CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report, 1929, Part B

CONTENTS

OTTAWA

F. A. ACLAND

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1930

No. 2255

CANADA
DEPARTMENT OF MINES
HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1929, Part B

CONTENTS

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1930

No. 2255

THE HIGHWOOD-JUMPINGPOUND ANTICLINE, WITH NOTES ON TURNER VALLEY, NEW BLACK DIAMOND, AND PRIDDIS VALLEY STRUCTURES, ALBERTA

By G. S. Hume

CONTENTS

INTRODUCTION AND ACKNOWLEDGMENTS

During the summer of 1929 geological mapping was continued in the foothills in Alberta in accordance with a program of mapping unit areas each 30 minutes in longitude and 15 minutes in latitude.[1] During the 1929 field season the Turner Valley sheet was completed and the adjoining parts of the Calgary Southwest and Bragg Creek map-areas were studied and mapped. The boundaries of the Turner Valley map-area are as follows: east boundary—longitude 114°, i.e., 5th meridian or east side of range 1; west boundary—longitude 114° 30′, i.e., approximately the centre

[1] Geological-topographical maps on a scale of one inch to one mile are being prepared for the Turner Valley quadrangle and for the eastern half of Bragg Creek quadrangle. Maps will also be issued, on a scale of 2 inches to 1 mile, of portions of these quadrangles in which the geology is too complicated to be represented on the 1-mile scale. These maps cannot be published and made ready for distribution until late in 1930 or even until 1931. For the meantime an effort is being made to provide, for those who require the information, hand-coloured copies, on a scale of 1 inch to 1 mile, of these sheets and also of a small area (tps. 21, ranges 3 and 4, W. 5th mer.) north of Turner Valley quadrangle that has been geologically surveyed. These hand-coloured copies may be obtained by applying for them. A charge will be made for them depending upon the amount of information asked for. By courtesy of the Supervisory Mining Engineer, Department of the Interior, a set of these hand-coloured maps will be displayed in his office at Calgary.—*Director*.

of range 4; south boundary—latitude 50° 30′, i.e., one mile north of the south boundary of township 18; north boundary—latitude 50° 45′, i.e., the north boundary of township 20.

A detailed study of samples of borings in Turner valley has not been made, but such surface geological features as can be observed have been carefully studied and mapped. For this reason the intricate fault system discovered by drilling in Turner valley is not indicated on the map.

The part of the Calgary Southwest sheet mapped includes tp. 21, ranges 3 and 4, W. 5th mer. This includes the north end of Turner valley and a part of an important anticlinal structure now known to exist in the vicinity of Fisher creek.

Bragg Creek map-area, which includes an area between longitudes 114° 30′ and 115° and between latitudes 50° 45′ and 51°, has been only partly mapped. The area mapped is as follows: east boundary—longitude 114° 30′, i.e., approximate centre of range 4; west boundary—a line running northwesterly from the southeast corner of the map-area to Elbow river at McLean creek, and on to Canyon creek at longitude 114° 45′ and from there north to the north boundary of the map-area; south boundary—latitude 50° 45′ at the southeast corner of the map-area; north boundary—latitude 51°, i.e., approximately one-half mile south of the north boundary of township 23.

To the north of Bragg Creek map-area is Jumpingpound map-area, comprised between longitudes 114° 30′ and 115° and between latitudes 51° and 51° 15′. The southeast quarter of this area was mapped in 1927. It includes a 2½ mile strip on the west side of range 4, all of range 5, and a 2-mile strip east of range 6, tp. 24, W. 5th mer.

During the summer of 1929 the writer was assisted in geological mapping by A. G. Pentland, J. C. Sproule, C. E. Michener, L. A. Hamilton, and R. G. Salt. All these assistants performed their duties in an able manner and the writer wishes to acknowledge his indebtedness to them in making possible the mapping of so large an area.

During the summer much helpful assistance was received from the staff of the Supervisory Engineer's office in Calgary. Through the courtesy of Mr. C. C. Ross the samples of a number of wells were examined and much information that had been acquired by Messrs. Spratt and Taylor from the examination of drill samples was put at the disposal of the writer. Mr. C. W. Dingman acted as guide to the Princeton summer school party who visited Turner valley during the summer under the auspices of the Geological Survey.

On a number of occasions Mr. P. D. Moore, resident geologist at Turner valley for the Imperial Oil Company, Limited, contributed helpful information and suggestions in regard to the solution of some problems of foothills geology. The horizons used as markers in the wells in Turner valley have been worked out by Mr. Moore and by Mr. Spratt of the Supervisory Engineer's office and the names used for these key horizons are adopted in this report. A change has been made in the definition of the Kootenay-Fernie boundary in accordance with certain information that has been acquired by Mr. Moore and in part substantiated by observations of the writer. The change brings the stratigraphy of the Fernie in

Turner valley more into harmony with what is known of this formation where it outcrops elsewhere in the foothills and is an important contribution to the geology of the foothills.

STRATIGRAPHY

In the area mapped in 1929 the stratigraphic succession is in general the same as described for Turner Valley area in Summary Report 1926, part B, and for Bragg Creek area in Summary Report, 1927, part B. The stratigraphic succession is as follows:

Table of Formations

—	Formation	Thickness
		Feet
Tertiary	Paskapoo	4,000
Upper Cretaceous	Edmonton	1,300?
	Bearpaw	0 to 100
	Belly River	2,000? to 2,700
	Upper Alberta shale ("Upper Benton") with Cardium bands	1,900
	Lower Alberta shale ("Lower Benton")	850
Lower Cretaceous	Blairmore Kootenay	625+ 450 to 575
Jurassic	Fernie	225 to 240
Palæozoic	Pre-Fernie limestones	?

PRE-FERNIE LIMESTONES

These limestones are important on account of the production of naphtha gas from them in Turner valley. They are not exposed within the area mapped, but were studied on Highwood river within the mountains. There the upper part of the limestone series is highly bituminous as elsewhere and at certain horizons it has a high degree of porosity. As has been shown in former reports[1] porous limestones occur on Moose mountain within Bow River Forest reserve and similar conditions are said to obtain in the case of the limestones that outcrop to the west on Red Deer river within the mountains. This widespread evidence of porosity is very important, since conditions similar to those found in Turner valley may be expected to occur over wide areas in the foothills belt and where under favourable structural conditions the limestones may act as reservoir rocks for oil and gas.

[1] Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 3; Econ. Geol. Ser., No. 5, p. 68 (1928).

FERNIE FORMATION

The Fernie formation, like the underlying Palæozoic limestones, is known to outcrop only in the western foothills and adjacent mountains. It consists of dark shales with limestone bands and contains some sandy shales and sands mostly brown in colour. In Turner valley the Fernie is productive of oil and gas from the so-called Dalhousie sands.[1] The Dalhousie sands are believed to be between 225 and 240 feet stratigraphically above the limestone. About 120 feet stratigraphically below the Dalhousie sands is a glauconite zone which is recognized as a key horizon[2] in many wells in Turner valley. About 70 feet stratigraphically below the glauconite zone and 35 to 50 feet above the limestone is a fossil belemnite zone also recognized in drill samples in many Turner Valley wells. This same belemnite zone occurs in the Fernie outcrop on Canyon creek, Moose Mountain area.

Formerly it was considered that the Home sand, a productive oil sand in Turner valley, was the base of the Kootenay formation overlying the Fernie. There is no doubt that there are non-marine Kootenay strata immediately underlying the Home sand and that below this and above the Dalhousie sand there are certain dark sandstones and shales that are probably in part Kootenay rather than Fernie as was formerly assumed. The discovery that at least part of these strata between the Home and the Dalhousie sands are Kootenay was made by P. D. Moore as a result of the examination of the core from Dalhousie No. 1 well. Some evidence in support of this new interpretation has been noted by the writer in a section on Sheep creek within the Bow River Forest Reserve. For practical purposes, the Dalhousie sand rather than the Home sand is considered as the division between the Kootenay and the Fernie formations and the Fernie formation in Turner valley is thus thought to have a thickness of 225 to 240 feet. This brings the section in Turner valley more nearly in harmony with the section of Fernie as exposed on Canyon creek, Moose mountain, where the Fernie is 200 to 225 feet thick.[3]

KOOTENAY FORMATION

No detailed study of the Kootenay formation has been made by the writer, although Kootenay sections have been seen in a number of localities. In Canyon creek, Moose Mountain area, the Kootenay is overlain by the Blairmore conglomerate. To the east this conglomerate thins out and is not recognizable in well samples from Turner valley. Near the top of the Kootenay coal seams occur and in Turner valley this coal horizon is for practical purposes considered the top of the formation. There are small coal seams in the Blairmore formation so that the occurrence in any well of coal does not necessarily mean the Kootenay formation has been encountered. About 275 feet stratigraphically below the Kootenay coal seam encountered in the Turner Valley wells, is a fairly pure quartz sand

[1] The name Dalhousie sands was first applied to this productive zone by P. D. Moore of the Imperial Oil Co. on account of production from these sands on Dalhousie No. 5 well.

[2] These key horizons were first recognized by P. D. Moore, Imperial Oil Co., Ltd., and J. G. Spratt of the Supervisory Engineer's office. For a graphic log of Turner valley see Madgwick, T. G.: "The Oil and Gas Situation in the Prairie Provinces"; Bull. Can. Inst. of Min. and Met., April, 1929, p. 553.

[3] Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 2.

known as the Home sand on account of commercial production of oil being encountered at this horizon in Home No. 1 well. The stratigraphic thickness between the Home and Dalhousie sands seems to be somewhat variable between 175 and 300 feet. This suggests that the Kootenay-Fernie contact lies between these two horizons and is an erosional contact. As the contact cannot be recognized in well samples the Dalhousie sand is for practical purposes tentatively considered to be the top of the Fernie formation. The thickness of the Kootenay formation from the coal at the top to the Dalhousie sand is thus 450 to 575 feet. Above the Home sand the Kootenay formation is non-marine and consists mostly of dark, greenish grey sandstones and dark, sandy shales. A short distance below the Home sand the sediments become quite dark and are calcareous with limestone bands.

On secs. 15 and 22, tp. 21, range 4, W. 5th mer., in Fisher Creek area, rocks resembling Kootenay outcrop to the west of a thrust fault of large throw. At this locality impure limestones carrying Unios as well as other pelecypods and gasteropods outcrop. The limestones are quite arenaceous and with them are very siliceous sandstones which have a tendency to be conglomeratic although pebbles are scarce. Below the limestones only a few feet stratigraphically there is a thin coal seam. Pits have been sunk at various intervals along the eastern edge of the hill and the coal seam has been found at a number of places but is not of commercial importance. In the Imperial Highwood No. 1 well drilled on sec. 36, tp. 18, range 3, W. 5th mer., at a depth of 3,460 feet, a fossil gasteropod zone occurs in a limestone band. The horizon of this limestone band is below the Home sand which was encountered at a depth of 3,300 to 3,340 feet. No coal, however, occurs below this limestone band in the Highwood well, although the horizon of the limestone is considered to be the same as that which outcrops on secs. 15 and 22, tp. 21, range 4, W. 5th mer.

For mapping purposes it was impossible in Fisher Creek area to divide the Blairmore from the Kootenay and on the map both Kootenay and Blairmore are mapped as Blairmore. The western half of sec. 15, tp. 21, range 4, is probably all Kootenay, as the limestone band carrying fossils occurs on the crest of the ridge in the south-central part of the section and also in an outcrop 200 feet south and 300 feet east of the NW. cor. of sec. 15. In this latter outcrop a Unio was found, so that the fossils are probably non-marine. A non-marine origin would also seem probable on account of the presence of the small coal seam below the limestone band. The extent of the Kootenay formation in this area beyond section 15 is not definitely known as the coal seam which has been used as the division between Blairmore and Kootenay was nowhere observed. On the basis of structure, however, it would seem that the fault block which embraces the west of section 15, the west of section 22, the east of section 16, the east of section 21, and the southeast corner of section 28 should be all included in the Kootenay formation.

The Kootenay formation is not known to outcrop elsewhere in Turner valley or the Calgary Southwest map-areas, but occurs in Bragg Creek map-area in the vicinity of Canyon creek.

BLAIRMORE FORMATION

The Blairmore formation is overlain by the Lower Alberta shale ("Lower Benton") and underlain by the Kootenay formation. At the base of the Lower Alberta shale is the so-called grit zone which for practical purposes is considered the division between the Lower Alberta shale and the Blairmore. The grit, however, is part of the Lower Alberta shale rather than the Blairmore formation.

About 100 feet below the grit zone is a coarse sand sometimes called the Stockmen sand, and somewhat more than 100 feet below this is another sandstone zone called the McDougall-Segur sand on account of oil production from it in the McDougall-Segur wells. Many other wells in Turner valley have had production of oil from this same horizon. Maroon shales very commonly occur below the McDougall-Segur sand, but their position is not always the same nor are they apparently always present. The rocks of the Blairmore formation have on the whole a greenish colour, although some of the sandstones in the outcrops are quite grey and resemble the Belly River sandstones to a marked degree. They do not, however, show as much crossbedding as the Belly River strata, although both are of non-marine origin.

In Highwood area a large body of conglomerate, forming a hill on sec. 34, tp. 18, range 3, occurs within the Blairmore formation. This conglomerate is in the form of a large lens and the horizon cannot be traced for any great distance. Another of these conglomerate lenses occurs on sec. 6, tp. 22, range 4, where it also forms a hill and is remarkable for the occurrence of a large number of igneous pebbles up to 3 or 4 inches in diameter, but mostly smaller. Most of these igneous pebbles are feldspar porphyries, but other igneous varieties are present as well as quartzites both white and reddish, argillites, and chert. No limestone pebbles are present. The igneous pebbles must have been derived from an igneous mass to the west. Igneous pebbles are known to occur elsewhere in the Blairmore formation.[1] The Blairmore contains a few thin seams of coal, but in this area none of the seams is of commercial importance.

ALBERTA SHALE

Alberta shale is a new name proposed for the series of marine shales mostly Colorado and Montana in age occurring in Turner valley and adjoining areas between the Blairmore and Belly River formations. In former reports this shale has been described under the name "Benton" formation.

In 1861 Meek and Hayden[2] gave the name "Fort Benton group" to a series of shales at Fort Benton on the upper Missouri river which they believed to be equivalent to a group of strata that farther east lie below the Niobrara. As geological work proceeded over a wide area it was found that the Niobrara division did not always consist of marls and limestones and except on faunal evidence it became very difficult to distinguish the Fort Benton group from the Fort Pierre group which overlies the Niobrara

[1] Rose, B.: "Crowsnest Coal Field, Alberta"; Geol. Surv. ,Canada, Sum. Rept. 1916, p. 110.
[2] Proc. Acad. Nat. Sci., Phil., 1861, p. 419.

division. For this reason Clarence King in 1875 proposed the name "Colorado group" to include the Fort Benton, Niobrara, and Fort Pierre groups of Meek and Hayden. It was later recognized that there was a marked faunal break at the top of the Niobrara and in 1889 George H. Eldridge proposed the name "Montana group" for the Fort Pierre and Fox Hills which overlie the Niobrara, restricting the name Colorado group[1] to the Fort Benton and Niobrara of Meek and Hayden.

Between the Blairmore and Belly River formations in Turner valley and adjoining areas is a series of marine sediments mostly shales which have in former reports been included under the Benton formation. In early reports[2] dealing with Turner valley the Blairmore was called Dakota formation. The Dakota formation is Upper Cretaceous in age and when it was discovered that the strata which in the Blairmore area occupy the stratigraphic position of the Dakota were mostly if not entirely Lower Cretaceous in age, the name Dakota was no longer tenable and the name Blairmore was introduced.[3] Later the name Blairmore formation was applied to Turner Valley area. No typical Dakota is at present known in western Canada and it is possible the lower part of the so-called Benton formation may be of this age. The greater part of the so-called Benton formation is, however, Colorado in age, although at the top of the formation there are a few hundred feet of marine shales of Montana age. Since the so-called Benton formation of western Canada is obviously not the Fort Benton of the Missouri River sections and since the name Colorado shale is not applicable and has been used to include strata between the so-called Dakota and Montana it is proposed to introduce a new name—Alberta shale—for the marine strata lying between the Blairmore and Belly River formations. The Alberta shale is divisible into an upper and a lower part, distinct faunally and separated by the Cardium. The faunal break occurs at the base of the lowest Cardium band and hence the Cardium bands are part of the Upper, rather than the Lower, Alberta shale.

The Alberta shale has already been described[4] under the name Benton formation. It has been shown[5] that the upper part carries a marine Montana fauna, whereas the remainder of the formation is, so far as known, Colorado. For mapping purposes the division into Montana and Colorado cannot be made, as both are shales only distinguishable on faunal evidence. Within the Alberta shale, however, are one to three bands of sandstones often capped by conglomerates and underlain by sandy shales. These are the so-called Cardium bands, since in certain areas this fossil occurs in them. The fossil is, however, not confined to these bands. The Cardium bands are thin to the east but thicken in the west and there form prominent ridges due to the rocks of the bands being much harder than the enclosing shales. In Turner valley a Cardium band is recognized in outcrops on Sheep creek and occurs in well samples as a band of sandstone and sandy shales. About 100 feet below this is a thin conglomeratic zone, the pebbles of which have been recovered from many wells. This thin conglomeratic

[1] For the early history, *See* Stanton, T. W.: "The Colorado Formation and Its Invertebrate Fauna"; U.S. Geol. Surv. Bull. 106.
[2] Geol. Surv., Canada, Mem. 122 (1921).
[3] Leach, W. W.: "Blairmore Map Area, Alberta"; Geol. Surv., Canada, Sum. Rept. 1912, p. 234 (map)
[4] Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 7.
[5] Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1926, pt. B, p. 6.

zone is but the eastern equivalent of a much more prominent, thicker band that occurs farther west. In many parts of Turner Valley map-area it is possible to map this conglomeratic Cardium band, for it is persistent and tends to outcrop. In the southwest corner of Turner Valley map-area a third Cardium band occurs below the second from which it is separated by about 240 feet of strata. The Cardium bands are part of the Upper, rather than the Lower, Alberta shale, since upper Colorado fossils occur above the lowest band and lower Colorado fossils beneath it. The lowest Cardium band thus marks the division between the Upper and Lower Alberta shale. It has been found advantageous to map separately the Upper and Lower Alberta shale and in so far as possible the division has been made where the faunal break occurs, that is at the base of the lowest Cardium band. Unfortunately the lowest Cardium band cannot be traced throughout the whole area mapped and where it does not outcrop the dividing line is drawn at the base of the second Cardium band. This is, of course, not strictly correct, for the lowest Cardium band is thus thrown into the Lower Alberta shale where it does not rightly belong. Also where single outcrops of only one Cardium band occur it is not always possible to tell to which band the outcrops should be assigned and, therefore, the division between the Upper and Lower Alberta shales is only approximate at such places. In Bragg Creek map-area only two bands separated by 350 feet of strata were observed and there the lower band appears to mark the division between the Lower and Upper Alberta shale. In the southwest corner of Turner Valley map-area, however, there are three bands with shales separating them, the thickness from the top of the highest band to the base of the lowest band being 340 feet. The lowest band is poorly developed and the other two bands may be separated in most places due to the fact that the conglomerate of the upper band has an ironstone matrix. It is thought the Cardium bands should be considered parts of a zone in which the bands do not everywhere hold the same stratigraphic positions.[1]

As has already been stated the division between the Lower Alberta shale and the Blairmore is made at the "grit" zone. The grit zone is assigned to the Lower Alberta shale since a small thickness of black shales occasionally is found below it. In Highwood area this grit zone is as much as 40 feet thick and is highly siliceous. It thins to the north and at Bragg creek on Elbow river is not more than a few inches thick. It is recognized as a horizon marker in all wells in Turner valley. The Lower Alberta shale contains some bands of extremely black shale and it is not uncommon to find oil associated with these layers. There are, however, no reservoir rocks at these horizons and consequently no production of oil from them in any of the Turner Valley wells, although "shows" of oil in certain parts of the Lower Alberta shale have been found. The thickness of the Lower Alberta shale is considered to be about 850 feet. On

[1] In mapping the Bow River section Rutherford has mapped the Cardium bands with the shales separating them as a formation, whereas on Turner Valley and Bragg Creek map-areas each Cardium band of conglomerate and sandstone has been mapped separately. To the north and west of Turner Valley area the Cardium bands become very thick and may be properly grouped and in the Mountain Park area their stratigraphic position is occupied by the Bighorn formation. The Blackstone and Wapiabi formations of Mountain Park area thus occupy the same stratigraphic positions as the Lower Alberta shale ("Lower Benton") and the Upper Alberta shale ("Upper Benton"), respectively, of Turner Valley area. East of Turner Valley area on the Plains the Cardium bands are no longer recognized and the strata between the Belly River and Lower Cretaceous are thus the equivalent of the Alberta shale of the foothills area.

account of the amount of deformation suffered by the shales, measurements of thickness are somewhat uncertain.

The Upper Alberta shale cannot be divided into upper Colorado and Montana for mapping purposes. It does not contain as much fissile shale as the Lower Alberta shale and is distinct from it faunally. Its thickness is believed to be about 1,900 feet. The division between marine Montana of the Upper Alberta shale and Belly River is rather indefinite. These marine Montana shales of the top of the Upper Alberta shale are replaced upwards by non-marine sandstones and shales of the Belly River. In many places in the western part of the map-area, heavy-bedded sandstones making a zone up to 50 feet thick occur below a considerable thickness of dark shales which are overlain by typical Belly River sandstones and shales. In a few localities marine Montana fossils have been found above the zone of heavy-bedded sandstones, whereas on Quirk creek in the southern part of Bragg Creek map-area, the heavy-bedded sandstones are capped by a thin layer containing chert pebbles and oysters. The presence of oysters is indicative of non-marine conditions and hence on this basis it would be permissible to assign these heavy-bedded sandstones to the Belly River. Since, however, marine fossils occur above this zone in other localities and these marine fossils are identical with fossils that occur below the zone of heavy sandstones it would be equally permissible to include the heavy-bedded sandstones and the shales above them in the Upper Alberta shale. The thickness of the beds above the zone of heavy sandstones and below typical Belly River strata is somewhat variable, but is at least 200 feet and may in certain areas be somewhat more. On sec. 7, tp. 18, range 3, W. 5th mer., a Belly River-Upper Alberta shale contact quite different from that described above occurs. The contact at this place seems fairly sharp. Dark shales grade upwards into sandy shales which are overlain by 40 to 50 feet of very massive sandstones. Above these sandstones are less massive sandstones and shales with a thin coal seam, and 120 feet stratigraphically above the bottom of the heavy sandstones is a conglomerate bed, 1 foot thick, containing green, black, and grey chert and pink quartzite pebbles. This conglomerate is overlain by 6 to 8 feet of shaly sandstone which in turn is overlain by a thin zone of pebbly sandstone. About 200 feet still higher stratigraphically, an oyster zone occurs in more sandstone. All the beds above the sandy shales overlying the Upper Alberta shale undoubtedly should be assigned to the Belly River formation. All the dark shales lying above the 50-foot zone of heavy sandstones on Quirk creek and elsewhere may be represented by typical non-marine Belly River strata in the Sheep River locality on section 7, although the conglomerate and oyster zones do not appear to hold the same stratigraphic position in the various areas studied. If this is so the Belly River-Upper Alberta shale contact should be drawn at the base of the 50-foot zone of heavy sandstones in Quirk Creek area in spite of the fact that certain marine strata would thus be included in the Belly River formation at this place. Although such an interpretation would be quite satisfactory for western foothills sections of the Belly River it does not readily apply to eastern foothills exposures where the 50-foot zone of heavy sandstone as described from Quirk creek is not so thick and may be represented only by very thin sandstone beds in certain areas. In such a case the upper 200 feet of dark shales at the top of the Upper Alberta shale are ascribed to the Alberta shale. This 200 feet of strata thus forms a transition zone between the Upper Alberta shale and Belly River formations and in certain places on the map it, probably, is included within the Upper Alberta shale, whereas in other places where heavy-bedded sandstones outcrop it has been included in the Belly River. On this account the thickness of the Upper Alberta shale and Belly River at various localities may appear to be quite different.

BELLY RIVER FORMATION

Excellent exposures of Belly River strata are to be seen in many localities, although complete unbroken sections of the whole formation are found in only a few places. One of the best sections of Belly River that has been studied occurs on Highwood river on secs. 19 and 20, tp. 18, range 2, W. 5th mer. The coal seam at the top of the Belly River formation is being mined on section 20, and west of this on Highwood river and on a small stream that comes from the southwest the whole Belly River formation, with the exception of a small covered interval at both the top and bottom of the formation, is exposed. Careful measurements of the thickness were made at this locality. A plane-table traverse by C. E. Michener gave a thickness of 2,730 feet. A measurement by the writer with a tape over the same section gave a thickness of 2,700 feet. The difference is probably due to minor folds in the rocks as well as small errors in calculating the thickness in a few concealed places. It is, however, safe to say that the thickness at this locality is between 2,700 and 2,725 feet. This is a somewhat greater thickness than has formerly been ascribed[1] to the Belly River formation, but other measurements were based on incomplete sections, whereas this measurement should be more accurate in that it included a continuous section of the whole of the formation. It is quite possible, though, that the formation varies in thickness and as has already been pointed out strata that are included in the Belly River at one place may be included with the Alberta shale at another.

The upper part of the Belly River formation as observed on Highwood river on secs. 19 and 20, tp. 18, range 2, is predominantly shale with sandy shale and a few thin sandstone bands. Coal in thin seams occurs at a number of horizons and between 780 and 800 feet below the main coal seam at the top of the formation there are three seams from 6 inches to 3 feet thick. Below this coal zone the sediments are more sandy than above and ironstone is of common occurrence. About 1,040 feet below the top of the formation there is another coal zone with 2 feet of coal and shale separated by 4 feet of sandstone and shale from another coal seam 1 foot thick. Below this the shales become greenish in colour, whereas above it they were mostly dark or grey. The thin coal stringers, however, persist to 1,215 feet below the top of the formation below which the sediments are predominantly sandstones and green, sandy shales. Many of the sandstones are in massive beds and light grey in colour. This alternation of greenish shales and massive sandstones persists almost to the Upper

[1]Geol. Surv., Canada, Sum. Rept. 1926, pt. B.

Alberta shale contact above where a few thin carbonaceous or coaly layers again occur. Ironstone bands are of common occurrence within the lower 550 feet of the formation, although they are relatively scarce in the central part where the heavy-bedded sandstones occur. Except for sandstone and sandy shale exposed at the place where the Belly River-Alberta shale contact was drawn the lowest 385 feet of the formation are not exposed in this Highwood section.

BEARPAW FORMATION

Overlying the coal seam at the top of the Belly River on sec. 20, tp. 18, range 2, and on Bull creek on section 8 is a thin series of sandy shales carrying marine fossils. The shales are very much contorted and the thickness is difficult to measure but is thought to be not more than 100 feet. Overlying the sandy shales are fairly massive sandstones carrying thin stringers of coal. These sandstones are thought to be Edmonton in age and the shales between them and the coal at the top of the Belly River formation are thought to belong to the Bearpaw formation. On the original Sheep River map (Geol. Surv., Canada, Pub. No. 1724) Slipper showed the Bearpaw formation extending slightly north of Tongue creek in township 19, range 2. Above the Belly River formation in this area there are some dark, sandy shales which may be the equivalents of Bearpaw strata elsewhere. However, since the exposures are so poor and it is impossible to definitely determine their age all strata above the Belly River coal seam have been mapped with the Edmonton formation.

EDMONTON FORMATION

No detailed study of the Edmonton formation has been made, although outcrops have been observed in a number of places. On the south branch of Sheep creek downstream from the Black Diamond bridge a good section of Edmonton rocks is exposed, although the section does not include the whole of the Edmonton formation. On Highwood river Edmonton strata are exposed for about 4 miles from sec. 10 to sec. 20, tp. 18, range 2. The two sections are quite unlike, particularly in the upper part of the formation. In the southern foothills the St. Mary River formation overlies the Bearpaw formation. The St. Mary River formation was traced by Stewart[1] from Oldman to Highwood river " where beds of the series generally known as the Edmonton are identical with the lower part of the St. Mary River formation ". The Edmonton on Highwood river, however, does not seem to be quite the same as the Edmonton as exposed farther north and it is probable, therefore, that the Edmonton formation as mapped on the Highwood is not the exact time equivalent of the Edmonton as mapped to the north. Sufficient detailed studies have not been made to determine wherein the differences lie, but certain observations may be of value as indicating changing conditions within the formation. According to Stewart " within the lowermost 100 feet (of the St. Mary River formation) there is always at least one bed composed largely of oyster shells with other brackish water fossils in less amounts ". Oyster beds occur on Highwood

[1] Stewart, J. S.: "Geology of the Disturbed Belt of Southwestern Alberta"; Geol. Surv., Canada, Mem 112, p. 39 (1919).

river in a number of places, but owing to the intricate nature of the folding it is not certain whether these beds occur at one or more horizons. Such oyster beds as occur, however, are more than 1,000 feet below the horizon that was considered to be the Edmonton-Paskapoo contact. Several small coal seams occur above the oyster zone, and at the contact with the Paskapoo or just below it is a zone containing Unios, gasteropods, and a few small pebbles. The upper part of the formation, therefore, may be freshwater in origin, whereas the oysters would indicate brackish water conditions. On the south branch of Sheep creek east of the Black Diamond bridge the Edmonton formation consists of an alternation of light grey sandstones with greenish shales. Small coal seams occur and Unios and gasteropods occur in many horizons. No oyster beds occur and it is possible, therefore, that there is a change from brackish water conditions in Highwood area to more nearly freshwater conditions farther north. Slipper[1] estimated the Edmonton formation to be 1,300 feet thick on Sheep river near the Black Diamond bridge. It is believed by the writer that the Edmonton at this locality is thrust faulted and that the thickness may be much greater than Slipper's estimate.

PASKAPOO FORMATION

The division between the Edmonton and Paskapoo is made on lithological grounds. The soft sandstones and green shales of the Edmonton are overlain by more massive, yellowish weathering sandstones and greenish shales of the Paskapoo. It has been shown[2] that in a section at Priddis, a conglomeratic sandstone with quartzite pebbles overlies greenish shales presumed to be Edmonton in age. There is some evidence at this place of an erosional contact, but on Highwood river at the presumed contact on sec. 10, tp. 18, range 2, no such evidence was observed. No detailed work on the Paskapoo formation has been done by the writer. Slipper,[1] however, has estimated a total thickness for the Paskapoo formation of 4,000± feet.

HIGHWOOD-JUMPINGPOUND ANTICLINE

STRUCTURE

On Highwood river, on secs. 19 and 20, tp. 18, range 2, Belly River strata dipping easterly are exposed. On the same river Belly River strata again occur on sec. 7, tp. 18, range 3, but dip westerly. The structure thus indicated is a major anticline with Belly River rocks on both flanks. Between these Belly River exposures there are numerous bands of Upper and Lower Alberta shales with Cardium sandstones and conglomerate bands as well as a number of areas of Blairmore rocks. These bands within the major anticlinal structure are the results of folding and faulting, thrust faulting predominates, but folding is also important. On this major anticline on Highwood river there are two well-marked synclines each exposing Upper Alberta shales. These synclines should be considered as subsidiary folds on the main anticlinal structure. The more easterly of these synclines crosses Highwood river in section 21, range 3, and the more westerly is on

[1] Slipper, S. E.: "Sheep River Gas and Oil Field, Alberta"; Geol. Surv. ,Canada ,Mem. 122, p. 10 (1921).
[2] Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1926, pt. B, p. 7.

the west of section 17, and the east of section 18, range 3. Between these two synclines there is a faulted anticlinal area exposing Lower Alberta shales, but the main anticlinal part of the major anticline lies east of the more easterly syncline and west of the easterly dipping Belly River beds on sections 19 and 20, range 2. Except on the extreme flanks this anticlinal area is almost wholly composed at the surface of Lower Alberta and Blairmore strata with faulting and a minor amount of folding determining the horizons exposed.

From the standpoint of oil and gas prospects this anticlinal area is considered of great importance not only because it is a well-developed anticline, but also because within it there are wide areas of Blairmore rocks where drilling can commence at horizons much lower than anywhere possible in Turner valley. This anticline was traced southwards as far as the south boundary of township 18 and is known to continue much farther. Traced in a northwest direction the anticline plunges downwards and the Blairmore rocks which are exposed in large areas on Highwood river become covered with younger rocks. There are, however, considerable areas of Blairmore exposed on the south branch of Sheep river on the strike of this anticline, the largest area being in the vicinity of Macabee creek, but the strata of this area also plunge under Alberta shales on the north of sec. 6, tp. 20, range 3, and on the north branch of Sheep creek the rocks between the Belly River flanks of the anticline are entirely Alberta shales.

The northward plunge of the anticline as a whole is well shown on both the subsidiary synclines previously mentioned. As was stated these synclines where they cross Highwood river expose Upper Alberta shales. The downward plunge of the structure to the northwest allows younger rocks of Belly River age to occupy the central part of both synclines and this results in a remarkable change in the character of the topography. Whereas the areas underlain by Alberta shales are comparatively flat, the areas occupied by Belly River rocks are ridges, the difference in elevation being several hundred feet. The Belly River ridge in the more westerly syncline commences on the north of sec. 19, tp. 18, range 3, and except where it is cut transversely by a valley south of the south branch of Sheep creek, can be traced continuously into the Bow River Forest reserve to the western edge of the map-area. The Belly River ridge in the more easterly syncline is broken into a number of hills which form one continuous ridge from sec. 8, tp. 19, range 3, to sec. 22, tp. 20, range 4. The south branch of Sheep creek occupies a canyon-like valley where it cuts across these synclines and Belly River rocks are exposed on the sides of the valley in an almost continuous section. The anticline between these two synclines is to a considerable extent modified by thrust faulting and north of the south branch of Sheep creek a further subsidiary syncline is developed on the anticline and as a result another small ridge of Belly River rocks occurs extending from the NW. cor. sec. 35, tp. 19, range 4, for 3 miles in a northwest direction to end within the Bow River Forest Reserve.

Northwest of the north branch of Sheep creek the major anticline continues and has been traced to Jumpingpound creek in township 24, range 5, where it ends. It has already been pointed out that the anticline plunges downward from Highwood river in a northwest direction and, whereas there are large areas of Blairmore rocks exposed on Highwood river, only Alberta shales occur on the north branch of Sheep creek. This downward plunge in a northwesterly direction does not, however, continue farther northwest, but just slightly south of the north branch of Sheep creek is replaced by a rising structure plunging southeasterly and as a result Blairmore rocks are again brought to the surface in the vicinity of Fisher creek beginning on secs. 9 and 10, tp. 21, range 4, and extending into and over a high structural area in the vicinity of sections 15 and 21, but diminishing in width northwestward until they finally disappear below Lower Alberta shales in sec. 18, tp. 22, range 4. This area of Blairmore rocks is remarkable in that within it are exposed rocks lower stratigraphically than any elsewhere known to be exposed on this anticline and gas seepages issue at a number of places on section 21. As already stated in the discussion of the stratigraphy it is probable that the lowest horizon exposed on sections 15 and 21 belongs to the Kootenay, but as it has been impossible to divide the Blairmore and Kootenay at this locality the rocks for mapping purposes have been grouped with the Blairmore.

The two subsidiary synclines which, on a previous page, have been described as extending from Highwood river to the north branch of Sheep creek, cannot be traced north of the north branch of Sheep creek. There are present, however, some smaller synclines which to a certain extent are modified by faulting. One of these synclines, occupied by Upper Alberta strata, extends from sec. 34, tp. 20, range 4, to sec. 20, tp. 21, range 4. The synclinal structure of this area is only apparent at the northern end where a Cardium band is exposed and can be traced around the end of the syncline. Elsewhere the west limb of the syncline is cut off by a thrust fault. Another smaller syncline, also occupied by Upper Alberta shales, extends from sec. 32, tp. 21, range 4, to sec. 7, tp. 22, range 4. This syncline is an elongated, fairly narrow trough and plunges from both ends downwards toward the centre. West of it, in an anticlinal area, faulted on the east side, another band of Blairmore rocks occurs. This band is less than a quarter of a mile wide, but can be traced from sec. 31, tp. 21, range 4, to sec. 25, tp. 22, range 5, where it plunges downward under Lower Alberta shales. This anticline ends approximately at Elbow river on sec. 11, tp. 23, range 5, where the Cardium member is exposed in an extremely narrow, but well-marked, anticline. On Fish creek this anticline is the crest of the major anticlinal structure. The limits of the major anticline are well defined by the easterly dipping Belly River on secs. 17 and 20, tp. 22, range 4, and the westerly dipping Belly River about $1\frac{1}{2}$ miles west of the eastern boundary of the forest reserve. The major anticline here as elsewhere is, however, not a simple structure but is broken by faults and embraces a number of subsidiary anticlines and synclines superimposed on the main structure.

Between Elbow river and Jumpingpound creek the major anticlinal structure is occupied by the Two Pine anticline already described in Summary Report 1927, part B. Blairmore rocks are exposed in a belt up to $\frac{3}{4}$ mile in width and about $4\frac{1}{2}$ miles long, with Lower Alberta shales exposed on both flanks. This anticline plunges downward at the north end or may be cut off by a fault on sec. 35, tp. 23, range 5, and sec. 2, tp. 24, range 5. North of Jumpingpound creek on the strike of the main anticlinal structure only Upper Alberta and Belly River beds are exposed and the anticlinal structure is no longer apparent.

The main anticlinal structure herein described is 40 miles long between Jumpingpound creek in township 24, range 5, and the southern boundary of the Turner Valley sheet in township 18, ranges 2 and 3. It extends still farther southeast for an unknown distance. The Belly River ridges which constitute the eastern flank of this anticline can be traced continuously, except in a small area on the so-called New Black Diamond structure, throughout the whole distance, and the strata have an easterly dip. Due to subsidiary folds on the main anticlinal structure the western flank, although everywhere clearly delimited by the westerly dipping Belly River rocks, has not the same degree of continuity as the eastern flank. This results in the major anticline having a greater width in certain localities than in others, but at no locality is the anticlinal structure not clearly apparent throughout the distance it has been traced. This anticline is indeed a most remarkable structure and is considered the major anticline of the foothills belt for the area under consideration.

Within this major anticline faulting of all degrees of magnitude from a few feet to several thousands of feet occurs. Most of the faulting is of the reverse or thrust faulting type, but a minor amount of normal faulting is present. The normal faulting is considered to be the result of a readjustment or settling back after the main thrust faulting occurred and is in consequence relatively insignificant as far as concerns the major structure. It seems quite apparent that the first stage in the deformation of the sediments resulted in the formation of gentle synclines and anticlines. As stresses accumulated these gentle folds were severely compressed, until finally the folds were broken by thrust faults. A readjustment following the thrust faulting caused, as already mentioned, a slight amount of settling resulting in normal faults.

It has been repeatedly observed that where the strata have been tilted at angles in excess of 65 degrees, thrust faulting becomes prominent, but this is, perhaps, more the condition where Blairmore or Belly River beds are involved than where Alberta shales occur. It is thought the Alberta shales being less competent than either the Blairmore or Belly River formations yielded more easily by flowage and shearing and that as a result the Alberta shales are likely to be somewhat variable in thickness where they occur in severely compressed folds. It has not yet been possible to estimate the amount of this thickening and thinning of the Alberta shales, but it is probable that it is considerable. It is also noticeable that where the Cardium members of the Upper Alberta shale become fairly thick and hard in the western part of the map areas studied, they have yielded by faulting, whereas the rest of the Alberta shale being less competent yielded by folding. The Belly River, Blairmore, and Kootenay formations contain a considerable amount of shale or sandy shale alternating with harder sandstone beds and in contrast with the Palæozoic limestones are probably to be considered as being non-competent formations, although more competent than the Alberta shale and Fernie formation which are largely shales. Thus the structures observable in the Belly

River, Blairmore, and Alberta shale seem to indicate that severely compressed folds in non-competent beds at the surface may be replaced at depth by faults in more competent beds and, therefore, since a great many faults, some of large magnitude, have been observed in the major anticline under discussion, it is probable that at depth faulting is even more prevalent.

The faulting in the foothills is of great interest scientifically, as well as of great importance commercially. Recent drilling on the New Black Diamond structure west of Turner valley has revealed the presence of a low angle thrust fault with dip to the west of probably about 18 to 20 degrees. This fault occurs at the surface in sec. 2, tp. 20, range 3, W. 5th mer., and although the actual fault plane is concealed its presence is certain on account of the proximity of Upper Alberta shales (Upper Benton) with the upper beds of the Belly River formation. Close to the fault the strata are highly tilted and for this reason it was originally believed this fault had a steep dip to the west. A much lower angle of the dip, however, was revealed by drilling in the Von Weymarn (New Black Diamond) and Outwest wells.

In June, 1928, Dr. T. A. Link published a popular article on Turner valley in the "Imperial Oil Review." A cross-section of Turner valley was given and from this it is quite obvious that Dr. Link considered that a fault of low dip to the west underlies the whole of Turner valley.[1] This fault is shown as occurring at the surface east of the Belly River ridge on the east flank of Turner valley. The writer believes there is evidence to support this view and such a fault is thought to occur on secs. 8 and 17, tp. 20, range 2, just west of the Black Diamond bridge over Sheep creek. The fault is believed to extend in a northwest and southeast direction and although no evidence has been found for its presence southeast of the Black Diamond bridge due to lack of outcrops, there is considerable evidence to the northwest to show that it probably extends for many miles. This fault may have a fairly steep dip where it cuts the surface and may become a low angle fault under Turner valley. At present the main evidence for such a fault under Turner valley has been deduced from a study of samples of the Great West No. 1 and British Dominion No. 1 wells. Both of these wells after drilling a large thickness of Alberta (Benton) shales passed through a fault into stratigraphically higher beds. It is now known that there are a number of faults within the Turner Valley anticline. These faults are probably subsidiary faults to the main thrust fault and join it at depth. If this explanation of faulting is the correct one the Turner Valley anticline is a faulted drag-fold above a low angle thrust fault that appears at the surface east of the eastern Belly River ridge of Turner valley.[2] It is not known, assuming that such a low angle fault is present under Turner valley, whether or not it would be likely to join up far to the west at a great depth under the surface with the low angle fault that is known to occur under the new Black Diamond structure. It might be supposed, however, if such low angle faults are the major structural

[1]Since the above report was written the Sterling Pacific well on sec. 33, tp. 18, range 2, in Turner valley, is reported to have drilled more than 1,300 feet of Palæozoic limestone and below this to have passed through a fault into Cretaceous strata.

[2] For diagrams illustrating this faulting *See* Link, T. A.: "Imperial Oil Review", Sept. 1929.

features of the foothills, that all other minor faults would be subsidiary to them and join them at depth probably at low angles also. Such a system of fault blocks thrust over one another on low angle major thrust planes would be somewhat similar, though on a much smaller scale, to the "decke" or "nappe" structure of the Alps.

It is not considered here that the presence of a low angle thrust fault under Turner valley is by any means proved. The evidence of faulting in Turner valley has not been studied in detail by the Geological Survey and the rejection or proof of the hypothesis of low angle faulting will depend on the study of much additional data. Such an explanation of faulting in the foothills, however, offers many interesting lines of speculation and it is hoped that the above discussion will tend to stimulate thought in the solving of many difficult problems. The rapidity with which the sharp folding and faulting of the disturbed belt passes eastward into relatively undisturbed strata has always been a puzzling phenomenon, an explanation for which is readily postulated if the whole foothills is an overthrust mass thrust over relatively low dipping strata. On the hypothesis of the foothills as a whole being a thrust mass the strata below the main fault plane may be much younger than the strata lying immediately above and it would not be inconceivable on such a theory that Cretaceous or younger rocks might underlie the Palæozoic limestones productive of oil and gas in Turner valley.[1]

OIL AND GAS PROSPECTS

At the present time Turner valley is the only field in the foothills of Alberta that is producing oil in commercial quantities and, therefore, in estimating the potential value of other neighbouring fields it is natural to compare them with Turner Valley field. Unfortunately a complete study of Turner valley has not been possible. It is known that fairly complicated faulting exists within the Turner Valley anticline. Whether this faulting in Turner valley is more or less complicated than in the major anticline which extends from Highwood area to Jumpingpound creek is not known, nor is it known if the faulting is of the same character as that observable in various parts of the foothills outside of Turner valley. It is also unknown as to what degree the faulting in Turner valley has affected production of oil and gas. It has been suggested that the comparatively high degree of porosity found in the producing horizon in certain parts of Turner valley may be due to a localized considerable fracturing of the productive limestone, but no data bearing on this matter have as yet been assembled by the Geological Survey. For many years geologists have regarded a certain amount of faulting in an oil structure as a favouring feature, but excessive faulting may be detrimental. In the absence of a reasonably complete knowledge of the governing conditions in Turner valley, the drawing of conclusions regarding the potentialities of anticlines in other parts of the foothills becomes somewhat hazardous, although on theoretical grounds it might be argued that many anticlines in the foothills are as favourable as that of Turner valley. The forces that caused the folding

[1]Since writing the above report the author has been informed by T. G. Madgwick, Petroleum Engineer, Department of the Interior, that this general question of overthrusting of the whole of Turner valley was discussed several years ago at a meeting of the Alberta Society of Petroleum Engineers, at which he put forward this theory.

and faulting in Turner valley also caused the other structures of the foothills and one general type of structure might be expected to occur throughout. But even assuming that one general type of structure characterizes the foothills belt it does not follow that the prospects for oil and gas are uniform. Turner valley for instance is an anticline on the extreme eastern edge of the foothills belt, whereas the anticline extending from the Highwood to Jumpingpound creek is what might be termed an inner fold and it is known that, in a general way, metamorphism increases from east to west in the foothills and if, as may be the case, the naphtha content of the gas of Turner valley is the product of natural distillation due to metamorphism distillation in more westerly and thence more metamorphosed folds may have proceeded to a still farther degree. There does not seem, however, to be any method of determining the degree of metamorphism or of estimating its effect on the possible oil content at any locality, so that conclusions based on theoretical considerations may be of little value owing to the presence of conditions, the effect of which it is not possible to evaluate. Evidences of oil and gas exist at various localities on the anticline which extends from Highwood river to Jumpingpound creek, but it should be remembered that these relate only to the surface rocks and their bearing on possible production from lower horizons cannot be determined until wells are drilled.

On the anticline which extends from Highwood area to Jumpingpound creek the largest gas seepage known is on Bull creek (Coal creek) on sec. 6, tp. 18, range 3, just south of the southern boundary of Turner Valley map-sheet. This seepage issues from Blairmore rocks through a certain amount of drift cover. Several other gas seepages have been observed in various places, the most important of which are on sec. 21, tp. 21, range 4. One of these may be observed on the edge of Fisher creek in a spring on the northwest side of the trail where it crosses Fisher creek. Three others are known on the same section, each issuing from a spring in which the water tastes quite strongly of sulphur. These seepages also appear to issue from Blairmore strata. When it is recalled that the original well in Turner valley was drilled in proximity to a gas seepage which, from description, seems to have been of the same character as the gas seepages described, the significance of these gas seepages may be appreciated. On Highwood river globules of oil were noted at the Blairmore-Alberta shale contact and at many places in the Lower Alberta shales, but particularly on sec. 28, tp. 18, range 3, just slightly east of the Warner well location. On Quirk creek, on sec. 27, tp. 20, range 4, in Lower Alberta shales, seepages of oil can be seen along the creek for a considerable distance. The Alberta shales at this locality are well exposed in the creek valley and numerous small, stagnant pools of water in small depressions in the shales were, at the time of the writer's examination, covered with films of oil. Globules of oil could also be obtained by breaking the shales. Globules of oil also were seen in the Alberta shales at the Alberta shale-Blairmore contact on sec. 9, tp. 21, range 4. These shows of oil are very impressive, especially when it is considered how easily the evidences of oil may be washed away by running water and they seem to point to the conclusion that the metamorphism has been such that under favourable structural conditions in proper reservoirs oil might reasonably be expected to occur.

In regard to favourable structure it has already been stated that there is a regional anticline extending from Highwood area to Jumpingpound creek. This anticline would be expected to be a favourable location for oil accumulations, but it is hardly reasonable to suppose that the whole anticline will prove productive. If oil were present or were formed during the early stages of deformation of the sediments of the foothills it would be reasonable to expect that accumulations would begin as soon as well-defined anticlines were formed. Subsequent deformation with the development of more intensive folding and faulting might cause a further distillation of oil or might cause some natural distillation of the oil already present, but probably would at least cause a rearrangement of the oil in the anticline in harmony with the new structural conditions. Subsidiary anticlines developed on the main structure would probably become the loci of accumulations or where faults cut the main structure accumulation would probably take place against the faults. As has already been shown, the anticline which extends from Highwood area to Jumpingpound creek contains a number of subordinate anticlines and is considerably faulted. These secondary structures besides determining the most favourable areas for oil accumulation are also important factors controlling the depth from the surface to the possible productive zones and hence are of vital importance in the selection of well sites. It is believed a detailed study of local conditions in relation to major features should be made prior to the location of any well.

The subsidiary anticlines within the major anticlinal structure have already been outlined in a general way and their location and extent are shown on the geological maps now in course of publication. The highest structural area within the major anticline occurs in the vicinity of Fisher creek. At this place lower Blairmore or possibly Kootenay rocks are exposed and evidences of both gas and oil have been observed. In numerous other localities, however, Blairmore rocks have been brought to the surface and in them at a number of places oil and gas have also been seen. All these areas are considered favourable for oil or gas accumulations provided suitable porous horizons occur at depth. It is known that the limestones show porosity where they outcrop from Highwood mountains to the area west of Red Deer river and hence it is reasonable to assume this porosity also occurs under the whole foothills belt. A number of wells are being drilled on the major anticline which extends from Highwood area to Jumpingpound creek and one well has been abandoned. Three wells listed below are south of the southern boundary of Turner Valley map-area but are on the extension of the major anticline.

Well	L.s.d.	Sec.	Tp.	Range	Notes
[1]Western Alberta No. 1	11	7	17	2	W. 5th mer., drilling
[1]Banner No. 1	6	34	17	3	" "
[1]H. B. Oil and Gas Co	8	1	18	3	" "
Highwood No. 1	3	36	18	3	" abandoned
North West Co	8	35	18	3	" drilling
Warner No. 3	3	28	18	3	" "
Calgary Dev. and Prod	....	21	19	3	" "
Anglo-Pacific	4	27	19	3	" "
Angus	5	33	19	3	" "
Innerfold	2	6	20	3	" "
Gibraltar	4	18	20	3	" "
Richfield	4	25	20	3	" "
Brock	2	35	20	3	" "
Elbow	11	35	22	5	" "
Signal Hill No. 2	9	35	23	5	"

[1]South of Turner Valley map-area.

Some of these wells commence in Blairmore strata and hence at the surface are high structurally. It does not necessarily follow, however, that the possible productive zones will also be penetrated under high structural conditions in these wells since thrust faults may be encountered in drilling. A number of other wells commence in Lower Alberta shales and still others in Upper Alberta strata and, as revealed by the mapping, it is believed a number of these wells will encounter thrust faults and hence it is likely that the Palæozoic limestone will prove to be very deep.

In the case of the Turner Valley anticline the relationship between a well's position and the production of naphtha from the limestone is not well understood. The opinion has been publicly expressed that the naphtha content increases down the dip of the productive horizon and this has led to the hope that light crude oil might be encountered still farther down the dip. It is true that some wells high on the structure show a lower naphtha content than certain wells farther down the flank of the structure, but this is not everywhere the case. The Geological Survey has, however, no exact information on this question, but even if it is so that in Turner valley the naphtha content does increase down the dip, it may be as already pointed out that the same conditions do not hold farther west. In the light of present knowledge, therefore, it is impossible to determine in advance of drilling what areas on any particular anticline are most favourable, although, as already mentioned, the details of the structure within any anticline in all probability determine the locus of oil and gas accumulations.

TURNER VALLEY

Reference has been made to Turner valley in the preceding discussion of stratigraphy and oil prospects. No full account of the detailed structure can yet be given. There are two features of Turner valley, however, which have become apparent as the result of field work done in 1929. The first of these is a thrust fault at the north end which, it is believed, thrusts

Alberta shales over the Edmonton formation, thus having a throw of more than 2,000 feet. This is a strike fault, but it cuts across the north end of Turner valley and for practical purposes is believed to form the northern limit of Turner Valley field. The McDougall Oil Company's well in the SE. ¼, sec. 16, tp. 21, range 3, drilled through a considerable thickness of Belly River strata and probably encountered Alberta shales in the lower part of the well. The samples from the surface to 590 feet are missing and it is not certain that these were of Edmonton strata, though they are assumed to have been. The basis for this assumption is mainly physiographic, the topography of the valley north of the fault showing a remarkable resemblance to the topography of the valley south and west of Priddis which is known to be underlain by Edmonton strata.

The other feature of Turner valley to which it is desired to draw attention is the southern end. On Longview hill, directly south of Turner valley, Belly River strata are exposed and on the southern side of the hill the Belly River strata dip south. Along Highwood river, directly south of Turner valley, Edmonton rocks occur and the anticlinal structure is no longer present. The folding in the Edmonton strata is, however, of a most intricate nature. Longview hill thus forms the southern end of Turner Valley field in the same way as the Belly River ridges on the east and west flanks are spoken of as the limits in these directions.

Between Longview hill at the south end of Turner Valley field and the thrust fault already described at the north end, the distance is approximately 18 miles. Throughout this whole distance the prospects for oil and gas would seem, from a structural point of view, to be quite favourable. The Merland well on the northern flank of Longview hill has given favourable results from the Fernie horizon and the Freehold No. 1 and Invaders No. 1 wells in the northern end have given encouraging results as drilling proceeds. But even under equally favourable structural conditions wells that penetrate the Palæozoic limestone may get quite different results. The amount of production is apparently dependent on the degree of the porosity of the limestone and where a high degree of porosity has been encountered it is possible that it has resulted from a certain amount of local fracturing of the limestone.

NEW BLACK DIAMOND STRUCTURE

The New Black Diamond structure has previously been described in Summary Report 1926, part B. It lies about 2 miles west of Turner valley on Sheep creek and extends to the eastern edge of what is popularly called Waite valley, which occupies a part of the main anticlinal structure extending from Highwood area to Jumpingpound creek. It thus lies between the Turner Valley and the Waite Valley anticlines which normally would be the position of a syncline. The structure at the surface, however, is an anticline with the crest in the NE. ¼ sec. 34, tp. 19, range 3. The rocks exposed on this anticline are Upper Alberta shales. On the west flank, which extends for about a mile west of the crest, the dips rarely exceed 20 degrees. This is an abnormal condition in foothills structures. On the east flank the dips are steep near the crest of the anticline, but a small syncline in which Belly River rocks are present occurs on sec. 2, tp. 20, range 3. East of this syncline there is a relatively narrow belt of westward dipping Alberta shales the dip of which increases to the east until on the eastern part of section 2 the Alberta shales are thrust over the Belly River and occur in juxtaposition with strata that represent the highest part of the Belly River formation. The thrust plane is not exposed, but its position can be very closely determined since the interval between the outcrops of the two formations is relatively small. All exposures of rocks near the assumed position of the fault have a steep dip and for this reason it was assumed that the dip of the fault plane was steep. Drilling has proved, however, that the fault plane does not have a steep dip at depth; wells drilled almost a mile west of the outcrop of the fault have encountered the fault at depths such as show it is a low angle fault with a dip to the west of probably not more than 20 degrees. In the wells Belly River strata were encountered below the fault, although one well drilled into Blairmore before reaching the fault plane. Although this condition was not suspected and has been the cause of much disappointment, it serves to clarify a number of anomalies in regard to the New Black Diamond structure. In the first place the New Black Diamond structure is only a superficial anticline which has resulted from the overthrusting of the surface rocks along a relatively flat thrust plane with a buckling or drag on the eastern edge. This in part explains the steep dips on the eastern flank and the low dips on the western flank. It is known from drilling that the fault plane cuts the strata above it at a low angle, since one well passed from Alberta shales to Belly River rocks when the fault was encountered and another well farther west penetrated a certain amount of Blairmore before passing into Belly river below the thrust plane. Under such conditions, therefore, it would seem that the fault plane has a dip slightly more than the dip of the beds on the west flank of the anticline, a dip that for a mile rarely exceeds 20 degrees and in certain places is considerably less.

As already stated both of the wells which penetrated the fault plane encountered Belly River strata below it. This is interpreted to mean that they passed from a superficial anticline into a syncline. The thrust fault cuts across the western limb of this syncline. Thus, in reality, between the Turner Valley and Waite Valley anticlines there is a syncline as normally would be expected. All wells that drill through the low angle thrust fault in the New Black Diamond area thus drill into a syncline. The thrust fault apparently cuts across the formations that lie above it at an angle slightly greater than the dip of the strata and if toward the west of the New Black Diamond structure the fault has cut into the limestone, it might be possible to get production above the fault plane. Whether within the New Black Diamond structure the fault plane does or does not cut the limestone is impossible to predict since the dip of the fault plane is unknown. From such data as are at present available it would seem that there is very little hope that the limestone lies above the fault plane within the New Black Diamond area; if it does not, the entire New Black Diamond structure is eliminated as far as getting production from the limestone above the fault plane is concerned. The New Black Diamond structure is considered to be limited to the west by a fault just east of the Angus well. This fault is probably a subsidiary fault connecting with the main low angle thrust fault at depth, but nothing is known in regard to how far west the low angle fault extends. Between the Angus well and the fault shown just east of it, the Alberta shale on Sheep creek dips at about 15 degrees. This suggests that the subsidiary fault may also have a low dip. The prospects for production from the Angus well would seem, therefore, to depend on reaching the limestone above the fault plane, a condition that may possibly exist, but concerning which predictions are of little value, on account of the complicated nature of the structure.

PRIDDIS VALLEY AND THE AREA EAST OF TURNER VALLEY

The valley lying west of Priddis is approximately 2 miles wide. It is flanked both to the east and to the west by fairly high ridges and the valley itself though it contains a number of small morainic hills and glacial lakes is relatively flat bottomed. Some interest has been taken in the oil and gas prospects of this valley due presumably to the assumption that it is developed on an anticline. Such, however, is not the case. The strata on the east ridge are Paskapoo sandstones with an easterly dip. Underlying them and occupying the whole valley are Edmonton rocks and on the west ridge are Belly River strata. On the east side of the Belly River ridge the strata dip easterly, whereas on the west side the strata dip westerly. The Belly River ridge thus is the anticline and in this case the anticline forms a ridge rather than a valley due to the presence of hard sandstones which more effectively have resisted the forces of erosion than the softer Edmonton strata lying in the valley to the east. This ridge has not been traced its whole length, but the anticline extends both north and south of the south fork of Fish creek which it crosses in secs. 4 and 5, tp. 22, range 3. North of the south fork of Fish creek in section 8 there is some evidence of faulting in the anticline and strata dipping as high as 70 degrees to the west have been observed. In general, however, the dips are much less and vary in amount between 20 and 55 degrees. To the east on the NE. $\frac{1}{4}$ sec. 4, tp. 22, range 3, is a fault of fairly large throw in the Edmonton formation. There is evidence that this fault continues for a considerable distance southeast and occurs at or near the base of the ridge which forms the east flank of Turner valley in the south part of township 21 and the north part of township 20. In this area the Belly River formation is overthrust onto the Edmonton and consequently the coal seam which occurs farther south on the east flank of the Turner Valley ridge is not found to the north. It is very difficult on account of lack of exposures to trace this fault northwest from sec. 4, tp. 22, range 3, but it is believed to cut across the NE. cor. sec. 31, tp. 22, range 3, and just north of this in the Sarcee reserve the Belly River formation may be overthrust on to the Paskapoo. The fault at this locality occupies a valley between Belly River hills on the west and a Paskapoo ridge on the east. It is possible, though, that there may be a slight amount of Edmonton in the valley, although no outcrops were observed. If a small thickness of Edmonton is present it must, of course, occur between the Belly River and Paskapoo and the throw of the fault would not be so large as would be the case if Belly River were overthrust onto Paskapoo.

The presence of this large fault in Priddis valley where the strata in general have much lower dips than in the foothills farther west implies that other faults of less throw are probably also present, although due to the lack of abundant outcrops their presence cannot be detected. It would be expected, therefore, that if wells should be drilled on the anticline that crosses the south fork of Fish creek in sections 4 and 5 or on the eastern flank of this anticline in Priddis valley, they would in all probability encounter as complicated structural conditions as are met in Turner valley. Wells commencing on the top of the anticline would start drilling near the top of the Belly River formation, or if drilled on the eastern flank of the anticline would start in the Edmonton formation. The position of the well, therefore, would determine the stratigraphic thickness that it would be necessary to penetrate to reach any probable productive horizons. Assuming the Belly River formation to be 2,000 feet thick in this area, a well commencing at the Belly River-Edmonton contact would have to drill the following stratigraphic thicknesses to the various horizons as indicated.

To the top of the Blairmore 4,750 feet
To the Home sand in the Kootenay 5,650 feet
To the Dalhousie sand in the Fernie 5,825 feet
To the top of the Palæozoic limestone 6,050 feet

The actual drilling depth to any of these horizons would depend on the degree of dip of the strata and might, as already pointed out, be influenced by thrust faulting which would further tend to increase the depth. Although drilling to some of these horizons might not be impossible any considerable amount of dip of the strata would put the Palæozoic limestone so deep that it is believed the prospects for oil and gas would not warrant the great cost at the present time. In the area lying east of Turner valley, or in any area in proximity to the foothills where wells commence drilling on the Edmonton or Paskapoo formations, the depths to the horizons indicated above will be increased by the thickness of strata overlying the Belly river. The stratigraphic thickness from the top of the Edmonton to the Palæozoic limestone is believed to be not less than 7,300 feet, so that it is obvious wells commencing in the Paskapoo formation have relatively small chance of reaching the lowest productive zone in Turner valley.

SOME STRATIGRAPHIC SECTIONS IN THE FOOTHILL REGION, BETWEEN BOW AND NORTH SASKATCHEWAN RIVERS, ALBERTA

By C. S. Evans

CONTENTS

INTRODUCTION

During the summer of 1928, a geological party under the direction of the writer traversed some of the main streams of the foothill belt between Bow and North Saskatchewan rivers. The objective was the mapping of outcrops on the lines of traverse and determination of characteristics of the sediments. The traverses were run with plane-table and telescopic alidade, and in some few instances by pace and compass. Dr. F. Foreman acted as chief assistant and Mr. J. F. Caley and Mr. L. G. Millward as assistants.

