shales the Grizzly Bear formation, as he has found them exposed in Grizzly Bear coulée.

The Brosseau formation is exposed along the river between Shandro ferry and Fort island, 25 miles east of Brosseau. The upper part of the formation consists of flaggy sandstones and clayey sandstones, which form prominent escarpments on both sides of the river down to Brosseau. The lower part of the formation consists of brown sandy shales, thin-bedded sandstones, and thin seams of coal. The coal seams have been opened up north of Beauvallon in secs. 11 and 14, tp. 55, range 10, W. 4th mer., by Mr. J. R. Prince and associates of Battleford. The Brosseau formation is at least 325 feet thick.

The lower Pierre series has not yet been subdivided, but the Lea Park formation includes that portion of the series which is exposed along the North Saskatchewan river. The formation consists of brownish and yellowish shales at the top, underlain by dark grey marine shales in which many typical lower Pierre fossils have been found. This formation is exposed at various points along the river from Fort island down to Battleford, a distance of 180 miles.

The lowest strata in the section are exposed in the vicinity of Lea Park at the mouth of Vermilion river, and belong to a horizon about 375 feet below the top of the Lea Park formation. The strata exposed along the river at Battleford belong to the upper portion of the Lea Park formation and are not as dark in colour as those at the mouth of Vermilion river. This indicates a change in strike to a more easterly direction.

In a small creek near Pronque station, 9 miles west of Battleford and 285 feet above the North Saskatchewan river, flaggy sandstones and arenaceous shales are exposed. These beds belong to the Brosseau formation, and are underlain by thin seams of coal which correspond to those opened up at Beauvallon.

Along the Turtleford line of the Canadian Northern railway which runs north from North Battleford, a prominent ridge separates the valley of Turtlelake river from the North Saskatchewan valley. Similar ridges are seen between Turtleford and St. Walburg, some of which rise 300 feet above the floor of the North Saskatchewan valley. Some, at least, of these ridges are not capped with glacial drift. It seems probable that they are underlain by rocks of the Brosseau formation belonging to the base of the Belly River series.

In this same district, 3 miles north of St. Walburg, in sec. 1, tp. 54, range 22, W. 3rd mer., Mr. J. McGuire has sunk a shaft 80 feet and reports coal at the bottom. As the shaft was flooded when visited in September, no definite information could be obtained. The clays about the shaft are quite sandy and resemble disintegrated lower shales of the Brosseau formation.

RED DEER AND SOUTH SASKATCHEWAN RIVERS.

The distance by river from the town of Red Deer to Saskatoon is about 725 miles. At Red Deer the low water line has an elevation of 2,785 feet above sea-level. At Saskatoon the elevation of the river is 1,555 feet. This difference of 1,230 feet between these two points represents an average grade to these rivers of 1·7 feet to the mile. The low water level at the junction of the Red Deer with the South Saskatchewan, 4 miles east of the 4th meridian, has an elevation of 1,895 feet. Neither of these rivers is navigable in low water. Sand-bars are so numerous in the South Saskatchewan that several places were found impassable in a flat-bottomed boat drawing 6 inches of water.

The geological sections from west to east show the formations in regular succession from the Paskapoo down to the lower Pierre.

The Bearpaw formation is exposed between the mouths of Willow and Hanalta creeks on the Red Deer, and consists of marine shales interbedded with thin layers of sandstone.

The Belly River series is of brackish-water origin. The upper member is productive in vertebrate fossil remains, principally those of the reptilian orders.

The Belly River series is underlain by the marine shales of the lower Pierre formation, in range 17, W. 3rd mer., near the mouth of Antelope creek.

The shales belonging to this formation are exposed at various points down to township 32, beyond which the valley becomes broad and shallow. A thick mantle of Quaternary deposits covers the underlying Upper Cretaceous beds.

PEACE RIVER SECTION, ALBERTA.

By F. H. McLearn.

CONTENTS.

INTRODUCTION.

During the field season of 1917 an examination was made of a section of the valley of Peace river, over 650 miles long, from Twelvemile creek, above the canyon, to Vermilion. The study was undertaken in the interest of oil exploration and, therefore, emphasis was placed on the stratigraphic succession and the structure.

Character of the District.

Land Forms. In the foothill region, extending along the valley from Ottertail river to Portage mountain, the river occupies a deep, broad valley. Above the valley-floor of wide flats, islands, and bars and extending to a height of from 500 to 600 feet, are terraces of variable breadth. In places, these are very wide. Several are particularly well developed and can be followed for miles. Above these gravel and sand terraces project high hills, to an elevation of 2,000 feet above the river, which are carved into mature erosion forms. The glaciation in the foothills was evidently of the valley type.

At Portage mountain the foothills abruptly disappear and give place to the broad undulating plateaus of the Great Plains. The Peace valley opens on the plains through two gaps. That between Bull Head and Portage mountains affords the most direct outlet, but is closed by a girdle of morainic hills. The river now turns to the south around Portage mountain through a second gap and it is in the floor of the latter that the post-glacial canyon is excavated.

The plateaus adjacent to the river descend eastward and northward. Where the valley is carved in sandstone it is narrow and gorge-like, whereas in shale or glacial material it is broader with flats and terraces. The terraces are nowhere so continuous or striking as within the foothills. The present valley in part follows pre-glacial valley courses and in part post-glacial courses. The valley in the great bend below the mouth of Montagneuse river is of the latter character.

Vegetation. In spite of the comparatively low average precipitation which in more southerly latitudes would be accompanied by prairie or even semi-arid conditions, much of the district is forested. This is due to conservation of moisture and the latter is thought to be caused by the comparatively low temperature (hence less evaporation) and the considerable depth of freezing of the soil. Isolated by the forests are open prairies or copse of variable size. Though the northerly exposures are wooded, the southerly exposures are without trees and are covered by a prairie vegetation, with the addition of a species of cactus.

The determining principle in the present agricultural settlement is the greater ease with which the prairie or copse areas may be reclaimed as compared with the forest. This tends to the isolation of the new farming districts by the enveloping forest, but is being overcome by the extension of railway facilities, and the highway afforded by the river to parts of the district.

STRATIGRAPHY.

The rocks exposed on Peace river may be resolved into an eastern and western succession, the former ascending from Vermilion chutes to Dunvegan and the latter descending from there to the mountains. Characteristics of the succession are: the presence of a marine Cretaceous fauna prior to, and quite unlike that of, the Colorado; subaerial delta deposits are present in the Colorado group.

Eastern Succession.

Devonian Limestone. Limestones of Devonian age outcrop from Vermilion chutes downstream.

Loon River Formation. The Loon River shales are exposed on the valley sides from Vermilion chutes to near Brown's trading post, and north and east of the great horseshoe bend underlie the plateaus adjacent to the river. They consist of dark blue to dark grey, friable weathering shale with a few rounded or flattened ironstone concretions. To the south where they are penetrated by the wells of the Peace River Oil Company, they are more arenaceous, particularly near the base. Thus in well No. 1 the following section rests on the limestone.

	Feet.
Shale	..
Sandstone	70
Shale	53
Sandstone	65
Shale	12
Sandstone	26
Shale with concretions and bands of ironstone	51
Palæozoic limestone	..

In No. 2 well about 1½ miles south of No. 1, the 70-foot bed of sandstone has increased to 106 feet and the 53-foot bed of shale has decreased to 14 feet. Both wells also show a number of smaller beds of standstone in the upper part of this formation, which are not present in the exposures downstream. Along the upper contact with the Peace River sandstones there is much replacement laterally of sandstone by shale, so that the contact rises stratigraphically northward. As exposed on the river in the north the even bedding and marine fossils point to a marine origin. It is possible, however, that the thick sandstones near the base of the formation in the south may be of non-marine origin, like the tar sands of the Athabaska at the same horizon. At the great horseshoe bend the thickness is 400 feet (estimated) and to the south in the oil wells 1,100 feet.

Peace River Formation. The rocks of the Peace River formation outcrop on both sides of the valley from a point about 14 miles above Carcajou point to Peace River. Where they are typically developed and exposed, they form steep valley-walls, the "Ramparts of the Peace." The formation consists of two sandstone members, with an intervening shale member and where all three outcrop, the sandstone components give rise to two cliffs, separated by a bench on the shale. In its southern development the upper sandstone is made up of massive, white to cream, crossbedded sandstone. The few concretions present are thin and horizontally extended. A discontinuous lignite seam is found near the top at some localities. The surface of the cliff walls weathers into an arabesque of hollowed and bossy sculpture. The thickness of this upper sandstone in the south is 130 feet, but due to replacement by shale above, it thins northward and near the mouth of Cadotte river is only 90 feet thick. At this locality the upper, massive, crossbedded, freshwater sandstone of the south is replaced by bedded sandstone and shale with marine fossils. Both the thickness and arenaceous content continue to decrease northward, until the entire member is replaced by shale; so that the contact with the St. John shale descends stratigraphically in that direction.

The middle shale member is made up of blue black, friable shale without fossils, but probably is of marine origin. The thickness is 30 feet.

The lower sandstone member differs considerably in structure and lithology from the upper. At the top it is characteristically massive and crossbedded and contains large spherical concretions similar to those of the lower part of the Grand Rapids sandstone of the Athabaska section. This passes down into bedded sandstone and shale. The shale is thin-bedded at the base and carries marine fossils. The top may be subaerial, but the lower part is certainly marine. The contact with the Loon River shales is arbitrarily chosen, being marked by a gradual transition from bedded sandstone and shale to shale below. South of Brown's trading post the thickness is about 160 feet, 7 miles below the mouth of Battle river it is 80 feet thick, and to the north it is only about 20 feet thick. Both this formation and the Loon River have a common fauna and this is now being studied. The affinities of this fauna are Lower Cretaceous (Albian and Aptian rather than Neocomian) and pre-Dakota, taking Cenomanian as the base of the Upper Cretaceous. As to Dakota there are three possibilities: it is represented by the top few feet of the Peace River sandstone; the lowest beds of the St. John are its marine equivalent; or there was no deposition in Dakota time.

St. John Formation. The St. John shales form the gentle valley slopes above the cliffs made by the Peace River sandstones, and underlie the adjacent plateaus, from the great horseshoe bend in the north to some distance south of the town of Peace River. There the Dunvegan sandstone comes in and underlies the plateau for some distance to the south. The St. John shale, however, continues to outcrop along the valley sides southwestward to the bend near the mouth of Burnt river, but occupies lower and lower elevations above river-level in that direction. It consists largely of dark blue to grey, friable shale with occasional rounded or banded ironstone concretions and is unfossiliferous as far as known. At Peace River the formation is estimated to have a thickness of from 500 to 540 feet, but a more exact figure cannot be given until the section on Smoky river is studied. The Dunvegan sandstone and Smoky River shales overlie the St. John shales in the direction of Dunvegan. This formation is correlated with the Colorado group of Upper Cretaceous time.

Western Succession.

Triassic. Owing to lack of time it was not possible to work out the details of the Triassic stratigraphy. A reconnaissance, however, revealed some new facts that are worthy of record. Dark purple limestones, hardened sandstones, and shales with *Psuedomonotis subcircularis* Gabb, outcrop at Rapide qui ne parle pas and also on the south bank of Peace river a couple of miles below the mouth of Ottertail river. About 4 miles above Fish creek on the north bank the strata exposed are steeply inclined to the west. Above are brownish weathering sandstones with stem and tree-trunk impressions. These are underlain by *Psuedomonotis*-bearing beds and probably mark the contact between the Triassic and the base of the Bull Head Mountain sandstone. At the mouth of Twentymile creek a second and probably lower Triassic horizon outcrops. This consists below of dark limestones, sandstone, and shale with *Dawsonites* and other ammonites. A little higher are lighter limestones and sandstones with *Terebratula,* etc. Previously the *Dawsonites* zone had not been recognized south of Liard river. The entire Triassic series must be quite thick and is probably all of marine origin.

Bull Head Mountain Sandstone. The Bull Head Mountain formation consists of a thick series of strata of freshwater origin lying between the Triassic shale below and the St. John shale above. It appears first in the canyon midway between Deep and Johnson creeks and continues to the west as far as Twentymile creek. As a result of the preliminary examination, this series of rocks may be divided into two members. The upper member consists of sandstones, shales, and coal beds and is well exposed in the canyon and on Gethring and Johnson creeks. The lower part is made up of massive, coarse, crossbedded sandstones and is exposed at the head of the canyon, on Portage and Bull Head mountains, and the high hills to the west. The sandstones overlying the *Psuedomonotis* beds about 4 miles above Fish creek probably represent the base of this formation. No fossils have been found in the lower part, but a few plants were collected in the upper coal-bearing shales and sandstones. These include a few cycads, conifers, etc., and a single specimen of a dicotyledon. Though it is not possible now to make any definite correlation with southern Alberta, the plant association of this flora suggests that of the lower part of the Blairmore formation of the Crowsnest district. The rich angiosperm flora (Dakota), however, that characterizes the top of the Blairmore, is not found here. The Bull Head Mountain formation should be correlated with the Peace River, and probably also the Loon River formations of the eastern succession, since it occupies the same stratigraphic position; it is, therefore, of Lower Cretaceous age.

St. John Formation. The St. John formation, as here interpreted, embraces all the strata lying between the Bull Head Mountain below and Dunvegan sandstones above. It consists of two thick shale members separated by a thin sandstone member. The lower shale unit consists of 800 feet of dark, thin-bedded, slightly arenaceous shale, and first appears in the canyon about midway between Johnson and Deep creeks. It is well exposed on the Hudson Hope anticline in the cliffs at Hudson Hope and in the lower part of Maurice creek. Below the Gates the structure carries it below river-level. The thin, even bedding points to marine conditions, although no fossils have so far been found.

The middle sandstone consists of 50 to 80 feet of massive, crossbedded sandstone with vertical rootlets and prostrate stems and evidently represents temporary subaerial delta conditions. It forms steep-sided islands and cliffs at the Gates and above Hudson Hope, and outcrops in the Maurice Creek gorge.

The upper shales are first seen at Deep creek. To the Gates they occupy the valley sides above the middle sandstone. From there to Cache creek and from near King's ranch to below North Pine river they underlie the entire valley slope and from Cache creek to below King's ranch and from near the mouth of Kiskatinaw river to below Montagneuse river they occupy the part of the valley side below the Dunvegan sandstone. They also underlie the plateau north of the river from the foothills to the Cache Creek escarpment and the plateau south of the river as far east as the South Pine at least. From the Gates to a little below the mouth of Kiskatinaw river a complete section of the upper shale is obtained owing to the east dip. Below the Gates it is made up of thin-bedded, dark, hard, and friable shale with banded concretions of ironstone. Fossil-bearing, dark, friable shales with concretions are found near river-level from a few miles below the mouth of Cache creek to within about 4 miles of North Pine river. Overlying this and appearing within about 2 miles of the river are black, paper-thin shales without fossils. Above this again come dark, thin-bedded, arenaceous shales with several large sandstone lenses. Downstream and higher are thin-banded sandstone and shale to the contact with the Dunvegan sandstone. Farther downstream there is much lateral replacement of sandstone and shale along this contact. The thin, even bedding and marine fossils point to marine conditions of deposition. The upper shale member is estimated to have a thickness of 1,300 feet in the vicinity of Cache creek.

