This document was produced
by scanning the original publication.

Ce document est le produit d'une
numérisation par balayage
de la publication originale.

CANADA

DEPARTMENT OF MINES

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

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

# Summary Report, 1927, Part B

CONTENTS



OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928

No. 2172

C 212

CANADA

DEPARTMENT OF MINES

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

## GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

# Summary Report, 1927, Part B

CONTENTS




OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928

No. 2172


MINES BRANCH LIBRARY

HINES BRANCH
LIBRARY

# OIL PROSPECTS NEAR BRAGG CREEK, ALBERTA

*By G. S. Hume*

## CONTENTS



## INTRODUCTION

During the summer of 1926 the Geological Survey topographically mapped an area lying between longitudes 114° 30′ and 114° 45′ and extending approximately 6½ miles north and 8 miles south of latitude 51°. This area comprises what is known as the south half of Jumpingpound sheet and the north half of Bragg Creek sheet. It includes: the western part of the north half of township 22 and all of townships 23 and 24, range 4; the north half of township 22, and all of townships 23 and 24, range 5; and the eastern part of the north half of township 22 and all of townships 23 and 24, range 6. The southwestern part of the area lies within the Bow River Forest Reserve and the mapped part of township 23, range 4, constitutes the western end of the Saracee Indian Reserve. During the summer of 1927 this area was geologically mapped by the writer assisted by W. A. Kelly, J. F. Caley, and A. F. Matheson, to whom the writer wishes to express his thanks.

## PHYSIOGRAPHY

The area studied in 1927 lies wholly within the Foothills belt. The maximum relief is approximately 1,700 feet, the lowest elevations, 4,000 feet, occur in the northeast and the highest, 5,700 feet, in the southwest. The summits of many of the hills approach 5,000 feet in elevation. As a general rule, the hills trend northwest-southeast in conformity with the strike of the strata and the trend of the mountains to the west. This results in numerous parallel hills and ridges separated by wide valleys many of which are occupied by fairly extensive muskeg areas. The topography as a whole is an expression of differential weathering and invariably the ridges and hills are composed of hard, resistant rocks, whereas the valleys are underlain by softer shales. The influence of thrust faulting is, in places, apparent in the topography, the east edge of the overthrust forming a steep, eastward face to the ridge or hill, whereas the gradient of the western slope reflects the westward dip of the strata. This effect, however, is to a large extent modified by the unequal resistance to weathering of the rocks even within one formation, and where the rocks are highly tilted the degree of slope of the west side may be as great or greater than the east slope.

Elbow river and Jumpingpound creek flow across the regional strike. The former is a river of fair size, but subject to large seasonal fluctuations and in the late summer the river bottom is occupied by extensive gravel bars. For the most part this river cuts across the strike of the rocks regardless of structure and in this respect is somewhat different from parts of Jumpingpound creek which are believed to show structural control. On the banks of Elbow river and to a less extent on Jumpingpound creek, terraces of river gravels are of common occurrence and are a record of the various stages of river development when the river occupied higher levels than at present. All other streams within the area are tributaries of the two major drainage systems and occupy the valleys between the various ridges.

## STRATIGRAPHY

The following account of the stratigraphy is based on the study of the south half of Jumpingpound and the north half of Bragg Creek map-areas. The outcropping formations range from the Edmonton of Upper Cretaceous age, to the Kootenay of Lower Cretaceous age, and by extending the Bragg Creek area only slightly west in the vicinity of Canyon creek, lower formations of Jurassic and Palæozoic ages outcrop.

*Table of Formations*

| | | Thickness in feet |
|---|---|---|
| Upper Cretaceous | Edmonton | |
| | Belly river | 2,000 |
| | Upper "Benton" with Cardium zones | 2,000 |
| | Lower Benton | 800 to 1,000 |
| Lower Cretaceous | Blairmore | 1,700 (?) |
| | Kootenay (Canyon Creek) | 350 to 375 |
| Jurassic | Fernie (Canyon Creek) | 200 to 225 |
| Palæozoic | Pre-Fernie limestones, etc | |

## PRE-FERNIE LIMESTONE AND DOLOMITES

On Canyon creek, a tributary of Elbow river in Moose Mountain area, a good section is exposed of the beds stratigraphically below the Fernie. The age of these rocks is not precisely known, but a few, poorly preserved corallites found only a short distance below the Fernie contact indicate a Palæozoic age. The contact of the Fernie with the Palæozoic limestones was not observed, but it is thought to be conformable, since there is no apparent difference in the attitude of the rocks in neighbouring outcrops. The top bed of the Palæozoic is extremely hard and cherty, but grades downwards into a more shaly, dark limestone which when struck with the hammer gives off a strong odour very like that of the gas from the Royalite No. 4 well in Turner valley. The limestone appears to be fairly dense for 250 to 275 feet below the contact with the Fernie, but between 275 and 325 feet there are a number of zones, each 8 to 10 feet thick, of very porous dolomite having a strong bituminous odour and containing a bitumen-like material in fissures and pores. Below this the limestones are light in colour, but within 40 feet two zones of cavernous dolomitic limestone were observed. One of these zones is approximately 5 feet thick and the other somewhat thicker. They are separated by about 15 feet of hard, dense, white limestone. Numerous vugs or caverns in the limestone are 8 to 10 inches in diameter and several inches in depth at the centre and are coated with a secondary deposit of carbonates. These vugs and the limestones both above and below them showed no trace of the bitumen-like material observed in the higher porous zone. The absence of this material and the white colour of the limestones below the porous zones, in contrast with the dark, bituminous limestones above the porous zones, seem to point strongly to the conclusion that the oil zone at this particular locality was originally confined to the uppermost 325 feet of strata. Only a reconnaissance study was made of the strata below the porous zone, but no further traces of petroleum nor of any great degree of porosity were observed.

## FERNIE FORMATION

In Canyon creek, Moose Mountain area, the Fernie rests directly on the Palæozoic limestones and no Triassic similar to that observed by Warren and Shimer in the Banff-Minnewanka area is apparent. Neither was the Rocky Mountain quartzite recognized, but since the age of the limestones below the Fernie is not precisely known it may be they, in part, represent the Rocky Mountain quartzite. In Banff area Warren[1] estimated the Triassic to be 3,400 feet thick and in Lake Minnewanka area, near Banff, Shimer[2] estimated rocks of the same age to be 1,500 feet thick. As the Triassic and possibly also the Rocky Mountain quartzite are not present in Moose Mountain area there must necessarily be an important disconformity between the Fernie and the Palæozoic, although as already stated the rocks of these two ages seem to be conformable.

---

[1] Warren, P. S.: "Banff Area, Alberta"; Geol. Surv., Canada, Mem. 153, p. 11 (1927).

[2] Shimer, H. W.: "Upper Palæozoic Faunas of the Lake Minnewanka Section, near Banff, Alberta"; Geol. Surv., Canada, Bull. No. 42, p. 3 (1926).

The Fernie as exposed on Canyon creek, Moose mountain, consists of shales which, particularly in the upper part, are sandy and carry a few calcareous layers. The shales are dark brown to black and have the appearance of being highly bituminous, but no tests were made to determine if bituminous matter actually were present. The contact with the overlying Kootenay was observed in a few places and the top of the Fernie shows evidence of erosion prior to the deposition of the Kootenay. In this respect the writer's observations are at variance with those of Cairnes[1] who says "in this region of the Foothills no evidence of an unconformity or any lapse of time exists between the Kootenay and the Fernie shales (in fact they gradually change into one another)". The base of the Kootenay contains some material possibly derived from the underlying Fernie and hence the lithological differences between the two formations at the contact are not marked, yet a close examination of the contact leaves no doubt of the existence of an erosional interval. No information was obtained to show whether this is only of local importance or has a regional significance. Owing to this erosional interval it is probable that the Fernie has a variable thickness. Accurate measurements made with plane-table and telescopic alidade in two places on Canyon creek, indicated the thickness to be 205 and 220 feet, respectively, but because of the slight amount of folding in the strata these amounts probably slightly exceed the true thickness. It is probable for the larger area over which Cairnes made observations that his estimate of thickness, 100 to 250 feet, is correct, although the writer's measurements on Canyon creek indicate that for this locality the thickness is between 200 and 225 feet. The existence of an erosional interval between the Fernie and the overlying Kootenay may explain the range of thickness 100 to 250 feet, given by Cairnes. He states the Fernie becomes "much thinner towards the east than inside the mountains."

## KOOTENAY FORMATION

In the vicinity of Canyon creek the Kootenay is represented by approximately 350 feet of sandstone and shale with coal seams near the top of the formation. The lower part consists of dark sandstones and shales and, like the limestones below the Fernie, the hard sandstones of the Kootenay emit a strong petroliferous smell when struck or broken. One of the coal seams in the top of the Kootenay has been mined and is reported to be 6 to 6½ feet thick. Most of the coal is concealed in the Canyon Creek section and such parts of the formation as outcrop consist of hard sandstones alternating with dark shales.

## BLAIRMORE FORMATION

The Kootenay beds are followed by a heavy conglomerate considered to be a basal part of the Blairmore. The upper part of the Blairmore consists of greenish and greyish sandstones, greenish sandy shales, dark shales, and a few maroon or red shale bands. Maroon shales outcrop on the north side of Elbow river at the bridge at Bragg creek, but are exposed

[1] Cairnes, D. D.: "Moose Mountain District, Southern Alberta"; Mem. 61 (sec. ed.), p. 32 (1914).

at low water only. They also occur on the south side of the river east of a small fault on the southeast corner of section 13, township 23, range 5. In both places they are high up in the Blairmore formation and although in neither case could the exact stratigraphical position be determined, the conclusion was reached that they represent the horizon of red shales exposed elsewhere in the Blairmore in the upper part of the formation. Another feature of the upper part of the Blairmore of importance in interpreting the structure is the presence of at least two conglomerate zones. Conglomerates and conglomeratic sandstones, believed to be the same stratigraphic horizon in each instance, are known in the following localities: (1) east of the "Benton"-Blairmore contact on the north side of Elbow river about the centre of the north half of section 12, township 23, range 5; (2) east of the "Benton"-Blairmore contact on the northeast part of the southwest quarter of section 26, township 23, range 5; (3) on the crest of the west spur of the hill that crosses the northwest corner of section 23, township 23, range 5, and extends northwest into the south portion of section 26; (4) west of the high knob of the hill on the south half of section 24, township 23, range 5; (5) on the north side of Elbow river a short distance east of the fault (*See* Figure 3) on the southeast quarter of section 13, township 23, range 5; (6) east of the fault (*See* Figure 3) about the centre of section 24, township 23, range 5.

If, as is believed, these conglomerates, and conglomeratic sandstones represent the same stratigraphic horizon in each case it is obvious that they present a phase of the Blairmore which is characteristic of this formation over a fairly wide area. The stratigraphic position is calculated to be 225 to 250 feet below the "Benton"-Blairmore contact.

On the north side of Elbow river, within the Bow River Forest Reserve and approximately 4,000 feet west of the west side of range 5, a small lens of fine conglomerate in the Blairmore formation is exposed. It is considered to represent the horizon marked by the conglomeratic zone already discussed, i.e., it is thought to occur 225 to 250 feet below the "Benton"-Blairmore contact, although at this place the contact is concealed. West of this outcrop of fine conglomerate and at an horizon considered to be approximately 500 feet stratigraphically below the "Benton"-Blairmore contact, another conglomerate zone occurs. The section that includes this conglomerate consists of, in ascending order: coarse and crossbedded sandstones; a conglomerate bed of variable thickness up to one foot; a few feet of strata that are for the most part concealed, but are believed to be sandstones; 3 to 4 feet of conglomerate and conglomeratic sandstones partly of a reddish colour and containing greenish, black, and grey chert pebbles, white quartzite pebbles, and a considerable amount of feldspar. In Blairmore area, according to Rose[1], within the Blairmore formation "there is one fairly persistent conglomerate band about 1,000 feet above the base of the formation, which looks much like the basal conglomerate but is distinguished by a large percentage of crystalline igneous pebbles". No igneous pebbles could be found in the conglomerate of Bragg Creek area, but the presence of feldspar suggests that part of the material may have been derived from the weathering of

[1] Rose, B.: "Crowsnest Coal Field, Alberta"; Geol. Surv., Canada, Sum. Rept. 1916, p. 110.

igneous rocks. How far the presence of feldspar in this conglomerate can be considered a diagnostic feature is problematical. Feldspar was seen in the conglomerate that outcrops on the north side of Elbow river east of the fault (*See* Figure 3) on section 13, township 23, range 5, and this outcrop for various reasons was assigned to the higher conglomeratic zone. Either, therefore, there is a mistake in assigning this conglomerate to the upper zone or else the feldspar is not restricted to the lower of the two conglomerates. It is hoped to make a more detailed microscopic study of the upper Blairmore sediments to determine if feldspathic sandstones are of wide occurrence, because if feldspar occurs at approximately the same horizon in such widely separated areas as Blairmore and Bragg creek, and, if it is derived from the weathering of a granitic body, it seems probable that the parent rock must have been exposed over a considerable area and at an elevation sufficient to allow transportation of material for long distances, since no granitic rock is known in the eastern Rockies, although the eastward thinning of the Blairmore indicates derivation of the materials from the west. The feldspathic zone may prove to be of regional importance and if so may afford a valuable key horizon throughout the southern Foothills belt.

In regard to the fauna and flora of the Blairmore no detailed report is at present available, although considerable material has been collected. Fairly well preserved plant material occurs at several localities within the area studied, and in the section on Elbow river within the Bow River Forest Reserve the plant zone is estimated to be 1,300 feet below the "Benton"-Blairmore contact. At about 200 feet lower, stratigraphically, than the plant zone, is a fossil horizon containing abundant remains of gastropods and pelecypods.

The total thickness of the Blairmore as measured on Elbow river within the Forest Reserve is approximately 1,700 feet. The lower 150 to 200 feet of sediments are dark in contrast with the light grey and green sandstones and shales of the upper part. At the base of the formation on Elbow river, at the mouth of Canyon creek, there is a heavy conglomerate approximately 20 feet thick, but somewhat variable in this respect. It is overlain by an equal amount of light grey, siliceous sandstones. The pebbles of the conglomerate vary in size up to one inch or more and consist of grey, black, and green chert and white quartzite.

It has been considered by the writer and others that the Blairmore thins to the east. The estimated thickness within the Bow River Forest Reserve may, therefore, not be strictly applicable to the formation in more easterly localities. The thickness of Blairmore and Kootenay in Turner Valley area was estimated from well records to be approximately 1,000 feet, whereas the combined thickness of these two formations at the west side of Bragg Creek area is thought to exceed 2,000 feet. In Moose Mountain area Cairnes[1] estimated the Blairmore to be 900 to 1,700 feet thick, whereas Rutherford[2] estimated the Blairmore on Bow river to be 1,000 to 2,000 feet thick, the thinner section being in the eastern part of the area.

---

[1] Cairnes, D. D.: "Moose Mountain District, Southern Alberta"; Geol. Surv., Canada, Mem. 61 (sec. ed.) (1914).
[2] Rutherford, R. L.: "Geology along the Bow River between Cochrane and Kananaskis, Alberta"; Sci. and Ind. Research Council, Rept. No. 17, p. 23 (1927).

## LOWER BENTON MEMBER

Overlying the Blairmore is a series of marine, dark shales and sandy shales divided by a conglomerate and sandstone zone known as the Cardium, into a lower and an upper member. The lower member, called Lower Benton by Rutherford,[1] consists of dark shales and sandy shales and as a whole has a more finely laminated character than the Upper "Benton". It also holds fewer ironstone nodules and ironstone layers. Although a complete study of the fossils has not been made, the lower member is believed to be palæontologically distinct from the upper member and contains such fossils as *Prionotropis* and *Inoceramus labiatus*, neither of which is known to occur above the bottom of the Cardium zone. The contact between the Lower Benton and Blairmore is, in most places, marked by a fine grit zone of variable thickness, but usually from a few inches to 1 or even 2 feet thick. This grit zone was discovered by the writer during the 1926 field season in Turner Valley area, and is so characteristic of the contact wherever it has been observed that it forms a very reliable horizon both for field work and well records.

Because the Lower Benton shales are fairly soft and easily weathered they most commonly occur in low-lying areas. Where deformation has been severe they are in many places very much folded and somewhat faulted. General conditions thus are such that measurements of thickness are apt to be unreliable. The writer estimates the thickness of the Lower Benton to be 800 to 1,000 feet, the latter figure being the same as given by Rutherford for the thickness on Bow river.

## CARDIUM MEMBERS

In Bragg Creek area there are two members that apparently represent and occupy the same stratigraphic position as the Cardium zone of adjoining areas. The name applied to the zone is that of a fossil characteristic of it. Both members in Bragg Creek area are somewhat variable in character, but are easily recognizable. The upper consists of a small thickness of light grey sandstone overlain by dark shales grading up into sandy shales locally overlain by a bed of conglomerate. In extreme cases this conglomerate is 4 feet thick, but it is usually much thinner or absent. About 350 feet stratigraphically below this upper Cardium member occurs the second member which is usually much thicker than the upper member, but like it varies much in thickness from place to place. In this case, however, a conglomerate bed is invariably present. It is sharply separated from the overlying dark shales and is usually only 2 to 4 feet thick, although in places it is as much as 16 feet. Below the conglomerate there is in many cases as much as 40 to 50 feet of light-coloured, siliceous sandstone interbedded with grey, sandy shales grading downwards into less sandy strata and finally into dark shales of the Lower Benton. In both Cardium members the pebbles of the conglomerates are greenish, grey, and black chert, and white quartzite. They vary in size up to $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter and are solidly cemented together by a siliceous matrix. In

[1] Rutherford, R. L.: "Geology along the Bow River between Cochrane and Kananaskis, Alberta"; Sci. and Ind. Research Council, Rept 17, p. 24 (1927).

numerous places the lower conglomerate consists of fairly uniform pebbles of the size of peas. It seems to be a general rule that the coarser parts of the conglomerate are toward the top and the fairly uniform beds of fine conglomerate are in many places overlain by a coarser pebble phase. The conglomerate beds everywhere seem to overlie the associated sandstones and sandy beds and the relative positions of the conglomerate and sandy strata thus seem to afford a dependable means of determining overturning due to folding or faulting. In a few localities where from the attitude of the strata it might appear that the sandstones overlay the conglomerate, a close examination of the minute crossbedding in the sandstones showed that the beds were overturned.