The routes followed are shown on Figure 1. Work was started on Bow river between Kananaskis and Cochrane; thence the forest ranger trail was followed to Ghost river, township 27, range 7, and exploratory traverses were made between South fork of Ghost river and section 1, township 27, range 7, but within this distance no complete sections were found. The same trail was followed to Little Red Deer river and a traverse made east to section 13, township 29, range 6. From Little Red Deer river the trail was followed up Grease creek, up Harold creek, across a summit to Fallen Timber creek, and from there to Burnt Timber creek. A short section was made on Burnt Timber creek in the northeast corner of township 30, range 9. Traverses were then made along Red Deer river from Williams creek westward to Panther river, and the Panther was traversed westward to Barrier mountain, township 31, range 12. From Panther river the Park trail was followed north to Clearwater river along which an exploratory traverse was made eastward to township 35, range 9. From Clearwater river the Idlewild and Shunda forest trails were followed to Ram river where sections were made in township 38, range 12, and near Falls Cabin, township 36, ranges 13 and 14.

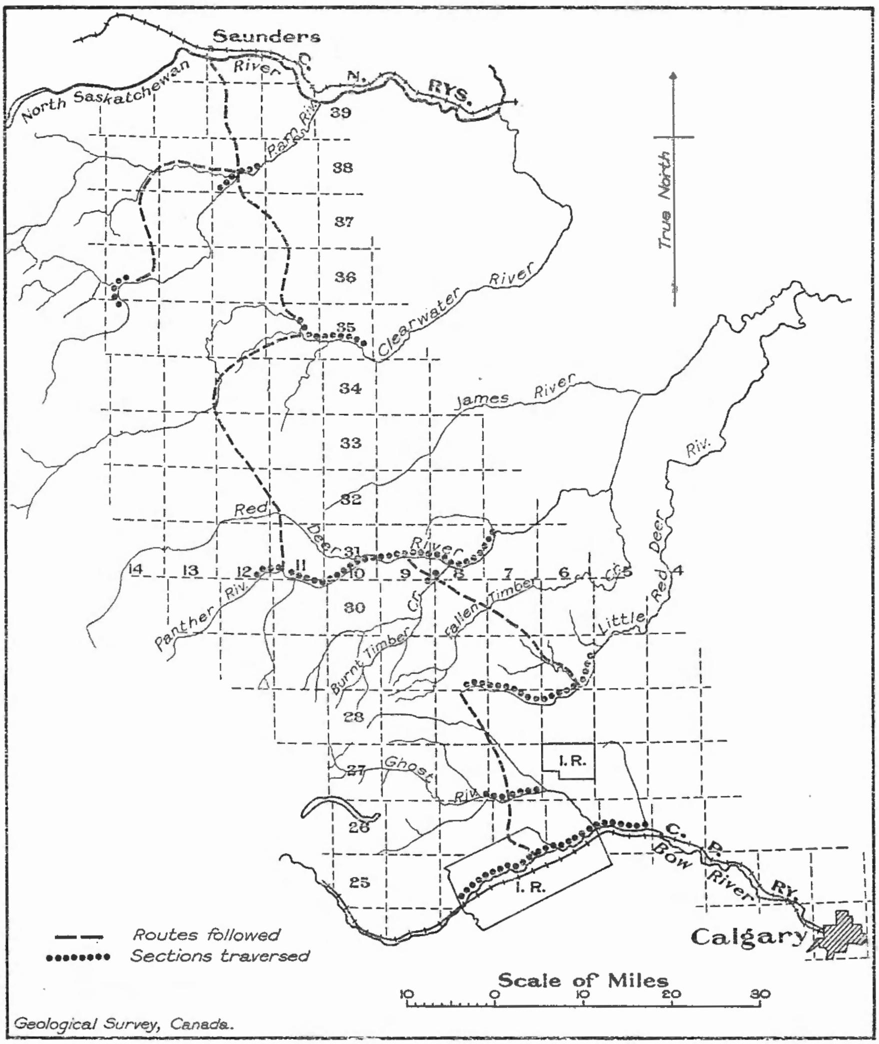

Figure 1. Index map of area to the northwest of Calgary, Alberta, showing routes followed and sections traversed.

Table of Formations

Upper Cretaceous........	Edmonton Belly River	The writer was unable to draw a boundary between these two formations
	Alberta shale [1]	*Upper Alberta.* Includes the so-called Upper Benton and Cardium beds
		Lower Alberta. Includes the so-called Lower Benton
Lower Cretaceous........	Blairmore................	Includes the strata between the base of the Lower Alberta and the base of a pebble conglomerate member. Holds the following typical plant species *Elatocladus smittiana* (Heer); *E. albertaensis* Bell; *Arthotaxites ungeri* Halle; *Sagenopteris mantelli* (Dunker); *S. mclearni* Berry
	Kootenay................	Includes the freshwater strata between the base of the Blairmore and the top of limestone strata carrying Jurassic fossils. Holds the following typical plant species: *Nilssonia schaumbergensis* (Dunker); *Pityophyllum graminaefolium* (Knowlton)
Jurassic..................	Fernie....................	Limestone and shale; lower limit undetermined
	Fernie (?) and older......	Limestone including beds carrying Carboniferous fossils

DESCRIPTION OF SECTIONS

Bow River and Vicinity

One well-exposed section of upper Alberta, from the base of the Belly River down to the uppermost Cardium sandstone member, was found along Oldfort creek. Sections of the Cardium sandstone member were found on Jacobs creek and at the Calgary Power Company's upper dam near Kananaskis. A section from some distance down in Blairmore, down into Fernie or older limestone, was obtained from core samples of Wabash Oil well No. 1, drilled near Kananaskis. No sections of Belly River, Lower Alberta, or Blairmore, sufficiently continuous to warrant measuring, were found along Bow river.

[1] In this volume, page 6B, G. S. Hume has proposed the new term Alberta shale and has defined it as follows.... "Alberta shale is a new name proposed for the series of marine shales, mostly Colorado and Montana in age, occurring in Turner valley and adjoining areas between the Blairmore and Belly River formations".... Hume divides the Alberta shale into Upper and Lower Alberta, the division being drawn at the base of the lowest Cardium bed.

SECTION MEASURED ALONG OLD FORT CREEK

	Feet	Inches	Feet	Inches
Belly River sandstone, base of......................				
....				
Upper Alberta				
Dark shales and sandy shales; some ironstone nodules. *Baculites ovatus* at 120 feet...........	510	–	510	–
Dark shale and sandy shale with bands ½ to 4 inches thick, of calcareous, shaly, fine-grained, crossbedded sandstone. *Scaphites* sp.? at 525 feet..	255	–	765	–
Sandy shale with bands ½ to 6 inches thick of carbonaceous, micaceous, calcareous, shaly, crossbedded sandstone. *Anomia* sp. and a small oyster from 765 to 880 feet.....................	360	–	1,125	–
Black shale, a few sandy layers....................	40	–	1,165	–
Sandy shale, with many crossbedded, shaly, fine-grained sandstone beds. *Scaphites ventricosus* and *Baculites* cf. *anceps* at 1,170 feet...........	50	–	1,215	–
Black shale. *Scaphites ventricosus*.................	40	–	1,255	–
Sandy shale, with numerous layers 3 to 4 inches thick of crossbedded, shaly, fine-grained sandstone; a few ironstone nodules.................	80	–	1,335	–
Black shale with some layers of ironstone nodules. *Scaphites ventricosus*..........................	155	–	1,490	–
Black shale; numerous ironstone nodules. *Scaphites ventricosus* and *S. vermiformis*..............	130	–	1,620	–
Black shale. *Scaphites ventricosus* and small *Baculites*....................................	155	–	1,775	–
Band of fine pebble conglomerate..................	–	8	1,775	8
Sandy shale and shaly sandstone..................	30	–	1,805	–
Hard, even-grained sandstone......................	7	–	1,812	–
Sandy shale and shaly sandstone..................	20	–	1,832	–
Hard, medium-grained sandstone..................	15	–	1,847	–

SECTION MEASURED AT UPPER DAM OF CALGARY POWER COMPANY, NEAR KANANASKIS

The measurable section on Oldfort creek ends at the 15-foot sandstone bed. The section is continued 4 miles to the west at the dam of the Calgary Power Company at Kananaskis, where there is a 16-foot hard sandstone bed, thought to be the same as the 15-foot sandstone bed at the base of Oldfort Creek section.

Upper Alberta (continued)	Feet	Inches	Feet	Inches
Hard sandstone, 16 feet thick, correlated with 15-foot sandstone at base of Oldfort Creek section.				
Hard, dark grey, sandy shale and shaly sandstone; poorly bedded; cliff-forming..................	29	6	1,876	6
Black shale with small, black, chert pebbles......	1	–	1,877	6
Light greenish, grey sandstone, with a few small, ironstone nodules..............................	14	6	1,892	–
Pebble conglomerate; sandy matrix; black chert pebbles with average diameter of ¼ inch......	1	4	1,893	4
Fine-grained, compact, platy, grey sandstone......	9	5	1,902	9
Dark grey, sandy shale..........................	6	4	1,909	1
Very hard, steel-grey sandstone..................	1	6	1,910	7
Dark grey, poorly bedded, sandy shale...........	9	2	1,919	9
Hard, steel-grey sandstone........................	10	–	1,929	9
Alternating thin beds of sandstone, shaly sandstone, and sandy shale.........................	27	11	1,958	–
....				

Lower Alberta

Dark grey, well-bedded shales.

SECTION MEASURED ALONG JACOBS CREEK

On Jacobs creek, 12 miles east of Kananaskis, a section was measured from the shales of Upper Alberta well down into the Lower Alberta. In this section the succession within the Cardium beds differs markedly from that existing in the sections given above.

DESCENDING ORDER

	Feet	Inches	Feet	Inches
Black, thin-bedded, fissile shales holding *Scaphites;* several hundred feet thick.				
Pebble conglomerate with coarse, sandy matrix; pebbles of black, green, grey, and white chert, up to 1 inch in diameter	20	6	20	6
Unconsolidated chert pebbles (as above)	1	7	22	1
Sandstone beds, 3 to 4 feet thick, alternating with sandy shale beds, 3 feet thick. The beds are lens-like	43	6	65	7
Evenly bedded, thin-bedded sandstone and sandy shales	12	–	77	7
Black and dark grey, sandy shales with a few ironstone nodules	48	–	125	7
Covered (apparently shales)	128	–	253	7
Thin-bedded, hard sandstone	5	–	258	7
Hard, grey, sandy shale	12	–	270	7
Black shales and sandy shales; ironstone nodules for several hundred feet, below which Lower Alberta fossils are present.				

In this section it is difficult to draw the boundary between Upper and Lower Alberta. If not drawn at the 5-foot sandstone at 258 feet it, presumably, lies 181 feet higher, at the base of the 12-foot zone of sandstone and sandy shale.

SECTION BASED ON CORE SAMPLES OF WABASH OIL WELL NO. 1, STONEY INDIAN RESERVE

Partial sections of the Blairmore and Kootenay were obtained from core samples of Wabash Oil well No. 1, on the Stoney Indian Reserve, near Kananaskis. Drilling was still continuing in early July when the samples were examined. Later examination by the Supervisory Mining Engineer branch,[1] at Calgary, completed the section well down into the Fernie or pre-Fernie limestones. The coal noted at various horizons is not represented in the core samples, but was reported by W. McMurphy, jun.

Log of Well

	Feet	Feet
Alluvium	106	106
Blairmore Formation		
Alternating sandstone and siliceous shale; 6-inch coal seam reported at 154 feet	69	175
Coal seam, 1 inch thick in shale	1	176
Alternating sandstone and shale; the shale dark grey (sandy) to black, some of it quite carbonaceous. Bedding planes in core samples show low dip; some slickensiding	397	573
Mostly sandstone; some shale and many bands of black chert pebble conglomerate; average diameter of pebbles $\frac{1}{4}$-$\frac{1}{2}$ inch	88	661

[1]Examined by Messrs. C. W. Dingman, G. L. Elliott, and J. G. Spratt.

Log of Well (Continued)

	Feet	Feet
Kootenay Formation		
Alternating sandstone and shale. Many veinlets of calcite. Shales commonly slickensided and drag-folds indicated by rapid variation in attitude of bedding in core samples. Coal at following horizons:		
3 feet coal with thin bands of shale at about 835 feet; 27 feet coal with shale or bone partings at about 889 feet; 7 feet coal at about 894 feet; 5 feet coal at about 1,036 feet; 4 feet coal at about 1,049 feet.		
A fossil plant at 953 feet determined as "probably Kootenay" by W. A. Bell	599	1,260
Fernie Formation		
Black shale with calcareous bands. Hard, limy shale, some pyrite. Belemnite guards at 1,400 feet	150	1,410
Core samples lacking	40	1,450
Black shale, partly calcareous	30	1,480
Fernie (and, or) Pre-Fernie		
Limestone. At 1,480 feet a grey limestone breccia with chert and pyrite at 1,630-1,635 feet, brecciated limestone; a gas blow at 1,629 feet; 6 inches of gypsum at 1,800 feet; finely porous limestone at 1,924-1,940 feet; 1 foot of gypsum at 1,985 feet; 1 foot of gypsum at 2,018 feet	561	2,041

SECTION ALONG LITTLE RED DEER RIVER

The traverse along Little Red Deer river yielded only a partial section of Belly River-Edmonton beds, which was measured between the boundaries of sections 28 and 27, township 28, range 6, and the boundary of ranges 5 and 6, township 29, a distance of 6½ miles. In presenting this section no attempt is made to give details of the alternations of sandstone and shale, for it is quite clear from the exposures that there is marked lateral variation. The shales are light greenish and dark grey to nearly black. The sandstones are chiefly coarsegrained, and light greenish grey, spotted with small, black specks. In the sandstone feldspar is present, but subangular quartz grains predominate and the numerous black specks are of chert. The matrix is commonly calcareous.

	Feet	Inches	Feet
Erosion surface			
....			
Sandstone and shale	500	-	500
Dark, siliceous, and calcareous shale containing two layers of *Unio* and gasteropod shells, practically unaltered; the species present include *Unio danae* and *Campeloma*? sp., regarding which Mr. McLearn states: "If Campeloma must be Edmonton or close to it"	3	-	503
Sandstone and shale	60	-	563
Two 4-inch Unio beds similar to above	1	-	564
Sandstone and shale	470	-	1,034
Layer of cobble conglomerate in coarse sandstone; cobbles to 6 inches in diameter and of blue, cherty limestone, white and red quartzite, and black chert, also many cobbles of igneous rocks with granitoid and porphyritic texture	1	-	1,035
Sandstone and shale	340	-	1,375
Small coal seam	-	6	-
Sandstone and shale. At 2,650 feet; plants assigned to Belly River by W. A. Bell	1,360	-	2,735
12-inch coal seam	1	-	2,736
Sandstone and shale	2,760	-	5,496
....			
Fault			

SECTION ON BURNT TIMBER CREEK

A short traverse along Burnt Timber creek in the northeast corner of township 30, range 9, gave the following section of Alberta shales.

Belly River sandstone, base of	Feet	Feet
....		
Upper Alberta Strata		
Dark grey, sandy shale with a few shaly sandstone beds, grading into black shale with a few scattered ironstone nodules. *Baculites ovatus* at 182 feet and 502 feet. A small drag-fold near top	502	502
Black shale, with scattered ironstone nodules. *Scaphites ventricosus* at 1,140 feet	760	1,262
Black shale, with layers of ironstone nodules. *Scaphites vermiformis* and small *Baculites* at 1,540 feet. A slip at 1,365 feet.	450	1,712
Hard, grey sandstone with *Cardium pauperculum*	25	1,737
Hard, grey, siliceous shale and shaly sandstone with two 10-inch bands of ironstone nodules	180	1,917
Hard, grey sandstone	49	1,966
Grey, sandy shale	13	1,979
Hard, grey sandstone	65	2,044
Lower Alberta Shale		
Dark grey, sandy shale with a few ironstone nodules. *Placenticeras* sp. at 2,171 feet	127	2,171
Black shale with occasional thin, shaly sandstone layers. *Inoceramus labiatus* and *Prionotropsis* sp. at 2,770 feet and 2,970 feet	1,135	3,306
Blairmore		
Hard, greenish sandstone and shale to fault	705	4,011

SECTIONS ON RED DEER RIVER

Two sections of Belly River-Edmonton beds were made along Red Deer river. The first was made between a point 1·5 miles east of Red Deer Ranger station and a point just west of Boundary cabin, a distance of about 6 miles. This section was measured across a wide, simple syncline and gave a thickness of 8,063 feet. The second section was measured between Boundary cabin and Williams creek. It was measured across an anticline and a syncline and gave a thickness of 8,720 feet. This thickness should be reduced somewhat due to close folding of beds in the trough of the syncline. The first section is given below, and details of alternations of sandstone and shale are omitted.

Erosion surface	Feet	Feet
....		
Alternating shale and sandstone. Freshwater pelecypods and deciduous leaves at 80 feet. Deciduous leaves at 140 feet. Two-inch coal seamlet at 480 feet	820	820
Coal, 9 inches; shale, 12 inches; coal, 3 inches	2	822
Sandstone and shale. Several 1-foot bands of conglomerate holding cobbles up to 8 inches in diameter, mostly of quartzite and shaly sandstone beds with *Unios* and *Physa* at about 1,722 feet. Four feet of coarse sandstone with red quartzite and white chert pebbles and cobbles with freshwater pelecypods at 2,222 feet	1,420	2,242
Sandstone and shale	2,080	4,322
Coal seam	1	4,323
Sandstone and shale. Several 1-foot beds of pebble conglomerate at 7,423 feet	3,740	8,063
....		
Upper Alberta, top of		

A section of Upper Alberta was measured in a broad syncline displayed along Red Deer river west of Red Deer Ranger station.

	Feet	Feet
Erosion surface		
....		
Upper Alberta		
Crumbly, sandy shales. *Baculites ovatus* at 180 feet............	380	380
Shale becoming less sandy and containing some large ironstone nodules. *Baculites ovatus* at 385 feet and 610 feet...........	240	620
Sandy shale with numerous thin, shaly, calcareous, fine-grained sandstone bands containing *Anomia* sp. and small oyster-like forms. *Baculites* cf. *anceps* at 1,460 feet...............	880	1,500
Dark shale with bands of ironstone nodules. *Scaphites ventricosus* at 1,680 feet..............................	380	1,880
Grey, medium-grained sandstone. Some thin beds with much white mica. *Cardium pauperculum*........................	12	1,892
Grey and buff-weathering, medium-grained sandstone in beds of 1 to 8 inches, alternating with beds 2 to 12 inches thick of shaly sandstone.......................................	10	1,902
Shaly, fine-grained sandstone and sandy shale, a few ironstone concretions...	57	1,959
Dark, sandy shale; some ironstone nodules in top 50 feet........	97	2,056
Shaly, irregularly bedded, fine-grained sandstone with 1 to 4-inch beds of medium-grained, crossbedded sandstone......	9	2,065
Shaly, very fine-grained sandstone; some ironstone concretions..	40	2,105
Sandy, dark shale with a 1-inch band of pebble conglomerate holding ¼-inch black chert pebbles.........................	28	2,133
Shaly, fine-grained sandstone and sandy shale with much mica..	30	2,163
Very hard, medium-grained sandstone; irregular markings (worm burrows or roots?)................................	6	2,169
Shaly, fine-grained sandstone and sandy shale, contains white mica..	15	2,184
Fine to medium-grained, light grey sandstone; crossbedded; very clean...	20	2,204
....		
Lower Alberta		
Dark shales		

A section of Blairmore was measured along Red Deer river just east of Red Deer Ranger station.

	Feet	Feet
River gravels thought to overlie Lower Alberta		
....		
Massive, greenish sandstone with interbeds of greenish, siliceous shale and dark grey shale. Two collections of plants from 120 feet and 130 feet, respectively, identified by W. A. Bell as Lower Blairmore.....................................	130	130
Alternating sandstone and greenish shale.......................	135	265
Greenish and dark grey, siliceous shale with 2 to 10-foot massive sandstone layers. Many carbonaceous plant remains......	180	445
Greenish sandstone outcrops with a few showings of dark grey and greenish shale; mostly covered between sandstone layers...	580	1,025
Pebble conglomerate..	3	1,028
Mostly covered; a few small outcrops of shale..................	450	1,478
Sandstone and dark grey and greenish shale with six bands of sandy, calcareous rock containing very many gasteropods and some freshwater pelecypods..........................	400	1,878
Pebble conglomerate—mostly black chert pebbles—also quartzite, white chert, and white limestone, average diameter ½–¾ inch...	24	1,902
....		

Thrust fault over. Belly River beds at base.

PANTHER RIVER

Three incomplete sections of Kootenay were measured on and near Panther river in township 31, range 11. These sections show that in this locality, which is within the Rocky mountains, the minimum thickness of Kootenay is 1,600 feet. A Kootenay flora was identified by W. A. Bell from the strata containing the following coal seams.

	Feet	Inches
Upper Seams		
Sandstone	-	-
Coal	1	4
Sandstone	6	-
Coal	-	10
Sandy shale	2	-
Coal	-	11
Black shale	3	5
Coal	5	11
Black shale	-	-
Lower Seam (200 feet lower down)		
Sandstone	-	-
Black, sandy shale	4	2
Coal	3	6
Black shale	4	6

No coal was found in a thousand feet of Blairmore exposed above a 24-foot pebble conglomerate bed.

SECTIONS ON RAM RIVER

Section along main Ram, and on South Fork, rivers in township 38, range 12.

	Feet	Inches	Feet
Erosion surface			
....			
Blairmore			
Reddish brown weathering, dark grey, sandy shales; fish scales only fossils (this may be Lower Alberta)	124	-	124
Conglomerate with 6-inch cobbles of chert and quartzite	1	8	126
Alternations of greenish shale and sandstone	256	-	382
Heavy-bedded, coarse, crossbedded sandstone	36	-	418
Alternations of shale and sandstone. Coal in 1 to 2-foot seam at 472 feet	108	-	526
Heavy-bedded, coarse, crossbedded sandstone	30	-	556
Alternations of sandstone and shale	272	-	828
Coarse, crossbedded sandstone, pyrite concretions	24	-	852
Nine feet of coal; a 2-inch shale parting	9	-	861
Alternations of olive-green shale and thin sandstone beds; flora identified as lower Blairmore by W. A. Bell	86	-	847
(Feet, Inches) Shale 3 1; Coal 7 2; Shale 2 5; Coal 3 2; Shale 4 4; Coal - 4; Shale - 6	21	-	968
Alternation sandstone and shale	122	-	1,090
Coarse, crossbedded sandstone. Lower part contains many flat ironstone concretions at all angles to bedding; above this the sandstone contains many shale fragments	88	-	1,178
Alternations of sandstone and shale	65	-	1,243
Coarse, yellow, crossbedded sandstone	10	-	1,253
Pebble conglomerate. Black chert. Pebbles 1 to 2 inches in diameter, of rose quartzite and grey limestone	1	-	1,254

	Feet	Inches
Shale	3	1
Coal	7	2
Shale	2	5
Coal	3	2
Shale	4	4
Coal	-	4
Shale	-	6

	Feet	Inches	Feet
Alternations of thin bands of shale and sandstone..........	140	-	1,394
Mostly shale; five 3 to 7-foot beds of fine sandstone. One calcareous band with freshwater gasteropods and pelecypods......	142	-	1,536
Massive sandstone beds. One bed contains pelecypods; *Unio* cf. *hamili* "probably Blairmore" according to F. H. McLearn......	40	-	1,576
Dense, black shale containing great numbers of small freshwater pelecypods and gasteropods....................	10	-	1,586
Alternations of sandstone and shale.......................	30	-	1,616
Two 1-foot bands of dense, black shale with small, freshwater pelecypods and gasteropods....................	3	-	1,619
Crossbedded, calcareous, and shaly sandstone and sandy shales. A few ½-inch coal seamlets...................	94	-	1,713
Alternations of sandstone and shale; 4 to 6-inch pyrite concretions in base. A Lower Blairmore flora according to W. A. Bell..	38	-	1,751
Dense, black shale, freshwater gasteropods and pelecypods	3	-	1,754
Alternations of grey sandstone and sandy shale; ½-inch discontinuous coal seamlets; some ironstone concretions. Lower Blairmore flora according to W. A. Bell.........	120	-	1,874
Covered; probably shale................................	60	-	1,934
Coarse, crossbedded, light grey sandstone, some pebble conglomerate..	38	-	1,972
Pebble conglomerate: chert and fine, white, cherty limestone pebbles, average diameter ½ inch up to 2 inches..	45	-	2,017

....

Kootenay	Feet	Feet
Mostly siliceous shale, some thin sandstone which contains much white mica..	85	2,102
Brownish, sandy shale with mica..............................	14	2,116
Covered..	10	2,126
Sandy, dark shale and very hard, crossbedded sandstone; contains mica, some pyrite nodules. A few poorly preserved plant remains...	42	2,168
Covered..	56	2,224

....

Fernie		
Fetid, dense, bluish grey, cherty limestone. Several more limy bands from which *Trigonia* sp., *Rhynchonella* sp., and a species of *Oxytoma* with very wide posterior wings. Placed by F. H. McLearn in Jurassic—probably Fernie..........	70	2,294
Fernie (and, or) Older		
Covered..	96	2,390
Dense, dark, fetid limestone; weathers blue and white; some of it shaly, sandy, cherty; 4 to 5 inches bedding joints....	90	2,480
Dense, white and light grey, fetid limestone, 1-24-inch bedding joints; some of it brecciated..............................	84	2,564
Covered..	156	2,720
Very porous, light grey limestone............................	24	2,744
Finely crystalline limestone.................................	92	2,836
Coarsely crystalline limestone. Carboniferous brachiopods....	20	2,856
Hard, grey, cherty limestone................................	48	2,904

SECTION NEAR FALLS CABIN, SOUTH FORK OF RAM RIVER, TOWNSHIP 36, RANGES 13 AND 14

Crumpled beds close below Belly River

	Feet	Feet
Upper Alberta Shale		
Sandy shales, some shaly, fine sandstone beds; *Scaphites* at 440 feet	490	490
Dark grey, calcareous shales grading down into black shales with nodules	180	670
Sandy shale, some nodules. *Scaphites ventricosus*, *Inoceramus umbonatus*, small *Baculites* at 1,050 feet	380	1,050
Black shale, layers of nodules about every 5 feet in lower part. *Scaphites ventricosus*, *Scaphites ventricosus* cf. *stantoni;* small *Baculites* at 1,440 feet	630	1,680
Sandstone with mica, some layers of shaly sandstone	33	1,713
Dark grey and greenish grey, sandy shale; occasional ironstone band	110	1,823
Very hard, shaly sandstone	21	1,844
Relatively soft, black, sandy shale	36	1,880
Heavily bedded, hard, grey sandstone containing mica at top. Irregular, root-like markings	32	1,912
Dark grey, sandy shale; a few ironstone nodules at top	22	1,934
Fine, hard sandstone, a 1-inch ironstone band	30	1,964
Lower Alberta Shale		
Black shale with occasional 10-inch bands of calcareous, sandy shale. Nodules 2 feet in diameter at base. *Inoceramus labiatus*, at 2,720 feet; *Prionotropis* sp. at 2,880 feet. Small crumples at 2,310 and 2,960 feet, for which 70 feet have been allowed. Beds crumpled at base of section and quite sandy, probably close to Blairmore contact	1,280	3,244

RECONNAISSANCE SURVEY OF FOOTHILL AREA IN WAPITI RIVER BASIN, ALBERTA

By C. S. Evans and J. F. Caley

Illustration

A geological reconnaissance of Wapiti River basin was carried out during the summer of 1929. The senior writer was unable to be in the field, and so this report is the result of the junior writer's field work. Mr. A. C. Nixon acted as assistant.

The area covered lies along Wapiti river, from Big Mountain creek west to the mouth of Nose creek and from there south to the 16th base line. Grande Prairie, on the Northern Alberta railway, about 6 miles north of Wapiti river, was the starting point. A pack train was used, since travel can be only along trails south of Wapiti river. Wapiti sheet No. 412, on which sectional surveys are shown south to the Wapiti, and Simonette sheet No. 362, which shows the 16th and 17th base lines, were used to tie the pace and compass traverses made during the summer.

CHARACTER OF THE COUNTRY

In a general way the area shows characteristic foothill topography. The northeastern part, along Wapiti river, is fairly flat, but the surface becomes gently undulating towards the southwest, where the hills become higher forming the true foothills. In the northeast the elevation is about 2,500 feet and this gradually increases towards the south and west where some of the hills attain an elevation of about 6,000 feet. For the most part the area is quite thickly wooded with fairly small poplar, pine, and spruce. There is considerable muskeg. Small flats and meadows along some of the streams are the only open spaces.

The area drains to Wapiti river by Iroquois, Pinto, and Nose creeks, and by Narraway river (called Crooked river on Simonette sheet). All these streams flow north. Their valleys in most places are quite wide, but the streams have become sharply incised within the wider valleys; a feature that is more marked towards their mouths. In many places the banks so formed are cliff-like and as much as 200 feet high. There are a few small lakes.

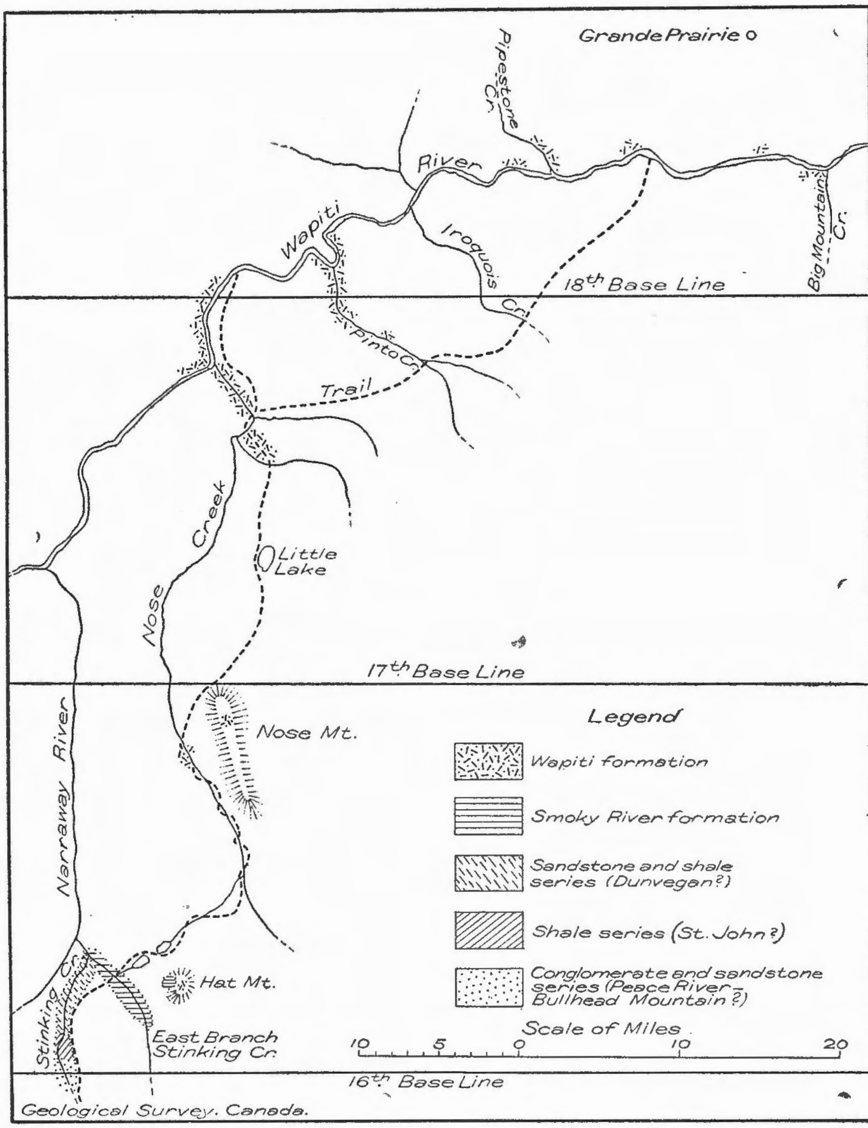

Figure 2. Sketch map of Wapiti River area, Alberta.

GENERAL GEOLOGY

All the rocks observed in this area, with the exception of some limestone at the extreme southwest corner, are of Cretaceous age, and consist of sandstone and shale, with some conglomerate and a few coal seams. Both marine and freshwater strata are represented. The complete succession was not observed. That part of the area northeast of Hat mountain is underlain by beds having quite low dips. Southwest of Hat mountain the strata are highly disturbed.

WAPITI FORMATION

These strata outcrop along Wapiti river westward to the mouth of Nose creek and were traced southward along Nose creek to a place just west of Nose mountain. Sandstones were found on the summit of Hat mountain and are considered to belong to the Wapiti formation, although they may be a part of the Smoky River formation.[1]

Wapiti strata form Nose mountain in townships (as projected) 63 and 64, range 11.

In general the formation consists of sandstone and shale and some coal seams. The sandstone on fresh fracture is light grey and it varies from medium to coarse grain. It is crossbedded and contains bone fragments in many places. Along Wapiti river it weathers to a cream colour and in many places presents a semi-detached, pillar-like structure. On Pinto creek this form of weathering is less common and the colour is darker. The shale is mostly greenish grey, shows little evidence of bedding, and crumbles easily when weathered. On Pinto creek, about 3 miles downstream from the trail crossing, two seams of coal were found, one 2 feet and the other 3 feet thick. One thousand feet farther downstream a 3-foot seam and a 4-foot seam were found. On Nose creek 1 mile downstream from the trail crossing a 3-foot seam and two 18-inch seams were found.

The thickness of this formation was not determined; that part of it exposed between Wapiti river and Nose mountain is estimated to be 1,100 feet thick.

SMOKY RIVER FORMATION[2]

Below the Wapiti sandstone is a black shale series with some sandstone in its upper part. This shale outcrops on the lower, west slope of Hat mountain and is also exposed along the east branch of Stinking creek from its mouth upstream for about 3 miles. Several hundred feet of grey, cliff-forming sandstone is exposed at the top of Hat mountain. Below this is about 100 feet of dark grey shale, black shale, and a sandy shale. The shales rest on 8 inches of black-chert-pebble conglomerate that lies on a 25-foot massive sandstone member. Below the sandstone is dark grey shale with ironstone nodules, which contains a *Scaphites ventricosus* fauna. Still lower down in this shale member, but to the west on Stinking creek, an *Inoceramus*, resembling *labiatus*, was found. The shale below the 25-foot sandstone member is thought to be the lower shale of Smoky

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1918, pt. C, p. 2.
[2]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1918, pt. C, pp. 1-7.

River formation;[1] the 25-foot sandstone is correlated with the Badheart.[1] The shale strata above the sandstone may be the upper Smoky River shales. As previously mentioned, the sandstone on the top of Hat mountain may be Wapiti.

SANDSTONE AND SHALE SERIES (DUNVEGAN?)

Below the shale series described as Smoky River is a series of sandstones and dark shales. This series outcrops along Stinking creek from the junction of the east branch to near the 16th base line. The contact between this series and the Smoky River shales is sharply defined near the mouth of the east branch of Stinking creek. The series consists of zones of massive sandstone alternating with somewhat thicker zones of thinner bedded sandstones and dark shales. The thinner bedded sandstones are grey and of medium grain and in many places contain a large amount of clastic mica. The thick sandstones are interbedded with grey shale that contains poorly preserved plant remains. These sandstones are medium to fine grained, crossbedded, and contain some coal seamlets. One fragment of an *Inoceramus* was found in the thinner bedded part of this series. Both marine and freshwater sedimentation are indicated. This series may correspond to the Dunvegan.[2]

SHALE SERIES (FORT ST. JOHN?)

Below the sandstone and shale series, and forming with it a continuous outcrop on Stinking creek, is a thick zone of dark shale. The shales are commonly paper-thin and contain bands of ironstone. No fossils were found. This series may correspond to the Fort St. John.[3]

CONGLOMERATE AND SANDSTONE SERIES (PEACE RIVER—BULLHEAD MOUNTAIN?)

Just south of the 16th base line on Stinking creek a 50-foot bed of conglomerate outcrops. This conglomerate has chert and quartzite pebbles averaging 1 inch in diameter; the largest seen measured 8 inches. Below the conglomerate is sandstone that contains plant remains and some thin ribbons of coal.

This sandstone outcrops for a mile south of the 16th base line on Stinking creek. It is probably of Lower Cretaceous age corresponding to Peace River[4] or Bullhead Mountain[5] formations.

[1]McLearn, F. H.: Idem.; and Geol. Surv., Canada, Mus. Bull. 42, p. 119 (1926).

[2]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1918, pt. C, pp. 2-4.
Spieker, E. M.: Province of B.C. Dept. of Land, Rept. of Oil Surveys in the Peace River District, 1920, pt. K, pp. 13 and 18.

[3]McLearn, F. H.: Idem.
Spieker, E. M.: Idem.

[4]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1917, pt. C, pp. 14-21.

[5]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1917, pt. C, p. 16.

OIL AND GAS PROSPECTS IN CENTRAL SASKATCHEWAN

By P. S. Warren

CONTENTS

INTRODUCTION

During the field season of 1929, the writer conducted geological investigations in central Saskatchewan, covering an area included in the Moose Jaw, Regina, Yorkton, and Elbow sectional sheets, the western half of the Kindersley sectional sheet, and that part of the Tramping Lake, Saskatoon, Humboldt, and Nut Mountain sectional sheets south of the 52nd parallel of latitude. The investigation comprised a continuation of that commenced in the previous year in the area covered by the Rush Lake, Swift Current, and parts of the Red Deer Forks and Maple Creeks sectional sheets. The writer was ably assisted during the 1929 field season by Mr. M. B. B. Crockford.

The area lies partly on the second and partly on the third prairie level. Missouri coteau, or, as it is more generally termed, the Coteau, forms the division between the two levels. The area under consideration lies, for the most part, on the second level.

The Coteau is the most significant physiographic feature of the area. It has a general northwesterly trend with an irregular, indented escarpment. It enters the area from the south about range 20, west of the 2nd meridian, and crosses the northern border at about range 15, west of the 3rd meridian. The significance of the Coteau as a physiographic feature is greatly enhanced by the great heaps of glacial moraine that have been piled upon it. It is considered that at least half the height of the escarpment is due to the glacial drift. This feature is best observed by viewing the Coteau from the west, whence it appears as a series of rough, morainal hills. The height of the escarpment varies in different places. In the southern part of the area, the great morainal heaps stand at a height of about 1,000 feet above the level plain to the east. In the northern part, the height has diminished to from 200 to 300 feet above the plain.

The area to the west of the Coteau is, in general, much rougher than that to the east. Certain isolated areas stand above the level of the plain, such as Touchwood hills, Last mountain, and Allan hills. They are all heavily covered with glacial drift in the form of terminal moraine.

Several large coulées are cut through the level plain of the second prairie level and are now generally occupied by small streams or lakes. They trend, for the most part, in a southeasterly direction and were probably formed during the retreat of the glacier. The most significant of these coulées are Qu'Appelle valley and the valley of Last Mountain lake.

South Saskatchewan river is the largest stream flowing through the area, but only a very small part of the area drains to this river. The drainage of the greater part is to the east and southeast and follows, for the most part, post-glacial drainage channels. Drainage, on the whole, is poor, and the country is dotted with many "alkali" lakes and sloughs.

GENERAL GEOLOGY

The area studied is underlain by a flat-lying series of Upper Cretaceous sediments which are, for the most part, shales and sandstones. Owing to the level nature of the country and the heavy covering of glacial drift, exposures of these beds are rare over most of the area. The various formations encountered during the investigation are tabulated below:

Table of Formations

Formation	Description	Thickness
		Feet
	Glacial drift; boulder clay, sand, and gravel	20–200
	Light-coloured sands, shales, and clays with incipient coal seams	50+
Bearpaw	Dark grey to black shales with ironstone nodules, occasionally sandy	400+
Belly River	Light-coloured sands and shales with occasional indurated bands	400+

BELLY RIVER

The Belly River beds, as exposed in this area, show considerable lithological variation. For the most part, the beds observed probably represent the Pale beds—the uppermost formation of the Belly River series—but since the beds in some of the exposures differ considerably in lithology from the typical Pale beds, it seems preferable not to employ that name for the Belly River beds in this area.

Belly River beds outcrop in the vicinity of Herschel, on South Saskatchewan river at Outlook, and farther east near Hanley. The exact distribution of these beds is difficult to ascertain, due to lack of exposures. They undoubtedly underlie Allan hills in their eastward extension, as small gas seepages are reported from that vicinity.

The Belly River beds, as exposed in the area, contain a marine fauna which was obtained both at Herschel and Outlook. Such a fauna marks a change in the character of deposition of the upper part of the Belly

River—from freshwater deposits in exposures farther west in Alberta, to marine deposits in its eastern extension. It is evident that the Belly River beds thin rapidly eastward as the sandstones are replaced by shales.

The Herschel exposures reveal about 30 feet of alternating beds of light grey argillaceous sandstone and sandy shales, with one bed of indurated, buff-coloured, rusty-weathering sandstone. A thin bituminous seam is developed in the upper part of the sequence. This development strongly resembles the Pale beds.

The exposures at Outlook and Hanley show buff-coloured, slightly indurated sandstones and sandy shales with an admixture of grey shale. Although of practically the same horizon as the Herschel outcrops, the character of the formation is sufficiently altered to preclude the use of the name Pale beds.

In the northeast corner of the area, in tp. 25, range 1, W. 2nd mer., dark grey and black shales are exposed in road cuts in the valley of Swan river. These shales seem to represent a horizon beneath the Pale beds, probably corresponding to the Lea Park shale of Battleford area, which they resemble lithologically. As the outcrops are isolated, no definite correlation can be attempted at the present time.

BEARPAW

The Bearpaw is a monotonous series of dark grey to black, bentonitic shales, generally containing an appreciable amount of sand. Clay-ironstone nodules are characteristic of most of the formation, many occurring in well-marked zones, and crystals of selenite are remarkably abundant at certain horizons. On the weathered surface, all traces of its shaly character are lost through the action of rain on the bentonite content of the shale. The expansion of the bentonite in the presence of water, and the subsequent drying process, usually obliterate all traces of stratification and produce a smooth, homogeneous surface, finely dissected by mud-cracks. Structural features are, therefore, extremely difficult to ascertain.

The clay-ironstone nodules lend a considerable relief to the monotonous character of the shale. The occurrence of these nodules is exceedingly sporadic. In certain areas they are abundant and may occur in well-defined beds, whereas in other areas they are entirely absent. The impression was obtained that the nodules occurred only in certain horizons, though they may be absent in these horizons in certain areas. Another type of nodule is the sandy variety. These nodules vary greatly in character, and are found only where the Bearpaw assumes a sandy character. They are more often fossiliferous than the clay-ironstone nodules, but they are not nearly so plentiful.

The Bearpaw shale, in places, contains an appreciable quantity of sand. In such places the shale is usually light grey on the weathered surface and clay-ironstone nodules are typically absent. The upper part of the Bearpaw shale as observed in the slump blocks in Dirt hills, where it is immediately overlain by post-Bearpaw beds, is quite sandy. The sand is of a rusty colour and occurs in thin layers in the shale, giving a ribboned appearance to the formation. This appears to be a Fox Hills phase representing shallow water conditions. Marine fossils of Montana age have been collected from these beds.

The Bearpaw shale is fossiliferous, though sparingly so. The fossils usually occur in the nodules, but only in abundance in very definite horizons or localities.

The Bearpaw shale is widely spread over the area. It is well exposed on South Saskatchewan river as far north as Outlook, where it is observed overlying the Belly River beds. Exposures were also observed along the banks of the southern part of Last Mountain lake and along the upper reaches of Qu'Appelle valley. The shale forms "badland" topography south and west of the town of Milestone, where the best exposures of the formation in the area can be obtained. The formation is seldom exposed in the Coteau.

The northern limit of Bearpaw shale may be represented by a line passing in a general easterly direction immediately south of the town of Outlook. North of this line the Belly River beds extend eastward, but apparently thin out and disappear just east of Allan hills. East of this point the Bearpaw boundary cannot be distinguished, as exposures fail completely, and even if present it is doubtful if the Bearpaw could be distinguished from the underlying Lea Park shale.

POST-BEARPAW

For the purpose of this report, all the freshwater beds lying above the Bearpaw shale are grouped together. This course is adopted partly on account of difficulties in applying classifications of these beds as used in different areas, and partly because all these beds, as observed in this area, with the possible exception of the white clay beds, seem to belong to the same lithologic unit.

No good section could be obtained. The strata are exposed in several places along the Coteau south of the main line of the Canadian Pacific railway, but without exception the exposures showed faulted beds. They were observed in place, however, along the banks of lake of the Rivers, but only a thin section is exposed.

They consist of alternating beds of shale and sandy shale, with some beds of consolidated sandstone. The strata are typically light grey in colour, though the more strongly cemented sandstone beds are buff-coloured. A development of typical white clay[1] beds was present in practically all exposures. At least one bituminous layer is present, which, in places, assumes the proportions of a workable coal seam.

It is by no means certain that the white clay beds all occur at the same horizon in this area; in fact, an exactly opposite impression was obtained, though no definite proof was forthcoming. The lack of any considerable section of the formation in one exposure mitigated against any detailed stratigraphic study.

One interesting observation of the white clay beds in the slump blocks at Claybank gives a definite clue regarding the correlation of that bed with occurrences in other areas. A sedimentary break was observed at the top of the white clay bed where a distinct disconformity cuts out a good portion of the white beds, which are replaced by a buff weathering

[1]It has been customary to apply the name Whitemud to any development in Saskatchewan of refractory white clay, but it is now known that the white clays do not everywhere occur at the same horizon.

sand. McLearn mentions a similar break above the white clay beds at East End[1] and the evidence seems sufficiently convincing to allow for a correlation of the white beds in the two areas.

A set of sandy beds with lithological characteristics very like the post-Bearpaw beds and with which they have been correlated are exposed on Avonlea creek several miles east of Claybank. A development of white clay in one locality is considered additional proof that they are post-Bearpaw.

GLACIAL DRIFT

The entire region is mantled by heavy deposits of glacial drift, which vary greatly in character and thickness in different parts. On the more elevated parts, such as Missouri coteau, Last mountain, and Touchwood hills, the drift assumes the character of a terminal moraine comprising great, irregular hills of, usually, unsorted boulder clay. In the lower areas, the surface of the country is exceedingly flat and the drift well sorted. Intermediate areas occur where the moraine has been only partly modified, producing a low, rolling topography. Beds of gravel are much in evidence in such areas, in some cases covering large areas, and much utilized for road material.

STRUCTURAL GEOLOGY

The general structure of the formations underlying the area is extremely simple. The dip is to the south and east and is very gentle. The nature of this dip can be obtained only over a broad area in reference to the Belly River beds. These beds are exposed at Herschel, tp. 33, range 17, W. 3rd mer., at an elevation of 1,960 feet. It is believed that the horizon represented at this place is near the top of the series. The top of the Belly River sandstone can be observed on South Saskatchewan river at Outlook at an elevation of about 1,650 feet. At Moose Jaw, a bore-hole passed through sandy beds believed to be Belly River, the top of which stands at an elevation of 1,318 feet. Another bore-hole to the south and east of Moose Jaw, tp. 15, range 19, W. 2nd mer., pierced the same set of beds at about the same elevation. These data show the average dip of the Belly River-Bearpaw contact to be about 4 feet a mile in a southeasterly direction, the more pronounced dip being in the northwesterly part of the section.

Little information could be obtained regarding structural features with reference to the post-Bearpaw beds. Dyer has shown that over a wide region the general dip of the Whitemud beds incorporated in this formation is to the east.[2] Owing to the slumping and faulting of the beds and the possibility of the occurrence of more than one Whitemud bed in the post-Bearpaw in the area, it is doubtful if any observations on the elevations of the white beds are of definite value.

The base of the Whitemud beds on the west side of lake of the Rivers, in sec. 3, tp. 11, range 28, W. 2nd mer., is at an elevation of 2,240 feet. In sec. 28, tp. 10, range 26, faulted post-Bearpaw beds contain Whitemud beds at an elevation of 2,540 feet. At Claybank the post-Bearpaw beds are not in place, but the Whitemud beds must occur above an elevation of

[1]Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 21.
[2]Geol. Surv., Canada, Sum. Rept. 1926, pt. B, p. 30.

2,340 feet, as undisturbed Bearpaw shale occurs at this elevation. Northwest of Claybank on the Coteau, faulted Whitemud beds are exposed at an elevation of 2,330 feet. East of Claybank on Avonlea creek flat-lying Whitemud beds are at an elevation of 1,975 feet.

These figures, making allowance for inaccuracies due to the faulted nature of the beds, show that the dip of the post-Bearpaw is not in accord with the regional structure in this area. In fact, the data so far obtained are rather indicative of structural features of considerable magnitude in the southern part of the Coteau within this area. The data, however, are not sufficient to give any indication of the character or size of the structure.

At Claybank, interest has centred mostly on a succession of fault blocks occurring along the face of Dirt hills. The fault blocks dip to the northwest and strike a few degrees east of north. The succession of strata exposed in each block includes some 50 feet of the upper sandy part of the Bearpaw and post-Bearpaw beds, making a total thickness of over 200 feet. A Whitemud horizon is generally present about 100 feet above the top of the sandy member of the Bearpaw. The base of one fault block exposed in a quarry shows an excellent example of a drag-fold.

On the eastern side of Dirt hills, the beds are flat-lying and presumably undisturbed. In sec. 23, tp. 12, range 24, W. 2nd mer., the top of the sandy member of the Bearpaw is exposed at an elevation of 2,350 feet. The post-Bearpaw beds have been eroded for the most part, but using the data obtained in the fault blocks at Claybank, the horizon of the Whitemud beds in this locality should be about 2,450 feet. This is the highest elevation of the Whitemud horizon known in this region, though in one of the slump blocks at Claybank the horizon is but slightly lower and about 2 miles to the south in section 12 of the same township the same horizon appears to be about 50 feet lower.

Exposures of the Whitemud and associated beds were observed also on Avonlea creek about 7 miles to the east of this point. There, the Whitemud beds are at an elevation of 1,975 feet, demonstrating a dip to the east of nearly 70 feet a mile. It is very doubtful, however, if the dip between these two points is regular, but this could not be ascertained for certain on account of lack of exposures.

On the east side of township 22, Bearpaw is exposed at a higher elevation than the Whitemud beds on Avonlea creek about 2 miles to the west, demonstrating a sharp rise of the strata to the east of the creek. The change from the flat-lying post-Bearpaw beds to the Bearpaw shale is so sudden that faulting is suspected.

ECONOMIC GEOLOGY

In an area such as this where the rocks represented are entirely sedimentary, the features of economic interest are limited to non-metallic deposits. Of these, the deposits of sodium sulphate and clay have been the subject of previous investigations by various workers. The increasing demand for road metal for surfacing dirt roads has provoked interest in the large glacial gravel deposits which appear to be generously distributed throughout most of the area. The development of the oil and gas fields in Turner valley and at Wainwright in Alberta has promoted considerable interest in prospecting, by means of drilling, for oil and gas—so far with little success. Some of the more important of these prospects will be mentioned in some detail below.

HERSCHEL WELL

The Rosetown Lease Holding and Development Company, Limited, has drilled a well near the town of Herschel in legal subdivision 16, sec. 4, tp. 31, range 17, W. 3rd mer. The hole was drilled to a depth of 2,100 feet, where it was abandoned. The company is preparing to continue drilling to a greater depth. A little gas and showings of oil were reported.

Grey sandstones and sandy shales are exposed in the neighbourhood of the well, which are identified with the Pale beds of the Belly River series. Sandy beds with a considerable intermixture of shale were penetrated by the drill to a depth of 370 feet. Within 100 feet of the bottom, the drill again encountered sandy beds, according to the driller's log. These undoubtedly lie at the base of the Colorado shale.

The outcrops of Pale beds in the neighbourhood of the drilling operations showed no structural features of a character suitable for the accumulation of oil and gas.

PIKE LAKE WELL

This well is situated in the SE. ¼ sec. 13, tp. 34, range 7, W. 3rd mer., and the venture is being promoted by the Pike Lake Oil and Gas Development Company, of Saskatoon. When visited during the season, the hole had reached a depth of over 1,800 feet. The log shows the upper 500 feet as predominantly sand with some sand again appearing at about 1,780 feet, which contained a show of oil.

The location of this well is in an old sand dune area, and exposures of the underlying formations are nowhere visible. For this reason it is impossible to base any judgment on gas or oil possibilities on structural relationships. So-called oil seepages in the neighbourhood appear to be iron springs only.

HANLEY WELLS

Exploration for gas and oil in Hanley district was actuated by gas seepages in water wells. Friable sandstones exposed at the surface in this area have been identified as belonging to the Belly River series, and it appears to be in these sands that the small gas flows originate.

A well was drilled in SE. ¼ sec. 6, tp. 31, range 4, W. 3rd mer., which obtained a small flow of gas from an horizon apparently below the Belly River sands. Gas is still escaping from this hole. More recently the Canadian Western Natural Gas, Light, Heat, and Power Company, Limited, of Calgary, commenced a hole in legal subdivision 9, sec. 28, tp. 30, range 5, W. 3rd mer. Evidence of structure was obtained through shallow drilling to known horizons. Data obtained from the company show a thickness of 200 feet of Belly River sands at the surface, and sands were again encountered at the base of the Colorado shale at about 2,060 feet. No oil or gas was reported from this lower horizon, and the well was abandoned.

To the southwest of this location, near the town of Outlook, the Eden Valley Oils, Limited, have initiated drilling operations in sec. 35, tp. 28, range 8, W. 3rd mer. The hole was commenced in the upper beds of the Belly River sands. No definite knowledge of structure capable of accumulating gas or oil in commercial quantities was obtained in this district.

KENASTON WELL

Drilling operations were commenced in the NE. ¼ sec. 18, tp. 29, range 2, W. 3rd mer., near the town of Kenaston, with the view to prospecting for oil and gas. The hole has a reported depth of 200 feet, where it was lost in quicksand. Operations are expected to be continued by Associated Securities, Limited, of Moose Jaw.

There are no exposures of the underlying formations in this neighbourhood, and, therefore, no evidence of any structure capable of producing oil. The quicksand reported at 200 feet is probably Belly River sands.

SIMPSON WELL

The Simpson Oil Company, Limited, have drilled a hole to test for gas and oil in legal subdivision 2, sec. 9, tp. 29, range 25, W. 2nd mer., the location being near the town of Simpson. When visited during the season it was reported at a depth of 2,200 feet. No structural features could be determined in the neighbourhood on account of lack of outcrops.

The log of the well shows the glacial drift to be 360 feet thick, the top of the Belly River sands at probably 440 feet, and the base of the Colorado shale about 2,100 feet.

GESSEL-DETTA WELL

This well is situated in Qu'Appelle valley in the NE. ¼ sec. 26, tp. 21, range 29, W. 2nd mer., and is being drilled by the Gessel-Detta Oil Company, Limited. It is located on an erosion remnant of Bearpaw shale near the side of the valley. There are many exposures of Bearpaw shale in this part of the valley, but there is no evidence of any structure capable of producing oil.

When visited the hole was reported to be several hundred feet in depth and had penetrated sandy beds believed to be Belly River sandstone.

CLAYBANK AREA

Considerable attention has recently been directed to the gas and oil possibilities in the neighbourhood of Claybank. This interest has led to a certain amount of drilling, mostly shallow holes, to determine structure. The total results obtainable from such prospecting are not as yet of sufficient value to base definite conclusions regarding oil possibilities.

The most promising area for investigation by shallow drilling is the east side of Dirt hills where the strata are apparently undisturbed and attain a high elevation. A closure to the east can be demonstrated by surface outcrops, though faulting may account for some of the difference in elevation. A slight closure to the south is also indicated, but to the west and north outcrops fail to produce sufficient evidence to determine structure in the underlying beds and here shallow drilling might be used advantageously.

STRATIGRAPHY, CLAY AND COAL DEPOSITS OF SOUTHERN SASKATCHEWAN

By F. H. McLearn

CONTENTS

INTRODUCTION

Detailed studies in southern Saskatchewan, made in 1927 and 1928, were continued in 1929. They included in 1929 examination of: Twelve-mile Lake valley from about the middle of the lake east to Willowbunch; Big Muddy valley near the south end of Big Muddy lake; Wood creek; parts of the area between Wood Mountain (new) and Fir Mountain; and parts of Rocky creek. As in other years surveys were made with plane-table and stadia alidade and the elevations of important key horizons were obtained for the purpose of working out the structure. Much trenching of outcrops was necessary in order to obtain unweathered sections for observation and sampling.

Important results were: the finding of two refractory clay zones in Big Muddy valley, the higher of which appears to be the equivalent of the higher zone reported last year[1] from Willowbunch and Hay Meadow valley; the finding of plant fossils in the Whitemud and at several horizons in the Ravenscrag; the at least tentative dating of the Whitemud formation on the basis of plant evidence; and the finding of fairly well-preserved non-marine invertebrate faunas in the Ravenscrag at several localities.

O. L. Backman, C. O. Hage, and Edward Leith gave most satisfactory assistance in the field. Most of the instrument work was done by Backman. C. M. Sternberg obtained a number of important fossil vertebrate collections and also assisted in the collection of fossil invertebrates and plants. In the laboratory F. J. Fraser continued work on the petrography of the sediments. W. A. Bell made a preliminary, and Professor E. W. Berry a more extended, examination of the plant fossils. Professor W. G. Worcester of the University of Saskatchewan furnished important information on the clay deposits.

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1928, pt. B, pp. 35, 41 (1929).

		East End	Tp. 5, range 19, W. 3rd mer. to Pinto plateau	Pinto plateau, south of Horsethief Guide	Rocky creek	Twelvemile lake	Willowbunch village	Hay Meadow	Big Muddy valley at crossing highway 34	South of Big Muddy lake	Willows to Willowbunch lake
Tertiary	Palæocene	Ravenscrag	Ravenscrag	Ravenscrag	Ravenscrag	Ravenscrag	Ravenscrag	Ravenscrag	Ravenscrag	Ravenscrag	Ravenscrag
							Coal-bearing cream facies	Coal-bearing cream facies	Coal-bearing cream facies	Coal-bearing cream facies	
							Willowbunch member (refractory clays, etc.)	Willowbunch member (refractory clays, etc.)	Willowbunch member (refractory clays, etc.)	Willowbunch member (refractory clays, etc.)	
										Coal-bearing: A grey facies	
		Coal-bearing cream facies				Coal-bearing cream facies	Coal-bearing	Coal-bearing	Coal-bearing	Coal-bearing: A cream, yellow facies	
		Coal-bearing grey facies	Coal-bearing	Coal-bearing	Coal-bearing	Coal-bearing grey facies					A yellow, cream facies Coal-bearing
Mesozoic	Cretaceous	Non-coal-bearing *Triceratops*	Non-coal-bearing *Triceratops* Including Sandstone B	Non-coal-bearing	Non-coal-bearing *Triceratops*	Non-coal-bearing				Coal-bearing: A grey facies	A grey facies Coal-bearing
		Whitemud (refractory clays, etc.)	Probably removed in pre-Ravenscrag time	Whitemud (refractory clays, etc.)	Removed ? or poorly developed ?	Whitemud (refractory clays, etc.)			? Whitemud of Willows, Big Muddy, etc. (refractory clays, etc.) ?		? Whitemud of Willows, Big Muddy, etc. (refractory clays, etc.) ?
		Sandstone A	Probably removed in pre-Ravenscrag time	Sandstone A	Sandstone D	Sandstone D					Sandstone E ?
		Bearpaw	Bearpaw	Bearpaw	Bearpaw	Bearpaw					

STRATIGRAPHY

BEARPAW OR PIERRE

Shales of the upper part of the Bearpaw or Pierre[1] formation occur in the western part of Twelvemile lake, in the lower part of Wood creek, in the lower parts of the coulées heading into Fir Mountain area, and on Rocky creek. No determinate fossils were found in them. By the addition of beds of sandstone in the upper part they pass up into the overlying sandstones of Sandstone D and in places it is difficult to know just where to draw the boundary.

SANDSTONES A, D, E

The sediments of Sandstone D, which lie between the Bearpaw and Whitemud of Twelvemile lake, are very variable. They consist in places, and particularly in the west, of thick, massive, yellowish or yellowish green weathering, greenish grey, fine to superfine sandstones, with clay ironstone bands and more rarely hard, grey, rounded concretions or hard ledges. They pass in places into alternating thick zones of the above lithology and thick zones of thin-bedded, ⅛-inch to 6-inch, sandstone and dark grey shale. In places they even consist chiefly of thin-bedded sandstone and shale. Some beds, particularly the thinner ones, contain film-thin layers of comminuted woody and other plant remains. No roots or upright stems or other than prostrate plant remains were found. Poorly preserved pelecypods, apparently marine, were found at one locality, but were too poor to identify. Channelling on a scale of at least about one foot in depth was observed at a few places in the thin-bedded sandstone and shale part. All the sandstones examined in the laboratory are feldspathic and contain some muscovite, rather rare biotite, rather rare hornblende, and a fairly complete heavy mineral suite. There is no deficiency in apatite, garnet, or epidote. The conditions of deposition may have been in part marine, but if so were sufficiently near the site of marginal flood-plain or delta deposition to admit the accession of plant debris, and the conditions may have been in part non-marine. The base everywhere consists of thin-bedded sandstone and shale and gradually passes into the shales of the Bearpaw below. It is doubtful if the passage to Bearpaw takes place everywhere at exactly the same horizon.

The sandstones which lie between the Bearpaw and the Whitemud on Wood creek and in the coulées south and east of Fir Mountain are chiefly like those of Sandstone D of Twelvemile lake and show a similar conformable relation to the Bearpaw.

The sandstones over the Bearpaw on Rocky creek are also similar to those of the more massive part of Sandstone D of Twelvemile lake. They are, if anything, a little finer and consist of fine to superfine, feldspathic, yellowish or yellowish green weathering, greenish grey sandstone with flat ironstone concretions. They contain some hornblende and a fairly complete heavy mineral suite. A single specimen of a plesiosaur vertebra was collected in this sandstone by Sternberg. Conditions in part marine, or at least not remote from the sea, are inferred.

[1]If the Belly River extends this far east it is presumed that the name Bearpaw is applicable, otherwise Pierre.

The question arises: can these sandstones of Rocky creek be correlated with those of Twelvemile lake, Wood creek, etc., considering that the former apparently underlie Lower Ravenscrag beds of Lance age and the latter underlie Whitemud beds of at least somewhat earlier age, i.e. Edmonton or early Lance? It may be, as will be shown when discussing the Whitemud, that some beds at the top of these sandstones on Rocky creek represent a feeble development of the Whitemud, or a remnant of it. This at least admits the possibility of a pre-Whitemud age of the sandstones on Rocky creek and permits a tentative correlation of them with the beds of Sandstone D at Twelvemile lake, Wood creek, etc., which they so closely resemble lithologically.

The beds of Sandstone A, or "yellow sandstones" of East End area in the eastern part of Cypress hills, and of the vicinity of Horsethief Guide[1] in Pinto plateau occupy the same stratigraphic position as the beds of Sandstone D of Twelvemile lake, etc., i.e. between the Bearpaw and Whitemud, and show conformable relation to both. They differ chiefly from the beds of Sandstone D in structure. The western phase, Sandstone A, lacks characteristically the very thin bedding and also the very thick, massive beds of the eastern phase, Sandstone D, and contains beds of moderate thickness.