The small fauna of this formation is correlated with that of the Colorado group of the Upper Cretaceous.

Dunvegan Formation. The Dunvegan sandstone first appears in the escarpment at Cache creek, but a few miles downstream the higher elevations upholding this formation recede toward Charlie lake. It reappears in high hills in the north bank a little below the mouth of Kiskatinaw river. Rapidly descending on the valley sides, it forms cliffs to within a short distance of river-level. Below Montagneuse river and continuing past Dunvegan it outcrops to river-level. The formation is made up of light, massive, crossbedded, soft sandstones with large flat concretions, and weathers into castellated forms. The crossbedding is on a scale of about 2 feet, truncated above, tangential below. Grains consist of quartz, feldspar, a little mica, and a black mineral. Other areas of this formation are more argillaceous and locally thin-bedded. A thin lignite seam in the sandstone varies in thickness, but never exceeds 6 inches. There is also a rather prominent bed of shelly limestone, chiefly of freshwater shells, in the cliffs below Montagneuse river and below Dunvegan. The crossbedded structure, coal beds, and freshwater fossils point largely to subaerial conditions of deposition, but the presence of *Inoceramus* and *Ostrea* indicates partial brackish water conditions, and probably the sea was not far away at any time. The formation has a thickness of about 530 feet. Both above and below it exhibits gradational contacts with continuous formations.

This fauna includes *Ostræa anomioides, Barbatia micronema, Brachydontes multilinigera,* and *Corbula pyriformis.* It is correlated with the Colorado group of the Upper Cretaceous.

Smoky River Formation. The Smoky River shales outcrop at the top of the cliffs from below Montagneuse river to the great bend below Dunvegan. They underlie the adjacent plateaus, including those south of the river at Dunvegan, to an unknown distance. The base only of the formation is present on the Peace. The exposed strata consist of dark, friable shale with concretions and a few marine fossils. A part of this formation is considered to be of upper Colorado age.

Lateral Changes in Sedimentation.

From Peace river northward three changes are noted: a decrease in thickness, replacement of sand by shale, and the substitution of subaerial by marine conditions of deposition. In the section from the mountains eastward the most striking change is the decrease in thickness of the St. John shales. The horizon of the subaerial sandstone member of the St. John in the west is probably replaced by marine shale in the eastern part of the section. In the west the entirely subaerial Bull Head Mountain sandstone appears to be the shoreward equivalent of the Peace River and Loon River formations.

STRUCTURE.

Foothills.

The saliant features of the foothill structure in this district are the long, low, east dips, of 10 degrees and less, and the steep west dips. The latter, effecting only 2 miles or less of section, and separated by 10 to 12 miles of low east dip, are probably related to incipient overthrusting. The structure as a whole represents the dying out of the effects of the Rocky Mountain overthrust. The border of the foothills is marked by an anticlinal structure pitching southward. This consists of a single large anticline on Portage mountain and in the canyon and of two anticlines on Bull Head Mountain.

Great Plains.

The transition from foothills to plains structure is very abrupt and takes place where the Portage Mountain anticline is succeeded by an area of gentle undulation and overthrust faulting extending as far east as the Gates. This includes a broad, low anticline at Hudson Hope and a small broken anticline at the Gates. From there to Cache creek there is a low east dip, under one-half degree, with a local west dip equally low near the mouth of Cache creek. Eastward to several miles below St. John, the structure seems to be almost flat. Near the North Pine river and downstream the structure steepens with an east dip so as to bring the Dunvegan sandstone almost to river-level a few miles below the mouth of Kiskatinaw river. From here to the bend at Montagneuse river the structure is flat. The section is east-west to this point. From the mouth of Montagneuse river southward a north-south section is cut and here a small south dip is revealed. Where the river turns east past Dunvegan an east-west section is again exposed and flat structure indicated. Beyond the mouth of Burnt river, the Peace turns to the northeast and so continues to Peace River, Here the strata rise downstream and the inclination near Peace River amounts to some 40 feet per mile to the south.

From Peace River northward a north-south section is exposed and at first reveals a south dip of about 10 feet per mile. In the vicinity of the No. 2 well and extending to Tar island the structure is practically flat, although there is probably a slight rise of 1 or 2 feet per mile. Downstream from here there is a slight dip north of a few feet per mile to a point about 10 miles below the mouth of Cadotte river. Beyond this there is a gentle rise and a final flattening out. The above structure applies to that observed above river-level. It is possible, however, owing to the thinning of the Loon River shales northward and the consequent rise of the limestone contact, that the lower strata below river-level, which would be reached by drilling, would be slightly tilted southward as compared with the overlying strata above river-level. This applies particularly to the section north of Tar island.

ECONOMIC GEOLOGY.

Oil.

The discovery of oil this summer in the No. 2 well of the Peace River Oil Company, about 15 miles below Peace River, lends particular interest to this part of the district. The well is situated on the high strata where the south dip flattens out northward. The oil occurs at two horizons, beds of sandstone in both cases, near the base of the Loon River and not far above the limestone contact. The upper sandstone is met with from 842 to 948 feet in the drill-hole. Above 852 feet this bed yielded gas; from 852 to 905 feet it contained a highly viscous oil; from 905 to 910 feet it carried salt water, and from 910 to 948 feet was firmly cemented and barren of oil, gas, or water. Below this is a 14-foot shale bed followed below from 962 to 1,032 feet by the second oil sand. This is impregnated with an oil of somewhat better quality. This horizon would produce a few barrels per day. An analysis by the Mines Branch (Edgar Stansfield, Chief Engineering chemist) gave:

(*a*) Specific gravity at 60° F.		981·
(*b*) Distillation test,		
Below 150° C.		2·0% by volume naphtha.
" 150–200		4·87
" 200–250	5·3	66·3% illuminating oils.
" 250–300	56·2	
" 300–325	5·2	
Residue and loss		26·5% lubricating oil.

Oil of similar gravity was found at the corresponding horizons in the No. 1 well 1½ miles downstream. The two sandstones are of less thickness here and the shale between thicker. The thinning of these oil sands northward no doubt limits the possibilities of exploration in that direction, since with their disappearance there would be no reservoir to contain oil. As far as structure alone is effective, it should be noted that it is of a gentle nature north of the wells, with very low dips. The conditions obtaining at the wells, therefore, might be expected to prevail over a considerable area from the wells north, limited in that direction more particularly by the wedging out of the sandstones. Were the strata thrown into undulations of a more pronounced nature, more circumscribed areas favourable to boring could be pointed out. In accordance with the recently stated theory of David White it is not improbable that the heavy gravity of the oil is related to this gentle structure.

To the west past Dunvegan and St. John no favourable structures for boring were located. At Hudson Hope there is a broad low anticline. The anticline at the Gates is broken by a fault. About 600 feet below river-level the upper shales, sandstones, etc., of the Bull Head Mountain sandstone would be met with. Below this the lower sandstones of that formation are too massive to serve as a suitable reservoir. The Triassic shales and sandstones must be over 3,000 feet below river-level at Hudson Hope.

Log, No. 2 Well[1].

Well No. 2, Peace River Oil Co., Peace River, Alberta.
Begun July 21, 1917.
Drilled to 980 feet, October 13, 1917.
Elevation above river-level on October 15, 1917—32 feet. Water at 38 feet.

Material.	Thickness. Feet.	Depth. Feet.
Sand, earth, gravel	10	10
Coarse gravel	46	56
Blue clay	33	89
Dark blue shale—a little gas at 89 feet	36	125
Sand rock	19	144
Blue shale—thin bands sand rock. At 253 feet, small showing gas	162	306
Grey sand rock. At 308 feet, gas with faint showing of oil	23	329
Blue shale—very small showing salt water 327-329 feet	54	383
Sand rock	12	395
Blue shale	62	457
Sand rock, gas at 459 feet—smells of oil	16	473
Blue shale	25	498
Lime rock	6	504
Blue shale	66	570
Sand rock	11	581
Blue shale	31	612
Lime rock	38	650
Blue shale	25	675
Lime rock	36	711
Blue shale	51	762
Lime rock	17	779
Blue shale	63	842
Sand rock. Hard at 842 feet; at 843 feet softer with gas; at 845 feet gas strong—strong smell oil; 845-848 feet heavy flow gas, sand soft; 848-852 feet very hard; at 852 feet softer with slight amount oil; 878 feet more oil, deeper; from Friday night until Monday morning about 2 barrels oil in well; 905-910 feet soft sand rock, getting salt water; oil stops here; 934-944 feet very hard sand rock; no water here	106	948
Blue shale	14	962
Sandstone, with oil; fills to 120 feet in less than a day after bailing; hole 6-in. diameter at this depth	18	980
Oil-bearing sandstone	52	1,032
Sandstone—carrying water above	11	1,043
Sand with thick tar	4	1,047
Sand	10	1,057

Coal.

Peace River Sandstone. Lignite occurs in the upper sandstone member of the Peace River sandstone, approximately 25 feet below the top at a point about 10 miles below Peace River. It is also found at a similar horizon near Peace River on Heart river, etc. Owing to the lateral changes in composition and thickness this coal horizon can hardly be considered from the standpoint of large scale operations. However, where locally the coal is of good quality and of sufficient thickness and is of marketable value not far (a few feet) from the face, i.e., all coal removed can be sold, small scale

[1] Log furnished by Mr. Slack, head driller. Published with the permission of the Peace River Oil Co.

operations may be advisable. A sample of a layer of lignite 7 inches to 1 foot 2 inches thick, underlain by 4½ feet of lignite shale (ash 58·29 per cent) gave the following analysis (Mines Branch, E. Stansfield, Chief Engineering chemist).

	Per cent.
Moisture	14·2
Ash	13·9
Volatile matter	28·9
Fixed carbon	43·0

The greatest thickness of clean lignite measured in the cliffs by the writer was 1 foot 6 inches. Marketable coal of greater thickness, however, may be present in places.

Dunvegan Sandstone. The Dunvegan sandstone cannot be looked upon as a coal producer. A small lignite seam is present in the cliffs below Montagneuse river but is never thicker than 6 inches.

Bull Head Mountain Sandstone. The coal beds exposed in the Peace River canyon have been described by John D. Galloway and no special examination was made of them during the past summer. A 5-foot seam of coal was found nearly opposite the mouth of Johnson creek, but it is not known how this bed holds its thickness laterally. A sample gives the following analysis (Mines Branch, E. Stansfield, Chief Engineering chemist).

Moisture	0·9
Ash	3·3
Volatile matter	18·5
Fixed carbon	77·3
Split volatile ratio	8·66
Classification	High carbon bituminous.
Coking properties	Agglomerates slightly.

EXPLORATIONS IN THE VICINITY OF GREAT SLAVE LAKE.

By A. E. Cameron.

CONTENTS.

INTRODUCTION.

The field season of 1917 was spent by the writer in continuing the exploratory and geological work begun in the summer of 1916 in the region adjacent to Great Slave lake, North West Territories.

The field work as authorized was to survey and examine Hay river between the terminus of the Vermilion wagon road and Alexandra falls; to explore Buffalo river and, if possible, map the large lake in which this stream rises; and, time permitting, to explore Beaver river which enters Mackenzie river a few miles below the outlet of Great Slave lake, making a survey of the shore-lines and islands of Mackenzie river between Great Slave lake and the mouth of Beaver river.

During the course of the season it was found possible to carry out all the work above outlined with the exception of the exploration of Beaver river which proved to be navigable for only about 6 miles above its mouth. A survey was also made of the north shore of Great Slave lake from Mackenzie river eastward to Slave point to connect with the survey of the north shore made in 1916.

The route traversed in reaching the field was by way of Peace river from Peace River Crossing, Alberta, to Fort Vermilion, a distance of 300 miles, thence overland 91 miles by the wagon road from Vermilion to Hay river. From the terminus of the wagon road, known to the Indians at Hay River post as the "Horse tracks", Hay river was ascended 25 miles to a point where it crosses the 6th meridian of the Dominion Land Surveys at sec. 25, tp. 114, range 1. The river was then descended to Great Slave lake. The same route was followed in returning from the field in September.

Acknowledgments.

The writer wishes here to acknowledge his appreciation of the kindnesses he received at the hands of all with whom he came in contact during the season, especially to the Rev. Mr. Bowring and his assistants of the Anglican Mission school at Hay River, to the Rev. Father Bousso, of the Roman Catholic mission at Hay River, and to Mr. A. P. Clarke, post manager of the Hudson's Bay Company at Fort Vermilion.

Previous Work.

In 1911, Hulbert Footner, journalist, descended Hay river from the "Horse tracks" to Alexandra falls and in 1910 Sergeant Mellor of the Royal North West Mounted Police made a patrol up Buffalo river and about the eastern end of Buffalo lake in order to determine the western limit of range of the Wood Bison. With the exception of the publications describing these two journeys no information was available regarding the country adjacent to the rivers traversed during the season.

GENERAL CHARACTER OF THE DISTRICT.

Wagon Road from Fort Vermilion to Hay River.

This road which has been made by the traders, the Hudson's Bay Company, and Revillon Frères, to facilitate the carriage of freight to their outposts on Hay river, follows a general west-northwest direction from Peace river at North Vermilion to Hay river, a distance of 91 miles. For the first 60 miles it traverses a broad level plain of alluvial soil lightly wooded with poplar, willow, and alder and containing many large, open, prairie sections which have a luxuriant crop of prairie hay. The plain is dissected by numerous small streams tributary to Boyer or Paddle river and the land where under cultivation in the vicinity of Fort Vermilion produced excellent crops of wheat, oats, and garden vegetables. In the succeeding 15 miles the road crosses the low divide between Boyer and Hay rivers and the country here is hilly and very stony. The road passes two small lakes, Summit and Devils lakes, which lie between low ranges of hills and form the source of Meander river, one of the principal tributaries of Hay river. The country consists of a series of low ridges of glacial drift with a maximum elevation of 1,300 feet where crossed by the 29th base-line. To the south of these lakes the Watt mountains, 2,500 feet in elevation, rise above the plain and are apparently formed of Cretaceous sediments overlain by a thick mantle of glacial drift.

Meander River valley, down which the wagon road runs to Hay river, contains considerable areas of open prairie lands and is bordered by low hills of glacial drift covered with a light growth of poplar, spruce, and willow.

Hay River.

This river, rising in the foothills of the Rocky mountains to the north of Fort St. John, B.C., and fed by numerous small tributaries, is one of the largest streams discharging its waters into Great Slave lake. It crosses the 6th meridian a few hundred yards south of sec. corner 25, tp. 114, range 1, and flows from this point in a northeasterly direction. Though of a meandering character it holds its direction of magnetic north (north 35° 30′ east astr.) throughout the total distance of 225 miles to its mouth on Great Slave lake.

Throughout the 26 miles from the 6th meridian to the mouth of Meander river at the "Horse tracks," the river has an average width of 200 feet and is very swift and broken by a succession of rapids. The valley here has a width of less than half a mile and the adjacent country is of a gently rolling, drift-covered character wooded with scrubby spruce and poplar, much of which has been burnt over in recent times.