In Bragg Creek area the lower Cardium member, and to a less extent the upper member, form the crests of elongated, very narrow ridges such as occur in sections 14 and 23, township 23, range 5 (*See* Figure 3). Other hills of similar shapes, but on which are no outcrops, probably owe their form to the Cardium members and it is in many cases apparent from a close study of the drift that the Cardium members are present. However, since the Cardium members are very resistant and occur within a soft shale formation, their outcrops are quite common and it is possible to indicate their approximate position over the whole map-area. This is of decided advantage in working out the structure as the Cardium members provide key beds within a thick, weakly resistant formation of otherwise nearly uniform character, making the determination of structure very difficult.

In the northern part of the south half of Jumpingpound map-area, occurs a third Cardium member not recognized in Bragg Creek area. Not enough field work has been done to determine the total thickness of beds separating these three members, but such information as is available indicates a thickness of about 150 to 200 feet of shales between the lowest and intermediate member, and of approximately 300 to 350 feet between the intermediate and uppermost member. These figures suggest that the intermediate and uppermost members of the Jumpingpound area correspond with the two members of Bragg Creek area, and that the lowest member of Jumpingpound area is an additional member not recognized in Bragg Creek area. In Bragg Creek area where the shales between the two Cardium zones are best exposed, fossil evidence unmistakably indicates that the shales above the lower Cardium member belonged with the Upper, rather than the Lower, Benton.

### UPPER "BENTON" MEMBER

The Upper "Benton" is predominantly composed of shales and sandy shales. In certain parts ironstone nodules and layers are of common though irregular occurrence. In a recent report[1] on Turner Valley area, the writer pointed out that the upper part of the so-called Benton formation contains such fossils as *Baculites ovatus*, indicating a Montana age, whereas the remainder of the Benton is distinctly Coloradoan. For this reason the name Benton is not strictly applicable since, as originally

[1] Hume, G. S.: 'Turner Valley Oil Area, Alberta"; Geol. Surv., Canada, Sum. Rept. 1926, pt. B, p. 6.

defined, it designates strata of Colorado age. The term Upper "Benton," as here used, applies to a group of Montana and Colorado marine shales inseparable except on palæontological evidence.

In Jumpingpound area particularly, and to a less extent in Bragg Creek area, the Montana part of the Upper "Benton" is unmistakable, for in certain localities *Baculites ovatus*, as well as other fossils, occur in profusion. There is no doubt that the occurrence of this fauna which is similar in many respects to the Bearpaw fauna elsewhere in Alberta, led Cairnes[1] to believe that these beds were Bearpaw in age, but they cannot be Bearpaw, for that formation overlies the Belly River, whereas the beds in question underlie that formation and can be traced downwards into shales of similar lithological characters, but carrying a Colorado fauna represented by various species of Scaphites, Inoceramus, etc.

The contact between the Upper "Benton" and the overlying Belly River formation is gradational. There is a change, however, from marine to non-marine conditions. Towards the top of the Upper "Benton," in several localities, heavy-bedded sandstones and sandy shales occur that lithologically resemble the Belly River beds much more than they do the Upper "Benton," but they must be included in the Upper "Benton," since a close inspection of these beds in several localities showed that marine fossils are present and that the sandy beds are overlain by dark marine shales containing *Baculites ovatus*. Where fossils cannot be found or where the overlying shales are concealed, these upper sandy beds are likely to be confused with Belly River strata and hence may cause some error in placing the Upper "Benton"-Belly River contact, which, in general, must be arbitrarily drawn.

No definite measurement of the thickness of the Upper "Benton" has been made by the writer. The thickness of 2,000 feet assigned by Rutherford to these beds on Bow river seems applicable to this southern area so far as the available data indicate.

## BELLY RIVER FORMATION

The Belly River formation consists of non-marine, light grey sandstones alternating with greenish and dark shales. One or two coal seams occur at the top of the formation, but owing to lack of exposures it is not possible to tell whether or not these seams are always present. In certain localities at least one workable seam is known, but it is impossible to tell if this is everywhere the same seam, the probabilities are that it is not. Thin coal seams, none more than a few inches thick, have been observed close to the base of the Belly River formation in Turner Valley area, as well as in the present area. At other horizons a considerable amount of carbonaceous materials and wood fragments occur. In a number of places conglomerate beds have been seen in the Belly River. These vary in thickness and in the size of the component pebbles and when traced laterally seem to grade into sandstones. The conglomerate has its

[1] Cairnes, D. D.: "Moose Mountain District, Southern Alberta"; Geol. Surv., Canada, Mem. 61 (sec. ed.) (1914

greatest development in the south half of Jumpingpound map-area, in section 17, township 24, range 5, where a section measured by W. A. Kelly is as follows:

| | Feet | Inches |
|---|---|---|
| Sandstone | - | - |
| Conglomerate | 1 | 6 |
| Concealed | 4 | 0 |
| Massive sandstone with few pebbles | 4 | 6 |
| Very pebbly sandstone | 4 | 6 |
| Medium-grained sandstone | 3 | 0 |
| Very pebbly sandstone | 1 | 6 |
| Massive conglomeratic sandstone | 8 | 6 |
| Total | 27 | 6 |

In this section the pebbles are distributed through a zone that is relatively thick, for as a rule they are confined to a bed a few inches to one foot thick. The pebbles vary from very small to 1 or 2 inches in diameter and cobbles up to 4 and 5 inches in diameter are not uncommon in certain localities. The pebbles consist of black chert, white quartzites, and, occasionally, pink quartzites. The associated sandstones are in many cases highly crossbedded. Owing to the faulted character of the Belly River strata and the presence of only a very few sections that can be readily measured, the position of the conglomerate zone is not definitely known. At one place, however, it was estimated to be 750 to 800 feet above the Upper "Benton"-Belly River contact, but there is a possibility that more than one conglomerate zone exists.

The Belly River formation contains some plant remains, including leaves of dicotyledons and occasionally a few bivalve shells. Both flora and fauna are sparsely represented.

## EDMONTON FORMATION

Although strata of Edmonton age are believed to occur in the south half of Jumpingpound area, it is with difficulty that any division can be made between the Edmonton and Belly River formations. It seems probable that these two formations represent a period of continuous sedimentation and although the Edmonton as a whole is considered to be less lithified than the Belly River a satisfactory division can be made only where the coal seam, arbitrarily placed at the top of the Belly River, is present. It is believed, however, that a closer study of the faunas may yield considerable information, since invertebrate fossils, particularly Gastropods and Pelecypods, occur in great profusion in certain localities in strata now regarded as being Edmonton in age. Cairnes believed some Bearpaw shales were present in this area and thereby separated the Belly River from the Edmonton. It has already been pointed out that there are Pierre fossils in the Upper "Benton" and that it is believed the strata holding them were mistaken by Cairnes for Bearpaw. However, since Cairnes studied a much larger area than the writer and since the contact between the Belly River and Edmonton was not observed by the writer, it might be unsafe to conclude that no Bearpaw is present anywhere in the area, although our general information in regard to the distribution of the Bearpaw makes its occurrence within the area highly improbable.

## STRUCTURE

The map (Figure 1) accompanying this report shows that the writer interprets the formations somewhat differently from what Cairnes did on the Moose Mountain map. One of the most important differences from an economic standpoint is the placing of strata of the areas east and north of the village of Bragg Creek in the Blairmore instead of the Belly River. In isolated outcrops much difficulty is in many cases experienced in making a distinction between Belly River and Blairmore strata, but where a considerable part of either formation is exposed and the characters of the formation as a whole can be observed, the chances for confusion are not nearly so great. The reasons for assigning the strata in question to the Blairmore instead of the Belly River are as follows:

(1) *Lithological Peculiarities.* Although it is true that in isolated outcrops Belly River strata may resemble Blairmore, the latter is known to contain red or maroon shales which so far are not known to occur in the former. In the area east and north of Bragg Creek, red shales are to be seen on the north side of Elbow river at the Bragg Creek bridge, and on the south side of the river east of the small fault on section 13, township 23, range 5. These red beds occur with green shales and sandstones, but since the greenish colour is also marked in certain parts of the Belly River formation, the red shales alone are considered as a feature suggesting Blairmore. As has already been mentioned the contact of the Lower Benton and Blairmore is characterized by the presence of a peculiar and persistent grit zone a few inches to a foot or more thick, and unlike anything known elsewhere. The grit zone can be seen on the south side of Elbow river on the edge of the terrace on the west side of section 12, township 23, range 5. It is also present farther east, on the east of Blairmore area (*See* Figure 1) on the south side of Elbow river. This zone and the associated strata are so characteristic that alone they afford sufficient evidence on which to base the Blairmore age of the beds. The Belly River and the Blairmore strata differ in many respects, but an appreciation of these differences results from continuous observations and is not easily expressed. It depends on a close examination of such features as variations in texture, the amount of ironstone present, slight differences in colour of the rocks as a whole, etc. Besides, there are also a number of conglomerate zones in the Blairmore and at least one in the Belly River. Where the lower conglomerate of the Blairmore is present it is easily recognizable, but the base of the formation is rarely exposed and the conglomerate disappears eastwards and, hence, for an area like that east and north of Bragg creek, the conglomerate is not available as evidence. The presence of feldspar in a conglomerate that occurs high up in the Blairmore formation may possibly be a diagnostic feature, but as yet so little is known about the distribution of the material that discretion must be exercised in its use. The stratigraphic position of all conglomeratic zones, when used with other features, is apparently diagnostic; the areas in which the conglomerates occur have already been noted.

(2) *Faunal and Floral Characteristics.* Both the Belly River and Blairmore contain plants and as collections of these become larger and

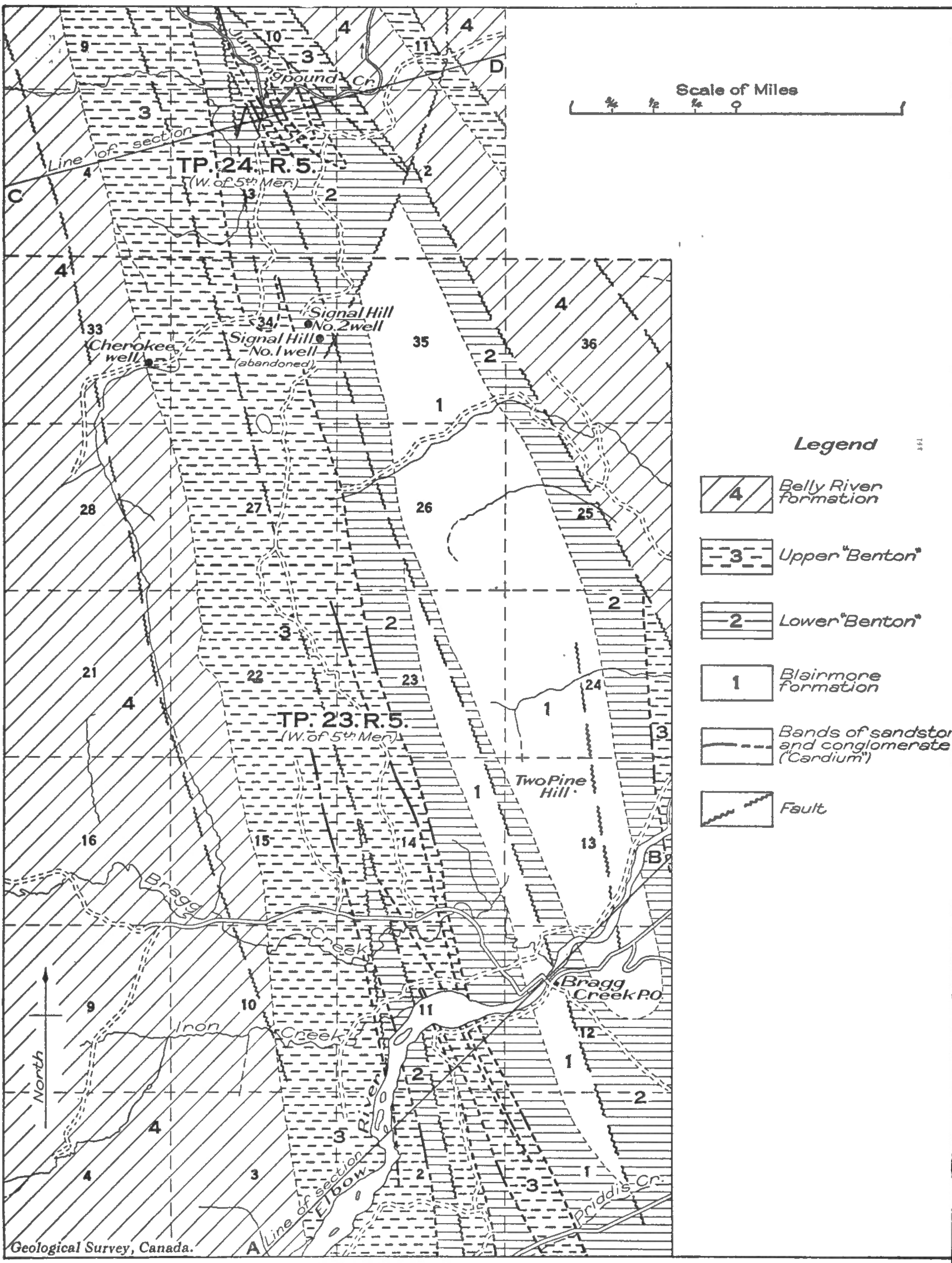


Figure 1. Geology of the Two Pine anticline, Bragg creek, Alberta. *See also* Figures 2 and 3.

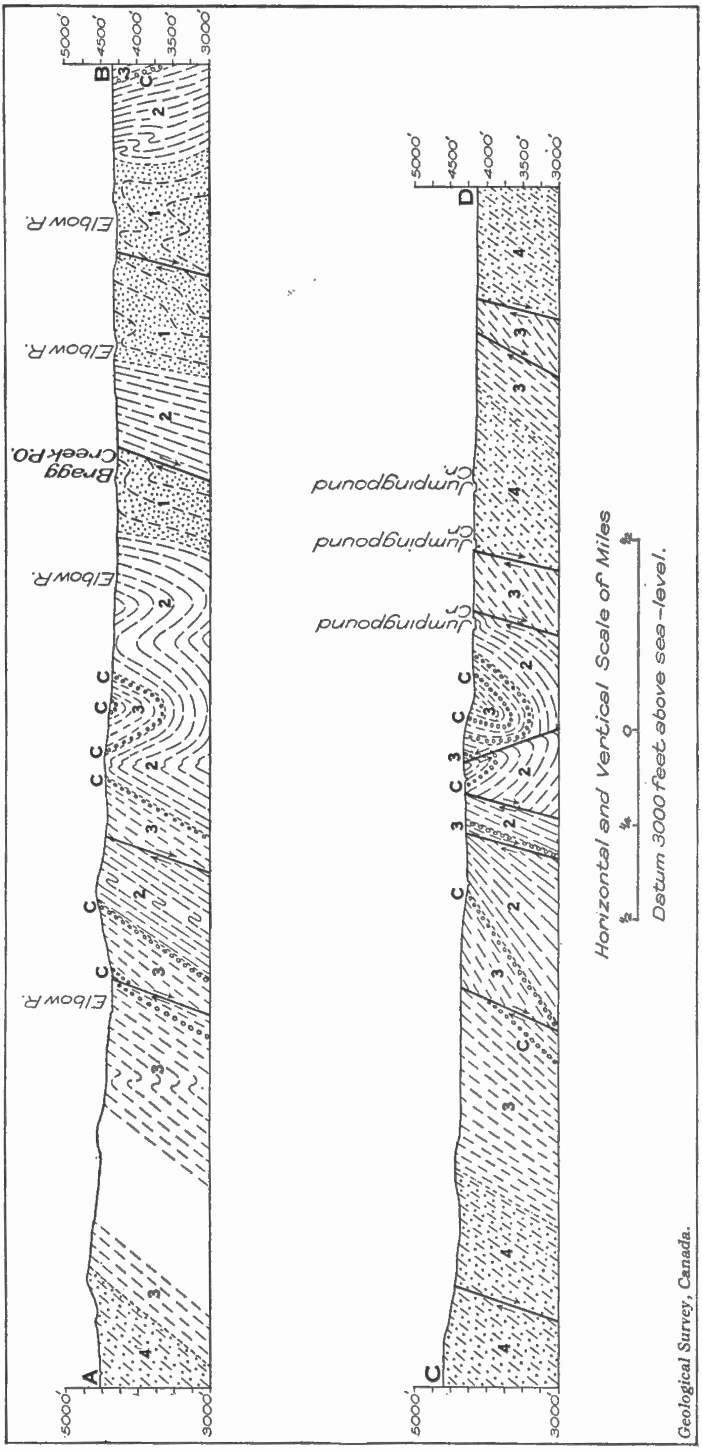


Figure 2. Cross-sections AB and CD, *See* Figure 1.
(1) Blairmore formation; (2) Lower Benton; (3) Upper "Benton"; (4) Belly River formation; (C) bands of sandstone and conglomerate (Cardium).

their study proceeds, each flora as a whole is being found to be quite characteristic, but individual plant fragments may be misleading. For example, dicotyledon leaves from Belly River rocks are known from various localities where there is no doubt concerning the identity of the formation, but although no such plants have been found in the Blairmore of Bragg Creek or Jumpingpound areas, their presence has been recorded in the upper Blairmore elsewhere. Thus it would be unsafe where dicotyledon leaves alone occur, to conclude that the formation is Belly River unless such plants could be determined specifically. The distinctions depending on the plants, although they may be obvious to a palæobotanist, are not always easily applied by the field geologist. A gastropod and pelecypod zone is known from the Blairmore formation and Unio beds occur in the Belly River. The services of a trained palæontologist are indispensable if age distinctions are to be made on faunas alone.

(3) *Structural Relationships.* Blairmore and Belly River strata may be distinguished by considering their relations with other known formations. Where the beds underlie "Benton" shales they are Blairmore, where they overlie, they are Belly River. Since thrust faulting may cause Blairmore beds to overlie "Benton" beds, position alone is not always a definite indication of age, but must be considered in relation to structure. Within the "Benton," fossils are of common occurrence and Upper "Benton" is readily divisible from Lower Benton, a feature which is of very great value in the interpretation of structure. To the east and west of the areas of Blairmore shown on the map, Lower Benton shales carrying such fossils as *Prionotropis* and *Inoceramus labiatus* occur and the latter fossil also occurs in the shale separating the two bands of Blairmore. These fossils are conclusive proof of Lower Benton age and since the structural relationships indicate that they occur on the flanks of an anticline the underlying beds are without doubt Blairmore in age.