The strata of Sandstones A and D have been called Fox Hills by various authors, but the writer has refrained from so naming them because they have not yet yielded any diagnostic fossils and the exact age of the overlying Whitemud formation has not been established. They will probably require a new name. The suggestion of Russell[2] that the basal sandstones of southern Saskatchewan be correlated with the Lennep (pre-Fox Hills) or with some lower part of the Fox Hills series is a good one if the Whitemud turns out to be of Edmonton age.

Sandstone E underlies the Whitemud in the vicinity of Willows and consists of thick beds of grey, fairly fine sandstone, yellowish and grey silts and shales, some finer-grained layers with prostrate plant debris of various kinds, clay ironstone concretions, and in the upper part a few brownish carbonaceous layers with some prostrate plant remains. No upright stems or roots and no coaly layers have been noted. Below this are fine-grained, friable, dark grey shales, with thin beds of somewhat coarser grade, ferruginous bands, and in places large lenses of grey sandstone. All are conformable and there is considerable lateral variation. Rarely, very fine plant debris occurs in film-like layers, etc. A small bone, possibly dinosaurian, was picked up on the surface of the lower and more shaly part, but whether it actually came from this horizon is not known. If the overlying white refractory clays are equivalent to the Whitemud beds of Twelvemile lake and of East End, Sandstone E is to be correlated with Sandstones A and D.

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 25 (1928); Sum. Rept. 1928, pt. B, pp. 32-35 (1929).
[2]Russell, L. S.: Proc. Am. Phil. Soc., vol. 69, No. 4, p. 152 (1930).

WHITEMUD

Whitemud, as used below, includes the refractory clays and sandy clays and strata associated with them between Sandstone A and the Ravenscrag in East End area, and elsewhere beds of similar lithology that can be correlated with them. The contact with the Ravenscrag is in places that of a local erosional unconformity. The much higher and later Palæocene zone of refractory clays, etc., of Willowbunch village, Hay Meadow valley, Harptree and Big Muddy valley will be described later as the Willowbunch member of the Ravenscrag formation.

The Whitemud formation occurs on both sides of Twelvemile lake in its eastern part, except where the base of the Ravenscrag descends stratigraphically along the plane of the erosional unconformity and comes to rest directly on beds of Sandstone D. It is comparatively thin at most Twelvemile Lake localities and is very variable. On the south shore it is, in its typical development of refractory clays and sandy clays, only from 6 to a little over 16 feet thick. In some places it consists mainly of refractory sandy clay or kaolinized sandstone, but refractory silts and clays are also present and are chiefly in the upper part. No coaly layer was found in the Whitemud of Twelvemile lake. In some places it is directly underlain by grey shales, brownish carbonaceous shales, and fissile shales, not typical of Sandstone D and possibly stratigraphically the equivalent of refractory clays and sandy clays elsewhere and, broadly speaking, a part of the Whitemud formation. To the west, in sec. 11, tp. 6, range 2, W. 3rd mer., the Whitemud is cut out by the descent of the Ravenscrag, but reappears to the southwest on Gollier creek.

On the north side of Twelvemile lake in secs. 20, 21, and the west half of 22, tp. 6, range 2, W. 3rd mer., the cliffs are not high enough to carry the Whitemud, but at one or two places in the middle of sec. 20, the top of Sandstone D shows some kaolinization and may represent about the contact with the Whitemud. From the middle of sec. 22, tp. 6, range 2, W. 3rd mer., eastward, the Whitemud is exposed, is 20 feet thick in places, consists of kaolinized sandstone or refractory sandy clay, silt, etc., and appears to have conformable relations above and below. From sec. 14, tp. 6, range 2, W. 3rd mer., to sec. 12, tp. 6, range 2, W. 3rd mer., the Ravenscrag descends and rests on beds of Sandstone D. To the east of this the Whitemud reappears. The exposure is not continuous, but enough is visible to show much variation. West of the point, in sec. 12, the Whitemud is nearly 40 feet thick at one place and consists of sandy clay or kaolinized sandstone with a little grey, chocolate, or purplish silt or clay at the top. To the east of the point on a conical hill the base is exposed and consists of grey, somewhat kaolinized sandstone. Farther east it consists of massive, greenish, partly kaolinized sandstone with film-thin layers of fine plant debris, mineral charcoal, etc., and vertical roots or stems. It is overlain by dark carbonaceous shale, grey shale, etc. This is a poor development of Whitemud and is cut off in sec. 7, tp. 6, range 2, W. 3rd mer., by descent of the Ravenscrag. Kaolinized sandstone, etc., reappears in sec. 8 and is underlain by grey and brown, carbonaceous shales. At one place it passes laterally into the shales, the contact being locally an erosional one, and the kaolinized sandstone being later than and cutting down across the shales. To the east of this the exposures are poor, but 10 feet of partly kaolinized sandstone is present. In the western part of sec. 10, on the east side of a tributary valley, at about lake-level, 15+ feet of white, kaolinized sandstone is overlain by 2 feet of clay. A little farther east kaolinized sandstones, refractory clays, etc., are absent and their place taken by grey and brown carbonaceous shales, very thin sandstones, etc. To the east of this massive kaolinized sandstone comes in again and appears to cut down across the grey and brown shales, etc.

On both branches of Wood creek, in the coulées south and east of Fir Mountain and on Gollier creek, there is a better development of the Whitemud formation. The original deposition was more favourable and there was less removal in post-Whitemud, pre-Ravenscrag time. At one locality on Wood creek are over 26 feet of kaolinized, feldspathic sandstone, overlain by more than 12 feet of kaolinized sandstone, silts, and refractory clays. In one part of Wood Creek valley, however, only about 11 feet of clay and silty clay can be recognized as of Whitemud character and the stratigraphic position of the remainder of the typical Whitemud sediments is taken by grey shales. At another locality on Wood creek a brown, fissile shale is present with kaolinized sandstone, etc., above and below it. This shale carries a good fossil flora. The changes here to abnormal Whitemud lithology appear to be the result of lensing and lateral variation without contemporaneous erosion.

In the area east and south of Fir Mountain one exposure shows 12+ feet of white, kaolinized sandstone overlain by 14 feet of purplish clay. Another has 13 feet of white, kaolinized sandstone and silt overlain by 13 feet of clay. Yet another shows 13 feet 4 inches of silt and kaolinized sandstone overlain by 16 feet 6 inches of clay. A poorly preserved *Unio* shell was found in the formation on a cone-like hill east of Fir Mountain station. At one place on Gollier creek 45 feet of white, kaolinized sandstone is overlain by clay at the very top of the cliff.

At one locality on Rocky creek at the top of Sandstone D are 8 or 10 feet of light greenish or yellowish, partly kaolinized sandstone, weathering light grey, with heavy mineral suite deficient in apatite, garnet, and epidote and overlain by a 6-inch bed of purplish, very fine sandstone. This may be a feeble development of the Whitemud or the base of a once complete Whitemud section mostly removed in pre-Ravenscrag time.

At the time of the preparation of this report only a preliminary examination has been made of the Whitemud of the Willows, Big Muddy, etc., areas. This Whitemud is very variable, particularly in the proportion of kaolinized sandstone to the plastic refractory clay. The kaolinized sandstones vary much in grain, in some places and in some layers being quite coarse, and elsewhere much finer. Although some non-refractory clay or shale appears to be present in places and some lateral variation in degree of kaolinization of sandstone occurs, no passing laterally of the greater part of the section into non-refractory shales, etc., has been observed, as in some parts of East End, Twelvemile Lake, Wood Creek, etc., areas. Vertical roots or stems and fine plant and woody remains are present and some of the clays are purplish in colour. Some of the clays are more refractory than those of the west, e.g. than those in East End and even in Wood Creek and Wood Mountain-Fir Mountain areas and the generalization has been made by a number of authors that the Whitemud clays are more refractory in the east than in the west. No erosional unconformity[1] has been observed at the top of this Whitemud, i.e., the Whitemud of Willows, Big Muddy, etc., and coal seams, although small, appear almost immediately over it.

History of Whitemud

There are four outstanding features in the history of the Whitemud formation: by Whitemud time apparently complete non-marine deposition had been attained; during Whitemud time the sediments underwent fairly thorough chemical weathering in the area of deposition and the weathered products were partly re-sorted; the extent of chemical alteration and the products so formed depended partly on the nature of the original sediments before alteration; the Whitemud sediments were partly eroded before the deposition of the Ravenscrag. One of the most important problems is the direction of the source of the original sediments before alteration.

The inference of a non-marine origin is based on the presence in places of erect or inclined roots or stems, and of leaves, coal seams, and a *Unio*.

An intra-regional or local theory of the origin of the Whitemud sediments has been explained in previous reports.[2] It requires certain favourable climatic and topographic conditions in the area of deposition, including in later Whitemud time at least a not too rapid accession of extra regional, unaltered, sediment, at least a temperate climate, a covering of vegetation, and a sufficient periodic fall of the water table to promote weathering. It is not necessary to infer that the conditions for alteration began coeval with the deposition of the basal of the kaolinized sandstones; indeed alteration may well not have set in until much of the sands, later altered to typical Whitemud sediments, had accumulated. One reason for believing this is that some thick massive beds of kaolinized sandstones show a gradual dying out of kaolinization below. Of course the alteration had set in prior to the formation of the lowest refractory clay beds, for they are interpreted as having originated by re-sorting and deposition of the clay produced by local weathering and kaolinization of the feldspathic sands.

The original sediments seem to have varied much from place to place. At one locality they would consist of very thick beds of feldspathic sand, at another of prevailing sand with large or small, rare or many, lens-like layers of silt or clay, and in places even of silt alone. In some places accumulation of plant matter made carbonaceous muds and more rarely there were roots, stems, etc., capable of preservation. The transition from coarse sand to silt or mud, etc., was abrupt in places and the sands lay with small-scale local erosional unconformity on the silts or muds. These variable sediments did not all respond alike to alteration. The original clays and finer silts do not seem to have altered to any extent and under certain conditions seem to have prevented or at least retarded alteration of the coarser sediments. Where the sands were not capped by impervious, very fine silts or clay, or where the circulation was not impeded by too many included beds of the same material, kaolinization went on freely.

---

[1]Observed during the 1930 field season on a small scale in Big Muddy valley.

[2]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, pp. 35–39 (1928); Sum. Rept. 1928, pt. B, pp. 37–38 (1929).

But where so impeded, kaolinization seems to have been retarded and the fine silts and clays of the original deposits do not seem to have been altered at all. It appears that kaolinization took place most readily in thick, moderately coarse sands without fine silt or clay bands and produced thick beds of kaolinized sands or sandy clays. So kaolinization varied laterally and it also varied vertically, depending on the depth of free circulation of groundwater, which in turn depended on the permeability of the original sediments. The result of this was that the lower part in particular of the Whitemud formation came to vary much laterally and vertically depending partly on the nature of the original deposit, i.e. the deposits before alteration.

In later Whitemud time when the higher parts of the kaolinized sand beds were worked over and re-sorted, accession of new extra-regional and unaltered fine sediment may well in places have led to contamination of the pure clays washed out of the kaolinized sands. The average lower refractory quality of the clays in the western occurrences of the Whitemud as compared with those in the eastern occurrences may be explained by assuming that they were nearer the source of the original sediment and were more liable to contamination. There is another possibility, of course, that the average lower refractory quality of the western clays is due to less complete kaolinization of the feldspathic sandstones there. It is proposed to test this alternative possibility by comparing the refractory character of the clay matrices of the western and eastern kaolinized sandstones.

As has been noted in previous reports a not inconsiderable amount of the sediments of the Whitemud formation were destroyed in the interval of erosion that preceded the deposition of the Ravenscrag beds. As previously stated the evaluation of the importance of this interval of erosion depends on the dating of the Whitemud.

Age of Whitemud

For over three years, since the beginning of this study, fossil evidence for the age of the Whitemud formation has been sought without satisfactory results. On the basis of general stratigraphic relations, the writer has suggested an early Lance, Edmonton, or some intervening date[1]. More recently Russell[2], in an interesting and informing paper on "Upper Cretaceous Dinosaur Faunas of North America" suggests a correlation "with some upper member of the Fox Hills series in central and eastern Montana."

As has been noted in previous reports it is unfortunate that no dinosaur remains of diagnostic value, and indeed no dinosaur or vertebrate remains of any kind, have yet been found in the Whitemud formation. For good evidence of this nature would solve decisively the age of this formation and the duration of the erosional interval between the Whitemud and the Ravenscrag.

During the past season a collection of fossil plants was found in the Whitemud formation on the west side of Wood creek, in sec. 15, tp. 5, range 3, W. 3rd mer. This flora has been studied by E. W. Berry, who

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1928, pt. B, p. 37 (1929).
[2]Russell, L. S.: Proc. Am. Phil. Soc., vol. 69, No. 4, p. 152 (1930).

with some reservations suggests the possibility of a correlation with the Laramie formation as restricted by the United States Geological Survey. Of the twenty-one species of this flora, two positively identified species and two tentatively identified pass up into the Ravenscrag formation. The flora thus appears to have little in common with the Ravenscrag floras, suggesting a pre-Lance age, but the known Saskatchewan floras are too small to base more than a mere suggestion on. Berry identifies the following species: *Ampelopsis montanensis* Ckl. (?), *Berrya racemosa* (?), *Ficus martini* Kn. (?), *Ficus* sp., *Ginkgo adiantoides* (Unger) Heer, *Grewiopsis* (?) sp., *Hicoria antiquorum* (Newb.) Hollick, *Leguminosites arachioides minor* Berry, *Palmocarpon* sp., *Pistia corrugata* Lesq., *Platanus aceroides heeri* ?, *Sequoia nordenskioldi* Heer, *Smilax inquirenda* Kn. ?, *Viburnum marginatum* Lesq., *Zizyphus coloradoensis* Kn., and new species of *Cupressinocladus*, *Equisetum*, *Grewiopsis*, *Luhea*, *Menispermites*, and *Nelumbo*.

The Whitemud of Big Muddy valley, Willows, etc., appears to occupy the same stratigraphic position with respect to subjacent strata as the Whitemud of Twelvemile lake, East End, etc., and until proved otherwise will have to be considered Whitemud. It is curious, however, that: no dinosaurs have been so far found over it; coal seams, although thin, immediately overlie it; and no erosional unconformity has been observed above it[1]. It was for these reasons that the writer, in a former report[2] regarded it as a possible third refractory clay zone and a part of the Ravenscrag formation. Other possibilities are that the beds of Lower Ravenscrag *(Triceratops)* age are absent here, are very thin, or if once present were removed by erosion, in Ravenscrag time. Important objections could be raised against the possibility of the clay of this eastern Whitemud being derived from erosion of clays of the western Whitemud during the interval of post-Whitemud erosion.

RAVENSCRAG

The Ravenscrag includes beds of Lance and Palæocene age. Although in places the Ravenscrag appears to be conformable with the earlier Whitemud formation, in many places its relation to earlier formations is that of a local erosional unconformity and it rests directly on various levels of the Whitemud, on Sandstones A or D, and even on the Bearpaw. The last condition is that beds of Lance *(Triceratops)* age lie directly on the Bearpaw and the break includes the time of deposition of Sandstones A and D and the Whitemud formation; this unusual condition occurs for many miles down Frenchman river, east of tp. 5, range 19, W. 3rd mer.

Sediments

In a very general way the Ravenscrag sediments are included in two facies, a grey or sombre facies and a cream or buff or yellow weathering facies. Both may contain coal seams.

Beds of the grey or sombre facies weather almost white, grey, dirty yellowish grey, or greyish green, or more rarely brownish, yellow, or even purplish. They stand up well in cliffs. The unweathered colours are light to dark grey, greenish grey, greyish green, and more rarely yellowish

[1] *See* Note on page 53.
[2] McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1928, pt. B, p. 35 (1929).

green or yellowish. Carbonaceous layers are brown to black. In places near the base are fairly coarse sandstones, but most of the sediments are of fairly fine sand, silt, or clay grade. Bentonitic sandstones and clays are present in a few places and particularly at one horizon where they are occasionally associated with some volcanic-ash-bearing sediment. Erect or inclined stem or root remains, prostrate woody, stem, leaf, frond, or other plant remains, mineral charcoal, and other comminuted plant material are present. The wood or large stem and root remains are in places carbonized or recorded as clay fillings and the wood remains are also in places lithified with the structure well preserved. At one horizon over a fairly wide area are remains of short, upright tree stumps with the wood lithified. One stump was originally at least 4 feet across at the base. Carbonaceous layers of all degrees of carbonaceous contents are present. A few beds are calcareous or dolomitic. Although a few beds, with merely local variations, maintain their identity even for miles, most show considerable lateral variation. Channelling and refilling are observed in places. Some of the sandstones show crossbedding with horizontal or inclined cut off on a scale of about 2 feet. Others show a finer crossbedding on a scale of 1 inch or 2 inches high, probably the result of ripple-marking. Individual beds are from 1 inch or 2 inches to 10 feet thick; thicknesses of 1 to 5 feet are common. Within the individual layers in places there is also a much thinner lamination, down to a fraction of a mm.; e.g., film-thin lamination of fine, comminuted plant debris or very fine lamination of grain and colour. All the sandstones contain some feldspar, as well as quartz, and a fairly complete, heavy mineral suite. Some of the sandstones have a fairly high proportion of clay grade, 15 or 20 per cent. Other sandstones have practically no sediment of clay grade. Some of the sediments of silt and clay grade show a good shale or friable structure. Some of the carbonaceous shales are fissile.

The cream or buff facies, on the whole, include sediments of finer grain than those of the grey facies and characteristically appears cream or yellowish or buff in the cliffs. Some of the unweathered sediments are yellowish, but most are light and dark grey, greenish, light greenish grey, yellowish green, etc. The surface cream, yellow, etc., colours are due to the washing of the weathered products of a few layers over the surfaces of the rest. The prevailing grades of sediment are very fine sand, silt, and clay, although sandstone of medium sand grade is also present. The bedding is much as in the grey facies. Many of the sediments are a little calcareous or dolomitic. Coal seams of commercial value and carbonaceous shales are present. Plant stem, wood, leaf, etc., remains also occur, but less abundantly than in the grey facies.

Zones and Horizon Markers

No entirely satisfactory method of subdividing the Ravenscrag has yet been found. The most satisfactory tested so far is that proposed in 1929, involving a two-fold division into Lower and Upper,[1] the former the lower non-coal-bearing and the latter the coal-bearing part. It happens that no dinosaur remains have been so far found above the first coal seam and where dinosaurs from this zone have been identifiable they have been of Lance *(Triceratops)* age. Hence this method of division has the ad-

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1928, pt. B, pp. 38-42 (1929).

vantage of separating the part that can be correlated with the Lance, from that which can be correlated with the Palæocene. The only important objection that can be raised against it is the difficulty of drawing accurately a uniform upper limit. For it would be unwarranted to assume that the first coal seam, in every section, in all parts of southern Saskatchewan, is one and the same seam and that it represents everywhere the same horizon. Moreover, particularly where specimens are scarce, it cannot be assumed that the position of the highest specimen locally represents the maximum upward range of the dinosaurs. Therefore, the writer does not feel justified in separating the Lower Ravenscrag as a distinct formation and in giving it a higher status than a member. Whatever objection may be raised against the first coal seam as a regionally uniform upward limit to a non-coal-bearing zone, its value, locally, where it can be traced and readily identified, is great, for it has served locally in both East End and Twelvemile Lake areas as an important horizon marker and has aided much in working out of the structure.

In Twelvemile Lake valley, between Twelvemile lake and St. Victor, a further division is possible into a local middle and upper Ravenscrag based on difference of facies. For the lower part of the coal-bearing Ravenscrag is there prevailingly of the grey or sombre facies and the upper part of the cream or yellow facies. Moreover, at the top of the grey facies is a rather characteristic zone that can be traced for miles, consisting in descending order of: greenish yellowish sticky clay, in part bentonitic, and in places passing into silts and fine sandstones containing volcanic ash; a thin carbonaceous layer; a whitish weathering sandstone or coarse silt showing much lateral variation; a level of fossil tree stumps; and a thin coal seam, the Krieg seam. Some difficulty is experienced in tracing the contact between these two zones out of the area mentioned as there appear to be changes in facies to the east at least. However, where this contact and volcanic ash-bearing zone can be recognized it serves as an important horizon marker and the determination of the structure between Twelvemile lake and St. Victor is based on it.

The Willowbunch member, where present and exposed, serves as a useful horizon marker and has proved to be very valuable for working out the structure in Big Muddy valley and other places. It has not been located in Cypress hills. The Ravenscrag section in the vicinity of East End does not go high enough to carry it. However, in other parts of Cypress hills higher Ravenscrag is preserved and the Willowbunch member should be sought there. Of course, there is the possibility that it does not extend that far west.

The zoning that can be based on fossil plants needs also to be considered. Plants were collected from three horizons in the Ravenscrag: from the lower non-coal-bearing Lance part, from the middle ranges of the formation, and from near the horizon of the Willowbunch member.

The flora collected from the lower and Lance, *Triceratops*-bearing, part contains sixteen species as identified by Berry. Two of these are in common with the Whitemud flora and one doubtfully is. Berry notes that two species, *Ficus ceratops* Knowlton and a species of *Fraxinus*, are elsewhere confined to the Lance and that a third species, *Rhamnus cleburni* Lesq., is elsewhere probably confined to the Raton and Denver. Eight species pass up higher in the Ravenscrag and three doubtfully do. Although larger collections are required before any final decision can be made it looks as though the basal Ravenscrag has a flora different in some respects from that of the remainder and greater part of the formation. The flora of the lower part of the Ravenscrag in southern Saskatchewan includes the following species, identified by Berry: *Aralia notata* Lesq., *Euonymus xantholithensis* Ward ?, *Ficus ceratops* Kn., *Ginkgo adiantoides* (Unger) Heer, *Hicoria antiquorum* (Newb.) Hollick, *Juglans rugosa* Lesq., *Leguminosites arachioides minor* Berry, *Platanus aceroides latifolia*, *P. gullelmae heeri* Kn., *Rhamnus cleburni* Lesq., *Trochodendroides cuneata* (Newb.) Berry, *Viburnum newberryanum* Ward ?, and new species or varieties of *Fraxinus*, *Grewiopsis*, *Pterospermites*, and *Viburnum*.

The collections from the middle ranges of the Ravenscrag include thirty-one species, of which, as Berry notes, five are in the lower Ravenscrag flora of southern Saskatchewan and six are in the highest flora at the horizon of the Willowbunch member. *Aristolochia crassifolia* Ckl. is confined to this flora in southern Saskatchewan.

The third and highest flora, near the horizon of the Willowbunch member, numbers thirty-eight species positively or tentatively identified by Berry. Twenty-three species are not present in the lower levels of the Ravenscrag.

Although there appears to be some zoning of fossil plants in southern Saskatchewan further deductions concerning it will have to be postponed until more collections are made.

Some collections of non-marine invertebrates, including species of *Viviparus*, were made, but they have not yet been studied and their contribution to the zoning and correlation of the Ravenscrag cannot now be stated.

WILLOWBUNCH MEMBER

The zone of refractory clays, sandy clays, etc., high up in the Ravenscrag formation in Hay Meadow valley, south of the village of Willowbunch, south of Harptree, in Big Muddy valley, and in sec. 2, tp. 1, range 24, W. 2nd mer., is here given the name of Willowbunch member of the Ravenscrag formation. The type locality of this member is just south of Willowbunch village. It is more than 400 feet above the base of the formation.

At Willowbunch the beds of this member are exposed high in the valley and coulée sides south and southwest of the village. These are overlain by beds of the cream or yellow facies. The thickness varies from 13 to nearly 20 feet. The sediments consist chiefly of the finer grades, silts and clays. Coarse, kaolinized sandstone was noted at one locality. The average grain is thus much finer than in the Whitemud. A section in, approximately, the northwest corner of sec. 15, tp. 5, range 28, W. 2nd mer., is as follows:

	Feet	Inches
Green and purplish clay	0	7
Purplish, finely friable clay	3	4
Pale green, finely friable clay	1	10
Purplish brown, partly carbonaceous clay	1	2
Black, carbonaceous, coaly shale	0	2½
Dark purplish clay with brown streaks and lenses	0	6
Purplish, hard, silty clay, with coarsely friable fracture	1	9
Coarse and fine silt, very fine sandstone with mm. film-like layers of fine plant debris. Small-scale crossbedding in places with horizontal cut-off	5	0
Massive, coarse, white, kaolinized sandstone	5	6

In Big Muddy valley this member occurs at a high level on the valley sides. East of highway 34 it is on the south side of the valley and south of Big Muddy lake it is on both sides of the valley to the International Boundary. It is overlain by fine sediments of the cream or yellow facies and it is underlain in descending order, south of the lake, by a zone of the grey facies, a zone of the cream or yellow facies, and a zone of the grey facies. A section west of the Keogh ranch is as follows:

	Feet	Inches
Greenish and white silt	1	0
Yellowish green, fine silt	0	4
Grey, fine silt	2	11
White, kaolinized, superfine sandstone with numerous minute, spherical, ferruginous concretions	4	7
Yellow, concretionary band	1	2
Light purplish clay	2	0
Light purplish, hard silt	1	3
Greyish, hard silt	3	7
Greenish, massive silt, yellowish at top	5	7

As at Willowbunch the beds are mostly of fine grain. At one Big Muddy locality, however, coarse, sandy clay is present.

MIOCENE GRAVELS

During the 1929 field season, Sternberg [1] collected fragmentary mammal remains from gravels at several localities in Big Muddy and Wood Mountain areas, which have been dated tentatively as Middle or Upper Miocene by Simpson.

CLAY

Tests of clay samples collected in 1929 were made in the Ceramics Division of the Mines Branch and were reported on by J. G. Phillips.

Whitemud Clays

On the east side of Wood Creek valley, in the east side of sec. 27, tp. 5, range 3, W. 3rd mer., and on a cone-shaped hill, 8 feet of white, kaolinized sandstone was sampled (W955). The results are briefly as follows: very sandy, but fairly plastic; fusion point p.c.e. 30; high-heat-duty refractories. At the same locality a sample of a 5-foot 6-inch bed of greyish, slightly purplish hard clay (C772) gave the following results: smooth, good plasticity, works very well; satisfactory drying behaviour at 65 degrees C.; 33 per cent water of plasticity; 7·7 per cent average drying shrinkage; fusion point p.c.e. 29; clean, light buff colour; hard; refractories.

To the west of Wood Mountain (new), in sec. 15, tp. 5, range 4, W. 3rd mer., 6 feet of white, massive, kaolinized sandstone (W925) gave the following: very sandy, but fairly plastic; satisfactory drying behaviour at 65 degrees C.; 27 per cent water of plasticity; 5·6 per cent average drying shrinkage; fusion point p.c.e. 31; white colour; fairly hard; refractories, the rather unfavourable working properties probably restrict its use. Seven feet of purplish massive clay over the above, sample (C741), gave the following results: quite plastic, somewhat tough, works well; cracks slightly in drying at 65 degrees C.; 28 per cent water of plasticity;

[1] Sternberg, C. M.: Trans. Roy. Soc., Canada, now in press.

7·2 per cent average drying shrinkage; fusion point p.c.e. 27+; white, full of black specks; hard, cracks in drying, dirty from iron specks. Seven feet of purplish, massive clay over the preceding, sample (C740), gave: somewhat sandy, but fairly smooth; works well, rather tough; cracks rather badly in drying at 65 degrees C.; 32 per cent water of plasticity; 8·3 per cent average drying shrinkage; fusion point p.c.e. 28; white, full of black specks; hard; cracks in drying, dirty from iron specks; high drying shrinkage.

At a locality in a coulée southeast of Fir Mountain in sec. 8, tp. 5, range 4, W. 3rd mer., a sample (W940) from the top 1 foot 11 inches of a bed of white, kaolinized sandstone gave the following results: very sandy, but very plastic; fusion point p.c.e. 31; high-heat-duty refractories. A sample (C751) from a 3-foot 9-inch bed of purplish grey, hard clay in the same section gave the following: smooth, quite plastic, tough; satisfactory drying behaviour at 65 degrees C.; 29 per cent water of plasticity; 6·7 per cent average drying shrinkage; fusion point p.c.e. 32; white, clean; hard; high-heat-duty refractories, stoneware, has possibilities as ball clay.

A sample (C730) of 1 foot 7 inches of light grey clay, weathering whitish on surface, on the east side of Gollier creek, in sec. 17, tp. 5, range 2, W. 3rd mer., gave the following results: smooth, clean-looking, very good working properties; cracks slightly on drying at 65 degrees C.; 28 per cent water of plasticity; 6·8 per cent average drying shrinkage; fusion point p.c.e. 30; white, clean colour; hard; high-heat-duty refractories in stoneware, in terra-cotta.

Willowbunch Clays

The clays of this member of the Ravenscrag formation were sampled in Hay Meadow valley, at Willowbunch, and in Big Muddy valley south of Big Muddy lake.

In Hay Meadow valley, in sec. 18, tp. 4, range 2, W. 3rd mer., a sample (W941) of 1 foot 6 inches of white silt gave the following results: quite plastic; works well; satisfactory drying behaviour at 65 degrees C.; 27 per cent water of plasticity; 7·1 per cent average drying shrinkage; fusion point p.c.e. 26; light buff colour; hard; low-heat-duty refractories, stoneware, terra-cotta. A sample (C755) from a 1-foot 4-inch bed of pale green clay, overlying the above, gave: smooth, quite plastic, works very well; satisfactory drying at 65 degrees C.; 37 per cent water of plasticity; 9·1 per cent average drying shrinkage; fusion point p.c.e. 26; buff to brown; hard; low-heat-duty refractories, stoneware, buff face bricks; has high drying shrinkage. A sample (C754) of 2 feet of purplish clay higher in the same section gave the following results: smooth, quite plastic, works very well; satisfactory drying behaviour; 29 per cent water of plasticity; 7·3 per cent average drying shrinkage; fusion point p.c.e. 27; clean, light buff colour; hard; second grade refractories, stoneware, terra-cotta. Also in Hay Meadow valley, in sec. 13, tp. 4, range 3, W. 3rd mer., a sample (C762) of 6 feet of dark purplish, hard clay gave the following results: somewhat sandy, quite plastic, works well; satisfactory drying behaviour; 23 per cent water of plasticity; 6·4 per cent average drying shrinkage; fusion point p.c.e. 28; almost white; hard; second grade refractories, stoneware, terra-cotta.

Near Willowbunch, in about sec. 22, tp. 5, range 28, W. 2nd mer., a sample (W1063) of 5 feet 6 inches massive, coarse, white, kaolinized sandstone gave: very sandy, coarse, fairly plastic; fusion point p.c.e. 27; possible use in low-grade refractories, would probably require addition of plastic fire-clay. About 250 feet east of above, a sample (W1072) of 1 foot 4 inches greenish clay mottled with purplish gave the following results: smooth, quite plastic, works very well; satisfactory drying behaviour; 28 per cent water of plasticity; 7·3 per cent average drying shrinkage; fusion point p.c.e. 26; buff colour; hard; stoneware, terra-cotta, low-heat-duty refractories. Above this a 3-foot 10-inch bed of purplish clay was sampled (W1073) and gave the following results: smooth, quite plastic, tough, works very well; satisfactory drying behaviour; 31 per cent water of plasticity; 7·6 per cent average drying shrinkage; fusion point p.c.e. 30; almost white colour; hard; high-heat-duty refractories, stoneware, terra-cotta.

On the east side of Big Muddy valley, in sec. 1, tp. 2, range 22, W. 2nd mer., a sample (W1101) of 6 feet 3 inches of dark purplish grey, hard clay gave the following results: smooth, quite plastic, very tough; cracks badly; 36 per cent water of plasticity; 8·6 per cent average drying shrinkage; fusion point p.c.e. 32+; almost white colour; hard; ball clay, high-heat-duty refractories, if grog (this clay calcined) were added, or for lower grade refractories if refractory sandy clay were mixed.

COAL

Coal samples collected in 1929 were examined in the Fuel Testing Laboratories of the Mines Branch, and were reported on by C. B. Mohr.

In Twelvemile Lake, Wood Creek, and Fir Mountain areas the first coal seam in the Ravenscrag varies much in thickness. In the NW. corner sec. 10, tp. 5, range 4, W. 3rd mer., it has the following section in descending order: 3 feet 9 inches lignite with a small parting near the base; 4 inches clay parting; 9½ inches lignite. A sample from both benches gave: moisture 40·7; ash 19·2 (32·3); volatile matter 22·2 (37·5); fixed carbon 17·9 (30·2); fuel ratio 0·80. The figures in brackets are for dried sample. On the east side of Wood Creek valley between secs. 24 and 27, tp. 4, range 3, W. 3rd mer., the first seam of the Ravenscrag has the following section in descending order: 8 inches shaly lignite; 3½ inches clay parting; 2 feet 5 inches lignite; lignitic shale with mineral charcoal. A sample from the upper bench gave: moisture 28·8; ash 34·5 (48·5); volatile matter 20·1 (28·2); fixed carbon 16·6 (23·3); fuel ratio 0·83. A sample from the lower bench gave: moisture 35·8; ash 17·6 (27·3); volatile matter 26·8 (41·8); fixed carbon 19·8 (30·9); fuel ratio 0·74.

There are several rather thin and variable seams in the beds of the grey or sombre facies of the Ravenscrag in the valley east of Twelvemile lake. The Krieg seam is near the top of these beds. In the NW. ¼ sec. 33, tp. 5, range 30, W. 2nd mer., this seam is 1 foot 3 inches thick and a sample gave the following: moisture 31·2; ash 8·2 (12·0); volatile matter 30·9 (44·9); fixed carbon 29·7 (43·1); sulphur 0·5 (0·8); B.T.U. 6,050 (8,800); fuel ratio 0·96. The Krieg seam in the SE. ¼ sec. 3, tp. 6, range 1, W. 3rd mer., is 1 foot 4½ inches thick and gave the following: moisture 39·0; ash 12·2 (20·0); volatile matter 27·7 (45·4); fixed carbon 21·1

(34·6); fuel ratio 0·76. A seam lower down in the grey beds in the NW. corner sec. 36, tp. 5, range 1, W. 3rd mer., is 1 foot 6 inches and a sample gave the following: moisture 34·3; ash 19·7 (30·0); volatile matter 23·0 (35·0); fixed carbon 23·0 (35·0); fuel ratio 1·00. A coal seam near the bottom of these grey beds at the east end of Twelvemile lake, south side, in the upper middle part of sec. 4, tp. 6, range 1, W. 3rd mer., contains 1 foot 10 inches of lignite. A sample gave: moisture 32·6; ash 20·3 (30·1); volatile matter 24·9 (37·0); fixed carbon 22·2 (32·9); fuel ratio 0·89.

There are a number of seams in the beds of the cream or buff facies of the Ravenscrag between Twelvemile lake and St. Victor. East and west of St. Victor on both sides of the valley is an important seam at the bottom of this facies, the St. Victor seam. It thins out to the west and can hardly be recognized near Twelvemile lake, unless some black, carbonaceous shale represents the horizon of it. Just northeast of St. Victor on the north side of the valley and east of where a north-south road winds up the valley side the St. Victor seam contains the following in descending order: 7 inches of lignite and shale; 1 foot 10 inches lignite; ½ inch clay; 1 foot 5½ inches lignite; 6 inches somewhat fissile brown shale with prostrate plant remains, coaly at top; 11 inches brown and black carbonaceous shale with mineral charcoal and coaly streaks. A sample of the 1-foot 10-inch and 1-foot 5½-inch benches gave the following: moisture 44·0; ash 9·3 (16·6); volatile matter 25·8 (46·1); fixed carbon 20·9 (37·3); sulphur 0·9 (1·7); B.T.U. 4,350 (7,750); fuel ratio 0·81. The following seam is either the St. Victor or a seam a little above it in the buff or cream facies west of St. Victor on the south side of the valley in NE. ¼ sec. 12, tp. 6, range 30, W. 2nd mer., and at about the level of the bottom of the valley. The section is as follows in descending order: 11 inches black friable shale; 1 foot 4 inches lignite. A sample from the 1 foot 4 inches gave: moisture 34·2; ash 20·2 (30·7); volatile matter 23·2 (35·2); fixed carbon 22·4 (34·1); fuel ratio 0·97. A seam on the east side of the road between St. Victor and Willowbunch in the southernmost border of sec. 1, tp. 6, range 29, W. 2nd. mer., is probably the St. Victor seam and shows how it changes to the east. The section there is as follows in descending order: 6 inches black clay shale, 7 inches grey clay; 3 inches black, coaly shale; 1½ inches brown clay; 1 foot 5 inches lignite; brown clay. A sample of the 1-foot 5-inches lignite gave: moisture 40·5; ash 7·2 (12·1); volatile matter 27·1 (45·5); fixed carbon 25·2 (42·4); sulphur 0·6 (1·0); B.T.U. 5,090 (8,560); fuel ratio 0·93.

Other seams occur throughout the beds of the cream or buff facies between Twelvemile lake and the vicinity of St. Victor. East of Twelvemile lake in sec. 34, tp. 5, range 30, W. 2nd mer., a seam in the buff beds consists of 1 foot 6 inches of lignite and shale underlain by 4 feet 6 inches of lignite. A sample from the entire section gave: moisture 38·9; ash 18·5 (30·3); volatile matter 21·5 (35·2); fixed carbon 21·1 (34·5); fuel ratio 0·98. West of St. Victor, on the south side of the valley, in about the central-east part of sec. 12, tp. 6, range 30, W. 2nd mer., in the buff beds, is a 3-foot coal seam. A sample gave: moisture 38·5; ash 10·8 (17·6); volatile matter 23·8 (38·7); fixed carbon 26·9 (43·7); sulphur 0·9 (1·5); B.T.U. 4,960 (8,070); fuel ratio 1·15. Eighteen feet below this is a seam 1 foot 4 inches thick, a sample of which gave: moisture 40·2; ash 8·4 (14·0); volatile matter 27·6 (46·2); fixed carbon 23·8 (39·8); sulphur

1·1 (1·8); B.T.U. 4,770 (7,980); fuel ratio 0·85. A seam in the cream beds a little above the St. Victor seam on the southernmost border of sec. 1, tp. 6, range 29, W. 2nd mer., has 7 inches of somewhat shaly lignite underlain by 3 feet 2 inches+of lignite. A sample of the 3-foot 2-inch bench gave: moisture 39·3; ash 8·9 (14·6); volatile matter 25·6 (42·1); fixed carbon 26·2 (43·3); sulphur 0·3 (0·5); B.T.U. 4,890 (8,060); fuel ratio 1·05.

On Rocky creek, at the base of the coal-bearing part of the Ravenscrag and just above the dinosaur-bearing beds are three coal seams. A measurement of the lowest seam at one locality was as follows, in descending order: 5½ inches lignite, 2 inches greenish shale; 1 foot 11 inches lignite. A sample of both lignite benches gave: moisture 31·5; ash 12·8 (18·6); volatile matter 28·1 (41·1); fixed carbon 27·6 (40·3); sulphur 0·4 (0·6); B.T.U. 5,690 (8,300); fuel ratio 0·98. At the same locality the third seam is 12 feet 5 inches higher than the above and first seam and consists, in descending order, of: 3 inches lignite; 1 inch brownish shale parting; 2 feet 3 inches lignite. A sample of the lignite gave: moisture 28·9; ash 19·3 (27·2); volatile matter 28·1 (39·5); fixed carbon 23·7 (33·3); fuel ratio 0·84.

A number of good seams are found in the Ravenscrag in Big Muddy valley, south of Big Muddy lake. In this area the Willowbunch member is underlain in descending order by beds of grey or sombre facies, beds of cream and yellow facies, and beds of grey or sombre facies. Near the top of the lower grey or sombre facies is a seam that can be traced for some distance along the west side of the valley. This, the Keogh seam, is 3 feet 6 inches thick north of the Keogh ranch house in about NE. ¼ sec. 4, tp. 2, range 22, W. 2nd mer.; a sample gave: moisture 40·3; ash 8·3 (13·8); volatile matter 25·5 (42·8); fixed carbon 25·9 (43·4); fuel ratio 1·00. The same seam just south of the above in sec. 4, tp. 2, range 22, W. 2nd mer., contains: 2 inches lignite; 2 inches shale; 3 feet 3 inches lignite. A sample gave: moisture 36·3; ash 6·6 (10·4); volatile matter 26·0 (40·9); fixed carbon 31·1 (48·7); sulphur 0·5 (0·8); B.T.U. 6,030 (9,460); fuel ratio 1·20. Sixty-five feet above the Keogh seam in NE. ¼ sec. 4, tp. 2, range 23, W. 2nd mer., is a seam 2 feet 5 inches thick. A sample gave: moisture 39·2; ash 8·3 (13·7); volatile matter 28·0 (46·0); fixed carbon 24·5 (40·3); sulphur 0·9 (1·4); B.T.U. 5,260 (8,640); fuel ratio 0·87. A seam 3 feet 4 inches thick, in the lower sombre beds between the Willowbunch member and the Keogh seam in NE. ¼ sec. 7, tp. 2, range 22, W. 2nd mer., gave the following analysis: moisture 39·3; ash 6·3 (10·3); volatile matter 27·8 (45·8); fixed carbon 26·6 (43·9); fuel ratio 0·96. A seam 15 feet higher than the preceding seam is 3 feet 5 inches thick. A sample gave: moisture 39·8; ash 7·6 (12·7); volatile matter 26·5 (44·0); fixed carbon 26·1 (43·3); sulphur 0·8 (1·25); B.T.U. 5,580 (9,286); fuel ratio 0·98. A coal seam above the Willowbunch member in NE. ¼ sec. 11, tp. 2, range 23, W. 2nd mer., has the following section in descending order: 4 feet 7 inches lignite; 9 inches brown shale of silt grade; 4 feet 2 inches lignite; 1¾ inches brown shale; 2 feet 3 inches+lignite. A sample of the lower 2-foot 3-inch and 4-foot 2-inch benches gave: moisture 37·4; ash 9·2 (14·7); volatile matter 26·6 (42·6); fixed carbon 26·8 (42·7); sulphur 0·2 (0·4); fuel ratio 1·00. The sample of the uppermost and 4-foot 7-inch bench gave: moisture 36·9; ash 13·5 (21·4); volatile matter 27·5 (43·6); fixed carbon 22·1 (35·0); fuel ratio 0·80.

APPENDIX I

Additional Notes on the Petrography of the Sediments

By F. J. Fraser

In the 1927 samples, one grain of kyanite was noted.[1] In the 1928 samples kyanite or staurolite has been noted in a few. To date, either or both of these minerals have been noted in sixteen out of upwards of one hundred samples collected in 1929. Neither of these minerals occurs in any amount of the concentrates. The samples which contain kyanite or staurolite are strikingly uniform in appearance, and average about 40 per cent clay. As far as optical examination of the concentrates has proceeded, apatite is absent when kyanite or staurolite occurs.

The kyanite grains occur in rectangular habit, with good cross cleavage, extinction up to 30 (commonly undulose), birefringence low, polarization colours usually grey. Grains often show decomposition, with irregular edges due to corrosion.

The staurolite grains show moderately strong pleochroism from golden yellow to colourless, and tend to be equidimensional with irregularly fractured edges; saw-like edges due to fracture, common in large detrital grains of this mineral, are not characteristic of the staurolite in these samples.

---

[1]Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 51.

GROUND WATER RESOURCES OF REGINA, SASKATCHEWAN

By Howard E. Simpson

CONTENTS

INTRODUCTION[1]

The author spent one month during June and July, 1929, in association with Mr. W. A. Johnston of the Geological Survey and his assistants, Mr. R. T. D. Wickenden and Mr. Norman B. Keevil, in a survey of the ground water resources available to the city of Regina for a public water supply. The purpose of the survey was to determine to the fullest extent possible, the best available ground water supply for Regina and to note such ground water relations as might be of importance in connexion with any and all possible surface water supplies.

Mr. Johnston and assistants had entered the field somewhat earlier, had made a very thorough survey of the Pleistocene deposits in the vicinity of the city, and had mapped the same. The author is greatly indebted to Mr. Johnston for this work and also for daily co-operation, conference, and advice throughout the entire month spent together in the field. This report is based upon the co-operative work of the entire party.

Published reports on the geology and ground water resources of southern Saskatchewan by Mr. J. Stansfield (1) (2) and papers by Mr. W. S. Dyer (3) and Mr. P. S. Warren (4) have been consulted and freely used by the author in the preparation of this report.

[1]Numbers in parentheses refer to references listed in Bibliography, p. 104.

Several reports upon the city water supply of Regina which have been found of value are listed in the bibliography. The author of the most complete of these reports (9), Mr. R. O. Wynne-Roberts, Consulting Engineer, of Toronto, joined the field party for several days and co-operated in the survey and conferences.

The author is also greatly indebted to both Mr. D. A. R. McCannel, City Commissioner, and Mr. J. W. D. Farrell, Superintendent of Waterworks, for information, co-operation, and assistance in the office and field.

At the close of the field work an oral report was presented to His Worship the Mayor, Mr. James McAra, the City Commissioner, Mr. McCannel, and the Superintendent of Waterworks, Mr. J. W. D. Farrell, and recommendations were made for prospecting by means of the drill and for the collection of samples of water for chemical analysis. These recommendations have already largely been carried out under the direction of Mr. Farrell and his reports on the same have been incorporated herein.

Valuable assistance was also received from the local well drillers who were most familiar with the ground water conditions. Among those who courteously gave logs and well records are Mr. Marshall, Manager, and Mr. Rigsby of the Canadian Well Supply Company; Mr. Thom, of McPherson and Thom; Mr. W. T. Cowley, Manager of the Saskatchewan Drilling Company; and Mr. H. C. Eberhart, driller for the City Waterworks. Much information was also gathered from private individuals interested in certain wells and in the public water supply.

On May 30 and 31, 1930, a field conference was held at Regina between Mr. Nicholas S. Hill, jun., of New York, Consulting Engineer; Mr. R. O. Wynne-Roberts, of Toronto, Consulting Engineer, and the author, with Commissioner McCannel and Superintendent Farrell. During this conference all important field points mentioned in this report were visited, and all of the conclusions and recommendations thoroughly discussed. Some minor modifications have been made in the text of the report as a result of helpful criticisms and suggestions during this conference.

TOPOGRAPHY

The city of Regina is located on the broad, rolling Prairie Plains of southeastern Saskatchewan. The region owes its level character primarily to the flat-lying strata beneath the surface, which were formed from fine sediments during the Cretaceous. The topography before the advance of the first great ice-sheet southward was shaped, so far as details were concerned, by rain and river erosion, and the bedrock was covered with a layer of mantle rock and soil which originated from the decay and disintegration of the rock formation beneath. With long exposure to the wash of rain and the wear of streams deep valleys were carved and hills formed. The process of erosion went on through a long period of Tertiary time until the country was reduced to a general base-level above which rose a few remnants of earlier and higher levels, such as Moose mountain far to the southeast, and Wood mountain far to the southwest, of Regina. These rose conspicuously above the base-levelled surface which, due to the subsequent elevation, had been deeply trenched by the master streams, as in the case of the drift-filled depression extending south-southeast from between Carlisle and Cooper, to the vicinity of Carrievale. This, also, is far to the southeast of Regina.

Comparatively little influence is shown in the topography of the region today by the bedrock and the old preglacial features. The hills and ridges which dominated the preglacial landscape are subdued and covered with a heavy mantle of drift, the valleys are largely filled with glacial debris, and only the more prominent features of hill and valley, now greatly modified, are seen.

During the Glacial period the great ice-sheets, which over-rode Saskatchewan, developed in northern Canada. There is abundant evidence to show that the Glacial period was marked by the advance and retreat of several successive ice-sheets rather than that of a single one.

The last stage of glaciation is the most important in so far as surface topography is concerned. The drift blanket of this stage has been laid down so recently that, except for the master streams which carried a large supply of the water from the melting ice, the tributaries have scarcely begun the work of trenching and eroding this young land surface.

The general topography of this region has a conspicuous northwest to southeast trend with the Glacial Lake Regina plain, about 30 miles in width and several times that in length, as the central feature. This lake plain is separated on the southwest from the Missouri escarpment, the most dominant feature of the landscape, by a belt of rolling ground moraine averaging perhaps 20 miles in width. On the northeast it is closely paralleled by a strong recessional moraine, a part of the Moose Mountain morainic system, from which it is separated only by a narrow belt of ground moraine which is in places overlain by extensive deposits of outwash gravel and sand.

The Missouri escarpment, the northeast edge of coteau du Missouri, rises rather abruptly above the prairie plains about 50 miles southwest of Regina. The escarpment is made more prominent and the Coteau made stronger in relief by the great quantity of morainal drift piled upon it in the belt 20 to 30 miles in width, known as the Coteau morainic belt. The large number of small, irregularly shaped hills, interspersed with small lakes, which are found here, give a somewhat wild and rugged aspect to the country.

The Glacial Lake Regina plain is remarkably level, yet its surface shows in places gentle sags and swells, and so distinct is this sag and swell type of topography in some localities that it assisted in deceiving early geologists into believing that this was very smooth ground moraine.

Regina lies within the eastern margin of this old lake plain and near its middle. The city is only about 8 miles out from the southwest front of the Moose Mountain moraine mentioned above. This moraine is a hilly belt 10 to 12 miles wide, the elevations of which consist of low, rounded knobs of glacial till with occasional gravel kames, while the depressions between are for the most part irregular, undrained kettles. The belt has in places a very rough, irregular topography rather heavily covered with small forest growth or scattered bunches of poplar. The surface portion, at least, of this recessional moraine was deposited during a pause in the retreat of the last ice-sheet of the Glacial period. Lakes, marshes, and undrained areas abound and the topography of the moraine fashioned by the ice and ice-water during the pause in the recession of the ice remains practically unmodified.

Eighteen miles northwest of Regina the moraine is cut through by Qu'Appelle river just below Craven at the outlet of Last Mountain lake. Here it turns somewhat more to the west and continues in the general direction of the Elbow. A succession of kame-like hills with outwash gravel and sands are especially well developed along its southwest margin from Qu'Appelle valley at Craven to Pilot Butte. This moraine by lying as it does so near to, and rising above, the lake plain on which Regina stands is the dominant topographic feature in the immediate vicinity of the city. From the southwest front of the Moose Mountain moraine the smoother till belt or ground moraine slopes gently down to the borders of the old floor of the glacial lake within the eastern margin of which Regina now stands. The surface of this till sheet is commonly gently undulating, the sag and swell type of topography of the ground moraine being characteristic.

The topographic form and the sandy, gravelly character of the recessional morainal area strongly favour the absorption of rainfall by the soil. The "gumbo" soil of the old lake plain, though level lying, resists absorption and thus favours evaporation. The areas are thus seen to influence the absorption of the rainfall into the ground waters in opposite ways.

DRAINAGE

Regina is a long distance from any considerable body of water, either river or lake. The nearest important water body is Qu'Appelle river, the master stream of the region. This river crosses the Glacial Lake Regina plain from west to east and enters the Moose Mountain moraine at a point about 20 miles north of Regina. It cuts directly through this moraine in a broad, deep valley on its way to join Assiniboine river which flows into Red river at Winnipeg. Its waters are led thence through the outlet of lake Winnipeg, Nelson river, to Hudson bay.

The drainage of the Regina plain enters Qu'Appelle river from both the northwest and southeast. From the northwest comes the Upper Qu'Appelle which broadens into Buffalo Pound lake, ½ mile wide and 16 miles long, with its outlet only a short distance above the confluence of Moosejaw creek, the first important tributary of the Qu'Appelle. Last Mountain lake, more than 50 miles in length and ½ to 2 miles in width, with its important western tributary, Arm river, also enters from the northwest about 18 miles northwest of Regina. From the south, besides Moosejaw creek, which drains the entire southwest side of the Regina plain, comes Waskana creek, which drains the eastern side of the plain, passing through the southwest portion of the city of Regina on its way to a junction with Qu'Appelle river 18 miles northwest of the city.

Boggy creek rises on the drift prairie far to the northeast of Regina, cuts its way westward through the Moose Mountain moraine to the Regina plain where it turns northwest across the plain and joins the Qu'Appelle at Craven Junction, about 16 miles northwest of Regina. This is the point at which the river is nearest the city. The history of the public water supply of Regina deals largely with the drainage basin of Boggy creek.

Draining the front of the recessional moraine for most of the distance between the point where Boggy creek leaves the Moose Mountain moraine and where Qu'Appelle river enters it, is Flying creek. This flows northwest along the eastern edge of the Regina plain and enters the master stream immediately opposite the drainage from Last Mountain lake, its largest tributary. The future history of the public water supply of Regina may be as closely associated with the drainage basin of this creek as it has been with Boggy creek.

Something over 100 miles to the northwest of Regina, South Saskatchewan river makes a sharp "elbow" as it turns from an eastward to northward course to join with the North branch and form Saskatchewan river proper. It is possible that the ultimate water supply of Regina, Moose Jaw, and this entire region may be derived from this surface source.

CLIMATE

GENERAL CONDITIONS

Regina is in a region of temperate climate and moderate rainfall. Its location near the centre of the great interior plain of North America gives it a climate that is continental in character—it has warm summers and cold winters. Its position in the northern belt of prevailing westerly winds and near the most frequented northern path of the eddying cyclones that move eastward in this belt gives a marked variety to the direction and velocity of its winds and almost wholly determines the variations of its weather.

TEMPERATURE

One of the chief characteristics of the continental climate is the wide difference in temperature between summer and winter. Temperatures of 90 degrees Fahrenheit are not uncommon in the summer, whereas 30 to 40 degrees below zero is not infrequently recorded in the winter. Owing to the low relative humidity of the atmosphere, however, these extremes are not so keenly felt as the much more moderate extremes in the regions where the atmosphere is moister. The mean annual temperature for Regina is 33 degrees F. The highest maximum ever recorded at Regina is 107 degrees F. on July 18, 1886, and the lowest minimum recorded is −56 degrees F. on February 1, 1893. This record gives the rather remarkable range of 163 degrees between the highest and lowest observed temperatures.

The winters are long and severe, and the summers comparatively short. The growing season, or the period between the latest and earliest killing frosts, averages 114 days. The number of days embraced in this period are few, yet because of the long periods of sunlight which at the maximum, about June 21, exceed 16 hours a day, the growth of vegetation is very rapid. Again, growth is favoured by the high percentage of clear sky during the growing season. Owing to these very favourable conditions wheat and other hardier cereals seldom fail to reach maturity.

The streams are closed by ice for about five months, and the surface of the ground is sufficiently frozen to prevent ready absorption of moisture for about 6 months of the year. During the other 6 months the soil is in condition to absorb the rain, which then largely goes to increase the ground water supply.

The relations of temperatures to ground water are very complex. They include the immediate and direct relations that govern the amount, rate, and form of precipitation; those that determine the porportionate parts of the rain and snow that evaporate, run off, or are absorbed, as affected by the evaporativity of the atmosphere, and by the freezing, baking, etc., of the surface; and those that govern the movement of ground water. The last item is commonly overlooked, but its importance may be suggested by the fact that water at 100 degrees F. has a viscosity only a little more than half that of water at 50 degrees F. and hence percolates nearly twice as rapidly through sand of a given texture as water at 50 degrees; both absorption and flow, therefore, vary greatly with the temperature.

PRECIPITATION

Controlling Conditions. The moisture that falls as rain or snow over Regina comes chiefly from the Atlantic ocean and the gulf of Mexico. As the areas of low pressure, technically called cyclones, with their eddying winds, move eastward across the continent with the prevailing westerly winds, the warm, moist air from the south and southeast is drawn into eddies and causes southerly winds and mild temperature. Because this air is passing from warm to cooler regions and ascends, it is cooled, and a portion of its vapour is condensed into clouds, from which rain or snow is precipitated. With the passing of the stormy area the winds become northwesterly, and cold air flows in with considerable force: the sky clears, and the temperature falls. These cyclonic storms are large in area, moderate in force, and beneficial in effect. They should not be confused with the violent rotatory storms of small diameter properly called tornadoes, which occasionally occur in the middle and eastern parts of the United States, though seldom in Saskatchewan. These tornadoes have narrow tracks and extend over small areas.

The precipitation of Regina is directly cyclonic in winter and indirectly cyclonic in summer. During summer it occurs chiefly in the form of local showers and thunderstorms in the southeast quadrant of the low-pressure areas. On the whole, and in all seasons of the year, Regina has a large majority of clear days with bright sunshine.

Distribution. The average annual precipitation at Regina for twenty years, 1910-1929 inclusive, is approximately 14·8 inches, allowing 10 inches of snowfall as the equivalent of 1 inch of rainfall.

To give a clear idea of the relation of rainfall to ground water the records should show not only the amount of precipitation but the rate of fall, the conditions of the land surface at the time, the cloudiness, and the direction and velocity of the wind that follows the rain. A slow rate of fall, if long continued, permits a large amount of the water to soak in, whereas a rapid fall of brief duration saturates only a thin surface layer and compels much to run off. Rain that falls on a moderately dry surface is absorbed more rapidly than that falling on a frozen surface. Into the frozen soil it is scarcely absorbed at all, and even the snow melts in the spring before the ground is thawed out and runs off over the frozen surface. The precipitation of winter and early spring is of little value as compared with that of summer. The snow is commonly a few inches deep from December to March and rarely attains a depth of more than a foot or two. Snow may fall, however, at any time from September to May.

The monthly, seasonal, and annual precipitation of Regina and several other stations of the Canadian Meteorological Service in the vicinity of the source of Regina's ground water supply is given in the accompanying table.

Average Monthly, Seasonal, and Annual Precipitation

(1910–1929)

Stations	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Fort Qu'Appelle	0·78	0·60	0·88	0·81	1·71	2·59	2·55	1·59	1·57	1·13	0·67	0·53
Indian Head	0·94	0·73	1·34	1·07	2·05	4·47	2·54	1·83	1·76	1·30	1·01	0·75
Regina	0·54	0·46	0·74	0·72	1·68	3·07	2·35	1·72	1·34	0·99	0·70	0·44
Qu'Appelle	0·89	0·70	1·24	1·26	2·10	3·33	2·78	1·98	1·97	1·42	1·04	0·74
Yellow Grass	0·56	0·52	0·77	1·02	1·88	2·92	1·98	1·49	1·68	0·89	0·87	0·64
Average	0·74	0·60	0·99	0·98	1·88	3·28	2·44	1·72	1·66	1·15	0·86	0·62

—	Winter	Spring	Summer	Autumn	Annual
Fort Qu'Appelle	1·91	3·40	6·73	3·37	15·41
Indian Head	2·42	4·46	8·84	4·07	19·79
Regina	1·44	3·14	7·14	3·03	14·75
Qu'Appelle	2·33	4·60	8·09	4·43	19·45
Yellow Grass	1·72	3·67	6·39	3·44	15·22
Average	1·96	3·85	7·44	3·67	16·92

Most of the precipitation occurs in well-distributed showers during the late spring and the summer. The approximate percentages for the seasons are for winter, 10 per cent; spring, 21 per cent; summer, 49 per cent; and autumn, 20 per cent. Only a small part of the total precipitation occurs during the period when the ground is frozen and absorption is least, and a large proportion, probably 70 per cent, occurs when absorption is greatest.

The winds that sweep across the almost level prairies with great force blow the snow about and heap it in drifts where obstacles are found and cause a marked evaporation directly into the air without melting.

Variations. Severe general midsummer droughts occur at irregular intervals, although during such droughts many small areas may have practically normal precipitation. The table, page 72, shows the variations in the annual precipitation for Regina since 1910.

Yearly Variation of Precipitation in Regina, 1910-1929

Year	Precipitation		Precipitation as water	Departure from normal
	Rain	Snow		
	Inches	Inches	Inches	Inches
1910	11·05	26·6	13·71	−1·09
1911	14·52	40·3	18·55	+3·75
1912	9·11	15·8	10·69	−4·11
1913	12·39	15·6	13·95	−0·85
1914	9·62	23·8	12·00	−2·80
1915	8·12	17·8	9·90	−4·90
1916	17·29	57·6	23·05	+8·25
1917	6·18	25·1	8·69	−6·11
1918	9·42	17·9	11·21	−3·59
1919	8·43	32·3	11·66	−3·14
1920	12·06	24·5	14·51	−0·29
1921	18·35	17·8	20·13	+5·33
1922	11·02	33·6	14·38	−0·42
1923	16·72	35·3	20·25	+5·45
1924	8·17	47·7	12·94	−1·86
1925	12·53	37·8	16·31	+1·51
1926	12·21	43·0	16·51	+1·71
1927	16·48	60·5	22·53	+7·73
1928	10·15	20·1	12·16	−2·64
1929	5·26	57·7	11·03	−3·77

Relation to Water Table. The influence of meteorologic conditions upon the ground water supply is best seen in the fluctuations of the water-level in shallow wells and in the flow of streams.

During the early summer, when rainfall is heaviest, the water table stands highest and all wells contain water. As the rainfall decreases in the late summer and early autumn, evaporation from the soil and through vegetation rapidly lowers the ground water level below the bottoms of many of the wells, and they go dry.

In autumn, owing to lessening evaporation, the water table may rise and the water may again enter the wells and dry stream beds, even though the rainfall continues to diminish.

With the long winter, during which the precipitation occurs in the form of snow and the percolating surface is frozen into an impervious cover, a second period of drying up of wells comes on, owing to the loss of water through underground drainage, to seepage into streams, and in small degree to pumping without chance of replenishment except by lateral movements, which are very slow. In some wells the first period passes into the second without renewal of supply until the frost leaves the ground in the following spring.

The influence of meteorologic conditions on the deeper wells is less evident, owing to the fact that in the deeper formations the movements of water are slower, replenishment comes from greater distances, and the water is under greater hydrostatic pressure. Under such conditions local changes in temperature and rainfall have little effect, and that only after a long period of time.

GEOLOGY

Two very distinct geological systems are represented in the formations near the surface in the vicinity of Regina—the Pleistocene and the Cretaceous—the former by the loose, unconsolidated mantle materials consisting chiefly of the lake clays and the glacial drift, the latter by the more firmly consolidated bedrock beneath. Evidence regarding both of these systems is found in outcrops along the sides of the deeper stream valleys and in the cuttings and records of wells. Some information has been secured concerning the still deeper bedrocks from the record of the deep boring at Moose Jaw, 40 miles west of Regina, which passed through both the Pleistocene and Cretaceous and even the underlying Jurassic strata into limestone of Devonian or Carboniferous age (1), and from other deep holes drilled for oil or water located at greater distances from the city.

The following table of formations presents the geologic succession in the immediate vicinity of Regina:

Table of Formations

Period	Series	Formation	Lithology
Pleistocene	Glacial	Regina clay	Lake clay
		Glacial drift	Till, gravel, and sand
Cretaceous	Montana	Pierre (Bearpaw)	Blue-grey shale
	Colorado		Shale
	Dakota		Sandstone and shale

Aside from more recent alluvial and æolian deposits, which, although widespread in this region, are thin and comparatively unimportant, and are in themselves reworked materials, the Pleistocene period is represented by two distinct formations in the vicinity of Regina, the Regina clay and the glacial drift.