North of the "Horse tracks" the valley widens and shallows and the river, straightening its course, widens to from 400 to 600 feet and flows smoothly and sluggishly for a distance of 116 miles through a rather flat muskeg and brûlé country, which is in places relieved by low hills of glacial drift.

Devonian limestones come to the surface 116 miles below the "Horse tracks" and show in the river valley as low limestone ramparts, causing the river to narrow and increase its current. From this point for a distance of 33 miles, rapids occur in quick succession wherever the channel has been cut down to the limestones, until 149 miles below the "Horse tracks" the waters plunge 105 feet over the Alexandra falls and a mile farther down take a second drop of 46 feet, forming Louise falls. The country through which this portion of the river flows has in general the irregular relief of glacial morainal drift. The drift overlies Devonian limestones, the low ridges being covered with jack-pine and poplar and the hollows between containing a spruce muskeg.

Below the falls the river has cut a narrow gorge, about 250 feet deep, in the limestones, through which it rushes in a continuous rapid for a distance of 6 miles before it clears the escarpment. For the succeeding 40 miles it flows with steadily diminishing velocity until about 4 miles from the lake it loses itself in a maze of channels amongst the delta deposits. Only one of these channels, however, finds its way to the lake separate from the main body of the river, the others all coming together and issuing as one stream into the lake.

The peculiar physiographic feature of a river having a well formed delta at some distance from the margin of the body of water into which it empties is even more clearly shown on Buffalo river and, taken together with the numerous remnants of old lake beaches previously noted on both shores of the lake, clearly indicates that the Great Slave lake of early post-Glacial times was of much greater extent than the present lake.

Buffalo Lake.

Buffalo lake, lying between latitudes 60 degrees north and 60° 30′ north and longitudes 115 degrees west and 116 degrees west, is a body of water covering an area of approximately 200 square miles. It is everywhere very shallow, its greatest depth scarcely exceeding 10 feet. Confined to the north by a low range of hills of glacial drift, the lake acts as a collecting basin for the waters draining the northern slopes of Cariboo mountain. Three comparatively large streams flow into the southern end of the lake. Each of these is building a delta which is gradually encroaching on and slowly filling in the whole of this portion of the lake. The shore-line is everywhere low and swampy, particularly on the south side where, in places, willow and alder bushes are actually growing in 2 feet of water. A few islands, composed of glacial boulders of Pre-Cambrian granites and metamorphics, occur along the northern shore. The smaller of these islands resemble cairns of glacial boulders and are bare of vegetation, whereas upon the larger islands, scrubby spruce, poplar, and willow have found a foothold. These islands clearly represent outliers of the low, east and west, glacial, morainal ridge which forms the north shore of the lake. The lake is evidently the remnant of a much larger moraine lake of early post-Glacial times.

Buffalo River.

Buffalo river, which discharges into Great Slave lake, makes its exit from the northeast corner of Buffalo lake and flowing in a northwest direction for a distance of 5 miles cuts through the low range of hills which marks the northern boundary of the lake. It then makes a wide swing to the right and after following a general course of magnetic north (north 36 degrees east astr.) for a distance of about 25 miles, swings first to the right again and then to the left in a wide curve until finally it straightens to a true north course which it follows for 25 miles to its outlet on Great Slave lake.

In the upper portions from Buffalo lake to the "Big bend" the river valley is cut through a series of morainal ridges separated by flat muskegs and brûlé. The outside of each curve shows banks cut into glacial clays and gravels. Boulder rapids separated by stretches of smooth though swift running water are numerous. Below the Big bend the ridges become more numerous and of greater height and the cut banks frequently show sections of the glacial clays and drift 80 to 100 feet high. Here the river rapidly increases its current and runs turbulently along in a succession of rapids amongst and over large boulders washed from the drift. At a few places along its course it has cut down into the underlying Devonian limestones, forming low ramparts similar to those already referred to on Hay river. About 3 miles above the mouth it suddenly expands and, diverging into numerous channels, loses itself in a delta of about one square mile in area. These divergent streams soon unite again in a single stream which forces its way through a low barrier of glacial drift and lake sediments and discharges its waters into Great Slave lake.

The volume of water carried by the river is subject to rapid fluctuation due to the shallow nature of Buffalo lake in which it has its source. Even comparatively light winds soon raise a surf on the lake which carries the water in the direction of the wind and raises the level of the lake on the windward side. In strong winds an increase of 2 feet or more in the level of the lake was noticed and when the wind blows in the direction of the outlet the discharge down the river is greatly increased.

Mackenzie River.

Mackenzie river where it leaves Great Slave lake is divided by Big island into two channels. The southern one has a width of 7 miles at the lake, but rapidly contracts until in 5 miles it has narrowed to 4 miles and has become choked with islands. It carries the main body of water and is the channel used by the steamers, but is everywhere shallow and in low water some difficulty is experienced in navigating it. The current here has a velocity of at least 3 miles an hour.

The north channel, 7 miles north of the main channel, has a width of about 1½ miles at its point of effluence, seldom exceeds 2 feet in depth, and shows very little current until close to its junction with the south channel at the lower end of Big island.

Below Big island, Mackenzie river keeps an average width of about 4 miles for a distance of 20 miles and shows only a very slight current. This portion of the river is known locally as Beaver lake and is reported to be rarely more than 12 feet in depth.

Beaver River.

Beaver river, which enters Beaver lake from the south about 25 miles below the outlet of Great Slake lake, was ascended 8 miles to Lady Evelyn falls. It is for the most part shallow and in all places very swift, being practically unnavigable from its mouth. The adjacent country is a low muskeg with occasional ridges of glacial drift which, where crossed by the river, form typical boulder rapids. About 6 miles above its mouth Devonian limestones make their first appearance in the valley, forming low cascades where the river cuts across the beds. The valley here is from 60 to 80 feet deep and shows heavy deposits of glacial material overlying the limestones. Two miles farther up stream are Lady Evelyn falls where the river precipitates itself over a limestone cliff with a sheer drop of 48 feet. These falls owe their origin to the same cause which produces Alexandra falls on Hay river. The limestones exposed are the same as those forming the Louise falls, but the overlying shales having pinched out, the Alexandra falls on Hay river are here represented by a long series of low cascades from 3 to 15 feet high. No gorge is developed below the falls, though the valley walls are steep and in many places show cliffs of limestones.

GENERAL GEOLOGY.

From the determination of fossils collected by the writer in 1916 and by Mr. Kindle and E. J. Whittaker in 1917, the following table of formations has been compiled. The table also shows a probable correlation with a composite, Peace River, Manitoba, and New York section.

Table of Formations.

Great Slave Lake section.	Composite correlation.
Quaternary	
Lake and river deposits.	
Glacial deposits.	
Unconformity.	
Cretaceous	
Meander shales.	Loon River shales.
Unconformity.	
Upper Devonian	
Hay River limestones.	Chemung.
Hay River shales.	Chemung.
Simpson shales.	Portage.
Middle Devonian	
Slave Point limestones.	Manitoban limestones.
Presqu'ile dolomites.	Winnipegosan dolomites.
Pine Point limestones.	Elm Point limestones.
Unconformity.	
Upper Silurian	
Fitzgerald dolomitic limestones.	Gypsum and upper limestones.
Redrock arenaceous limestone.	
Unconformity.	
Pre-Cambrian	
Granites, gneisses, and metamorphics.	

Description of Formations.

Pre-Cambrian. Pre-Cambrian rocks are exposed on Great Slave lake east of the North arm and at several places on Slave river above Fort Smith. On the shores of the lake they show as coarse granites and gneisses intruding greenstone schists and metamorphics. On Les Iles du Large a massive bed of coarse, clear white quartzite is found overlying the granites, but whether the contact is intrusive or not was not apparent. On Slave river the granites underlie Palæozoic sediments and the sections frequently show 5 to 10 feet of a coarse arkose lying between the granites and the Palæozoic sediments.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The section in the gorge on Hay river shows 221 feet of thick and thin-bedded, hard, fine-grained, light-coloured limestones and at least another 75 feet is exposed in the river valley above the falls. About 40 feet from the base of the limestones occurs a bed of soft fossil clay shales 47 feet thick. The presence of this shaly member in the limestone series has been the cause of the formation of the two falls on Hay river. At the falls on Beaver river the limestones are similar to those at Louise falls on Hay river. The shaly member is here absent and in place of an upper fall there is a long series of low cascades from 5 to 15 feet high.

Cretaceous. Soft, fissile, dark shales of Cretaceous age are exposed in the valley of Hay river at intervals throughout the distance between the 6th meridian and Grumbler rapids. The contact between these and the underlying Devonian limestones is not exposed, but would probably show, as elsewhere in western Canada, an unconformity. The shales show numerous large concretions and occasional ironstone bands and closely resemble the Loon River shales of the Peace River section. A few miles below the 6th meridian a sandstone layer 25 feet thick shows in the valley and this very probably represents the Peace River sandstones of the Peace River section, which are known to thin out to the east and north.

Recent. The entire region is overlain by a heavy deposit of glacial drift. Cut banks on the river valleys frequently show sections 20 to 100 feet thick of boulder clays and gravels of glacial origin.

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

STRUCTURAL AND ECONOMIC GEOLOGY.

Stratigraphic studies have revealed the presence of a gentle anticline stretching across the lake from Pine point on the south shore to Nintsi (Windy) point on the north shore. On the south shore the apex of the anticline is shown on the east side of Pine point and the lowest beds exposed show the Pine Point series of bituminous limestones and limy shales. The presence of higher strata, the overlying Presqu'ile dolomites, both to the east on Burnt islands and to the west at Presqu'ile point, clearly demonstrates the anticlinal structure. On the north shore the crest appears to lie in the erosion basin of Sulphur bay. The Presqu'ile dolomites are exposed on the east shore of Nintsi point, at various points on the shores of the bay, and eastward to Jones point; whereas the overlying Slave Point limestones are shown on Slave point west of Nintsi point and again near House and Moraine points northeast of Jones point.

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

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

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

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

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

CROWSNEST AND FLATHEAD COAL AREAS, BRITISH COLUMBIA.

By B. Rose.

CONTENTS.

INTRODUCTION.

In 1915 and 1916 structural and surface mapping of the coal-bearing and associated formations of the Rocky mountains in southern Alberta was carried on by the writer. In 1917 this work was continued westward, a few remaining localities in Alberta were examined, and the Crowsnest and Flathead areas of British Columbia were investigated. Data for the areal mapping of the coal areas of the Rocky mountains south of 50 degrees north latitude and between 114 degrees and 115 degrees west longitude have now been procured, although much of that for the outlying districts of the British Columbia section is of a reconnaissance type because suitable topographic maps for detailed field work were not available.

The present description falls naturally under two headings, the Crowsnest coal areas and the Flathead coal areas. The Crowsnest coal areas in British Columbia include those sections which are tributary to the main valleys of Michel creek and Elk river through which the Crowsnest branch of the Canadian Pacific railway runs. The Flathead coal areas include those sections along the Flathead river whose natural outlet is southward by way of the Flathead valley to American points. The separate sections will be described under local names.

Previous investigations in the Crowsnest coal area were made by McEvoy in 1900[1] and by Leach in 1901[2]. The Flathead coal area was visited by Dowling in 1913[3] and in 1914 MacKenzie[4] investigated the southern part of this area. Yearly reports of the progress in coal mining appear in the annual reports of the Minister of Mines for the province of British Columbia.

The field work in 1917 covered a period of four and one-half months, from June 1 to October 15, and during that time efficient and cheerful assistance was given by P. G. Dobson, E. Hughes, and R. Comette. I wish to thank the mining companies and many residents of the district for favours which helped in the progress of the work.

1 Geol. Surv., Can., Sum. Rept., 1900, pp. 85-95.
2 Geol. Surv., Can., Sum. Rept., 1901, pp. 69-81.
3 Geol. Surv., Can., Sum. Rept., 1913, pp. 139-141.
4 Geol. Surv., Can., Sum. Rept., 1914, pp. 41-42.
Geol. Surv., Can., Mem. 87.

GENERAL GEOLOGY.

There is in the southern Rocky mountains of British Columbia and Alberta a conformable series of sedimentary rocks ranging in age from Pre-Cambrian to Upper Cretaceous. These rocks are folded and faulted and at no place is the whole succession exposed. On the Alberta slope of the mountains the series extends to higher formations than in British Columbia where erosion since the Rocky Mountain uplift has removed some of the younger formations. The workable coal of the Crowsnest and Flathead areas is a high grade bituminous coal contained in rocks of the Kootenay formation. A few small seams of a semi-cannel character occur in the series above the Kootenay formation. A summary description of the formations follows.

Table of Formations.

Pleistocene and Recent	Superficial deposits.
Eocene ?	Kishinena formation.
Cretaceous.	Flathead Beds. Elk Conglomerates. Kootenay formation.
Jurassic.	Fernie formation.
Devono-Carboniferous	
Pre-Cambrian and Cambrian.	

Pre-Cambrian and Cambrian. In the Clarke range east of the Flathead river a series of siliceous dolomites, metargillites, quartzites, magnesian limestone, and argillites with intruded and intercalated lavas reach a thickness of nearly 14,000 feet.[1] This is the Lewis series of Daly who assigns to the formation ages ranging from Beltian to Middle Cambrian. The only fossil found in the series was *Beltina danai.* Later, Adams and Dick described a continuation of this section in the vicinity of North Kootenay pass where the Lewis series is conformably overlain by shale and limestone containing fossils belonging to the lower part of the Middle Cambrian.[2] The Lewis series is then at least pre-Middle Cambrian, and Schofield, working in the Cranbrook area to the west, argues for its Pre-Cambrian age.[3] The North Kootenay Pass section was examined by the writer and it was noted that the Kintla formation, which is here largely composed of reddish argillite and quartzite, at the top of the Lewis series, is separated from the Middle Cambrian shale and limestone by 200 to 300 feet of reddish white sandstone with a conglomerate layer, containing pebbles of white and opalescent quartz up to one-half inch in diameter at the base. This conglomerate marks a disconformity between the Kintla formation at the top of the Lewis series and the overlying rocks and it is suggested that it be used provisionally as the dividing line between the Pre-Cambrian and the Cambrian. The conglomerate and the overlying sandstone may then be considered to represent the Lower Cambrian, provisionally.

Devono-Carboniferous. The great limestone series which comprises a large part of the Palæozoic rocks of the Rocky mountains is represented in the Crowsnest and Flathead areas by rocks of Devonian and Carboniferous ages. Rocks of Ordovician and Silurian ages which occur farther north are not known here. The rocks consist largely of evenly-bedded, compact, grey limestone. The upper portion, lying con-

[1] Daly R. A., Geol. Surv., Can., Mem. 38, 1912, p. 49.
[2] Adams, F. D., and Dick, W. J., "Discovery of phosphate in the Rocky mountains," Commission of Conservation, Canada, p. 13.
[3] Schofield, S. J., Geol. Surv., Can., Mem. 76, 1915, p. 52.

formably under the Fernie formation, consists of light-coloured quartzite and siliceous limestone which may probably be correlated with the Rocky Mountain quartzite (Pennsylvanian) of the Bow River section. A measured section, starting at Crowsnest station on the Canadian Pacific railway, eastward along Crowsnest lake, gives a thickness of approximately 10,000 feet and the base is not exposed here. The only place where the contact with the underlying Middle Cambrian was seen is in the North Kootenay Pass section. Here the rock overlying the fossil-bearing Cambrian strata is a massive, dark grey, unfossiliferous limestone and above this the first fossils found are of Devonian age. The fossils towards the top of the series are all of Carboniferous age, so the series as a whole is classed as Devono-Carboniferous.