## TWO PINE ANTICLINE

The anticline represented on Figure 1 and which is shown by these relationships is somewhat modified by thrust faults and some minor folds. The western band of Blairmore is probably a small fault block shoved up over Lower Benton beds, but the eastern and wider band, although somewhat folded and faulted within itself, shows reverse dips on the two flanks and is thus a sharp, faulted anticline which on account of the prominence, known as Two Pine hill, in section 13, it is proposed to call the Two Pine anticline.

The presence of Lower Benton strata on both flanks of the eastern belt of Blairmore shown on the map (*See* Figure 1), clearly demonstrates the anticlinal relationships, but there is a considerable amount of complex folding within the exposed part of the Blairmore, the best section of which is shown on the banks of Elbow river. For the most part the dips of the strata are steep and at the contact of the Lower Benton and Blairmore on the east flank of the anticline on the south side of Elbow river, there are a few feet of strata that are overturned. To the southeast it is quite apparent from regional relationships that the anticlinal axis plunges downwards and the Blairmore is covered by Lower Benton strata. The exact place where

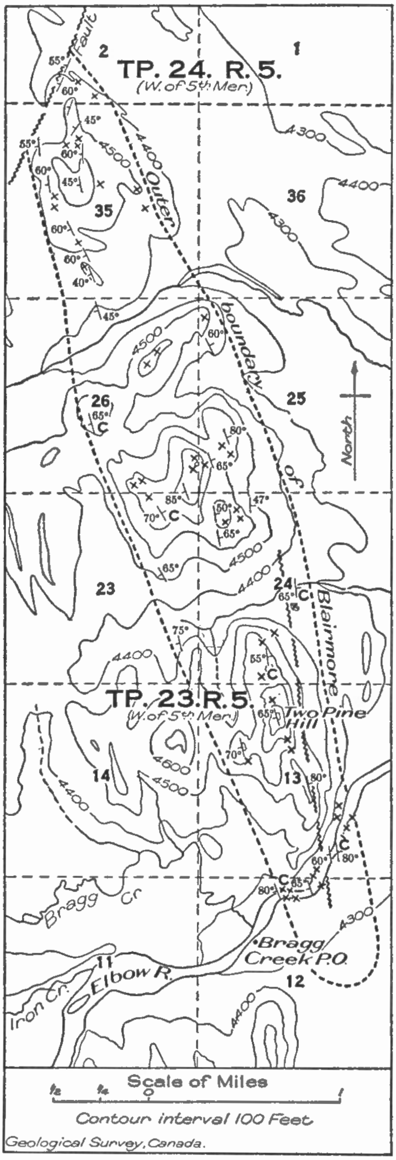


Figure 3. Blairmore formation on Two Pine anticline; outcrops shown by crosses or dip and strike symbols, conglomerate by (C); *See also* Figure 1.

the Blairmore disappears is unknown owing to lack of exposures. To the northwest, on the strike of the structure, eastward dips are visible in the Blairmore on the northwest quarter of section 25 and westward dips on the west side of the Blairmore belt in section 26. Northwest of this, the anticlinal relations are not apparent and although, in section 35, there seems to be an eastward dip on the east side of the Blairmore belt, the exposures are so small that the direction of dip could not be determined with certainty. It is reasonably certain, though, that either the anticlinal structure continues into section 35 and vicinity, or that the eastern limb is cut off by fault. In constructing the accompanying map the presence of a band of Lower Benton to the east of the Blairmore is assumed and the structure interpreted as anticlinal rather than faulted. In the north part of section 35, township 23, range 5, and the south part of section 2, township 24, range 5, there is a very marked change in strike from northwest to northeast. Northeast strikes also occur in Belly River beds in the north part of section 2, township 24, range 5. It is believed that the change of strike has been brought about by a normal fault transverse to the regional strike. The Two Pine anticlinal structure is thus terminated in the northwest by a normal fault. The normal fault is considered to occur at, approximately, the contact of the Blairmore and Lower Benton on the west flank of the hill which crosses from section 35 to section 2. This is thought to be the position, because although there are no exposures, drift material from the grit zone at the contact of these two formations can be traced for some distance along the local strike. It is very difficult to form any opinion regarding the amount of throw of the normal fault and it is assumed to die out to the southwest. Traced in a northeast direction the fault swings to the north and to slightly west of north. Accompanying this change in direction is a change from a normal to a thrust fault. Where the fault crosses Jumpingpound creek it is a thrust fault of small throw, but farther northwest, outside the present map-area, it is a thrust fault of much larger throw. It seems, therefore, that this fault is pivoted about the area in the vicinity of the south part of section 11, township 24, range 5, that the northwest part is a thrust fault increasing in throw to the northwest, and that the southwest part is a normal fault which probably increases in throw to a maximum at the northwest end of the Two Pine anticlinal structure, but farther southwest gradually decreases until it disappears. It cuts off the northwest end of the Two Pine anticlinal structure, since no Blairmore rocks have been observed in this vicinity north of the fault and are not present anywhere on range 5 on Jumpingpound creek.

One feature of the Two Pine anticlinal structure apparently has not been understood by a number of people who hold oil and gas leases in this vicinity. The lower rocks, i.e. the Blairmore, occur in the highest topographic features, whereas the flanks of the anticlinal structure are marked by valleys. This is exactly the reverse of the situation in Turner valley where the flanks of the anticline are ridges and the axial part, occupied by "Benton" shales, underlies a valley between the ridges. The explanation of the origin of the topographic features is the same for both areas: these features are the results of weathering acting on strata of different hardness and resistance, the softer rocks now occupy the low-lying or valley areas and the harder rocks form the hills whose heights in some degree are proportional to the resistance of the rocks composing them.

## OIL AND GAS PROSPECTS

The steep dips of the strata that occur in the Two Pine anticlinal structure, as well as the folding and faulting within the anticline, are indications of rather severe metamorphism. A certain amount of deformation of the rocks resulting in the formation of anticlines is favourable for the accumulation of oil and gas where a source for these materials exists, because during the deformation, the oil and gas are squeezed out of the petroliferous-bearing formations into horizons suitable for their retention under favourable structural conditions. On the other hand, too severe deformation is considered harmful, for in extreme cases all oil and gas are either completely driven out of the severely compressed rocks or are destroyed. To what extent the deformation of the Two Pine anticlinal structure has affected the content of any oil or gas horizons within it cannot as yet be estimated because of the fact that very little information regarding the oil prospects of the foothills, exclusive of Turner valley, is known. A comparison with Turner valley is very difficult because the strata there visible at the surface are soft shales which undoubtedly reacted to severe stress in a way very different from that followed by the more resistant and harder rocks of the Blairmore formation, which form the outcrops over the central part of the Two Pine anticline. In the absence of data on the detailed structure of the Blairmore underlying Turner valley any comparison of the Blairmore strata of Turner valley with the corresponding beds of Two Pine anticline is impracticable, so far as it bears on the relation of metamorphism to oil occurrence.

The presence in the Two Pine anticline of commercial quantities of oil and gas depends primarily on the existence of reservoir rocks suited to contain oil and gas if such occur. No drilling having been completed the best inferences are afforded by the study of the outcrops of the various formations. On Canyon creek and Elbow river in the vicinity of Moose mountain, the Blairmore, Kootenay, Fernie, and the upper part of the Palæozoic, formations are exposed. All of these have not been closely studied with the object of finding to what extent they would afford reservoirs for oil and gas, but it is known that the upper part of the Palæozoic holds highly porous zones containing a bitumen-like material such as would be left after the dissipation of a former content of petroleum. Not only are the porosity and bitumen-like content striking facts, but the occurrence in several wells in Turner valley of oil and gas in what appears to be the same horizon leads to the assumption that this porous zone is of regional extent and that where it occurs under favourable metamorphic and structural conditions it may be expected to yield oil and gas. General conditions thus seem to warrant the assumption that the porosity of the Palæozoic rocks will be maintained under the area of the Two Pine anticline and, provided metamorphism has not been too severe, the Palæozoic beds may be expected to yield large quantities of oil and gas. Other possible oil and gas horizons younger than those in the Palæozoic rocks may be present in the Two Pine anticline, but the available information does not warrant assuming the existence of any horizons other than those that produce oil from the Blairmore in Turner Valley area. If wells are drilled on the Two Pine anticlinal structure and commence in the Blairmore formation, it is obvious that little or no production should be expected from the higher parts of this formation, because even though some oil and gas shows might be encountered there is no cover to retain any oil or gas that originally may have been present. In the lower part of the Blairmore and in the underlying Kootenay and Fernie, some oil and gas production might result if porous horizons exist, for these formations at their outcrops on the east side of Moose mountain are mostly dark-coloured rocks with indications of petroliferous materials. Present available data, however, seem to point to the Palæozoic rocks as being the most promising reservoir horizons and, therefore, it is believed that any contemplated wells should be planned to reach this deep zone of porosity.

It is very difficult to estimate the depth to the Palæozoic porous zone on the Two Pine anticlinal structure. The thickness of strata to be drilled obviously depends not only on the stratigraphical thickness but also on the degree of inclination of the strata. The following table illustrates the increase in drilling depth for a vertical hole with an increase in dip.

| Degree of dip | Strati-graphical thickness | Approximate drilling thickness |
|---|---|---|
| 0 (Horizontal beds) | 100 | 100 |
| 20 | 100 | 106 |
| 30 | 100 | 115 |
| 40 | 100 | 130 |
| 45 | 100 | 141 |
| 50 | 100 | 155 |
| 60 | 100 | 200 |
| 70 | 100 | 292 |

It will be noticed that for small dips up to 20 degrees, the drilling thickness is very little in excess of the stratigraphical thickness, but for a dip of 60 degrees the thickness that must be drilled is twice the thickness of the strata and for dips greater than 60 degrees the drilling depth increases so rapidly that it would be impracticable to drill through any great stratigraphical thickness. On Canyon creek and Elbow river, in the vicinity of Moose mountain, the thickness of strata from the top of the Blairmore to the porous zone within the Palæozoic rocks has been estimated to be approximately 2,500 feet. The Blairmore, Kootenay, and Fernie formations, however, are known to have a somewhat variable thickness and it has been thought that the Blairmore formation thins fairly rapidly to the east. It is very difficult to estimate the amount of thinning, but possibly a thickness of 2,000 feet for the strata from the top of the Blairmore to the porous Palæozoic zone would be a fair estimate of the thickness of these strata in the Two Pine anticlinal structure. From the table as given above and from the dips for the Blairmore rocks as shown in Figure 3, the drilling depth at any point on the Two Pine anticline can be roughly estimated, but it should be remembered that such estimates depend on the assumption that the dips as shown on the surface continue to depth, a condition which is hardly likely to occur. If drilling is attempted on the Two Pine anticline the drilling sites should be selected where the surface dips have a minimum value and where minor folding is least marked. Even though drilling sites were selected where the surface dip is 60 degrees the depth in a well to the Palæozoic porous zone would be estimated to be not more than 4,000 feet, provided dips greater than 60 degrees were not encountered at any point in the well. For dips less than 60 degrees the drilling depth to the porous Palæozoic horizon would be less than 4,000 feet for wells that commence in the Blairmore formation. As far as can be judged from the outcrops, the lowest dips on the Two Pine anticline occur in the south part of section 35 and the north part of section 26, township 23, range 5. At these places, from the limited number of exposures available for study, there did not seem to be any surface indication of minor folding. Well sites chosen within this area would have the advantage of being in a valley in easy reach of water and, in a dry season, could be made accessible by a limited amount of labour and expense in repairing the already existing trail from Bragg Creek.

There are at present two drilling sites in proximity to the Two Pine anticlinal structure. These are the Cherokee well on section 33, township 23, range 5, and the Signal Hill No. 2 well on section 34, township 23, range 5. The Cherokee well started very close to the Belly River-"Benton" contact where the strata dip to the west at an inclination of from 55 to 65 degrees. If an average dip of 60 degrees be assumed, and, as the "Benton" is approximately 3,000 feet thick, it follows that the Cherokee well could not reach the top of the Blairmore at a vertical depth less than 6,000 feet. Also, if a thickness of approximately 2,000 feet from the top of the Blairmore to the porous Palæozoic zone be accepted as correct and the 60-degree dip continues throughout the well, the drilling depth to the porous Palæozoic zone would be approximately 10,000 feet. It is, of course, possible that the degree of dip of the strata decreases in depth, but since the stratigraphical thickness from the top of the "Benton" to the porous Palæozoic zone is considered to be 5,000 feet, the drilling depth under the most favourable conditions that could reasonably be assumed would be very great.

Signal Hill No. 2 well is located on the west flank of the Two Pine anticlinal structure, but is separated from it by a thrust fault following the strike of the formations and a normal fault transverse to the strike (*See* Figure 1). Drilling commenced at an horizon some distance down in the Lower Benton, the total thickness of which is believed to be not more than 1,000 feet and is probably somewhat less. There is no direct evidence of the existence of the thrust fault shown on the map east of Signal Hill well, but since the fault is present to the southeast and northwest, it is probably also present in the intervening area. The effect of such a fault on possible oil and gas production is important. If Blairmore beds are thrust over and rest against "Benton" strata, any porous horizons in the westward-dipping Blairmore formation would be expected to be sealed by the "Benton" shales. Porous zones occur in the upper part of the Blairmore formation in Turner valley and not improbably occur in this area also. From observations on several thrust faults within this general area it is known that the fault planes are steep, usually departing by only 15 to 20 degrees from the vertical, although in exceptional cases flat fault planes are present. The exact position and inclination of the fault in the Signal Hill well area are not known and, therefore, it is not possible to make a reliable estimate of the depth at which the fault should be encountered in the Signal Hill well. The most probable depth would seem to be about 2,000 feet, but might be somewhat more. If the porous horizons of the Blairmore formation are encountered above this depth the prospect for the occurrence of oil and gas in them would seem to be favourable, judging from conditions that occur in Turner Valley area. The whole situation at the Signal Hill well, however, is so complicated by faulting that predictions are not of much value. It is thought, however, that prospects of production from Blairmore strata below the thrust fault are not good, since below the thrust fault the migration of oil and gas is likely to be eastwards up the dip towards the outcrops on near-by hills where escape would probably take place owing to lack of a suitable retaining cover. If in the Signal Hill well, production is not secured from the Blairmore above the thrust fault, prospects of production will depend on the finding of the Palæozoic oil and gas-bearing horizons at a much greater depth. As neither the exact amount of thrusting due to the fault nor the dips of the strata encountered are known, it is not possible to predict the depth at which the lower porous zone would be reached.

# STRATIGRAPHY, STRUCTURE, AND CLAY DEPOSITS OF EAST-END AREA, CYPRESS HILLS, SASKATCHEWAN

*By F. H. McLearn*

CONTENTS



## INTRODUCTION

An area in the eastern end of Cypress hills, 17 by 19 miles, was examined in the summer of 1927. This area lies north and south of Frenchman river and east of longitude 109 degrees. The town of Eastend is situated in the middle of it. This detailed study of a small area was undertaken as a basis for more extended studies in southern Saskatchewan.

Acknowledgment is made to A. Pentland, H. Johnson, and O. L. Backman for valuable assistance in the field. In the office, F. J. Fraser, Borings Division, has made sizing tests of the sandstones and has determined their mineral contents. Appendix I, on heavy minerals in the sandstones, has been prepared by him. The fossil plants have been studied by W. A. Bell and the fossil vertebrates by C. M. Sternberg. Dr. T. W. Stanton of the United States Geological Survey has kindly examined the non-marine invertebrates from the Ravenscrag formation. Acknowledgment is also made to Messrs. H. Jones and Gregg, of Eastend, for courtesies rendered by them.

Although no very detailed geological examination of this area has ever been made, it has received considerable attention from time to time. G. M. Dawson,[1] as geologist to the British North American Boundary Commission, studied the geology along the international border, but made no particular examination of this area. He maps most of Cypress hills as Lignite Tertiary. R. G. McConnell was the first to do actual geological work in Cypress hills and in his report[2] describes both the geography and geology at some length. He arranges the strata in four formations, the Pierre, Foxhills, Laramie, and Miocene. He saw the white band at the bottom of his "Laramie", he understood its possession of qualities distinct from the remaining part of the "Laramie," and observed its extension throughout parts of southern Saskatchewan. He does not, however, treat it as a separate formation. The irregularity of its component beds did not

[1] "Report on the Geology and Resources of the Forty-ninth Parallel", Montreal, 1875.
[2] McConnell, R. G.: "Cypress Hills, Wood Mountain, and Adjacent Country"; Geol. Nat. Hist. Surv., Canada, Montreal, 1885.

escape him, but the disconformity between the white band and the rest of the "Laramie" was not seen by him. Nor was the economic importance of the clays in the white band realized at that time; at least no mention is made of it. The Miocene, the Cypress Hills formation of later reports, is thoroughly described and its relation to the "Laramie" pointed out. Vertebrate fossils, including mammals and turtles, collected by McConnell and T. C. Weston, were studied by Cope and are described in an appendix to McConnell's report. He dates the fauna as Oligocene then included in the Miocene. Later, Cope made further studies[1] of these collections. Weston continued his collecting and Lambe spent part of a season in this area. On the study of these collections Lambe prepared several papers[2]. With the work of Ries and Keele[3] the importance of the refractory clays in the white band at the base of the "Laramie" began to be appreciated. In his report on the "Clay Resources of Southern Saskatchewan"[4] Davis gives the results of the testing of numerous samples. He also revises the section as follows: Cypress Hills beds (Miocene of McConnell); Ravenscrag beds (upper and greater part of the "Laramie" of McConnell); Whitemud beds (white band and basal part of the "Laramie" of McConnell); Foxhills; and Pierre. He expresses the view that the Whitemud clays have come from the east. In 1921 Sternberg[5] recorded fragmentary *Triceratops* remains from the Whitemud beds and dated them as Lance. Dyer gives a brief description of the formations of this area. He also claims that the sandstones of the Whitemud formation increase in coarseness eastward and advances it as an argument confirming Davis' theory of the eastern source of the Whitemud sediments.[6] McLearn followed Davis and Dyer in their interpretation of an eastern source of the Whitemud sediments.[7]

## GEOGRAPHY

The highest land is in the north-central and northwest corner of the map-area, where there is a high, rolling upland, the Anxiety Butte upland, at an elevation of from 3,600 to 3,900 feet. It is part of an irregular, rolling surface, extending to the north and west where it rises much higher. It is everywhere underlain by the resistant Cypress Hills formation. It is deeply dissected in the northwest corner of the map-area by the valleys of the upper part of Conglomerate creek and its tributaries, and is also highest there, being at an elevation of about 3,700 to 3,900 feet. The valleys have steep, sloping sides, but wide bottoms in their lower downstream parts. There is some glacial drift on the upland in this corner of the map-area, but owing to the very considerable amount of post-Glacial erosion little or no drift remains in the valleys. The eastern part of this upland lies north,

---

[1] Cope, E. D.: Cont. Can. Pal. III, pt. I (1891).
[2] Lambe, L. M.: Cont. Can. Pal. III, pt. IV (1908), and papers in Trans. Roy. Soc., Canada.
[3] Ries, H., and Keele, J.: Geol. Surv., Canada, Mem. 25, p. 45 (1913). Keele, J.: Geol. Surv., Canada, Mem. 66, p. 26 (1915).
[4] Davis, N. B.: "Report on the Clay Resources of Southern Saskatchewan"; Mines Branch, Dept. of Mines, Canada (1918).
[5] Sternberg, C. M.: Can. Field Nat., vol. 38, No. 4, pp. 69-70 (April, 1924).
[6] Dyer, W. S.: "Oil and Gas Prospects in Southern Saskatchewan"; Geol. Surv., Canada, Sum. Rept. 1926, pt. B, p. 348 (1927).
[7] McLearn, F. H.: in McLearn and Hume, "The Stratigraphy and Oil Prospects of Alberta, Canada"; Bull. Am. Ass. Petrol. Geols., 11, No. 3, p. 249 (March, 1927).

west, and southwest of Anxiety butte and is a little lower than the western part just described, being at an elevation of from 3,600 to 3,700 feet. It is not dissected to the same extent as the western part. It has a rolling surface mantled with boulder clay, etc., and bearing many undrained shallow lakes. The Anxiety Butte upland, in its western part, is separated from the lower Eastend upland to the south by the valley of Conglomerate creek and its southern border is steep, being formed by the steep slopes of Conglomerate Creek valley. In its eastern part no valley lies between this upland and the lower Whitemud upland to the east. Southeast of Anxiety butte it is about marked by a zone of southerly slopes at a grade of about 100 feet to the mile. On its eastern border it presents steep slopes to Swift Current creek, the valley of which separates it from the northern extension of the much lower Whitemud upland to the east. Southeast of Anxiety butte it is about 2 miles across the valley from the edge of one upland to that of the other and the drop is 500 feet.