REGINA CLAY

The Glacial Lake Regina deposit is a grey clay, showing characteristic brownish weathering. It is very sticky and tenacious in character when wet, but falls to pieces as it dries, forming a granular mass. The clay is often referred to as "gumbo.' It contains a few small stones up to 1 inch or 2 inches in diameter, but commonly smaller. These were probably deposited on the lake floor from floating masses of ice broken off from the front of the glacier and are, therefore, "ice rafted" material.

The character of this gumbo is well illustrated in the use of the roads of this region. Because of the absence of other road material in the vicinity and the expense of procuring it from a distance, graded dirt roads are the common type on the Regina plain. These are excellent in dry weather, but in wet weather they are exceedingly difficult to travel. Auto traffic over the Regina clays is almost impossible in the spring and during and after rains.

The surface of the old lake bed is nearly level, but has slight undulations, broad swells, and shallow depressions. Where these irregularities are most pronounced the hollows are occupied by marshes. The small pebbles and the slightly undulating surface of the lake deposit caused it to be classed in studies of some of the earlier geologists as till.

The thickness of this formation at Regina is approximately 40 feet. Greater thicknesses probably occur at other points beneath the plain, especially to the westward near its axis. It thins out to the eastward.

GLACIAL DRIFT

Beneath the Regina clay and elsewhere at the surface covering the bedrock over the entire area of the region is the Glacial drift. This formation is for the most part till, or boulder clay, and is composed of a mixture of clay, sand, and gravel, with occasional boulders—all of which was deposited directly by glacial ice. In places at the surface, within or underlying this boulder clay, are deposits of sand or gravel or both. These are assorted drift, ice-laid material, reworked by the waters flowing from the melting ice-sheet which deposited them underneath or in front of the glacier. They are found extensively among the moranic ridges and in front of the morainal belt. Since these deposits may have been made either during the advance or retreat of the ice they may be overlain, interbedded with, or underlain by the till. The most extensive deposits of coarse gravel and sand were probably laid down as outwash plains or as valley trains between the recession of one ice-sheet and the advance of the next. They are, therefore, sometimes deeply buried by the upper till sheets. Those deposited in front of the ice during a pause in the last retreat overlie the till sheet usually as an apron in front of the recessional moraine. A good exposed section of the drift occurs on lower Boggy creek just northwest of Bredin. Here a younger and older till are shown with a very bouldery outwash between, all overlying Pierre shale.

The thickness of the drift is very variable, but in general it is from 30 to 40 feet under the more level plains and 100 to 200 feet in the heavier topography of the morainal ridges.

PIERRE SHALE

The Pierre (Bearpaw) shale belonging to the Montana series is known both by outcrops and by well records to underlie all of southern Saskatchewan. This formation consists chiefly of a blue-grey shale, which is soft and fissile in character and contains many fossils that show it to be of marine origin. In the upper portion there are in some places thin layers of fine blue sand. In the deep well at Moose Jaw these sandy beds are so well marked that Dyer (3) suggests that they may possibly represent the extension eastward of the Belly River formation which is well developed in Alberta. Other thin beds of sandstone were also found in the Moose Jaw well somewhat below the middle of the formation. The Pierre shale is reported to be 1,500 feet thick in places.

In the deep oil test well drilled at Riverhurst (4), the Montana series is represented by two, dark, blue-grey shale formations, both of marine origin as shown by the numerous fossils. The two formations, similar in physical characteristics and in fossil content, are separated by a sandstone and sandy shales. These three formations are believed to be the Bearpaw shale, uppermost, the Belly River sandstone, and the Pierre shale. The Bearpaw shale is grey and becomes quite sandy in places. Studies along South Saskatchewan river at Riverhurst and above indicate a dip to the northeast, in the Montana series, of 6·5 feet a mile.

The Belly River beds as exposed on South Saskatchewan river west of Riverhurst show yellowish sands and sandy shales, together with one small seam of lignite coal. The uppermost bed is in places a hard, massive sandstone. In its eastern extension the formation takes on more and more the characteristics of marine sedimentation. The formation is believed to be 450 to 600 feet thick in that vicinity.

Beneath the Belly River sandstone lie the Pierre shale and the Colorado shales. These formations are not exposed on the river in this vicinity, but the log of the Imperial Oil Company's well shows the combined thickness of these formations to be about 1,715 feet, which corresponds quite closely with that shown in the log of the Moose Jaw well. The two formations resemble one another so closely in physical characteristics that it is impossible in the data supplied in the log of the Imperial well to distinguish them. The base of the shale (the top of the Dakota sandstone) should occur at Riverhurst at a depth of about 2,430 feet.

COLORADO SHALES

The Pierre formation passes below by gradual transition into the Colorado formation, a series of marine shales similar to the Pierre in character. South of the international border these are further differentiated into the Niobrara and the Benton shales, the former having a marked lime content and being, therefore, more grey in colour and less fissile and the latter very dark in colour, almost glossy black in some of its phases. These shales are reported to be about 1,300 feet in thickness so that "A drill having entered the Pierre would pass continuously through nearly 3,000 feet of much the same type of sediment before striking a change of formation, with the possible exception of the sandstone beds mentioned above." (3)

DAKOTA SANDSTONE

Beneath the Colorado shales lies the Dakota sandstone. This represents the sandstones of the Blairmore-Kootenay beds of the Cretaceous, in Alberta. It does not crop out at any point in this vicinity. South of the International Boundary it is widely known, for it is the source of water in all of the 20,000 flowing wells in the Dakota artesian basin. This formation consists of fine, grey, ferruginous sandstone, very friable in character, interbedded with layers of sandy shale, some of which are very firm in texture and in the lower portions may be both pyritiferous and concretionary. In places it includes beds of fine, incoherent, nearly white sand. At the base of the formation in some places the sandstone passes into conglomerate. Its thickness differs greatly, for in some places it has been reported very thin and in others it is believed to be nearly 500 feet thick.

OLDER FORMATIONS

A considerable thickness of rocks of earlier Palæozoic age are widespread throughout Red River valley and the Upper Mississippi valley. They are older than the Cretaceous formations and rest unconformably on the uneven floor of the older crystalline rocks. These Palæozoic rocks consist of beds of sandstone, limestone, and shale repeated in varying order. They do not outcrop in southern Saskatchewan and nothing is known regarding their presence here except in a few deep wells.

GROUND WATERS

Owing to the scarcity of surface waters throughout most of the prairie region of southern Saskatchewan, the problem of securing an adequate ground water supply for villages and cities has been a serious one from the period of the earliest settlement. In most of the larger cities, surface supplies have been secured from the larger streams and lakes. In some cases, however, as in Regina, nearby lakes are too small or too highly mineralized, and adequate streams are far distant.

There are but two geological formations in the vicinity of Regina which serve as reservoirs for any considerable amount of ground water, the Dakota sandstone and the Glacial drift. Of these the latter only can be considered as a feasible source of a city water supply. Each formation, however, will be considered in its relation to ground waters.

BEDROCK WATERS

Pre-Cretaceous Formation Waters. Of the formations below the Cretaceous little is known except from the records of the Moose Jaw deep well. This well was drilled to a depth of 3,310 feet and is said to have passed the base of the Dakota sandstone, the lowest representative of the Cretaceous, at 2,980 feet. It is thought that in the lower 330 feet this hole penetrated the Jurassic rocks and entered limestone or dolomite of Palæozoic age. Water was found at the 3,300-foot horizon, which, however, was salty and unfit for domestic use.

The depth of any formations that may underlie the Dakota sandstone is so great that it would not be economically feasible to drill and maintain wells for a city supply from them unless large flows were obtained, and this is highly improbable. Also, the water has remained in these formations so long and travelled so far that it is very highly mineralized and, therefore, unfit for human use.

Dakota Sandstone Waters. That the sandstone of Cretaceous age known as the Dakota underlies Regina is highly probable, since it is penetrated by a number of wells in southern Saskatchewan and Manitoba. Nearest and most important among these wells of record is that of the deep well at Moose Jaw where the sandstone was pierced at a depth between 2,840 and 2,980 feet. Water was reported at the 2,950-foot horizon, but it was salty and unfit for domestic use.

At Deloraine and Morden in southern Manitoba the Dakota sandstone has been reached and yields to the pump strongly saline water in each of these localities.[1] At Devils lake and Leeds in North Dakota flowing wells from the Dakota sandstone furnish ample city supplies, yet these are so strongly saline as to be unsatisfactory for public use.

In general the Dakota sandstone is one of the most important aquifers in North America and in fact in the world. It supplies 20,000 flowing wells in the states of North Dakota, South Dakota, Minnesota, Iowa, and Nebraska. The amount of salinity decreases to the southward and eastward and it becomes highly useful for municipal supplies and especially for stock and farm use.

The elevation of the surface at Regina and the depth of the Dakota formation, about 3,000 feet, make it impossible to secure a flowing well and the supply, even though it should be found in adequate amounts, would be very expensive to secure and maintain.

The experience at Devils lake, North Dakota, and elsewhere in the northwest, of drilling to such depths through the soft Cretaceous shales, has shown great difficulties due to caving. The water is so saline and of such high temperature as to be wholly unsuited for public use. It is, no doubt, excellent for fire protection.

Cretaceous Shale Waters. The Cretaceous shales include the Pierre formation, which probably immediately underlies the drift in the vicinity of Regina, and the Colorado shales. All of these are classed by geologists as bedrock, though certain members are so soft and unconsolidated that they flow and cause serious caving during drilling.

These formations have been pierced by many wells throughout southern Saskatchewan and entirely penetrated in the Moose Jaw deep well in which their base was found overlying the Dakota sandstone at 2,840 feet. In this hole water was reported at horizons at 1,160 and at 2,820 feet.

In some areas water is secured in limited quantity for farm wells in thin layers of blue sand which is interbedded with layers of Pierre shale at depths ranging from the top of the shale to 300 or possibly 500 feet below the top. These waters are permanently hard and contain a very considerable amount of mineral matter in solution.

In general, however, these shale formations are highly impervious and are among the least useful of all rock formations for the purpose of water supply. It is certain that no city supply could be secured from them.

It may be concluded, therefore, that there is no opportunity to secure potable ground water in any quantity sufficient for a city supply for Regina, from any bedrock formation or from beneath the drift.

All prospecting should, therefore, be confined to the drift and should cease when bedrock is reached. Unfortunately the colour of the drift and that of the underlying bedrock of the Pierre shale from which it is largely derived, is so similar that it is difficult even for the drillers to determine when the plane of contact is passed and it is usually impossible to tell from an ordinary well record where the drift ends and the bedrock begins. This is, however, an important matter in prospecting and only experienced drillers should be engaged for this kind of work.

[1] Malcolm, W.: "Oil and Gas Prospects in the Northwest Provinces"; Geol. Surv., Canada, Mem. 29, pp. 75-85 (1913).

PLEISTOCENE WATERS

Since there is practically no chance of obtaining a suitable supply of water from the bedrock formations, there remains only the unconsolidated formations of the mantle rock for consideration.

The two recent formations, the alluvial and æolian deposits, although noticeable on the surface, the former in sandy and "gumbo" areas and the latter in stream valleys, are so thin as to be unimportant and, also, they are only the glacial deposits beneath reworked by the wind and running water. They need not be considered as sources of ground water supply.

Regina Clay Waters. The Regina clay which immediately underlies the city of Regina to a depth of approximately 40 feet has not been heretofore clearly distinguished from the glacial drift; in fact, it has been referred to by some geologists as the "Regina till." This clay, most commonly called "gumbo," is one of the least permeable of sedimentary rocks; it is, therefore, not a good water-bearing formation. In the early history of the city many homes were supplied from shallow bored wells and this is true in North Annex today. The yield is, however, very small. So slight in fact are the water supplies that may be obtained from this source that the securing of sufficient water for farm use is one of the most serious agricultural problems of the region. Over considerable areas, due to the presence of the Pierre shale immediately beneath the clay, deep well water supplies are not procurable and only shallow wells securing their meagre supplies from seepage are obtained. These cannot at any time furnish water for a considerable amount of live stock and in the two annual periods of low ground water level they are liable to go entirely dry. One of these periods is in August and September when the precipitation is very scant and evaporation is high, and the other in February and March, since from November to March, ordinarily, no water can enter the ground and circulation near the surface is stopped by freezing. Under such conditions, and in the absence of surface water which is very scant also in this region, resort is had to "dug-outs," as the excavations for artificial ponds are termed. These are conspicuous on many of the farms of the region and in some localities are practically the only source of water supply for stock use and in many cases for household purposes as well.

The "dug-outs" are usually located in slight depressions or "draws" where they collect some rainfall, but they are chiefly supplied from the run-off of the melting snow of spring. The lake clay, or gumbo, is so impervious, and the evaporation, due to the cool northern climate, so slight, that unless used up, water remains in these artificial depressions all summer, if they are located so as to secure a good supply. The "dug-outs" make it possible to have some stock on all of the farms and to operate farm machinery, though gasoline power has largely replaced steam power in this region.

Underground cisterns are also common. They are made of concrete, lined with cement, and are filled with snow in the spring and also connected with the eaves-spouts from the roofs of houses, barns, and other buildings. With the roof space necessary on a farm in this region, sufficient water may be obtained in this way for household use throughout the year and with conservation a considerable amount of good soft water may be had for use with the engines and for the stock. With proper filter installation an excellent supply of pure, soft, wholesome water may be thus obtained for the farm.

No considerable amount of water may be obtained in the lake clays for any village or city supply.

Glacial Drift Waters. A consideration of the problems connected with the study of a ground water supply for Regina becomes chiefly a study of the waters of the Glacial drift. Exposed sections of the drift are few and superficial; therefore, a study of well records is of the highest importance. This has been supplemented by careful field observation and study of all evidences of the natural recovery of ground waters, including seepage, springs, and the flow of surface streams in dry weather.

The drift laid down during the Glacial period is of two distinct kinds: (1) Boulder clay, or till, a dense yellow or blue clay, containing sand, gravel, pebbles, boulders, mixed irregularly through it, and (2) assorted drift, including sand, gravel, and silt.

The boulder clay was deposited directly by the ice in the peculiar mixture in which we find it. The gravel, sand, and silt were carried, assorted, and deposited in the beds in which we find them by the action of water. The gravel and sand were deposited by streams of water flowing away from the front of the melting ice-sheet, and the silt was laid down in quiet water into which it had been carried by the running water. The assorted drift may be considered as including the Regina clays, since this material is essentially the finest of the glacial debris reworked by running water and deposited slowly as a fine silt on the floor of a large glacial lake. Here may also be included such thin beds of alluvium as are found in the major valleys and the æolian material found both upon the sand-plains and the lake clays, since they, also, are only Glacial drift reworked by running water and wind in recent times.

Drillers occasionally find old soil beds or forest litter consisting of logs, twigs, bark, leaves, and roots deeply buried in the Glacial drift of the region. These beds lie between separate sheets of the drift, and clearly show that a warm period, bringing vegetation and forests, occurred between two separate advances of the glacial ice in this region.

The boulder clay is a relatively impervious formation and, therefore, absorbs water slowly, holds little, and yields very scanty supplies to large tubular or dug wells. It affords enough perhaps to supply the needs of a farm, but the quality is generally poor because of heavy mineralization resulting from long contact of the water with the clay.

Gravel and sand are commonly found in layers, lenses, or irregular-shaped bodies, within the boulder clay, but much thicker and more widespread deposits of these are found in places at the base of the drift immediately overlying bedrock and between the layers of boulder clay laid down by different advances of the ice. There were undoubtedly two, and probably more, advances in this region. These deposits are capable of acting as reservoirs holding water in large amounts in the open spaces between the grains of sand and gravel, which is rendered available for use at the surface by means of wells. Some dry sands are found, but this does not prove that all parts of these sands are incapable of furnishing water. From the mode of origin of these sands, as glacial outwash, they possess a gradual slope toward the southwest, and by following a dry sand bed in that direction a water-bearing portion may be found. These sand and gravel deposits are especially thick in the deep valleys which had been carved into the surface of the old upland plain by the rivers and creeks before the Ice age, or in the drift itself in the intervals between the different advances of the ice. In the vicinity of Regina these sand and gravel deposits are found in beds of 10 to 20 feet in thickness in the drift sheet beneath the city and between the lake clays and the bedrock shale and in still thicker deposits in valleys of ancient streams between drift sheets which slope gradually down from the great Moose Mountain moraine on the northeast toward the city.

Deposits of sand and gravel in the form of kames, outwash plains, and in irregular patches, also occur overlying the till sheet, especially in the southwestern side.

All gravels and sands of the drift are apt to contain considerable quantities of ground water of high quality, unless they are so situated above the ground water level as to be drained naturally. The heavy beds of gravel and sand occupying the buried channels of ancient preglacial valleys and the filled valleys of present rivers are especially good sources of ground water supply in many instances; since they furnish natural storage basins of great capacity. In such situations the water may be found in sufficient quantities for industrial and city supplies.

The chemical quality of this water, though hard, especially in temporary hardness, is generally good, since it is the nearest of all ground water to its original source, the rainfall, and since it is generally in slow motion through this coarse material it has not gathered much mineral matter from the relatively insoluble gravel and sand.

Probably the great majority of the house and farm wells of Saskatchewan derive their supply of water from the Glacial drift, but only an exceptional deposit of gravel and sand, deeply located, will yield a sufficient amount of water to be considered for a city supply. Such, however, are those of the recessional moraine to the north and east of Regina, and *it is here alone that we may hope to secure an adequate ground water supply for the city.* These waters are good for drinking purposes and though hard, the hardness is temporary, and by softening treatment they may be made into a good domestic water.

Qu'Appelle river meanders widely on its broad, flat valley floor over glacial deposits consisting of sand and clay of the Ice age, overlain with the finer muds and silts deposited during river floods of recent times. Drilling tests in this valley show the filling material to be nearly 200 feet deep, all relatively fine. Analyses of the water indicate a high and undesirable mineral content.

ARTESIAN WATERS

All deep-seated waters, including those of the Dakota sandstone and any that may be located below, are probably under considerable artesian pressure and would rise, therefore, in the wells under sufficient head to make it possible to recover them by means of the pump. Owing to their depth and the elevation of the surface at Regina it is not probable that flowing wells could be secured from any of the bedrock formations.

Flowing wells may be secured, however, from the drift in localities where conditions are favourable, but these areas are undoubtedly very local in extent.

The earliest flowing well in the vicinity of Regina was a government well located about 4 miles south of the city (NE. ¼ sec. 21, tp. 16, range 19, W. 2nd mer.). This yielded a flow of 8,640 gallons a day, but is now dead. Two other flowing wells were early drilled in the same township (NE. ¼ sec. 33, and SW. ¼ sec. 34). There is now one flowing well in this area. It is located at a schoolhouse about 5 miles southeast of Regina (SW. ¼ sec. 3, tp. 17, range 19, 2nd mer.).

The wells in this small artesian area are undoubtedly from a gravel or sand layer of the drift which has its outcrop at the surface in the higher morainic belt several miles to the northeast and dips southward underneath the Regina clay. Because of its limited extent these gravels probably occupy a small stream valley as a valley train, or are in the form of a narrow, buried, outwash plain held in between the Regina clay and the till sheet or the Pierre shale and are, therefore, in the form of an artesian slope.

Three other small artesian areas of importance in connexion with the ground water supply of Regina have been discovered through prospecting and development. The first and most important yet developed is in the valley of Boggy creek located about 8 to 10 miles northeast of the city (secs. 11, 12, and 14, tp. 18, range 19, W. 2nd mer.). This was discovered while drilling a test hole recommended by Mr.Wynne-Roberts in 1912 (9) and since that time this area has been the chief source of water supply for Regina. Boggy Creek area will be fully described later in connexion with the history of its development.

The second artesian basin is that in the small valley about Mallory springs on a branch of Silver stream about 5 miles east of the city (secs. 25 and 26, tp. 18, range 19, 2nd mer.). This was discovered in 1927 as a result of test drilling recommended also by Mr. Wynne-Roberts in his report of 1912 (9). This small basin will also be fully described later in the history of the development of the Regina water supply.

The third artesian area is that of Flying Creek basin about 14 to 16 miles north and northwest of the city. The occurrence of this artesian basin was predicted by the writer as a result of the field survey of July, 1929. Test wells drilled at Mound springs in October of the same year proved the forecast correct and other drillings at Cooper springs and Dickson springs will probably yield flowing wells. This area will be discussed later in connexion with the proposed improvements in the water supply of Regina.

Mallory, Boggy, Victoria, Blythe, and Mound groups of springs are all more or less artesian in character, since they are supplied in part at least by one or more sand and gravel water-bearing beds buried at moderate though variable depths beneath the till sheet laid down by the latest advance of the glacial ice. They represent interglacial or subglacial outwash deposits which slope westward from the recessional moraine and pass underneath the northeastern margin of the Regina clay near the northwest-southeast line along which these springs occur. The overlapping clay prevents the escape of these waters to the westward and causes them to fill the porous reservoirs of the glacial gravels back a considerable distance and up the frontal slope toward the crest of the moraine which provides the intake area. The pressure from this head causes the artesian water to break upwards through the thin and somewhat porous overlying till, forming the several groups of springs, the water from most of which, coming from 30 to 50 and even 150 feet below the surface, has a temperature of 38 to 42 degrees Fahrenheit. The close approximation of this temperature to the mean annual temperature of the region (35 degrees Fahrenheit) indicates deep-seated origin of these waters as compared with that of the shallow waters of the surface outwash sand and gravel east and southeast of Regina, the temperature of which was from 50 degrees to 60 degrees at the time of observation, being determined by local surface conditions in summer.

The Pilot Butte springs which determined the location of the water supply of the Canadian Pacific railway are apparently in a thick surface deposit of outwash sand and gravel. It is possible that these, also, are somewhat artesian in character.

Dickson springs and Cooper springs are similar to the former groups and have their sources in the same shallow artesian supplies, though their location is probably determined by the erosive action of Flying creek and its tributary where they cut through the Regina clay and expose the Glacial drift beneath. The source of all of these is no doubt similar to that of the artesian wells at and near the school 5 miles southeast of the city. The strong eastern trend of the Moose Mountain moraine to the east of Regina takes it out of the immediate relation to the Regina clay from which it is separated by a broad belt of ground moraine. The artesian conditions so characteristic of the morainal front from Mallory springs northwest to Mound springs are not, therefore, duplicated in the region to the south and east of Mallory springs. The so-called "Eastern Region" does not, therefore, present as suitable a situation in which to search for a city water supply as does the Flying Creek Basin.

HISTORY OF THE REGINA WATER SUPPLY

EARLY SUPPLIES

The first public water supply of Regina consisted of ordinary, open, dug wells located at convenient points about the city. From these water was pumped to fill large cisterns which served as reservoirs for purposes of fire protection.

The first of these wells was probably the one located at the corner of Broad and South Railway streets. This was dug to a depth somewhere about 50 feet and it is reported that when water was struck it came in so fast that the well digger could not get his tools out. The specifications for the underground storage connected with this well, dated June 5, 1900, call for a wooden cribbing 12 feet deep, 14 feet wide, and 20 feet long, with a 2-foot covering on top.

The well on Halifax street near Market Square was probably the second. It was dug to a depth of 55 feet and under ordinary conditions was filled with water to a depth of about 18 feet. This is reported to have been a strong well, capable of watering over 100 head of cattle at one time.

A third well was located at the corner of Victoria and Winnipeg streets and supplied all of the residents in that neighbourhood.

A fourth was located near the post office. The town hall on the opposite corner contained the fire pump and the headquarters of the fire brigade. All of the early city wells are now abandoned.

All of these early city wells probably secured their supply from the drift immediately underneath the lake clays on which the city stands. The water having its origin largely in the rainfall upon the higher morainic region a few miles to the northeast, travelled down the general slope to the southwest and passed underneath the city. Being held in the gravelly and sandy layers beneath the lake clay and above the till of the drift or the impervious Pierre shale, they were under a slight artesian pressure. A good supply of wholesome water was yielded to these wells, which was ample for the time, and the fact that some water could be secured from dug wells of 50-foot depth or greater almost anywhere made a large public supply unnecessary for a time.

DEVELOPMENT OF BOGGY CREEK[1]

The first system of waterworks for Regina was installed in 1904. It was originally designed to utilize a surface supply, that of Boggy creek, to be taken at a point about 8 miles northeast of the city and at an elevation of about 75 feet above its street level. The flow of this creek was very variable, being large during the spring run-off but diminishing rapidly until in summer it was comparatively small. During July of the year of installation it did not exceed 200,000 gallons (U.S.) a day.

It was planned to increase the available daily flow throughout the year by the storage of the spring run-off, and to draw upon this impounded water during the remainder of the year. A dam about 15 feet in height was, therefore, constructed across the creek, which created a reservoir capable of holding about 80,000,000 gallons (U.S.), equivalent by itself to a supply of approximately 240,000 gallons (U.S.) a day for eleven months of the year. The flow of the creek would be ample at least for the other month. Thus it was planned to provide for a minimum daily plant capacity of about 400,000 gallons (U.S.) a day.

The local surface indications pointed to the probability of this surface supply being further increased by seepage from the ground waters. Fifteen-inch tile with cemented joints were used in the construction of the conduits through which the water would flow by gravity to the city.

In the construction of this conduit, the excavation was in dry lake clay and glacial till until a point about 3,000 feet below the storage dam was reached. Here at a depth of 20 feet the clay was penetrated and a large flow of ground water was encountered. This came from a deposit of glacial gravel and sand which underlay the clay and was, therefore, on this slope, under a slight artesian head. This head was sufficient to maintain the water at a depth of 7 feet in the completed trench.

From the point where this ground water was first discovered, to the reservoir, a distance of over a half mile, the trench ran through stretches of clay alternating with stretches of sand and gravel. The flow of water from the latter formation was so great and so persistent that it was decided

[1]For the history of the system from 1904 to 1908 the writer is largely indebted to Lea and Smith's Report (8).

to utilize it as a part of the supply. With this in view the tile was laid in the water-bearing part of the trench with joints partly open and covered with clean gravel. By this method portions of the conduit were made to serve also as collecting works.

When the system was put in operation the ground water supply was found to be sufficient in quantity and superior in quality to the impounded surface water, the inlet valve was, therefore, kept closed and the entire supply, amounting to about 600,000 gallons (U.S.) a day, obtained from the underground source.

This arrangement was continued unmodified until 1906 when the consumption of water in the city had so increased that the supply from this source alone became inadequate, and a branch collecting line of 6-inch open-joint tile was laid extending eastward from the main conduit at a point about 1,800 feet below the reservoir.

The following year a similar collecting line was laid for some distance along the eastern side of the reservoir. This increased the supply to an amount sufficient for all purposes up to 1908. In that year Messrs. Lea and Smith prepared a report suggesting further development of the Boggy Creek ground water supply (8). In the report the Boggy Creek water bed was described as follows:

> The present source of supply is from ground water collected in infiltration mains laid a few feet beneath the surface in the area adjacent to the storage reservoir. Up to this time no effort has been made to determine to what degree the ground water supply from Boggy Creek area can be developed, or to ascertain the depth and extent of the water-bearing deposits of gravel and sand. It is a matter of greatest importance that as correct an estimate as possible should be made of the available yield of the Boggy Creek supply, both from surface and ground sources.
>
> The surface water from the storage reservoir has so far not been used to any extent on account of the deterioration which takes place in its quality during the summer months. This is partly due to the inflow of spring water from the creek, and to infiltration through the bottoms and sides of the reservoir.

Boggy Creek area was fully described by Mr. R. O. Wynne-Roberts in a very complete report to the city in 1912 (9), which report followed a very comprehensive survey of the Boggy Creek watershed. As a result of this report three wells were drilled to test out the area. By these the conclusions of Mr. Wynne-Roberts as to the artesian character of the Boggy Creek basin were fully confirmed and the rapid development of this water field followed.

The drainage basin of Boggy creek has an area of 72 square miles above the pumping station. Its extreme length is 13 miles and extreme width 7 miles. The elevation rises rapidly from 1,924 feet at the pumping station to about 2,400 feet. Owing to the irregular morainic topography which characterizes the headwaters area, it is difficult to fix the boundaries definitely (9). It is highly probable that the ground water drainage comes from a considerably larger area than that of the surface watershed indicated in the above-mentioned report. The topography of the area is for the most part of the highly morainic type with the hills and irregular ridges among which are many depressions commonly known as kettles. In many of the latter are small ponds, marshes, or sloughs. Small seepages and springs are common throughout the area. Many of these dry up during the summer due to the lowering of the ground water table and to excessive evaporation.

The surface material is of glacial till, or boulder clay, with large quantities of assorted gravel and sand heaped in kames or spread over the surface as outwash deposits and interbedded within and beneath the boulder clay. The latter are deposits formed during interglacial periods and are similar to those found on the surface. Conspicuous among the gravel deposits at the surface are those used by the Canadian Pacific railway (sec. 20, tp. 18, range 15) for road ballast.

Most important of these deposits are the sheets of sand and gravel, interbedded with boulder clay, which appear to lie beneath the floor of the valley and dip with the general topography to the west-southwest. These probably represent outwash material, presumably in the form of valley trains, in a preglacial or interglacial valley, which were deposited in front of the ice during an interval in the recession. Due to their general extent, their dip beneath impervious formations, and their heading in the morainal region of large percolation from rainfall they are excellent artesian aquifers. There are at least three of these gravel formations interbedded with boulder clay in Boggy Creek valley: one slightly beneath the surface, variously given as 6 to 20 feet; a more important one at a depth of 40 to 60 feet; and the deepest 150 to 180 feet beneath the surface. These gave rise to the Boggy Creek springs and to the first and second artesian horizons of the city wells. The upper of these sand and gravel beds was exposed in the construction of Boggy Creek reservoir when it was found about 6 feet beneath the north side of the stream dipping south. It was again cut by the trench in laying the conduit through the hill (secs. 1 and 2, tp. 18, range 19) and when cut through, a copious supply of water was obtained from the gravel beneath, which was used by the city for a supply of water for several years. The depth and thickness and even the occurrence of these beds of sand and gravel and clay, which are of glacial formation, are, however, very irregular.

Boggy creek flows almost entirely across the recessional moraine in a general direction from east to west. Its flow is rather sluggish due to the slight gradient of its bed in this part of its course, and though having morainal springs in the first 5 miles of the headwaters area it loses its water, except in spring, in its central part and is dry most of the year. Mr. Wynne-Roberts cites an observation on October 6, 1912, when, after a heavy rainfall, the stream was flowing about 250,000 gallons a day through sec. 18, tp. 18, range 17. This flow entirely disappeared into the ground in the next three-fourths of a mile westward as a result of the porous condition of the drift.

Mr. Wynne-Roberts estimated the run-off from the Boggy Creek drainage basin, apart from flood-water, to be 1,400,000 gallons a day, and the available yield by the extension of the works then in progress to be 3,000,000 gallons a day.

"EASTERN PLAN"

In the 1912 report Mr. Wynne-Roberts (9) also suggested the possibility of developing an additional supply along several other creek valleys within 20 miles in an easterly direction from the city. This is commonly known as the "Eastern Plan." The complete development of this source was estimated to yield a total of 7,000,000 gallons daily at a cost then estimated at $1,106,000, exclusive of land or right of way. It was thought that the "Eastern" supply would come from a relatively small area and development could be proceeded with in such a way as to keep pace with the demands on the system.

Mallory Springs. In 1927 a further investigation of the "Eastern" source of supply was authorized with a view to its development. Accordingly the location nearest the city, known as Mallory springs, and its neighbourhood, was prospected by test borings. These springs were located in the head of a ravine (sec. 26, tp. 17, range 19) in which there is a muskeg 300 yards long. The catchment area was reported to be about 15 square miles. The results indicated that a supply of 750,000 gallons a day could be expected from this locality. Construction work was begun in 1928 and a pipe-line extended from the city to this location. Nine wells were sunk in this area, the average depth of which is 130 feet. Of these, four wells were producers in 1929 and three were in the nature of test-holes being put down in locations from which it would not be possible to secure a satisfactory flow. The fourth non-producer formerly flowed, but owing to its location on higher ground has ceased due to heavy production from the lower flowing wells. The quality of the water at Mallory Springs area was found to be similar to that of Boggy Creek area, clear, cold, and hard. The result of the Mallory Springs development was a 25 per cent increase in supply. The pipe-line to Mallory springs was a part of the general "Eastern Plan" and further extensions may be made when necessary. In addition to the development at Mallory springs four test borings were made at a location 1½ miles farther east (SE. ¼ sec. 30, tp. 17, range 18, W. 2nd mer.) on land commonly known as the Judge Embury quarter, without important results.

Slough Creek, or "The Hay Meadow". The next unit in the "Eastern Plan" is the Slough Creek flat known also as "The Hay Meadow". The stream takes its rise in a spring (sec. 25, tp. 17, range 18, W. 2nd mer.) and flows through marshes and hay meadows until it passes as an insignificant stream under the Canadian National Railway bridge (section 10). Though there is a fall of 18 feet a mile in this stream bed there is little erosion. Its watershed and boundary are very difficult to define and a large part of the area is composed of hay-marshes through which sheet water probably moves at an imperceptible velocity except in wet seasons.

Previous to the arrival of the writer three test holes had been drilled by hand in this area, by Mr. Johnston's party. The indications were not favourable for any considerable supply of ground water, since the spring, as nearly as could be located, and all other waters found, were warm, 50 to 65 degrees in temperature, indicating very shallow sources.

This appears to be a broad, gently sloping area of till overlain with shallow outwash sand at the surface. A small amount of water, most of which falls directly upon this area of not more than 6 square miles, seeps down through this sand and gradually moves over the impermeable till formation to the southwest. Unless this till is underlain by heavy outwash beds of earlier sands and gravels, of which there are no evidences, the amount of water that could be recovered from this area is inconsiderable. The engineers' estimate in 1912 of "possibly 500,000 gallons per day" (9) does not appear to be warranted.

Central Portion of the "Eastern Plan". The remainder of the territory involved in the "Eastern Plan" was gone over in as detailed a manner as time would permit.

There is no apparent geologic evidence to show the presence of any considerable amount of ground water in the basin of Silver stream outside of Mallory Springs area, or in Slough Creek area as indicated above, Balgonie Creek area, or Hicksvale Creek area, except possibly at Sturgeon springs on Balgonie creek. This will be referred to later. No cold springs were found revealing the rise of waters from deep-seated sources in any of these areas. The springs found were so warm as to indicate shallow origins.

Also, there was no considerable amount of surface water in the streams draining through these areas over the strong slopes, and no evidence of any considerable amount of deep ground water beneath the clays of the lake plain to the southwest. Waskana creek appears to be roughly the southwest boundary of any important water-bearing strata leading from this region. The artesian wells a few miles south of Regina are evidently tapping the southernmost of the drift aquifers leading down from the Moose Mountain recessional moraine and overlapped by the Regina lake clays.

Immediately south of these artesians many dry holes have been drilled and such water as has been found is not good. These holes include two wells sunk by the Public Works Department of the Provincial Government. Saline water in comparatively small quantities was obtained, but otherwise these holes were dry. In holes below the clay only shales of various kinds have been found. The Weardale well (sec. 13, tp. 15, range 19) was 2,425 feet deep. This condition is in striking contrast with the conditions of the surface and subsurface drainage to the northwest of both Boggy creek and Flying creek described later.

Eastern Portion of the "Eastern Plan". Areas still farther east considered in the "Eastern Plan", including Pile-of-Bones creek (Rastad creek) and Many Bones creek, were so far from the city that they were covered by only one reconnaissance. It is believed that these could be of little value to Regina except as additional development in connexion with areas mentioned in the "Eastern Plan" nearer the city.

Mound Springs. Reference was made by Mr. Wynne-Roberts in his report of 1912 to certain springs located 14 miles due north of Regina on Albert street (sec. 31, tp. 19, range 19) which he termed "Tregarva springs". Mound springs at the head of Spring creek, a tributary of Flying creek in the section mentioned, are about 6 miles northeast of Tregarva. They are evidently the springs referred to.

Mr. Wynne-Roberts mentions 10 or 15 acres of muskeg with springs to the number of 60 to 100. He also says that on October 17, 1911, the stream under the highway bridge west of the springs was flowing 320,000 gallons a day and he estimated that under a development with 15-foot head, 1,000,000 gallons a day could be developed. Two miles west, at the Broadside farm on Spring creek, a flow of 486,000 gallons a day was found in the stream, indicating further drainage into the stream between these two points.

PRESENT SYSTEM, 1929

The present waterworks system of Regina is owned and operated by the municipality, the supply being obtained from the springs, artesian wells, and pumped wells in two of the glacial artesian valleys which lead down from the Moose Mountain moraine to the Regina plain. These artesian basins are supplied by the rainfall upon large catchment areas within this moraine, the topography soils and mantle rock of which are highly favourable for percolation.

BOGGY CREEK AREA

The main well field is in the valley of Boggy creek about 6 to 8 miles northeast of the city and the secondary field at Mallory springs about one mile to the south of this. The Boggy Creek wells obtain their water from the drift at two horizons, one at about 50 feet and the other at about 160 feet in depth. The latter is near the contact with the underlying shale.

Wells have been drilled in this area to a number in excess of 150. They vary in diameter from 6 inches to 8 inches and in depth from 60 feet to 180 feet. They are cased to the heavy artesian horizons in the glacial drift and the bottoms are left open so that the water may enter freely. No screens have been used because of the fear of clogging.

Each drilling has been given a number in chronological order. Some have been unsuccessful due to boulders, bent casing, or mishap to tools. Of all wells drilled to the water table none can be considered dry. Some have silted up and choked with sand, decreasing the flow and in some cases cutting it off almost entirely. In other cases where the wells are on pipe-lines the pipes have become rusted so badly, that they have broken off at the top of the concrete in the bottom of the catch basin, and the sand entering the collecting lines has gone into the wells and choked them. Some of the well casings have been so corroded that they have broken in and blocked the flow. The average life of a casing is said to be between five and seven years, the upper vein of water being less severe on the casings than the lower. The result of the development of this field has been a yield of 2,500,000 gallons a day, without pumping.

MALLORY SPRINGS AREA

At the time of the survey in June-July, 1929, Mallory Springs area was undergoing transition from a flowing artesian field to a pumped field. Three artesian wells were being pumped temporarily with air yielding 750,000 gallons of water a day and the others as a result ceased to flow. A large Kelly gravel-concrete well was being installed.

CITY WATERWORKS YARD WELLS

At the city waterworks yard, located on Broad street between Dewdney street and 8th avenue, two wells and one deep test boring have been sunk.

Well No. 1, drilled by Rigsby, is 6 inches in diameter and 88 feet in depth. The water-bearing material is a 10-foot vein of coarse, light yellow to buff sand overlying clay.

Well No. 2, located 10 feet south of No. 1, was drilled in 1929 by Rigsby. It is 6 inches in diameter and 192 feet deep and is cased 184 feet, 5 inches. The head is about 40 feet below surface and with the drop pipe at 90 feet the drawdown reached this point. The water-bearing sand is finer than that in No. 1 and is overlain by clay.

Test hole No. 3, H. Eberhardt, driller, is located midway between No. 1 and No. 2. It was drilled to a depth of 305 feet and abandoned. It apparently ended in Pierre shale, since "ramshorn" fossils were reported.

Wells No. 1 and No. 2 are pumped into the city water supply when needed.

PRESENT NEEDS

The population of Regina and its average daily consumption of city water are reported for several years as follows:

Year	Population	Consumption
1916	26,127	2,410,000
1921	34,432	2,500,000
1926	37,329	2,900,000
1929	55,000 (estimated)	3,604,000

Water consumption figures for 1929, with a population approximating 55,000, is as follows:

	Gallons
Average daily consumption	3,604,000
Maximum, general average	4,000,000
Minimum, general average	3,000,000
Absolute maximum, July 29, 1929	5,099,000

The present yield of a general maximum of 4,000,000 gallons a day is distributed as follows:

	Gallons
Boggy creek, artesian flow	2,500,000
Pumpage	750,000
Mallory springs, pumpage	750,000
	4,000,000

Based on an allowance of 75 gallons a person a day the average daily requirement should be about 4,000,000 gallons a day. To cover all possible fire hazards and make a liberal allowance for the development of the city in the early future there should be an early development to 8,000,000 gallons a day.

New developments should, therefore, be made to at least duplicate the present capacity of Boggy Creek and Mallory Springs areas.

PRIVATE GROUND WATER SUPPLIES

The record of private water systems utilizing ground water supplies in the vicinity of Regina may be of value as indicating something of the present general ground water conditions.

The Imperial Oil Company, located on Winnipeg street just beyond the northern city limits, has one of the largest industrial water systems in the city. It supplies 400,000 to 500,000 gallons of water a day in addition to condensed steam. The company maintains connexions with the city supply for emergency. Its first well was sunk in June, 1917. The deepest well was put down to 247 feet, but the casing was pulled back to 120 feet, from which point four to five wagon loads of gravel and mud were blown out by compressed air. Too much material was blown out and as a result caving occurred and shut off the water supply in this well.

The best well (No. 12) is 98 feet deep. Some indication of its capacity is shown by a yield of 5,500,000 gallons during the month of March, 1929. The individual yield of the three other wells now in operation, all with depths about 90 feet, was 2,168,000 gallons, 5,022,500 gallons (No. 13), and 4,934,000 gallons (No. 14) in the same time. A total of 17,000,000 gallons of water was used during the month.

The company wells are pumped constantly 24 hours a day unless out of order, since if a stop is made the pumps tend to sand up and the valves are cut out. All wells have 10-inch casings set with 10-inch hack-sawed screens each 10 feet in length.

Several water veins are encountered in these wells, no one of which gives an abundant supply. At 100 feet a bed of black sand is found which is fine, enters the casing, and gives trouble. The best wells are finished just above this at a depth of about 90 feet and probably draw their water supply from the glacial drift.

The quality of water appears to be about the same as the city water, though it is probably somewhat more highly mineralized. It formed a hard scale on boilers until a softening plant was installed, in which it is treated with lime and soda ash.

One old well known as the "Boiler House well" is used as "cold water" to condense gasoline and for drinking purposes.

The ground water level is reported to have lowered about 3 or 4 feet since the first well was installed.

The Canadian Pacific railway secures a considerable supply of good water from outwash sand and gravel on the southwest front of the recessional moraine about one-half mile east of Pilot Butte. Two collecting galleries, with several flowing wells sunk in the bottom of each, were formerly used. These wells, varying in depth below the surface from 24 to 28 feet, were sunk through several feet of sand and 2 or 3 feet of gravel to clay, presumably till.

In the autumn of 1929 the company engaged the Kelly Well Company to construct a gravel wall concrete well about 60 feet south of the original galleries. From this well the company has been pumping at the rate of 400,000 gallons a day and believe they can secure 1,000,000 gallons a day if required. The Kelly well goes approximately to the same depth as the old wells in the galleries.

The General Motors Company plant on Winnipeg street from 4th avenue to 8th avenue is supplied from a 5-inch well 242 feet deep, which yields 100 gallons a minute to an air lift. The head stood 70 feet below ground during the test. This well is cased with 166 feet of 6½-inch casing and 242 feet of 5-inch casing.

The Western Manufacturing Company on East Dewdney street at St. John avenue supply their sash and door factory with water from a 6-inch well 209 feet deep, which yields 40 gallons a minute to the air lift. The head is 40 feet below the surface.

The Saskatchewan Co-operative Creamery Company at Albert street and 11th avenue is reported to have sunk a hole to a depth of 300 feet without obtaining water.

The McCallum-Hill Company at Scarth street and 12th avenue, the Leader Publishing Company on Hamilton street between 11th and 12th avenues, the Adanac Brewery Company at Albert street and 4th avenue, the P. Burns Packing Company on Winnipeg street between 9th and 10th avenues, the Crystal Brewing Company located at Winnipeg street and 9th avenue, and the Regina Brewing Company located at Dewdney street and Toronto avenue, all have private wells similar to the above.

These industrial wells indicate that a fair supply of water similar in origin and character to the city water occurs in the glacial deposits beneath the Regina clay and above the Pierre shale underneath the city. This is inadequate for a city supply and should be devoted to industrial uses.

SURFACE WATER PROJECTS

SASKATCHEWAN RIVER (5) (6) (9) (10)

The engineers of the Canadian Pacific Railway Company, shortly after the location of the line, predicted that the supply of water to the district, which includes Moose Jaw and Regina, would ultimately be taken from South Saskatchewan river. The Irrigation Department of the Dominion Government prepared plans and estimates of a scheme to supply the district from this source (6). And also a commission appointed by the Provincial Government during the years 1919-20 studied the possibility of the development of South Saskatchewan river as a source of water supply for Regina, Moose Jaw, and the country district adjoining. The report of this commission shows that an initial development of 6,000,000 gallons a day could be obtained from this source at an estimated capital expense of $5,700,000 and that by further development, at an additional cost of $1,300,000 or $7,000,000 in all, the system would bring approximately 11,000,000 gallons a day from South Saskatchewan river near Riverhurst. The distance from the river to Regina is 112 miles. Regina's share of the cost of the system would be at least one-half the total amount.

Government records show the quantity of water in the river to be ample. In quality the river water is much softer than the ground water from Boggy Creek area, but it might not be clear.

The Saskatchewan River scheme does not promise a cheap supply From this source an adequate supply could, however, be secured capable of meeting the needs of the city for many years to come. It is estimated that two years' time would be required for the initial stage, which would provide the 6,000,000 gallons a day for the district. It is argued by those who favour this plan that the soft water from the river, as compared with the hard ground water, would represent a large saving to the citizens in the cost of repairs to heating systems, water softening apparatus, soap, extra fuel used due to scale, general convenience, etc., and that this saving would largely compensate for the larger cost.

CARLISLE LAKES (MOOSE MOUNTAIN AREA) (10)

These lakes have been mentioned as a possible source of supply. They are about 525 feet above the city and about 115 miles distant to the east-southeast. A gravity pipe-line could possibly be made to serve the city from this source. The quantity of water available is uncertain. Regarding the quality, this source of supply is, according to R. H. Murray of the Provincial Department of Public Health, very similar to the Boggy Creek area ground water as regards mineral content. It is a medium hard water, but is suitable for drinking purposes and public supply with no treatment other than chlorination. It is slightly less attractive from a chemical standpoint than the Saskatchewan River water.

LAST MOUNTAIN LAKE OR "LONG LAKE" (10)

This is the nearest large body of surface water to Regina. It is 50 miles in length north and south and from 1 to 2 miles wide. It lies near the upper end of Qu'Appelle river and occupies a glacial water course. It has a very large drainage area said to measure 5,600 to 5,800 square miles. The average water-level in the lake is about 300 feet below Regina. The distance from a possible intake near Keddleston beach to Regina is 35½ miles. The difference in elevation between the lake and the highest hill over which the water must be lifted to reach the city is 352 feet. The development would be capable of delivering approximately 5,750,000 gallons of water daily. The quantity available is ample.

Analysis of the water shows that its mineral content is about double that of the Boggy Creek ground water supply. The hardening minerals are slightly less and the non-hardening minerals considerably more than in that supply. The removal of the hardening minerals could be done by a process similar to that which would be required for the Boggy Creek ground water supply. According to Professor Thorwaldson of Saskatchewan University, the removal of the non-hardening minerals would be impractical owing to the quality of the water. The Provincial Analytical Chemist's final conclusion regarding the quality of Long Lake water is that "it is not suitable for a city supply."

BUFFALO POUND LAKE AND QU'APPELLE RIVER

Three miles above the confluence of Moosejaw creek with Qu'Appelle river and 35 miles northwest of Regina, the river broadens into Buffalo Pound lake which is ½ to ¾ mile wide and 15 miles long. It, therefore, roughly parallels Last Mountain lake and Arm river at a distance of about 20 miles west of the former and 10 miles west of the latter. All three occupy straight, broad, deep, glacial valleys trending northwest to southeast.

Buffalo Pound lake has been considered in connexion with the possible water supply for Regina, chiefly as a part of Qu'Appelle river and as a storage reservoir for the diverted waters of Saskatchewan river. By the use of Eyebrow lake, Qu'Appelle river, and Buffalo Pound lake, and by pumping from Saskatchewan river 86 feet over the watershed into the headwaters of Qu'Appelle river, and again by pumping from the Qu'Appelle over an elevation of nearly 300 feet to the city of Regina, 60 miles of pipeline out of the possible 115 miles could be eliminated.

The total solids of Buffalo Pound lake are high, though the hardness is low. The lake is, however, shallow, probably not more than 6 to 10 feet in depth, and the channel of the river leading to it is tortuous, weedy, and ill defined. This could be straightened considerably and pollution hazards could be eliminated by filtration and sedimentation.

The waters of Qu'Appelle river are not only too highly polluted to be used for city purposes without treatment, but they are highly mineralized throughout most of the year as well. Their use would necessitate pumping the water to an elevation of approximately 300 feet to pass over the elevation in the vicinity of Ardmore and Albatross. Neither this lake nor Qu'Appelle river could be considered as related to the water supply of Regina only as a constituent part of the Saskatchewan River project.

POSSIBLE DEVELOPMENTS

(1929)

BOGGY CREEK BASIN

After spending considerable time in the developed part of Boggy Creek basin and the areas included in the "Eastern Plan" the survey was extended to the north and the northwest of the city to examine lower Boggy creek and its tributaries, because that appeared to be the natural direction of drainage from the heavy morainal region northeast of Regina and because it was reported that there was considerable water flowing in lower Boggy creek and its tributaries.

Victoria Springs. In the vicinity of Victoria Plains, about 6 miles northeast of Regina, are several springs which while draining into Boggy creek appear to have a drainage area distinct from that now supplying the city water and to the northwest of it.

The nearest of these to the city is one-third of a mile east and one-fourth of a mile north of Victoria Plains station. It is located at the base of a low hill composed of till, located near the east edge of the Regina clay (E. ½ sec. 15, tp. 18, range 19, 2nd mer.). The water is cold and there is a considerable boggy area. The flow runs a short distance into the pasture and disappears. A second small spring about 1,000 feet northeast of this (NW. ½ sec. 14, tp. 18, range 19) is flowing from a low, boggy mound into the midst of a marsh.

It is reported by local farmers that the city dug a well in the vicinity of this spring. It was drilled in the flats to the depth of about 100 feet and water was reported only at the 30 to 40-foot level. It is also reported that the creek never ran dry in this vicinity until the city began taking water above.

Other springs 1¼ miles northeast of Victoria Plains (SE. ¼ sec. 14, tp. 18, range 19) yield clear, cold water from small, boggy mounds, but the streams disappear within 100 feet of the springs.

Across the road south of these (NE. ½ sec. 11, tp. 18, range 19) a small spring flows from a boggy mound which shows considerable spring deposit of calcareous tufa. The lowest temperature of the water measured was 43 degrees.

All of these indicate a considerable sub-surface drainage from the northeast not included in the present Boggy Creek developments.

Because of the fact that the city owns land in this vicinity, and that it is in close proximity to the Boggy Creek pump works, it was recommended that the city drill a test well at once (SW. ½ sec. 13, tp. 18, range 19) one-third of a mile north of the southwest corner of the section and about 100 feet north and east of a culvert in the road.

Blythe Spring or Arrowhead Spring. The Blythe spring is found 4 miles north of Victoria Plains (SE. ¼ sec. 3, tp. 19, range 19) on a south facing hillside at the margin of the Regina clay where it overlaps the ground moraine. A bog area of about one-half acre is deeply trampled and wallowed by bison and cattle, making a depression of 5 feet or more in rear. There are at least two definite spring openings with slow flows to the bog, but no flow issues from the bog. The lowest temperature measured was 45 degrees.

FLYING CREEK BASIN

After completing the survey of lower Boggy creek attention was turned to Flying Creek basin, since in its location between lower Boggy creek and the recessional moraine northeast of Regina it appeared to offer possibilities of large water supplies from glacial gravels draining in this direction.

The Flying Creek catchment area is estimated to have an area of about 105 square miles, which is considerably larger than that of Boggy creek, estimated by Mr. Wynne-Roberts to be 72 square miles in area.

The northeast part of the area is quite heavily covered with brush and lies within the knob and kettle topography of the recessional moraine. It has, therefore, very little clearly defined surface drainage and seems an ideal area for collecting rain water and conveying it to underground formations.

Cooper Springs. The first springs located in Flying Creek basin were those on Mrs. M. Cooper's farm (middle of the S. ½ sec. 28, tp. 19, range 20) on the north branch of Flying creek, 2 miles north of Tregarva. These empty into a narrow valley coming from outwash material overlying dark blue boulder clay. They form a boggy area of more than 2 acres with many spring openings. They have excavated a well-defined creek valley which is at least 4 feet deep and 14 feet wide with a stream about 2 inches deep by 8 inches wide. This stream is said not to have varied since Mr. M. Cooper, deceased, settled on this farm in 1883. The water is used for all purposes about the house and farm.

The water has a slight alkaline taste, but no colour or odour and showed a temperature of 38 degrees on July 19. This is the coldest water found anywhere in the vicinity of Regina. The rocks in the bed of the stream show iron and possible manganese deposit.

One other spring reported on this stream is that of Jno. Benny (NE. ¼ sec. 29, tp. 19, range 20). This is located well up on the hillside on the south bluff of the creek valley. The minimum temperature obtained was 47 degrees. The spring enters a trampled marsh which terraces down the hillside to the stream. It is unimportant.

Dickson Springs. Dickson springs on the South branch of Flying creek are of almost equal importance. They are on land (SW. ½ sec. 21, tp. 19, range 20) owned by G. A. Dickson, a resident for twenty-one years. Many openings occur in 3½ acres of marsh land on this quarter. Some holes have been sounded with fence posts and long rods, all of which disappeared out of sight. Boulders in the valley floor indicated the presence of a coarse, glacial outwash as the source of water.

Immediately west of this place (SE. ¼ sec. 21, tp. 19, range 20), on E. T. Dickson's farm, is an equal amount of bog land with other strong springs. Temperatures of 38 degrees were found in these springs. There was no spring deposit apparent. The springs are said to vary with a change of weather and will occasionally flood the bottom immediately preceding a storm. They are a never failing source of supply of excellent farm water. The G. A. Dickson well on the side hill upland on the east side of the road was bored to a depth of 31 feet and contains 8 feet of water. There is no variation in depth except during heavy pumping and it is never dry. Its water leaves a trace of iron on cooking utensils. The N. T. Dickson well on the west side of the road is bored to a depth of 30 feet, and has 3 feet of water which cannot be pumped out. Fine sand comes with the water. The water from Dickson springs is joined a short distance below (SW. corner NW. ¼ sec. 20) by the water from a small, bubbling spring of cold water which stains the rocks yellow. Seepages are found in several places upstream on this section.

Other small seepages in the lower valley (NW. ¼ sec. 20) make a showing of water in the stream for short distances. Coarse boulder outwash cut through by the railway in diverting this stream reveals the character of this outwash deposit.

Mound Springs. The western group of Mound springs is located 14 miles north of Regina on Albert Street road, and 1 mile west on land (NE. ½ sec. 36, tp. 19, range 20) that is owned by Mrs. H. Greethy of Regina. It includes many strong springs near the centre of the quarter northeast of the house. The water is clear, cold (40 degrees F. measured), and is said to always rise before a rain. Spring creek, which drains these springs into Flying creek, is open all winter but 3 miles down it is dry in summer.

East across the road allowance, on Mr. Bruce MacKinnon's place (NW. ½ sec. 31, tp. 19, range 19), is a much larger mound of several acres containing many spring openings, all with spring deposits forming an extensive mound. These are the Eastern Mound springs, the headwaters of Spring creek.

Qu'Appelle Valley. Qu'Appelle valley is a deep, broad, glacial or preglacial valley which has been filled during and after the glacial period with outwash from the front of the glacial ice and with river alluvium to a very considerable depth. Ground water gradually flows down streamward through the sand and alluvium beneath the surface of this valley and above the bedrock into which the valley is carved. The movement of this underflow is undoubtedly very slow, but its volume must be considerable, judged by many valleys of the glaciated region where thick beds of coarse glacial material are overlain with fine river-borne material, silt, and alluvium. This underflow water is relatively independent of the water in the river, from which it is sealed off by the fine mud and silt that have been deposited by the stream itself.

Sand and gravel occur in Qu'Appelle valley, as is shown by their appearance in places on the surface where hillside springs occur, as on the south side 3 miles below Lumsden (section 1), and wells are reported as drawing water from this source. Some of these wells furnish a scanty amount, but those at Lumsden yield moderate amounts without showing signs of failure. Few if any springs appear on the north side of the valley.

The homes in the city of Lumsden secure plenty of water in very fine sand at a depth of 15 to 30 feet. The Lumsden Coal Company well by the bank is 20 feet deep, ending in fine sands. The City Hall well, 20 feet deep, has 3 to 4 feet of water in fine sand. One deep test hole was drilled at Lumsden in July, 1912, which is reported to be 580 feet in depth. Fresh water was reached at 30 feet which stood about 15 feet deep in the hole. Below this was blue clay, and additional water was secured in the main water-bearing bed at a depth of 150 feet. There was a large amount of water with head only 10 feet below the surface. This water was reported as salty and with high mineral content.

NEW DEVELOPMENTS, 1929-1930

UNDER PREVIOUS PLANS

In accordance with previous recommendations and plans, developments were being made during the season of 1929 at Boggy Creek area, Mallory Springs area, and in certain other areas of the "Eastern Plan." The results of these may be summarized as follows:

Mallory Springs Area. Wells Nos. 10, 12, and 13 were pumped by compressed air at the rate of 675,000 gallons a day. When pumping was begun on these three wells the natural flow of the other wells in the area ceased.

While these wells were being pumped the Kelly well No. 1 (gravel-concrete) was completed and a Pomona deep well turbine pump of 1,500,000 gallons a day capacity installed. During the latter part of the summer this well was yielding at the average rate of 2,000,000 gallons a day, pumping for 12 to 15 hours each day. The pumping by air on other wells of the area was, of course, stopped. Since pumping the Kelly well No. 1 the springs in the area have dried up completely.

A drawdown in the Kelly well No. 1 for a 12 to 15-hour run varied from 5 to 15 feet from a head of 14 feet beneath the surface. On a 48-hour run the drawdown was 28 feet during the first 24 hours and 4 feet additional during the second 24 hours. On the day following, the water had risen again to within $2\frac{1}{2}$ feet of its usual height. The well was pumped on alternate days throughout the winter.

Kelly well No. 2 was completed close to artesian well No. 17 and a similar pump installed. This well was pumped only for a 6-hour pumping test, when it gave very satisfactory results. It is regarded as a supplementary unit, though it can be run simultaneously for a short time.

Golf Course Well. Well No. 152 does not appear to belong to Boggy Creek area proper. After considerable experimentation with both air-lift and portable gas-driven pump, an electric-driven pump was installed which yielded about 600,000 gallons a day with a drawdown of about 14 feet. This did not appear to influence the yield of any other wells. It is the intention to construct a larger Kelly Junior well and it is hoped that 1,000,000 gallons a day may be pumped directly from this to the reservoir.

Boggy Creek Area. Wells No. 155, No. 156, No. 157, and No. 158 give a combined natural flow of 162,000 gallons a day. Equipped with the air lift these wells yield 411,000 gallons a day. Experiments with well No. 96 with compressed air showed an increased flow, as it did also with tractor-driven, centrifugal pump. A reduction in the natural flow of nearby wells resulted, though the total yield was increased. As a further experiment a 10-inch well, No. 160, was drilled alongside and was equipped with a 10-foot Cook screen. This well gave a very good natural flow which can be increased considerably by pumping, although there is a reduction in the flow of nearby wells.

Kelly well No. 3 was completed at Boggy creek close to No. 119. This well taps a water horizon from 65 to 98 feet which does not flow naturally at this point but stands 12 to 14 feet below ground surface. A pumping test from January 1 to 14 at the rate of 750,000 gallons a day affected the flow of some of the nearby wells.

Eastern Plant. Test drilling east of Mallory springs seems to show only a fair amount of water in this locality. The water-bearing veins are rather thin and composed of fine material from which it would be difficult to extract water in large quantities.

Slough Creek or "Hay Meadow." For the Slough Creek or Hay Meadow section of the "Eastern Plan," three test holes were drilled (S. $\frac{1}{2}$ sec. 25, tp. 17, range 18, 2nd mer.) 150, 175, and 182 feet in depth. Pumping tests on some of these with a compressed air outfit, found nothing worth following up.

Balgonie Creek. At "Sturgeon springs" (sec. 18, tp. 17, range 17, 2nd mer.), test holes were put down 150 to 180 feet in depth. The water-bearing sandbed, 0 feet to 17 feet with ground water level at −5 feet, indicated that this was glacial outwash on the surface. A pumping test with air yielded at the rate of a little over 65,000 to 70,000 gallons a day during the first hour, with a drawdown nearly to the bottom of the water-bearing stratum. This did not indicate sufficient capacity and warrant further consideration by the city.

Spring Measurements, Flying Creek Basin. Measurements were made of the flow from Mound, Cooper, and Dickson springs in Flying Creek basin by the Regina Waterworks Department, the results of which are as follows:

Spring Measurements

Number	Date	Mound No. 1	Mound No. 2	Cooper	Dickson
1	August 7	110,000	149,040	103,680	....
2	" 8	160,000	183,060	132,840	42,120
3	" 21	103,680	125,000	199,260	....
4	" 22	....	....	....	42,120
5	October 18	250,000	....	....	....
6	" 21	255,000	295,000	....	....
7	" 22	....	....	190,000	90,000
8	" 23	295,000	336,000	....	....
9	" 24	295,000	336,000	218,000	90,000
10	" 25	218,000	336,000	210,000	104,000
11	" 26	336,000	380,000	255,000	119,000
12	" 28	336,000	336,000	218,000	119,000

Notes on Spring Measurements. Mound Springs weir No. 1 is located at the bridge on the road between sec. 36, tp. 19, range 20, and sec. 31, tp. 19, range 19. Mound Spring weir No. 2 is located near the farm house ½ mile below No. 1. It, therefore, catches the water that has already gone over No. 1. Further readings were affected by snowfall.

Notes by Superintendent Farrell on the measurements numbered above.

1. Late afternoon, very warm day.

2. Before 10.00 a.m. (Before much evaporation.)

3. Late afternoon, extremely hot day. (Evaporation at highest.) Season two weeks advanced over 1 and 2. Why are Cooper springs so high?

5. Readings October 18-26, increasingly high. A phenomenon that is noted in the neighbourhood, and also at the Moose Jaw Waterworks, that the springs flow stronger in the autumn than during the previous summer.

8-12. From October 23 to 25 Mound springs flow was affected by water escaping from the test well that was being drilled.

10. Low readings at weir No. 1, Mound Springs, possibly due to ice forming around most of upper springs. Read in early morning before sun appeared from behind clouds.

11. High reading at Cooper springs, probably an error with the gauge read.

Mention had been made of the reports of increased flow of Mound, Dickson, and other springs: (a) irregularly, before a period of rain or snow, and (b) seasonally, in autumn and winter.