In the area examined these rocks form the main range of the Rocky mountains separating the Crowsnest coal areas of British Columbia from the Crowsnest coal areas of Alberta; a minor range, the Wisukishak or Erikson ridge, crosses the Canadian Pacific railway between Crowsnest and Michel stations and the high mountains of the MacDonald range west of the Flathead valley.

Fernie Formation. Lying conformably on the Devono-Carboniferous rocks and passing gradually into the Kootenay formation above is a great shale formation containing marine fossils of Jurassic age. Brown-black and grey-black, thinly laminated, and fissile shales predominate. In the Crowsnest areas there is a persistent band of quartzite from 50 to 100 feet in thickness near the base of the formation and in the Flathead areas light grey shales occur towards the top. Black, platy shales containing fossil ammonites were found near the falls on Fording river. Calcareous shale and shaly limestone occur in the lower part of the section in the Elk River valley. At the top the shale becomes arenaceous and alternating bands of brownish sandstone and shale lead up to a massive, coarse-grained sandstone, above which there are plant remains and coal seams. The base of this heavy sandstone is used as the dividing line between the Fernie shales and the overlying Kootenay formation.

The thickness of the formation is over 3,000 feet in the Elk River valley. The formation thins towards the east and the maximum thickness in the Crowsnest coal areas on the Alberta slope of the Rocky mountains is between 700 and 800 feet. The formation is widely distributed throughout the area. It is commonly found in the valleys about the borders of the coal basins.

Kootenay Formation. The Kootenay formation contains all the workable coal of the district. It consists of alternating sandstones, shales, and coal seams with considerable conglomerate towards the top of the section. Massive, coarse-grained, and cross-bedded, grey sandstones stand out prominently. The shales are soft and friable and so they and the coal seams are usually covered with debris. The formation is of subaerial origin as is shown by the character of the sediments—coarse, cross-bedded, and ripple-marked sandstones, fossil land plants, and shales associated with coal seams. The succession varies from place to place and it is impossible to correlate the coal seams at different localities without much more detailed work. It is also difficult to designate an upper limit for the formation. The character of the strata above is much the same except that the sandstones are coarser and there are a number of conglomerate bands. On the Alberta side of the Crowsnest pass and in the Flathead valley a prominent conglomerate marks the upper limit of the coal formation, but in the Crowsnest areas of British Columbia there are a number of small coal seams above the first conglomerate.

A section measured on the Elk River escarpment north of Morrissey shows 216 feet of coal in 3,200 feet of strata.[1] The lower 2,200 feet of this section contains 205 feet of coal in nineteen seams ranging in thickness from 1 to 46 feet and above this there is a conglomerate layer which may represent the upper limit of the Kootenay formation. To the north in the Upper Elk Valley coal basin the Kootenay reaches a

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[1] McEvoy, J., Geol. Surv., Can., Sum. Rept., 1900, pp. 86-88.

thickness of 3,500 feet,[1] but it thins out to the south and east. In the Flathead valley there are approximately 1,100 feet of strata[2] and at Blairmore, Alberta, a measured section shows a thickness of 450 feet.[3]

The formation is of Lower Cretaceous age, as determined from the fossil plants.

Elk Conglomerates and Flathead Beds. As described above, the Kootenay formation grades upward into conglomerates and coarse sandstones with shales and thin seams of a semi-cannel nature. These beds have been called the Elk Conglomerates to distinguish them from the less conglomeratic strata below and above. The strata above the Elk Conglomerates are mostly green and reddish shales, and sandy shales interbedded with sandstones and some conglomerates. This part of the series has been called the Flathead Beds. The rocks are found in territory about the headwaters of Flathead river and on some of the higher mountains east of Elk river.

The combined thickness of the Elk Conglomerates and the Flathead Beds is estimated at 6,500 feet. From their lithologic character and their location in the stratigraphic column, they are thought to be the equivalent of the Blairmore formation of the Crowsnest section in Alberta. This formation is classed with the Dakota group of the Cretaceous.

Kishinena Formation. Tertiary lake deposits are exposed along the Flathead river where it has cut through the glacial drift of the valley floor for a distance of from 10 to 12 miles northward from the American boundary. Outcrops are confined to bluffs along the main stream and a few of the tributary creeks where they traverse the main valley floor. The rocks consist of semi-indurated and thin-bedded clays, sands, gravels, and very thin lignite seams. A local accumulation of angular Carboniferous limestone boulders up to 2 and 3 feet in diameter, embedded in a clay matrix, form a stratum 25 feet in thickness at Squaw rock, 7 miles north of the American boundary. The colour of the rocks is predominantly grey-yellow to buff, although brown and red colours show in some of the clays.

The relation of the formation to the underlying rocks is not known and it is difficult to make an estimate of its thickness, but according to Daly, who described and named the formation, at the International Boundary it is at least 700 feet thick,[4] The beds have been deformed since deposition and are now found with dips of from 15 to 50 degrees to the east and southeast. From the evidence of freshwater shells the age of the Kishinena formation is provisionally placed as Eocene,[5] but may be referred to a much younger period in the Tertiary.

Superficial Deposits. Glacial gravels mantle the lower slopes and cover the floors of the main valleys. They were deposited by Pleistocene valley glaciers. Recent stream action has removed and terraced the gravels and has in many places cut through them to bedrock. Talus deposits along the steep slopes and a general veneer of rock debris on the gentler slopes mark the effects of recent weathering.

STRUCTURAL GEOLOGY.

The Rocky mountains were built by a great thrust from the west, which threw the rocks into a system of parallel folds and faults with a general north-south alignment. This is expressed topographically by a series of parallel mountain ranges with steep faces to the east and gentle slopes to the west. The more resistant rocks, the massive Devono-Carboniferous limestones and the Pre-Cambrian siliceous and dolomitic rocks,

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1 Rose, B., Geol. Surv., Can., Sum. Rept. 1916, p. 64.
2 MacKenzie, J. D., Geol. Surv., Can., Mem. 87, p. 27.
3 Rose, B., Geol. Surv., Can., Sum. Rept., 1916, p. 64.
4 Daly, R. A., Geol. Surv., Can., Mem. 38, p. 87.
5 MacKenzie, J. D., Geol. Surv., Can., Mem. 87, pp. 36-37.

form the higher ranges, whereas the softer Cretaceous sandstones and shales have been eroded into lower ridges. Thus the Crowsnest coal areas of British Columbia lie in a basin between the high lime mountains west of the Elk river and those of the main range forming the British Columbia-Alberta divide.

In the Flathead area the thrust faulting was followed by a period of normal faulting and the Devono-Carboniferous rocks of the MacDonald range to the west have been dropped relatively to the Pre-Cambrian rocks of the Clarke range to the east. The Flathead valley has been eroded along this fault plane and the coal areas occur in remnants of Cretaceous rocks that have been left on the east slope of the MacDonald range.

Additional information on the structure will be found under the description of the individual areas.

ECONOMIC GEOLOGY.

Crowsnest Coal Areas.

The Crowsnest coal areas include all the coal areas tributary to the Crowsnest branch of the Canadian Pacific railway. This is in accordance with the popular usage of the term "Crowsnest." The chief coal basin in the district, which has been variously referred to as the Crowsnest Pass coal field, the Crowsnest basin, the Elk River field, etc., is here called the Fernie basin after the town of Fernie, the largest shipping point of the district. Local names are given to the separate areas as follows: (1) the Fernie basin; (2) Line and Alexander creeks; (3) Taylor and Tent mountains; (4) Corbin.

The Fernie Basin. The Fernie basin is the largest connected area of coal-bearing rocks in the Crowsnest district of British Columbia. Its major structure is that of a broad, flat syncline upturned at the ends. It occupies the mountains east of Elk river and extends 35 miles in a north and south direction from the hills north of Michel to the hills south of Morrissey. In width it varies from 4 to 13 miles. The centre of this basin is occupied by the Elk Conglomerates and Flathead Beds and the Kootenay coal-bearing rocks outcrop continuously around the border on the north, west, and south sides, but are broken by faulting and folding on the east side. The upper beds have been removed by erosion where Michel creek crosses the basin near its north end and for a short distance to the north and south the whole width of the basin is occupied by the coal-bearing rocks.

The drainage from the basin is radial, except where Michel creek cuts across. On the west numerous creeks run to Elk river. On the east most of the creeks are tributary to Michel creek and the southeast part of the basin is drained by the headwaters of Flathead river. The best mining locations are along these tributary creeks, for where the creeks have eroded their valleys the coal is exposed much nearer the centre of the basin and the dips on the coal seams are much flatter.

A number of sections measured on the west side of the basin give a good idea of the coal content.[1]

At Morrissey 23 seams give 216 feet of coal in 3,676 feet of measures.
At Fernie 23 seams give 172 feet of coal in 2,250 feet of measures.
At Sparwood 23 seams give 173 feet of coal in 2,050 feet of lower measures.
At Sparwood 24 seams give 43 feet of coal in 2,015 feet of upper measures.

An estimate of the quantity of workable coal in the basin, made by McEvoy, is calculated on the basis of 100 feet in thickness of workable coal over an area of 230 square miles and gives 22,595,200,000 tons, of 2,240 pounds each.[2]

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[1] Dowling, D. B., Geol. Surv., Can., Mem. 69, p. 10.
[2] McEvoy, J., Geol. Surv., Can., Sum. Rept., 1900, p. 95.

The structure of the east side of the basin is more complicated than that of the west side and is difficult to interpret because of the heavy tree growth and scarcity of rock outcrops. The east arm of the main syncline, followed south from where it crosses Michel creek, passes into an overturned anticline which plunges southward and carries the coal beneath the surface on the west side of Leach creek. The anticline is followed to the east by a minor syncline and this is cut off by a fault to the east of Michel and Leach creeks. Hence, the valley of these creeks is also underlain by the coal formation. An east-west fault along the upper course of the Flathead river offsets the coal measures about one mile to the west on the north side of the river and the northward extension connects by way of the ridges east of McEvoy creek to Mount Taylor where it is cut off by the north and south fault mentioned above. Here for a distance of 8 miles the coal formation slopes west with a dip of from 30 to 60 degrees and contains several easily minable seams of coal, two of which are over 10 feet thick.

At present there are two working collieries in the Fernie basin, both operated by the Crow's Nest Pass Coal Company: the Coal Creek colliery near Fernie and the Michel colliery at Michel. Formerly mines were operated at Morrissey and at Hosmer, but these have been closed for a number of years. No details of mining operations are given here. These are reported regularly in the Annual Reports of the Minister of Mines for British Columbia. Production reached a maximum in 1913 when 1,258,937 tons, of 2,240 pounds each, came from this basin.

Line and Alexander Creeks. An undeveloped area of coal-bearing rocks lies just west of the main range of the Rocky mountains north of Crowsnest station in the area drained by Line and Alexander (North Michel) creeks. To the west of this area and separating it from Elk River valley is the Wisukishak range or Erikson ridge, a minor range of mountains which like the main range is largely composed of Palæozoic limestone. In structure the Wisukishak range is an anticlinal fold which has been thrust eastward and in places faulted over the Jurassic and Cretaceous rocks lying between the two lime ranges. These were folded into a syncline and have been eroded to low hills. Fernie shales flank the two ranges and Kootenay coal-bearing rocks occupy the middle of the syncline capping the hills.

The area occupied by the Kootenay formation extends from 50 degrees north latitude southward for 18 miles and is from 2 miles to 1 mile and less in width. To the north this basin connects with the coal on the east side of Fording river and to the south plays out about 6 miles north of the Crowsnest branch of the Canadian Pacific railway. The northern half of the area is drained by Line creek, which cuts through the Wisukishak range to Elk river. The southern part drains by Alexander creek to Michel creek. A small area between the headwaters of these two creeks is drained by Grave creek, which also cuts across the Wisukishak range to Elk river.

Some prospecting was done on Crown mountain in the southern part of the area a number of years ago, but the workings are badly caved and little information regarding the amount of coal can be obtained. A report on the property shows eight seams of coal, with a combined thickness of 65 feet, in 500 feet of measures.[1]

No prospecting has been done on Line and Grave creeks, but the formation is continuous northward to Fording river where a number of good seams have been opened; so that the basin is well worth developing.

Taylor and Tent Mountains. In the area lying between the Fernie basin and the main range of the Rocky mountains to the east a number of mountains are capped by rocks of the Kootenay formation. In each case a synclinal basin forms the mass of the mountain, but there is so much local faulting and folding that thorough prospecting must be done before attempting mining. The two largest mountains of this group are Taylor mountain, south of Michel creek, and Tent mountain, north of

[1] Rept. of Minister of Mines, B.C., 1911, p. 124.

Michel creek. The best coal exposures were seen on Tent mountain, which lies on the British Columbia-Alberta divide. Here, recent prospecting on the eastern or Alberta slope has exposed seams of 6, 15, 5, 7, 40, and 15 feet thickness in 550 feet of measures. The dip is from 35 to 45 degrees to the west and for a distance of 6 miles and a width of 1 mile the measures appear to be unbroken. A good site for mining can be had at the foot of the mountain and 5 miles of railway along an easy grade will connect with the Canadian Pacific railway at Crowsnest.

Corbin. The mountain south of Corbin, locally called Coal mountain or Coal hill, like Taylor and Tent mountains is included in the group of mountains lying to the east of the Fernie basin which are capped by rocks of the Kootenay formation. At this place the Corbin Coal and Coke Company has been mining for a number of years.

The coal measures have been very closely folded and faulted and the coal and shales squeezed into pockets on the limbs of the folds. Two mines have been driven on the limbs of a monoclinal fold and in each case the coal seam is over 100 feet thick. Another pocket of coal lies close to the surface on the west slope of the mountain and is being mined by stripping and steam shovel. Diamond drilling shows that this pocket covers an area of over 20 acres with a thickness of from 150 to 200 feet. It is not known that all the pockets represent the same seam of coal, but it is probable that the largest ones may be correlated with the 40-foot seam on the east slope of Tent mountain.

The Corbin colliery has been operating since 1908 and, according to figures obtained from the reports of the Minister of Mines for British Columbia, has produced 765,514 tons, of 2,240 pounds each, up to the end of 1917.

Flathead Coal Areas.

The headwaters of the Flathead river follow an east and west line of normal faulting with downthrow on the south side. About 6 miles east of the Fernie basin the river turns rather abruptly to the south and from here to the American boundary, a distance of 24 miles, follows another line of normal faulting with downthrow on the west side. These two lines of faulting mark the north and east limits of the MacDonald range. This range in the vicinity of the faults is composed largely of Devono-Carboniferous limestone, but at three points along the valley there are remnants of Kootenay coal-bearing strata resting on the limestone. These are south from Corbin by wagon road 13, 19, and 32 miles. A fourth area of coal-bearing rocks lies to the west of the Flathead valley on the Wigwam River divide. Local names are given to the separate areas as follows: (1) Flathead townsite; (2) Don Cate's slide; (3) Howell and Cabin creeks; (4) Flathead-Wigwam divide.