The Eastend upland lies south of the Anxiety Butte upland. It occupies the west-central and southwestern parts of the map-area and is crossed by Frenchman valley which separates it into a northern and southern part. It is at an elevation of 3,400 to 3,500 feet, is rolling but definitely sloping, and about 200 feet below the Anxiety Butte upland. It is underlain by the Ravenscrag formation and mantled by boulder clay, etc., on whose uneven surface lie many undrained, shallow lakes. In the southwestern corner of the map-area and on this upland is an area of small lakes and kame-like hills, possibly a morainal area. Two eminences rise without abrupt boundaries on this upland and are underlain by strata of the Cypress Hills formation; they may be regarded as southern outliers of the Anxiety Butte upland. One of these eminences is Ravenscrag butte north of Frenchman valley, the other is an unnamed eminence on the southern and opposite side of Frenchman River valley. The western and southern boundaries of the Eastend upland are off the map-area. It is bounded on the east, in its northern part, by Eastend coulée. In its southern part it is bounded on the east by a long, low slope to a broad, shallow valley, sloping and draining to the north and partly dissected by Galleon coulée and Morrison coulée.

The eastern third of the map-area, from north to south, is occupied by a third and yet lower upland, the Whitemud upland, at an elevation of from about 3,050 to 3,200 feet and, in this map-area at least, sloping to the north. Its surface is undulating and drift-covered, with some undrained lakes, sloughs, etc. It is developed on the Ravenscrag formation chiefly.

A fourth important geographic unit is the valley of Frenchman river which enters the western border of the map-area and cuts across the Eastend upland in an easterly direction, except for a short north-south stretch a little west of the town of Eastend. Near the middle of the map-area beyond the junction with Eastend coulée, it enters the low Whitemud upland and turns south and southeast, cutting through the Whitemud upland, the walls of the valley becoming higher with the rising of that upland in a southeasterly direction. The valley is 400 to 500 feet deep in the west, where it cuts through the Eastend upland, and 1½ to 2 miles broad. The valley bottom is flat, narrow in the west, but broad in the east. From these flats, drift-covered slopes rise gradually to the steep cliffs on the valley margins. The present river is cutting down a little and also planing laterally, particularly where the valley is narrow, as on the west border of the map-area, and at the town of Eastend, but in places where the valley is broad there is little lateral planation and the drift-mantled spurs are not truncated. The steep cliffs along the borders of the valley are cut by short valleys or gullies, with rounded bottoms underlain by boulder clay, gravel, silt, etc. The cliffs and gulch sides are in many places washed clean of drift, leaving bare cliffs of naked rock. This is most marked on the northern bank where for 5 miles along the cliff there is an almost continuous outcrop. In addition, from the present river bottom, recent or narrow valleys or canyons cut in the drift or rock, run back to the cliffs, and continue as very deep and steep-walled canyons, carved out of the flat or rounded bottoms of the gulches. These canyons, like the high cliffs, give good rock exposures. Some of the side gulches are not penetrated by the recent canyons, however, and retain their smooth, flat, or rounded bottoms. To the south, beyond Eastend and to where it passes off the southeastern corner of the map-area, the river flows on a broad, flat bottom with sinuous oxbow curves and leaving some oxbow lakes. There is little incising and practically no lateral planation. The sides of the valley are steep and are highest in the south-east, nearly 300 feet above the bottom.

Eastend coulée is a broad, flat-bottomed valley, silt and drift covered. Although not much higher than Frenchman valley, north of it Swift Current creek flows northward and south of it the Frenchman continues eastward and southward.

The valleys, and even some of the tributary valleys and gulches, are pre-Glacial or Interglacial and the amount of post-Glacial erosion is not interpreted as great.

## STRATIGRAPHY

### MARINE SHALES

Friable dark shales and somewhat arenaceous dark shales, with, in places, round concretions, occur on the lowest slopes and flats of all the large valleys of Eastend area and are known to extend down to river-level in the central and eastern parts of the area. They contain marine fossils only, which are not common and not well preserved, but are sufficient to demonstrate the marine origin of the shales. *Baculites grandis* was found in concretions in dark, friable shale at river-level on the west bank of Frenchman river near the mouth of Morrison coulée. Poor specimens of the following were found in arenaceous shale near the contact with the "Yellow sandstones," in a canyon on the south side of Frenchman valley southwest of the Eastend cemetery: *Scaphites* ? sp.; *Corbicula* sp.; *Lucina* ? sp.; *Liopistha sp.;* and *Lingula* sp. These marine shales are apparently conformable with the "Yellow sandstones" above.

## YELLOW SANDSTONES

Between the marine shales below and the Whitemud beds above are very fine sandstones and shales, varying much in thickness, but in places 65 to 100+ feet thick. They consist mostly of massive sandstone above and alternating beds of sandstone and shale below. The massive sandstone may be in direct contact with the basal Whitemud sandstone and grade into it so that the actual boundary may be difficult to determine or may be separated from it by a bed of shale or zone of alternating sandstone and shale. The contact appears to be a conformable one. The massive sandstone is very fine grained, commonly yellowish, rusty, or buff in colour, but grey in places, and contains many small yellow or reddish ironstone concretions and in places large sandstone concretions. It is crossbedded in places on a large scale. The lower part consists of beds of grey and yellowish, or rusty, very fine sandstones, arenaceous shales, etc. No coal seams are known to be present in this area. Four samples of the massive sandstone were tested in the laboratory (*See* Appendix I by F. J. Fraser). All four are below fine sand grade and are of superfine sand or coarse silt grade. The percentage of clay grade is from 4 to 9. All four samples are either calcareous or dolomitic. The component grains are of feldspar, quartz, dark argillite, biotite, and muscovite. The heavy mineral suite includes zircon, tourmaline, garnet, epidote, andalusite, ilmenite, apatite (absent in one sample), and rutile (absent in one sample but common in two). No hornblende was reported.

No fossils were found except just at the contact with the marine shales, where the pelecypod *Gervillia* was observed. No plant fossils were found and practically no roots or plant debris of any kind. The basal part is probably marine, but it is difficult to say at present whether the upper part is marine or non-marine. With the evidence now at hand it is also difficult to either date or name these beds.

Stratigraphically they have, in a sense, the position of both the Estevan and Foxhills beds. If marine, these beds should be called Foxhills. The typical Estevan of eastern Saskatchewan is a fairly thick formation, contains coal beds, and carries a Lance dinosaur fauna through a range of about 150 feet. To be called Estevan, therefore, a formation or member should be of non-marine origin and of Lance age. Until more evidence is gathered it will be necessary to defer any decision as to the dating or naming of the Yellow sandstones.

## WHITEMUD

This stratal unit is the white band of McConnell's report and has been named Whitemud by Davis, who included it, as a division, in the Fort Union formation. Its status as member or formation is best deferred until more is known of the stratigraphy of southern Saskatchewan. Its light-coloured sediments form a prominent white band in the cliffs on the valley sides in many parts of Eastend area. Good exposures occur on both the north and south slopes of Frenchman valley from Eastend to the west border of the area, on the west slope of Eastend coulée, and on both slopes of Frenchman valley in the southeastern corner of the map-area.

This is the type area for the Whitemud beds. The exact limits of the formation, however, have not yet been clearly defined. It is, therefore, necessary that the limits herein tentatively adopted be clearly stated. The lower contact with the yellow sandstones is apparently a conformable one and the base of the Whitemud beds is drawn where the sediments pass from very fine yellowish or grey sandstone to less fine sandstone and where the clay in the sandstone becomes appreciable and sufficient to give the rock a white or pale grey or pale green colour. The upper limit is tentatively drawn, not at the top of the typical Whitemud sediments, but at an unconformity hereafter to be described, and, where the disconformity is obscure, about midway between the top of the typical Whitemud sediments and the first coal seam in the overlying Ravenscrag formation. This upper limit will be better understood when the disconformity is described. If the limits are so drawn the thickness of the Whitemud beds is about 75 feet.

The sediments peculiar to and typical of this stratal unit are partly kaolinized feldspathic fine sandstones, partly kaolinized feldspathic and arenaceous silts and semirefractory and refractory clays. In addition, and in lesser amount, are dark grey and greenish shales, carbonaceous shales, and thin coal seams.

The partly kaolinized feldspathic sandstones are pale grey and pale green to nearly white. At a distance they appear almost snow white. Although they have no cement they stand up well in cliffs. They consist of grains of feldspar, quartz, muscovite, dark grey to black, hard shale or argillite, some biotite, peculiar brown spherules, a very considerable proportion of semirefractory clay, and a variety of accessory heavy minerals. There is little staining by oxide of iron. The grains are irregular and angular in shape. Fraser reports a somewhat greater proportion of quartz grains than in either the Yellow sandstones or Ravenscrag beds. Many of the feldspar grains show partial decomposition. The brown spherical aggregates are secondary. The heavy minerals determined by Fraser include zircon, tourmaline, ilmenite, anatase, and rutile in fair proportions and apatite, garnet, and epidote much rarer.

The Whitemud sandstones are fine grained. Of eleven samples examined ten fall within Boswell's classification of a fine sandstone, i.e., having the grains less than 0·25 mm. and greater than 0·10 mm. in diameter. Only one sample falls within the medium sand grade, i.e. having grains between 0·5 mm. and 0·25 mm. diameter. In all samples examined there is a high percentage of sediment of silt and clay grades. The silt content in the samples examined varies from 16·5 to 72·4 per cent and roughly varies inversely with the percentage of sand grade. The proportion of clay grade is considerable in all samples examined, varying from 12·5 to 46 per cent.

Six of the samples examined fall within the coarse silt or superfine sand grade. All these samples also contain high percentages of clay, i.e., are mixtures of sediment of silt and clay grades. They are pale green or grey or white and consist of grains of feldspar, quartz, white mica, black or dark grey argillite, and some brown spherical aggregates. There is very little staining by oxide of iron. The heavy mineral suite is as in the sandstones. Ironstone concretions are present in places.

The semirefractory clays are white to pale green and grey.

The carbonaceous shales are brown or black and some of them carry plant remains, stems, etc. The coal is lignitic like that in the Ravenscrag beds. No special study has been made of the dark shales.

The Whitemud beds vary much from place to place, but a common section, phase A, which may be called the typical section, is one which has already been briefly outlined by Dyer[1]. It is described below in greater detail and important departures from it are pointed out. It consists of the following four zones in ascending order: a thick zone of partly kaolinized feldspathic fine sandstone; a bed of coal or carbonaceous shale or zone of beds of coal, carbonaceous shale, grey shale, clay, sandstone, etc.; a zone of beds of semirefractory clay, arenaceous silt, and partly kaolinized feldspathic sandstone; and, if the contact with the overlying Ravenscrag beds be drawn tentatively as herein, a zone of dark shale.

The lowest zone varies from 40 feet to somewhat less than this in thickness and consists, in many places, entirely of the partly kaolinized feldspathic fine sandstone, which is for the most part massive, but may vary slightly in colour from light yellowish green to white, in proportion and size of mica flakes, and in grain and in amount of clay, i.e., in degree of kaolinization. These variations may be manifested as two or three separate thick layers or as gradual changes either vertically or laterally. Not enough of the samples collected have yet been tested to determine the nature of the variation. Samples "1", "2", and "3" show lateral changes near the base of the zone. No. "1" is of the yellowish green phase and is low in clay, in spite of its fine grain, and its low percentage of sand grade. Nos. "2" and "3" are lighter coloured, "3" is about white, and both are much higher in percentage of clay than "1". The lowest part is commonly somewhat yellowish green and is a poor cliffmaker, whereas the middle and upper parts are commonly white or very pale green and grey and are good cliffmakers. In one section a thick bed of light green micaceous variety overlies a thick bed of the white or very pale grey variety. As among the samples so far tested the greenish yellow phases are low in clay, it may be that on the average there is greater kaolinization in the middle and upper parts. However, the sample lowest in clay is of the pale grey variety and came from near the top of the zone, so that whatever the average variation may be there is at least some lack of uniformity. In some sections there is crossbedding on a large scale and of the aqueous type. A few carbonaceous streaks appear in places and a few large concretions are found. At the top of this zone and immediately under the bed of coal or carbonaceous shale of the second zone, the sandstone is brownish or brownish red, has roots, some apparently long tap roots, and other plant remains. In a few places the upper beds of this zone consist of dark shales, etc., possibly a transition to phase E.

[1] Dyer, W. S.: Geol. Surv., Canada, Sum. Rept. 1926, pt. B, p. 33 (1927).

The second or carbonaceous zone varies much in this area. On the north side of Frenchman valley, north and northwest of Knollys, this zone where present is comparatively thin, from about 8 inches to about 3 feet 9 inches, and consists of few layers. West of Eastend where present on the north side of the valley, it consists chiefly of a layer of brown carbonaceous shale. North of Eastend and on the west side of Eastend coulée the zone is much thicker and includes three carbonaceous or coaly layers. On the south side of the valley, south and southwest of Knollys, the zone is thin.

The zone of semirefractory clay above the carbonaceous zone varies much in thickness and in component beds from place to place. The beds are somewhat irregular, and not very thick, commonly from a few inches to 3½ feet, but thicker in places. They are chiefly of beds of semirefractory clay, clay-bearing arenaceous and feldspathic silt, and clay-bearing or partly kaolinized, feldspathic fine sandstone. The clays and silts of the Whitemud beds are almost exclusively confined to this zone. Some of the clay beds show very fine banding. A few beds carry plant debris. The combined thickness of the carbonaceous and clay zones varies from about 10 to about 30 feet.

The highest zone is of dark shale and consists chiefly of thick beds of dark grey and green shales, clay shales, and arenaceous shales. The thickness varies from about 10 to 25 feet.

There are important departures from the foregoing typical or "A" phase. In a few rare sections, "B" phase, the part between the carbonaceous and dark shale zones, normally occupied by the clay, silt, and sandstone of the clay zone, consists almost entirely of the massive clay-bearing, partly kaolinized sandstone. This phase is very rare. In another type of section, phase "C", there is no carbonaceous zone and the beds of the clay zone rest immediately on the massive sandstone of the basal zone. Sections on the north side of Frenchman valley in the very western part of the map-area and in other parts of the area where the carbonaceous zone is absent, are of this phase. Dyer has noted in places the absence of the carbonaceous layers[1]. No exact example has been found of a section, phase "D", combining the peculiarities of phases "B" and "C", in which the position of the carbonaceous beds of the carbonaceous zone and of the clay and silt of the refractory clay zone, is occupied by massive clay-bearing sandstone so that the section would consist of thick, massive clay-bearing sandstone below and dark shale above. A section south of Knollys is close to this phase, however. Other sections, phase "E", are more difficult to understand. The uppermost dark shale zone increases in thickness at the expense of the lower zones of typical Whitemud development. The positions of the refractory clay and carbonaceous zones, and even much of the massive sandstone zone, become occupied by dark shale, etc., so that in places the section consists of only a few feet of the white or greenish, clay-bearing, massive sandstone overlain by a considerable thickness of dark shale, silts, and fine greenish sandstones, as in the northern part of the sheet, just north of Southfork, and in the extreme southeastern corner

[1] Dyer, W. S.: Op. cit., p. 33 B.

of the map-area on both sides of Frenchman valley. This phase of the Whitemud beds is further discussed under "Origin of Sediments."