Regarding the irregular variation by which the flow of springs and artesian wells increase before a storm, this is a common and well understood phenomena. Such springs and wells are known as "barometric" springs and wells. The variations are due to differences in air pressure, the flow being greater when the barometer is "low" and there is relatively less weight of air upon the ground water surface and less when the barometer is "high" and the pressure of the air upon the ground water surface is relatively greater.

Various explanations have been offered for the seasonal variations in the springs about Regina, notably: (1) that "the removal of growing crops has something to do with it, in that less water is being used to supply vegetation" (R. O. Wynne-Roberts); (2) that "a larger part of the flow may be absorbed during the dry weather" (W. A. Johnston); (3) that it may be due to lag, "in that the water from the melting snows of the early spring and summer rains were reaching these outcropping springs around the end of September and in October" (J. W. D. Farrell).

This is a phenomenon with which the author is somewhat familiar through studies of streams, springs, and ground water supplies on the south slopes of Turtle mountains in North Dakota.

An illustration in point is Oak creek, which passes through Bottineau. This stream is fed by springs and well-defined seepages and has in parts of its upper course a continuous flow 2 or 3 feet wide and as many inches deep. As it flows out upon the plain, this water is absorbed into the heavy mantle of drift and during the summer season the flow does not reach within a mile or two of Bottineau, except after a heavy rainfall.

Peculiarly, however, the distance which this stream flows increases in early autumn even before autumn rains occur, indicating a rise in ground water level in the foothills. The author has ascribed this to a seasonal decrease in evaporation on the south-facing slopes of the "mountains" in the early autumn, and the resulting rise in ground water level due to the normal gravity flow from beneath the higher levels to lower levels[1].

The complete explanation probably includes more than one of these explanations: (a) in the case of Turtle mountains and the upper part of the catchment area of Flying Creek basin there would be slight effect due to the removal of growing crops, since the regions are both largely covered with scrub forest and bunches of poplar. (b) The flow is undoubtedly much more quickly absorbed in summer due to dry weather and resulting low ground water level, which in turn may be due in a large part to increased evaporation as well as to decreased rainfall. (c) The importance of lag in the flow underground may be, and probably is, an important factor, the value of which could perhaps be determined only through studies in the rate of flow through the shallow artesian aquifer, a bit of investigation that might be of considerable value to Regina.

Mound Springs. In accordance with the author's recommendations of July, 1929, two wells were drilled in October to test the Mound Springs area. Well No. 1 struck water-bearing sand at 15 to 50 feet which flows from 51,000 to 170,000 gallons a day. The static head is about 10 feet above the surface. Drilling was continued to 90 feet without striking any more water-bearing beds.

[1]Simpson, Howard E.: "Report on the Bottineau Water Supply," June 26, 1926 (MS.).

Well No. 2 was drilled about 200 feet south of well No. 1. Good water-bearing beds were struck at 40 to 50 feet and a natural flow of about 500,000 gallons a day from an 8-inch casing was secured. The static head of this well is 19 feet above the surface. Drilling was continued to 150 feet in yellow and blue clay without finding more water.

Analysis of the waters of these two wells shows that the water of well No. 2 is a softer water than that of well No. 1. This is probably due to the amount and freedom of the flow. Well No. 2 probably indicates much more closely than well No. 1 the quality of water to be secured here for a city supply.

Well No. 3 was drilled about 3,000 feet northeast of No. 1 and No. 2 to a depth of 163 feet. Water found in sandy clay at a depth of 143 to 146 feet rose to 26 feet below the surface, but could be removed with a bailer faster than it came in.

Note. "Mound springs looks like a very considerable source. I hardly feel competent to estimate but will be surprised if it does not go over 2,000,000 gallons per day. The Cooper and Dickson springs are considerably lower than Mound springs and would involve extra pumping expense. I hope that development at Mound springs will intercept sufficient of the waters going to Cooper and Dickson, so that it will not be necessary to have developments at these points." (J. W. D. Farrell, March 29, 1930.)

Qu'Appelle Valley. In accordance with the author's recommendation in July, 1929, three test holes were drilled in Qu'Appelle valley to test the water-bearing quality of the alluvial and glacial material underlying the surface.

In hole No. 1, 241 feet deep, NW.¼ sec. 27, tp. 20, range 20, W. 2nd mer.) the water originally stood 2 feet above ground and trickled over the top of the pipe. On pumping from the 185-foot horizon the well filled up with fine black sand. After cutting the casing at the 80-foot horizon, the water stood 6 feet below the surface and yielded 10 gallons a minute to the pump for a six-hours' test. In pumping the following day the yield dropped to 6 gallons a minute and the water became dirty. The temperature of the water was 42 degrees F. This water seems very hard.

Test hole No. 2 (SW.¼ sec. 34, tp. 20, range 20, W. 2nd mer.) was drilled and a depth of 289 feet, of which 42 feet were in shale, was found, filled with yellow sand and clay to the top of the 4½-inch casing at a depth of 40 feet.

Test hole No. 3 (SE. ¼ sec. 33, tp. 20, range 20, W. 2nd mer.), drilled 217 feet in depth, of which 50 feet were in shale, was filled with yellow sand and clay from the 145-foot level after a few minutes pumping with 125-foot air line. Temperature 42 degrees to 43 degrees F. This north hole is the only one of promise.

Note. Qu'Appelle valley had the appearance of a possibility that required exploration in order that nothing might be overlooked. The apparent meagreness of the supply and its hardness do not make it sufficiently attractive to offset the very considerable pumping lift that would be necessary to get water up from the valley to the city. (J. W. D. Farrell, Letter March 29, 1930.)

CONCLUSIONS

(1) There appear but two available sources of water supply for Regina:

(1) South Saskatchewan river, a surface water supply, and

(2) The shallow artesian ground water supply having its source in Glacial drift of the Moose Mountain moraine.

(2) The river water would require treatment to remove turbidity, filtration, and also chlorination to render it potable and safe. It would have to be brought 115 miles at the cost of several million dollars and would require a considerable time to secure it, but it would be soft, ample, and permanent.

(3) The glacial artesian water would require no treatment to render it wholesome or bacteriologically pure, though softening is desirable because of its hardness. The cost would be only a fraction of that required to procure a supply from Saskatchewan river, since the present supply may be supplemented by another in Flying Creek basin within 16 miles of the city. The new supply may be made available in a much shorter period of time and it would be adequate and dependable at least until the demand exceeds 8,000,000 gallons a day.

(4) It is desirable to preserve all the supply the city now has and at the same time to obtain an additional supply without interfering with the present flow and pumpage. This may be done by the development of the Flying Creek basin while continuing and conserving the present sources in Boggy Creek area and Mallory Springs area. Although the new development would have the same general origin as the old, there could be no considerable interference between them.

(5) Boggy Creek artesian area, because of its several water-bearing horizons of glacial gravels in a well-defined glacial valley and its large catchment area in a heavy morainal region, has probably the largest natural storage reservoir of any ground water area in the vicinity of Regina. Its proximity to, and elevation above, the city, makes the transmission of this water by gravity from the many flowing wells directly to the city, highly economic.

It may, therefore, although continuously delivering a very considerable supply of water to the city at no expense of pumping at the wells, permanently retain a large supply in reserve underground which should be drawn upon by pumping only in times of emergency. Such pumping should also be as far as possible from wells that do not affect the natural flow of other wells.

(6) Mallory Springs artesian area should continue to serve as a valuable supplemental area to Boggy Creek artesian area. It is not believed that pumping in this field will interfere seriously with Boggy Creek area, since these two areas appear to be separate and distinct, though from the same general source. Because of its location and elevation Mallory Springs area may be pumped more economically than any other available area. It will, undoubtedly, yield a much larger amount to the pumps than it will yield through flowing wells, a total at least of 750,000 gallons a day.

(7) There is no geological evidence to show that the various areas of the "Eastern Plan" beyond Mallory springs will yield any considerable amount of ground water which would repay the cost of procuring the same. They are all of little value compared with the areas in Flying Creek basin.

(8) Small amounts of ground water might be secured in the vicinity of Victoria springs, which, because of its close proximity to the Boggy Creek plant, might warrant development, but this should be considered essentially as an extension of Boggy Creek area, and its development does not appear to be economic at the present time except in the eastern edge (SW.¼ sec. 13, tp. 18, range 19). This has been proved good artesian territory by a test recommended by the author in July, 1929, and may be considered a part of Boggy Creek area.

(9) Flying Creek basin offers the only field comparable with that of Boggy Creek basin as a source of a considerable ground water supply for Regina. Its yield will probably equal that of Boggy Creek area if fully developed, since it is supplied from a larger catchment area. Owing to its shallower depth, provided no deeper horizons are discovered, it may be variable and affected to a greater extent by the seasons. The minimum yield available from this area is estimated to be between 3,000,000 and 4,000,000 gallons a day, of which one-half may come from Mound Springs area and the other half from Cooper Springs and Dickson Springs areas in the ratio of about two to one.

(10) Qu'Appelle valley between Lumsden and Craven is filled to a depth of between 100 and 200 feet, with glacial deposits and alluvium. It, therefore, contains a large amount of water. The material is so fine that the water could be secured only by pumps from gravel-treated wells. The quality of water, being hard and highly mineralized, is less satisfactory than that of any of the glacial artesian areas above mentioned and the cost of installation and pumping up 300 feet and 20 miles into the city all tend to make this source uneconomic and undesirable.

RECOMMENDATIONS

(1) The glacial artesian ground waters, having their origin in the Moose Mountain moraine to the northeast and north of the city, are recommended as the exclusive source of water supply for Regina, at least until such time as the city may require more than 8,000,000 gallons a day.

(2) It is recommended that Boggy Creek basin be developed to its maximum capacity *as an artesian field* yielding continuously all that it may through flowing wells under natural pressure, with full underground natural reservoir in reserve for emergency. This maximum artesian flow is evidently about reached at the present time in the amount of 2,500,000 gallons a day. Two or more wells of large capacity may be installed for emergency conditions, but they should be held in reserve. In emergency the yield of this field for a limited time may probably be brought up to 4,000,000 gallons a day by heavy pumping. This recommendation should not be construed so as to prevent regular pumping from wells that do not

affect the natural flow of the basin. All abandoned holes should be plugged immediately above the water vein and securely sealed in order to prevent loss of water and head and consequent deterioration of the basin.

(3) It is also recommended that the natural flow of Boggy Creek basin be supplemented by pumping from one or two wells in Mallory Springs area. This area should yield 750,000 gallons a day in this way. This, with the natural flow from Boggy Creek area, will furnish a sufficient amount of water for the present needs of the city under average conditions, at the least possible cost.

(4) It is further recommended that Mound Springs area of Flying Creek basin be fully developed by the use of two or more moderately large wells and that these be pumped to capacity whenever necessary to supplement the natural flow from Boggy Creek basin plus the pumpage from Mallory Springs area. The cost of pumping at Mound springs will be greater than that at Mallory springs, therefore, preference in pumping should be given the latter. The pumping of the former will probably be required for the present only during seasons of heavy demand. It is estimated that this area will yield 1,500,000 to 2,000,000 gallons a day.

(5) Following the development of Mound Springs area, Cooper Springs area and Dickson Springs area may be developed and held in reserve for emergency purposes, or they may be reserved for later development as the needs of the city increase. The lower elevation and the distance of these areas from the city are such as to make pumping relatively more expensive than the areas already developed or than Mound Springs area.

(6) It is recommended that the eastern end of Victoria Springs area, (SW. ¼ sec. 13, tp. 18, range 19), having been proved good artesian territory, outside the main Boggy Creek basin, should be developed by one pump well of medium capacity connected directly with the Boggy Creek plant.

The remainder of Victoria Springs area and Blythe (Arrowhead) Spring area should be kept under observation and test holes may be sunk if and when found advisable.

(7) It is especially recommended that all wells hereafter sunk for use with the pump be constructed with large diameter and finished with gravel wall or gravel pack, and large coarse screens. For flowing wells in Boggy Creek basin, a large number of 6-inch or 8-inch wells without gravel treatment appear to be satisfactory. These wells are, however, not suited to the pump except in cases in which they are finished in gravel. In such cases the use of slotted pipe or non-corrosive wide slot screens is recommended.

It is believed that if these recommendations are followed the city of Regina will have a good and ample supply of ground water for many years to come. The combined Boggy Creek, Mallory Springs, and Flying Creek areas, when fully developed, may be expected to yield approximately 8,000,000 gallons a day with 9,000,000 or 10,000,000 gallons available for short periods of time in emergency. The water will be bacteriologically pure and the quality, though hard, will compare favourably with that of other cities of the Prairie Provinces not situated on large rivers. The cost will be moderate and the maintenance low.

BIBLIOGRAPHY

(1) Stansfield, J.: "Surface Deposits of Southern Saskatchewan"; Geol. Surv., Canada, Sum. Rept. 1917, pt. C, pp. 41-52.
(2) Stansfield, J.: "Surface Deposits of Southeastern Saskatchewan"; Geol. Surv., Canada, Sum. Rept. 1918, pt. C, pp. 42-48.
(3) Dyer, W. S.: "Oil and Gas Prospects in Southern Saskatchewan"; Geol. Surv., Canada, Sum. Rept. 1926, pt. B, pp. 30-38.
(4) Warren, P. S.: "Geology and Oil Prospects in the Vicinity of Riverhurst, Saskatchewan"; Geol. Surv., Canada, Sum. Rept. 1926, pt. B, pp. 39-42.
(5) Russel, B., Chief Field Inspector, Department of the Interior: "The South Saskatchewan Water Supply Diversion Project"; Department of the Interior, Irrigation Office, Sess. Paper No. 25, pp. 99-112.
(6) Montague, T. M., in charge of field party: "Report on the South Saskatchewan Water Supply Diversion Project"; Department of the Interior, Irrigation Office, Sess. Paper No. 25, pp. 112-130, March 31, 1914.
(7) Saskatchewan Water Supply Commission, McPherson, A. J., Chairman and Chief Engineer, MacBean, W. F., and Teare, Thos.: "Synopsis of Report of Saskatchewan Water Supply Commission, on the Feasibility of Diverting a Supply of Water from the South Saskatchewan River for Domestic and Industrial Purposes in the Moose Jaw-Regina District"; 45 pp., Printed by order of the President in Council, 1920.
(8) Lea, R. S., and Smith, O. W., Consulting Engineers: "Report on the Water Supply of the City of Regina, Saskatchewan," March, 1908 (MS.).
(9) Wynne-Roberts, R. O., Consulting Engineer: "Report on Additional Water Supply for Regina"; January 18, 1912 (MS.).
(10) Farrell, J. W. D., Superintendent of Waterworks: "Water Supply Report"; August 7, 1928 (MS.).
(11) McAra, J., and Thornton, L. A., City Commissioners: "Water Supply," December 20, 1928 (MS.).

APPENDIX A: ANALYSES OF WATER

—	Lumsden Coal Co.	Lumsden City Hall	Dickson springs	Cooper springs	Mound springs	City tap water
Calcium carbonate	207	1,196	....	....	71	91·5
Calcium sulphate	374	....	673	652	537	402
Calcium chloride	....	....	....	....	....	....
Calcium nitrate	....	....	....	....	....	....
Magnesium carbonate	318	352	442	434	371	266·5
Magnesium sulphate	....	455	29	....	....	....
Total encrusting solids	899	2,003	1,144	1,086	979	760
Sodium carbonate	128	....	....	....	....	....
Sodium sulphate	128	16	378	288	201	105·5
Sodium chloride	39	189	11	9·8	8·14	13·5
Sodium nitrate	....	....	....	....	....	....
Organic matter, etc	240	450	120	115	90	85·5
Total non-encrusting solids	535	655	509	412·8	299·14	204·5
Total solid matter on evaporation	1,300	2,705	1,634·5	1,495	1,270	964·5
Weight of encrusting solids in 100 Imp. gallons	lb. 8·99	lb. 20·03	lb. 11·41	lb. 10·86	lb. 9·79	lb. 7·58
Date	August 2, 1929					March 2, 1930

Analyst: Milton Hersey Company, Winnipeg.

Samples from Test Drillings: Mound Springs and Qu'Appelle Valley

Hole No.	Mound Springs No. 1			Mound Springs No. 2	Qu'Appelle No. 1					Qu'Appelle No. 2				Qu'Appelle No. 3		
Depth in feet at which sample was taken	15	40	45	57	30–50	68–110	122–128	158–167	201	22–70	93	146	168	15	55	130
Mineral solids	1,080	1,420	1,280	900	5,980	5,360	6,840	4,550	3,600	2,360	1,520	2,000	1,660	1,560	1,080	2,160
Chlorine	4·9	9·9	12·4	6·9	49·5	29·6	54·3	39·5	49·4	74·2	29·6	24·7	88·8	43·7	9·8	187·8
Silica	40	20	20	4	30	20	10	30	20	20	10	40	10	110	30	20
Iron and alumina	5	20	5	4	10	10	10	20	20	20	20	30	10	20	20	10
Lime	200	280	240	180	920	890	770	630	570	520	260	300	220	360	300	160
Magnesia	159·4	195·6	188·3	105	572·2	528·8	691·8	280	325·9	65·1	123·2	159·4	133·1	148·5	173·8	123·1
Sulphur trioxide	356·7	507·6	500·8	212·6	2,846·9	2,558·7	2,942·9	2,126·6	1,477·8	1,090·7	422·2	823·2	493·9	576·2	425·3	780
Temporary hardness	300	440	310	320	570	460	400	430	560	320	470	350	570	410	280	400
Permanent hardness	220	330	320	140	1,950	1,890	2,080	1,250	870	400	......	260	......	195	300	......
Total hardness	520	770	630	460	2,520	2,350	2,480	1,680	1,430	720	470	610	570	605	580	400
Alkalinity	......	......	......	......	......	......	......	......	......	......	670	......	......	......	......	......
Date	November and December, 1929				September 1929					October, 1929				October, 1929		
Analysts	Andrews and Cruickshanks, Regina.															

Samples from Test Holes Southeast of Pilot Butte

Hole No.	C	E	F	H	I	S1 Sturgeon spring
Depth, in feet, at which sample was taken	100	first 50	112	54–59	165	Surface
Temperature, degrees F.	....	43°F.	....	42°F.	....	49°F.
Mineral solids	2,400	900	2,440	810	1,700	400
Suspended matter	....	....	100	....	....	....
Chlorine	39·5	29·7	153·3	29·6	34·6	14·8
Silica	10	10	20	20	5	5
Iron and alumina	10	5	10	10	5	5
Lime	280	170	360	210	140	140
Magnesia	130·3	86·9	159·3	72·4	76·1	43·4
Sulphur trioxide	730·8	253·8	967·2	246·9	632·1	48
Temporary hardness	380	370	290	310	340	147
Permanent "	160	80	430	100	0	49
Total "	540	450	720	410	340	196
Alkalinity	....	....	....	....	500	....
Date	October, 1929		September, 1929	October, 1929		
Analysts	Andrews and Cruickshanks, Regina.					

APPENDIX B: LOGS OF TEST HOLES

Location. SE. ¼ sec. 30, tp. 17, range 18, W. 2nd mer.

Drilled by city of Regina, Waterworks Dept., Oct. and Nov., 1928

Driller's Logs

No. 1

—	Depth in ft. From	Depth in ft. To
Yellow clay	0	20
Gritty, blue clay	20	80
Blue sand and gravel	80	125
Gritty, blue clay	125	165

No. 2

—	Depth in ft. From	Depth in ft. To
Yellow clay	0	25
Gritty, blue clay	25	50
Sand and blue clay	50	55
Gritty, blue clay	55	80
Black sand and clay, water	80	105
Black sand	105	120
Sand, water	120	129
Sand and gravel	129	151

No. 3

—	Depth in ft. From	Depth in ft. To
Top soil	0	2
Yellow clay	2	25
Gritty, blue clay and water	25	75
Rock, blue clay	75	80
Black sand and clay	80	112
Black sand and water	112	120
Gritty, blue clay and water	120	128
Gritty, blue clay	128	200

No. 4

—	Depth in ft. From	Depth in ft. To
Blue clay	0	24
Gritty, blue clay and water	24	50
Rocks	50	75
Grey clay	75	90
Blue clay, sand, and water	90	108
Gravel, sand, and water	108	109
Blue clay and water	109	120
Gritty, blue clay	120	170

Notes. Test Hole No. 1. From 80 to 125-feet layer, water trickled over casing while working, dropping back to 1 foot below ground level. Bailing at approximately 25 gallons a minute lowered water 10 feet below ground level.

Test Hole No. 2. Above 129-foot layer, water in very small quantities. From 129 to 151 feet artesian flow at ground level of 72,000 gallons a day; static head 2 feet above ground level.

Test Hole No. 3. None of waters rose to surface and did not yield enough for drilling purposes.

Test Hole No. 4. Water never came to surface and did not supply enough for drilling purposes.

Location. Qu'Appelle valley

Drilled by Messrs. MacPherson and Thom, Regina, September and October, 1929

Driller's Logs (partly condensed)

No. 1			No. 2			No. 3		
—	Depth in ft.		—	Depth in ft.		—	Depth in ft.	
	From	To		From	To		From	To
Black surface loam	1	7	Surface soil and grey, light-coloured clay	0	12	Black loam, sand, and water	0	10
White or grey, soft substance	7	11	Black soil	12	13	Gravel and water	10	15
Grey, sandy clay	11	30	Black sand	13	19	Fine sand and clay	15	30
Sandy, dark clay, water	30	60	Yellow sand	19	23	Gravel, sand, and water	30	62
Sand and gravel, with streak of clay	60	85	Clay and sand	23	30	Gravel, sand, yellow clay	62	75
Gravel and sand	85	95	Loose, sandy shale, water	30	45	Finer sand and gravel, mixed	75	85
Black clay	95	102	Sandy clay, grey	45	75	Coarse gravel, sand, little clay	85	105
Sand, water	102	110	Shale, water	75	93	Finer sand, traces of blue clay, and shale	105	110
Dark brown clay	110	122	Heavy sand	93	109	Sand, gravel mixed with clay	110	120
Sand and gravel, with clay	122	160	Sea mud, water	109	133	Coarse gravel, water	120	140
Shale	160	178	Shale	133	148	Find sand mixed with clay	140	145
Sand, gravel	178	204	Heavy sand	148	157	Coarse gravel and rocks	145	150
Hard pan	204	241	Sandy shale	157	163	Sand and clay, mixed	150	167
			Heavy clay and gravel, water	163	172	Shale and soapstone	167	217
			Light sand	172	180			
			Heavy sand	180	197			
			Shale	197	239			

Notes. Test Hole No. 1. Insufficient water at 185-foot layer to stand pumping test. At 80-foot layer, pumped at rate of 10 gallons a minute for 6 hours with drawdown of 6 feet; finally became choked. Temp. 42 degrees. Water very highly mineralized.

Test Hole No. 2. Broken casing not able to apply pumping test; water very highly mineralized.

Test Hole No. 3. Started pumping test from 120-140-foot layer, but well became choked; water highly mineralized.

Test Drillings Southeast of Pilot Butte

Location. S. ½ secs. 25 and 26, N. ½ secs. 23 and 24, tp. 17, range 18, W. 2nd mer.; also NE. ¼ sec. 18, tp. 17, range 17, W. 2nd mer.

Drilled by Saskatchewan Well Drilling Company, August, September, October, 1929

Driller's Logs (condensed)

A

—	Depth in ft. From	Depth in ft. To
Sand and little water	0	15
Sand and clay (silt)	15	74
Fine sand, little water	74	76
Boulder clay	76	112
Gravel and sand, little water	112	114
Boulder clay	114	129
Muddy sand	129	132
Boulder clay	132	150

B

—	Depth in ft. From	Depth in ft. To
Soft clay	0	40
Black clay	40	99
Muddy sand, gravel, and water	99	104
Blue boulder clay	104	148
Coal	148	149
Blue boulder clay	149	153
Sea mud	153	165
Layers of clay mixed with gravel, water	165	175

C

—	Depth in ft. From	Depth in ft. To
Sandy clay	0	13
Boulder clay	13	31
Grey clay	31	38
Brown boulder clay	38	57
Blue boulder clay	57	99
Sand and gravel, water	99	106
Blue boulder clay	106	138
Sand, gravel, and clay layers, water	138	150
Grey clay mixed with sand layers, small supply of water	150	182

D

—	Depth in ft. From	Depth in ft. To
Sandy clay	5	10
Muddy sand	10	24
Boulder clay, seepage water very slight	24	150

Notes. Test Hole No. A. Not sufficient water at any layer to test for capacity.

Test Hole No. B. Very little water at any layer.

Test Hole No. C. Water from 99-106 feet, layer rose to 6 feet below ground level. Was pumped 7 hours at the rate of 8 gallons a minute. Water lowered from 6 feet of surface to 80 feet from surface. Temperature, 42 degrees.

Test Hole No. D. Insufficient water for test.

E1	Depth in ft. From	To	F	Depth in ft. From	To
Sand	0	10	Sand, some water	0	25
Sandy gravel, clay	10	28	Muddy sand	25	35
Gravel, water	28	30	Soft clay	35	45
Sandy clay	30	35	Blue boulder clay	45	68
Coarse gravel, water	35	38	Sandy clay, water	68	75
Sandy clay or boulder clay	38	150	Blue clay	75	85
			Sandy clay	85	133
			Hard pan	133	152
E2			**G**		
Sand	0	14	Sandy top soil	0	5
Clean sand and gravel, and water	14	18	Soft, muddy clay	5	28
Sandy, blue clay	18	40	Coarse sand, water	28	45
			Clay, stones, boulders, little water	45	165
			Blue clay	165	200

Notes. Test Hole No. E1. Static level of water from 35-38-foot layer, 2½ feet below ground. Pumped at rate of 9 gallons a minute and lowered water to 17 feet below ground. Temperature of water 43 degrees.
Test Hole No. F. Insufficient water for test.
Test Hole No. E2. No test made.
Test Hole No. G. Insufficient water for test. Static water-level 5 feet below ground level.

H	Depth in ft. From	To	I	Depth in ft. From	To
Top soil	0	2	Sand with coal layers and water	0	35
Yellow sand, water	2	10	Sandy clay	35	48
Muddy sand	10	25	Coarse gravel, water	48	49
Soft clay	20	35	Sand and gravel with clay, water	49	92
Muddy sand and gravel, water	35	45	Clay	92	93
Coarse sand and gravel, water	45	63	Muddy gravel, water	93	108
Soft, gravelly clay	63	165	Gravelly, blue clay, sand	108	154
			Gravel, sand, water	154	158
			Clay	158	160
			Coarse sand and gravel, water	160	170
			Clay	170	172
			Sand, gravel, water	172	175
			Clay	175	195
			Gravel, water	195	196
			Clay	196	198
S1			**S2**		
Sand, water-bearing from 5-17 feet	0	17	Sandy top soil	0	5
Sandy clay	17	28	Water-bearing sand	5	8
Blue boulder clay	28	113	Blue boulder clay	8	70
Blue sand	113	134	Sand, gravel, water	70	76
Blue clay	134	148	Blue boulder clay	76	90
Sandy, blue clay	148	165	Sand, gravel, water	90	100
Blue clay	165	180	Blue boulder clay	100	150

Notes. Test Hole No. H. Static level of water from 45-63-foot layer, 10 feet below ground. Pump at rate of 8 gallons a minute.
Test Hole No. 1. Water from 48-49 feet rose to 10 feet below ground, but would not stand bailing. Water from 160-170-foot layer rose to ground level, pumped for 5 hours at 28 gallons a minute with drawdown of 27 feet.
Test Hole No. S1. Pumped from 5 to 17-foot layer at rate of 65,000 to 70,000 gallons a day and drew water down to 17 feet. Temperature 42 degrees.
Test Hole No. S2. Insufficient water to stand pumping test.

Location. North of Regina at Mound springs

Drilled by City of Regina, Waterworks Department, Oct., Nov., Dec., 1929, and Feb., 1930

Driller's Logs (partly condensed)

Mound Springs No. 1		Depth in ft.		Mound Springs No. 2	Depth in ft.		Mound Springs No. 3	Depth in ft.	
—		From	To	—	From	To	—	From	To
Top soil		0	3	Top soil	0	2	Top soil	0	2
Yellow clay		3	8	Yellow clay	2	14	Yellow clay	2	20
Blue clay		8	12	Blue clay	14	40	Boulders	20	26
Yellow clay	water	12	15	Sand and gravel, water	40	59	Yellow clay	26	61
Sand and gravel		15	38	Yellow clay	59	70	Gritty, blue clay	61	79
Yellow clay and gravel		38	40	Blue clay	70	165	Yellow clay	79	120
Clay and sand		40	45	Water, blue clay	165	175	Gritty, blue clay	120	143
Gravel and sand		45	50	Gritty, blue clay	175	196	Gritty, blue clay and water	143	146
Yellow clay, no water		50	90				Gritty, blue clay and gravel	146	159
							Blue clay	159	163

Notes. Test Hole No. 1. From 15-foot layer, flow 51,000 gallons a day
Static head 10½ feet
From 40-foot layer, flow 129,000 gallons a day
Static head 10½ feet
From 45-foot layer, flow 170,000 gallons a day
Static head 10 feet.

Test Hole No. 2. From 40 to 59-foot layer, natural flow of 500,000 gallons a day; let run 1½ days no change. Static water-level 19 feet above ground.

Test Hole No. 3. Water from 143 to 146-foot level rose to 26 feet from ground level; could be lowered right down with bailer.

CRETACEOUS STRATIGRAPHY OF THE MANITOBA ESCARPMENT

By S. R. Kirk

INTRODUCTION

The summer of 1929 was spent in studying the Cretaceous rocks of Manitoba from Swan River valley southwards to the International Boundary. Exposures were examined in the areas of the Swan River, Duck Mountain, Riding Mountain, Manitoba House, Virden, Brandon, Turtle Mountain, and Dufferin sectional map-sheets. The greater part of the time was devoted to the eastern edge of the Cretaceous area, upon which the best exposures can be observed; especially to that part lying to the north of Assiniboine valley, on which least previous information was available. It is the purpose of this report to describe the stratigraphy of the marine Cretaceous of Manitoba as seen along the escarpment.

The thanks of the writer are due to R. T. D. Wickenden who gave valuable assistance during the greater part of the summer, and to E. C. Hicks who acted as assistant during Mr. Wickenden's temporary absence in another field. In addition to acting as assistant Mr. Wickenden made collections from various of the exposures examined, for the purpose of studying the micro-faunas. He is at present engaged in this study at Harvard University. As this work is not yet completed only a few general references to preliminary results can be given, but it is hoped that it will prove to be of great assistance in the elucidation of the stratigraphy of the Cretaceous; especially in subsurface correlation. In connexion with the work of the summer the writer is also indebted to the Borings Division of the Geological Survey, to the Department of the Interior at Calgary, and to various well drillers in Manitoba, for information kindly provided; to W. A. Bell of the Geological Survey and to J. B. Reeside, jun., of the United States Geological Survey, for their opinions on fossil specimens submitted to them; to F. G. Wait for partial analyses of limestones, and to F. J. Fraser for a report on separation of heavy minerals from sandstone samples.

PREVIOUS WORK

Since the early discoveries of Cretaceous rocks in Assiniboine valley by Hector in 1857 and by Hind and S. J. Dawson in 1858, numerous references have appeared to marine strata of this period in Manitoba area. These include reports of the Cretaceous found in natural exposures and in well drillings, associated principally with the names of R. Bell, J. W. Spencer, G. M. Dawson, A. R. C. Selwyn, J. B. Tyrrell, D. B. Dowling, W. McInnes, A. MacLean, and R. C. Wallace; ecomonic aspects of these rocks are dealt with in reports from the Mines Branch and from the Geological Survey under the names of J. W. Wells, J. Keele, H. Ries, and S.C.

Ells. It will be sufficient for present purposes, however, to make reference only to those contributions that have been more important in the elucidation of the marine Cretaceous stratigraphy of the area under consideration in this report.

G. M. Dawson[1], during the Boundary Commission survey of the 49th parallel in 1873-4, examined the shales of the Pembina escarpment. He applied the name "Pembina Mountain group" to the shale beds seen on the escarpment near the 49th parallel, regarding them as probably belonging to the 4th or Fort Pierre group of Meek and Hayden's Upper Missouri section, and referred to the 3rd or Niobrara division of these writers some specimens of limestone from Morris (Boyne) river in which he found *Inocerami*, oysters, and micro-fossils. At the same time R. Bell[2], and with him J. W. Spencer,[3], recognized the extension of Cretaceous beds from Assiniboine valley into Swan River valley and Porcupine mountain. Specimens of limestone and marl collected by Spencer on Swan river and Thunder hill were examined by Dawson who noted their similarity in lithology and foraminiferal content to the Niobrara specimens from Morris river, which he had previously examined. The extensive explorations in northwestern Manitoba by J. B. Tyrrell[4] and his assistant, D. B. Dowling, between the years 1887 and 1890, provided the basis for the most comprehensive stratigraphical study of the Manitoba Cretaceous yet attempted. Tyrell recognized, in the Manitoba section, representatives of Meek and Hayden's Dakota, Benton, Niobrara, and Pierre groups, the last of which he subdivided into the Millwood series below and the Odanah series above. During the summers of 1914 and 1915 A. MacLean[5] made a detailed study of Pembina mountain, Manitoba, and proposed lithological units for the Cretaceous of that area, recognizing the occurrence of two distinct groups of calcareous shales in the part of the section classified by him as Niobrara. D. B. Dowling[6] has since criticized MacLean's correlation of the upper members of the Pembina Mountain section with the Millwood and Odanah of Tyrrell.

GEOGRAPHY

The Manitoba escarpment is the most prominent topographical feature in the province. It consists of the relatively steep eastern face of a line of hills, with a general north-northwesterly trend, bordering the low-lying Red River valley and lake plain of Manitoba from whose western edge, at elevations of 900 to 1,100 feet, it rises in series of benches to form the eastern slopes of Pembina, Riding, Duck, and Porcupine mountains, and Pasquia hills, which lie to the west of the second meridian. These mountains stand out as blocks of the eastern eroded edge of the Great Plains Cretaceous in Canada and are separated by the wide valleys of

[1] "Report on the Geology and Resources of the Forty-ninth Parallel"; B.N.A. Boundary Commission, Montreal (1875).

[2] "Report on the Country between Red River and the South Saskatchewan, Etc."; Geol. Surv., Canada, Rept. of Prog. 1873-74 (1874).
"Report on the Country West of Lakes Manitoba and Winnipegosis, Etc."; Geol. Surv., Canada, Rept. of Prog. 1874-75 (1876).

[3] "Report on the Country between the Upper Assiniboine River and Lakes Winnipegosis and Manitoba"; Geol. Surv., Canada, Rept. of Prog. 1874-75 (1876).

[4] "The Cretaceous of Manitoba"; Am. Jour. Sci., ser. 3, vol. 40, pp. 227-232 (1890).
"Report on North-western Manitoba, Etc."; Geol. Surv., Canada, Ann. Rept., vol. V, pt. E (1893).

[5] "Pembina Mountain, Manitoba"; Geol. Surv., Canada, Sum. Rept. 1914, pp. 69-71.
"Pembina Mountain, Southern Manitoba"; Geol. Surv., Canada, Sum. Rept. 1915, pp. 131-133.
"Pembina Mountain Area, Southern Manitoba"; MS.

[6] "The Turtle Mountain Coal Measures"; Trans. Roy. Soc., Canada, sec. 4, pp. 38-39 (1920).

Assiniboine river, Valley river, Swan river, and Red Deer river. Pembina mountain, in the south, rises to elevations of over 1,600 feet, and summit levels of over 2,200 feet are reached in Riding, Duck, and Porcupine mountains; the greatest elevations of over 2,500 feet being on the top of Duck mountain.

To the west of the escarpment stretches the second prairie level, higher and more diversified than the lake plain or first prairie level to the east. It is drained and deeply dissected by the valleys of Pembina river and Assiniboine river and its tributaries, and from its surface, in the south, Turtle mountain rises as a prominent feature, extending southwards beyond the International Boundary.

Due to the dense growth of forest and other vegetation on the mountains of the northern section of the escarpment and to the generally heavy covering of drift, good exposures of bedrock are relatively rare. Numerous small streams descending the face of the escarpment have, however, cut good sections in the Cretaceous rocks and from these it is possible to work out the stratigraphical succession. The greater part of the summer was spent in following the courses of the streams and in measuring the exposed sections. Owing to the generally horizontal attitude of the beds it was found that measurements of thickness could, in most cases, readily be made by Locke level. At a number of points the elevations of established horizons were determined by hand levelling.

GENERAL GEOLOGY

The following is a table of units proposed for the marine Cretaceous rocks of the Manitoba escarpment.

Table of Formations

—	Pembina Mountain section	Riding Mountain section
Pierre	Odanah beds—250 feet+	Odanah beds—300 feet
	Riding Mountain beds—50-80 feet	Riding Mountain beds—200 feet
	Pembina beds—80 feet—	
Pierre or Niobrara?	Boyne beds—140 feet	Vermilion River beds—250-300 feet
	Morden beds—200 feet	
Niobrara or Benton?	Assiniboine beds—70 feet	Assiniboine beds—70 feet
Benton	Keld beds—90 feet	Keld beds—60-65 feet
	Ashville beds—100-150 feet (unexposed)	Ashville beds—170 feet
	Basal beds—90 feet (unexposed)	Basal beds—19-90 feet

Riding = Mountain

Millwood

Vermillion River formation

Millwood

Ashville

Basal

= ~~Fabex~~ Favel

The thicknesses given are approximations reached after evaluating all available evidence and apply only to the region of the Cretaceous escarpment in Manitoba. Formational units are extended through both the northern and southern areas only in those cases where correlation is believed to be fully justified by the evidence, and different terms are used where evidence for definite correlation is at present lacking or indefinite.

The section as given for Pembina Mountain area is a modification of that proposed by MacLean; the Riding Mountain section is based mainly on the exposures studied during the summer on Vermilion river in townships 23 and 24, range 20.[1] In the northern section the Ashville beds are the "Benton" of Tyrrell, the Keld and Assiniboine beds are the "Niobrara", and the Vermilion River and Riding Mountain beds are the "Millwood" of the same author. In the southern section the beds from Keld to Boyne (inclusive) are the "Niobrara" of MacLean and the Riding Mountain beds are the division that he correlated with Tyrrell's "Millwood".

In the stratigraphical account that follows, the description of the Morden, Boyne, and Pembina beds in the south is deferred until the complete succession has been dealt with for the northern area and for such divisions in the southern area as are directly correlated with the northern section.

BASAL BEDS

The basal beds of the Upper Cretaceous in Manitoba have been correlated with the Dakota sandstone of Meek and Hayden's classical section. The correlation of such a basal sandstone formation cannot be regarded as necessarily exact in a time sense, but as the Manitoba "Dakota" occurs below a shale group of undoubtedly Benton age and is in general similar to the type Dakota, it at least represents the same facies and may be regarded as its approximate time equivalent.

The only exposures of the Basal beds seen in the area examined lie on Swan river, between SW. ¼ sec. 6, and SE. ¼ sec. 9, tp. 37, range 26, and on Roaring river between NE. ¼ sec. 18 and NW. ¼ sec. 22, tp. 36, range 26. Other exposures have been recorded at more northerly localities; on Kettle hills at the south end of Swan lake, on Red Deer river north of Porcupine mountain, and on the shores of Wapawekka lake north of Saskatchewan river, where, according to McInnes,[2] the so-called Dakota overlaps the underlying Palæozoic limestone and rests directly on the Precambrian surface. Such evidence as is available indicates that, in Manitoba, the Basal beds rest upon an irregular surface of Devonian rocks; although the suggestion has been made by Dowling[3] that the Cretaceous may be underlain by Jurassic beds at the Neepawa well. This suggestion was doubtless based on the occurrence of Jurassic beds under the Cretaceous in the well at Moose Jaw. In Manitoba no evidence is available by which such a contention can be either proved or disproved.

[1]All ranges given in this report are west of the Principal meridian.
[2]"The Basins of the Nelson and Churchill Rivers"; Geol. Surv., Canada, Mem. 30, p. 66 (1913).
[3]Dowling, D. B., Slipper, S. E., and McLearn, F. H.: "Investigations in the Gas and Oil Fields of Alberta, Saskatchewan, and Manitoba"; Geol. Surv., Canada, Mem. 116, p. 37 (1916).

Little can be added to the description given by Tyrrell[1] of the exposures on Swan river and Roaring river. The showings in the banks are mostly small and discontinuous, so that no definite succession can be worked out. On the north bank of Swan river in NE. ¼ sec. 5, tp. 37, range 26, a bed of light-coloured clay, which is claimed to be refractory, occurs at the river level. In the bank at 7 feet above water-level a band 2 feet thick of dark, highly carbonaceous sandstone with calcareous cement is found to be crowded with the shells of *Ostrea* sp. and *Modiola tenuisculpata* Whiteaves; a species probably identical with *Modiola (Brachydontes) multilinigera* Meek. Higher in the bank an incoherent, fine, white sand occurs with some green sand towards its base and containing streaks and lenses of lignitic material and a black plastic clay. The sand contains numerous brown nodules cemented by iron oxide. Above this point the river banks show a few low sections of green sand containing *Lingula* sp. and beds of white sand associated with lignitic material. These soft, sandy beds appear to pass laterally into hard sandstone, ledges and masses of which lie in the bed of the river, isolated by the removal of the surrounding incoherent portions of the beds of which they formed a part. These harder sandstone lenses vary in colour from green to light grey and white, the cementing material being calcareous. In some cases the beds are ferruginous and weather to a reddish brown colour. Crossbedding can be seen and pyrite nodules and fragments of carbonized wood are common. At one point in SE. ¼ sec. 6, tp. 37, range 26, a large concretionary structure of grey calcareous sandstone, composed of three intergrown, almost spherical masses, 6 feet in diameter, shows the same type of structure as that described at Kettle hill by Tyrrell[2]. Lignite is common, but is mostly disseminated in fragments or thin lenses. No thick or continuous bands have been seen.

Hard, calcareous sandstone masses found on Roaring river show a marked botryoidal structure on their exposed surfaces and on that river a heavy ferruginous sandstone is found containing very coarse sand grains from 1 to 2 mm. in diameter. These grains are well rounded and many of them are composed of a bluish opalescent quartz. *Lingula* sp. and fragments of fish teeth and coprolites are found in the beds on Roaring river.

The thickness of the so-called Dakota in Manitoba is undoubtedly very variable, although a good deal of the variation commonly ascribed to it is probably due to differences in interpretation of the records of wells. It has to be borne in mind that the Basal beds in Manitoba are not a constant sandstone, for they include beds of clay and shale, of more or less arenaceous character, and it is known that there are sandy shale members in the overlying Ashville beds. Thus the top of the formation seems to be gradational into the Ashville or Lower Benton and accordingly it cannot be exactly placed. In the old Vermilion River bore-hole a thickness of 19 feet of sandstone was recorded, according to Tyrrell's interpretation, whereas at the well of the Dauphin Oil Syndicate,[3] 4 miles farther north, information supplied by Mr. Eagle showed that only one bed of sand, probably less than a foot in thickness, was passed through. This information, together with the log of the well, supplied by the Department of the Interior, suggests to the writer that at least 30 feet and probably as

[1]Geol. Surv., Canada, Ann. Rept., vol. V, pp. 109-113.
[2]Geol. Surv., Canada, Ann. Rept., vol. V, p. 76.
[3]Drilling in 1929.

much as 90 feet of the section may here be assigned to the Basal beds, although very little of it is pure sand. In the Mack well on Ochre river a thickness of 88-90 feet may again be placed as Basal beds, and in the south thicknesses have been given of 92 feet in the Morden well and 273 feet at Rathwell. In the record of the Neepawa well no sand or sandstone is mentioned and the base of the Cretaceous is placed by Dowling under an entry of "clay, sandy—19 feet." It seems clear, therefore, that the Basal beds are variable both in thickness and in lithology and that they cannot be depended upon to continue as a consistent, porous horizon for any great distance.

ASHVILLE BEDS

The name Ashville is used for the band of shale which succeeds the Dakota beds and which has formerly been classified as the whole of the Benton in Manitoba. There is good reason to believe that it represents only the lower part of the Benton and consequently may be regarded as equivalent to the Graneros shale of the western United States.

The Ashville beds do not outcrop anywhere in Manitoba to the south of Assiniboine river, but they are known in that region from well records. They appear first to the east of Riding mountain in the vicinity of Kelwood, Norgate, and McCreary, where they are exposed in several roadside ditch cuts. Good showings of their upper beds are found to the north of Riding mountain on Edwards creek and Vermilion river. They form the banks of Wilson river for a distance of 5 miles in the neighbourhood of the village of Ashville, from which occurrence the name is taken. They are seen again on Valley river, north of Ashville, at a few localities to the east of Duck mountain, and on the west branch of Favel river, on Roaring river, and in Thunder hill.

The rock of the Ashville is generally a dark grey, or almost black, shale; carbonaceous and essentially non-calcareous in composition and capable of being worked into a soft clay. Pyrite is present and secondary growths of well-formed selenite crystals are abundant, together with the yellow powdery incrustation on lamination planes and joint fissures common to all the non-calcareous shales of Manitoba. This material may owe its colour to the presence of a small amount of melanterite, this mineral being found also as an efflorescence on the surface of some talus banks of the shale. The shale is soft and breaks down readily into thin, irregular flakes, so that the cut banks of streams on which it is exposed are almost invariably covered by a loose talus of its fragments. On drying these weathered particles tend to assume a dull, silvery grey colour. Some of the beds are highly fissile and of a chocolate brown colour; material of this type being, in most cases, heavily charged with brown, fragmentary remains of small fishes. Bands of this type of shale are found in the banks of Wilson river between 2 and 3 miles east of Ashville and on Roaring river 4 miles east of Kenville. Some beds of the Ashville shale on Roaring river contain a considerable proportion of fine sand. Thin bands of bentonitic clay are numerous, as they are, indeed, throughout the whole of the Manitoba Cretaceous.

Although the Ashville beds are predominantly non-calcareous they include some calcareous concretions as well as bands of impure limestone. Limestones are seen in ditch cuts in the vicinity of Kelwood, Norgate, and McCreary where it appears, from levelling, that there are two bands separated by about 14 feet of shale. The lower of these, about 9 inches in thickness, is a grey stone, splitting into thin slabs and containing fragmentary fish remains in abundance. It weathers to a reddish brown colour and contains a considerable quantity of fine sand. This bed is probably only of local extent. The upper of the two limestones is similar in appearance, but is less arenaceous and has a thickness of 9 inches to 1 foot. It splits into irregular slabs determined by the shells of oysters with which it is crowded. The matrix of the rock is found, on microscopic examination, to be composed of calcareous prisms, presumably from the shells of an *Inoceramus*. Fish teeth and scales are also present. It is believed that this upper limestone is of rather wide extent and that it may be correlated with a similar band seen on Valley river, Wilson river, and the west branch of Favel river. At each of these localities the overlying beds are exposed and show the limestone to be capped by an unusually thick layer of bentonitic clay, varying between 2 feet and 8 inches; a coincidence that supports the correlation. The position of this oyster-bearing limestone on Vermilion river is 35 feet below the top of the Ashville beds. Another feature of interest is the occurrence of a thin, highly phosphatic band among the shales on Wilson river, ½ mile southeast from Ashville. It is jet black and entirely made up of teeth, vertebræ, and other bones of fishes. On its surfaces "cone-in-cone" structure is strongly developed and it is, in places, covered by an incrustation of brown iron oxide. A sample submitted to the Division of Chemistry, Department of Mines, for partial analysis, showed a phosphate content corresponding to 18·41 per cent P_2O_5. Unfortunately no greater thickness than 2 inches of this material has been found. The phosphate content of this band is far above that of any of the other fish-bearing limestones analysed.

At the top of the Ashville beds there is a gradual transition through a few feet of shale to the dominantly calcareous beds of the overlying Keld group. This transitional zone can be located in many of the river bank sections from Riding mountain northwards to Swan River valley. The base of the Ashville is nowhere exposed along the Manitoba escarpment, but the thickness may be taken at about 178 feet for the Vermilion River section. This figure was obtained from the old Vermilion River borehole and agrees closely with information from the recent Dauphin Oil Syndicate well.

KELD BEDS

This name is given to a group of calcareous shales and impure limestones which overlie the Ashville beds and are well exposed on Vermilion river to the east of the village of Keld.

The Keld beds give better and more numerous exposures along the Manitoba escarpment than any of the other members of the Cretaceous and, on account of superior hardness and jointing, their upper beds tend to hold vertical faces on many of the river bluffs. Their most southerly exposure is on the south side of Assiniboine river immediately to the west of the Ladysmith ferry, where, at a low state of the river, a few feet of the top of the beds are exposed. They reappear 65 miles to the northwest near the foot of Riding mountain where they are seen in cut banks and ditches on the new highway between Kelwood and Norgate and give further exposures on Ochre river, Edwards creek, Vermilion river, and Wilson river. In Duck Mountain area they are found on the north branch of Pine river, on both branches of Sclater river, on both branches of Favel river, and on Roaring river. They can also be seen on Thunder hill in Swan River valley.

The total thickness of the Keld beds on Vermilion river is between 60 and 65 feet, and similar thicknesses are observed on other rivers of Riding mountain and Duck mountain. The following section, in descending order, is measured on the left bank of Vermilion river in SE. ¼ sec. 2, tp. 24, range 20.

Shale—grey, speckled, calcareous (base of Assiniboine).

Limestone—4-8 inches—grey, speckled, weathering white. *Metoicoceras* sp., *Anomia* sp., etc.
Shale and limestone—17 feet—alternating bands, grey to buff with prominent 6-inch band of limestone at base. *Inoceramus labiatus* abundant.
Shale—9 feet—grey, speckled, calcareous—*Inoceramus labiatus* abundant.
Clay—41 inches—bentonitic, weathering white.
Shale—35 feet—grey, speckled, calcareous; with several white clay bands.
Clay—6 inches—bentonitic, weathering white.

Shale—grey, slightly calcareous—transitional to non-calcareous shale below (top of Ashville).

The base of the Keld beds may be placed, somewhat arbitrarily, at the highest of a group of three bentonitic clay bands which occur within a thickness of 5 to 6 feet interbedded with the transitional shales of the top of the Ashville beds. The beds consist of speckled, calcareous, and somewhat carbonaceous shale: mainly dark grey in colour. In the lower 35 feet the shale is rather fissile, but passes upwards, in the succeeding 9 feet, into shale of a more compact type which weathers to a bluish grey colour. The top 18 feet of the beds consist of an alternation of a similar calcareous shale with beds of impure, slabby limestone in layers up to 6 inches in thickness. These upper beds weather to a light buff colour and in this condition present a somewhat chalky appearance.

Calcareous Foraminifera are abundant throughout the beds, but megascopic fossils are rather rare in the lower 35 feet. Included in this part are *Ostrea* sp., fragments of an *Inoceramus*, and numerous fish vertebræ and scales: the latter mostly referable to *Ichthyodectes* sp. Larger fragments of fishes showing portions of the vertebral column have also been found in the corresponding beds on Ochre river, Edwards creek, and the west branch of Favel river. The upper beds are characterized by the great abundance of *Inoceramus* shells, most of which have the typical form of *Inoceramus labiatus* Schlotheim, as found in the Greenhorn limestone of the western United States. Shells of this species practically build the whole of the slabby limestone layers in the upper 18 feet, with the exception of the extreme top layer from which they are absent. On account of the great abundance of this characteristic fossil the beds may, with some confidence, be placed as Benton and equivalent to the Greenhorn limestone; a correlation which has already been suggested by Warren and Rutherford.[1] *Inoceramus labiatus* Schlotheim has not been positively identified from any higher beds in Manitoba. Along with it in the Keld beds occur other species of *Inoceramus* and some *Ostrea congesta* Conrad, together with fish remains.

The top bed of the Keld as seen on Vermilion river is a band of relatively hard shale or impure limestone, varying in thickness from 4 inches to 9 inches in different exposures. Except for its division at some of the exposures by a shaly parting it is a compact bed and on weathering it assumes a very light grey colour and stands out as a conspicuous capping on the top of the *Inoceramus labiatus* limestones and shales. This band, although thin, is constant in lithological and palæontological characters over a wide area. It is found at Ladysmith ferry on Assiniboine river and, although not definitely identified on Ochre river, is picked up again in Dauphin valley on both branches of Edwards creek, on Vermilion river, and on Wilson river. A band of similar nature is found on Slater river a short distance to the west of the ridge highway, but the zone has not been recognized in Swan River district. Where it occurs it provides a good marker band at the top of the *Inoceramus labiatus* beds. This top zone is characterized by abundant, small pelecypod shells less than $\frac{1}{4}$ inch in diameter and referable to *Anomia* sp. *Inocerami* are also common, the most abundant being a relatively small, strongly convex form resembling, although probably distinct from, *Inoceramus corpulentus* McLearn. The greatest palæontological interest of this bed, however, centres around the occurrence in it of Ammonites. Most of the specimens of these collected are rather poor impressions which do not show sutures. On account of the similarity of certain of the smaller specimens to young *Prionotropis* the writer was at first inclined to regard the band as the beginning of a group of beds equivalent to the Carlile or upper Turonian of the western United States. The presence of the corded keel of *Prionotropis* cannot be conclusively proved, however, and Dr. J. B. Reeside, who has kindly examined specimens submitted to him, regards these as referable to *Metoicoceras* and near to *Metoicoceras whitei* Hyatt. Accordingly, the band is here retained with the *Inoceramus labiatus* beds of the Keld and placed as the top bed of that division.

ASSINIBOINE BEDS

MacLean[2] proposed the names Assiniboine limestone and Assiniboine shale for the heavy bed of limestone and underlying calcareous shale which outcrop on the right bank of Assiniboine river from sec. 36, tp. 8, range 11, to sec. 16, tp. 9, range 10. The term Assiniboine is here retained and applied to the same group of rocks over the more extended area of the Manitoba escarpment as far north as Porcupine mountain. It should be pointed out, however, that MacLean included, in his Assiniboine shale, the *Metoicoceras* band and underlying *Inoceramus labiatus* beds which have here been separated as the Keld beds.

The Assiniboine beds do not outcrop to the south of Assiniboine river, but are exposed, in whole or in part, on Ochre river, the east branch of Edwards creek, Vermilion river, Wilson river, Valley river, the north

[1] "Fossil Zones in the Colorado Shale of Alberta"; Am. Jour. Sci., ser. 5, vol. 16, pp. 134–135 (1928).
[2] "Pembina Mountain Area, Southern Manitoba"; MS.

branch of Pine river, the north branch of Sclater river, the east branch of Favel river, Roaring river, Swan river, Woody river, Bowsman river, Kematch river, and Birch river. They are also known, from talus fragments, to be present in Thunder hill. The most complete sections are those on Vermilion and Ochre rivers.

On Vermilion river the Assiniboine beds follow the *Metoicoceras* band without any marked break or change in lithology. The section on this river has a total thickness of 72 feet and is measured, in sec. 35, tp. 23, range 20, in the following descending order:

Shale—dark grey, fissile, non-calcareous (base of Vermilion river).

Limestone and shale—3 feet thin, alternating layers; strongly iron-stained.
Shale—20 feet—dark grey, calcareous, with several thin bands of hard limestone.
Limestone—4-5 feet—hard, grey, weathering buff; highly fossiliferous.
Shale—45 feet—grey, speckled, calcareous.

Limestone—(*Metoicoceras* band of the Keld).

The lower 45 feet of the section consists of foraminiferal shale, indistinguishable lithologically from the shale of the underlying Keld beds. Although megascopic fossils are rather rare, such as do occur associate the shale with the overlying heavy bed of limestone. The 4-foot limestone band is the most conspicuous member. It is dark grey and of crystalline appearance on a freshly fractured surface, but weathers to a buff colour and, in that condition, has the appearance of a sandstone. It is characterized by great abundance of small oyster shells. Microscopic examination shows the rock matrix to be composed largely of calcareous prisms of a thick *Inoceramus* shell. Below the limestone some thin bands (1 inch or less in thickness) of hard limestone of similar character are interbedded with the upper layers of the preceding shale. The limestone is followed by calcareous shales, darker in colour and probably more carbonaceous than those below, with 3 feet of predominantly limy beds at the top. These top beds are strongly stained by a ferruginous seepage from the base of the overlying non-calcareous shales.

Fossils found in the 4-foot limestone include the following: *Serpula semicoalita* Whiteaves, *Serpula* cf. *intrica* White, *Ostrea* sp., *Ostrea congesta* Conrad, *Inoceramus* sp. (fragments of a very large flat shell), *Belemnitella manitobensis* Whiteaves, teeth of *Lamna manitobensis* Whiteaves, *Ptychodus* sp., and numerous other fragments of fishes, together with coprolites. The same fauna is present, although more sparingly represented, in the shales beneath the limestone and continues to the top of the group. Of the fossils mentioned the large *Inoceramus*, the small oyster shells, the *Serpulae* and the *Belemnitella* are distinctive of the Assiniboine beds and are found in all exposures.

On Ochre river in SW. ¼ sec. 32, tp. 22, range 17, the section is as follows:

Shale—grey, non-calcareous (base of Vermilion river).

Limestone—5 feet—hard, grey, weathering buff; highly fossiliferous.
Shale—18 feet—grey, speckled, calcareous.
Limestone—8 inches—hard, grey, fossiliferous.
Shale—43 feet—grey, speckled, calcareous.

Shale and limestone—(top of Keld).

Faunally and lithologically the section is similar to that on Vermilion river, except for the presence of two limestones, of which the upper is the heavier and agrees more closely in thickness and appearance with the 4-foot limestone on that river. The upper 5-foot limestone bed on Ochre river is directly overlain by the non-calcareous shale of the succeeding group. Its upper surface is strongly stained by iron oxide and, in places, is replaced by selenite, due to the presence of considerable quantities of pyrite disseminated through the higher beds.

It is worthy of note that one, and only one, heavy bed of limestone from 4 to 6 feet in thickness, occurs at each of the better exposures of the Assiniboine beds. In each case the appearance of the rock and the fauna agree with the description of the bed on Vermilion river. These characteristics, together with the stratigraphical relation to the underlying beds, are so constant as to leave no room for doubt as to the general equivalency of the limestones seen at the various localities from Assiniboine river to Porcupine mountain. All can be referred with certainty to the upper 30 feet of the Assiniboine beds as here defined, but it is not equally certain that all represent precisely the same horizon within that thickness. Thus on Vermilion river and on Valley river the 4-foot limestone is succeeded by between 20 and 30 feet of calcareous shales of the same group, with a concentration of thin, limy bands at the top, above which the succeeding dark, non-calcareous shales of the Vermilion River beds begin. At other localities, notably on Ochre river and on the east branch of Favel river, the limestone is succeeded immediately by the Vermilion River shales. At every exposure that shows the boundary between Assiniboine and Vermilion River beds, brown iron staining of the top of the former is pronounced. Two possible interpretations of the prominent limestone suggest themselves. The lower 8-inch band of limestone on Ochre river may be on the same horizon as the 4-foot limestone on Vermilion river, in which case the upper 5-foot limestone on Ochre river is placed on a level with the top limy layers on Vermilion river. Such a correlation would give close agreement in the thicknesses of the two sections, but would involve considerable lateral variation in the thickness of the individual limestone beds. Alternatively, the heavy band of limestone may be the same in all localities, as seems to have been assumed hitherto. In this case it appears that higher beds of the Assiniboine are present above it in some, but not in all, exposures. This condition might be explained by the existence, below the base of the Vermilion River beds, of a break or disconformity in the succession, with an unequal amount of erosion at the different localities. Although such a contention can not be proved it has some support in the much later faunal development of the lowest fossiliferous horizon in the Vermilion River beds.

The general correlation of the Assiniboine beds can not at present be made with certainty. They have hitherto been classified, along with the underlying Keld beds, as Niobrara, the chief reason being their calcareous character and the presence of Foraminifera. Tyrrell placed the 4-foot limestone of Vermilion river as the top of the Niobrara in Manitoba. When MacLean had shown that the lithologically similar rocks from Morris (Boyne) river (identified by Dawson in 1874 as Niobrara) actually lay some 200 to 250 feet higher in the Pembina Mountain section than the limestone on Assiniboine river, it was clear that the accepted correlation of the calcareous shale beds in the north and south was not well founded. The fauna of the Assiniboine beds contains no species conclusively diagnostic of Niobrara. If the beds are Niobrara then there is no room in the Riding Mountain section for the higher Benton or Carlile beds of the western United States. On the other hand they are lithologically unlike the Carlile and do not contain any of its characteristic fossils. Palæontological evidence being lacking it would be unwise to make any definite assignment of age to the Assiniboine beds, but their apparently perfect conformity with, and lithological similarity to, the Keld beds weighs the balance in favour of placing them tentatively as Benton, of later age than the Greenhorn and thus time equivalents of at least part of the Carlile.

VERMILION RIVER BEDS

The Assiniboine beds on Vermilion river are succeeded by a group of dark, carbonaceous, and predominantly non-calcareous shales. These are the lower part of the Millwood series of Tyrrell's section. The thickness cannot be determined exactly as exposures are discontinuous and dependable marker bands are lacking, but it is estimated at between 250 and 300 feet on Vermilion river. About 70 feet of the lower part of the group are unexposed, but the gap is filled by the record of the old Vermilion river bore-hole in which an entry of "soft, dark, grey clay shale" shows that there is no marked lithological change from the bottom shale seen above the Assiniboine beds about a mile farther down the stream.

The best exposures are in the high, concave banks of Vermilion river where it follows a general northeasterly course through the central part of township 23, range 20, and marks the northern boundary of the Riding Mountain forest reserve. In this section of country occurs the largest single exposure of Cretaceous rocks seen anywhere along the hills of the Manitoba escarpment. This exposure is in SE. ¼ sec. 22, tp. 23, range 20, practically on the south line of the section, where the high left bank of the river gives a continuous showing of 112 feet of flat-lying beds, all belonging to the group defined as Vermilion river. Exposures on other parts of Riding mountain and Duck mountain are not numerous. The bottom 12 feet are seen on Ochre river in sec. 30, tp. 22, range 17, and a further section of 40 feet of a higher portion is found in a ravine cut by a small stream, tributary to that river. There are several outcrops on the east branch of Edwards creek within a distance of 2 miles to the south of the Dauphin dam. Some of the basal beds are seen on the east branch of Favel river, and small showings are found on Swan river, Woody river, and Bowsman river, and better exposures on Kematch and Birch rivers.

The following is a composite section, measured on Vermilion river from sec. 35 to sec. 17, tp. 23, range 20:

Shale—greenish grey and very soft, slumping to clay (base of Riding mountain).

(6) Shale—32 feet—dark grey, non-calcareous with bands of clay ironstone and septaria containing Pierre fossils; transition to overlying beds gradual.

(5) Shale—80 feet—dark grey, non-calcareous, weathering to lighter pinkish grey; containing some brown fish scales, etc.