Flathead Townsite. At the bend of Flathead river and lying between Squaw creek on the west and North Kootenay pass on the east is a faulted-in block of coal-bearing rocks. The outcrops are found in a bunch of low, tree-covered hills between the river flat and a steep limestone mountain to the north. The east and west normal fault mentioned above passes just north of the coal basin and the rocks of the Kootenay formation are here adjacent to Devono-Carboniferous limestone. The strata dip to the north at angles of from 30 to 40 degrees, except near the fault plane where the drag has folded them sharply upwards with steep dips to the south. The trough or basin thus formed is approximately 1 mile wide. Its east and west extent is hidden, but it is also about 1 mile.

The coal has been prospected by tunnelling, open-cutting, and diamond drilling. Cabins have been built and a townsite, locally called Flathead townsite, has been surveyed. Four coal seams of 6, 8, 10, and 16 feet thickness, covering an area of approximately one square mile, are proved.

Coal has been found about 1 mile west of this block on both sides of the Flathead river, but the rocks are so much deformed here that it is doubtful if any workable seam will be found.

Don Cate's Slide. Five miles south of the bend in the Flathead river, Mr. Donald Cate has done considerable prospecting for coal. There is here an open mountain side where rock and snow slides have removed the trees and this open space is called by travellers in the valley, "Don Cate's slide."

The coal is found in a low ridge of hills lying between the main river course and high limestone mountains to the west. These hills are tree and soil-covered and no outcrops were seen except at the prospects. At the main prospect an east and west trench across the top of a ridge exposes six seams of coal, one of which is 40 feet and the others from 4 to 10 feet in thickness. The strike is north and south and the dip vertical. One mile and a half north from here the big seam is exposed in a tunnel close to the main wagon road. It is here 45 feet thick, strikes southwest, and dips 42 degrees to the southeast.

West of this area are steep mountains of Devono-Carboniferous limestone and east of the Flathead river are Pre-Cambrian rocks. The coal area lies just west of the normal fault which marks the course of the Flathead valley and is a remnant of Kootenay rocks resting on the eastern slope or the down-faulted block of mountains to the west.

Howell and Cabin Creeks. The most southerly area of coal along the Flathead valley is close to the American boundary. On the west side of the valley, beginning at a point about 9 miles north of the boundary and extending southward for 5 miles across the courses of Howell and Cabin creeks, is an eastward dipping block of Kootenay rocks. This block lies in a notch in the mountains between higher mountains of Devono-Carboniferous limestone to the north and south. The hills rise from 1,000 to 2,000 feet above the floor of the valley to the east.

The whole thickness of the Kootenay formation is exposed here, overlain by the band of hard conglomerate and resting on Fernie shales which are in turn underlain by Devono-Carboniferous rocks to the west.

In structure the area is a down-faulted block or graben. Normal faults with an east and west trend separate it from the higher limestone mountains to the north and south.

The coal outcrops on the hills from 2 to 3 miles west of Flathead river and dips eastward under the valley with dips of from 25 to 35 degrees. It has been prospected by tunnelling and open-cutting on Howell and Cabin creeks and coal seams of 7, 8, 4, 36, and 25 feet in thickness have been proved. The total thickness of the formation on Cabin creek is 1,147 feet.[1]

Flathead-Wigwam Divide. Remnants of Kootenay rocks with some coal cap a number of mountains on the divide between the Flathead and Wigwam rivers at the heads of Howell and Cabin creeks. These are all close to the McLatchie line, a surveyed line running south from Crowsnest to the American boundary, and coal occurs near mile-post 27 and on several mountains east and west of this line between mile-posts 33 and 35. In all probability this is the coal sought for by Mr. Leach in 1901.[2] A preliminary examination seems to show that these remnants are not important. Only stringers of coal were seen and these are on high mountains in a very inaccessible region.

LIGNITE AREA OF SOUTHERN SASKATCHEWAN.

By A. MacLean.

The field examined extends from the Manitoba-Saskatchewan boundary to range 21, W. 2nd mer., and from the International Boundary on the south, northward to the north side of the eighth row of townships. In the western part of this area the topo-

[1] MacKenzie, J. D., Geol. Surv., Can., Mem. 87, p. 41.
[2] Leach, W. W., Geol. Surv., Can., Sum. Rept., 1901, pp. 73-75.

graphy is characterized by the hilly front of the Missouri coteau and the broken and irregular uplands to the southwest of it. From the foot of the coteau the country slopes gently to the eastward, falling from an elevation of 2,339 feet at Ceylon (tp. 6, range 20, W. 2nd mer.) to 2,028 feet at Webster (tp. 5, range 16, W. 2nd mer.), 1,870 feet at Estevan (tp. 2, range 8, W. 2nd mer.), and 1,610 feet at Gainsborough near the Manitoba boundary. This part is deeply dissected by the valley of the Souris, and, in the region adjacent to it, by the valleys of its tributaries, Long, Short, and Moose Mountain creeks.

The best exposures of the underlying strata are in the vicinity of Estevan, and from there down the river to beyond Roche Percée. Other exposures are to be found in the neighbourhood of Halbrite and in the valleys of the Missouri Coteau region. For information on other parts of the field it is necessary to consult the records of drill-holes and for access to these the writer returns thanks to the well drillers, farmers, and prospectors of the district. It is hoped to construct a type section of the coal-bearing formations in the vicinity of the best exposures (Estevan and Roche Percée) and with the aid of this section to place the rocks of the limited and isolated exposures in other parts of the area. This seems to be the only plan feasible, but it is attended with considerable difficulty. The rocks—sands, clays, and lignites—are of shore formation, and as is common with this type of deposit the lateral variation is considerable, so that correlation through the criteria of physical characteristics and fossil remains is open to question.

On exposure surfaces the beds may show a dip of 2 or 3 degrees in any direction. These minor fluctuations are to be found in all parts of the field so far examined, but south of Neptune the dip is much greater. Near Halbrite it is increased locally to 15 degrees, 45 degrees, and even 90 degrees. Near the larger stream valleys part of this dip may be due to slipping and differential subsidence, but the occurrence of these rolls at points distant from the streams leads to the belief that there has been some decided surface strain over the area.

A composite section of the rocks of the eastern part of the district gives the following arrangement, which is subject to revision.

Composite Section, South Saskatchewan Lignite Fields.

Rock.	Thickness.	Depth of bottom of beds.	Elevation of bottom of beds.
A. Till	6	6	1,880
B. Dark brownish-green colloidal clay with a little silt, weathering to a coarse nodular mud, showing on exposure surface no sign of bedding	10	16	1,870
C1. Lighter coloured colloidal silt, with bedding well marked by reddish coloured laminæ or bands. This colour is also often expressed in streaks and flashes	6	22	1,864
Lignite seam (2 inches).			
C2. Same as C1, but lighter in colour and with laminæ better marked. Colloidal at top and bottom, but less so in middle. At the base is a hardened, calcareous concretionary band and a 2-inch seam of lignite	8	30	1,856
D. Silt or non-colloidal sandy clay, lighter in colour than C, and with laminæ better marked. At base is a calcareous clay ironstone, forming in weathered exposures a shelf above the beds next below. Near Roche Percée these beds are more massive, the sand coarser, and the colour present in flashes rather than along the laminæ. In all cases observed this bed carries a number of Unio shells (sp. undet.) at about 5 feet from the base	15	45	1,841
E. Light grey sandy clay, darker and colloidal at the base and top; less so in the middle. At the base is a 6-inch seam of lignite	25	70	1,816
F. Grey, very fine-grained, non-colloidal clay, with a 10-inch seam of lignite at the base	7	77	1,809
G. Sand, buff in colour, massive in structure, often cemented to form a sandstone which breaks from exposure faces in large columnar blocks	15	92	1,794

Rock.	Thickness.	Depth of bottom of beds.	Elevation of bottom of beds.
H. *Lignite* with bands of clay	2		
Grey, colloidal clay	3		
Lignite (first workable seam)	5	102	1,784

The above section is taken from an exposure in middle of north side of sec. 11, tp. 1, range 7, W. 2nd mer. The following section in continuation of the above is from an exposure in the north half of sec. 24, tp. 1, range 7, W. 2nd mer. (2 miles north and 1 mile east of the former location).

H. *Lignite* (as above), but here 11 feet higher	5	67	1,795
I. Fine-grained clay, 6 inches to 1 foot	1	68	1,794
Yellow, ochreous sand and white, fine-grained, non-colloidal clay	13		
Lignite band, 2 inches	....	....	....
Sandy, non-colloidal clay or silt	3	84	1,778
J. *Lignite*, (second workable seam)	4	88	1,774
K. Sand to base of the exposure	3	91	1,771

The continuation of the section may be taken from the log of the bore-hole of the Souris Valley Oilfields Company. The well was located one-half mile south of the above exposure, and was started in the valley at an elevation of 1,780 feet. Starting at the second seam of lignite, which is here 5 feet lower, the section is:

J. *Lignite* (second workable seam)	4	11	1,769
K. Blue-grey clay mixed with sand, darker toward the base	21	32	1,748
L. *Lignite* of good quality (third workable seam)	6	38	1,742
M. Dark grey clay	5	43	1,737
M. Below this are clays and sands to bottom of bore-hole at 236 feet	193	236	1,544

As provisionally correlated with the exposures and well record near Estevan (at sec. 17, tp. 2, range 7, W. 2nd mer.). Elevation at surface 1,890 feet, the continuation from the lignite seam at J (second workable seam of the district) is:

J. *Lignite* (second workable seam of district; the upper Estevan and Bienfait seams), 7 to 10 feet	10	47	1,843
K. Heavy, colloidal, sandy clays with some small lignitic bands	35	82	1,808
L. *Lignite*, interbanded with stiff clays, the workable lignite varying from 3½ to 12 feet and upward. (The third workable seam of the district, the lower Estevan and Bienfait seam and the main Bienfait and Taylorton seam)	15	97	1,793
M. Heavy, dark, very colloidal clay	4	101	1,789
N. Light-coloured, sandy clay	77	178	1,712
O. Very coarse sand containing a high percentage of quartz, cemented to a very compact mass by a small amount of colloidal clay	46	224	1,666
P. Clay	5	229	1,661
Q. *Lignite*	2	231	1.659

Several wells have continued below this lower coal "Q." The section as continued is taken from the log of the bore-hole at Taylorton (S.W. ¼ sec. 4, tp. 2, range 6, W. 2nd mer. Elevation of top of hole, 1,860 feet).

Q. *Lignite*. As in above section, but 2 feet lower	3	203	1,657
R. Grey sands	97	300	1,560
S. Mostly grey clays with some sand in lower 30 feet	110	410	1,450
T. *Lignite*, of very good quality 4 feet 2 inches thick	4	414	1,446
U. Light blue clay with a few sand streaks; 18 inches of lignite occurs near the middle	180	594	1,266
V. *Lignite*, soft	2	596	1,264
W. Grey clays and sands	27	623	1,237
X. *Lignite*, of very good quality	4	627	1,233
Y. Blue clays and sands	186	813	1,047
Z. Soft shales, said to become harder with depth	37	850	1,010

This represents the bottom of the section as obtained from this well. From a well drilled about 16 miles north of Estevan, Mr. Maley reports that this shale continues for at least 500 feet, becoming harder with depth. If it is the same shale as at Taylorton, then at the latter place it would be at least 550 feet thick.

The shales at the bottom of the section are described as being very much like slate —which description accords with the character of the Odanah shales of the Pierre. They are for the present considered as Pierre, representing the upper Odanah. It is as yet undecided where the limits of the upper Pierre, the Fox Hills Sandstone, lie in the section. So far no exposure of these has been found in the area, although they may occur in the northern part of the field.

In the section given previously it is to be noted that there are three workable seams available, in the Estevan, Roche Percée, and Bienfait districts. Sometimes a smaller seam, 2 or 3 feet thick, occurs at a depth of about 200 feet. At about 400 feet there is a seam, fairly constant, 4 feet thick, and between 600 and 700 occurs another seam 4 feet thick. These two lower seams are said on analysis to be higher in fixed carbon than the upper seams.

Most of the lignite mining is done within a radius of 15 miles of Estevan and in the southeast quarter of this area. In addition to this, lignite seams are worked at present in the Gladmar district (tp. 3, range 19, W. 2nd mer.) and in the Neptune district (tp. 4, range 16, W. 2nd mer.). Lignite mining was attempted at Halbrite, but the shattered condition of the seam, together with its high dip, made mining unprofitable. No attempt is made at present to correlate the Gladmar, Neptune, or Halbrite seams with any of the others. The notes on the following condensed section indicate the tentative correlation of the seams in the Estevan-Bienfait-Roche Percée fields. The seams are not continuous through the whole area. In some places they split up, or pinch out completely, to start in again at some distance from the last observed occurrence. In other places they have been removed by erosion. This is true of the upper seam at Estevan, and of both upper seams at the Hawkinson mine to the west of Bienfait. In the Roche Percée district and along Short creek it would appear that all three seams are represented. The condensed section is as follows:

Condensed Section, South Saskatchewan Lignite Fields.

No.	Rock.	Thickness.	Depth (in the section).	Remarks.
1.	Colloidal, sandy clays, with some non-colloidal clays and silts. Includes some small lignite bands and ends at base in a 15-foot band of buff sandstone.	97	97	Occurs only south of the river along Short creek. Northwest of this removed by erosion.
2.	*Lignite.* The first workable seam. This is marked as "H" in the extended section.	5	102	Occurs only in Roche-Percée district. Eroded at Estevan.
3.	Sand and silt, 16 to 20 feet.	20	122	
4.	*Lignite.* The second workable seam. Marked as "K" of extended section.	4	126	Upper Estevan seam. Eroded in part near Bienfait.
5.	Stiff, blue-grey clay or in some cases incoherent sand, 20 to 50 feet.	25	151	
6.	*Lignite.* The third workable seam. Marked as "L" of other section.	6	157	Wooloomooloo, Andersen, Shand, and Bienfait—Taylorton seam.
7.	Dark grey clays and sands.	130	287	
8.	*Lignite,* "Q" of extended section.	2	289	
9.	Sands and clays.	207	496	
10.	*Lignite,* "T" of extended section.	4	500	
11.	Clays and sands with streaks of lignite.	209	709	
12.	*Lignite,* "X" of extended section.	4	713	
13.	Blue clays and sands.	186	899	
14.	Shales, extending to a depth of at least 500 feet.			Probably the Odanah of the Pierre.