No fossils have yet been found in the typical Whitemud beds, i.e., in the three lowest of its four zones. The dark grey and greenish clays or shales, fine greenish sandstones, etc., however, which in some places replace them laterally, or at least occupy their stratigraphic position (phase E), contain dinosaur and other land and freshwater invertebrates and appear to be of Lance age. On the northeast bank of Frenchman river, just off the southeast corner of the map-area, in dark green shale immediately over typical Whitemud white, clay-bearing sandstone, at the same stratigraphic level as some typical Whitemud sandstone not 100 yards away, part of a crest of horned dinosaur was found, to which Sternberg gave the field identification of *Triceratops*. A few fossils were also found just north of the village of Southfork in the dark and greenish shales and very fine sands, which are so well developed there at the expense of the other zones (phase "E"). Although these fossils cannot be identified as to species, they afford additional evidence that dinosaurs are present in the dark shales, etc., of the sections of phase "E" whatever the exact relations of these beds may be to the normal sediments of the Whitemud. One specimen, a vertebra of an herbivorous dinosaur, came from just at the border between the light sandstone and dark shale. The following land and freshwater vertebrates came from the overlying dark shales, etc., and from below a bed of dark green sandstone locally taken as the base of the Ravenscrag: scales of the ganoid (pike fish) *Lepisosteus occidentalis*, plates of the sturgeon *Acipenser* sp. indt., part of a jaw of the fish *Kindleia fragosa*, part of a vertebra of the fish *Pappichthys* ?, vertebra of a small fish, fragments of the carapace of at least three species of Trinychid turtles, rib of the Rhynchocephalian reptile *Champsosaurus*, crocodile teeth, teeth of horned dinosaur (smaller than the average *Triceratops* tooth, but may be of that genus), fragment of tooth of a duck bill dinosaur, fragments of ribs of herbivorous dinosaur, and fragments of the phalanges of a carnivorous dinosaur. The identifications are by C. M. Sternberg. If these beds are equivalent in time with the typical Whitemud sediments, as well as equivalent in stratigraphic position, the typical Whitemud beds are also of Lance age. The typical Whitemud beds are certainly not later than Lance, for the basal Ravenscrag beds up to the No. 1 coal seam contain dinosaur remains and are of Lance age. If the typical Whitemud beds of the Eastend area are equivalent in age to those farther east (which they probably are, but are not yet proved to be) they are not earlier than Lance, for the underlying Estevan beds carry dinosaurs of Lance age, on Rocky creek[1]. The available evidence, therefore, points to a probable Lance age for the typical Whitemud sediments and to a Lance age for the dark grey and green shales, silts, and fine sands which in places occupy their stratigraphic position (phase E). Beds similar to the Whitemud have been reported from North Dakota and northeastern Montana and may be of the same age. They have been placed in the Fort Union formation, but on what fossil grounds is not known. No sediments of

[1] Sternberg, C. M.: Can. Field Nat., vol. 38, No. 4, pp. 66-70 (1924).

the Whitemud type have yet been reported from Alberta. They are absent from Red Deer Valley area and if once present were removed during the interval of erosion prior to the deposition of the sediments of the Paskapoo formation.

In the absence of several lines of converging evidence or of overwhelming fossil evidence it is difficult to determine whether any given strata are of marine or non-marine origin, but the Whitemud beds are in part at least non-marine and there is no evidence that any part is marine. The presence of coal beds, roots, and other plant debris in the carbonaceous zone indicates non-marine conditions. The presence of land reptiles, freshwater fish, and plant debris in the dark shales and fine sandstones of phase E, together with the rapid lateral changes in the beds, favour a non-marine origin for these strata. The presence of some plant débris and the irregularity of bedding in the semirefractory clay zone point to flood-plain, rather than marine, deposition for that part of the section.

### LOCAL UNCONFORMITY

At the top of the Whitemud beds there is an erosional unconformity which, although probably representing only a short time interval, is met with over nearly all the Eastend area and has an important bearing on the distribution of the Whitemud clay beds. It has been made use of in tentatively assigning an upward limit to the Whitemud beds. In some places this unconformity is obscure, but in other places is most apparent. After the deposition of the typical Whitemud beds and the dark shales above them and prior to the deposition of the dark green sandstone, the dark shale, and the No. 1 coal seam of the basal Ravenscrag, there was an interval of erosion which affected some places more than others. In some places there is no apparent evidence of erosion and the actual position of the unconformity is difficult to locate, particularly if the lowest beds of the Ravenscrag are dark shales like the highest Whitemud beds. It is difficult to say in these places whether there is a break in the succession or whether there is an unbroken sequence. In many places, however, there is no doubt of the presence of an unconformity, where the contact with the dark green sandstone cuts downward across the dark shale, the semirefractory clay zone, the carbonaceous zone, and even in a few places to within 5 or 10 feet of the bottom of the partly kaolinized sandstone zone, representing a removal of at least 65 to 70 feet of Whitemud strata. In such places the slope of the contact varies from a few degrees to almost vertical. Where the Whitemud is cut in to any extent, the basal rock of the Ravenscrag is a dark green, medium-grained sandstone, which to some extent at least is thickest where the depth of penetration is the greatest. It is as though the hollows were filled with the dark green sand and then the dark grey or green mud deposition were resumed. Along the contact and in the bottom of the dark green sandstone, particularly where the contact is steep, are irregularly shaped fragments of the dark shale, clay, and white clay-bearing sandstone of the Whitemud which probably had fallen in from the side; in one place some of these fragments are 18 inches across.

One phase of the unconformity deserves particular attention. In places the contact follows a long way, some part of the Whitemud carbonaceous zone, and the basal Ravenscrag is a thick bed of the dark green sandstone, e.g., in sections BC and GH (*See* map). Superficially in such places a conformable contact is suggested, even though the refractory clay and dark shale zones are not present. It was, therefore, considered necessary to examine a part of this contact in detail and to determine whether or not it is conformable. This was done for section GH. The carbonaceous zone in this section is fairly thick and contains three carbonaceous or coaly beds that can be readily recognized and traced for a long distance. Careful observation shows that the base of the Ravenscrag dark green sandstone rises and falls, the contact being in some places with the lower coaly bed, in other places with the middle black carbonaceous shale layer, in other places with the upper coaly layer and even with higher beds. One artificial exposure of the contact shows the effect of erosion on a small scale. A soft grey shale under the upper coaly layer and its subjacent brown carbonaceous shale layer was easily eroded and carried away, undermining the coal and carbonaceous layers and causing them to partly cave in. The dark green sand of the basal Ravenscrag was later deposited under and around the partly broken and fallen coaly or brown carbonaceous layers. Another artificial exposure of the contact shows in detail the effect of erosion. A coaly layer has been partly destroyed and undermined, so that its broken end extends out into the dark green sandstone of the basal Ravenscrag. It is concluded, therefore, that there is in this part of the section, not a continuous sequence but an erosional break. It is not known, however, how much or what kind of Whitemud sediment has been removed. The plant-bearing, brown carbonaceous shales in their original state of mud with matted vegetation and the coaly layers in their original state of peaty layers with logs, sticks, stems, etc., appear to have been more resistant than the clay shales and sandstones in their original state of clay, sand, etc. This probably explains why the contact of the basal green sandstone of the Ravenscrag is with the carbonaceous zone in so many places.

There is no angular unconformity. What folding there is in the Whitemud appears to be shared by the Ravenscrag and the distance between the base of the carbonaceous layer in the Whitemud and the No. 1 seam in the Ravenscrag is fairly uniform, about 55 to 60 feet over much of Eastend area.

Where there is lateral substitution of the typical Whitemud sediments by the dark shales, etc., of phase E, it is difficult to locate the break and to obtain evidence of erosion. In some such places there may be little or no break in the sequence.

The erosional interval is not a long one, and erosion is merely a local phenomenon of Lance time, for the Whitemud beds are probably of Lance age and the basal Ravenscrag below the No. 1 coal seam appears without doubt to be of Lance age. The break, therefore, is merely of the nature of a local erosional unconformity and cannot be compared in magnitude with that between the Edmonton and Paskapoo of Alberta; the Edmonton is pre-Lance and probably pre-Whitemud and the Paskapoo is not only post-Lance and post-basal-Ravenscrag but post-Fort Union.

RAVENSCRAG

The name Ravenscrag was given by Davis to that part of the Fort Union formation, i.e., Fort Union as interpreted by him, lying between the Whitemud beds and the Cypress Hills conglomerate. The Ravenscrag beds underlie a large part of the area and are exposed in the higher parts of the cliffs on both slopes of Frenchman River valley from Eastend westward, on the west slope of Eastend coulée, at Anxiety butte, and on both sides of Frenchman valley in the southeastern corner of Eastend map-area. There are also a few exposures on Conglomerate creek and its tributaries.

In Eastend area where the contact is with the lower zones of the Whitemud, the basal part consists of thick, dark green, massive sandstones in places crossbedded on a large scale. Where the lower contact does not penetrate deeply into the Whitemud, the sandstone passes into dark grey or greenish shale both laterally and upward. Where thick and massive it carries numerous, large, irregularly shaped concretions that appear to be merely well cemented and resistant parts of the normal sandstone. In the lowest part of the dark green sandstone, near the contact as already noted, are fragments from various beds of the Whitemud. Above the dark green sandstone are about 25 feet or less of dark shale, etc., and above this is the No. 1 coal seam of the Ravenscrag. Above this are greyish and yellowish sandstones, shales, clay shales in beds of a few inches to 10 feet thick, and coal seams. There is a considerable amount of plant material in this part of the formation and some of the coal seams, particularly the large seam mined at Anxiety butte, have numerous roots and other plant material in the underlying shale. The higher part of the Ravenscrag consists of thick beds of buff sandstone with some shale layers and a few very thin coal beds. The thickness of the Ravenscrag varies and the original total thickness is not known, for the Ravenscrag sediments suffered considerable erosion before the deposition of the cypress Hills formation. The thickness in the western part of the map-area on the north side of the valley just northwest of Knollys, is about 240 feet.

Seven samples of the dark green sandstone have been examined in the laboratory by Fraser (*See* Appendix I). All are of sand grade, three of fine sand grade and four of medium sand grade. The percentage of sediment of clay grade in these samples is much lower than in any of the Whitemud sandstones, 2 to 9 per cent. The component grains are feldspar, quartz, black grains of argillite or hard dark shale, muscovite, and rare biotite. There are also a few rare chert grains and a few green and pinkish grains. Some of the grains are stained with oxide of iron. The heavy mineral suite includes zircon, tourmaline, garnet, epidote, andalusite, apatite, rutile, ilmenite, and hornblende. The last is only abundant in one specimen and scarce, rare, or absent in others. Of seven samples examined from sandstones between the No. 1 coal seam and the top of the formation, one is of medium sand grade, two are of fine sand grade, and four are of silt or superfine sand grade. The clay in two samples of medium and fine sand grades, respectively, is 3 and 12 per cent. Four samples are calcareous. The component grains are feldspar, quartz, argillite, muscovite, and biotite (common in some samples). The heavy mineral suite includes zircon, tourmaline, apatite, garnet, rutile, epidote, anatase, andalusite, and ilmenite. The suite differs little from that of the dark green sandstone.

The basal part of the Ravenscrag, below No. 1 coal seam, carries dinosaurs and is of Lance age. Southwest of the Crawford ranch and on the north slope of a long spur, in SE.¼ sec. 17, tp. 17, range 21, near the base of the Ravenscrag and in a shale layer between two thick beds of the dark green sandstone, fragments of bone were collected which Sternberg states to "have every appearance of herbivorous dinosaur bones, but on account of their very fragmentary nature" they cannot be definitely placed. The locality where Mr. H. Jones of Eastend collected a supraorbital horn core of *Triceratops*[1] and where Sternberg found fragments of horned dinosaur crest was revisited by Sternberg and the writer. Additional fragments of the crest of horned dinosaur were discovered and found to be coming from the beds of dark green sandstone which overlies the Whitemud beds at this locality. The horn core collected by Mr. Jones probably came from the same horizon. At other localities dinosaur bones were found to range up to within 5 feet of No. 1 coal seam.

Above No. 1 coal seam fossils are rare and consist chiefly of plants and non-marine invertebrates. The few vertebrate remains are either too long ranging to be diagnostic or too imperfect and fragmentary for identification. On the north side of Frenchman valley northwest of Knollys, and about 25 feet above the No. 1 coal seam, in a bed of light grey silty clay shale the following were found:

*Onoclea sensibilis* Newberry
*Lemna ? sculata ?* Dawson
*Sequoia nordenskioldi* Newberry (non Heer?)
*Cocculus haydenianus* Ward
*Planera* sp.
*Sapindus* sp.
*Apocynophyllum* sp.

The identifications are by W. A. Bell, who states that "the assemblage suggests a Fort Union age, but it is perhaps too small to positively correlate the beds containing it with the Fort Union rather than with the Lance. It would seem to be pre-Paskapoo as none of the above species are present in the Paskapoo florule recently described by Berry." A few non-marine gastropods were found with this flora. Just north of the Crawford ranch near Chimney coulée the following non-marine fish and reptilian remains were found in shale and sandstone just above the No. 1 coal seam:

Scales of the ganoid *Lepisosteus occidentalis*
Plates of the sturgeon *Acipenser* sp. indt.
Fragments of fish jaw
Fragments of rib of the *Rhynchocephalian* reptile *Champsosaurus.*

The identifications are by Sternberg who notes the long range of the determinable species and genera, which does not permit a correlation.

[1]Sternberg, C. M.: Can. Field Nat., vol. 38, No. 4, pp. 66-70 (1924).

On the northern border of the Eastend map-area, on the upper part of Conglomerate creek, in grey shale and sandstone, the following were collected:

*Unio priscus* Meek and Hayden
*Sphaerium planum* Meek and Hayden ?
*Campeloma multilineata* Meek and Hayden
*Viviparus trochiformis* Meek and Hayden
*Goniobasis tenuicarinata* Meek and Hayden
*Thaumastus limnaeiformis* Meek and Hayden
*Physa* sp.
*Hydrobia* sp.

The above identifications are by Dr. T. W. Stanton, who states that:

"This is a Fort Union assemblage of forms, though practically all of the species are known to range down into the Lance formation. When they are found in the Lance, however, they are almost always associated with a number of distinctive forms which are not known to range above the Lance. Among them are *Tulitoma thompsoni* and a series of peculiar *Unio* species, mostly short, high forms, many of which are highly sculptured. A collection as large as the one under examination ought to contain some of these distinctive Lance species if it came from the Lance. In the absence of all such forms and in consideration of its stratigraphic position I think that you would be justified in referring the Ravenscrag formation to the Fort Union. It certainly is not younger than Fort Union."

Therefore, the weight of the evidence furnished by plant and invertebrate fossils is in favour of a Fort Union age for the beds above the No. 1 coal seam which contains these fossils. It is desirable that determinable and diagnostic vertebrate remains be found in this upper greater part of the formation. It is important to know whether or not dinosaur remains extend above No. 1 coal seam and what effect the evidence of fossil mammals would have on the dating of this formation.

The basal part of the Ravenscrag, below No. 1 coal seam, is to at least some extent non-marine, for it contains in places, numerous dinosaur bones. There is sufficient accumulative evidence to demonstrate that the rest of the Ravenscrag is non-marine, for it contains coal beds, roots, and non-marine fossils, including plants, freshwater pelecypods, gastropods, and vertebrates and a terrestrial reptile.

## CYPRESS HILLS

This is the Miocene of McConnell's report. It underlies the high upland in the northern part of the map-area from its western margin eastward to Anxiety butte, and also occurs on the higher part of Ravenscrag butte and on the uppermost part of a small butte on the south side of Frenchman valley. There is a very considerable erosional break between the Cypress Hills and Ravenscrag as McConnell observed long ago.

The Cypress Hills formation consists of thick beds of conglomerate, a peculiar shale or clay conglomerate, grit, sandstone, and shale. The conglomerate in places is little consolidated and consists chiefly of boulders of grey, purplish red, or pinkish quartzite. The boulders are well worn, rounded or oval in shape, and vary in size from ¼ inch to 18 inches in the longest diameter. A peculiar bed consists of irregularly shaped shale or hardened, clay-shale fragments, fine sand, and a few quartzite pebbles; this rock contains many of the bones collected. The sandstones are mostly coarse, are in places little consolidated, and in places buff in colour. There is little shale in the formation. The conglomerate occurs in a number of thick, irregular beds.

Some fossils were collected in this formation last summer and have been identified by C. M. Sternberg. The following were found in Calf creek: a fish vertebra; a lower molar tooth of the forest horse *Mesohippus westoni;* a nasal horn core of the titanothere *Titanotherium prouti;* fragments of right dentary with part of last molar, of teeth and of ribs, an upper molar, the proximal end of ulna, left radius and metacarpal bone of the titanothere *Megacerops;* part of left dentary with P4 and roots of M1 and 2 of the Rhinoceras *Caenopus occidentalis;* anterior end mandible of the Rhinoceras *Acceratherium;* left upper molar of the deerlike ungulate *Leptomeryx speciosus* Lambe; part of left dentary with P2, 3, 4, and M1, and part of a left dentary with P4, and M1 and 2 of the deerlike ungulate *Leptomeryx mammifer* Cope; two lower molars of a Leptomeryx; upper premolar of a canid. On a small creek flowing into Calf creek the left upper third molar of *Megacerops* was found. From Conglomerate creek were found: part of upper premolar of the giant hog *Elotherium* and the second lower premolar, dorsal vertebra, and the proximal end of the left radius of *Megacerops.* At Anxiety butte were found fragments of the teeth of *Megacerops;* proximal end of a titanothere radius; and fragmentary teeth of the Rhinoceras *Hydracodon.* This has long been known as an Oligocene or lower Miocene fauna, as it was called in McConnell's time, when what is now known as Oligocene was then included in the Miocene. The abundance of these freshwater amphibious and terrestrial vertebrates points to a non-marine origin of the Cypress Hills formation.

## ORIGIN OF WHITEMUD SEDIMENTS

The origin of the Whitemud clays and clay-bearing sandstones is an important problem. The subject has been deferred until all the sediments have been described. No claim is made that there is sufficient evidence to solve the problem at present, nor is it possible in the space available to take into account all the possibilities and all phases of the problem. It is believed that important evidence is to be found in the feldspathic nature of the sandstones of the Ravenscrag, Whitemud, and Yellow sandstone members, the high percentage of refractory or semi-refractory clay in the sandstones of the whitemud beds, and the comparative thinness and irregularity of the clay beds. The evidence furnished by the heavy mineral suites is considered, but it is not yet possible to evaluate its importance. The greater refractory quality and purity of the clays in the east as compared with those in the west, and the claimed increase in size of grain of the Whitemud sandstones from west to east have already been submitted as evidence by Davis and Dyer respectively. The problem includes two distinct, although to some extent linked, phases which must not be confused and which must be considered separately; first, whether

MINES BRANCH
LIBRARY

the semirefractory and refractory Whitemud clays are the result of extra-regional weathering of feldspathic rocks, or whether they are the result of local weathering of feldspathic sands and of their re-sorting in the region of deposition; second, whether the Whitemud sediments have come from the east, from the Precambrian area of Manitoba and Ontario, etc., or from the west or southwest, i.e. from the Cordillera region.

Extra-regional weathering of the feldspars is inferred, if not actually stated, in Davis' account of the origin of the clays. Wherever the kaolinization took place and produced the clay in the clay beds, extra-regional weathering will not explain the origin of the clay which occurs in such appreciable quantities in many of the white and light grey sandstones of the Whitemud beds. It is unlikely that sediments of mixed, medium, and clay grade could be laid down together. There is the possibility which could be verified by experiment, that, if sand were deposited in very thin layers in times of strong current, clay depositing in time of quiet water would settle down between the sand grains. But even if this were possible surely some kind of banding would result. It is probable that the texture of the clay-bearing Whitemud sandstones can only be explained by weathering in situ of a feldspathic sand, the clay occurring in small patches where the feldspar grains would have been.