(4) Shale—36 feet—dark grey, mainly non-calcareous, but including bands of grey, speckled, calcareous shale within the lower 12 feet; numerous, thin, lenticular bands of clay ironstone and septarian concretions containing Pierre fossils.

(3) Shale—45 feet—dark grey to black, non-calcareous, with calcareous concretions and a few lenticular bands of grey crystalline limestone showing "cone-in-cone."

(2) Shale—70 feet ?—no exposure. "Soft dark grey clay shale" of Vermilion River well record.

(1) Shale—8 feet—dark grey, non-calcareous.

Limestone and shale—(top beds of Assiniboine).

The shales of this section are dark, tenacious, and well jointed where washed clean by the stream, but on exposed banks they weather into thin flakes which form an abundant talus and assume, when dry, a dull, silvery grey colour with a slightly pinkish cast. Pyrite is present and secondary development of selenite is strong. Lithologically these shales are indistinguishable from the Ashville and from the Morden and Pembina of the southern section. White bands of bentonitic clay up to 4 inches in thickness are numerous.

The occurrence of calcareous shales in the lower part of No. (4) of the above section is of interest. These are found in bands from 1 foot to 2 feet in thickness. They are dark and more or less carbonaceous, but weather to a light grey colour with white specks showing on the lamination planes. They resemble the calcareous shales of the Keld and Assiniboine beds and are practically indistinguishable from parts of the Boyne beds of Pembina Mountain area. Mr. Wickenden reports the finding in them of an assemblage of Foraminifera which, although less abundant in species, resembles that found by him in the Boyne beds.

Apart from fragmentary, brown fish remains, which are scattered more or less abundantly throughout the beds, megascopic fossils have been found only in the clay ironstone layers and calcareous concretions of Nos. (4) and (6) of the above section. In the clay ironstone beds of No. (4) crushed shells of *Baculites ovatus* Say? are very abundant. Several small and imperfectly preserved Scaphites have been found together with aptychi in the associated septarian concretions. The Scaphites, although not sufficiently complete for positive identification, may, according to Dr. Reeside, be placed tentatively as *Discoscaphites* cf. *nicolleti* Morton. Small shells of *Yoldia* sp. are common both in the concretions and in the clay ironstones and the latter contain abundant impressions of fucoids. The general aspect of this group of fossils is Montanan and the probable *Discoscaphites* is suggestive of late Pierre age. This fauna is of great interest as it is the first to be found above the Assiniboine beds in the Riding Mountain section. It would appear either that the Niobrara and early Pierre are represented in the comparatively thin and mostly unexposed lower part of the section, or else that one or both are absent. In the description of the Assiniboine beds reference has already been made to the possibility of a disconformity at the top of that group, but definite evidence on this point is lacking.

The top of the Vermilion River beds is seen on the right bank of the river in SW. ¼ sec. 16, and N. ½ sec. 8, tp. 23, range 20, but has not been located elsewhere. The sections referred to show a gradual transition through several feet to the new and distinctive type of lithology of the Riding Mountain beds.

RIDING MOUNTAIN BEDS

The division of the Pierre in Manitoba for which the name Riding Mountain beds is proposed is the upper part of Tyrrell's Millwood series. Like the overlying Odanah series of that author it is defined on a purely lithological basis.

The Riding Mountain beds differ rather markedly in appearance and properties from the Vermilion River beds. They consist of a rather light grey to greenish grey, non-calcareous shale in which nodules and irregular bands of ironstone are abundant. The shale is hard when dry and shows lamination, but is not markedly fissile. In this condition it tends to break into small, equidimensional particles, quite distinct from the thin flakes of the dark Vermilion River beds. It slakes readily in water and passes directly to a very tenacious and plastic clay. As a result of this property exposed surfaces of the shale are almost invariably covered by clay from its disintegration. When dried the clay surface becomes hard and strongly mud-cracked. The plasticity of the material causes numerous clay slides where the Riding Mountain beds occur on the steeper slopes of the Manitoba hills, as can be well seen on the high ground to the south of Vermilion river in township 23, range 20. By its slumping over the Vermilion River beds the top of these beds has in some places been completely covered. Another feature of the Riding Mountain beds is the presence of a certain amount of fine sand, disseminated through the shale or clay. The amount varies in different places, but in some of the beds is sufficient to give to the rock, in its dry state, a slightly gritty feel.

The Riding Mountain beds are exposed on the east branch of Edwards creek about 3 miles south of the Forest Reserve boundary and are seen on the high ground to the south of Vermilion river in the locality already mentioned. To the north of Duck mountain they are found in the banks of Swan river, 5½ miles west of Arran, Saskatchewan, and are indicated by banks of clay with ironstone nodules on Bowsman, Kematch, and Birch rivers, within the boundary of Porcupine forest reserve No. 2. There are small showings on the east bank of Assiniboine river at Kamsack, Saskatchewan, in which a considerable quantity of yellow bentonitic material is present, and good exposures on that river near Millwood. In the southern part of the field the same beds are found at numerous localities along the upper edge of the Pembina escarpment and their top is seen on Souris river, 1 mile south of Wawanesa.

Although good sections of the Riding Mountain beds are somewhat rare the presence of the group can generally be recognized by the distinctive topography and the character of the soil in areas which it immediately underlies. On it are developed rounded hills or buttes whose sides are generally almost bare of vegetation. Around these buttes dark brown, weathered fragments of ironstone are scattered on the surface of the ground and, in dry weather, the latter assumes a hard, mud-cracked condition. This type of surface expression is seen in Swan River valley to the north of Pelly, Saskatchewan. It is also noticeable at many places along the slopes of Assiniboine valley in the part of its course in which it runs between Fort Pelly and the neighbourhood of Virden, on the west side of and parallel to Duck and Riding mountains. It is especially marked in the neighbourhood of Harrowby and Millwood, the type region of Tyrrell's Millwood series. In the southern part of the field the same type of topography is seen in Pembina valley west of Kaleida, in the valley of Deadhorse creek 6 miles southwest of Morden, and at many points near the top of the Pembina escarpment. In the neighbourhood of Millwood and Harrowby spherical and ellipsoidal concretions are abundant, from which an assemblage of well-preserved Pierre fossils can be obtained. Among the species found are *Pteria linguiformis* Evans and Shumard, *Inoceramus tenuilineatus* Hall and Meek, *Inoceramus* cf. *nebrascensis* Owen, *Lucina occidentalis* Morton, *Aporrhais* sp. ?, *Cinulia* sp., *Dentalium* cf. *gracile* Hall and Meek, *Eutrephoceras dekayi* (Morton), *Baculites compressus* Say, *Baculites ovatus* Say, *Scaphites nodosus* var. *quadrangularis* Meek and Hayden, *Scaphities nodosus* var. *brevis* Meek, *Heteroceras* cf. *tortum* Meek and Hayden, and fragments of a small crustacean. The occurrence of most of these as well as of a few other species was observed by Tyrrell. A similar group of fossils has been obtained from near the top of the beds on Souris river near Wawanesa.

The thickness of the Riding Mountain beds in the vicinity of Vermilion river and Edwards creek may be estimated at about 200 feet, but it undoubtedly increases westwards, for the beds can be observed on the slopes of Assiniboine valley at Millwood through a vertical range of at least 350 feet. In Pembina Mountain area the thickness is greatly reduced and has been estimated by MacLean at a maximum of 80 feet.

ODANAH BEDS

The name Odanah series was proposed by Tyrrell for a group of shale beds of distinctive lithological character found by him at Odanah, near Minnedosa, as well as on Riding mountain and in the valley of Assiniboine river to the west and south. MacLean later adopted the term for similar beds seen on the top of Pembina mountain. It is by no means certain that the base of the Odanah represents a precise stratigraphical plane; nevertheless the beds referred to this group are, in the experience of the writer, so consistent in their character and in their occurrence that their recognition as a unit in the Manitoba Pierre seems to be necessary.

The Odanah shale is a relatively hard, brittle rock and is often referred to in the province as "slate." Analyses have shown it to be highly siliceous. When moist the shale is of a dark greenish grey colour, but on drying turns to a light steel or slightly greenish grey and resembles parts of the underlying Riding Mountain beds. Unlike the latter, however, it does not disintegrate in water as can be seen by its abundance as gravel in many of the streams of the Manitoba escarpment. In parts the rock is fissile, but more commonly it is rather compact and breaks into sharp-edged splinters and slabs with a tendency to sub-conchoidal fracture. In natural and artificial cuts it is capable of holding steep or vertical faces, and it is everywhere traversed by numerous joints whose surfaces show black or reddish brown staining by iron oxide. Ironstone nodules occur in bands in the shale and in some exposures compact, ellipsoidal, grey, limestone concretions are found. Thin beds of yellow, bentonitic clay varying up to 4 inches in thickness have been observed in the shale at many localities. The Odanah shale was formerly used at Larivière for the manufacture of dry, pressed brick.

Exposures of Odanah shale are numerous at and near the top of Pembina mountain and Riding mountain. With the exception of the underlying Riding Mountain beds which are uncovered in the deep valleys of Assiniboine, Souris, and Pembina rivers, and of overlying beds in Turtle mountain, the Odanah shale is the only bedrock seen in the southwestern part of Manitoba. Westward extension of this lithological facies beyond Manitoba is not known and no beds definitely referable to it have been seen in Duck or Porcupine mountains. Gravel of a shale of a somewhat similar appearance, but of softer consistency, has been found in stream beds at elevations of between 1,400 and 1,500 feet on the south side of Porcupine mountain, which may indicate the continuation of the facies in that direction, with gradually changing lithology.

The Odanah beds have generally been regarded as unfossiliferous. Although it is true that fossils are comparatively rare, nevertheless they do occur, both in the shale and in the associated concretions. Fossils found in the shale are generally crushed and unsatisfactory for definite identification. Portions of *Baculites* and *Scaphites* have been found at several localities as well as gasteropods and small pelecypods referable to *Anisomyon*, *Yoldia*, and *Pteria*. Impressions left by fragments of fibrous *Inoceramus* shells are rather common and traces of fucoids are found. From grey, calcareous concretions, near Dand, specimens of *Baculites ovatus* Say and embryonic *Baculites* showing the coiled apex of the shell have been obtained, together with *Discoscaphites* cf. *nicolleti* Morton and aptychi of *Scaphites*. *Lucina occidentalis* Morton has been found in concretions 3 miles south of Ninga.

The base of the Odanah shale can be located, approximately, on the east branch of Edwards creek and, more precisely, to the west of Riding mountain between Millwood and Binscarth. It is also seen at a few localities in Pembina Mountain area and is well shown on Souris river, 1 mile south of Wawanesa. At the last of these localities 73 feet of shale is exposed in the almost vertical face of the bank in a big bend in the river. The upper 25 feet are Odanah shale and these are underlain by typical, soft Riding Mountain beds. Here the transition from one to the other appears to be accomplished in a vertical distance of about 10 feet.

The doubtful validity of the base of the Odanah, as a stratigraphical plane, has already been referred to. Levels run on it near Birnie to the east of Riding mountain and near Binscarth to the west show a rise of 220 feet to the west in the 80 miles separating the first and second locations. If the approximate level of the Odanah at Wawanesa be taken into consideration it is found that a general inclination is indicated in a direction slightly to the east of south. Such an attitude, being completely out of agreement with the general southwesterly dip of the Cretaceous in Manitoba, can hardly be interpreted as evidence of structure. It seems more probable that the Odanah is merely a special lithological facies bearing replacement-overlap relations to the underlying Riding Mountain beds and that it thins and disappears northwards and westwards, whereas the generally earlier, but partly equivalent, facies of the Riding mountain thickens and passes westwards into the Bearpaw of Saskatchewan. Insufficient data have yet been collected for any final conclusions to be drawn as to the nature, attitude, and relations of the Odanah.

Tyrrell estimated the thickness of Odanah beds present in Riding mountain at 300 feet. From the record of the Deloraine well and the position of the overlying Boissevain sandstone at the base of Turtle mountain he calculated a total thickness of 400 feet of Odanah in that area. These may be allowed to stand as general estimates for the districts mentioned.

PEMBINA MOUNTAIN SECTION

As a result of his studies in Pembina Mountain area in 1914 and 1915 MacLean[1] recognized the following succession in the outcropping Cretaceous.

	Feet
Pierre:	
Odanah beds	250
Millwood beds	50 to 70
Pembina beds	80 to 20
Niobrara:	
Cheval beds	25 to 20
Boyne beds	113
Morden beds	250
Assiniboine limestone	4 to 8
Assiniboine shale	160

The upper part of MacLean's Assiniboine shale and the Assiniboine limestone can be correlated definitely with the portion of the Riding Mountain section lying between the Keld and Vermilion River beds, as has already been explained in the description of that section. In the upper part of the section the beds designated Millwood, by MacLean, agree in lithology with the thicker series of Riding Mountain beds in the north and the Odanah beds likewise agree in both areas. Thus in MacLean's Pembina Mountain section the beds from the bottom of the Morden to the top of the Pembina occupy the same stratigraphical position as the Vermilion River beds. The underlying horizon is well established in both areas, but strictly speaking no more can be claimed for the overlying beds than that they are lithologically the same in both areas and lithologically distinct from the beds of any other part of the Cretaceous in Manitoba. Nevertheless in the absence of better evidence it seems justifiable to correlate, as is done in this report, the Millwood beds of MacLean's section with the Riding Mountain or upper Millwood of the northern section.

The term Cheval seems to be unnecessary and is omitted. Beds included by MacLean under that name have close affinity with the underlying Boyne beds and they are, accordingly, included with these as their upper members. Thus the Pembina Mountain section is as given on a previous page. The middle portion of the section which remains for consideration may be stated, briefly, to consist of two groups of dark, non-calcareous shale (the Morden and Pembina) separated by a group of predominantly calcareous shale (the Boyne).

MORDEN BEDS

The Morden beds consist of dark grey and, in places, almost black carbonaceous shale. These shale beds are non-calcareous and generally fissile, weathering into irregular flakes and drying to a light grey colour. Pyrite occurs commonly and secondary growths of selenite crystals are abundant between the planes of lamination. The rock is practically indistinguishable lithologically from the shales of the Ashville and the Vermilion River beds and is similar to that of the Pembina beds. Included in the shale are numerous septarian concretions, the largest seen in the field having a diameter of 8 feet and consisting of an intergrowth of several ellipsoidal

[1]"Pembina Mountain Area, Southern Manitoba"; MS.

masses. A careful search for fossils has been made in these concretions, but without result. Apart from small, brown, fish scales of the types seen commonly in all of the dark shales in Manitoba, no megascopic organic remains have been found in any of the outcrops.

Small exposures of the Morden beds are numerous near the foot of the Pembina escarpment, especially in the portion lying within township 1, range 5, and larger outcrops occur in Pembina valley near the International Boundary, in the valley of Deadhorse creek to the southwest of Morden, and on the south branch of Morris river at and near Leary where the shale was formerly the basis of a pressed brick industry. They are found again in small exposures on Assiniboine river at the mouth of Cypress river and 1 mile to the west of it. Four miles below the mouth of Cypress river the limestone of the Assiniboine beds is overlain by a few feet of dark, calcareous shale which, like the beds above the limestone on Vermilion and Valley rivers, should probably be included in the Assiniboine beds. This leaves the exposure at the mouth of Cypress river as the lowest definitely known outcrop of the Morden. Mr. Wickenden reports the finding of an identical micro-fauna in the beds at Cypress river and 1½ miles to the southwest of Morden.

The thickness of the Morden cannot be determined by direct measurement as there is no single section showing the whole of the beds, but the estimate given by MacLean at 250 feet seems to the writer to be rather too high to agree with the elevations at which the bottom and top beds appear on Assiniboine river and Morris river, respectively. The thickness may be placed at about 200 feet as a general estimate for the region of the Pembina escarpment.

BOYNE BEDS

The Boyne beds follow the Morden beds without any precisely definable plane of division, but their top can be more exactly placed.

Good exposures of the Boyne beds are found in Pembina valley near the International Boundary and showings continue up that valley in a northwesterly direction at least as far as secs. 4 and 5, tp. 2, range 7, where the bridge between Darlingford and Windygates crosses the valley. Further exposures occur in the valley of Deadhorse creek, 4 miles southwest of Morden, on the south branch of Tobacco creek 4½ miles west of Miami, and on the south branch of Morris river at and near Babcock where certain of the beds were formerly mined and used for the manufacture of natural cement. The most northerly showing, known to the writer, occurs 1½ miles west of Treherne where the road between townships 7 and 8 crosses a ravine cut by the north branch of Morris river.

The thickness of the Boyne beds may be placed at about 140 feet, but as in the case of the Morden beds this is determined by computation and not by direct measurement of any one section. In the lower part of the sections, as seen on Morris river and Pembina river, the base is gradational from the underlying dark shales of the Morden and it is everywhere difficult to define. In so far as they can be observed on Morris river the Boyne beds appear to be entirely composed of speckled, calcareous shales resembling those of the Keld and Assiniboine. In the lower half of the section they are dark, carbonaceous, and fissile and weather to a brownish grey colour, but in the upper half they become less carbonaceous and lighter in colour. It is in this part that the cement beds occur. The upper 30 feet are composed of a very compact rock in alternating bands of light and dark grey; weathering at the top to a light buff coloured material of chalky consistency. In Pembina Valley section the top beds are more completely chalky in character in the upper 30 feet, but between these and the darker calcareous beds at the bottom there is a considerable thickness of dark grey, non-calcareous shale which must be included in the Boyne, although lithologically it is the same as the Morden. At most localities a band of selenite is found at the top of the upper chalky beds where they are overlain by the dark shales of the Pembina.

Fossils found in the Boyne beds include fragments of *Inocerami* and clusters of *Ostrea congesta* Conrad having the steep marginal deflexion of the fixed valve characteristic of that species. Small pelecypods and a small gasteropod, of no diagnostic value, have been collected near the top and a single, crushed specimen of a *Baculites* has been found in Deadhorse creek. Fish vertebræ and large scales of *Ichthyodectes* sp. are of common occurrence.

Mr. Wickenden reports a large micro-fauna from the Boyne beds which he compares, tentatively, with the upper Taylor or Navarro of Texas. It is further of interest that this micro-fauna contains a number of forms identical with those found by him in the calcareous shales of the Vermilion River beds, which are definitely associated with fossils of Pierre age. The writer hesitates, however, to make definite correlation of the Boyne beds with the Vermilion River beds in spite of this and of their apparently similar position in the Manitoba sections. They were first classified by Dawson as Niobrara and their lithology, together with the occurrence in them of typical *Ostrea congesta* Conrad, is in agreement with such a correlation. If they are Niobrara, however, it appears that there must have been extensive fluctuations in the Upper Cretaceous seas of the Manitoba area to account for the profound difference in the stratigraphical succession shown by the section on Riding mountain. Definite correlation of the Boyne and Morden beds must be left to the future discovery of more conclusive evidence.

PEMBINA BEDS

The name Pembina is given to the group of beds found overlying the Boyne in all localities where the top of that group is exposed in Pembina Mountain area.

Exposures are seen in Pembina valley between the International Boundary and a point in that valley to the west of Kaleida. They are also found on the escarpment front in a road cut 8 miles south of Morden, in the valley of the south branch of Tobacco creek 4½ miles west of Miami, and in railway cuts in Morris valley west of Babcock. No exposures of these beds have been found in the region of Tiger hills to the north of Pembina mountain.

The beds consist predominantly of dark, non-calcareous shales interbedded with the lower part of which is a series of relatively thick bands of bentonitic clay. The alternation of the dark, almost black, shale with the white clay gives to the basal part of the beds a conspicuous banded appearance and gains for them the name of the "black and white" beds.

The exposed thickness of Pembina beds is very variable. The longest section is found on the left bank of Pembina river in NW. ¼ sec. 22, and SW. ¼ sec. 27, tp. 1, range 8, just below the Mowbray bridge. Neither the bottom nor the top of the beds is actually exposed, although the character of the lower members suggests that the bottom of the bank is near the base. A total thickness is measured, on two exposed banks at this point, of about 60 feet of shale. In the bottom 11 feet of shale are included at least six conspicuous bands of white clay, the largest of which has a thickness of 8 inches. These clay bands alternate with the black shale in layers of approximately equivalent thickness. The remainder of the section consists of shale, varying between black and chocolate brown; the latter variety being very fissile and containing abundant, small, brown fish scales and other fragments. This material bears close resemblance to the brown shales found in the Ashville on Wilson river and to parts of the Vermilion River beds. Pyrite is found in the shales, and growths of selenite crystals are abundant as is the generally associated yellow, powdery incrustation common to all of the non-calcareous selenite-bearing shales.

MacLean's estimate of 80 feet for the thickness of Pembina beds is retained, but must be regarded as a maximum for the region of the Pembina escarpment in Manitoba. The thickness seen is considerably less at most of the exposures north of Pembina valley. On Tobacco creek, west of Miami, it is only 8 feet, but here the soft, ironstone-bearing clay of the overlying Riding Mountain beds has slumped heavily on the top and it is probable that the whole thickness is not seen. In this section eleven bands of white clay, ranging from ½ inch to 11 inches in thickness, alternate with black and brown shale. In Morris valley, west of Babcock, the greatest thickness of Pembina beds observed is 27 feet. There the shale is largely of the brown, fissile type and the clay bands are rather less conspicuous than in the southern exposures. Again there has been slumping of the overlying Riding Mountain beds.

The top of the Pembina beds appears to pass gradually upwards through a brownish green, soft shale into the overlying beds, although, on account of the common slumping of these higher beds, good sections showing the transition are rare. Such beds, apparently transitional in character between those of the Pembina and Riding Mountain, can be seen in a roadside ditch in SW. ¼ sec. 21, tp. 2, range 6, to the east of which rises a butte composed of typical Riding Mountain shales. The Pembina beds were classified by MacLean as of Pierre age and on account of their affinity with the overlying group may confidently be so retained. Organic remains, apart from fragments of fishes, are lacking.

STRUCTURE

The general attitude of the Cretaceous strata in Manitoba can best be determined by reference to the prominent limestone horizon of the Assiniboine beds. The position of this horizon has been found along the escarpment at various points from Pembina Mountain area as far north as the southern slopes of Porcupine mountain. Throughout this distance of 280 miles it rises consistently northwards, thus showing that the line of the Cretaceous escarpment is not coincident with the strike of the strata.

As the levelled outcrops of the limestone are in almost perfect alinement along the escarpment, sub-surface information from the region to the west of the line of outcrop is necessary for computation of strike and dip. For this purpose the record of the Deloraine well alone is satisfactory. On the assumption that the limestone is represented in the Deloraine well by the top of a band of grey, calcareous shale, 185 feet in thickness, calculations have been made to include various combinations of the known levels of the same horizon to the east and north. These give generally concordant results, the strike, as computed, varying between north 42 degrees west and north 48 degrees west and the dip, towards the southwest, between 9·3 and 8·8 feet a mile. Based as these figures are on a single western location they cannot be regarded as entirely satisfactory; but until further data are obtained they may be taken as a general indication of the attitude of the Cretaceous beds.

As reliable key horizons have not yet been detected in the higher (Pierre) part of the section, calculations of strike and dip cannot be made for these upper beds. Some variation in the amount of the dip is to be expected, however, as the Deloraine well record indicates a marked expansion of the total Cretaceous section westwards from the escarpment; the increase in thickness being mainly above the assumed position of the Assiniboine beds. It has already been shown that measurements on the base of the Odanah give anomalous results for strike and dip, which are not considered reliable.

In the sections measured along the streams of the escarpment the general absence of any disturbance of the practically horizontal stratification is striking, but there is evidence of slight warping of the bedding planes at some points. A rise and fall in marker bands of the Ashville, Keld, and Assiniboine beds can be detected on measuring the sections in sequence along Ochre river, Vermilion river, and Wilson river, but in no case does this amount to more than a few feet. The structures indicated are very minor ones and might well be accounted for by slightly uneven settling of the sediments beneath.

In only one locality is a structure of any significance clearly indicated; namely at Thunder hill in Swan River valley. Thunder hill lies on the boundary between Manitoba and Saskatchewan and mainly to the north of the 52nd parallel. It stands as an isolated prominence in the valley, distinct and widely separated from Porcupine mountain to the north and from Duck mountain to the south. In plan the hill is roughly rectangular with a length of about 9 miles and a width of over 3 miles; its long axis running in a northeast-southwest direction or parallel to the general trend of Swan River valley. The summit, near the northeastern end, rises to over 400 feet above the floor of the valley. On the northwest, northeast, and southeast it is bounded by steep slopes, but towards the southwest it merges in a gentler slope into the rising floor of the valley.

Rock exposures are rare on the hill as it is largely drift covered and well wooded, except where cleared for cultivation. The best exposures seen are in ravines on the north face, in or about sec. 23, tp. 35, range 30, where horizontal shale beds can be seen through a vertical distance of about 40 feet. At the base occurs non-calcareous shale which is followed by speckled calcareous shale with limy bands bearing *Inoceramus labiatus*

Schlotheim at the top. The beds seen clearly belong to the Ashville and Keld. A further showing of flat-lying, calcareous shales was found in a new well in sec. 24, tp. 35, range 30. On the south slope of the hill, in NE. ¼ sec. 13, tp. 35, range 30, there are again showings of the Keld beds in scarped banks. There they have a steep but irregular inclination in the general direction of the slope. This is not convincing as evidence of dip, however, as the rock may be in a slide. No exposures of higher beds than the Keld have been seen by the writer, but numerous fragments of typical Assiniboine limestone were picked up and may safely be taken as evidence of the existence of these higher beds in place on the hill. Spencer[1], in 1874, observed the occurrence of fossiliferous shales on Thunder hill, and Dowling[2] apparently saw the limestone and higher beds, probably up to and including the base of the Vermilion River beds.

The outcrops of these recognized horizons on Thunder hill are at elevations of around 1,700 feet. The same stratigraphical horizons in other parts of Swan River valley to the south, east, and north of Thunder hill are at decidedly lower levels. On the south side of Porcupine mountain, in the valleys of Birch, Kematch, Bowsman, and Woody rivers, the Assiniboine beds lie on or near the 1,300-foot level. These exposures all lie to the north and east of Thunder hill. On the east branch of Favel river, 24 miles due east of Thunder hill, the limestone has been accurately determined at an elevation of 1,321 feet and the same bed appears at about 1,300 feet on Swan river, 3 miles from the base of the hill on the south side. At this locality, on the right bank of the river, in NE. ¼ sec. 31, tp. 34, range 29, the limestone is sharply flexed in an asymmetrical anticline about 10 feet in height. The rock is partly brecciated in the vertical limb of the fold and its fissures are filled with crystalline calcite. In itself this structure is a very minor one, but it is of interest as giving some evidence of disturbance of the beds in the near vicinity of Thunder hill. To the west of this small fold the limestone disappears and flat-lying Vermilion River beds occupy the low banks, but it reappears within ½ mile, thus showing a slight local reversal of the general regional dip.

Tyrrell[3] recognized the anomaly of the occurrence of calcareous ("Niobrara") beds in Thunder hill at elevations higher than were to be expected from the general attitude of the Cretaceous. He suggested two theories by way of explanation; that there might be a great increase in thickness of the Cretaceous sediments in Swan River valley or that the horizons seen on the hill might belong to the Pierre. Measurements on Favel river and on Roaring river show that there is no such increase in the thickness of the beds as postulated in his first proposal and, now that the exposures in the surrounding country are better known and that the sequence and character of the beds have been determined, it is not possible to uphold the second suggestion. The conclusion is reached that Thunder hill contains a structure in which the strata are raised some 300 to 400 feet above their level in the surrounding district.

Data are not yet sufficient to make precise definition of the nature of the Thunder Hill structure possible, but the apparently flat attitude of the beds near the summit, together with the steep flanks and almost

[1]Geol. Surv., Canada, Rept. of Prog. 1874-75, p. 64 (1876).
[2]Geol. Surv., Canada, Ann. Rept., vol. V, pt. E, p. 108.
[3]Geol. Surv., Canada, Ann. Rept., vol. V, pt. E, pp. 108-109, 212.

level top of the hill (as seen from the east), is suggestive rather of a structure bounded by faults or monoclinal folds than of an anticlinal arch. The beds within the hill are presumed to dip towards the southwest. There is evidence of a continuation of the structure on Swan river, 3 miles north of Pelly or 16 miles to the southwest of the main part of Thunder hill. From NW. ¼ sec. 1, to SW. ¼ sec. 10, tp. 34, range 32, a few small showings, mainly of dark, non-calcareous and gypseous shale, occur in the river banks, along with a small amount of calcareous shale. The showings are poor and the relations of the beds obscure, but they are believed to be in place and they probably belong to an horizon near the base of the Vermilion River beds. These exposures lie directly in the line of the axis of Thunder hill. Within a few miles of them and at similar elevation both to the southeast and northwest, higher beds of typical Riding Mountain lithology form the country rock.

As the Thunder Hill structure is in every way exceptional in the visible Cretaceous rocks of the escarpment it presents a difficult and, up to the present, unsolved problem. It appears to be necessary to postulate a direct and very much localized uplift, but the cause of such uplift can only be guessed at. Small dome structures have been recorded in the Devonian rocks to the east of Porcupine and Duck mountains and it is possible that there may be a connexion between the two phenomena. One theory of the Devonian domes is that they may be due to underlying deposits of gypsum or salt; but this has not been substantiated. At any rate it is doubtful if the expansion of even a very large gypsum deposit could, on passing from anhydrite, exert sufficient pressure to lift such a large covering mass of rock as that in Thunder hill.

At Minitonas hill, another more or less isolated prominence in Swan River valley 20 miles to the east of Thunder hill, there is also some reason to suspect structure. Exposures of Ashville beds to the southwest of it on Roaring river show quite marked variations in dip, all of which cannot be accounted for by sliding of the banks, whereas on the west branch of Favel river, immediately to the east of the hill, the Ashville and Keld beds give undoubted evidence of minor faulting. No rock exposures have been found on the hill itself, but the somewhat disturbed attitude of the strata near it suggests the possible existence here of a structure similar to that of Thunder hill.

ECONOMIC GEOLOGY

The Cretaceous formations described in this report have some economic interest as raw materials for brick, tile, and cement manufacture and as a possible source of oil and gas. Apart from these aspects little of potential commercial importance has yet come to light. The small amount of lignite present in the Dakota sandstone is of no economic significance and reports of the finding of coal within the shales appear to be based on occasional fragments of lignified drift wood or on the mistaking of darker beds in the shale for coal. The phosphatic band reported on Wilson river is too thin to be of commercial value, but it is possible that similar material may exist elsewhere in greater quantities, although so far none has been found.

At the present time none of the Cretaceous shales is in use for the manufacture of brick and tile, but in the past the Morden and Odanah beds of southern Manitoba have been used for this purpose. It is possible that more satisfactory means of using these materials may be found and their use revived. The available supply is practically unlimited.

Reference has already been made to refractory clay in the Dakota on Swan river, between secs. 5 and 8, tp. 37, range 26. This material is present in considerable quantity and the fact that it is associated with a deposit of good sand may prove to be of value.

The calcareous shales of the Boyne were formerly the basis of a natural cement industry, but there has been no production from them for several years.

In recent years considerable interest has been shown in the oil and gas possibilities of the Manitoba Cretaceous. The shales from the Ashville up to and including Vermilion River and Pembina beds are known to be more or less petroliferous. Yields of oil given by samples are generally low, however, the highest figure given by Ells[1] for shale in Manitoba being 7·5 gallons a ton, Wallace[2] quotes the oil content of the shale above the Assiniboine limestone near Treherne at 8 to 10 gallons a ton. Under present economic conditions these yields are too low to give any direct commercial value to the oil-shales.

A good deal of drilling for oil has been done, but without any favourable result up to the present time. The general absence of major structures in the known part of the Cretaceous area and the presence of only one horizon (the Dakota) which might be expected to serve as a porous container are unfavourable to the general prospect of oil production. At some localities small flows of natural gas have been struck in shallow wells and in most of these cases the gas is in domestic use by the well owners. These occurrences are mostly in the southern part of Manitoba, at and near Waskada, Hartney, and Treherne, but a gas well of similar nature is reported from the neighbourhood of Gilbert Plains to the north of Riding mountain. In all of these cases it appears that the flow of gas is obtained directly from shale beds.

Until more is known about the Thunder Hill structure it would be unwise to attempt to evaluate its possible economic significance. It should be pointed out, however, that it is very doubtful whether a sufficient, effective capping exists there to make the structure a possible oil and gas container.

With increase in detailed knowledge of the Cretaceous stratigraphy and the co-operation of well drillers it should be possible in the future to determine the presence or absence of structure with greater certainty than can yet be done and thus to evaluate more precisely the oil and gas possibilities.

---

[1] "Cretaceous Shales of Manitoba and Saskatchewan, as a Possible Source of Crude Petroleum"; Mines Branch, Sum. Rept. 1921, pp. 34–41.

[2] "Oil and Gas in Manitoba"; Ind. Devel. Board, Man., Rept. No. 8 (1926).

GOLD, COPPER-NICKEL, AND TIN DEPOSITS OF SOUTHEAST MANITOBA

By J. F. Wright

CONTENTS

Illustrations

INTRODUCTION

In southeast Manitoba during the summer of 1929, nine mineral deposits were being explored by diamond drilling or underground work, and a dozen or more were being investigated by preliminary surface work. Of these mining developments, the most extensive is that of Central Manitoba Mines, Limited, on the Kitchener gold vein north of Long Lake, where the production of gold during 1928 was $409,595 and during 1929 $450,865. In Beresford-Rice Lakes gold area, underground work had reached the 500-foot level on the Gem lake and the 725-foot level on the San Antonio deposits, respectively, 15 miles southeast and 17 miles northwest of central Manitoba. Three copper-nickel sulphide bodies of Oiseau area and one in Maskwa area were being diamond drilled, and surface prospecting was fairly widespread in these areas. In the autumn of 1928, Manitoba Tin Company and Jack Nutt Mines were organized to commence exploration of the tin-bearing pegmatites in the vicinity of Shatford and Bernic lakes, Oiseau area. In June, 1929, two tin-bearing pegmatite bodies were being explored underground, and eight other pegmatite bodies were being opened by surface trenching. No work was being done on the lithium-bearing pegmatites of this area.

A part of the summer of 1929 was spent studying in detail the geology of the gold, copper-nickel, and tin deposits mentioned above, and in this work the writer was ably assisted by Messrs. J. A. Syme, F. D. Shepherd, and O. R. Shuttleworth. Thanks are due Messrs. C. B. Emery, Jackson Bull, P. E. Billinghurst, Harry Donaldson, I. M. Marshall, D. F. Kennedy, and P. F. Osler for information regarding the respective properties under their supervision and for other courtesies extended the party.

The mineral deposits and prospecting areas of southeast Manitoba are all within 50 miles of the end of steel, consequently they are easily reached in winter by sleigh, from Great Falls or Lac du Bonnet, and in summer by hydroplane from Lac du Bonnet. All heavy supplies and equipment for the year must be taken to the properties during the winter months by sleigh over the frozen lakes and muskegs. In summer, San Antonio can be reached, travelling light, in a day, by motor boat and motor road from Riverton, and central Manitoba in 1½ days following the same route. Gem Lake deposit is rather inaccessible in summer, and can best be reached by canoe from Lac du Bonnet, the trip taking 1½ days without a heavy load. Maskwa and Oiseau areas are easily reached by canoe in one day from Lac du Bonnet and Pine Falls, respectively, at the end of steel on Winnipeg river. The tin prospects can be reached in a day from either Pointe du Bois or Lac du Bonnet and Oiseau river.

CENTRAL MANITOBA, SAN ANTONIO, AND GEM LAKE GOLD DEPOSITS OF BERESFORD-RICE LAKES AREA

GENERAL GEOLOGY

Central Manitoba, San Antonio, and Gem lake are the most important of the known gold deposits within the prospecting belt extending from near mileage 90 on the Manitoba-Ontario boundary northwest 60 miles and varying from 1 mile to 15 miles in width. This gold district is known as the Beresford-Rice Lakes-English Brook district. The outline of the favourable prospecting ground is that of the areas of volcanic and sedimentary strata, the large areas of granitic rocks are, so far as is known, barren of commercial gold or other mineral deposits. The bedrock is Precambrian, and the formations known in the district may be grouped as follows from youngest to oldest.

	Diabase
	Gold-bearing quartz
	Pegmatite
	Granite and granite-gneiss
	Granite porphyry
	Granodiorite and granite
	Gabbro and diorite
Rice Lake series.....	Wanipigow phase: coarse-grained quartzose sediments (quartzite arkose)
	Beresford phase: lavas (rhyolite, dacite, andesite, basalt and derived chlorite, carbonate, and sericite schists)—and interbedded chert, tuff, and other pyroclasts, iron formation, and greywacke
	Manigotagan phase: fine-grained quartzose sediments and derived quartz-mica and quartz-garnet gneiss and schist.

The members of the Rice Lake series are metamorphosed, some beds being so highly altered that the original character of the rock cannot be recognized. Although many of the rocks of the Beresford volcanic phase appear massive and unaltered in outcrop, a microscopic study of thin sections shows that over wide areas the minerals of these fresh-appearing rocks are altered to secondary products. Amongst the outcrops of this series are many of massive-appearing, black to green rock, thin sections of which show only an aggregate of saussurite, uralite, hornblende, actinolite, chlorite, carbonate, magnetite, and leucoxene. The structural relations of many occurrences of these rocks could not be determined, and they may be thick flows, or dykes or sills injected during the period of vulcanism, or later basic intrusives. The highly altered character suggests that these rocks perhaps belong to the volcanic series, for the minerals of the younger basic intrusives are fresh or only slightly altered. Many of the gold-bearing quartz veins are adjacent to bodies of these altered basic rocks.

The detailed structure of the Rice Lake series is unknown. It is believed that the strata form the south limb of a large synclinal fold. Where bedding is recognizable, the dip is steep to the north. The dip of the schistosity, secondary cleavage, and axial planes of the drag-folds also is uniformly to the north. The massive thick beds of quartzose sediments of both the Wanipigow and Manigotagan phases show a uniform strike and dip over wide areas, and their bedding and secondary structures are parallel. Intervening beds of less competent formations, as slate, chert, tuff, greywacke, and iron formation, are highly crumpled, consequently in these horizons there is no definite relation of the bedding to the secondary structures, except that in many exposures cleavage is parallel the axial planes of the drag-folds, which dip steeply north and plunge northwesterly. The top of the beds is recognizable only at a few horizons, and in a comparatively flat country it is difficult to know the actual dip of the drag-folded horizons. For these reasons the rocks locally may be complexly folded, even though the secondary structures dip uniformly to the north. The data available, however, suggest that over considerable areas the structure is simple, but that perhaps locally there is some close folding, the nature of which is unknown.

GENERAL CHARACTER OF GOLD DEPOSITS

The majority of the gold-bearing quartz bodies are within members of the Beresford phase of the Rice Lake series. The quartz is along shear zones within the volcanic rocks and forms lenticular, vein-like bodies and many lenses and stringers irregularly scattered throughout the schistose and jointed rock. At many localities conditions were unfavourable for the deposition of large quartz bodies; the most favourable conditions appear to have been along zones wherein the rock is highly jointed or brecciated, and only slightly sheared. Included bits of schist and more massive wall-rock are abundant in some of the gold-bearing quartz. It would seem that the quartz bodies formed by deposition along joint-planes and by replacement of the schistose rock as the quartz only locally shows a banded character to suggest cavity filling. The location of the shear zones is controlled by lines of weakness, as many of the quartz bodies are in shear zone developed along the contact of lava flows, the contact between a lava flow and a chert or tuff bed, the contact of a gabbro dyke and lava flow, or within thin flows of fine-grained lava adjacent to masses of medium-grained, basaltic lava. So far as can be determined, there is little evidence of marked displacement along any particular plane within a shear zone, the deformation apparently being of the nature of a jointing and granulation of the rocks within a number of parallel, lenticular areas along a belt several miles in length and several hundred feet in width.

The gold deposits of the whole prospecting area are similar in their general geological features, although in details individual deposits naturally vary considerably. The gold is both free and contained in the sulphides, especially chalcopyrite. Gold tellurides were recognized only locally. Some of the free gold is in flakes or films coating joint-planes, whereas considerable is in specks or grains within apparently unfractured quartz. Of the sulphides, pyrite and chalcopyrite are the most widespread and abundant, pyrrhotite, arsenopyrite, tetrahedrite, galena, sphalerite, and molybdenite are present sparingly in a few quartz bodies. Specularite and tourmaline are also present at one or two localities. Shreds of chlorite and of white sericitic mica are abundant along joint-planes in some quartz. The carbonates, calcite, siderite, ankerite, and dolomite are present both in the quartz and in the schistose rock adjacent to some quartz lenses. Large bodies of the basaltic wall-rock at the San Antonio are in part altered and replaced by quartz, albite, calcite, ankerite, and pyrite crystals. Pyrite is also very abundant and shows excellent crystal form in the schistose rock adjacent to many quartz bodies.

On the basis of colour, mineral content, and texture, the quartz bodies of the area may be divided into the three following types: (1) large, dyke-like or roughly circular bodies of white to grey pegmatitic-appearing quartz, carrying abundant crystals of white feldspar and in some cases pink feldspar and muscovite. A few of these bodies contain grains of pyrite and chalcopyrite, and small patches of ankerite. A number of such quartz bodies have already been opened up, but they have not averaged over a trace in gold. The pegmatitic quartz bodies are not considered to be worth investigating as gold prospects, although in the future they might be valuable as a source of silica. (2) Fairly large, lenticular bodies of fine to medium, evenly granular, white quartz. This quartz contains considerable calcite and ankerite, also shreds of white mica. Sulphides are generally scarce, and free gold is present in small bits erratically distributed throughout the mass. Much of the quartz of this type is barren and, in consequence of the erratic distribution of the gold, the average gold content of any body is disappointingly low, although very high assays can be easily secured by selective sampling. (3) Bodies of smoky, dark-grey to nearly black, greasy-appearing quartz, consisting of intermixed areas of, respectively, large and small quartz grains and without, or only small quantities of, feldspar, mica, or carbonate minerals. Quartz of this type is crossed by numerous small cracks and joints of irregular orientation. Some specimens of dark quartz are crossed by seams of white quartz. Grains, veinlets, and irregular-shaped patches of pyrite and chalcopyrite are erratically distributed throughout bodies of quartz of this type. Most of the gold ore of the district is this dark, highly fractured quartz. However, a few bodies of dark quartz, apparently identical with the gold-bearing quartz, are barren or carry only a trace of gold. The cause of the dark colour of quartz is discussed in considerable detail by Edward F. Holden[1], and it is suggested by that author that "smoky quartz owes its colour to atoms of silicon, formed by the disintegration of silica, through the action of radium radiations". In this field the dark coloration of the quartz is regarded as a favourable feature. Thus, there may be some connexion between the gold content and the presence of radioactive substances in the quartz.

CENTRAL MANITOBA DEPOSIT

History

The more important gold-bearing veins comprising the property controlled by Central Manitoba Mines, Limited, are on the Growler, Kitchener, Tene, Tene 6, and Hope mineral claims in the northern part of township 22, range 16, east of the principal meridian, and about 3 miles northeast of the east end of Long lake. The vein on the Kitchener was discovered in 1915, but little work was done on it until the autumn of 1924, when the WA D Syndicate commenced work in this area. The first surface work in this vicinity done by this company was on the Hope vein just south of Wentworth lake. In 1925 the Kitchener, Eclipse, Tene, and Growler veins, located from ½ to 1¼ miles west of the Hope, were explored, and in 1926 the Tene 6 and Roger veins, about midway between the Kitchener and Hope, were prospected. In 1925 Central Manitoba Mines, Limited, capitalized at 4,500,000 shares of $1 par value, was incorporated to continue the development of this group of quartz veins. John Taylor and Sons, of London, England, took over a controlling interest in the company. By the end of 1926, the Kitchener vein had been explored to the 375-foot level, and at this horizon the ore-shoot was 550 feet long. At the end of 1926, ore of a gross value of approximately $1,100,000 was developed. In 1927, a 150-ton unit of cyanidation mill was built, and at the end of 1929 considerable of the Kitchener ore-shoot had been milled, and over $1,000,000 in gold has been produced. The Kitchener vein has been explored to the 520-foot level, but the gold content below the 375-foot level is erratic, and on the average low. The Tene 6 vein has been explored to the 320-foot level, and the Roger vein to the 175-foot level. In all some fifty diamond drill holes have been drilled to depths varying from 125 to 1,000 feet below the surface, to explore the continuation of the veins and rock structures at depth. Drilling to the 1,200 and 1,600-foot horizons on the Kitchener vein is now in progress. The results of the exploration work of the past year have been disappointing in locating new ore.

General Geology

The bedrock exposed on the south side of the mineral claims is andesite and basalt with thin chert and tuff beds (Figure 3) belonging to the Beresford phase of the Rice Lake series. The volcanic rocks are followed to the north by a body of medium-grained gabbro and diabase, apparently intrusive into the lavas. Andesitic lava, showing pillow structure, outcrops north of the gabbro body, which varies from 400 to 850 feet in width.

[1]Am. Min., vol. 10, pp. 203-50 (1925).

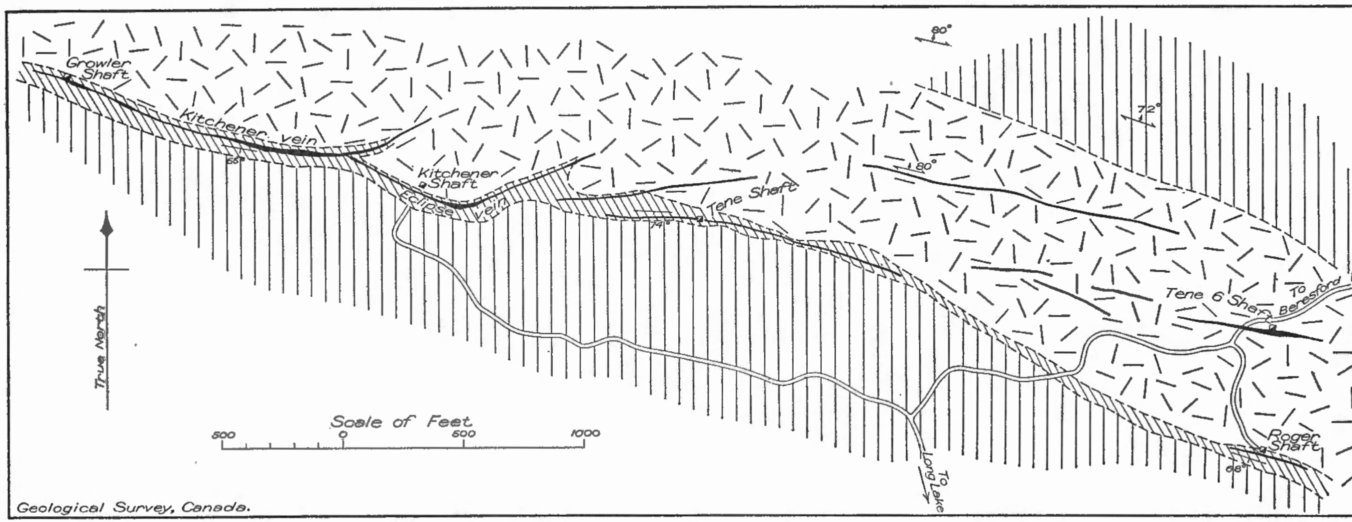

Figure 3. Plan showing geological relationships of the Kitchener, Eclipse, Tene, and other veins, Central Manitoba Mines, Limited, Beresford-Rice Lakes area, Manitoba. Quartz veins and shear zones shown by solid black; andesite and basalt by vertical ruling; chert and tuff by diagonal ruling; gabbro and diabase by irregular pecked pattern.

Small dykes of granite porphyry cut the gabbro, andesite, chert, and tuff. Bodies of the granite porphyry are exposed along the workings on the 375-foot level of the Eclipse vein (Figures 4 and 5) and in the chert along the 520-foot level of the Kitchener vein. The Growler, Kitchener, Eclipse, and Tene veins are within the chert adjacent to the south margin of the gabbro and diabase (Figure 3). The Tene 6 and Hope deposits are within the gabbro-basalt-diabase mass.

The gabbro-diabase typically is a massive-appearing, medium-grained, black rock. Locally, slightly porphyritic phases are developed and other large outcrops have the appearance typical of diabase. Some outcrops show a mottled appearance, due to large, rounded hornblende crystals in a fine-grained feldspathic and chloritic groundmass. Other outcrops show large crystals of greyish feldspar surrounded by hornblende and chlorite. The proportion of dark to light minerals varies within short distances, and some specimens contain quartz. In thin section under the microscope, the minerals are slightly altered to secondary products. The mass varies in mineralogical composition from quartz diorite to gabbro, the various types being intermixed, the abundant type being a hornblende gabbro. What appear to be small inclusions of andesite and chert are present in the gabbro along its contact, and underground, along the Kitchener and Eclipse veins, a crush-breccia of chert is cemented with the gabbro. In most places the gabbro-chert contact is sharp and the gabbro, through a foot or more away from the contact, changes gradually from a dense rock at the contact to a phase of medium grain. At a few places the margin of the gabbro over a breadth of a few feet is slightly porphyritic. At other places a zone from 2 inches to 10 inches in width is developed wherein veinlets of gabbro and beds of chert alternate. A few of these gabbro veinlets cut across the chert layers and a number of small apophyses from the gabbro mass penetrate 2 or 3 inches into beds of laminated chert.

The chert bed containing the quartz veins varies in thickness from 20 to 100 feet and it was traced fairly continuously along the gabbro contact for 6,400 feet and possibly extends another 3,000 feet, although 2,000 feet of this distance is drift covered. The chert is a very fine-grained, greenish grey, white, and black laminated rock, and interlayered with it are grey, massive, siliceous rocks composed of fragments of quartz, feldspar, and felsitic rock. This coarser material perhaps represents slightly water-sorted volcanic ash. Some beds of the chert are complexly folded and brecciated and the Kitchener and Eclipse veins are along a folded and brecciated zone of chert (Figures 3 and 4). A few small, discontinuous dykes of granite porphyry were recognized within the chert (Figures 4 and 5). These granite porphyries are grey rocks with rectangular-shaped feldspar phenocrysts in a dense groundmass. They show a narrow, chilled margin against the chert and this feature distinguishes in the outcrop the granite porphyries from the tuff beds. The granite porphyry dykes cut the gabbro, but they are cut by the quartz veins. The only rock noted cutting the quartz veins is a small, discontinuous, black, diabasic dyke cutting across gabbro, chert, and the Kitchener vein west of the main shaft.

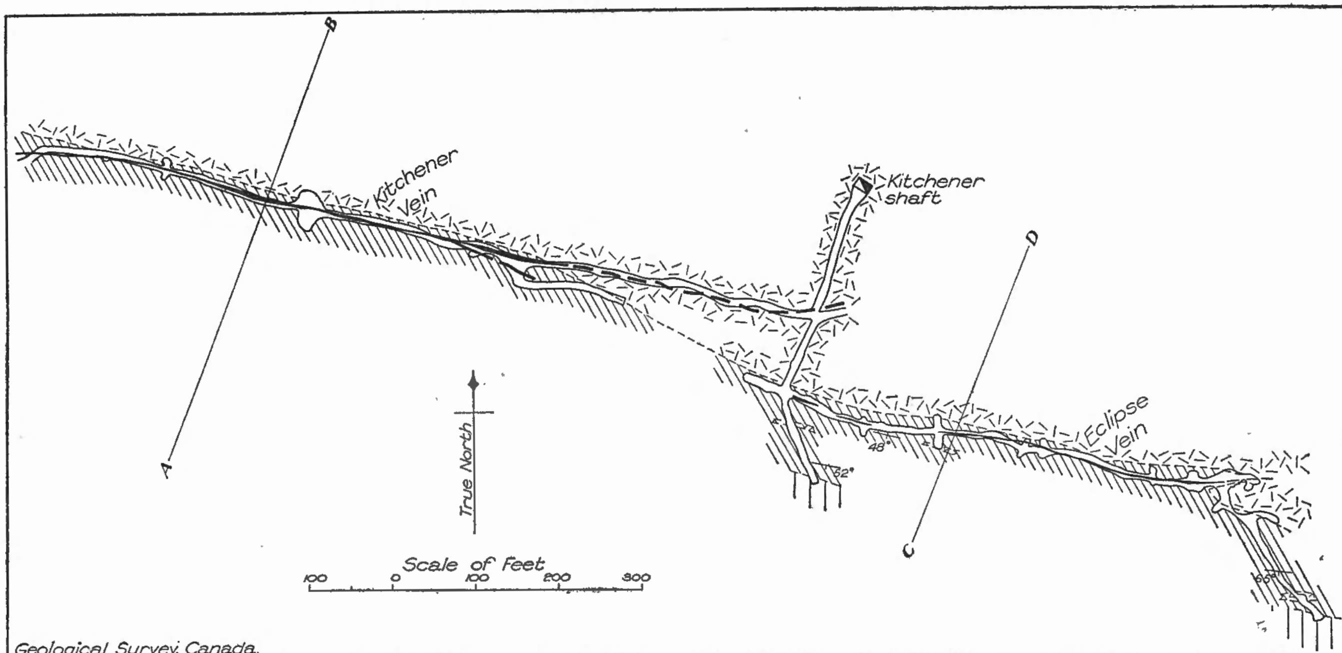

Figure 4. Plan of part of 375-foot level, Central Manitoba Mines, Limited, Beresford-Rice Lakes area, Manitoba. Quartz veins shown by solid black; andesite by vertical ruling; chert and tuff by diagonal ruling; gabbro and diabase by irregular, pecked pattern; granite porphyry by angle pattern. (For cross-sections along lines AB, CD, *See* Figure 5.)

Structural Geology

South of the Central Manitoba veins, the strike of the schistosity of the lavas and sediments is from south 74 to 81 degrees east and the dip steeply north. An examination of the surface outcrops of the chert bed south of the gabbro body suggests that the bedding of this horizon is also parallel to the schistosity and, therefore, dips north, but underground work indicates that the dip of the chert-gabbro contact along the Kitchener vein (Figure 5) varies from vertical to 40 degrees south, the average dip being 62 degrees south above the 400-foot level and about 40 degrees south from the 400 to 520-foot levels. The regional dip of members of the Rice Lake series north of the east end of Long lake is north. It is impossible, however, to determine the top or bottom of the beds adjacent to the veins, hence it is not known whether a synclinal fold is here developed or the beds are locally overturned. Very careful field work failed to locate outcrops of a chert bed similar to the one wherein the veins are developed, either north or south of the veins, and this suggests that the southward dip is perhaps due to local overturning of the strata rather than close folding. The possibility of the body of southward dipping chert andesite strata being faulted to their present position must also be considered, although no evidence of extensive faulting can be found from a study of the rock exposures south of the quartz veins. West of the Growler mineral claim the gabbro-diabase body ends abruptly, and a belt of highly schistose rock, trending approximately north 50 degrees west, outcrops along the west side of a small depression between the andesite on the west and gabbro on the east. Projected eastward, this belt of schistose rock would pass under a long, swampy depression extending south of east to Dove lake, and about 2,000 feet south of the Kitchener vein. Diamond drill holes at 60 degrees and pointed a little west of north from the north edge of this depression south of the middle of the Kitchener vein intersected and followed a zone of carbonate schist, which may represent a fault zone. The numerous swamps and the absence of definite structural features of the rocks exposed make the determination of the underground structure difficult from surface studies, and the deep drilling already completed has not been extensive enough to correlate the structures intersected.

The gold-bearing quartz veins on the Central Manitoba property are located along what appears to be a zone of fracturing varying in width from 25 to 250 feet and over 2 miles in length. Within this main belt of deformation, there are a number of smaller zones wherein the rocks have been sheared and brecciated and in a few of these lenticular shear zones gold-bearing veins have developed. The shear zones and gold-bearing quartz veins are roughly arranged *en echelon* along a strike of from south 75 to 85 degrees east (*See* Figure 3). At the west end of the property and on the Growler mineral claim the dip of the shear zones is nearly 60 degrees south, in the central area on the Tene 6 the dip is steeply north or vertical, and on the Hope at the east end the dips are also from vertical to 75 degrees south. The quartz veins on the Growler, Kitchener, and Tene mineral claims, at the west end of the zone of fracturing, are within the chert adjacent to the gabbro and eastward pass into the gabbro (Figure 3). The underground workings along the Kitchener and Eclipse veins show

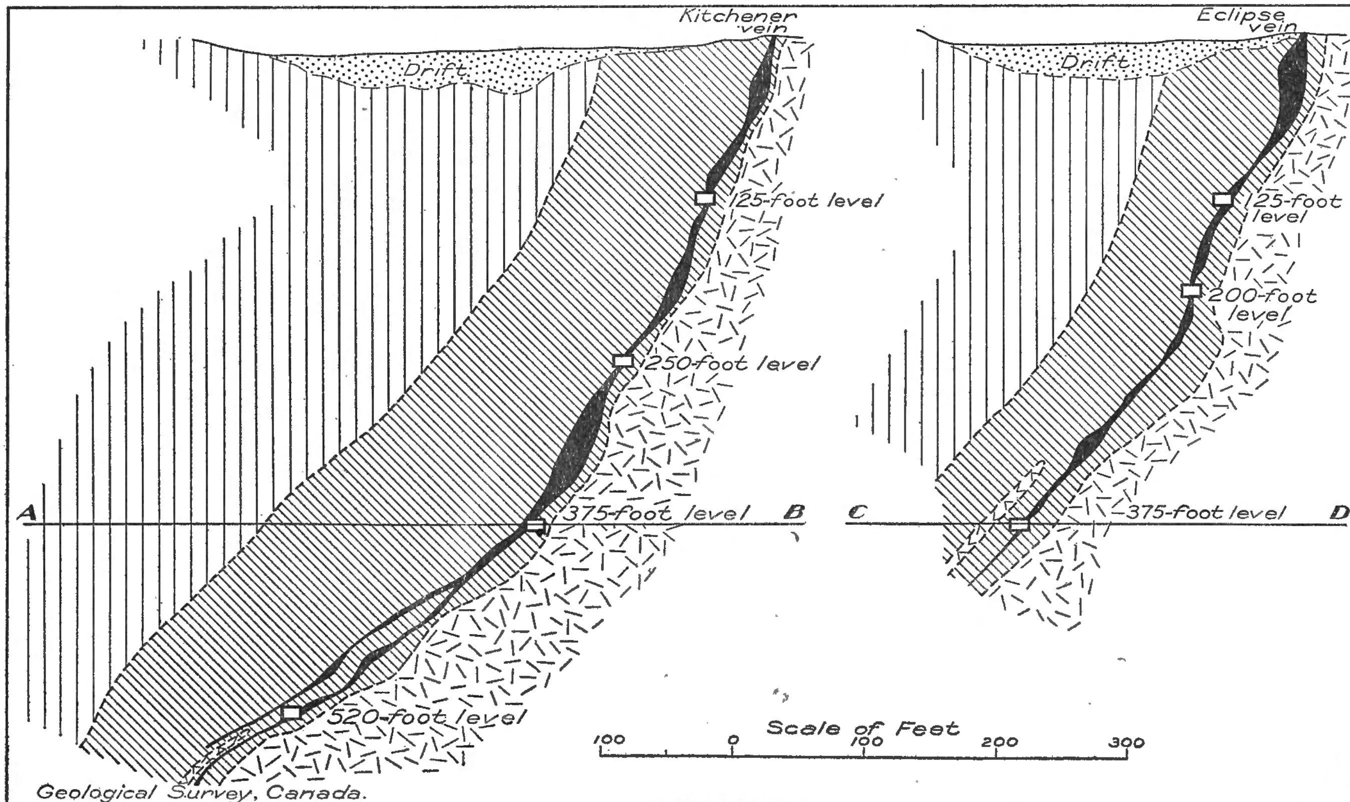

Figure 5. Vertical cross-sections along lines AB and CD of Figure 4, Kitchener and Eclipse veins, Central Manitoba Mines, Limited, Beresford-Rice Lakes area, Manitoba. Quartz veins shown by solid black; andesite by vertical ruling; chert and tuff by diagonal ruling; gabbro and diabase by irregular, pecked line pattern; granite porphyry by angle pattern.

this relationship excellently (Figure 4). Just west of the Kitchener shaft, the gabbro contact swings slightly south, and at this point the shear zone and quartz veins leave the chert and continue within the gabbro. On the 125-foot level a band of chert varying from 1 to 5 feet in width also continues within the gabbro 50 feet or more along the shear zone, and this tongue of chert is interpreted as a layer spread apart from the chert bed and included within the magma that consolidated to form the gabbro body. Just east of where the Kitchener vein enters the gabbro, the Eclipse vein commences within the chert adjacent to the gabbro. To the east this vein also enters the gabbro. Both the Kitchener and Eclipse veins are not gold-bearing within the gabbro. The chert bed is drag-folded and highly jointed west of the points where the shear zone and vein enter the gabbro, and the largest bodies and best grade of ore are located within the bays along the gabbro body. The drag-folding and jointing of the chert are the result of a slight movement of the south or hanging-wall side east and upward relative to the north or foot-wall side of the vein. A succession of shear zones are developed along the gabbro-chert contact eastward to the east side of the Tene mineral claim, where the gabbro contact swings south and the main fracture zone continues within the gabbro (Figure 3). The Tene 6 and Hope veins are along this main zone within the gabbro. To the east the main fracture zone gradually crosses the gabbro body, and east of the Hope mineral claim the andesite along the north side of the gabbro is intensively sheared across widths of from 10 to 60 feet. The shear zones at the east end of the main fracture belt are larger and the rocks are more highly schistose than at the west end. In the highly schistose zones, the quartz is in small, lenticular bodies. The quartz at the west end of the main fracture zone is a dark, smoky variety, whereas in the Hope and to the east the quartz is a white, sugary-appearing variety.

Description of the Deposit

Both the Kitchener and Eclipse quartz bodies are of variable width and length on the levels explored, and the character of the deposit varies considerably from point to point along the same level. In places, the whole width of the drift is in quartz, whereas in many other sections considerable chert is present in the quartz as long bands and angular fragments. On the 375-foot level the Kitchener quartz body is fairly continuous for 1,320 feet, but of this length only 550 feet was commercial ore. The average width of the ore lenses is about 4 feet, with some sections narrower and others, especially where drag-folds are extensively developed, are 20 feet or over in width. On the 250-foot level the average gold content was valued at $11.45 for a length of 900 feet and an average width of 5·1 feet. The quartz is the dark variety showing many joints and other small, discontinuous cracks. No free gold was seen in the quartz, nor has free gold been found in the few thin sections of the ore examined microscopically. Some chalcopyrite and locally considerable pyrite are present in the quartz, also a little pyrrhotite. The results of the metallurgical tests show that most of the gold is free and in very small particles, only a very small proportion of the gold being associated with the sulphides. An analysis of an average sample of the Kitchener ore is as follows:[1] gold, 0·78 ounce

[1]Godard, J. S.: "Experimental Tests of Gold Ore from the Kitchener Mine, East Central Manitoba"; Investigations of Ore Dressing and Metallurgy, 1926, Mines Branch, Ottawa, pp. 72–79.

a ton; copper, 0·40 per cent; lead, nil; zinc, trace; iron, 1·67 per cent; nickel, 0·009 per cent; insoluble, 92·54 per cent. The small percentage of nickel in the ore probably is in the pyrrhotite, for in Oiseau River area to the south, the pyrrhotite in sheared zones close to gabbro and peridotite is nickeliferous. Above the 375-foot level, the average dip of the Kitchener vein is approximately 62 degrees south, whereas between the 375 and 520-foot levels the dip flattened to nearly 38 to 40 degrees south (Figure 5). Although the quartz vein is fairly continuous on the 520-foot level, the gold content is low in the flat-dipping section of the vein. Just below the 375-foot level, the gabbro contact bulged outward down the dip similar to the bulges along the strike. This contact might be expected in depth to again steepen, in which case another lens of ore might be present at some point below the 520-foot horizon.