If the correlation suggested is correct then the third workable seam is the most productive of the district. Unfortunately, near Estevan it is badly split up, there being three beds of clay totalling 5 feet, separating four seams of coal, totalling 7·5 feet. The lowest of these, 3·5 feet thick, is the one worked at the Wooloomooloo mine, just outside of Estevan. At the Andersen mine, 5 miles to the southwest of the Wooloomooloo, the clay partings have disappeared and there is 12 feet of workable coal. At the Shand mine the seam is 9 feet thick, and at Taylorton 7 feet, increasing toward the north to 15 feet and upward at Bienfait. South of the river near Roche Percée this seam has been reported by Mr. E. Pierce, but it has not been worked. With the exception of the Wooloomooloo all the mines at Estevan are at present operating on the second seam (No. 4 condensed section). The top seam, No. 2 of section, is worked at Roche Percée and along Short creek.

Of the three lower seams, those of probable importance are marked 10 and 12. The first seam, as analysed for Mr. Symons of the Western Dominion Collieries, showed a fixed carbon content of 42 per cent and the lowest a fixed carbon content of 48 to 51 per cent. Although marked at 500 feet in the section, the first of these two lower seams generally occurs in well borings somewhere in the neighbourhood of 400 to 450 feet. It is reported by Mr. Livengood at Torquay at 427 feet, and at a point a few miles northeast of Estevan at 400 feet. Mr. Darling located it at nearly 400 feet in the vicinity of Tableland and Mr. Symons reports it in the Taylorton bore-hole at 409 feet. Mr.

Peterson gives the depth of the lowest seam at Estevan as 600 feet and at Taylorton it occurs at 623 feet. The two seams appear to be fairly consistent in their occurrence over a wide area, and the lignite is probably better than the upper seams, but, at present, the depth at which they occur would prevent their being operated in competition with the lignite beds nearer the surface. The 2 or 3-foot seam ("Q" and 8 of the two sections, respectively) recurs fairly consistently in bore-holes at a depth of 200 to 250 feet. Near Estevan it is reported by Mr. Maley at 231 feet. It is not at present important except for the possibility of its increasing in thickness or being linked up with another seam in some other part of the field.

The lignite at Halbrite has not been located in the section. The clays and lignite here have been subjected to pronounced folding and crumpling—to which, of course, the clays have yielded most. The lignite has been badly shattered so that it mines as a very dirty seam and wherever prospected carries the undesirable features generally associated with "outcrop" coal. This lignite, however, is probably higher in fixed carbon than that of the undisturbed seams. The features noted of the Halbrite lignite are to a large measure characteristic of the seams worked near Neptune by Wm. Ewing (S.E. ¼ sec. 22, tp. 4, range 16, W. 2nd mer.) and by Wm. Dee just west of the above. In this district there appear to be three seams, the first of which, covered by sand, is 4·5 feet thick. Under this is 15 feet of clay which lies above the next seam, 4 feet thick, and below this, under 25 feet of clay, is the third coal seam. All the seams are rather steeply inclined and the lignite shows signs of being disturbed and shattered. As a result, mining produces an excessively high percentage of slack, which under present circumstances is a complete waste. The lignite is probably fairly high in fixed carbon as compared with the undisturbed seams. This feature, together with the possibility of saving the slack now wasted, should be considered in the search for raw lignite for briquetting plants.

Near Gladmar two mines are operated, one by H. Slater and one by Eidsness Bros. The former is located in N. ½ L. S. 6, sec. 11, tp. 3, range 19, W. 2nd mer. The output is about 1,000 tons per year. The mine of Eidsness Bros. is located in L. S. 3, sec. 11, tp. 3, range 19, W. 2nd mer., and has an output of 3,000 to 3,500 tons per year. The output of both mines supplies the local demands of the district, being teamed from the mine mouth for considerable distances.

The area supplied with fuel from the Estevan-Bienfait district is practically confined to Manitoba and Saskatchewan, extending from Moosejaw and Regina to Winnipeg. A very small amount may cross the boundary to the settlers in North Dakota and Montana, in the districts contiguous to the producing or distributing points on the Canadian side. The fuel is used in the area indicated for domestic and power-producing purposes. For the former the lignite is generally delivered as screened lump and for the latter as run of mine, screened lump, nut, pea, and slack. The disposition of the latter presents a problem which is worth consideration. In the process of mining, the production of slack varies from 6 per cent in the larger and better equipped mines to 25 per cent in the smaller mines. This is even higher in the mines where the lignite is shattered. At the present time a very small amount of the slack is shipped, but the greater portion, practically all, is shovelled back in the old workings, dumped in any required fills, or scattered over the field, where, through the possibility of spontaneous combustion, it becomes a potential menace to the mining plant or the community. When briquetting becomes an accomplished commercial process this slack can all be utilized, but at the present time much more slack is produced than can be disposed of. There is a possibility that lignite might be used in the larger power producing factories as a powdered fuel if a plant were devised for the satisfactory handling of it. In such a plant a large percentage of the slack could be used.

The price of lignite at the mine mouth is from $1.75 to $2 a ton for screened lump. This is delivered to the consumer in Winnipeg at from $5.50 to $6 a ton, as compared with Drumheller or Lethbridge coal at $9.50 to $10.50 and hard coal at

$12.50 a ton. It is not yet known at what price briquettes made from the Saskatchewan lignites could be profitably delivered at the larger centres, but the possibility of making their manufacture a continuous operation throughout the year should cut down the difference that now exists between the apparent cost of production of lignite and the price of its delivery to the consumer. At present the difficulty in handling and storing the raw material, except in winter, makes it impossible to start large deliveries for future use before the beginning of October. This means that at the mines a large equipment is required to handle the heavy production demanded in the winter months. During the remaining half year the plant, and the investment represented, are comparatively idle, but still remain as a charge on the coal recovered during the other half year. It is to be noted in addition that winter deliveries cannot begin until the time when the demand for freight carriers for the movement of the grain crop is so insistent that no surplus coal can be handled and hence no reserve of this fuel can be accumulated at points of retail distribution. As a result the districts dependent on the coal are at the mercy of whatever circumstances an uncertain winter season may impose on freight movement. Consequently, not only for the conservation of much of the lignite now wasted, and for the efficient utilization of labour and transportation systems in the summer season, but also for the protection of the constantly increasing population dependent on this fuel, it is highly desirable that not only should some scheme for better utilization of the lignite be sought and found, but this scheme should be put into practical operation with the least possible delay.

SURFACE DEPOSITS OF SOUTHEASTERN SASKATCHEWAN.

By J. Stansfield.

CONTENTS.

INTRODUCTION.

The deposits at or near the surface in southeastern Saskatchewan belong to two geological horizons, Pleistocene and Eocene, although those of an earlier period, the Cretaceous, are met with in some of the shallow borings (less than 300 feet deep) of part of the district. One deep boring, that at Moosejaw, passed through the Cretaceous and underlying Jurassic strata into limestones of Devonian or Carboniferous age.

PLEISTOCENE.

The deposits of this period are often referred to as drift. They cover practically the whole surface of the area under examination, the only exceptions being the exposures along the valley slopes in the southern and southwestern parts of the district, and the alluvial deposits of the valley floors, which are largely reworked materials from the drift. Unfortunately sections which would allow of the study of the drift in depth are almost non-existent.

East of Missouri coteau the drift is thick in the northern part of the district, where it reaches 175 feet at some points, and perhaps even more. It thins southward, so that in places along the Souris river a thickness of from 2 to 4 feet may be seen, for example west of Halbrite.

At one or two points along the coteau the drift is absent and the stratified deposits which underlie the plateau west of the coteau are visible, as at Claybank. The general impression conveyed by a view of the country west of the coteau is that of a huge morainic pile. Well records along the Lethbridge line of the Canadian Pacific railway indicate drift thicknesses of 100 feet, close to the coteau, but farther west the drift appears to be thinner, and the observations of McConnell,[1] in this connexion, may be recalled. "Some, at least, of the kame-like hills and ridges which crown the coteau, owe their shape, not to accumulations of drift, but to irregularities in the surface of the older rocks."

Two important drift types are developed within the district as till sheets. They will be referred to as the Regina and Weyburn types, respectively. The till sheet referred to as the Regina type is not entirely confined to the area here discussed. It extends beyond Moosejaw and Regina, and from Sedley to the "Soo" line, extending along the railway approximately as far as McTaggart. This till is a grey clay, sometimes showing brownish weathering, and is of very sticky and tenacious character when wet, but falls to pieces as it gradually dries. The clay is often referred to as "gumbo". It contains a very few small stones up to 1-inch or 2-inches diameter, but more commonly smaller. The surface of this till sheet is almost horizontal, but on close observation it is seen to possess slight irregularities, broad swells, and slight hollows, which are sufficient to distinguish it from the deposit of a lake bed. Where the irregularities become more pronounced the hollows are occupied by sloughs.

East and south of the area where the Regina type is seen at the surface the till possesses a more sandy texture. In colour it is brown, and in it boulders up to 6 inches in diameter are common, larger ones up to 10 feet in diameter being present also. The surface of this till is not quite so flat as that of the Regina type, and it is diversified by occasional morainal ridges. Sloughs are common where this till is developed. Along the eastern boundary between the Regina and Weyburn types the latter usually possesses an elevation of from 40 to 60 feet higher than the former. This suggests that the Weyburn till overlies the Regina till, being younger, but the evidence of well diggings which were personally examined is not sufficient to establish this as yet.

South and west of the Regina type the Weyburn type occurs, extending to the coteau, with occasional breaks where more sandy soil types are exposed. West of the coteau the till is similar to the Weyburn type, but it is piled up into a great series of moraines.

ECONOMIC GEOLOGY.

The economic geology of the region may be discussed under the following heads: coal, potash, road material, soils, and underground water.

Coal.

This subject has been the special study of D. B. Dowling and A. MacLean for the southeastern part of the district, and of B. Rose for the southwestern part. For details the reader is referred to the descriptions given by them in the publications of the Geological Survey and to Mr. MacLean's summary report, 1916, pages 156-159.

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[1] Geol. Surv., Can., Ann. Rept., N.S., vol. I, 1885, pt. C, p. 62

Potash.

In the autumn of 1917, the Saskatchewan Development Company began boring with a diamond drill with the object of testing reported occurrences of potash in the district between Weyburn and Halbrite. The writer also examined the district for indications of potash. Along the Canadian Pacific railway between Weyburn and Halbrite efflorescences of white salts occur on the surface of the ground at different points, or at cut exposures along roads or river banks. These are best seen after prolonged absence of rain, and disappear after rain, so that they are readily soluble salts. The efflorescences are strongest on exposures of drift and not so large on exposures of the underlying clays and sands.

The presence of soluble salts in the drift does not necessarily mean that similar salts may be found in commercial quantity in the strata beneath. A sample of water from a newly-dug well of shallow depth, entirely within the stratified series beneath the drift (Fort Union? beds) at NE. ¼ sec. 11, tp. 7, range 13, W. 2nd mer., was taken. The analysis is given in the section dealing with underground waters (analysis No. 9).

Although the examination of underground waters by analyses is not sufficient to definitely decide against the probability of finding large amounts of potash salts in drilling, yet definite evidence of this character should be obtained before the commencement of drilling operations.

Road Materials and Building Stone.

Within the area mapped the only materials available for road materials, or for construction purposes, are the boulders from the drift, and the sands and gravels which occur at points along the morainic belts. The boulders from the till are only of sufficient importance to be noticed in the parts of the district where the Weyburn till type is developed, and west of the coteau. The relative abundance of the boulders varies from place to place. In the older settled parts the field stones may be seen collected into piles, and in the remainder of the district the boulders are still in or on the ground and will only be built into piles in the future. Boulders large enough to be used for building purposes occur most prominently in the ground moraine, that is, in the lowest portions of the drift. The two districts noted where these were most abundant were between Weyburn and Ralph, and between Ogema and Glasnevin. Along the lower slopes of Moosejaw creek below Moosejaw large boulders occur which have been used to some extent as crushed stone for macadam, the dolomite boulders being retained for lime burning.

The boulders of the drift of the region have been derived from the north and northeast, from the Pre-Cambrian and Palæozoic areas. A very few small boulders derived from the harder members of the Mesozoic strata may be seen in the morainic piles, for example at Boggy creek. Only in the south and southwest of the district have boulders derived from the west (Rocky Mountain quartzite) been noticed. These occur in the lower part of the drift. The boulders commonly met with in the drift consist of the following types: granites, pegmatites, quartz, and syenites, with gneissic varieties of the same, predominate, the syenites, pegmatites, and granites being commonly reddish in colour, or sometimes light grey; next in order of importance come boulders of Palæozoic buff dolomite, often pitted; less abundant than the foregoing types are dark greenish boulders, some of which are gneissic and some coarse-grained, but most of which are dense and fine-grained. Reddish or pink quartzite is much less common than the other types.

Occasional buildings occur throughout the district which have been built from field stones, either whole or broken and dressed. The boulders are not present in sufficient quantity to form the basis of any industry, but will be used locally as long as they last. Probably they will receive more attention as a source of macadam for road dressing, when the country has developed further than at present. The field stones available are altogether insufficient for dressing all the roads of the district and their use will only result in the production of small strips of macadam road separated by longer stretches of dirt road. The dirt roads of the district are satisfactory in dry weather for the traffic they carry, but in wet weather they are difficult to travel. This is especially true of the roads over the Regina type of till, where automobile traffic during the spring thaw and for some time thereafter is impossible. There seems to be little prospect of macadamizing the roads of the Regina till type, as they are so far distant from available sources of road materials that the cost would be prohibitive, except for restricted localities such as the immediate vicinities of the cities of Regina and Moosejaw.

Sands and sandy gravels are found along the morainal ridges, near Boggy creek, Pilot Butte, Odessa, etc., along the northern morainal belt, at and near Weyburn along the Weyburn moraine, south of Halbrite, and at Estevan (possibly connected with a small morainal belt). The largest areal extent of gravel and sand in the region, which has come under the writer's notice, is at and around Horizon. It appears to be fluvioglacial outwash material derived from the north. It has been quarried extensively for ballast at Horizon, by the Canadian Pacific railway. A smaller volume of fluvioglacial gravel occurs south of Bayard, at the coteau.

The sands and gravels of the northern part of the region have been the subject of special investigation by L. Reinecke, during the past season.

Soils.

The district under consideration is still in the early stage of agricultural development and belongs to the grain-growing belt of Saskatchewan. The soils are very fertile and in seasons of normal rainfall produce highly satisfactory crops, of which wheat and oats are the most prominent, though flax is cultivated in considerable amount and winter rye could be grown successfully if more attention were directed to it. Hay does not form a crop, except in the sloughs and marshes, where the luxuriant but coarse "slough-grass" is cut. This "slough-grass" and oats in the sheaf form the stock foods of the region.

The gradual impoverishment of the soil, which attends continual cropping without application of fertilizer, changes the agricultural outlook and the advantages of mixed farming become apparent to the farmer. In this region, stock raising is tried to a limited extent only, as yet. The chief drawback has been the lack of a sufficient water supply in some parts of the district, but as prospecting for water continues the size of the area in which mixed farming does not appear possible is gradually decreased. The feasibility of sheep raising compared with raising cattle or horses, deserves consideration, as the farmer requires a smaller amount of water. The provision of adequate shelter for sheep would affect the cost involved.