That this weathering might have taken place in Whitemud time has suggested a theory of local or intra-regional kaolinization or alteration in the region of deposition. It is proposed that the typical clay and clay-bearing Whitemud sediments might have originated in the following manner: feldspathic sands were transported to this area (southern Saskatchewan, etc.) from some source and after deposition were partly kaolinized in Whitemud time; some of this material, thus altered, still remains undisturbed as the partly kaolinized feldspathic sandstone; some of it, however, was reworked in Whitemud time, sorted, and laid down in shallow depressions, flood-plain shallow lakes, etc., on the old Cretaceous surface, to form the beds of refractory or semirefractory clay that occur intercalated with beds of partly kaolinized sandstones, silts, etc., in the refractory clay zone. This is a theory of intra-regional kaolinization, or alteration in the area of deposition. No uplift is inferred, only the erosion and redeposition that takes place on any alluvial plain. No considerable thickness of sediment is involved. The clay beds are not thick, are irregular, and the entire refractory clay zone is only 10 to 30 feet thick. Special conditions are required, of course, at least a temperate climate, some moisture, a covering of vegetation, and a sufficient periodic fall of the water table to promote weathering. Some of the sediments of the basal sandstone zone may have accumulated fairly rapidly, but the beds of the clay zone must have accumulated much more slowly to permit scour, sorting and redeposition, and re-weathering of the residue sands. The comparative thinness and irregularity of the clay beds and their alteration with sandstone and silt are in keeping with this hypothesis of intra-regional or local weathering of the feldspars. It would be more difficult to explain thick clay beds extending over a wide area by this hypothesis. In terms of this hypothesis the somewhat greater proportion

MINES BRANCH
LIBRARY

of quartz grains in the washed residues of the Whitemud sands as compared with those of other sandstones in the local section is explained by the greater amount of kaolinization that the Whitemud sands have undergone and the consequent reduction in proportion of feldspar grains. The Whitemud sands before kaolinization must have been very highly feldspathic. It might be argued in criticism of this theory that some of the sandstone beds in the refractory clay zone should be free of clay, as residues of kaolinized sands that had been washed free of clay, and that none such has been found in the samples tested. But these residue sands would again continue to be weathered on the old Whitemud surface and would again become partly kaolinized. It is conceivable that some of the clay beds might have originated by the kaolinization of highly feldspathic sand, carried almost or entirely to the point of completion or nearly so; such clays would carry a residue of quartz grains, and would be massive and lacking in any fine bedding. It is not possible to say whether clays of this origin are present. Many of the clays show a very fine bedding. The sand and clay beds show the effect of leaching and the reducing action of vegetation in the absence of iron oxide staining, but some iron has been concentrated in ironstone concretions and minute spherules. Some kaolinization of the Whitemud sands may have taken place at the end of Whitemud time during the interval of erosion, but it was probably not important.

The establishment of this hypothesis depends basically on whether it can be shown that the kaolinization of the Whitemud sands took place in Whitemud time. The greater amount of clay and its relatively greater purity in many Whitemud sandstones compared with that in other sands, of the Cretaceous section, suggest that specially favourable conditions may have existed in Whitemud time. More, however, needs to be known of the relative susceptibility to alteration of the sandstones of the local formations.

It has long been recognized, since Tyrrell pointed out the source[1] of the gold-bearing sands of the Edmonton formation, that a great part at least of the Cretaceous sediments of the plains have their source in the west. The increase of coarseness of the sediments westward and the replacement of marine by delta or marginal alluvial plain conditions in this direction all show this. However, it cannot be said to be established that none of the Cretaceous sediments of the plains came from the east. Davis has claimed that a reversal of drainage took place in Whitemud time and that the Whitemud sediments came from the east. In favour of this he cites the greater purity and more refractory quality of the clays in the eastern part of their area of distribution, as compared with those in the west, and observes that the clays should be purer and more refractory the nearer their source. An examination of a few analyses given by Davis[2] shows that the western clays, compared with the eastern, are higher in $SiO_2$, $K_2O$, and $Na_2O$ and lower in $Al_2O_3$ and $H_2O$, i.e., they are less altered clays. This being so, should not the argument be reversed,

[1] Tyrrell, J. B.: Geol. Nat. Hist. Surv., Canada, Ann. Rept. N. S., vol. II, pt. E, pp. 134-5 (1887).
[2] Op. cit., pp. 15, 40, 58, 71.

would not the clays become more altered the farther from their source, for some weathering always accompanies transportation.

Davis, however, may have had in mind contamination with sediment, from the west. Davis evidently assumes that the kaolinization took place in the east, in the Precambrian area of the Canadian shield and his hypothesis combines extra-regional kaolinization and an eastern source. The first indeed, to a considerable extent presupposes the latter, for the Precambrian area to the east is the more favourable region for a possible source of sediment and as having topographic features more favourable to prolonged chemical weathering. At least its possibilities as a source of well-leached sediment are greater than those of the western Cordilleran region. However, if the Whitemud clay-bearing sandstones are the result of the weathering *in situ* of feldspathic sands, they were at the time of transportation to the area, highly feldspathic and not predominantly well leached sediments and the argument that they came from the east because well-leached sediments would be more likely to have come from there is considerably weakened. A more convincing argument in favour of an eastern source is the one advanced by Dyer, that the grain of the Whitemud sandstones increases eastward. If this holds true of all the Whitemud sediments of southern Saskatchewan, eastern Montana, etc., the evidence is not to be ignored, but more samples taken over a wider area are necessary before it is established; the east end of Cypress hills seems to have been an area that received comparatively fine sediments in late Cretaceous time. This hypothesis presupposes a reversal of drainage in Whitemud time, in an area which before and after apparently was receiving western sediment. It, also, if the hypothesis of extra-regional weathering be accepted, presupposes that the eastern Precambrian area supplied feldspathic sediment. Could this be possible? Perhaps more investigations to establish the amount and nature of these eastern sediments are required before this question can be definitely answered. But if these sediments were originally feldspathic when delivered into the area of deposition, why could they not have come from the west, as much of the Cretaceous sediments on the plains evidently have. The western sediments are feldspathic, for Stewart has demonstrated the feldspathic nature of the late Cretaceous and early Tertiary sandstones of the disturbed belt of southwestern Alberta, and Rutherford has noted the presence of feldspar in the Cretaceous sediments of western Alberta. The sandstones of the formations underlying and overlying the Whitemud are feldspathic and they are assumed to have had a western source. The mineral composition of the Whitemud sandstones is much like that of the sandstones of the overlying and underlying beds. The bulk minerals are quartz, feldspar, argillite, muscovite, mica, biotite (in the yellow sandstones and Whitemud beds). The heavy mineral suite of the Whitemud sandstones and silts differs chiefly from the suites of the yellow sandstones and Ravenscrag sandstones in the presence of anatase and in the small proportion or absence of garnet, epidote, and apatite, which are easily weathered minerals, and the Whitemud sandstones have evidently undergone more alteration than the sandstones of the other formations. The absence or low proportion of garnet and epidote can hardly be advanced as argument for derivation from the east, as these minerals are present in the rocks of the eastern Precambrian area of Manitoba and Ontario. The investigations of heavy minerals in Canadian sandstones, however, have not yet advanced far enough to warrant important interpretations. Otherwise the problem of the source of the Whitemud sediments seems to rest on the question whether the eastern Precambrian area would be expected to supply feldspathic or thoroughly weathered sands and whether the increase in grain of the Whitemud sandstones eastward is general.

The replacement laterally of the typical Whitemud sediments by dark shale, greenish silt, fine sand, etc., as in the sections north of Southfork and in the extreme southeastern corner of the map-area, is difficult to explain at present. It appears to be lateral replacement, the original mud of the shales and the original silt and fine sand being deposited contemporaneously with the typical Whitemud sands or these sands as they were before alteration. If this is so their unaltered character requires explanation. The possibility still remains that there may have been an interval of erosion before the deposition of the dark shale, but probably an earlier interval of erosion than that described under "Unconformity."

## STRUCTURE

In the working out of detailed structure in southern Saskatchewan, considerable care must be exercised in the selection of horizon markers. The top of the typical Whitemud sediments, the white kaolinized sandstones and clays, cannot be used, for it is an uneven line, up and down stratigraphically, particularly where affected by the unconformity. The contact between the yellow sandstones and marine shales is not a satisfactory one for refined work. The contact between the Whitemud and yellow sandstones in this area can everywhere be located within 5 or 10 feet vertically and can be used for all but the smallest scale structure. The coal seams are the best horizon markers, providing that their identity is constantly checked. The base of the Whitemud carbonaceous zone is a good horizon and can be identified by its position in the Whitemud beds. The No. 1 coal seam is even a better marker. It extends all over Eastend area and its identity can be established by its persistent shale parting, its shaly upper bench, and its position near the base of the Ravenscrag formation. In Eastend map-area it is almost everywhere about 55 to 60 feet above the base of the Whitemud carbonaceous zone. The other coal seams in the Ravenscrag are not satisfactory horizon markers. They change in thickness from place to place and are difficult to trace.

The major structure in the northern part of the map-area is a dip to the east. In the eastern part there is a regional dip from north to south, i.e. from Anxiety butte to south of Whitemud. On this is superimposed a peculiar secondary structure of small irregular folds. Most of these are on a small scale, as examination of the structure sections (*See* map) will show. It is difficult to know just what allowance should be made for landslide or settling down the valley sides; of course, any recent landslide can be detected, but pre-Glacial slipping is very difficult to determine. It is difficult to explain much of the secondary structure by landslide, however. Too large masses are involved and many are so situated as to have no relation to any topography favourable to land sliding. These secondary folds have not the regularity that results from orogenic causes. If the secondary folds are due to irregularity in settling of the sediments they will not persist to very great depths.

Little can be determined of the structure on Conglomerate creek and its tributaries; the structure of this part is mostly inferred from the structure on Frenchman river.

## ECONOMIC GEOLOGY

### OIL AND GAS

Until more work is done it is not advisable to make any inferences regarding oil and gas possibilities. There do not appear to be any large favourable structures in Eastend area. The secondary structures are small. The problem is, are any of these structures large enough for oil and gas production, have they sufficient closure, and do they persist in depth?

### COAL

The coal and coaly beds in the Whitemud are too small to be of economic importance. The No. 1 coal seam in the Ravenscrag formation has greater possibilities and has been mined northwest and southwest of the town of Eastend. It has been followed from the western border of the map-area almost to Anxiety butte. It consists of a lower bench of coal of fair quality, a parting of shale, and an upper bench of shaly coal. The thickness of the lower bench is 1 foot 4 inches to 3 feet 5 inches, the parting varies from 3 inches to 9 inches, and the upper bench from 1 foot 1 inch to 2 feet 7 inches, including coaly shale. A sample taken from both benches at a locality southwest of Knollys, where the total seam is 4 feet 7 inches and includes a 5-inch and an 8-inch shale parting, gives the following analysis:

| — | As received | Dry basis |
|---|---|---|
| Moisture | 36·0 | |
| Ash | 17·7 | 27·6 |
| Volatile matter | 25·6 | 40·0 |
| Fixed carbon | 20·7 | 32·4 |
| Sulphur | 0·4 | 0·7 |
| B.T.U. | 4570 | 7130 |
| Fuel ratio | 0·80 | |

The coal is non-coking. In a small gully just west of the clay quarry northwest of the town of Eastend, the No. 1 seam was also sampled. There the lower bench is 3 feet 5 inches, the parting 8 inches, and the upper bench 1 foot 2 inches. A sample from the lower bench gives the following results:

| — | As received | Dry basis |
|---|---|---|
| Moisture | 37·5 | |
| Ash | 9·3 | 14·8 |
| Volatile matter | 27·0 | 43·2 |
| Fixed carbon | 26·2 | 42·0 |
| Sulphur | 0·4 | 0·6 |
| B.T.U | 5790 | 9260 |
| Fuel ratio | 0·95 | |

The coal is non-coking. A sample from the upper bench gave the following results:

| — | As received | Dry basis |
|---|---|---|
| Moisture | 32·8 | |
| Ash | 21·7 | 32·3 |
| Volatile matter | 23·4 | 34·8 |
| Fixed carbon | 22·1 | 32·9 |
| Sulphur | 0·2 | 0·4 |
| B.T.U | 4740 | 7060 |
| Fuel ratio | 0·95 | |

The sample is non-coking. The lower bench is evidently of much better quality than the upper, being much lower in ash and higher in B.T.U. The somewhat high ash of the first sample given above is due to inclusion of coal from the upper bench in the sample. The coal of all these samples is lignitic, with a fuel ratio of less than 1. What appears to be the No. 1 seam was also found in the southeastern corner of the map-area, near Whitemud. It is quite thin there, but still has its characteristic parting. Other seams are present in the Ravenscrag above the No. 1 seam, but are very irregular in thickness and difficult to trace. They were not all examined. In a section measured in detail on the north side of Frenchman valley northwest of Knollys, the only important seam observed above the No. 1 was a 4-foot seam consisting of lignite and lignitic shale. Between Anxiety butte and Chimney coulée only two of the upper seams have a fair thickness. The upper varies from about 5 to 7½ feet, the measurements including some coaly shale. The lower varies from 1 foot 8 inches to 4 feet 3 inches. The seam mined at Anxiety butte is probably the upper of these two seams.

CLAYS

Much work has been done on the sampling and testing of the Whitemud clays of this area by Keele, Davis, Worcester, and Hutt. The main object of last summer's work, however, was to study the geological relations of the Whitemud clays. Particular attention was devoted to those factors that control the continuity of the clay beds.

Actual clay layers are very rare in the basal massive sandstone zone of the Whitemud beds, but the sandstone itself on account of the partial or almost complete kaolinization that its feldspar grains have undergone, contains, in some places, considerable clay. One sample tested gave 46 per cent. At Claybank, in the east, this kaolinized or partly kaolinized feldspathic sandstone is used as part of the mixture in the manufacture of firebrick. It has also been proposed to separate the clay in sandstone by washing.

Most of the actual clay beds are in the clay zone, which as noted under stratigraphy consists of beds of clay, partly or completely kaolinized feldspathic silt, or superfine sandstone, and partly kaolinized fine feldspathic sandstone. Both the fine sandstone and the silt of this zone contain considerable clay. In some places kaolinized silt is quarried with the clay and used with it in the manufacture of clay products. Six samples of white or pale green silt from this zone have from 29·6 to 45·5 per cent clay. In one silt sample the kaolinization appears to be nearly complete, the plus 270 meshheads containing 92 per cent of silica by analysis.

A few observations on the exploration of the clay deposits may be worth noting. Where the green sandstone of the basal Ravenscrag is very thick, and it can then be readily recognized by its large concretions, some part of the Whitemud beds is likely to be absent, and particularly the clay zone on account of its position in the upper part of the Whitemud. However, if the bottom of the green sandstone does not penetrate too deeply into the Whitemud basal sandstone, enough of the kaolinized sandstone may be left to be of some economic value. The unconformity between the Ravenscrag and Whitemud beds thus has an important influence on the continuity of the Whitemud clay-bearing zones. The contact, however, rises and falls rather abruptly in places, so that productive localities may be in close proximity to those that are unproductive. If the sections on the map be examined it will be seen that in places the contact between the Ravenscrag and the Whitemud is high enough to leave undisturbed all of the Whitemud section, the dark shale above the refractory clay zone, the carbonaceous zone, and the zone of massive kaolinized sandstone. In other places it descends and follows about the carbonaceous zone and the refractory clay zone is absent, but much of the basal sandstone zone remains. In other places it descends so far that much of the basal sandstone is gone. It will be noted that in places, according to the sections on the map, the refractory clay zone is much thicker than in other places. Another factor in the continuity of the Whitemud productive zones is the apparent replacement laterally by shale, i.e. the productive zones are absent because apparently they were never deposited (but *See* under origin of sediments). The refractory clay zone will be found to vary very much; the thickness of individual beds varies from place to place and there is considerable variation laterally in kind of sediment, some sections having more sandstone or more clay. The carbonaceous or coaly zone, where present, can be used as a guide in the search for clay in Eastend area. If clay beds are sought for, the section above the coaly horizon should be uncovered and examined. Only very rarely is clay or even silty clay present in the lower zone of massive kaolinized sandstone. Below the carbonaceous zone the kaolinized sandstone for the most part will be found, but in places the clay content is low and in some places this zone is partly occupied by dark shale, etc., particularly the upper part.

# APPENDIX I

## PETROGRAPHY OF THE SEDIMENTS: MECHANICAL ANALYSIS

*By F. J. Fraser*

### *Procedure*

Fifty grams of each sample, with the exception of one or two of coarser sediments, were sieved wet. Material passing through the 270 mesh (0·05 mm.) sieve was elutriated.[1] Results are shown in accompanying table. Boswell's[2] classification of sand, silt, and clay is used to indicate size limits or grades:

Greater than 0·5 mm. and less than 1·0 mm., coarse sand.
Greater than 0·25 mm. and less than 0·5 mm., medium sand.
Greater than 0·1 mm. and less than 0·25 mm., fine sand.
Greater than 0·05 mm. and less than 0·1 mm., superfine sand or coarse slit. (Silt grade)
Greater than 0·01 mm. and less than 0·05 mm., silt.
Less than 0·01, clay.

*Mechanical Analysis of Ravenscrag Samples*

| Sample No. | Sand, grade | | | Silt, grade | | | Clay, grade | Remarks |
|---|---|---|---|---|---|---|---|---|
| | Range of size, in mm. | | | | | | | |
| | 0·25 | 0·25 to 0·2 | 0·2 to 0·1 | 0·1 to 0·05 | 0·05 to 0·02 | 0·02 to 0·01 | 0·01 | |
| | % | % | % | % | % | % | % | |
| 10 | ...... | ...... | 22·0 | 52·0 | 14·0 | ...... | 12·0 | Calcareous |
| 11 | ...... | ...... | ...... | 67·0 | ...... | ...... | ...... | Calcareous |
| 12 | ...... | ...... | 35·0 | 27·0 | ...... | ...... | ...... | Calcareous |
| 26 | 30·5 | 33·0 | 23·0 | ...... | 10·5 | ...... | 3 | |
| 27 | ...... | ...... | ...... | 21·0 | 38·6 | 17·5 | 22·9 | |
| 28 | ...... | ...... | ...... | 34·4 | 32 | ...... | 33·6 | |
| 30 | ...... | ...... | ...... | 33·2 | 41·0 | ...... | 25·8 | Calcareous |

NOTE. Nos. 11 and 12 after treatment with hot acid; Nos. 10 and 30, analysis on original sample; 20 per cent of the insoluble residue of No. 30 is coarser than 0·05.