The Eclipse vein has been explored on four levels down to the 375-foot horizon. The outline of the chert-gabbro contact here is more irregular than along the Kitchener vein and the dip of the Eclipse vein varies from vertical to 75 degrees south. At the east end of the drift on the 200-foot level, the gabbro-chert contact dips 30 degrees north. The variations in the direction of the gabbro-chert contact are here only local features, extending some 20 or 30 feet vertically, and about twice these distances horizontally. The Eclipse vein is 380 feet long on the 200-foot level and 320 feet long on the 375-foot level. This ore-shoot appears to plunge slightly to the east. The vein has not been developed below the 375-foot level. On the surface, east of the Eclipse vein, the chert has been slightly sheared adjacent to both the north or gabbro content and the south or andesite contact. In this section some surface work and diamond drilling to shallow depths have been done, but the quartz bodies so far outlined are small and of low grade.

The Tene 6 vein is about 3,500 feet east of the Kitchener and this vein is near the middle of the gabbro body (Figure 3). The deposit at the surface is a lenticular body up to 19 feet wide and about 200 feet long, consisting of dark quartz, carrying considerable chalcopyrite. This quartz body for a length of 155 feet and across an average width of 15·5 feet gave assays ranging from $13 to $20 a ton, with many assays much higher than these figures. The shear zone in the gabbro continues a considerable distance beyond the ends of the quartz lens. In depth the quartz body ended, but other small lenses of quartz were encountered in following the shear zone down the dip, and also along the strike in the drifts. The quartz bodies and hence the ore-shoots in this shear zone are small and not closely spaced. The ore already developed on this property will probably be hauled by motor truck to the Kitchener mill.

The Roger vein is 500 feet south of the Tene 6 deposit and is along the gabbro-chert contact (Figure 3). Some underground work was done on this vein from an inclined shaft 175 feet deep, but the deposit was found to be small and lenticular at depth.

The west end of the Hope deposit is 1,400 feet east of the Tene 6 shaft. The gabbro east of the Tene 6 is sheared, but there is no evidence that the Tene 6 and Hope shear zones are continuous across the large, intervening, drift-covered area. The Hope shear zone is in gabbro near the north side of the gabbro body. This zone is well exposed 700 feet along its strike, and across widths varying from 9 to 75 feet. The dip of the shear zone is from 80 to 85 degrees north. Along the shear zone the gabbro is in part altered to a chlorite-carbonate-quartz schist. The quartz is distributed as a series of narrow, parallel veins and stringers throughout the schistose rock. Chalcopyrite, pyrite, and free gold are present in the quartz. No large, continuous body of quartz is exposed in the surface trenches along this shear zone. Several shear zones have been stripped to the east along the projected strike of the Hope zone, and a number of fairly large quartz veins have been opened up by prospect pits in the area to the east and south of the Hope. The quartz is a white, fine-grained variety, and all the deposits so far sampled in this part of the area are barren or carry on the average low values in gold.

SAN ANTONIO DEPOSIT

History and Development

This deposit is in the southwest corner of township 24, range 13, along the north shore of Rice lake, 4,500 feet east of the northwest corner of the lake. The deposit is about half a mile east of the Gabrielle, the original gold discovery of the area, and which was made in 1911. The outcrop of the San Antonio deposit was also located in May, 1911, but only a few prospect pits and trenches were dug on the property prior to 1922. In the summer of 1926 surface work was undertaken on the property by the Wanipigow syndicate. This work indicated an area about 100 feet wide and 1,200 feet long, and extending northwest from the point (formerly a small island) on the lake where No. 2 shoot (*See* Figure 6) was subsequently sunk, wherein several shear zones carrying quartz were present. In July, 1927, Wanipigow Mines, Limited, was incorporated and took over the property from the Wanipigow syndicate. In September, 1927, the name of the company was changed to San Antonio Mines, Limited, and except for two short periods, this company continued underground work up to the end of 1929. The original capitalization was 2,000,000 no par value shares. In 1927, No. 1 shaft was sunk on top of a hill and near what was thought to be the largest and central shear zone within the belt of schistose rock. As the underground work in the 125-foot level from this shaft did not disclose a well-defined shear zone and quartz body, work was abandoned from this shaft, and No. 2 shaft was sunk 950 feet to the southeast. In the twenty-eight months preceding the first of December, 1929, some 9,100 feet of underground work, including shaft and winze sinking, drifting, crosscutting, and station cutting, had been completed from No. 2 shaft. This work, or an average of nearly 320 feet a month, was done with one machine working two shifts a day and the average cost is reported as $29.40 a foot. Most equipment has to be transported to the property during the winter from Great Falls 65 miles distant by winter road.

General Geology

The quartz bodies on the San Antonio mineral claim are along shear zones in greenish black basalt and diabase, probably representing a thick lava flow. In thin section under the microscope the feldspar of this rock is altered to saussurite, albite, quartz, and calcite, and the ferromagnesian minerals are uralite, hornblende, actinolite, and chlorite. Thick-bedded quartzite and arkose with conglomerate lenses outcrop in the large islands south of the property. The strike of the sediments is south 80 degrees east and the dip 40 to 60 degrees north. The No. 2 shaft passed from basalt into sediments at about the 300-foot level, hence the contact between basalt on the north and sediments on the south is under the lake about 300 feet south of the shaft. The sheared zone carrying the quartz bodies outcrops at intervals at the foot and along the north side of a ridge crossed by several north-south depressions and followed to the north by a wide drift depression. Pillow lava outcrops at a few places along the foot of the hill north of this drift depression and to the east along the north shore of Rice lake. The high ridges north of this drift depression are of a porphyritic rock, near quartz diorite in average mineral composition. Locally this igneous rock is sheared and the lava along its south contact is highly schistose and carries some vein quartz. Small inclusions and schlieren-like patches of lava are locally present in this porphyritic rock and around the east end of the mass dykes of granite porphyry cut the schistose lava. The abundant phenocrysts of the body are oligoclase-andesine in crystals up to ½ inch across, the majority of the phenocrysts, however, being under ¼ inch across. Some outcrops show grains of bluish quartz in addition to feldspar phenocrysts. The greyish groundmass is of untwinned feldspar, probably both orthoclase and albite, considerable of biotite, chlorite, and sericite, and some calcite, epidote, zoisite, and magnetite. The body of porphyritic rock gradually narrows and ends just north of the west end of Rice lake. The mass is lenticular in outline, and is about 2 miles long and ½ mile wide at its widest point. The south contact dips north parallel the schistosity of the lava, and this mass of porphyritic rock perhaps is a sill or laccolith-like body. The arkosic sediments and the quartz-diorite porphyry are cut by narrow dykes of black diabase.

Description of the Deposit

No large and continuous shear zone or vein was exposed on the surface, the best showing perhaps being the one just north of No. 2 shaft. Here, an open-cut on the north side of the hill exposed about 3 feet of quartz and from 20 to 30 feet of sheared and massive basalt. The sheared basalt carries considerable of iron carbonate, quartz, and pyrite. Both east and west of the open-cut the quartz body branches and is irregular in outline. The quartz exposed at the surface was not encountered on the 150-foot level, although the basaltic rock was schistose and altered to secondary minerals along the short drifts and crosscuts. On the 300-foot level, considerable more drifting was done than on the 150-foot level, and in the drifts a few small quartz veins and stringers were found, also small bodies of grey carbonate rock. This grey carbonate rock passes outward, in some places through a narrow, brecciated zone and in others through a highly schistose zone, into only slightly schistose and altered basalt. In thin section under the microscope the grey carbonate rock consists of carbonates (ankerite, dolomite, and calcite) about 50 per cent, albite about 25 per cent, quartz 10 per cent, pyrite 10 per cent, leucoxene 3 per cent, and pyrrhotite 2 per cent. This rock is considered to represent

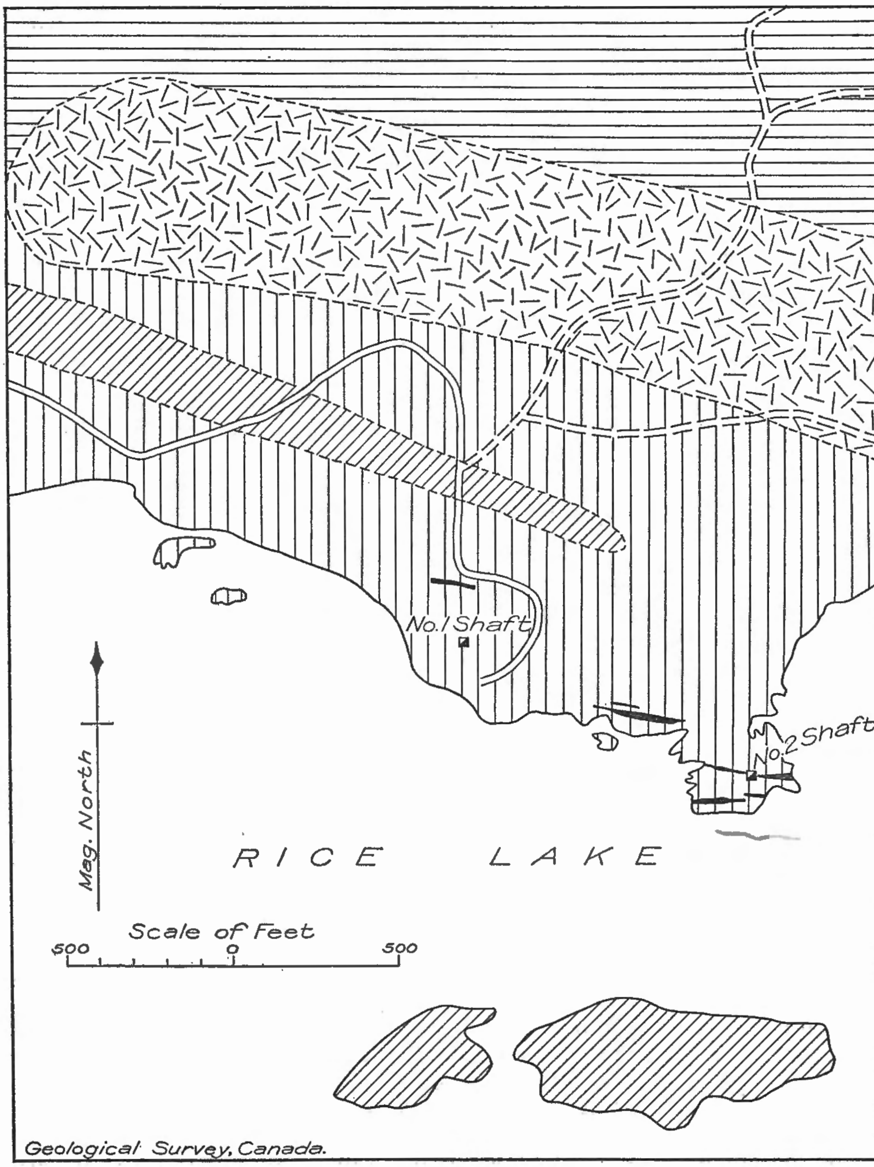

Figure 6. Plan showing geology in vicinity of San Antonio gold deposit, Beresford-Rice Lakes area, Manitoba. Quartz veins and shear zones shown by solid black; basalt and diabase by vertical ruling; quartzite, arkose, quartz-sericite schist by diagonal ruling; quartz diorite porphyry by irregular, pecked pattern; rhyolite and dacite by horizontal ruling.

diabase or basalt that has been highly altered by solutions carrying considerable of iron, and carbon dioxide. Most of the grey carbonate rock carries a little gold, and a few assays are reported to indicate the presence of commercial quantities of gold across narrow widths. The average, however, of a large body of this rock is low grade.

Most of the development work to date has been done on the 600 and 725-foot levels (Figure 7). On the 600-foot level the crosscut northeast from the shaft for the first 280 feet is in arkosic sediment, with highly schistose zones between the thick, massive beds. This crosscut continues northeast in slightly schistose basalt for 130 feet beyond the arkose-basalt contact. At this point a zone of highly schistose basalt was encountered, and this was followed north and northwest and southeast. About 40 feet northwest along the drift from the crosscut, a body of grey carbonate rock was outlined and found to be 39 feet wide at the widest point and 20 feet long. The winze from the 600 to 725-foot levels was commenced in this carbonate rock, and just southwest of the winze in the 725-foot level a long, narrow body of carbonate rock was outlined which may be the downward continuation of the body in the 600-foot level. If so, these bodies of carbonate rock appear to extend a greater distance vertically than horizontally, and they may be roughly lenticular in outline (Figure 8). On the 600-foot level several smaller lenses of carbonate rock were found along the drift for a hundred feet or more both northwest and southeast of the main body. A quartz vein was followed 80 feet along the 600-foot level from a point approximately 390 feet northwest of the main crosscut. This vein dipped from 20 to 30 degrees to the north, and its average trend was nearly east and west. The quartz carries free gold and the assays are reported to indicate a small body of good grade ore. Considerable more work was completed in the 600-foot level, including a crosscut 340 feet north across the basalt. No large, continuous bodies of quartz were found, although the diabase and basalt are jointed, sheared, and altered to chlorite schist with narrow zones of rock completely altered to chlorite-carbonate schist carrying pyrite.

On the 725-foot level the drift was extended northwest 450 feet from the winze and this work outlined the body of carbonate rock just northwest of the winze (Figure 8) and previously mentioned as perhaps a downward continuation of the body of similar rock on the 600-foot level. No large quartz vein was found along this drift, although the basaltic lava for most of the distance was altered to a chlorite-carbonate schist. At 450 feet along the drift northwest of the winze the direction of the workings was turned to nearly north, and 70 feet of schistose lava and 120 feet of black, fine-grained, hard rock were crossed. This hard rock, as seen under the microscope, is an aggregate of the secondary minerals epidote, chlorite, and carbonate in a matrix of quartz. Needles of tourmaline are abundant in some areas of the thin sections. A characteristic feature of the thin sections is large grains of leucoxene, some of which are slightly brownish and appear to be slightly altered titanite. This rock may be either a basic dyke or an andesitic lava highly altered and silicified. The hard rock passes gradually to the north into sheared chloritic lava, and about 30 feet north of the silicified, hard rock, a quartz vein was encountered in the sheared chloritic lava. This vein trends approximately northeast and dips nearly 70 degrees northwest, or nearly at right angles to the trend of the schistose zones on the 600-

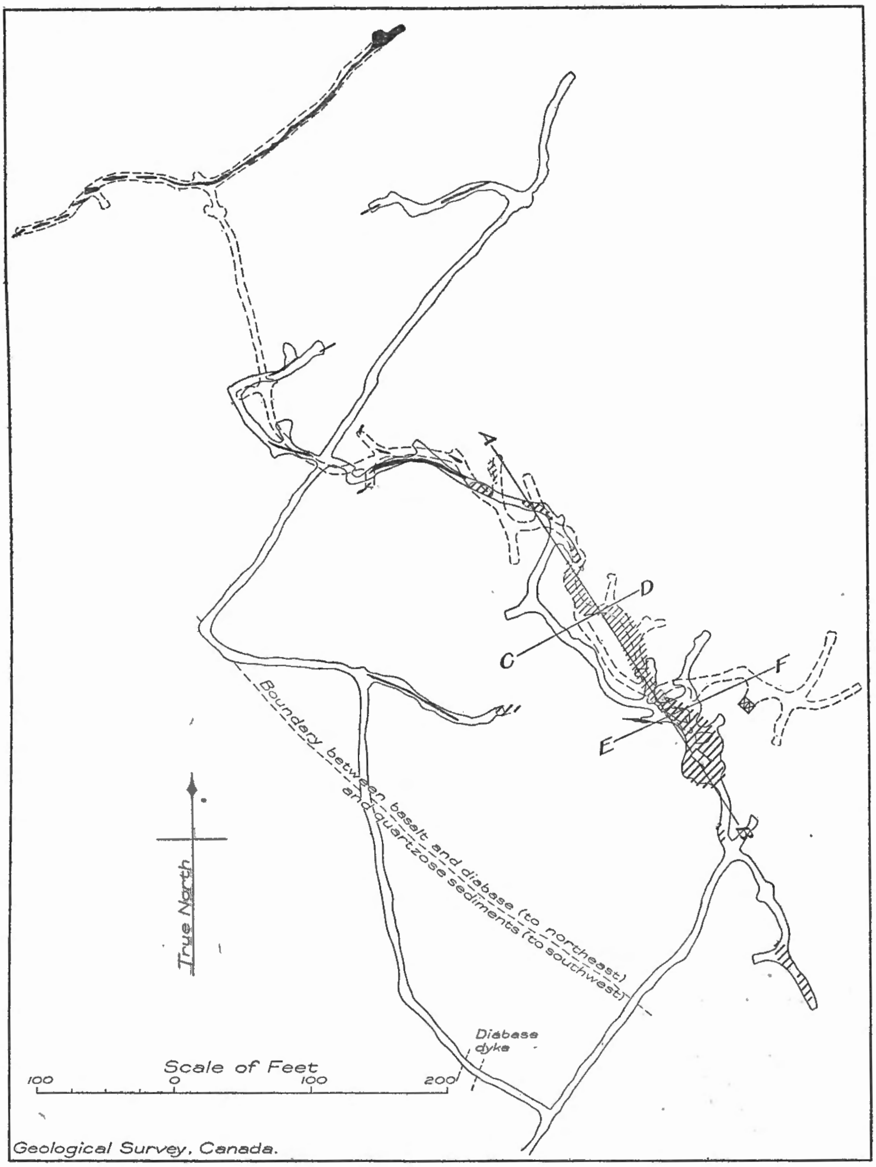

Figure 7. Plan of 600-foot and 725-foot levels, San Antonio mine, Beresford-Rice Lakes area, Manitoba. Quartz veins shown by solid black, irregular lines; 600-foot level shown by continuous line, 725-foot level by pecked lines; areas of carbonate on 600-foot level shown by heavy diagonal ruling; areas of carbonate on 725-foot level by light diagonal ruling.

foot level and near the winze on the 725-foot level. The northeast-trending shear zone and vein on the 725-level had been explored about 325 feet along its strike at the time the property was examined near the end of September, 1929, and a recently issued report of the company states the average gold content is $12.94 a ton for a length of 329 feet and across an average width of 3·8 feet. At one point the quartz is 11 feet wide, the average width northeast of where the vein was intersected is approximately 4½ feet. To the southwest of the drift, the vein is discontinuous and on the average is nearly 2½ feet in width. Both light and dark coloured quartz are present and seams of finely crystalline pyrite are present in the quartz adjacent the foot-wall. This is the most promising vein on the property, and the company plans at once to explore the continuation of this vein on the 600-foot level and also below the 725-foot level.

GEM LAKE

History and Development

The Gem Lake deposit is in township 20, range 17, east of the principal meridian, 3,000 feet south of the southwest branch of Manigotagan river and 2,200 feet west of mileage 91 on the Manitoba-Ontario boundary survey. The camps are around the northwest corner of Kickley lake, and the deposit outcrops on the top of the hill about 500 feet northwest of the west end of this lake. The deposit was discovered by Sandy McDonald and Dave Foster in June, 1926. Late that summer the deposit was sold to W. S. Kickley and associates of Winnipeg. Surface work was commenced at once, and the results of sampling completed early in the winter of 1927 indicated a small shoot of good grade ore. Gem Lake Mines, Limited, capitalized at 4,500,000 no par value shares, was organized to develop the property, and mining machinery and equipment were later installed. Considerable additional surface work was done by this company during the summer of 1928 on a number of sheared zones and quartz bodies in the area surrounding the original discovery. By the early summer of 1929, some 1,500 feet of drifting and crosscutting had been completed on the 125-foot level and 1,100 feet on the 250-foot levels. The shaft is now 500 feet deep, and at present exploration is in progress on the 375 and 500-foot horizons.

General Geology

The bedrock exposed in the vicinity of the deposit is basalt and sheared andesitic lava. Cherty tuff beds are intercalated with the flows, and wide zones of lava adjacent to the contact of the basalt flows or cherty tuff beds are altered to chlorite-carbonate schist. A few small, irregular-shaped bodies of granite porphyry intrude the cherty beds and schistose lava. One or more thick flows of basalt outcrop just south of the deposit, and those, still farther south, are followed by acidic, greenish grey flows with a few thin beds of cherty tuff, pyroclastic materials, and flow breccias. North of the deposit towards Manigotagan river, the greenish grey, highly schistose lava is followed by slightly schistose grey to black dacite and andesite flows. To the north, along Manigotagan valley, chert, slate, and greywacke beds predominate, the lava flows

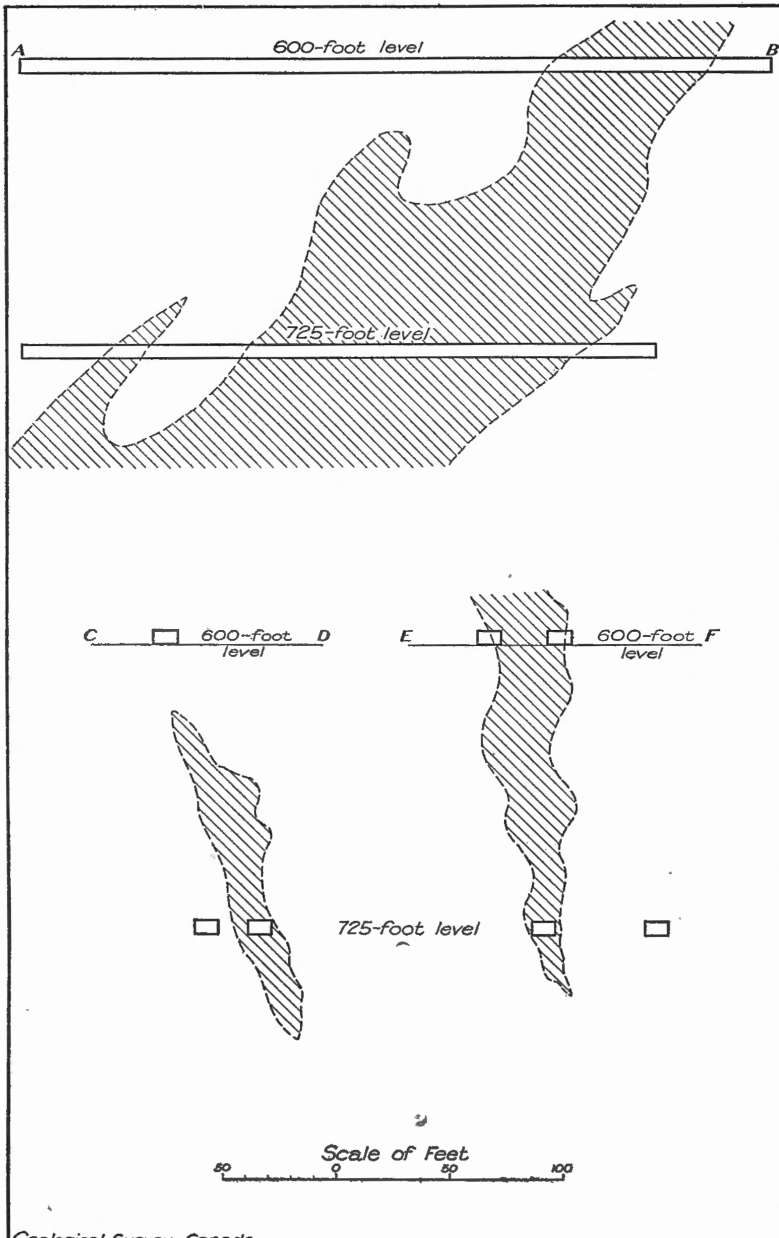

Figure 8. Diagrammatic vertical sections along lines AB, CD, and EF (*See* Figure 7), 600-foot and 725-foot levels, San Antonio mine; to show conjectured disposition of body of carbonate rock (by diagonal ruling).

being thin. The strike of the bedding and schistosity of the strata vary from south 68 to 84 degrees east, and the dip from 72 to 80 degrees north. The top of the beds is to the north and, therefore, successively younger strata are crossed from south to north.

Description of Deposit

The gold-bearing quartz is along shear zones within a belt of greenish grey, schistose lava 400 feet wide at the shaft. This belt of schistose lava lies between a thick body of fairly massive, coarse-grained basalt on the south and medium-grained schistose andesitic lava on the north. The general trend of the schistosity is south 75 degrees east, and the dip 76 degrees north. To the east the belt of schistose rock narrows, but apparently continues along a depression north of Kickley lake to and beyond the Manitoba-Ontario boundary. To the west of the shaft the highly schistose zone is traceable only ¼ mile, although west of this for a mile or more the lava at certain points is highly schistose along the general strike of the main schistose zone. Within this zone of schistose lava, there are narrow zones wherein the rock is deformed to a greenish, ribbon-like schist. Some beds are also complexly drag-folded, and these structures appear to plunge about 40 degrees westward. The quartz is for the most part localized in stringers, lenses, and veins along the shear zones. One of these shear zones, about 150 feet north of the shaft, averages nearly 12 feet in width for 600 feet along the strike. The average width of the quartz lenses and stringers present is nearly 2·4 feet for 210 feet along the strike. For a length of 110 feet and across a width of 8 feet the quartz-schist averaged $8.20 in gold a ton. Three other parallel shear zones are developed within the zones of schistose lava and these carry some quartz, but most of this quartz is barren or carries only a trace of gold.

The long crosscuts (*See* Figure 9) north from the shaft on the 125 and 250-foot levels cross the southern part of the belt of schistose lava and the three drifts on the 125-foot level and the two on the 250-foot level follow shear zones within this belt of schistose lava. The first shear zone intersected on the 125-foot level is 40 feet north of the shaft and this zone was followed 75 feet west and 55 feet east. Only two small lenses of barren quartz were encountered in this work. The second shear zone is 60 feet north of the shaft and this zone was followed east 240 feet and west 230 feet. To the east a lenticular quartz vein was followed practically the whole distance, but the assays were all low. At the east end of this drift a mass of white, sugary-appearing quartz was exposed across 18 feet, but as the gold content was low no further work was done to outline this quartz body. The shear zone continued almost the whole length of the drift running west from the main crosscut, but here only a few small lenses of quartz are present. At 45 feet farther north along the main crosscut a third shear zone was intersected and followed east 170 feet and west 65 feet. Only a few small lenses of quartz were found in this work. The main crosscut was extended north in all 240 feet from the shaft, but no definite shear zones or quartz bodies were intersected in the last 135 feet of schistose and jointed lava crossed.

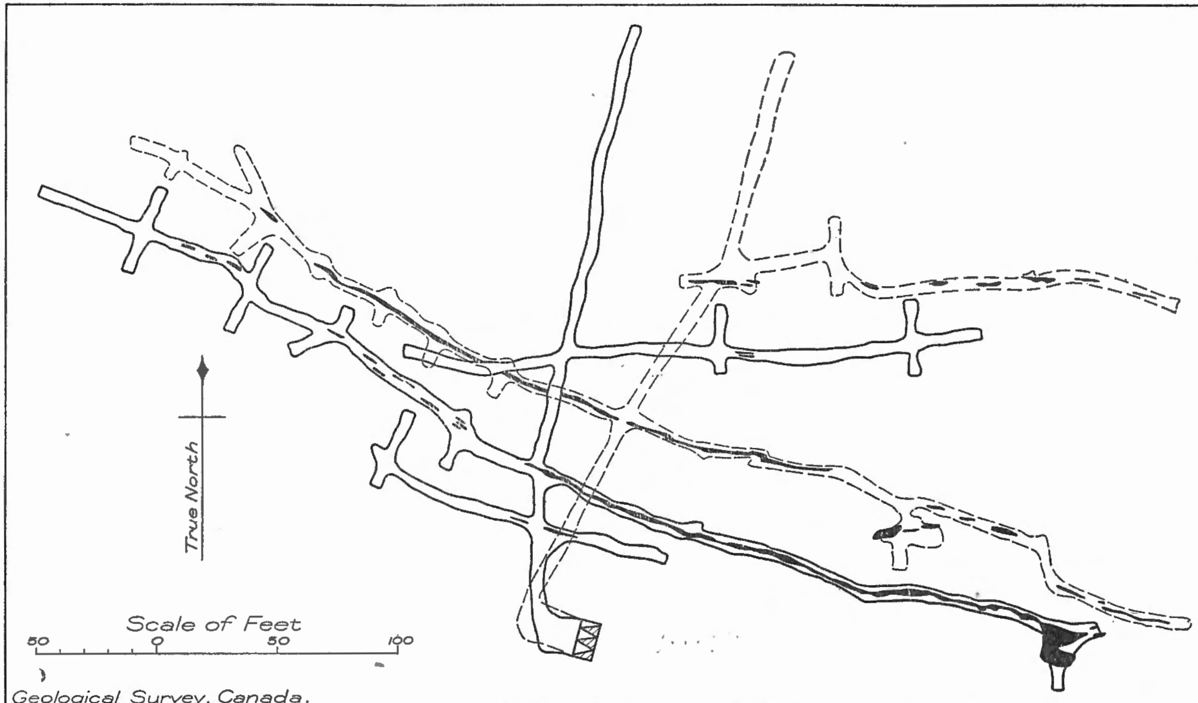

Figure 9. Plan of 125-foot and 250-foot levels, Gem Lake Mines, Limited, Beresford-Rice Lakes area, Manitoba. Outline of 125-foot level shown by continuous line; outline of 250-foot level shown by broken line; quartz veins shown by solid black.

On the 250-foot level, two shear zones were intersected in the crosscut extending north 250 feet from the shaft. The first of these shear zones is 85 feet north of the shaft and was followed westward 230 feet and eastward 240 feet. For the first 145 feet west of the main crosscut, a series of quartz stringers and veins in the schist average approximately 3 feet in width. The assays in this section indicate an ore-shoot averaging $44 a ton in gold across an average width of 3·5 feet and 145 feet in length. Three tons of this ore was shipped to the Ore Dressing Laboratories, Department of Mines, Ottawa, during the winter of 1928, and the mill runs of this material confirmed the assay results of the channel samples.[1] This ore-shoot was not located in the workings on the 125-foot level, and, so far as is known, the ore-shoot at the surface and on the 250-foot level are two unconnected lenses. Only small lenses of quartz are present along the continuation of the drift west of this shoot. Although quartz is present for 90 feet along this shear zone east of the main crosscut, the gold content here is low. Towards the east end of this drift several quartz lenses are present, but these carry on the average only a trace of gold. A second schistose zone was intersected 65 feet north of the ore-shoot, and although a fairly well-defined shear zone is present, no commercial bodies of gold-bearing quartz were found in the 190 feet this zone was followed east of the crosscut. At places the sheared zones within the belt of schistose lava are indefinite and hard to follow in drifting. Perhaps quartz bodies would be found at numerous other points within this wide belt of schistose lava, if additional and longer crosscuts were made transverse the strike of the schistosity. The quartz bodies are lenticular in outline and considerable work will have to be done to determine the general size and arrangement of the ore lenses within this wide belt of schistose lava.

SUMMARY OF ECONOMIC FEATURES OF GOLD DEPOSITS

Some underground work has been undertaken on seven other gold deposits in Beresford-Rice Lakes area besides the three deposits described in the foregoing paragraphs, and considerable surface work has been completed on twenty-five additional veins. The deposits on which the most extensive underground work has been completed include the Ora Grande to the 500-foot level, the Eldorado to the 500-foot level, the Cryderman to the 250-foot level, the Gold Pan to the 200-foot level, the Gold Pan Extension to the 125-foot level, the Moose to the 100-foot level, and the Selkirk to the 535-foot level. Mills were also built at the Gold Pan and Selkirk and these properties produced some gold prior to 1923. Free gold is widely distributed in the district. One hundred gold-bearing veins are known within an area 12 miles wide and extending 60 miles northwest from the Gem Lake deposit. Many of these gold-bearing quartz veins, however, are too small to be of commercial value, and the average gold content of many of the large quartz bodies is far too low to be commercial.

The majority of the gold-bearing veins of the field are within the Beresford or volcanic phase of the Rice Lake series, only a few quartz bodies are developed within members of the Manigotagan and Wanipigow sedi-

[1]Personal communication, Mr. W. B. Timm.

mentary phases of this series. Up to the present, quartz veins opened up within the sediments have not proved to be of commercial grade, and for this reason little prospecting has been undertaken in areas underlain by the sedimentary rocks. A few gold-bearing quartz veins are also present in the gabbroic and granodioritic phases of the granitic intrusives, and two deposits in these rocks, the Eldorado and Selkirk, have been thoroughly explored to the 500-foot level without success. This work proved the gold-bearing quartz bodies in the granitic rocks to be markedly lenticular and the lenses were too widely spaced to be developed and mined profitably. A few gold-bearing quartz bodies in the granite areas have been located within or close to inclusions of Rice Lake rocks or basic phases of the granitic rocks, as in the area from English brook eastward and also north of Wanipigow lake and river. The results of the development of the Eldorado and Selkirk deposits indicate, however, that the veins within the granitic rocks are not likely to prove profitable for large scale development, although if a mill were present nearby, a small tonnage of very rich ore could be mined from some of the known small quartz bodies. So far as is known, however, not one of these deposits is large enough to warrant the expenditure necessary to install mining machinery and to construct a mill.

As already indicated the gold-bearing quartz bodies are of lenticular outline and are located along shear zones. The Central Manitoba, Gem Lake, and San Antonio deposits are along zones of deformation of considerable width and length. The positions of such belts of deformed rock appear to be controlled by some local feature, such as a chert or tuff bed within lava flows or between a massive, thick flow or gabbro body, and thinner schistose flows. Along such zones, the rocks locally are highly schistified, or jointed and schistified. The most continuous quartz bodies are along the zones wherein the country rock is jointed and only slightly schistified. The schistose rock adjacent to the quartz bodies is not known to carry gold unless considerable quartz is present, and in this respect the deposits differ from those of most large gold camps, as at Kirkland lake and Porcupine a large proportion of the ore is mineralized schist at some horizons. Individual quartz bodies may not be expected to continue to great depths, but where a strong shear zone is developed, a succession of gold-bearing quartz bodies may be expected to occur down the dip or possibly in the walls adjacent to the bodies already explored.

The fairly extensive developments already completed on the deposits of the area indicate that the gold-bearing quartz bodies are not only decidedly lenticular, but that both barren and gold-bearing bodies of quartz may be present along the same shear zone. In fact, a single quartz body may become barren or practically barren of gold along the strike or down the dip, as was well illustrated in the case of the Cryderman and Kitchener veins. Up to the present the bodies of smoky, highly fractured quartz have been found to be the most valuable. To evaluate lenticular quartz bodies carrying free gold erratically distributed requires very detailed sampling, and only a few of the quartz bodies of the field are opened up in a manner to permit of any but a very general sampling.

Much of the sampling of the past has been done at intervals of 100 or 200 feet along the strike in the hope of proving a very large ore-shoot. It is probable that very detailed work would locate small shoots of gold ore along a few of the known deposits, and perhaps the future of the field as a gold producer will depend in a large measure on the location of a considerable number of small, rather than a few large, deposits. Considerable prospecting has already been done in the district, although fairly large, staked areas have been only hurriedly examined by prospectors. As many of the shear zones outcrop along depressions, discoveries may yet be made in areas considered to have already been carefully investigated.

The gold-bearing quartz is assumed to have originated from a granitic magma, but no bodies of acidic rocks were recognized in the gold field that might have originated from this magma as the veins appear to be younger than all the intrusive bodies in the area except a few small dykes of black diabasic rock. Gold-bearing quartz within the granodioritic and granitic intrusive bodies extends more than 500 feet below the present surface, indicating that the intrusives had consolidated to considerable depths before the gold-bearing quartz was deposited. The presence of gold-bearing quartz to such depths within the granitic bodies suggests that the temperature and pressure conditions within the intruded Rice Lake rocks would be favourable for the deposition of gold to a considerable depth below the present surface. The wide distribution of the gold-bearing quartz in the field indicates a deep-seated source of the mineralization, and it is difficult to assign the origin of the deposits to any particular intrusive body.

MASKWA AND OISEAU COPPER-NICKEL DEPOSITS

HISTORY

Late in 1917 a deposit of copper and nickel sulphides was staked in the northeast part of township 19, range 14, east of the principal meridian, in what is now known as the Maskwa River area. Considerable surface work and prospecting followed this discovery, and the Devlin Mining and Development Company was organized to explore the Mayville deposit. In the autumn of 1920 similar deposits of nickel and copper-bearing sulphides were discovered in Oiseau area, at a point north of Oiseau river and about 2½ miles west of the west end of Oiseau lake. The more important discoveries made in this area during the succeeding three years include the Chance, Devlin, Wento, and Cup Anderson deposits. In 1923 the Manitoba Copper Company was organized to explore the Wento and Cup Anderson deposits, and did surface work and diamond drilling at intervals until January or February, 1925. In the autumn of 1928, Ventures, Limited, and associates, optioned the Oiseau deposits, and the Consolidated Mining and Smelting Company of Canada, Limited, optioned the Mayville deposit. Both companies continued surface work and diamond drilling until late in the summer of 1929, when the options were dropped.

GENERAL GEOLOGICAL FEATURES

The known Precambrian formations in the vicinity of the copper-nickel deposits of Maskwa and Oiseau areas may be tabulated as follows, in descending order from youngest to oldest:

——	Oiseau area	Maskwa area
Deep-seated intrusives	Granite Gabbro and peridotite	Pegmatite Granite Gabbro
Rice Lake series	Wanipigow phase of quartzose sediments Beresford phase of volcanics including basalt, andesite, rhyolite, and associated tuffs and schists	 Beresford phase of volcanics including basalt, andesite, tuff, greywacke, and derived schists

The geological features of the Maskwa and Oiseau copper-nickel sulphide bodies are very similar. The deposits of both areas are in andesite pillow lava and associated quartzose tuff beds folded into almost vertical positions. The volcanic rocks are cut by dykes and boss-shaped bodies of peridotite and gabbro and by large and small bodies of granite. The sulphide bodies are along shear zones in the volcanic rocks close to the contacts of bodies of peridotite gabbro and granite. Locally, sulphides are also present in the marginal rock of bodies of peridotite and gabbro. Some bodies of peridotite and gabbro are cut by granite which, where in contact with sulphide bodies, as at the Chance and Devlin deposits, is penetrated by a few small veinlets of pyrrhotite and chalcopyrite. These veinlets of sulphides, however, extend only a few inches within the chilled margin of the granite, and no shear zones in the granite were seen that carried pyrrhotite and chalcopyrite.

The Chance and Devlin deposits, adjacent to bodies of peridotite, carry both copper and nickel, but the Wento and Cup Anderson, only a short distance from outcrops of peridotite and gabbro, are not known to carry nickel in addition to copper. Pentlandite is the nickel-bearing sulphide at the Mayville and Chance deposits; at the Devlin the pyrrhotite is nickeliferous. At the Wento and Cup Anderson, chalcopyrite, chalmersite, pyrite, and pyrrhotite are the abundant sulphides. The sulphide bodies carry only very small quantities of gold and silver, the assays already made show from a trace up to 3 or 4 ounces of silver and up to 0·06 ounce of gold a ton. Galena and sphalerite are present only sparingly. The deposits are clearly of the replacement type, and the results of the surface work and diamond drilling already completed suggest that the sulphide bodies are markedly lenticular. The area regarded most favourably for future prospecting varies in width from ½ mile to 1½ miles and extends west from the Wento to the east end of lac du Bonnet. This area is from ¼ mile to 2 miles south of the contact of the large granite body along the north side of Oiseau River area, and the country rock as known is alternating flows of andesite, and beds of tuff and greywacke, many outcrops of which are schistose and contain specks of chalcopyrite.

DESCRIPTION OF DEPOSITS

Wento

This sulphide body is in the middle of the west part of sec. 28, tp. 17, range 15. The bedrock exposed by the prospect pits is andesite lava and quartzose tuff. Granite outcrops immediately northwest of the pits and gabbro to the southwest. Small stringers of granite cut the gabbro and inclusions of andesite are present in the granite. The sulphide body appears to be in a small mass of lava and interbedded tuff within a bay in the gabbro body and around the end of a tongue of granite extending southeast from the large granite mass to the north. The sulphide body consists of schistified andesite lava and tuff carrying lens-shaped masses of solid sulphides and small stringers and bunches of disseminated sulphide. Along the gabbro-andesite contact at the east end of the deposit there are a number of small masses of titaniferous magnetite and massive chalcopyrite and pyrrhotite. The metallic minerals are younger than the gangue minerals, and the pyrrhotite, chalmersite, and chalcopyrite are intimately intermixed and appear to have crystallized together.

The development work on this sulphide deposit consisted of some fifteen test pits and trenches, a shaft 25 feet deep with about 20 feet of drifting, and three diamond drill holes inclined from north to south and reaching depths of from 150 to 200 feet below the surface. The drill holes intersected alternating beds of andesite and quartzose tuff, cut by granite and gabbro dykes. The gabbro has been sheared and impregnated with quartz carrying some chalcopyrite. The seams of chalcopyrite-bearing rock intersected by the drill cores were narrow. As exposed by the trenches the area of mineralized rock is 300 feet long and the width averages nearly 40 feet with a greatest width of 100 feet. Within this area two small lenses of copper ore are present. At the bottom of the shaft sunk on the larger of these sulphide-bearing lenses, assays across a width of 17 feet are reported to average 5·2 per cent copper. The second outcropping sulphide-bearing body is just east of the shaft and is reported to average 14 per cent copper across an average width of 7 feet and for 30 feet along the strike. These sulphide lenses are apparently shallow, as at a depth of 200 feet, as revealed by diamond drilling, dykes of gabbro and granite appear to be much more abundant than at the surface, and the sulphides are only sparingly distributed in narrow zones of schistose rock.

Beaver

Some surface work and diamond drilling have also been done on the Beaver and Diabase mineral claims adjoining the Wento in the west. Here five shear zones are exposed in andesite. Two of these shear zones carry some chalcopyrite and one bears some galena and sphalerite. The largest exposed shear zone is just south of the granite contact and about 1,600 feet northwest of the Wento workings. This zone is 250 feet long and averages about 12 feet in width. The chalcopyrite is distributed as specks throughout the schistose rock and in small lenses of more highly sheared rock erratically distributed throughout the zone of schistose rock. The average grade of the deposit was estimated to be less than 2 per cent copper. A sample of the galena and sphalerite-bearing rock from a small shear zone east of the main zone assayed 2·50 per cent lead, 6·10 per cent zinc, 0·20 per cent copper, and 3·40 and 0·06 ounces of silver and gold, respectively, per ton of 2,000 pounds.

Cup Anderson

The Cup Anderson sulphide body is near the middle of the north side of section 28, tp. 17, range 15, and approximately 2,900 feet northwest of the Wento. The bedrock exposed in the prospect trenches is a grey schistose tuff, locally showing bedding. Some beds carry round to subangular grains of smoky quartz up to ¼ inch in diameter. Other beds are black, fine-grained, cbloritic rocks that may be highly altered andesitic lava, and others are a black, slaty schist carrying red garnet. Granite outcrops about 300 feet north of the prospect pits and a small mass of pegmatitic quartz and granite outcrops just south of the south end of the central trenches. Small masses of peridotite are exposed just east of the surface workings and andesitic pillow lava and gabbro from the country rock are exposed south and west of the deposit.

The abundant sulphide of the Cup Anderson deposit is chalcopyrite; pyrite and pyrrhotite occur only sparingly. The chalcopyrite is distributed in the dark coloured, highly schistose, chloritic beds in specks, blebs, and veinlets. The thick, more massive beds are only sparingly mineralized with chalcopyrite along joint-planes and in layers containing an abundance of sericitic and chloritic materials. The deposit has been traced by a series of six trenches for 300 feet along an east-west direction and across a width varying from 6 to 100 feet. The strike of the bedding and schistosity of the enclosing tuff is from north 70 to 80 degrees west and the dip vertical to 80 degrees north. The walls of the trenches through the overburden are now slumped so that little can be seen of the surface exposures of this deposit. Considerable careful sampling was done by the Manitoba Copper Company during the summer of 1923, and according to information supplied by this company, the east long trench averaged 4·1 per cent copper across 94 feet. Another section in a trench west of this averaged 3·8 per cent copper across 28·5 feet. The average of considerable areas of slightly schistose tuff was less than 1·5 per cent copper. Zones varying from 6 to 12 feet in width, wherein the rocks were highly schistose, averaged from 6 to 7 per cent copper. Diamond drill holes in the heavily drift-covered area to the east of the surface exposures failed to locate the continuation eastward of this sulphide body beyond a point 200 feet from its last exposure, and also failed to intersect at depth ore of the grade and size indicated by the surface trenching.

Devlin

This deposit is in the north-central part of sec. 27, tp. 17, range 15, 5,500 feet east and a little south of the Cup Anderson. The country rock is andesite pillow lava with a thin chert bed and granite. The strike of the schistosity of the lava is south 70 degrees west, and the dip 75 degrees south. The drilling indicates that the dip flattens some in depth. A large mass of peridotite outcrops just west of the west end of the mineralized zone. The sulphide bodies are within the andesite just a few feet south of the granite contact.

The prospecting work at this locality has exposed three main bodies of sheared rock carrying sulphides. On the farthest west deposit, fourteen trenches cross a mineralized zone 800 feet long and averaging nearly 12 feet in width. In one of the trenches the sheared mineralized rock is 75 feet wide. Three diamond drill holes were put down on this deposit in the spring of 1929. In the mineralized zone the andesite and a discontinuous cherty bed, up to 4 feet in thickness, are schistified and jointed and the sulphides are distributed in small lenses and disseminated grains and specks. The sulphides noted are pyrrhotite, chalcopyrite, and white iron sulphide. The pyrrhotite carries some nickel and no pentlandite was recognized. The bodies wherein the sulphides are abundant vary from 2 inches to 2 or 3 feet in width and from 15 to 100 feet in length. Only two such sulphide-bearing lenses were noted and the schistified rock for distances up to 5 feet from these sulphide lenses carries considerable disseminated pyrrhotite and some chalcopyrite. Assays of channel samples cut at intervals of about 75 feet throughout the 800 feet and across an average width of 4½ feet are reported to average only 1·0 per cent copper and 0·5 per cent nickel.

The second locality where prospecting work had been done is approximately 500 feet east of the east end of the deposit described in the foregoing paragraph. Here two shear zones are exposed in andesite around the end of a small projection of granite extending east from the main granite body, the contact of which here trends northeast and at an angle to the strike of the schistosity of the lava. The northern of these shear zones is exposed 100 feet along its strike, which is east-west, the dip being 70 degrees south. The width of the sulphide-bearing rock varies from 2 to 8 feet. A shallow shaft has been sunk on this deposit, but, judging from an examination of the walls of the shaft and the material in the dump, the deposit is low grade, as chalcopyrite is abundant only in a few small patches of schistose rock. The southern shear zone, located 200 feet south of the northern zone, is exposed 250 feet along the strike and varies in width from 2 to 15 feet. A shallow prospect shaft has been sunk on this deposit, and samples cut across the more heavily mineralized part of this zone are reported to assay 2 to 3 per cent copper. The surface work, however, failed to locate a continuous body of copper ore of this grade, as the chalcopyrite is distributed in small patches throughout the sheared rock, the large intervening areas being only sparingly mineralized with chalcopyrite and pyrrhotite.

Chance

This deposit is along the west end of the line between secs. 26 and 35, tp. 17, range 15, and about 1,800 feet east of the occurrence last described. The rocks exposed in the prospect pits are peridotite, basalt, andesite, and granite. The sulphide lenses are in the peridotite and andesite adjacent to their contacts with granite. The mineralized zone trends east and west and has been traced by trenches at intervals for 1,600 feet. Most of the work has been done near the west end and here two shafts about 150 feet apart, each from 20 to 30 feet deep, have been sunk. The rock on the dumps is fine-grained andesite and peridotite cut by veinlets of crystals of hornblende up to 1½ inches long. Small veinlets and specks of pyrrhotite, pentlandite, and chalmersite are present in the hornblende veinlets and also in the adjacent peridotite and lava. Where the sulphides are abundant the black hornblende is bleached to a pale green or nearly colourless amphibole. The average assays of channel samples from the walls of the shafts gave 1·95 per cent nickel and 0·15 per cent copper. On the surface the sulphide bodies on which the shafts were sunk are exposed for only 25 feet along their strike and the average width is less than 4 feet. To the east of this point there is little definite information of the size and grade of this mineralized zone. At a few places the trenches show widths of 15 feet of limonite stained capping. Pyrrhotite is abundant in the trench farthest east and east of this the drift cover is thick.

Mayville

The Mayville deposit in Maskwa River area is approximately 16 miles north and west of the Wento. In 1923 a trail was cut between these two deposits, and for 10½ miles this trail crosses granite with lavas and sediments of the Rice Lake series along 2 miles of the north end and 3½ miles of the south end. The bedrock exposed near the Mayville is coarse-grained gabbro and andesite lava. Granite outcrops approximately 4,000 feet north of the deposit. The gabbro intrudes the lavas as a long, tongue-shaped body and as dyke-like masses. Both the gabbro and andesite are cut by the surrounding granite.

The Mayville sulphide body is along the south side and foot of a hill of andesite and gabbro. This hill is surrounded by swamp and the westward continuation of the sulphide body is under the swamp. The mineralized zone is exposed for 200 feet along a general trend of north 60 degrees east magnetic. In the spring of 1923, the Devlin Mining and Development Company drilled seven holes to intersect the sulphide zone at depths of from 200 to 350 feet, and in 1929, Consolidated Mining and Smelting Company of Canada, Limited, drilled five holes, three of these vertical to depths of 530, 506, and 508 feet, respectively, and two steeply inclined from the southeast towards the outcrop to lengths of 1,501 and 1,401 feet, respectively. The Diamond drill intersections indicate that the dip of the deposit is to the south. The sulphide body as exposed in the trenches consists of two bodies of schistose andesite and gabbro carrying pyrrhotite, pentlandite, and chalcopyrite. These bodies of sulphide-bearing rock are 4 and 7 feet wide, respectively, in the middle trench. At depth the diamond drill cores showed an alternating succession of gabbro dykes and andesite layers carrying sulphides. One of the intrusive dykes intersected in the drilling consisted almost entirely of labradorite crystals from ½ to 2 inches long and other dykes contain large hornblende crystals. The large feldspar and hornblende crystals are cut by veinlets of sulphides along cracks and cleavage planes. The andesite adjacent to such gabbro dykes carries sulphides only sparingly. Although short sections of the trenches and drill cores assayed over 4 per cent combined nickel and copper, the average of a body of mineralized rock of commercial tonnage is under 2 per cent combined nickel and copper.

Hititrite

Another body of sulphide-bearing rock is exposed on the Hititrite mineral claim approximately 4,500 feet south of the Mayville. Here three small outcrops of gabbro carry pyrrhotite, pentlandite, and chalcopyrite. The sulphide-bearing rock, as exposed by five test pits, measures 125 feet along the strike and has an average width of 15 feet. Small, included masses of andesite and one body of grey quartz-biotite schist are present in the gabbro along the sulphide-bearing zone. The sulphides are along joint-planes and slightly schistose zones within the gabbro adjacent to the bodies of included andesite, and also within the andesite. A few specks of chalcopyrite are also present in what appears to be massive gabbro. Assays of channel samples from the trenches showed from 0·27 to 3·23 per cent copper and from 0·19 to 1·68 per cent nickel. One sample assayed 0·02 per cent platinum. So far as is known the body of sulphide-bearing rock at this locality is small.

TIN DEPOSITS IN THE VICINITY OF SHATFORD AND BERNIC LAKES, OISEAU AREA

HISTORY

Specimens of pegmatite carrying cassiterite, the oxide of tin, were collected from a dyke outcropping on a small island near the east end of Shatford lake at the time this lake was being geologically mapped in 1924. In the autumn of 1924, Mr. K. E. Miller also discovered cassiterite in a pegmatite body at this locality, and staked some mineral claims. A little surface work was done and some nice specimens of cassiterite were collected. The area, however, attracted little attention as a possible tin field until the autumn of 1928, when Manitoba Tin Company, Limited, was organized and commenced to develop the original discovery on Shatford lake. Many visited the area and hundreds of mineral claims were staked in the surrounding country during the autumn of 1928 and the winter of 1928-1929. Jack Nutt Mines, Limited, was incorporated to develop deposits on the north shore of Bernic lake, and in June, 1929, this company was doing development at three localities. By the end of June, 1929, cassiterite had been discovered in four pegmatite bodies in the vicinity of Bernic and Rush lakes. Considerable prospecting was in progress in the area during the summer of 1929, but apparently no commercial tin deposits of importance were discovered.

GENERAL GEOLOGY

The known bedrock in the vicinity of Shatford and Bernic lakes is Precambrian and the formations recognized may be grouped as follows from youngest to oldest.

TABLE OF FORMATIONS

Deep-seated intrusives	Albite pegmatite (tin-bearing) Pegmatitic albite granite Microcline pegmatite Microcline granite Oligoclase granite Quartz diorite, granodiorite and granite with porphyritic phases Peridotite and gabbro
Rice Lake series	Beresford volcanic phase, including basalt, andesite, tuff, garnet beds, quartzose sediments, and derived schists.

The lavas of the Rice Lake series are dark coloured and locally show pillow structure. They are andesites and basalts in mineral composition. North of Bernic lake some of the basalt flows are thick, and the rock is of medium-grained gabbroic appearance. Many beds of the sediments are light grey quartzose types. A few beds are of special interest in that they carry abundant red garnet, and schistose phases of the garnet beds carry pyrite, pyrrhotite, and locally some chalcopyrite. Schistose garnet rock impregnated by quartz also is reported to assay a trace of tin. In some outcrops garnet is estimated to form over half the rock, and is distributed in zones varying in width from 2 inches to 3½ feet, and estimated to carry 90 per cent garnet, alternating with layers of black rock carrying only a few garnets in clusters of crystals scattered irregularly. Almandite is the abundant garnet, and it is for the most part in well-developed crystals, varying from $\frac{1}{10}$ to over 1 inch across. The garnet crystals include fragments of quartz, feldspar, and other minerals of the matrix, and also cut across the biotite flakes. Hornblende, actinolite, and anthophyllite are abundant in some specimens of garnet rock. The association and relation of the garnet beds to normal sediments suggest that the garnet-bearing rocks are recrystallized sedimentary beds of unusual composition, perhaps an ash bed.

The intrusive rocks are medium-grained, massive types except locally where a faint gneissic structure is developed. The intrusive mass between Shatford and Bernic lakes is porphyritic and varies in composition from granodiorite to granite. This is the only intrusive body known in the district that shows such excellent porphyritic texture. Other intrusive bodies of the area, however, as the one west of the west end of Bernic lake, vary in mineralogical composition from point to point, perhaps due to differentiation, and this, together with the range in mineralogical composition of the intrusives of the area from very basic to very acidic types, indicates that the magma underwent differentiation during consolidation. Pink and pinkish grey microcline-granite, representing a late phase of the period of igneous intrusion, outcrops over a wide area south of Shatford lake. Microcline pegmatites are present in the lavas and sediments along the margin of this intrusive. In a few pegmatites albite-oligoclase and cleavelandite are the abundant feldspars, and these bodies carry the cassiterite and other accessory minerals. These albite-pegmatites are perhaps the end differentiate of the magma that consolidated as the microcline granite.

DESCRIPTION OF PROPERTIES

Manitoba Tin Company

In the autumn of 1928 this company commenced work on the original tin discovery on the small island in Shatford lake, and also completed considerable surface work on the mainland both west and east of this locality. In the winter of 1929 good camps were built, and by the early summer a shaft had been sunk 110 feet on the north side of the large island just east of the original tin discovery. On the 100-foot horizon a crosscut was extended northwest to intersect the tin-bearing pegmatite, which was followed 60 feet by drifts.

Andesitic pillow lava is exposed along the south shore of Shatford lake and the majority of the pegmatites are within this formation just north of its contact with a large body of microcline granite. The andesite is followed to the north by a garnet-bearing bed and quartzose sediments. Only a few pegmatite bodies are present in the sediments. Northeast of Shatford lake, the sediments are intruded by a body of porphyritic granodiorite and granite, which extends northward to near the south shore of Bernic lake. The bedding of the sediments and the schistosity of the lava strike approximately east and west, and their dip is from 50 to 80 degrees north. The long direction of the pegmatite bodies appears to parallel the trend of the bedding and schistosity of the enclosing rocks.

The only known pegmatite at this locality carrying cassiterite in large grains and crystals is the original discovery on the small island near the east end of Shatford lake. This island is roughly lenticular in outline and, at a time of medium high water, is approximately 60 feet long and 40 feet across at the widest point. The tin-bearing pegmatite outcrops just above the water-level on the south side of the island and along the contact between a garnet bed on the north and pillow lava to the south. This pegmatite body cannot be over 12 feet wide, and it does not extend eastward 100 feet to the large island, for a trench in the west end of this island and along the projected strike of the tin-bearing pegmatite showed only lava and garnet rock. The westward continuation of the dyke under the lake is unknown.

In June, 1929, it was impossible to make a detailed examination of this pegmatite body, as only a few square feet of the tin-bearing pegmatite was exposed at the top of a small prospect shaft nearly full of water. The specimens in the dump, however, are of a pinkish albite-pegmatite. Within this pegmatite a zone, approximately 2½ feet wide at the top of the shaft, contains abundant quartz and muscovite, and the cassiterite is in this quartz muscovite phase of the pegmatite. The cassiterite is in crystals up to ¼ inch long, and as small grains distributed along the edges of bands or streaks wherein either quartz or muscovite are abundant or between grains of quartz and pinkish feldspar. The areas of pink feldspar in the quartz,muscovite phase are irregular in outline and are between large grains or areas of quartz. In thin section under the microscope this pegmatite carries abundant quartz and muscovite with some albite-oligoclase, cleavelandite, cassiterite, and fluorite. Grains of quartz muscovite and cleavelandite penetrate the albite-oligoclase and microcline crystals, and this relationship perhaps indicates two generations of mineral crystallization during the consolidation of the pegmatite magma. The fluorite is in small, irregularly outlined patches between large quartz and feldspar grains, suggesting a cavity filling. The size and continuity of this tin-bearing quartz-muscovite phase of the pegmatite body are unknown. It is reported that in the 100-foot level cassiterite was present in the normal feldspar pegmatite and that the quartz-muscovite phase, as developed at the surface, was not encountered in the short underground workings.

Several pegmatite bodies are exposed in prospect trenches on the point along the south shore of Shatford lake from 1,600 to 3,000 feet southwest of the main shaft. A few of these pegmatite bodies are large, up to several hundred feet in length and 60 to 100 feet in width, but these larger masses are not known to carry cassiterite or other valuable minerals, although locally the quartz and mica are segregated in pockets or irregularly outlined areas. In some of these pegmatites, cavities are lined with crystals of albite, stained brownish by circulating waters. One pegmatite contains crystals up to a foot across of a muscovite-like mica and reported to carry some lithium. This mica splits into curved, saucer-shaped flakes. Two pegmatites contain areas wherein beryl crystals, from ½ inch to 2 feet long and ¼ inch to 3 inches in diameter, are abundant. A number of other masses of the area carry a few crystals of beryl. By hand sorting perhaps several tons of beryllium ore could be mined from these pegmatites, but probably it would not be profitable to undertake to quarry and to market the beryl unless larger and higher grade deposits are found nearby.

The andesitic lava on the point 2,000 feet southwest of the shaft has been sheared and these zones locally impregnated by sulphides. Pegmatite bodies are present nearby, but no pegmatite was recognized within the shear zones, although in other parts of the area the pegmatite carries sulphides. A prospect shaft was sunk 30 feet along one of these shear zones, and the schistose lava on the dump contains considerable pyrrohtite, and some pyrite, arsenopyrite, chalcopyrite, molybdenite, galena, and sphalerite. The molybdenite is in quartz veinlets cutting the schistose lava. Several other rusty zones of schistose lava were exposed by surface trenches in the area west of this prospect shaft, but at all these localities no indications were found of a large deposit of sulphide-bearing rock of commercial grade.

The garnet bed exposed at the main shaft has been traced eastward at intervals for approximately 3,500 feet. At a point 2,200 feet east of the main shaft, a small prospect shaft was sunk 10 feet on a zone within the garnet bed carrying considerable chalcopyrite, but not of commercial grade across mineable widths. Some chalcopyrite was also found in several of the other trenches crossing the garnet bed and samples of sheared sulphide-bearing rock from a few of these prospect pits are reported to carry a trace of tin. The garnet of certain beds of this rock might be suitable for use as a powdered abrasive, if there were a demand for this product. At most points the chalcopyrite was present only sparingly in schistose phases of the garnet bed, and at the end of June, 1929, the development completed had not indicated possibilities of their being commercial bodies of ore carrying copper, and possibly tin and garnet.

Jack Nutt Mines

Late in 1928, Jack Nutt Mines, Limited, was organized to develop a pegmatite body carrying cassiterite, and exposed on the south end of a point on the north shore of Bernic lake in the southern half of sec. 15, tp. 17, range 15, E. prin. mer. Later this company acquired two large groups of mining claims west of Rush lake and along the south shore of Oiseau lake, respectively. Surface work completed in the winter of 1929 at the Bernic Lake locality exposed five, separate, small, irregular-shaped pegmatite bodies. At this locality a shaft was sunk 140 feet and some crosscutting was completed at the 100-foot horizon in an effort to locate the pegmatite bodies underground. Also, a small pilot mill was built, but it was operated only a very short time.

The country rock exposed at this locality is basalt cut by pegmatite. The long direction of the pegmatite bodies trends approximately north 10 degrees east, and nearly at right angles to the direction of the schistosity of the basaltic lava flows. The pegmatite bodies appear to dip eastward at angles varying from 5 to 60 degrees. About 700 feet north of the pegmatite bodies the medium-grained, black, basaltic lava is followed by finer-grained, black, andesitic pillow lavas, and to the south basalt, and andesitic flows and tuff beds are interbedded. Granite and granodiorite outcrop on the large island and on the mainland 2,200 and 2,500 feet respectively southwest and west of the point where the surface work was done.