Some soil samples have been taken to illustrate the different types developed in the region. Some of the samples were taken in the "burn-out" district, with the hope of being able to throw some light on the problems of that area. The "burn-out" district includes about 272,000 acres of land in tps. 6, 7, 8, and 9, ranges 16, 17, 18, and 19, W. 2nd mer. The typical "burn-out" presents a rough hummocky surface, which is caused by the presence of grass on a generally flat land surface, with hollows of varying sizes which are from 2 inches to 4 inches deep. These hollows are devoid of vegetation, or support only a very meagre growth. After cultivation the higher parts of the "burn-out" bear well and some of the lower patches afford a crop, though some do not produce a crop even after cultivation. The difficulties of production in this district, together with difficulties in obtaining a water supply, have caused the abandonment of large areas where settlement had been attempted.

The southwestern part of the area mapped does not have as copious a rainfall as the rest of the district, so that crops are often considerably lighter than where the rainfall is greater.

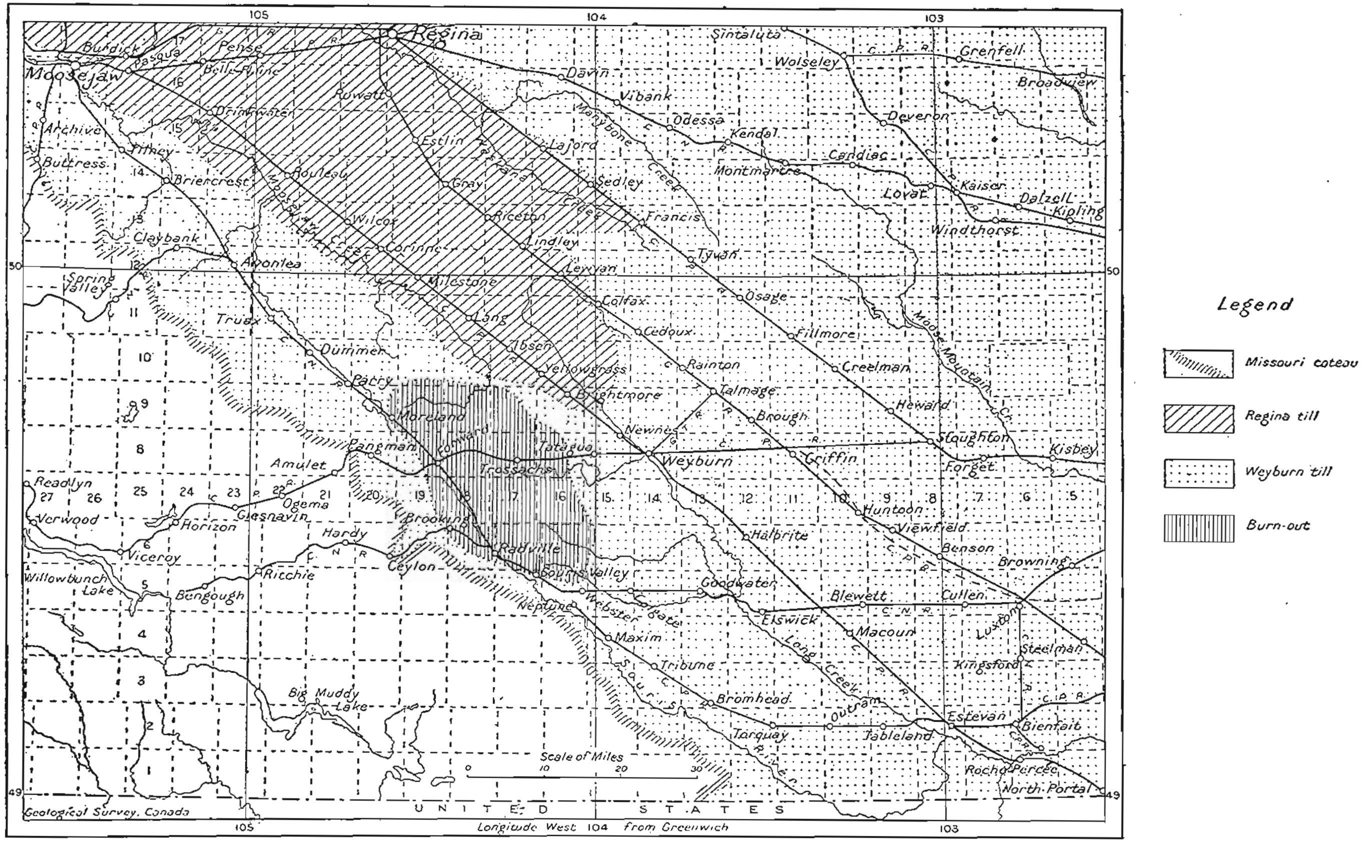

Figure 3. Part of southeastern Saskatchewan, showing general distribution of chief soils.

NOTE.—*Investigations made since this map was printed have shown that the "burnt- out" area is much more extensive than here indicated.*

Underground Water.

The provision of an adequate water supply for settlers in western Canada has always been a matter of direct concern to the government, and also to the management of the railways which traverse the region. Before the province of Saskatchewan was established the Public Works Department of the government of the North West Territories supplied a number of well-boring machines and test-augers for use by settlers in different districts. Many of the older wells of the area mapped were bored with these machines and many dry holes were also bored. Boring for water gradually passed from the Public Works Department to private companies and the machines were sold, or given to local improvement boards. At a later period, to meet a need for making deeper tests, well-drilling machines of certain types were imported, duty free, under certain working restrictions. Several machines were introduced and the policy was continued until the well-boring or drilling business was well established.

In certain parts of the district (tps. 1 to 17, ranges 5 to 27, W. 2nd mer.) special difficulty has been encountered in obtaining a satisfactory water supply. The writer was commissioned to make a study of the mode of occurrence of underground waters in this district and to procure information as to the best method to be pursued in obtaining water.

The farms of the district derive their water supply from several sources. Where possible, wells are used. Sometimes, and especially is this the case with shallow wells, the water may run inconveniently low in the autumn if the season has been particularly dry, or in February or March when the circulation of water near the surface is reduced by freezing. When a satisfactory well is not obtainable, a slough will serve to water stock, at least for part of the year. In the absence of a slough many farmers excavate artificial ponds or "dug-outs," as they are called, which collect rainfall and water derived from the melting of snow. Cisterns also are dug, which are lined with concrete and filled with snow in the spring, or connected with the drainpipes from the roofs of the barn and other buildings. With the ordinary amount of roof space on a farm a sufficient supply of water may be obtained in this way, throughout the year.

The problems connected with the underground water supply require a study of the drift deposits, as well as a study of the strata underlying the drift, where this may be possible, and a study of well records where these are obtainable. Exposed sections through the drift are very few in number in the district and are widely separated, so that the study of the drift below the surface can only be carried on to any extent by means of well records. The underlying strata are only exposed in the southern part of the area, and there only along stream cuts. Well records have to furnish most of the material for this part of the study. Well records and details of abortive tests have been gathered in large numbers both from farmers and well drillers or borers. The records vary in value, and it is not always easy or possible to determine which records may be inaccurate, as to figures of depth or character of materials passed through. As the work of collecting and studying the records is not yet completed, only a general discussion is possible.

Within the drift, which consists chiefly of clay, there are lenticular or more irregularly shaped bodies of sand, varying from fine quicksand to coarse sand or even gravel. These are capable of acting as reservoirs, holding water in their pore-spaces, which is rendered available for use at the surface by digging, boring, or drilling into the sand. Some dry sands are passed through, but this does not prove that all parts of these sands are incapable of furnishing water. From the mode of origin of these sands, viz., as glacial outwash, they may be considered to possess a gradual slope toward the southwest, and by following a dry sand body in this direction a water-bearing portion may be found.

Usually, in this district, there is no way in which the presence of water-bearing sand bodies beneath the surface may be determined, except by drilling. Examples of wells with dry holes close to them are so numerous that the results of drilling at any definite point cannot be anticipated with certainty from the information derived from records of drilling on adjacent farms, or even on different parts of the same farm.

Where the lighter drift types are developed there is little difficulty in obtaining water at shallow depths (less than 40 to 50 feet), though several dry holes may be made before the discovery of a satisfactory well. The best method of prospecting is to put down a series of holes, spacing them so as to test as wide an area as possible.

Where the heavier drift type (gumbo) is developed, sand lenses may or may not occur within the drift. As yet there are few localities sufficiently prospected to prove the absence of sand bodies within the drift. A large part of the district is unprospected, the unsatisfactory results obtained by some farmers acting as a deterrent to others, but there is no reason why this should be so. Prospecting in this district should aim to put down several holes, spaced to test as wide an area as possible, and the holes should go to the bottom of the drift to give a satisfactory test for a particular area.

Unfortunately, the colour of the drift and the bedrock (Pierre shale) underlying it, over a large part of the area, is very similar, viz., dark grey, almost black. It is not always easy to distinguish the two, and usually it is not possible to determine from a well record at what exact depth the drift gave way to the underlying bedrock. In general, when beginning a hole in the gumbo, it may be held to be unprofitable to continue prospecting below the drift, but it is of importance to make sure what is drift and what is bedrock.

The sand bodies are not ubiquitous. They were formed as glacial outwash along the front of a retreating, or in some cases, perhaps, an advancing glacier, so that any particular sand body may be comparatively large or comparatively small, either in respect to thickness or area. Thus sand bodies may occur within the drift at different depths, and in contiguous localities they may be met with, but are not necessarily the same sand bodies and may not be connected with one another. It can be seen, therefore, that it is only by the gradual, laborious, and sometimes costly process of prospecting and by the collection of all definite information bearing upon the question, that valuable generalizations with regard to the mode of occurrence of potable water may be made, and it would seem that there is as much still to be done in this way, in the district, as has already been done.

West of Missouri coteau the drift often contains sand or gravel bodies; but these are of irregular occurrence, as may be expected in a great series of morainic hills. Water is usually to be found here without much difficulty. There are some few localities west of the coteau where water problems have given trouble, thus far, and have not been solved satisfactorily; at Spring Valley, Ogema, Pangman, and sec. 28, tp. 6, range 27, W. 2nd mer., near Verwood.

Water in the Underlying Bedrock. Under the term bedrock are included the Tertiary or Fort Union? series and the Pierre shales of the Cretaceous. The term bedrock, is, in a manner, a euphemism, because certain members, especially of the Fort Union? series, are still unconsolidated, and even very soft, so that the term bedrock is used to distinguish these strata from the drift covering.

In the southern part of the area, south and west of a line running from Stoughton to Trossachs, and from Trossachs to Buttress, the Fort Union? series lies immediately beneath the drift. It consists chiefly of stratified clays, grey in colour, less commonly greenish-grey, and still more rarely brownish. Sand beds, often lenticular, which vary in thickness, occur interstratified and interdigitated with the clays. They are usually grey in colour, though sometimes iron-stained, and occasionally white. In some places certain layers of the sands are cemented by limonite or calcium carbonate, forming sandstones of friable character. The sands vary in grain, some are coarse, and even gravels are reported in well records; but the most common are fine, sometimes so fine as to be designated as quicksand, and often consisting of very fine sand associated with clay. In addition, lignite coal seams occur in these strata in some parts of the district, and occasionally thin bands of ironstone up to 2 inches or 4 inches in thickness may be met with in the series.

Where the Fort Union ? series underlies the drift, the prospect of obtaining potable water at a reasonable depth may be considered good. There are, as yet, very few localities which have given unsatisfactory results. Water of a sufficiently good quality for general use has been found at depths to 440 feet, in this part of the district, though most of the wells in these strata are less than 300 feet deep. The water bearing strata are the sands or the coals. In the case of the finer sand or quicksand, difficulty is often encountered in keeping the well free from the fine sand which enters the casing and plugs the well or destroys the valves of the pump. The construction of especially fine screens, or the packing of the well with pebbles or gravel outside the screen, are measures which need to be adopted in such cases. When the fine sands are thick they may be tapped, sometimes, by screens of more than ordinary length. In these cases specially constructed screens have to be depended upon, as packing with gravel outside could not be accomplished throughout the whole length of the screen.

In some few portions of the district there is uncertainty in the mode of occurrence of water at depth. Thus, in the vicinity of Ceylon there are several wells whose depths range from 260 to 439 feet, whereas in another hole more than 800 feet deep no water was obtained.

North and east of the line from Stoughton by Trossachs to Buttress the drift is underlain by Cretaceous strata. So far as known at present the Cretaceous strata belong to the Pierre shale horizon, the younger Fox-hills series not being definitely recognized. It is possible that it may be recognized in samples of drillings in some parts of the area.

There appears to be little hope of obtaining any supply of potable water from the Cretaceous strata of this region. Deep holes have pierced the Cretaceous at Moosejaw (3,310 feet), near Wilcox (1,450 feet), at Belle Plaine (1,551 feet), near Estlin (also known as the Kronau well, depth 2,410 feet), at McTaggart (800 feet), at NE. ¼ sec. 36, tp. 14, range 20, W. 2nd mer. (875 feet), at SE. ¼ sec. 24, tp. 15, range 20, W. 2nd mer. (575 feet), at road allowance secs. 33-34, tp. 15, range 19, W. 2nd mer. (300 feet), at NW. ¼ sec. 14, tp. 15, range 19; W. 2nd mer. (300, 463 feet), at SE. ¼ sec. 23, tp. 15, range 19, W. 2nd mer. (500 + feet), at NW. ¼ sec. 18, tp. 15, range 18, W. 2nd mer. (580 feet), at road allowance at NE. corner sec. 12, tp. 14, range 19, W. 2nd mer. (740 feet), at NE. ¼ sec. 33, tp. 13, range 19 (500 feet), at NW. ¼ sec. 14, tp. 14, range 18, W. 2nd mer. (985 feet), at Kronau (380 feet), at NW. ¼ sec. 29, tp. 13, range 17, W. 2nd mer. (575 ? feet), at Wilcox (400 feet), at NW. ¼ sec. 28, tp. 13, range 20, W. 2nd mer. (414 feet), at SE. ¼ sec. 23, tp. 13, range 21, W. 2nd mer. (370 feet), at NE. ¼ sec. 17, tp. 12, range 16, W. 2nd mer. (1,010 feet), at SW. ¼ sec. 21, tp. 11, range 15, W. 2nd mer. (400 ? feet), at Yellowgrass (475 feet), at SE. ¼ sec. 34, tp. 16, range 24, W. 2nd mer. (417 feet), at Pense (450, 600, 1,200 feet), and at several other points to shallower depths. Water was found in some of these holes; in the Moosejaw well at 1,160, 2,820, 2,950, and 3,300 feet, in the deep well near Wilcox at 700 feet, in the deep well near Estlin at 700 feet, and in Mr. Dave Kirby's well, at NE. ¼ sec. 36, tp. 14, range 20, W. 2nd mer., at 700 feet. In all of these places the water was salty and unfit for farm use. The Moosejaw well may be of value for fire protection. The Dakota sandstone was pierced in the Moosejaw well between 2,840 and 2,980 feet, but in no other well. In certain other districts, in parts of Wyoming, Colorado, and South Dakota, the Dakota sandstone is a source of potable water. In the southeastern part of Saskatchewan the Dakota sandstone must lie at least 3,000 feet from the surface. Drilling to such depths in the Cretaceous shales often presents great difficulties due to the caving of the shales, and any water from the Dakota sandstone would probably be salty. At Deloraine and Morden in Manitoba the Dakota sandstone has been reached and affords salty water at these localities[1].