The Ravenscrag samples are, as indicated above, mainly silts.

[1] Boswell, P. G. H.: "British Resources of Refractory Sands", pt. I, p. 20, London (1918).
Crook, T.: Appendix to Hotch and Rastall. "Sedimentary Rocks", p. 349, London, 1913.
Fraser, F. J.: "An Improved Form of Crooks' Elutriator"; Trans. Faraday Soc. 59, vol. XX, pt. 2 (Nov. 1924).

[2] Boswell, P. G. H.: Op. cit., p. 13.

*Mechanical Analysis of Basal Ravenscrag Green Sandstone Samples*

<table>
<tr><th rowspan="3">Sample No.</th><th colspan="3">Sand, grade</th><th colspan="3">Silt, grade</th><th>Clay, grade</th><th rowspan="3">Remarks</th></tr>
<tr><th colspan="7">Range of size, in mm.</th></tr>
<tr><th>0·25</th><th>0·25 to 0·2</th><th>0·2 to 0·1</th><th>0·1 to 0·05</th><th>0·05 to 0·02</th><th>0·02 to 0·01</th><th>0·01</th></tr>
<tr><td></td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td></td></tr>
<tr><td>7</td><td>60·0</td><td>20·0</td><td>10·0</td><td>........</td><td>5·0</td><td>........</td><td>5·0</td><td></td></tr>
<tr><td>32</td><td>6·8</td><td>51·0</td><td>25·2</td><td>........</td><td>13·5</td><td>........</td><td>3·5</td><td></td></tr>
<tr><td>45</td><td>........</td><td>........</td><td>10</td><td>........</td><td>36·0</td><td>........</td><td>........</td><td>Calcareous</td></tr>
<tr><td>73</td><td>........</td><td>10·0</td><td>33·5</td><td>29·5</td><td>8·0</td><td>10·0</td><td>9·0</td><td></td></tr>
<tr><td>75</td><td>2·0</td><td>13·5</td><td>49·5</td><td>........</td><td>33·0</td><td>........</td><td>2·0</td><td></td></tr>
<tr><td>77a</td><td>........</td><td>26·0</td><td>48·4</td><td>66·4</td><td>16·2</td><td>........</td><td>3·0</td><td></td></tr>
<tr><td>83</td><td>42</td><td>35·0</td><td>12·0</td><td>3</td><td>3·8</td><td>........</td><td>4·2</td><td></td></tr>
</table>

NOTE. No. 45 after treatment with hot acid.

The Ravenscrag green sandstone samples are, as indicated above, mainly sands.

*Mechanical Analysis of Whitemud Samples*

<table>
<tr><th rowspan="3">Sample No.</th><th colspan="3">Sand, grade</th><th colspan="3">Silt, grade</th><th>Clay, grade</th></tr>
<tr><th colspan="7">Range of size, in mm.</th></tr>
<tr><th>0·25</th><th>0·25 to 0·2</th><th>0·2 to 0·1</th><th>0·1 to 0·05</th><th>0·05 to 0·02</th><th>0·02 to 0·01</th><th>0·01</th></tr>
<tr><td></td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td></tr>
<tr><td>38</td><td>........</td><td>........</td><td>4·2</td><td>28·6</td><td>12·8</td><td>9·2</td><td>45·2</td></tr>
<tr><td>47</td><td>........</td><td>........</td><td>........</td><td>16·0</td><td colspan="2">54·4</td><td>29·6</td></tr>
<tr><td>48</td><td>........</td><td>........</td><td>........</td><td>10·0</td><td colspan="2">44·8</td><td>45·2</td></tr>
<tr><td>70</td><td>........</td><td>........</td><td>5·2</td><td>22·4</td><td>10·0</td><td colspan="2">62·6</td></tr>
<tr><td>76</td><td>........</td><td>13·0</td><td>28·0</td><td>16·0</td><td>4·0</td><td colspan="2">39·0</td></tr>
<tr><td>77</td><td>........</td><td>32·0</td><td>15·0</td><td>7·4</td><td>4·0</td><td colspan="2">41·6</td></tr>
<tr><td>79</td><td>........</td><td>17·8</td><td>16·8</td><td>8·2</td><td>5·4</td><td>19·8</td><td>32·0</td></tr>
<tr><td>82</td><td>........</td><td>........</td><td>........</td><td>59·8</td><td>6</td><td colspan="2">34·2</td></tr>
<tr><td>85</td><td>........</td><td>3·0</td><td>18·4</td><td>26·6</td><td>3·0</td><td>3·0</td><td>46·0</td></tr>
<tr><td>405</td><td>........</td><td>........</td><td>........</td><td>46·0</td><td colspan="2">18·5</td><td>35·5</td></tr>
<tr><td>407</td><td>........</td><td>17·5</td><td>49·0</td><td>........</td><td>21·0</td><td>........</td><td>12·5</td></tr>
<tr><td>500</td><td>........</td><td>........</td><td>........</td><td>33·2</td><td>19·0</td><td>8·8</td><td>39·0</td></tr>
<tr><td>501</td><td>........</td><td>........</td><td>........</td><td>42·2</td><td colspan="2">30·2</td><td>27·6</td></tr>
<tr><td>509</td><td>........</td><td>........</td><td>........</td><td>10·5</td><td>27·5</td><td>16·5</td><td>45·5</td></tr>
<tr><td>"1"</td><td>........</td><td>........</td><td>5·0</td><td>52·0</td><td colspan="2">15</td><td>28</td></tr>
<tr><td>"2"</td><td>........</td><td>15·5</td><td>25·0</td><td>........</td><td>19·5</td><td>........</td><td>40</td></tr>
<tr><td>"3"</td><td>55·5</td><td>16·0</td><td>24·0</td><td>........</td><td>16·5</td><td>........</td><td>37·5</td></tr>
<tr><td>Claybank</td><td>35·6</td><td>9</td><td>4·0</td><td>4·4</td><td colspan="2">13·0</td><td>34·0</td></tr>
<tr><td>Grey sandstone</td><td>........</td><td>........</td><td>32·0</td><td>41·5</td><td>9</td><td colspan="2">17·5</td></tr>
</table>

The samples fall into two classes: those that may be called sands, and those that may be called silts; both types contain considerable clay. Sample 407 has the lowest clay content, and the Claybank sample has the lowest silt content.

*Mechanical Analysis of "Yellow Sandstone" Samples*

| Sample No. | Sand, grade | | | Silt, grade | | | Clay, grade | Remarks |
|---|---|---|---|---|---|---|---|---|
| | Range of size, in mm. | | | | | | | |
| | 0·25 | 0·25 to 0·2 | 0·2 to 0·1 | 0·1 to 0·05 | 0·05 to 0·02 | 0·02 to 0·01 | 0·01 | |
| | % | % | % | % | % | % | % | |
| 15 | ........ | ........ | ........ | 83 | 10 | | 7 | Dolomitic |
| 17 | ........ | ........ | ........ | 90 | 5 | | 5 | Dolomitic |
| 94 | ........ | ........ | ........ | 91 | ........ | ........ | 9 | Calcareous |
| 210 | ........ | ........ | ........ | ........ | 96 | ........ | 4 | Dolomitic |

The yellow sandstone samples are, as indicated above, silts.

## *Notes on Mineral Constituents*

*Quartz.* Quartz is low in most samples and occurs as irregular, angular grains, but samples Nos. 7, 83 (Ravenscrag green sandstone), and the Claybank sample (Whitemud) contain occasional, rounded grains. These three samples also contain the largest quartz (and feldspar) grains; the largest, up to 1 mm. in diameter, are in the Claybank sample, in samples Nos. 7 and 83, the largest measure 0·5 mm. Strings of inclusions are common in the quartz grains, otherwise no outstanding features were noted.

A series of the washed and graded samples, which under the binocular had an appearance that suggested a comparatively high quartz content, were mounted in Canada balsam, and the number of quartz grains estimated. The results obtained are expressed in the following tables and confirm the general appearance of a low quartz content.

*Ravenscrag Samples*

| Sample No. | Estimated quartz content | Remarks |
|---|---|---|
| | % | |
| ........ | 20 | Original sample |
| ........ | 18 | 0·1 mm. grade |
| ........ | 11 | Original sample |
| ........ | 10 | 0·1 to 0·05 mm. grade |
| ........ | 21 | 0·1 grade |
| ........ | 5 | 0·1 to 0·02 grade |
| ........ | very low | 0·1 to 0·02 grade |

*Whitemud Samples*

| Sample No. | Estimated quartz content | Remarks |
|---|---|---|
| | % | |
| 85 | 31 | 0·05 grade |
| 85 | 70 | 0·2 to 0·1 grade |
| 407 | 35 | 0·1 grade; good plagioclase |
| 500 | 30 | 0·5 grade |
| 500 | 15 | 0·5 to 0·02 grade |
| 501 | 25 | 0·05 grade |
| 509 | very high | 0·2 to 0·01 grade |
| "2" | 40 | 0·2 to 0·1 grade |
| "1" | 20 | 0·1 to 0·05 grade |
| "3" | 30 | 0·1 grade |
| Grey sandstone | very low | 0·02 grade |

*"Yellow Sandstone" Samples*

| | | |
|---|---|---|
| 75 | very low | 0·25 to 0·2 grade |
| 210 | 20 | 0·05 grade; good plagioclase |

*Feldspar.* Feldspars make up the bulk of the sand and silt grades. The feldspars include orthoclase, microcline, and plagioclases of low extinction angle. Some of the grains have a higher refractive index than Canada balsam, others a lower index. Under the binocular the feldspars exhibit good cleavage and cream-white colour. If a sample contains much decomposing biotite, the feldspars have acquired a slight rusty stain.

*Clay.* The clay obtained in the process of elutriation calls for no special mention. In the case of the Whitemud beds, 30 grams of grade less than 0·02 mm., from sample No. 70, in 5 gallons of water, gave a suspension that showed no clear zone at the end of 30 days. Black grains of two types are abundant in "sand" grade. One type is very black with a splintering fracture, a tendency to flaking, and a dull lustre by reflected light. Crushed grains examined with high power show as aggregates of particles and have an appearance that suggests they are a hard shale or argillite. The other type is more brownish and usually slightly worn. Under reflected light these grains show minute, irregular, white and brown bands or veins. High power examination shows a fine-grained structure giving an aggregate polarization. These grains are, therefore, probably argillites more siliceous than the black grains.

*Muscovite.* Muscovite flakes are present in most of the samples. The relative abundance of muscovite in the samples examined is shown in the tables at the conclusion of this article. In those samples where none is recorded, a few flakes may be found if searched for. The largest flakes occur in the coarser samples, i.e. those of the Ravenscrag and Green Sand-

67538—4

stones, and measure up to 0·5 mm. across, posesss very frayed edges, and are in every case thin, flat flakes. No flakes with crystal edges were noted; the optical character is bi-axial. The smaller mica flakes in the Whitemud sediments suggest sericite. All the silt grades of the Whitemud samples contain much white mica.

*Biotite.* Biotite when present occurs in all stages of decomposition and is probably responsible for the small but appreciable content of rusty aggregates up to 0·1 mm. with which the biotite is invariably associated. Most of the biotite is fairly fresh and occurs in curved laminated flakes. Longest flakes are in the coarser samples. Biotite is commonest in the darker-coloured sediments, and although persistent, is never abundant.

*Siderite.* The Whitemud samples contain small amounts (up to 2 per cent in sample No. "1") of brown spherical aggregates, up to 0·1 mm. diameter of siderite, which after digestion in hot acid leave a white, very thin, siliceous shell. These aggregates are not visible in a hand specimen, but are strikingly persistent when the finer material is washed away.

*Calcite and Dolomite.* Calcite occurs as granular aggregates or rhombs in the calcareous samples. Dolomite occurs as pink rhombs, the intensity of the tint varying with the rotation of the stage in plane polarized light. The calcite and dolomite rhombs measure up to 0·5 mm. across. One or two fairly coherent samples were picked out of samples Nos. 7, 38, and 45, but the carbonates do not exist as a cement or detrital grains.

*Chert.* Chert with mosiac polarization was noted while estimating the quartz content in Whitemud samples Nos. "2" (grade 0·2 to 0·1), "3" (grade 0·1), and grey sandstone (grade 0·1).

*Selenite.* Secondary selenite crystals and aggregates up to 0·2 mm. diameter were noted (less than 0·5 per cent) in samples Nos. 75 and 27.

*Talc (?).* Occasional soft green grains were noted in the coarser grades; these are soft, look like talc under the binocular, but their identity has not been established; they do not occur in sufficient quantity to influence the colour of the sample.

*Coloration of Samples.* After washing in water many of the coarser grains are still badly stained with brown iron oxide mainly resulting from the decomposition of biotite. The brown staining combined with the effect produced by the black grains (shale and argillite?) would account for the grey-green colour of the "green sandstones". How far biotite, hornblende, and epidote contribute to the "green" colour of sands is a doubtful point.

## *Minerals Occurring in the Bromoform Separates*

*Procedure.* Twenty to thirty grams of the sample were taken, and after being disintegrated by immersion in water, the lighter particles washed off, and the residual "sand" panned—both operations being conducted in a 7-inch aluminium pie-dish. The final concentrate, weighing about a gram, was dried on a hot plate, and the grains of gravity exceeding 2·85 separated in a bromoform tube[1]. For rapid checking of additional samples, concentrates were reduced as far as possible by panning, mounted, and examined without further treatment. Only a part of the final concentrate obtained by use of the bromoform tube was mounted on one slide, the remainder being preserved for future reference, refractive index determination, and micro-chemical tests. Examinations of the concentrate in bulk reveal the presence of outstanding individual grains which might otherwise be missed when only part of a cencentrate is mounted on a slide. As the suite of heavy minerals is fairly constant, and the samples are presumed not to differ widely in age, one description of the heavy mineral has been deemed sufficient. Heavy minerals noted in the bromoform separate were zircon, tourmaline, apatite, rutile, anatase, garnet, epidote, andalusite, hornblende, ilmenite, and magnetite.

*Zircon.* The zircon grains may be conveniently divided into four types:

(1) Prisms capped with pyramids; all varieties occur from the spindle-shaped, many faceted forms similar to Figures 874, 875, page 520 in Dana's Text Book, 3rd edition, to long, needle-like prisms. All euhedral forms are capped with pyramids. Inclusions are frequent, and are generally elongate or globular. Clear crystals abundantly crowded with large inclusions are fairly frequent.

(2) Worn and ovoid grains. On the whole, these are not common. The "gneissic" type of Kruschov, i.e., ovoid and zoned crystals, are persistent but not common.

(3) Coloured zircons. These were frequently noted. Purple, euhedral-capped prisms are the commonest. Such zircons frequently may possess slightly etched faces, so faint as to be noted only on the clear grains. The size of the clear purple zircons seems to be very uniform 0·08 to 0·12 mm. in length. The purple is more of a tint, i.e., a rose purple, than a deep colour. Brown and smoky yellow zircons were noted. In view of Mackie's recent paper on Purple Zircons (Trans. Edin. Geol. Soc., vol. XI, part 11, Edinburgh, 1923) these purple zircons are of great interest.

(4) Cloudy grains. These form a heterogeneous collection. The cloudy and "dusky" zircon grains are nearly always slightly worn; some of these grains may be cassiterite, but no definite confirmation of this has yet been effected.

*Tourmaline.* This is undoubtedly a characteristic mineral of this suite of samples, although not abundant in all residues. Relatively large, up to 0·16 mm. in length, pink, slightly worn prisms, with rounded inclusions, are a distinct type. In the position of minimum absorption, they are colourless to a faint rose pink, and nearly always possess a faint shagreened appearance, presumably due to scaliness of the surface. In the position of maximum absorption, the large "pink" grains invariably appear opaque, but the smaller grains in this position are blue green or dark leek green. Green tourmaline grains are invariably long prisms, narrower than the "pink" tourmalines. On all grains pyramid capping is rare; when present

[1] Fraser, F. J.: A simple apparatus for heavy mineral separation. Econ. Geol., vol. XXIII, No. 1 (January 1928).

it is mainly confined to the green needle forms (0·08 mm. in length), but the majority show basal planes or partings with worn edges. The remaining tourmaline types that justify mention are: a dark green to dirty green, prismatic variety in stumpy grains containing patches of dense black inclusions; occasional dark honey-brown, rounded, and well-worn grains. Both types have been noted in the Benton formation from the Turner Valley oil field.

*Apatite.* This mineral occurs mainly in pellucid worn prisms; otherwise the grains are irregular and somewhat platy in appearance. Good euhedral forms are scarce. Smoky apatite is rare and good cored apatite very rare.[1] Reddish brown pleochroic apatites with longitudinal inclusions giving a "schiller" effect are persistent in some of the samples. The inclusions are very small and their nature up to the present, even with an oil immersion lens, remains undetermined. These brown apatites are soluble in hot hydrochloric acid, show straight extinction—R.I. near 1·63, and have negative elongation. They show maximum absorption in a direction opposite to that of tourmaline, and are strongly pleochroic. Incident light shows the characteristic sheen of apatite.

*Rutile.* This mineral occurs as dark red, rounded grains with characteristic lustre in incident light, and as yellow grains that usually show good crystal form. Elongated prisms are more common than flat, platy forms. The yellow colour varies from a light golden bronzy yellow to a deep amber. The lighter the colour, the sharper the crystal faces, and the greater the tendency to show good twinning planes at 65 degrees to the prism face. Knee twins are scarce but persistent; some are very perfect. Occasionally very small sagenitic aggregates occur. A notable form occasionally seen is a compound red brown prism, exhibiting numerous striations parallel to the elongation.

*Anatase.* This mineral is persistent in the Whitemud samples, but in no one sample is it abundant. The most common occurrence is that of tabular aggregates showing very sharp edges. Occasional dark brown, good prismatic grains occur, such grains always showing well-marked striations parallel to the basal plane; the colour of the tabular anatase is invariably light yellow, in some cases with a tinge of green. Only one patchy square grain was noted. Anatase in these samples may occasionally be suspected, but rarely confirmed under the low power; for this, a good strong field with a high power objective and low ocular gives best results. Examination of the residues with high powers frequently shows small yellowish grains of high refractive index and double refraction; which may be individual crystals or aggregates; the roughened surface suggests aggregates. Such grains may be referred to titaniferous compounds. Some of them may be sphene, but only one grain in the whole of the samples was noted that really suggested sphene.

---

[1] *See* Fleet, W. F., and Smithson, F.: "Dark Apatite in Some British Rocks"; Geol. Mag., London, vol. LXV (Jan. 1928).