The pegmatite exposed by the workings is a medium-grained albite-oligoclase variety, grading into fine-grained, pegmatitic albite-granite. The pegmatite body farthest north from the south end of the point extends 275 feet along the strike and is 60 feet wide at one point. This body is followed to the south by another body 275 feet long and averaging nearly 25 feet in thickness. At its south end this pegmatite body curves sharply east and ends. The three smaller pegmatite bodies to the east are apparently not over 4 feet in thickness and 100 feet in length. These smaller bodies dip flatly so that their surface outcrops appear large. Cassiterite was noted in a quartz-mica phase developed in a small projection along the east contact or hanging-wall side of the south large pegmatite body, and also in a small area of pink, pegmatitic granite along the east margin of the north body. Black tourmaline crystals up to 2 inches in diameter are an abundant constituent of all the pegmatite exposed at this locality, and it is only after some experience that the tourmaline can be distinguished from the black cassiterite without careful tests. In one of the smaller pegmatite masses, with an almost flat dip, the tourmaline crystals are oriented with their long directions at right angles to the wall of the pegmatitic body. Some of the mica of the quartz-cassiterite phase of the pegmatite is a white to yellowish green variety, with optical properties near those of paragonite. A microscopic study of three thin sections of this pegmatite suggests that the minerals commenced to crystallize in the following order: tourmaline, beryl, albite, cassiterite, muscovite, microcline, quartz, white mica, and cleavelandite. The thin section of this pegmatite showed little evidence of replacement of one mineral by another, though there may be two generations of mica and quartz. The tourmaline, beryl, cassiterite, and other accessory minerals commenced to crystallize early, and some of the soda feldspar and quartz late. As far as could be determined from a careful surface examination, the tin-bearing pegmatite forms only a small fraction of the whole mass. For this reason and considering the flat dip and apparently irregular shape of the pegmatite bodies, it would seem advisable to first explore and to thoroughly sample such deposits in open-cuts and inclined prospect shafts before commencing extensive underground work.

Rush and Stannite Pegmatites

These two pegmatite bodies are approximately 2,200 feet west and north respectively of the west end of Rush lake, in secs. 19 and 20, tp. 17, range 16. The Rush pegmatite is controlled by Jack Nutt Mines, Limited, and the Stannite group by K. E. Miller and associates. Only a small amount of surface work had been done to expose these pegmatites up to the middle of June, 1929.

The country rock on the Rush group is andesite lava with beds of quartzose tuff and of mica schist carrying red garnets. The pegmatite body probably is continuous 1,600 feet along its strike and at two points is 100 feet wide. The average strike of the contact of the pegmatite body is nearly east and west and the dip appears to be 75 degrees south. Small, included bodies of andesite lava are present in the pegmatite body. The pegmatite shows considerable range in texture, varying from a fine-grained pegmatitic granite with lath-shaped crystals of albite-oligoclase and areas of cleavelandite as the main constituents to a type of irregular grain consisting of large crystals of quartz, feldspar, and muscovite. Some outcrops show excellent graphic intergrowths of quartz and pink and white feldspar. The coarser-grained phases of the pegmatite form small, irregular areas erratically distributed throughout the pegmatite. Some of these areas of coarse pegmatite are less than 3 feet across. The accessory minerals of this pegmatite include beryl, tourmaline, cassiterite, triphylite, lepidotite, fluorite, epidote, arsenopyrite, sphalerite, magnetite, and perhaps others not recognized in the hurried examination of the deposit made by the writer. Only a few crystals of cassiterite were recognized in the trenches exposing the deposit when it was visited about the middle of June, 1929.

The pegmatite body on the Stannite group was exposed at intervals for a distance of 450 feet along the strike. The country rock is quartzose sediments and small blocks of these rocks are included in the marginal part of the pegmatite mass. This pegmatite is a coarse-grained type with some crystals of feldspar and muscovite up to a foot across. The only exposure noted that shows cassiterite is approximately 430 feet west of the No. 1 post of the Stannite No. 1 mineral claim. Here a small outcrop of coarse-grained pegmatite in contact with cherty sediments is exposed over an area of 4 square feet. The contact of this dyke here dips to the north and the cassiterite is concentrated in pockets along the hanging-wall. In addition to cassiterite this outcrop carries beryl and muscovite. The cassiterite crystals are up to ½ inch long, and are in small bunches distributed erratically throughout the small outcrop. Another fine-grained, aplitic pegmatite, outcropping 1,000 feet south of the Stannite pegmatite, carries considerable pinkish to purplish lepidolite-like mica, beryl, a green to bluish tourmaline, and a yellowish green muscovite. No cassiterite was recognized in this dyke.

Oiseau Lake Prospect

On the south shore of Oiseau lake at a point about 2 miles east of the west end, Jack Nutt Mines, Limited, did considerable trenching and some diamond drilling during the summer of 1929. This work was being done on a small point, which is an island if the water in the lake be high. Here, the bedrock is a series of alternating beds of greywacke, cherty-quartzite, garnet, and magnetite-carbonate rocks. The strike of the beds is nearly east-west and their dip 68 degrees south. The garnet-rich and magnetite beds were exposed by trenching for 200 feet along their strike and in both directions pass under the water of the lake. The width of these beds varies from 6 to 12 feet and the whole zone of alternating beds exposed is from 90 to 130 feet wide. The rocks along the contacts of these several alternating beds are sheared and in these zones a few small stringers of quartz and pegmatite are present. The sheared rock also carries some pyrrhotite and pyrite. Samples from this deposit are reported to assay a trace of tin, but no indications could be seen of the possibility of there being a promising deposit of tin ore at this locality.

SUMMARY OF ECONOMIC FEATURES OF TIN DEPOSITS

The known tin deposits in the vicinity of Shatford and Bernic lakes are in pegmatites characterized by abundant albite feldspar. The tin-bearing mineral is cassiterite occurring in small grains and crystals. Some of the pegmatite bodies have a flat dip and these cut the bedding and schistosity of the enclosing lavas and sediments. Other of the pegmatite bodies have a steep dip and appear to parallel the strike and dip of the bedding and schistosity of the older rocks. Within the pegmatite bodies, the cassiterite is localized to either coarse or fine-grained phases of the pegmatite, in some cases located along what appears to be the hanging-wall of the pegmatite mass and in others irregularly distributed throughout the mass. A careful microscopic study of thin sections of the pegmatite indicates that the cassiterite and other accessory minerals crystallized early from the pegmatitic magma, there being little evidence, except in the Shatford muscovite-quartz cassiterite phase for a replacement of earlier formed minerals during the final stages of the consolidation of the mass. No typical greisen has been recognized in the area, the tin-bearing quartz muscovite rock locally developed being a phase of the pegmatite. The tin and lithium-bearing pegmatites of the area are very similar in their general features and origin.

Tin deposits in pegmatites in other tin fields of the world have not produced large quantities of tin ore. Of the various types of lode tin deposits, moreover, the most promising commercially is that known as the cassiterite veins. These deposits, in addition to cassiterite, carry abundant quartz and such characteristic minerals as fluorite, topaz, and tourmaline. The country rock adjoining the deposits is altered to a quartz-muscovite aggregate known as greisen, and typically formed by the pneumatolytic alteration of granite. In Manitoba area, the granites show no evidence of alteration to greisen. Perhaps the present surface intersects the granite batholiths too deeply below their roofs for greisen to be expected in the granite, although cassiterite-quartz veins may be present along greisen-like zones within members of the Rice Lake series surrounding the granite batholiths. The fact that tin mineralization is associated with the granitic intrusives of the area gives some encouragement to continue prospecting this large district, and all future work should be directed towards a search for greisenized quartz veins, which are abundant in most tin fields, although the presence of such veins does not necessarily indicate a tin ore-body. So far as is known no cassiterite-quartz veins have yet been located in Manitoba area.

MISTAKE BAY AREA, WEST COAST OF HUDSON BAY, NORTH WEST TERRITORIES

By L. J. Weeks

INTRODUCTION

Work was commenced in 1929 on an area surrounding and including Mistake bay, an indentation in the west coast of Hudson bay, some 90 miles south of Chesterfield inlet. The purpose of the work is to be the production of a geological and geographical map on a scale of 4 miles to 1 inch, of an area lying between west longitudes 92 degrees and 94 degrees and north latitudes 62 degrees and 63 degrees. Messrs. D. F. Kidd and A. W. Derby assisted very efficiently in the field work. The writer also wishes to gratefully acknowledge the many courtesies extended by officials of the Department of Railways and Canals at Churchill, the Hudson's Bay Company, Dominion Explorers, Limited, and the Nipissing Mining Company, farther north.

With the completion of the Hudson Bay railway, access to Churchill at the mouth of Churchill river is made quite easy. The distance from Churchill to Mistake bay is about 225 miles. For this trip a 40-foot Peterhead trap-boat was used, carrying the personnel and summer's supplies. The trip was made in forty-eight hours running time. Arriving in the field a base was established at Tavane, an inlet in Mistake bay, where is located one of the working bases of Dominion Explorers, Limited. The party joined the S.S. *Ungava* at Term point, some 22 miles east of Tavane on September 15 and returned to Churchill.

GENERAL NOTES ON THE COUNTRY

It is thought that a general description of the coast, climate, ice conditions, vegetation, etc., may be of value to those who may contemplate travelling in the region.

Between Churchill and Dawson inlet, about 30 miles south of the mouth of Ferguson river, only two low-water harbours are available for small boats. These are located at, respectively, Hubbard point (Long point is a name often heard locally) and cape Eskimo. At Hubbard point a small snug harbour can be entered through about 1 or 1½ fathoms at low water. At cape Eskimo a large bay has several winding channels, and although exposed to the eastward yet is protected from heavy seas by shoals at the mouth of the bay. This harbour is not entirely satisfactory for small boats, as at high water the water surface to windward may be large enough so that in a moderate gale a boat may drag its anchors.

North of Dawson inlet, although actual harbours are not many, yet shelter can usually be obtained with ease in the lee of the numerous islands, shoals, or reefs.

Between Churchill and cape Eskimo are several highwater harbours, most of which are in the mouths of streams and rivers, the best known of which is perhaps that at the Nunallak post of the Hudson's Bay Company. This is a few miles north of Egg island and the harbour is the mouth of Egg river. The mouth of this harbour has over a fathom of water for a little over two hours at the top of the tide.

Across the mouth of Button bay, just west of Churchill harbour, it is advisable to keep some distance from shore as shoals extend out some miles to sea. From Hubbard point to Egg island, the coast is even and apparently void of shoal water at distances out to sea greater than 2 or 3 miles. From Egg island to cape Eskimo, however, shoals occur practically out of sight of land. A long line of shoals extend eastward from cape Eskimo. An area of great compass unreliability was encountered some 25 miles south of cape Eskimo and about 8 miles from shore.

Sentry island, about 8 miles north of cape Eskimo, has a long line of reefs running seaward from it, with an apparently deep but narrow passage through the reefs about 2 miles from shore.

On rounding Bibby island and entering Mistake bay, reefs and shoals increase tremendously in number and a native pilot is necessary. These add difficulties also to canoe work as at low tide it is sometimes difficult to get within miles of shore. Tidal currents are very strong, in places running 4 to 5 knots.

The floe ice in Churchill harbour broke up on June 20 in 1929. Easterly winds kept the drifting ice in the vicinity until late in July. Apparently there is a southerly drift to the ice on the west coast, as the bay around Mistake bay was clear of floating ice before Churchill harbour, during the summer of 1929.

On proceeding northward from Churchill, on July 23, no ice was seen north of Egg island and none was seen for the remainder of the summer. Ice was known, however, to lie practically all summer some 60 miles east of Churchill.

Official records of climatic conditions are lacking for this belt of country. During July and August, 1929, quite warm temperatures were encountered with no freezing at any time during the day. The rivers and lakes are as a rule open early in July according to natives of the country. In June and September, although quite warm weather may be experienced yet the nights are quite cool and often drop to sub-freezing temperatures.

In the area covered there is no tree growth whatever, although willows grow in masses in some places as high as one foot. Grasses and mosses cover practically all the country except bedrock.

Seal and white whale are found along the coast and are much more plentiful just after the break-up than later. Walrus congregate for mating on a small island in Mistake bay about the second week in August. None was seen at any other time. Inland a few barren land caribou were encountered. Fox trapping is the chief native winter industry. In general the traveller cannot depend on game animals for food, not only on account of their scarcity but also because of the protection afforded them by the North West Territories Branch. Walrus are absolutely protected and caribou during the greater part of the year.

Excellent fisheries occur both on the coast and on the larger rivers. The principal fish are a so-called salmon-trout, and jackfish. The latter are only found inland.

Prospecting. The country is hardly one that can be recommended to the individual prospector. Difficulties of access, the large stores of provisions and equipment required, and the added hazard of distance in case of accident make it desirable for prospecting to be undertaken by a large organization. The writer will not attempt here to discuss the merits of prospecting by airplane as opposed to prospecting by canoe. Suffice it to say that in the immediate vicinity of the field of work were two large groups of prospectors, each substantially equipped and backed by large mining organizations, the one carrying on all its reconnaissance by airplane, the other by canoe parties alone.

Along the coast are large areas of glacial drift. At Tavane and some 3½ miles to the southward, no outcrops occur. Inland areas of drift are usually largely covered with lakes. Seaward, countless shoals composed entirely of glacial boulders are found. Rocky reefs are present, but are distinctly in the minority.

Available information seems to point to the fact that Ferguson river as far as Kaminuriak lake, lies along the axis of a belt of volcanic rocks extending east-northeast, and intruded both on the borders and within its mass by granitic rocks. Mineralized bodies of small dimensions are quite numerous and are usually pyritic quartz veins.

The coast is difficult and dangerous for small-boat navigation. With the exception of fish, the country cannot be depended upon for game. Individual prospectors are not advised to enter the country unless adequately equipped and prepared for any contingency.

GENERAL GEOLOGY

It is not the purpose of this report to enter into a detailed discussion of the geology of the region. For the use of those entering the country, however, the following brief summary is included.

The geological succession may be represented by the following table.

Glacial drift
Diabasic dykes
Granite
(Intrusive contact)
Volcanic rocks and quartzite
Older granite (?)

The existence of an older granite is suggested by the presence of a contorted granite-gneiss unlike the unaltered granite which is known to intrude the volcanic complex.

The predominant group of rocks found in the area studied is composed of volcanic rocks and quartzite. Among the volcanics are found pillow lavas, tuffs, volcanic breccias, and fine-grained, altered, chloritic rocks. In this group are often found small areas of mineralization, usually pyritic. The quartzite member is composed almost entirely of a white, well-silicified, crossbedded quartzite. On a prominent point about 3 miles north of Tavane quartzite overlies volcanic rocks. At the mouth of Ferguson river quartzite underlies volcanics.

Numerous areas of granite, both large and small, are present. These are composed almost entirely of the fresh, unaltered granite such as was found intruding the volcanics at numerous places, more particularly on the lower reaches of Ferguson river.

Numerous diabasic dykes cut the granite north of Tavane. Some of these dykes are 100 to 150 feet wide. The presence of post-dyke faults is distinctly shown in this area, where one dyke is sharply faulted 300 feet.

DEEP BORINGS IN THE PRAIRIE PROVINCES

By D. C. Maddox

The duties of the Borings Division are to collect samples and records from wells put down for oil and gas, water, coal, or non-metallic minerals, to examine, report on, and store such samples, and to classify and file all information received so that it becomes readily available as a basis for replies to inquiries as to subsurface conditions in the area in question. The nature of the rocks traversed by the drill is determined and this information is correlated with what is known of the geology of the area, so that the geological column of the well is finally determined. The products of value—oil and gas, water, coal, gypsum, etc.—are recorded, the geological horizon from which they were obtained is determined as far as possible, and in the case of fluids or gases the nature of the producing horizon is carefully examined for porosity. The Borings Division, being a part of the Geological Survey, is especially well situated with reference to the determining of the horizons of well samples received, as the division may obtain the expert opinion of the field geologist in regard to rock types and of the palæontologist in the case of fossil remains.

Perhaps in no part of Canada is the value of the work of a division more evident than in the Prairie Provinces. The field geologist in this area is generally handicapped by the lack of outcrops except in the hilly areas. The climatic conditions of a good deal of the agricultural areas in the Prairie Provinces render the question of water supply one of great importance and one the solution of which is in many cases wholly dependent on the drilled well. Within recent years the intensive search for oil and gas has extended to the western provinces. The accumulation of oil and gas in commercial quantities is dependent on structural conditions and in the absence of outcrops the petroleum geologist in working out structure has of necessity to fall back on the results of drilling operations.

Twenty-one years of experience lies behind the operations of the Borings Division.

As regards drilling for water during the current year, though many wells were put down yet little of special interest developed. Information as to the southern Alberta artesian area was received in the form of a record sent in by Mr. H. Rones of a well put down at the Provincial Experimental Farm at Orion, Alberta. Many well drillers and owners co-operated in the work of collecting information. Due chiefly to the co-operation of Mr. Oszust, driller of Beaverlodge, Alberta, the logs of many wells drilled in the area of Wapiti sheet, No. 412, especially in the Beaverlodge, Wembley, and Rio Grande districts, were obtained. Dr. Archibald of the Dominion Experimental Farm kindly obtained the records of all wells drilled for water on the branch farms located in the western provinces. Mr. S. Dempsey, driller of Indian Head, forwarded much information on wells drilled in Indian Head district. Mr. J. G. Douglas forwarded several records from Edmonton district. Messrs. Duff, Flint, and Company of Regina continued the co-operation extended during 1928 in forwarding the logs of several wells drilled for the railways at points located on branch lines. Messrs. Layne, Bowler, and Company forwarded a few records. The names of other drillers and owners will be found in the tabulation that follows.

Some analyses of water were also received by the division and thanks are herewith extended to the senders: Mr. Allan C. Rankin of the University of Alberta for the analysis of water from twenty-four towns in this province; the Gravelbourg municipal authorities for information as to the water supply at that point; and to Mr. J. W. D. Farrell, the Superintendent of Waterworks at Regina, for information as to water conditions in that city.

The regulation of drilling for oil and gas, including the collection of samples and records, is under the jurisdiction of the Supervisory Mining Engineer of the Department of the Interior. The samples, after passing through the Calgary office, however, are forwarded to the Borings Division for examination and storage and the writer acknowledges with pleasure the receipt of much valuable information from the office of the Supervisory Engineer and the spirit of cordial co-operation which has characterized their relations with the Borings Division.

Never in their past history have the Prairie Provinces, more especially Alberta, seen such interest taken in oil and gas developments. The great increase in drilling operations is reflected in the number of samples received during the year—29,066 (*See* lists at end of this report), representing a section approximately 55 miles long and comparing with 16,706 received in 1928. A large proportion of these samples came from wells drilled in Turner valley, but numerous other areas were represented. Many of the fields in which a little exploratory drilling had been done in previous years were drilled either to prove structural conditions or to test horizons that had not been penetrated by previous drilling.

Due to lack of time no large amount of research work was done in connexion with well samples. A line of investigation, however, begun in previous years, was continued during 1929. This consisted of the special examination of field samples brought in by Mr. McLearn from sedimentary formations in southern Saskatchewan and studied by Mr. F. J. Fraser of the Borings Division, this study involving the determination of the heavy minerals and the mechanical analysis by means of elutriation. Mr. Fraser reports that about two hundred slides of heavy minerals obtained from well samples were made. This increases the number of slides made to date from the well material to about six hundred. Time has not permitted of detailed reports being made on most of these slides. One interesting result of this line of investigation is that the mineral hypersthene is apparently widely spread in the drift and, therefore, may prove to be a useful factor in limiting the base of the drift in well samples, a boundary that is often very difficult to fix when drift overlies soft grey shale.

Mechanical analyses of five samples of oil sand from two wells in Wainwright area were made at the request of Mr. Hume.

The number of samples examined during the year was 11,725 and reports were made with respect to 2,448.

Samples from several wells drilled some time back were examined. Of these, two logs of wells in Manitoba are given. In these logs, the numbers given under the heading "Rate of Effervescence with Acid, Cold, Hot," are an attempt to provide a criterion as to the carbonate content of the samples. The numbers refer to the comparative speeds of effervescence in dilute hydrochloric acid of strength 1 : 4. In acid of this strength true dolomite does not effervesce in cold acid, but does effervesce vigorously in hot; the comparative rates of effervescence in cold and hot acid, according to the scale given below, would be 0 and 7 respectively, whereas for limestone they would be 6 and 7. Dolomitic limestones will give figures for effervescence in cold acid intermediate between 0 and 7. Slightly calcareous rocks will give low figures for both hot and cold acid. The method is admittedly approximate, being based on the observer's judgment, but has the advantage of rapidity, a most important one where routine work is done on large numbers of samples. The key to the numbers is given below.

0 No effervescence.
1 Extremely slow.
2 Very slow.
3 Slow.
4 Medium.
5 Fast.
6 Very fast.
7 Extremely fast.

Log of Well of Stony Mountain Oil and Gas Company, Limited, SE. ¼ Sec. 29, Tp. 12, Range 2, E. Prin. Mer.

Depth (in feet)	—	Rate of effervescence with acid		Notes
		Cold	Hot	
~~1 to 2~~	Sand, dark grey	1	1	Medium grained
2 to 7	Dolomite, light grey	2	7	
15 to 30	“ “	2	7	
30 to 115	Limestone, light brown	6	7	
115 to 130	Dolomite, “	2	7	
130 to 140	“ “	2	7	Very little red dolomite
140 to 225	“ “	2	7	“ “
225 to 250	“ “	2	7	
255 to 310	“ light grey	2	7	
310 to 315	Limestone, “	5	7	
315 to 360	“ “	5	7	
365 to 415	“ “	4	7	
415 to 445	“ pink	4	7	
445 to 500	“ “	6	7	
500 to 510	“ “	6	7	
510 to 540	“ light brown	4	7	
540 to 550	“ “	5	7	
550 to 560	“ “	5	7	
560 to 565	Dolomite, “	3	7	
565 to 570	Limestone, “	6	7	
570 to 590	“ “	6	7	
590 to 595	“ “	4	5	
595 to 610	“ “	4	7	
610 to 650	Shale, green-grey	1	4	
650 to 660	“ green	0	1	
660 to 695	“ “	0	1	
695 to 705	Sandstone, light grey	1	1	Coarse grained. Very many grains rounded and etched
705 to 708	“ “	1	1	Coarse grained. Very many grains rounded and etched. Much biotite
708 to 740	Igneous “	1	1	Much biotite
740 to 1,010	“ light brown	1	1	Much green, shaly material. Much biotite

Summary:
First sample, drift
2-610 dolomites and limestones
610-695 greenish shales
695-708 coarse sandstone
708-1,010 igneous
Sulphates absent from all dolomites and limestones; no porous fragments noted

Log of Well, Sec. 29, Tp. 30, Range 17, W. Prin. Mer.

Depth (in feet)		—	Rate of effervescence with acid: Cold	Hot	Notes
25 to	35	Limestone, light brownish grey	6	......	Pyrite } Less than 10% residue after treatment with HCL
35 to	40	" "	7	......	" "
45 to	50	Limestone, dark brown.....	6	......	" "
50 to	60	Limestone, light brown-grey	6	......	" "
60 to	70	Limestone, dark brown.....	6	......	" "
70 to	80	Dolomite, cream...........	3	7	Approximately 10% residue of light-coloured, argillaceous material after treatment with HCL
80 to	100	" "	1	7	} Very pure. Less than 2% residue after treatment with HCL
100 to	115	" "	1	7	A little pyrite " "
115 to	125	" "	1	7	" "
125 to	135	" "	1	7	" "
135 to	145	" "	1	7	" "
145 to	155	" "	1	7	" "
155 to	165	" "	1	7	" "
165 to	175	" "	1	7	A little pyrite " "
175 to	185	" "	1	7	" "
185 to	195	" "	1	7	" "
195 to	205	" "	1	7	" "
205 to	220	" "	1	7	" "
220 to	230	" "	1	7	" "
230 to	240	" "	1	7	" "
250 to	260	" "	1	7	Porous " "
260 to	270	" "	1	7	" "
270 to	280	" "	1	7	" "
280 to	290	" "	1	7	Porous " "
290 to	300	" "	1	7	" "
300 to	310	" "	1	7	" "
310 to	320	" "	1	7	" "
320 to	330	" "	1	7	Porous " "
330 to	340	" "	1	7	" "
340 to	350	" brown..........	1	7	" "
350 to	360	" "	1	7	Less than 10% residue after treatment with HCL
360 to	370	" light brown and brown-red	2	7	Approximately 20% residue after treatment with HCL
370 to	380	" brown..........	1	7	} Less than 5% residue after treatment with HCL
380 to	390	" cream..........	1	7	" "
390 to	400	" brown..........	1	7	" "
400 to	410	" "	1	7	Porous " "
410 to	420	" "	1	7	" "
420 to	430	" cream and reddish	1	7	" "
430 to	440	Brown dolomite, cream and reddish	1	7	Biotite flakes } Less than 5% residue after treatment with HCL
440 to	450	" "	1	7	" "
450 to	460	" cream.....	1	7	" "
460 to	470	" cream and red	1	7	" "
470 to	480	" cream.....	1	7	" "
480 to	490	" brownish grey	1	7	" "
490 to	500	" "	1	7	Approximately 20% residue of light grey, argillaceous material after treatment with HCL
500 to	510	" cream.....	1	7	Less than 5% residue after treatment with HCL
510 to	520	" "	1	7	" " "
520 to	530	" "	1	7	" " "
530 to	540	" "	1	7	" " "

Log of Well, Sec. 29, Tp. 30, Range 17, W. Prin. Mer.—Continued

Depth (in feet)	—	Rate of effervescence with acid: Cold	Rate of effervescence with acid: Hot	Notes
540 to 550	Brown dolomite, cream.....	1	7	Less than 2% residue after treatment with HCL
550 to 560	" "	1	7	" " "
560 to 570	" "	1	7	Less than 10% residue after treatment with HCL
570 to 580	" "	1	7	" " "
580 to 590	" "	1	7	" " "
590 to 600	" "	1	7	Less than 5% residue after treatment with HCL
600 to 610	" "	1	7	
610 to 620	" "	1	7	
620 to 630	" "	1	7	
630 to 640	" "	1	7	
710 to 720	" "	1	7	
730 to 740	" greyish brown	1	7	Very pure. Many well-rounded quartz grains to 0·7 mm.
740 to 750	" "	1	7	" " "
750 to 760	" "	1	7	" " "
760 to 770	" cream.....	1	7	A few well-rounded quartz grains to 0·7 mm.
770 to 780	" "	1	7	Very pure. A few well-rounded quartz grains to 0·7 mm.
780 to 790	" "	1	7	
790 to 800	" greyish brown	1	7	Very pure
800 to 810	" "	1	7	"
810 to 820	" "	1	7	"
820 to 830	" "	2	7	
830 to 840	" cream.....	1	7	
840 to 850	" "	1	7	
850 to 860	" "	1	7	
860 to 870	" "	2	7	
905	" light grey.	3	7	A little calcite
905 to 915	Dolomite, light grey........	3	7	"
915 to 925	" "	4	7	A little calcite. Much argillaceous material.
925 to 930	" "	4	7	" " "
930 to 940	" cream...........	3	7	
940 to 950	" greyish brown...	3	7	A little calcite
950 to 960	" " ...	3	7	"
960 to 970	" " ...	3	7	
970 to 980	" " ...	3	7	
980 to 990	" " ...	3	7	A little calcite
990 to 1,000	" " ...	3	7	"
1,000 to 1,010	" cream..........	3	7	"
1,010 to 1,020	Limestone, "	6	7	
1,020 to 1,030	" "	7	7	
1,030 to 1,040	" "	5	7	
1,040 to 1,050	" "	5	7	
1,050 to 1,060	" "	5	7	
1,060 to 1,070	Dolomite, greyish brown...	4	6	Much limestone
1,070 to 1,075	" " ...	3	7	"
1,075 to 1,080	" " ...	2	7	
1,080 to 1,090	" " ...	2	7	
1,090 to 1,100	" " ...	2	7	
1,100 to 1,110	" " ...	2	7	
1,110 to 1,115	" " ...	2	7	
1,115 to 1,120	" " ...	2	7	
1,120 to 1,135	" " ...	2	7	
1,135 to 1,140	" " ...	4	7	Much limestone
1,140 to 1,145	Limestone, " ...	5	7	
1,145 to 1,150	" " ...	5	7	
1,150 to 1,155	" " ...	4	7	
1,155 to 1,160	" " ...	5	7	

Log of Well, Sec. 29, Tp. 30, Range 17, W. Prin. Mer.—Continued

Depth (in feet)	—	Rate of effervescence with acid: Cold	Rate of effervescence with acid: Hot	Notes
1,160 to 1,165	Limestone, greyish brown...	6	7	
1,165 to 1,170	" " ...	4	7	A little dolomite
1,170 to 1,175	" " ...	6	7	"
1,175 to 1,180	" " ...	6	7	
1,180 to 1,185	" " ...	6	7	
1,185 to 1,190	" " ...	4	7	A little dolomite
1,190 to 1,195	" " ...	6	7	
1,195 to 1,200	" " ...	6	7	
1,200 to 1,205	" " ...	7	7	
1,205 to 1,210	" " ...	7	7	
1,210 to 1,215	" " ...	7	7	
1,215 to 1,220	" " ...	7	7	
1,220 to 1,225	" " ...	6	7	
1,225 to 1,230	" " ...	6	7	
1,230 to 1,235	" " ...	6	7	
1,235 to 1,240	" " ...	6	7	
1,240 to 1,250	" " ...	6	7	
1,250 to 1,255	" " ...	6	7	
1,255 to 1,260	" " ...	6	7	
1,260 to 1,265	" " ...	6	7	
1,265 to 1,270	" " ...	6	7	
1,270 to 1,275	" " ...	6	7	
1,275 to 1,280	" " ...	6	7	
1,280 to 1,285	" " ...	6	7	
1,285 to 1,290	" " ...	6	7	
1,290 to 1,300	" " ...	6	7	
1,300 to 1,310	" " ...	6	7	
1,310 to 1,320	" " ...	6	7	
1,320 to 1,330	" " ...	6	7	
1,330 to 1,340	Limestone and sandstone, greyish brown	5	7	Coarse-grained, well-rounded sandstone up to 0·7 mm.
1,340 to 1,350	Shale, grey................	0	0	
1,350 to 1,360	" "	0	0	
1,360 to 1,365	" brownish grey.......	0	0	
1,365 to 1,385	" "	0	0	
1,385 to 1,400	" "	0	0	
1,400 to 1,405	" greenish grey........	0	0	
1,405 to 1,410	" "	0	1	
1,410 to 1,415	Sand, light brown...........	0	1	Medium to coarse grained. Well rounded
1,415 to 1,420	Sandstone, brownish grey...	0	3	Well rounded. A little grey shale
1,420 to 1,425	" light brown......	1	1	Well rounded. Coarse grained.
1,425 to 1,430	" white...........	0	0	" "
1,430 to 1,435	" "	0	0	" "
1,435 to 1,436	Shale, greyish green.........	0	0	Much coarse sand
1,436 to 1,437	Sand, brown................	0	0	Well rounded. Coarse grained
1,437 to 1,438	" white................	0	0	" "
1,438 to 1,440	" "	0	1	" "
1,440 to 1,444	" light brown...........	0	0	" "
1,444 to 1,447	Kaolinized, greenish grey, igneous rock	......	......	A little coarse sand
1,447 to 1,450	Sandstone, light grey........	1	1	Very coarse grained. A very little kaolinized rock
1,450 to 1,455	" "	1	1	Biotite } Coarse grained. Well rounded
1,455 to 1,458	" "	0	1	} " "
1,458 to 1,460	Kaolinized, greyish green, igneous rock			
1,460 to 1,462	" "			
1,462 to 1,468	Sandstone, brown...........	0	3	Coarse grained. Well rounded
1,468 to 1,469	Kaolinized, greenish grey, igneous rock			
1,469 to 1,470	Igneous rock, brown.........	1	2	Quartz. Biotite and hornblende
1,470 to 1,473	" "	1	2	" " "
				NOTE. All samples tested for sulphates with negative results.

Deep Wells (Samples and Logs Received During the Year)

Location					Description				Remarks
Ls.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
					ACADIA VALLEY				
16	34	25	4	4th......	1929	....	3,165	99	Fuego Oil Company No. 1
					ATHABASKA RIVER				
10	32	96	10	4th......	1929	....	240	25	International Bitumen No. 4
					BEAVER DOME				
10	24	2	11	4th......	1929	....	1,755	130	Madison No. 2
					BOW RIVER				
11	31	24	4	5th......	1929	....	3,527	428	Imperial Oil Co., Bow River No. 2
					CHAMPION				
8	8	16	23	4th......	1929	....	412	50	Hudson Bay Marland Oil Co., Champion No. 1
8	16	16	23	4th......	1929	....	112	20	" " " No. 2
16	15	16	23	4th......	1929	....	157	27	" " " No. 3
15	20	16	23	4th......	1929	....	100	21	" " " No. 4
6	22	16	23	4th......	1929	....	125	19	" " " No. 5
5	17	16	23	4th......	1929	....	100	20	" " " No. 6

Deep Wells (Samples and Logs Received During the Year)—Continued

Location					Description				Remarks
Ls.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
CHAMPION—Continued									
9	14	16	23	4th......	1929	....	135	22	Hudson Bay Maryland Oil Co., Champion No. 7
8	10	16	23	4th......	1929	....	135	24	" " " No. 8
1	3	16	23	4th......	1929	....	250	50	" " " No. 9
1	11	16	23	4th......	1929	....	100	15	" " " No. 10
16	12	16	23	4th......	1929	....	100	17	" " " No. 11
1	9	16	23	4th......	1929	....	201	45	" " " No. 12
2	17	16	23	4th......	1929	....	166	36	" " " No. 13
14	17	16	23	4th......	1929	....	69	13	" " " No. 14
3	21	16	23	4th......	1929	....	109	22	" " " No. 15
4	22	16	23	4th......	1929	....	124	27	" " " No. 16
6	15	16	23	4th......	1929	....	90	19	" " " No. 17
2	15	16	23	4th......	1929	....	98	17	" " " No. 18
14	9	16	23	4th......	1929	....	268	66	" " " No. 20
4	9	16	23	4th......	1929	....	102	28	" " " No. 21
8	8	16	23	4th......	1929	....	52	13	" " " No. 22
15	17	16	23	4th......	1929	....	100	25	" " " No. 23
10	6	16	23	4th......	1929	....	112	28	" " " No. 24
15	17	16	23	4th......	1929	....	68	17	" " " No. 25
10	9	16	23	4th......	1929	....	114	28	" " " No. 26
9	9	16	23	4th......	1929	....	160	40	" " " No. 27
10	17	16	23	4th......	1929	....	140	36	" " " No. 28
9	9	16	23	4th......	1929	....	164	41	" " " No. 29
16	8	16	23	4th......	1929	....	180	45	" " " No. 30
10	16	16	23	4th......	1929	....	184	46	" " " No. 31
9	9	16	23	4th......	1929	....	126	32	" " " No. 32
2	17	16	23	4th......	1929	....	200	50	" " " No. 33
	17	16	23	4th......	1929	....	228	57	" " " No. 34
8	16	16	23	4th......	1929	....	300	75	" " " No. 35
16	7	16	23	4th......	1929	....	288	36	" " " No. 36
16	12	16	24	4th......	1929	....	172	22	" " " No. 37
16	24	16	24	4th......	1929	....	140	18	" " " No. 38
8	19	16	23	4th......	1929	....	176	22	" " " No. 39
9	9	16	23	4th......	1929	....	2,130	209	Alberta Gas and Fuel Co., Champion No. 1

					CYPRESS HILLS				
9	31	7	4	4th.......	1929	3,623	4,000	139	Eagle Butte Co., No. 1
					DAUPHIN				
	14	24	20	1st.......	1929	....	890	93	Dauphin Oil Co., No. 1
					EDEN VALLEY				
14	35	28	8	3rd.......	1929	....	390	19	Eden Valley Oils, Ltd.
					EYREMORE				
4	36	17	18	4th.......	1929	....	240	46	Hudson Bay Marland Oil Co., Eyremore No. 1
13	24	17	18	4th.......	1929	....	201	45	" " " No. 2
5	25	17	18	4th.......	1929	....	125	10	" " " No. 3
14	23	17	18	4th.......	1929	....	201	8	" " " No. 4
12	23	17	18	4th.......	1929	....	268	62	" " " No. 5
13	13	17	18	4th.......	1929	....	180	41	" " " No. 6
2	25	17	18	4th.......	1929	....	93	17	" " " No. 7
1	25	17	18	4th.......	1929	....	84	21	" " " No. 8
2	25	17	18	4th.......	1929	....	108	28	" " " No. 9
10	24	17	18	4th.......	1929	....	128	31	" " " No. 10
11	24	17	18	4th.......	1929	....	164	41	" " " No. 11
11	23	17	18	4th.......	1929	....	168	42	" " " No. 12
8	26	17	18	4th.......	1929	....	128	31	" " " No. 13
5	24	17	18	4th.......	1929	....	144	36	" " " No. 14
7	26	17	18	4th.......	1929	....	236	59	" " " No. 15
9	23	17	18	4th.......	1929	....	88	22	" " " No. 16
6	23	17	18	4th.......	1929	....	412	67	" " " No. 17
	25	17	18	4th.......	1929	....	100	25	" " " No. 18
13	25	17	18	4th.......	1929	....	352	63	" " " No. 19
10	25	17	18	4th.......	1929	....	160	29	" " " No. 20
1	26	17	18	4th.......	1929	....	280	35	" " " No. 21
15	2	18	18	4th.......	1929	....	156	20	" " " No. 22
	2	18	18	4th.......	1929	....	360	46	" " " No. 23
15	2	18	18	4th.......	1929	....	352	45	" " " No. 24

Deep Wells (Samples and Logs Received During the Year)—Continued

Location					Description				Remarks
Ls.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
					GHOST RIVER				
1	19	27	6	5th.......	1929	....	2,270	222	Atlantic Keystone No. 1
15	5	27	6	5th.......	1929	....	850	90	Baymar No. 1
					HERRON STRUCTURE				
3	24	22	6	5th.......	1929	....	650	58	Herron Petroleum No. 1
					HIGH RIVER				
16	13	20	29	4th.......	1929	....	3,480	68	Ranchmen's Oil and Gas Co., No. 1
					HIGHWOOD				
6	34	17	3	5th.......	1929	....	470	43	Banner No. 1
8	1	18	3	5th.......	1929	4,074·4	930	90	Hudson Bay Marland Oil Co., Highwood No. 1
3	36	18	3	5th.......	1929	4,074·4	4,220	65	Imperial Highwood No. 1
3	28	18	3	5th.......	1929	....	250	23	Warner No. 2
3	28	18	3	5th.......	1929	....	480	46	Warner No. 3
					KEHO				
8	18	11	22	4th.......	1929	....	281	70	Hudson Bay Marland Oil Co., Keho No. 1
	18	11	22	4th.......	1929	....	200	50	" " " No. 2
	18	11	22	4th.......	1929	....	258	64	" " " No. 3

8	7	11	22	4th.......	1929	....	237	59	" " " No. 4
	17	11	22	4th.......	1929	....	379	96	" " " No. 5
	8	11	22	4th.......	1929	....	304	76	" " " No. 6
	17	11	22	4th.......	1929	....	348	86	" " " No. 7
	17	11	22	4th.......	1929	....	212	53	" " " No. 8
12	9	11	22	4th.......	1929	....	301	38	" " " No. 9
9	9	11	22	4th.......	1929	....	300	38	" " " No. 10
3	11	11	22	4th.......	1929	....	300	38	" " " No. 11
3	11	11	22	4th.......	1929	....	300	38	" " " No. 11
7	16	11	22	4th.......	1929	....	300	40	" " " No. 12
6	8	11	22	4th.......	1929	....	300	38	" " " No. 14
KINSELLA									
3	29	48	10	4th.......	1929	....	2,070	181	J. P. McDonald No. 1
LETHBRIDGE									
	36	8	22	4th.......	1929	....	1,802	151	Lethbridge Breweries No. 1
MILK RIVER									
4	4	2	12	4th.......	1929	....	2,660	161	Capital Oil Company, No. 1A
8	9	3	15	4th.......	1929	....	2,862	244	Commonwealth Petroleum No. 1
					1929	....	165	37	Geddes, Bletcher, Gayner, Ltd., No. 3
3	14	3	11	4th.......	1929	....	95	20	" " " No. 6
6	21	1	11	4th.......	1929	....	2,050	104	Range Oil and Gas Company, No. 2
MOOSE DOME									
16	29	22	6	5th.......	1929	....	490	43	Moose Oils No. 1
MOOSE MOUNTAIN									
11	35	22	5	5th.......	1929	....	2,557	302	Elbow No. 1
9	34	23	5	5th.......	1929	....	3,640	165	Signal Hill No. 2

Deep Wells (Samples and Logs Received During the Year)—Continued

Location					Description				Remarks
Ls.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
				MORLEY RESERVE					
....	....	....	....	....	1929	....	1,530	162	Norcon No. 1
....	....	....	....	....	1929	....	1,010	68	Gold Coin No. 2
				NEW BLACK DIAMOND					
4	35	19	3	5th.......	1929	....	730	24	Vanberta No. 1
1	3	20	3	5th.......	1929	....	3,510	218	Weymarn Petroleum, New Black Diamond No. 1
5	35	19	3	5th.......	1929	....	3,630	327	Outwest Petroleum No. 1
				PIKE LAKE					
8	13	34	7	5th.......	1929	....	1,810	57	Pike Lake No. 1
				PINCHER CREEK					
16	14	4	30	4th.......	1929	....	4,095	283	Alberta Gas and Fuel Co., Drywood No. 1
				QU'APPELLE VALLEY					
	26	21	29	2nd.......	1929	....	568	9	Gessel-Detta

					RED COULÉE				
	14	1	16	4th.......	1929	....	102	18	A. P. Con. Test Exploration Co., No. 7
	11	1	17	4th.......	1929	....	366	103	" " " No. 9
4	2	1	17	4th.......	1929	....	425	47	" " " No. 10
3	1	1	17	4th.......	1929	....	410	37	Ko-Top Oils, Ltd., No. 1
3	4	1	16	4th.......	1929	....	2,471	192	Vanalta No. 1
					RIBSTONE				
3	16	45	1	4th.......	1929	1,935·0	....	2	Meridian No. 1
5	25	46	1	4th.......	1929	....	3·230	356	Ribstone Oils No. 2
					RICKERT FIELD				
2	24	19	7	5th.......	1929	....	1,130	110	Indian Oils No. 1
					SIMPSON				
2	9	29	25	2nd.......	1929	....	2,195	7	Simpson Oil Company, Roycroft No. 1
					SKIFF				
9	36	6	15	4th.......	1929	....	822	72	Dauntless No. 1
4	27	5	14	4th.......	1929	....	3,067	314	Devenish Petroleum No. 3
					SUFFIELD				
15	4	17	8	4th.......	1929	....	3,220	154	Ontario Alberta No. 1

Deep Wells (Samples amd Logs Received During the Year)—Continued

Location					Description				Remarks
Ls.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
						TURNER VALLEY			
16	19	19	2	5th.......	1929	4,229·8	3,420	75	Advance No. 5
16	19	19	2	5th.......	1929	4,229·8	2,750	172	" No. 5A
16	22	20	3	5th.......	1929	....	1,560	138	Anaconda No. 1
5	20	19	2	5th.......	1929	....	4,850	416	A.P. Con. Test Exploration No. 1
5	20	19	2	5th.......	1929	....	4,450	395	" " No. 2
13	20	19	2	5th.......	1929	....	4,230	354	Baltac No. 1
6	12	20	3	5th.......	1929	....	5,077	207	British Dominion No. 2
11	20	19	2	5th.......	1929	....	4,050	315	Calmont No. 2
2	1	20	3	5th.......	1929	....	1,540	131	" No. 3
11	20	19	2	5th.......	1929	....	3,790	198	" No. 4
3	34	20	3	5th.......	1929	....	4,060	247	" No. 5
11	20	19	2	5th.......	1929	....	3,750	210	" No. 6
11	20	19	2	5th.......	1929	....	1,110	105	" No. 7
7	9	19	2	5th.......	1929	....	4,390	227	Commonwealth, Turner Valley No. 1
7	9	19	2	5th.......	1929	....	2,760	119	" " No. 2
12	34	20	3	5th.......	1929	....	3,250	193	Dalfin No. 1
10	31	19	2	5th.......	1929	....	4,260	379	Dalhousie No. 7
2	24	20	3	5th.......	1929	....	5,080	443	Dome No. 1
5	16	19	2	5th.......	1929	....	4,314	260	East Crest No. 1
4	16	19	2	5th.......	1929	....	1,823	167	" No. 2
8	1	20	3	5th.......	1929	3,971·5	4,684	117	Foothills No. 2
16	8	19	2	5th.......	1929	....	5,478	551	" No. 3
1	26	20	3	5th.......	1929	....	4,540	460	" No. 4
4	3	21	3	5th.......	1929	....	2,150	56	Freehold No. 1
8	20	19	2	5th.......	1929	....	3,830	320	" No. 2
10	1	20	3	5th.......	1929	....	4,230	429	Freeman Lundy No. 1
10	20	19	2	5th.......	1929	....	4,050	288	Hargal No. 1
10	20	19	2	5th.......	1929	4,198·7	5,280	1	Home Oil Co., No. 1
10	20	19	2	5th.......	1929	....	5,416	534	" No. 4
7	20	19	2	5th.......	1929	....	3,150	311	" No. 5
5	16	19	2	5th.......	1929	....	3,440	304	Homestead No. 1
14	20	19	2	5th.......	1929	4,204·6	5,353	30	Home Oil Co., No. 2

10	20	19	2	5th.......	1929	4,206·3	5,033	87	" No. 3
12	4	19	2	5th.......	1929	....	2,570	230	Hylo No. 1
14	17	19	2	5th.......	1929	....	4,330	394	Lowery Petroleum No. 1
10	17	19	2	5th.......	1929	4,215·8	5,660	130	Mayland No. 1
8	17	19	2	5th.......	1929	....	3,460	308	" No. 2
7	17	19	2	5th.......	1929	....	3,700	347	" No. 3
16	1	20	3	5th.......	1929	4,004·9	4,414	12	McLeod No. 2
16	1	20	3	5th.......	1929	4,029·0	4,880	4	" No. 3
16	1	20	3	5th.......	1929	4,007·0	5,230	162	" No. 4
15	1	20	3	5th.......	1929	....	1,100	86	" No. 5
13	4	19	2	5th.......	1929	....	3,930	350	Mercury No. 1
11	4	19	2	5th.......	1929	....	3,290	280	" No. 2
13	27	19	2	5th.......	1929	....	4,320	378	Merland No. 1
9	1	20	3	5th.......	1929	....	3,500	312	Midfield No. 1
4	31	19	2	5th.......	1929	....	1,750	14	Midroyal No. 1
14	4	19	2	5th.......	1929	....	2,805	14	Mill City No. 1A
14	4	19	2	5th.......	1929	....	2,260	172	" No. 1
11	4	19	2	5th.......	1929	....	3,390	254	Miracle No. 1
8	22	20	3	5th.......	1929	....	5,425	238	Model No. 1
14	12	20	3	5th.......	1929	4,017·8	5,330	90	New McDougall-Segur No. 2
14	12	20	3	5th.......	1929	....	2,520	169	" " No. 4
6	20	19	2	5th.......	1929	....	5,260	280	North West Associated No. 1
1	1	20	3	5th.......	1929	3,958·9	5,040	1	Okalta Oils, Ltd., No. 1
9	1	20	3	5th.......	1929	3,979·1	3,600	46	" No. 2
9	1	20	3	5th.......	1929	....	2,710	64	" No. 3
8	1	20	3	5th.......	1929	....	1,660	113	" No. 4
7	1	20	3	5th.......	1929	....	1,540	134	" No. 5
8	1	20	3	5th.......	1929	....	160	12	Ranger No. 2
16	1	20	3	5th.......	1929	4,001·3	3,870	22	Regent No. 1
16	1	20	3	5th.......	1929	....	1,860	156	" No. 2
16	1	20	3	5th.......	1929	....	2,100	175	" No. 3
3	13	20	3	5th.......	1929	....	5,050	333	Royalite No. 12
5	13	20	3	5th.......	1929	4,000·6	4,930	61	" No. 13
1	12	20	3	5th.......	1929	4,022·2	3,030	63	" No. 15
2	12	20	3	5th.......	1929	4,045·7	5,260	177	" No. 16
13	6	20	2	5th.......	1929	....	4,030	40	" No. 17
15	12	20	3	5th.......	1929	....	3,826	38	" No. 18
5	6	20	2	5th.......	1929	....	4,625	328	" No. 19
7	12	20	3	5th.......	1929	....	3,208	137	" No. 20
1	13	20	3	5th.......	1929	....	4,400	396	" No. 21
13	13	19	2	5th.......	1929	....	4,190	409	" No. 23
6	1	20	3	5th.......	1929	....	2,830	276	Sioux City No. 1
14	13	20	3	5th.......	1929	....	5,090	15	Spooner Oil Co., No. 2
9	5	19	2	5th.......	1929	....	1,930	179	Spray No. 1
15	33	18	2	5th.......	1929	....	4,200	409	Sterling Pacific No. 1
7	31	19	2	5th.......	1929	....	2,170	209	Structure No. 1
2	4	19	2	5th.......	1929	....	4,040	312	Sunlight No. 1
2	27	20	3	5th.......	1929	....	2,940	68	Turner basin

Deep Wells (Samples and Logs Received During the Year)—Continued

Location					Description				Remarks
Ls.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
					TURNER VALLEY—*Continued*				
2	24	20	3	5th.......	1929	....	5,370	63	United Oils No. 4
5	34	20	3	5th.......	1929	....	2,620	247	Vanalta, Turner Valley No. 1
7	14	20	3	5th.......	1929	....	3,550	254	Vimy Oils No. 1
1	20	19	2	5th.......	1929	....	4,020	357	Wellington No. 1
11	12	20	3	5th.......	1929	....	3,230	261	Widney Oils No. 1
					TWIN DOME				
10	16	21	28	4th.......	1929	....	400	32	Twin Dome Oil Co., Ltd., No. 1
					VERA				
	14	41	24	3rd.......	1929	....	3,180	109	Citizen's Oil and Gas Co., Unity Valley No. 2
13	14	41	24	3rd.......	1929	....	425	24	" " " No. 3
					VERMILION HILLS				
14	25	20	7	3rd.......	1929	....	450	30	Vermilion Hills Oil and Gas Association No. 1
					VIKING				
5	18	49	12	4th.......	1929	....	3,035	430	Hudson Bay Marland Oil Co., Viking No. 1
16	2	49	13	4th.......	1929	....	2,140	424	Northwest Utilities, Viking No. 15

WAINWRIGHT-FABYAN

16	36	44	7	4th.......	1929	....	2,043	175	Admiral No. 1
8	24	45	8	4th.......	1929	....	1,833	9	Fabyan Petroleum No. 1
9	36	44	7	4th.......	1929	....	2,213	12	Wainwell No. 1
15	36	44	7	4th.......	1929	2,191·05	2,029	2	" No. 2
9	36	44	7	4th.......	1929	2,215·07	2,068	1	" No. 3
15	36	44	7	4th.......	1929	2,206·9	2,052	72	" No. 4

WAITE VALLEY

4	27	19	3	5th.......	1929	....	130	2	Anglo-Pacific No. 1
8	33	19	3	5th.......	1929	....	790	39	Angus Oils No. 1
11	21	19	3	5th.......	1929	....	1,630	111	C. D. and P. No. 1
4	18	20	3	5th.......	1929	....	1,170	58	Gibraltar No. 1
2	6	20	3	5th.......	1929	....	1,970	180	Innerfold Oils, Ltd., No. 1
	25	20	3	5th.......	1929	....	3,070	247	Richfield No. 1
16	27	19	3	5th.......	1929	....	210	13	Rosalite No. 1

WILDCAT HILLS

2	9	27	5	5th.......	1929	....	1,560	62	Frontier No. 1

Shallow Wells (Logs Received During the Year)

Ls.	Sec.	Tp.	Range	Mer.	At or near	Flevation above sea-level Feet	Depth in feet and inches covered by records	Depth in feet to first rock	Depth from surface to water	Owner	Driller
	5	3	5	1st	Morden, Man.	988	11 9	....	9	Experimental Farm	
	....	3	5	1st	"	988	11 9	....	9	" "	
	5	3	5	1st	"	990	18 –	....	16	" "	
	5	3	5	1st	"	988	12 –	....	11	" "	
	35	9	10	1st	Lavenham, Man.	....	132 –	....	....	Canadian National railway	
	33	10	13	1st	Melbourne, Man.	1,265	55 –	....	50	Collart Bros.	N. Coutts
14	27	10	19	1st	Brandon, Man.	90	28 –	....	27	Experimental Farm	
13	27	10	19	1st	"	100	25 –	....	25	" "	
	27	10	19	1st	"	70	16 –	....	15	" "	
	27	10	19	1st	"	60 above river	18 –	....	14	" "	
	27	10	19	1st	"	80 above valley	25 –	....	23	" "	
	....	33	20	1st	Alonsa, Man.	....	110 –	80	110	Fort Smith	Fort Smith
	35	25	4	2nd	Yorkton, Sask.	15 above railway	90 –	....	72	Yorkton city	B. Hatherley
	2	3	5	2nd	Hirsch, Sask.	....	360 –	....	....	C. Zelickson	C. Zelickson
	28	14	11	2nd	Montmartre, Sask.	....	183 –	....	1,182	G. Gratton	S. Dempsey
7	34	14	11	2nd	"	....	159 –	....	156	E. Parren	"
	32	13	11	2nd	"	....	163 –	....	162	R. Swinton	"
	26	48	11	2nd	Melfort, Sask.	....	....	....	....	H. Brown	
3	12	18	12	2nd	Sintaluta, Sask.	....	113 –	112	112	J. Lewthwaite	"
	6	19A	12	2nd	Indian Head, Sask.	....	268 –	....	250	F. B. Holden	"
9	11	14	12	2nd	Montmartre, Sask.	....	111 –	....	104	J. Parker	"
9	7	19	13	2nd	Indian Head, Sask.	....	93 –	....	91	G. B. Prior	"
	26	18	13	2nd	"	....	196 –	....	194	B. F. Holden	"
	31	14	13	2nd	Odessa, Sask.	....	345 –	....	....	J. P. Schroeder	"
	32	16	13	2nd	Indian Head, Sask.	....	126 –	....	122	B. F. Holden	"
	1	18	13	2nd	"	....	41 –	....	33	Mr. Oldham	"
3	2	19	13	2nd	"	....	205 –	....	201	A. Woods	"
4	15	19	13	2nd	"	....	200 –	....	182	J. Heaslip	"
2	32	17	13	2nd	"	....	310 –	....	310	N. J. Sandercock	"
	30	8	14	2nd	Weyburn, Sask.	....	66 –	....	22	Weyburn city	Layne Bowler Co.
	34	47	14	2nd	Armley, Sask.	20 above river	175 –	135	....	B. Farmer	G. Hedman

	6	48	14	2nd	"	20 "	250	–	150		A. E. Nechlin	"
	31	47	14	2nd	"	20 "	140	–	135		C. Nechlin	"
	26	16	17	2nd	McLean, Sask.		310	–		300	H. C. Packham	S. Dempsey
	26	17	19	2nd	Regina, Sask.		141	–		105	Regina city	Kelly Well Co.
	24	20	20	2nd	Tregarva, Sask.		150	–		140	T. Patterson	T. Hay
	19	20	20	2nd	Regina, Sask.		252	–		248	D. J. Matheson	"
13	29	18	26	2nd	Tuxford, Sask.		41½	–		30	E. Mathieson	N. Franks
	34	27	25	2nd	Imperial, Sask.						W. Y. Porter	
	3	29	25	2nd	Simpson, Sask.						W. Y. Porter	
					Regina, Sask.		209	–			Western Manufacturing Co.	
		42	3	3rd	Rosthern, Sask.	1,680	40	–		20	Dom. Experimental Farm	
	1	11	5	3rd	Gravelbourg, Sask.		141	–		141	Gravelbourg town	T. Hay
	36	10	5	3rd	" "		143	–		143	" "	"
	1	6	7	3rd	McCord, Sask.		186	–			Can. Pac. railway	Duff, Flint, and Co.
	35	4	9	3rd	Mankota, Sask.		160	–			" "	" "
		29	12	3rd	Sovereign, Sask.		509	–		487	E. Mourre	S. Dempsey
2	2	30	13	3rd	"	2,000	490	–		490	W. Roesch	C. Fortin
		39	20	3rd	Scott, Sask.	2,178	216½	–		216	Agriculture Dept.	A. Anderson
		39	20	3rd	"	2,181	71	–		71	" "	"
	18	29	2	4th	Sibbald, Alta.		332	–		332	E. Armistead	J. Oszust
	3	29	3	4th	Benton, Alta.	75 above station	216	–	100	155	W. S. Hoover	"
		2	3	4th	Medicine Hat, Alta.		342	–		318	H. I. Wallace	O. K. Davies
		29	4	4th	Oyen, Alta.	2,500	213	–		213	C. McMurray	J. Oszust
5	6	6	6	4th	Orion, Alta.	2,250	820	–	350	776	G. Wagar	H. Rones
	7	6	8	4th	Medicine Hat, Alta.		1,225	–		200	O. J. Morrison	J. B. Holbert
	11	58	10	4th	St. Paul de Metis, Alta.		435	–			Industrial School	J. Douglas
	18	52	24	4th	Edmonton, Alta.		178	–	170	168	M. Ross	"
	19	52	24	4th	"		130	–		130	P. O. Hanson	"
	32	52	24	4th	"		273	–		273	Northeast Edmonton	"
	19	52	24	4th	"		168	–		168	C. Wilson's Dairy	"
	32	52	24	4th	"		240	–			MacDonald Hotel	
	32	52	24	4th	"		300	–			" "	
	32	52	24	4th	"		300	–			Northwest Brewing Co.	
	24	40	27	4th	Lacombe, Alta.	2,798	220	–	115	218	Dom. Experimental Station	G. Colby
	24	72	10	5th	Kinuso, Alta.	45 above river	18	–		18	W. L. McKillip	G. Colby
	16	71	8	6th	Wembley, Alta.	2,300	172	–	172	172	J. Miller	J. Oszust
	15	71	8	6th	"		131	–		131	R. Kranz	"
14	9	71	9	6th	"		276	–		276	A. Sherk and Sons	Hansen and McQuilty
	17	71	9	6th	"		166	–	69	166	C. F. Edgerton	S. Natros

Shallow Wells (Logs Received During the Year)—Continued

Ls.	Sec.	Tp.	Range	Mer.	At or near	Elevation above sea-level Feet	Depth in feet and inches covered by records	Depth in feet to first rock	Depth from surface to water	Owner	Driller
1	14	71	9	6th	"	....	131 –	30	131	J. Ulmer	J. Oszust
....		72	9	6th	"	....	160 –	155	155	G. Gitzel	"
3	31	72	10	6th	Homney, Alta	50 above river	108 –	....	104	O. Homney	C. Foster
4	25	71	10	6th	Beaverlodge, Alta	2,100	87 –	....	87	R. L. Perry	J. Oszust
1	15	71	10	6th	"	2,400	275 –	....	270	E. J. McNaught	Hansen and Mc-Quilty
	1	72	10	6th	"	2,485	230 –	102	135	W. D. Albright	G. S. Scott
	2	72	10	6th	"	....	185 –	....	185	J. A. Beaudet	C. J. Foster
	22	72	10	6th	"	....	228 –	185	170	Mrs. M. E. Fowler	S. Wager
	2	72	10	6th	"	....	234 –	100	234	R. Ireland	J. Oszust
	10	72	10	6th	"	30 above railway	171½ –	165	170	A. Johnson	"
1	15	71	10	6th	"	....	34 –	....	....	E. J. McNaught	
4	25	71	10	6th	"	2,100	50 –	....	....	R. L. Perry	
15	30	72	10	6th	Homney, Alta	....	108 –	....	90	Homney Dairy Farm	H. O. Homney
16	24	72	11	6th	Clearview, Alta	300 above river	153 –	130	150	J. Anderson	C. J. Foster
	33	71	11	6th	Halcourt, Alta	....	165 –	24	161	O. Ringstrom	J. Oszust
	14	71	11	6th	"	100 above railway	55 –	20	55	S. Bark	"
	5	71	11	6th	Rio Grande, Alta	....	298 –	....	290	A. J. Hill	"
	33	70	12	6th	"	....	100 –	80	25	J. D. Brown	"
	36	70	12	6th	"	....	81 –	20	76	E. F. MacDonnell	M. Sheridan
	1	71	12	6th	"	200 above river	125 –	15	125	J. O'Connell	C. Foster
	25	70	12	6th	"	....	65 –	40	60	D. Ramsay	Mr. Foster
	35	70	12	6th	"	45 above river	46 –	15	42	B. C. Scully	
	....	....	....	....	....	....	260 –	....	250	Burns and Co., Ltd.	Ontario Wind Engine and Pump Co.

OTHER FIELD WORK

Geological

B. R. MacKay. Mr. MacKay studied and mapped various coal-bearing areas in Alberta in the vicinity of Brûlé and Pocahontas and to the northward on Hay river. He also visited Smoky River coal area.

W. A. Johnston. Mr. Johnston completed the investigation of the surface geology, including the soils of the greater part of an area in southern Manitoba and southeastern Saskatchewan between latitudes 49 degrees and 52 degrees and from the Ontario boundary to longitude 102 degrees. He also commenced similar work in the area (Regina sheet) to the west in southern Saskatchewan, between latitudes 49 degrees and 52 degrees and longitudes 102 degrees and 109 degrees.

J. R. Marshall. Mr. Marshall commenced the geological mapping of the Pelican Narrows quadrangle (latitudes 55 degrees to 56 degrees, longitudes 102 degrees to 104 degrees), Saskatchewan.

S. H. Ross. Mr. Ross geologically and, in part, geographically surveyed an area of about 100 square miles centring about Ruttenstone lake, northern Saksatchewan.

C. H. Stockwell. Mr. Stockwell geologically mapped about one-fourth of a quadrangle that includes that part of the eastern portion of Great Slave lake, North West Territories, lying between latitudes 62 degrees and 63 degrees and longitudes 110 degrees and 112 degrees.

Topographical

D. A. Nichols. Mr. Nichols completed the topographical mapping of the east half of the Wildcat Hills sheet, latitudes 51° 15′ to 51° 30′, longitudes 114° 30′ to 115° 00′, Alberta.

W. H. Miller. Mr. Miller commenced the topographical mapping of the Brûlé sheet, latitudes 53° 15′ to 53° 30′, longitudes 117° 30′ to 118° 00′, Alberta.

R. C. McDonald. Mr. McDonald completed the triangulation control for the Brûlé sheet, latitudes 53° 15′ to 53° 30′, longitudes 117° 30′ to 118° 00′, and commenced the topographical mapping of the Nordegg sheet, latitudes 52° 15′ to 52° 30′, longitudes 116° 00′ to 116° 30′, Alberta.

INDEX

The Annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are three parts, A, B, and C. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.