It may be concluded, then, that in this part of the region potable underground water need not be looked for below the drift. In a general way it may be said that drilling to

[1] Malcolm, W., "Oil and gas prospects of the northwest provinces," Geol. Surv., Can., Mem. 29E, 1913, pp. 75 and 85.

greater depths than 400 feet would be unprofitable, and that very few holes deeper than 300 feet may be expected to provide potable water. The wells of Messrs. Jones and Runyon on the SE. ¼ sec. 12, tp. 14, range 20, and NW. ¼ sec. 6, tp. 12, range 19, W. 2nd mer., respectively, are 297 and 275 feet deep, and are very satisfactory. It is not clear whether these two wells draw their water from the drift or from the Cretaceous or Tertiary strata.

Flowing Wells. Flowing wells always attract more attention than common wells. The source and conditions of storage of the water are the same, but there is a difference in the height to which the water rises.

Flowing wells affording water from the drift furnish the municipal supply of Regina. The wells are situated on secs. 11, 12, and 14, tp. 18, range 19, W. 2nd mer., in the valley of Boggy creek.

About 5 miles southeast of Regina there are flowing wells on NE. ¼ sec. 33, SW. sec. 34, and NE. ¼ sec. 21, tp. 16, range 19, W. 2nd mer. The last-mentioned is a government well and has the strongest flow of the three, viz. 8,640 gallons per day. These wells apparently tap water contained in the drift.

There are flowing wells in the vicinity of Macoun, two on NE. ¼ sec. 8, tp. 4, range 10, W. 2nd mer., with depths of 217 and 258 feet, and one at NW. ¼ sec. 14, tp. 4, range 11, W. 2nd mer., with depth of 224 feet. The last-mentioned well has the strongest flow, viz. 2,160 gallons per day. These three wells draw their water from the Fort Union ? strata.

Quality of Water. The predetermination of the quality of the water obtainable at any point in the region is almost as difficult and elusive a problem as the search for water itself. Within the drift the shallow wells show very marked variations in quality. Potable, hard, rarely soft, water, and water so bitter as to be totally unfit for use, may be obtained from similar depths at points only 50 feet apart. This is so common that the striking of water unfit for use at a shallow depth may not be regarded as indicating widespread conditions in any locality.

Only a few chemical analyses of waters from the region are available as yet, and examples of all the types have not been examined, so that it is impossible to discuss them in detail at this time. Twelve water samples were taken and forwarded to Ottawa, and have been analysed by R. T. Elworthy of the Mines Branch. His results are given below:

1. SW. ¼ sec. 17, tp. 16, range 20, W. 2nd mer., Sask., H. McNally, Sept. 14, 1917.
2. NE. ¼ " 26, " 16, " 21, " " " " E. Nudd, " "
3. SE. ¼ " 32, " 15, " 21, " " " " W. H. McNurlen, Sept. 14, 1917.
4. Rouleau, Sask. Town supply, pumped from two wells simultaneously, " "
5. SE. ¼ sec. 12, tp. 14, range 20, W. 2nd mer., Sask., H. P. Jones, Sept. 14, 1917.
6. NE. ¼ " 33, " 16, " 19, " " " " flowing well, Sept. 14, 1917.
7. SW. ¼ " 30, " 13, " 18, " " " " R. Zimmer, Sept. 15, 1917.
8. NE. ¼ " 31, " 14, " 17, " " " " Reich. Sept. 15, 1917.
9. NE. ¼ " 11, " 7, " 13, " " " " Glen Topham, Sept. 15, 1917.
10. Halbrite, Sask. Town supply.
11. NW. ¼ sec. 14, tp. 4, range 11, W. 2nd mer., F. F. Beyer (flowing well), Sept. 15, 1917.
12. Sedley, Sask. Town supply. 54-foot well at south end of rink, Sept. 16, 1917.

Analyses of Waters from Southern Saskatchewan.

	1	2	3	4	5	6	7	8	9	10	11	12
Specific gravity at 15° C	1·0025	1·0020	1·0022	1·0019	1·0020	1·0019	1·0025	1·002	1·0022	1·0020	1·002	1·0025
Constituents in parts per million—												
Sulphuric acid (SO_4)	855	540	857	679	608	952	868	222	369	1,018	910	1,938
Chlorine (Cl)	167	136·5	112·5	145	356	80·4	318	40·2	209	58·3	229	104
Bicarbonic acid (HCO_3)	525	782	1,032	656	770	584	717	559	906	669	703	465
Silica (SiO_2)	31·8	22·4	29·4	26·3	22·7	27·4	23	18·3	20·7	32·4	28·8	24·7
Alumina (Al_2O_3)	10·1	2·6	41·7	3·4	5·8	3·1	11·2	0·8	1·5	22·5	4·6	5·4
Iron (Fe)	3·6	3·6	17·6	2·9	5·3	3·6	0·4	1·7	1·4	8·3	0·3	1·7
Calcium (Ca)	126	103	154	43·3	82	130	199	132	7·0	278	73·6	368
Magnesium (Mg)	59·2	41·3	100	18·4	24·7	73	99·2	24·3	8·3	99·7	28·7	185
Potassium (K)	10·1	21·2	38	34·1	15·7	15·3	7·7	16	4·7	18·7	4·7	11·8
Sodium (Na)	450	430	470	560	658	429	471	135	626	252	706	390
	2,237·8	2,082·6	2,852·2	2,168·4	2,548·2	2,297·8	2,714·5	1,149·3	2,153·6	2,456·9	2,688·7	3,493·6
Reacting values in per cent—												
Strong acids—												
Sulphate (r. SO_4)	28·61	20·15	23·53	24·39	17·92	31·31	23·31	15·51	13·52	31·36	25·65	39·64
Chlorine (r. Cl)	7·55	6·89	4·18	7·05	14·21	3·58	11·56	3·78	10·36	2·42	8·75	2·88
Weak acids—												
Bicarbonic (r. HCO_3)	13·84	22·96	22·29	18·56	17·87	15·11	15·13	30·71	26·12	16·22	15·60	7·48
Alkaline earths—												
Iron (r. Fe)	0·20	0·23	0·83	0·17	0·27	0·21	0·01	0·20	0·09	0·44	0·15	0·06
Calcium (r. Ca)	10·12	9·22	10·15	3·72	5·79	10·25	12·80	22·07	0·62	20·51	4·97	18·06
Magnesium (r. Mg)	7·82	6·09	10·83	2·60	2·87	9·47	10·52	6·70	1·19	12·13	3·19	14·93
Alkalis—												
Potassium (r. K)	0·42	0·97	1·28	1·50	0·57	0·62	0·26	1·37	0·21	0·71	0·16	0·29
Sodium (r. Na)	31·44	33·49	26·91	42·01	40·50	29·45	26·41	19·66	47·89	16·21	41·53	16·66
Properties of reaction in per cent—												
Primary salinity	63·72	54·08	55·42	62·88	64·26	60·14	53·34	38·58	47·76	33·84	68·80	33·90
Secondary salinity	8·60	....	....	....	....	9·64	16·40	....	....	33·72	....	51·14
Primary alkalinity	....	14·84	0·96	24·14	17·88	....	....	3·48	48·44	....	14·58	....
Secondary alkalinity	27·68	31·08	43·62	12·98	17·86	30·22	30·26	57·94	3·80	32·44	16·62	14·96
Hypothetical combination in parts per million—												
Potassium chloride (KCl)	19·4	40·3	72·3	64·8	29·8	29·1	14·9	30·6	8·9	35·8	8·9	22·3
Sodium chloride (NaCl)	259·7	193·6	128·8	188·4	563·6	110	513·0	42·1	337·5	67·7	370·9	153·9
Sodium sulphate (Na_2SO_4)	1,073·5	798·7	1,268·2	1,004·0	893·8	1,191·5	832·5	328·7	546·0	695·9	1,344·0	1,017·0
Sodium bicarbonate ($NaHCO_3$)	....	347·8	30·2	587·0	530·8	....	....	43·7	1,156·6	....	451·9	....
Magnesium sulphate ($MgSO_4$)	161·9	....	....	....	....	183·6	382·8	....	....	493·6	....	915·5
Magnesium bicarbonate ($Mg(HCO_3)_2$)	159·5	248·7	601·5	111	148·5	215·8	131·8	146·3	49·7	....	172·6	....
Calcium sulphate ($CaSO_4$)	....	....	....	....	....	....	....	....	....	217·7	....	737·1
Calcium bicarbonate ($Ca(HCO_3)_2$)	510·3	417·2	624·0	175	331·3	525·7	804·4	533·5	28·3	864·4	297·2	612·4
Ferrous bicarbonate ($Fe(HCO_3)_2$)	11·6	11·6	56·1	8·9	16·9	11·6	0·9	5·3	4·4	26·7	9·8	5·3
Alumina (Al_2O_3)	10·1	2·6	41·7	3·4	5·8	3·1	11·2	0·8	1·5	22·5	4·6	5·4
Silica (SiO_2)	31·8	22·4	29·4	26·3	22·7	27·4	23·0	18·3	20·7	32·4	28·8	24·7
	2,237·8	2,082·9	2,852·2	2,168·8	2,548·2	2,297·8	2,714·5	1,149·3	2,153·6	2,456·9	2,688·7	3,493·6

These waters are highly mineralized and the samples taken represent highly sulphatic and carbonated waters. All except one, No. 9, are strongly impregnated with calcium and magnesium. No. 3 is notably chalybeate. Nos. 7, 10, and 12 are high in magnesium sulphate (Epsom salts). No. 12 is the only one which is regarded as unfit for stock use. Without doubt the most interesting water is No. 9, which is soft and remarkable for its low lime and magnesium content. It was taken from a shallow well, recently dug in the Fort Union? strata on the side of a coulée, the Fort Union? strata being covered, on the prairie, by a small thickness of drift. Soft waters are obtained from the Fort Union? strata in other localities, but by no means generally.

Whether waters of the types represented by the above analyses (except No. 9) can be cheaply treated so as to remove the calcium and magnesium and bring them nearer to the composition represented by No. 9, would seem to be worth investigation.

It is well known that the chemical character of water from any given well changes from time to time. Many wells from this region are reported to have afforded soft water when first dug, the water becoming gradually harder with the lapse of time. Dr. Charlton, provincial analyst of Saskatchewan, informed the writer that the municipal supply of Regina shows an increase of magnesium content as compared with calcium, with the lapse of time.

The wells in the Fort Union? strata in the southwestern part of the region appear to furnish more highly mineralized waters than those farther to the east. For example, those at Verwood are much less pleasant to the taste than those of the Estevan district. The springs which issue from the Fort Union? strata along the southwest side of the Willowbunch trench appear to be highly charged with dissolved salts. The rainfall of this part of the region is lower than that to the east and north, and the facts noted above may be connected with this.

Municipal Supplies of Water.

Regina. The nature of the Regina municipal supply has been referred to under the head of flowing wells.

Moosejaw. The present supply is obtained from a filtration gallery in the bed of Sandy creek, a small tributary of Thunder creek, at Caron, about 12 miles west of the city. The water is pumped to a reservoir and piped to the city. Approximately 1,000,000 gallons a day are obtained from this source.

Formerly a small supply was obtained from springs at Snowdy Springs, about 8 miles southwest of the city. The yield from this source was approximately 150,000 gallons per day.

Still earlier, a trench in gravels in the slope of the bank of Moosejaw creek at the city formed the source of supply. This is not used at the present time, the supply being small.

Weyburn. The town supply is obtained from two wells whose dimensions are: depth 42 feet, diameter 25 feet; and depth 20 feet, diameter 22 feet, respectively. The former constitutes the main source. Electrically driven pumps force the water to the town, a distance of about 1¾ mile. The quality of the supply is very good.

Estevan. The town supply is obtained from the Souris river.

Rouleau. The town supply is obtained from three wells, close to each other, which have a depth of 215 feet and diameters of 6 inches. They afford an abundant supply for the town, and the quality of the water is of such character that it is used to some extent for locomotive boilers.

Yellowgrass. The town supply is obtained from a well 42 feet deep and 12 feet in diameter situated nearly a mile to the northeast. The water is pumped by a direct drive windmill.

Milestone. A satisfactory supply has not been located, though there are several fairly good wells just outside the townsite.

Francis. The water supply of Francis is obtained by gravity flow from a spring 2¼ miles east of the town.

Wilcox, Belle Plaine, Pense, Drinkwater, Grand Trunk Pacific Railway line, Trossachs, Pangman, Ogema. In the above-mentioned towns, and along the Grand Trunk Pacific line between Regina and Lampman, there is no satisfactory water supply. Considerable testing has been done in the vicinity of the first four villages and some of the holes passed through the drift, so that the deeper parts of these tests may be considered as wasted. That further testing in the drift may be rewarded by success is indicated by the successful completion of a well at Drinkwater in 1917.

The villages along the Grand Trunk Pacific railway between Regina and Lampman are in the same difficult position as those just discussed with the exception that no extensive testing has been done. Testing should be confined to the drift, and one or two unsuccessful results should not be considered as definitely closing the question.

Pangman and Trossachs possess limited supplies of water. The shallow tests in the immediate vicinity of these villages meet with bitter waters, but there seems to be no reason why potable water should not be obtained at some depth between 150 and 300 feet, perhaps less.

Ogema lacks a good water supply close at hand. Some testing has been done, but full details of this are not available.

Prospecting for Water. South and west of a line running approximately from Stoughton to Trossachs and from Trossachs to Buttress the drift is underlain by strata of the Fort Union? series, and in this series there is little difficulty, as a rule, in obtaining a satisfactory supply of water. Supplies of potable water have been found at depths ranging to 440 feet.

North and east of the line outlined, the Pierre shale of the Cretaceous underlies the drift, and there appears to be little or no hope of meeting with potable supplies of water by deep drilling in these strata. Prospecting should be confined to the drift in this part of the region.

West of Missouri coteau and east and north of it where the lighter drift types appear at the surface, there is usually little difficulty in obtaining water at comparatively shallow depths (0-100 or 150 feet). At a few localities, as McTaggart and Trossachs villages, it has been impossible to locate sufficient water supplies, up to the present. The method to be adopted is by trial, spacing the test holes to cover the greatest area possible.

Where the heavier drift type is developed prospecting should be confined to the drift, as the underlying rock belongs to the Pierre shale. There is no rule to guide the choice of location of testing, except convenience, tempered by considerations of safety of the supply, if found, from pollution. It may be necessary to put down several tests through the drift before striking water. The results from the drilling already done indicate that it is probable that systematic prospecting will greatly reduce the size of the areas now thought to be without potable water.

The Divining-rod[1]. Both willow twig and electrical water finder have been used extensively in the region, but it is apparent from the foregoing and from an examination of the results obtained that there is nothing to warrant their use. One of the most objectionable features of the practice sometimes followed by the "water-witch" is the collection of fees before producing results.

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[1] Ellis, A. J., "The divining rod. A history of water witching." U.S. Geol. Surv., Water Supply Paper No. 416, 1917.

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