*Garnet.* The garnet grains are invariably irregular, splintery fragments. Structure corresponding to the dodecahedral cleavage occurs too frequently to be a coincidence. Such structure is confined to the large fragments. The larger fragments are frequently decomposed; the pitted and worn surfaces impart a cloudy appearance to the grain, and the decomposition products transmit a certain amount of light under crossed nicols. Very few grains are zoned or exhibit anomalous double refraction apart from the cases cited above. Good salmon-pink grains are scarce; usually when the grains are pink the tint is faint with transmitted light, but they may be readily picked out by their colour under incident light, with a magnification of 16 times. One water-clear, faceted, isotropic grain with inclusions was referred to garnet. Brown garnets occur rarely as relatively large, irregular fragments.

*Epidote.* The mineral occurs as irregular grains, aggregates being rare. When fresh, the grains may be lemon-yellow, grass green, or colourless. Pleochroism is appreciable in the coloured grains, especially under high power. Colourless, platy grains with low birefringence giving good "compass needle" interference figures are helpful in residue containing much decomposed epidote with few green grains. It rarely happens that in these residues when the epidote is badly decomposed that a typical green epidote cannot be found. Further, a heavy residue containing any appreciable amount of epidote possesses a peculiar dirty yellow colour as seen with the naked eye, so that epidote may usually be suspected before the residue is optically examined. In the present suite of heavy minerals, the constant association of garnet with epidote is also helpful; decomposed epidote is difficult to identify in individual grains.

*Andalusite.* This mineral occurs sparingly in the coarser samples as irregular, colourless grains; very rarely do they possess a good rose pink to colourless pleochroism. In many grains, this tint is extremely faint or doubtful. During the initial stages of examination of the residues, andalusite or topaz was suspected, and it was not until a pleochroic grain was found that andalusite was, as such, recorded with certainty.

*Hornblende.* The hornblende calls for no special description or comment. In sample 83, brown hornblende is subordinate to the common green variety. In samples where the hornblende is rare, some of the smaller grains are bleached.

*Other Minerals.* One grain of kyanite was noted. Some small, irregular, light golden yellow grains having a low double refraction were noted; these may be staurolite, but their amount and the uncertainty as to identification does not justify inclusion in the accompanying table. Occasional, small, irregular, brown, isotropic grains of high refractive index were noted, these may be garnet splinters or picotite.

## *Tabular Statements of Occurrence and Relative Abundance of Heavy Minerals in Bromoform Separates, also Muscovite and Calcite*

In these tables dolomite is included with calcite: A, means abundant; S, scarce; C, common; and R, rare.

### *Ravenscrag Samples*

| Sample No. | Zircon | Tourmaline | Apatite | Rutile | Anatase | Garnet | Epidote | Andalusite | Hornblende | Muscovite | Biotite | Calcite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | C | S | C | C | R | S | C | R | ...... | R | R | C |
| 11 | C | C | S | S | R | S | R | S | ...... | R | ...... | C |
| 12 | C | S | C | C | ...... | C | R | S | ...... | ...... | C | C |
| 26 | S | R | S | ...... | ...... | C | C | ...... | C | ...... | C | |
| 27 | C | C | C | S | ...... | R | ...... | ...... | ...... | C | S | ...... |
| 28 | A | R | C | R | ...... | S | S | S | ...... | R | S | ...... |
| 30 | C | S | C | R | ...... | S | ...... | ...... | ...... | S | C | C |
| Present in | 7 | 7 | 7 | 6 | 2 | 7 | 5 | 4 | 1 | ...... | ...... | ...... |
| Absent in | 0 | 0 | 0 | 1 | 5 | 0 | 2 | 3 | 5 | ...... | ...... | ...... |

### *Basal Ravenscrag Green Sandstone*

| Sample No. | Zircon | Tourmaline | Apatite | Rutile | Anatase | Garnet | Epidote | Andalusite | Hornblende | Muscovite | Biotite | Calcite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | R | R | C | ...... | ...... | C | ...... | S | A | ...... | ...... | ...... |
| 32 | R | R | ...... | ...... | ...... | R | S | C | S | S | R | ...... |
| 45 | C | C | S | S | ...... | C | S | ...... | ...... | R | ...... | ...... |
| 56 | C | S | S | S | R | R | C | S | ...... | S | S | ...... |
| 73 | C | C | C | ...... | ...... | S | S | S | R | C | S | ...... |
| 75 | C | S | S | ...... | ...... | S | S | S | ...... | R | R | ...... |
| 77a | C | C | C | ...... | ...... | C | S | S | R | C | R | ...... |
| 83 | R | R | R | S | ...... | R | ...... | S | A | ...... | R | ...... |
| Present in | 8 | 8 | 7 | 3 | 1 | 8 | 6 | 7 | 5 | ...... | ...... | ...... |
| Absent in | 0 | 0 | 1 | 5 | 7 | 0 | 2 | 1 | 3 | ...... | ...... | ...... |

## *Whitemud Samples*

| Sample No. | Zircon | Tourmaline | Apatite | Rutile | Anatase | Garnet | Epidote | Andalusite | Hornblende | Muscovite | Biotite | Calcite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | C | C | ...... | S | ...... | ...... | ...... | ...... | ...... | C | ...... | ...... |
| 47 | C | C | ...... | R | ...... | ...... | ...... | ...... | ...... | A | ...... | ...... |
| 48 | C | C | ...... | S | R | ...... | ...... | ...... | ...... | A | ...... | ...... |
| 50 | C | S | ...... | S | R | R | R | ...... | ...... | C | C | ...... |
| 70 | C | C | R | C | ...... | ...... | ...... | R | ...... | R | ...... | ...... |
| 71 | C | S | ...... | S | R | ...... | ...... | ...... | ...... | R | ...... | ...... |
| 76 | C | S | ...... | C | C | R | ...... | ...... | ...... | C | R | ...... |
| 77 | C | C | ...... | S | S | ...... | ...... | R | ...... | C | R | ...... |
| 78 | C | C | ...... | C | ...... | ...... | ...... | ...... | ...... | C | R | ...... |
| 79 | C | C | ...... | C | ...... | ...... | ...... | S | ...... | S | R | ...... |
| 85 | C | C | ...... | C | ...... | ...... | ...... | S | ...... | A | ...... | ...... |
| 405 | C | S | ...... | S | S | ...... | ...... | ...... | ...... | C | R | ...... |
| 407 | C | S | ...... | C | S | S | ...... | S | ...... | C | S | ...... |
| 509 | R | R | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| "1" | C | S | S | C | ...... | S | ...... | ...... | ...... | S | S | ...... |
| "2" | C | S | ...... | ...... | ...... | ...... | ...... | S | ...... | S | R | ...... |
| "3" | C | S | ...... | S | ...... | ...... | ...... | S | ...... | C | C | ...... |
| WM grey sandstone | A | C | ...... | S | S | S | C | ...... | | C | C | ...... |
| x 30 a | C | C | ...... | S | S | S | ...... | S | ...... | S | S | |
| Claybank | C | C | R | ...... | ...... | S | ...... | ...... | ...... | S | R | ...... |
| Present in | 20 | 20 | 3 | 17 | 9 | 7 | 2 | 8 | 0 | ...... | ...... | ...... |
| Absent in | 0 | 0 | 17 | 3 | 11 | 13 | 18 | 12 | 18 | ...... | ...... | ...... |

## *"Yellow Sandstone"[1] Samples*

| Sample No. | Zircon | Tourmaline | Apatite | Rutile | Anatase | Garnet | Epidote | Andalusite | Hornblende | Muscovite | Biotite | Calcite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | C | S | C | C | ...... | C | R | R | ...... | R | C | C |
| 17 | S | S | C | C | ...... | S | S | R | ...... | C | C | C |
| 94 | S | C | C | ...... | ...... | R | R | R | ...... | R | C | C |
| 210 | C | C | ...... | S | ...... | S | C | S | ...... | S | C | C |
| Present in | 4 | 4 | 3 | 3 | 0 | 4 | 4 | 4 | 0 | ...... | ...... | ...... |
| Absent in | 0 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 4 | ...... | ...... | ...... |

[1] The writer is indebted to Mr. John B. Webb of the Hudson's Bay-Marland Oil Company for drawing attention to the occurrence of sphene, in a "yellow sandstone" sample, since when this mineral has been confirmed in others.

# ISLAND LAKE AREA, MANITOBA

*By J. F. Wright*

## CONTENTS



### Illustrations



## INTRODUCTION

Island lake was geologically explored fifty years ago by A. S. Cochrane, and a sketch map of the shore of the lake and a brief report on the general geology and resources of the area were published.[1] Since then, however, no geological work has been undertaken in this area, and it has been visited by few prospectors, due in large part to the hard and long canoe trip to this lake from the main transportation routes of the district. During the last three years, however, travel to and from the remote prospecting areas in northern Manitoba and western Ontario has been facilitated somewhat by the successful operation of hydroplanes in transporting prospectors and their light equipment to and from the field. Thus, areas remote and hitherto difficult of access by canoe are at present much more attractive prospecting fields than they were formerly, and, foreseeing that Island Lake area would soon be visited by prospectors, the work described in this report was projected with a view to obtaining information as to the regional geology and mineral possibilities of the area.

The west end of Island lake is approximately 115 miles east of Norway House. The present route to the lake is from Winnipeg to Selkirk by electric train or motor car; from Selkirk to Norway House by steamer, which makes weekly trips up and down lake Winnipeg from the first of June to the middle of October. From Norway House the canoe route usually followed is south to the mouth of Gunisao river (locally called Jack); up this river to the junction of McLaughlin river; up the McLaughlin to Little Goose lake; and up Ponask creek from the east end of this lake to Ponask lake. Ponask creek is very crooked and narrow, and if the water be low is unnavigable with large and heavily loaded canoes.

[1] Geol. Surv., Canada, Rept. of Prog. 1878-79, pt. C, pp. 29-41.

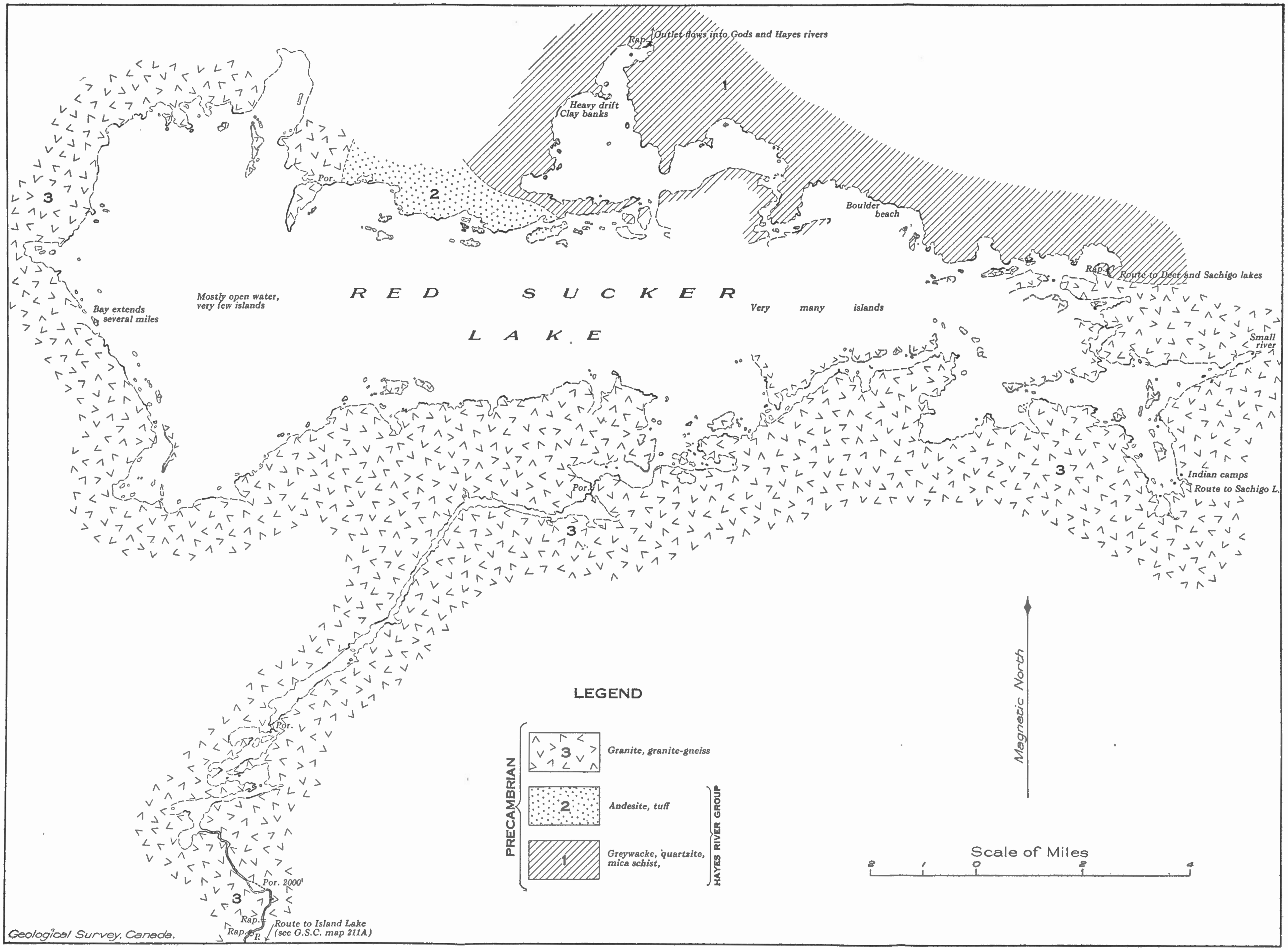


Figure 4.—Red Sucker lake and route from Island lake, northwest Manitoba.

The first of the height of land, or the Ponask, portages leaves the south shore of Ponask lake about 5 miles east of its outlet. These portages are four in number and are 1,400, 1,600, 6,200, and 6,500 feet long, respectively. They are connected by three shallow lakes; the two longer portages cross rocky, hilly country with wet swamps in the depressions, and, on the last small lake going east, the landings are very wet and soft.

The canoe route from the last Ponask portage to Fairy rock is downstream along a small river with several portages past rapids and falls; Pelican and Stevenson lakes are the two large lakes crossed, the route following the long, narrow, east arm of the latter lake for over 30 miles. At Fairy rock this river flows northeast, and the route turns southeast up a small tributary stream connecting a series of small lakes. Before Island lake is reached a second height of land is crossed by two portages, 1,650 and 4,300 feet long, respectively. The last portage is to a small bay on the north shore of Collins bay, and 8 miles west of the Hudson's Bay Company post.

The distance by canoe from Norway House is estimated at 160 miles, with thirty-four portages. The trip has been made in four days by Indians travelling almost continuously and without load. The usual time en route, however, is from seven to ten days and from ten to sixteen days from Winnipeg, depending upon weather conditions. The present freight rate on supplies from Norway House to Island lake is $15 per hundred pounds.

The canoe route formerly used from Norway House to Island lake was by Oxford, Knee, and Gods lakes, and the distance was much greater than the more direct route described in the preceding paragraphs. Within the last few years this route has been shortened considerably by leaving the Oxford Lake route near the east end of the first lake east of Robinson portage, and going directly east to Little Gods lake; south across this lake; across the northeast end of Beaverhill lake; and up Island Lake river. This new route was mapped topographically by R. C. McDonald in 1925, and, although the portages are not so numerous, they are of longer average length. This route is not recommended, however, unless the services of expert canoemen, familiar with Island Lake river, are available.

The east end of Island lake can be reached by canoe from Red lake by following the rivers connecting Red, Favourable, Deer, and Big Sandy lakes; and from Big Sandy lake on Severn river, by crossing northward a height of land to Sagawitchewan river, which flows into the long east bay of Island lake. This route, from Red lake, was mapped topographically in 1925 by J. W. Pierce, D.L.S.

The northwest corner of Island lake is approximately 145 miles southeast of mileage 219 on the Hudson Bay railway and some point on the railway, near the first Nelson River crossing, is the logical base for hydroplane and winter transportation to the area. The relief of the intervening country is at no place over 150 feet, and a winter road with low grades could easily be located by following the depressions and lakes.

The present winter route from the Hudson Bay railway to Island lake is via Norway House and is much longer than the more direct route suggested above.

The geographical base of the map accompanying this report was furnished to the Topographical Surveys Branch, Department of the Interior. During the summer of 1925 Mr. R. C. McDonald made a geographic control traverse of the main shore of Island lake, and established forty-two permanent reference mounds at intervals of from 2 to 5 miles along the traverse. The same summer the Topographical Surveys Branch, in conjunction with the Royal Canadian Air Force, took a series of oblique aeroplane photographs over Island lake.

In the spring of 1927 the Topographical Surveys Branch kindly supplied the writer with a preliminary map of Island Lake area, compiled from the oblique aeroplane photographs. This map greatly facilitated the geological mapping, in which work the writer was assisted by Messrs. L. H. Powell and A. W. Derby. Thanks are due the residents of the district, and especially to Mr. Geo. C. Collins of the Hudson's Bay Company, Rev. R. Chapin of the United Church Mission, and Father Du-Beau of the Roman Catholic Mission, for many courtesies extended the party during the summer.

## HISTORY AND RESOURCES OF THE AREA

Up to the present the fur-bearing animals are the only resource of Island Lake area that has been exploited, and the known history of the area dates from the commencement of trading by the Hudson's Bay Company. The first trading post[1] was at the east end of the lake, and the clearing about, and the foundation on, the site of this post may be seen on the north shore, at the east end of Sagawitchewan bay, about 1,000 feet east of the first small rapid on Sagawitchewan river. This post was outfitted from Severn and was in operation in 1824, but a few years later was abandoned on account of the scarcity of fur-bearing animals, fish, and game. The Indians were forced to leave the lake and migrated to Oxford House, Trout Lake, and Little Grand rapids.

About 1840 another fur-trading post was established by the Hudson's Bay Company, this time on the north end of Linklater island, at a point about one-half mile south of the present site. This post was soon abandoned, however, on account of the general scarcity of fur-bearing animals and food. No further attempt was made to trade in this area until the late autumn of 1864, when Mr. Cuthbert Sinclair went from Oxford House to Island lake with one York boat of provisions, and built a small post on the site of the present location. It is interesting to note that at this time beaver were exceptionally plentiful, as two hunters sent out by Mr. Sinclair were able in two days to kill fifty beaver on Linklater island. In 1927 no fresh signs of beaver were noted, although old beaver houses and dams are fairly numerous in certain parts of the area.

[1] Historical data kindly supplied by Mr. S. J. C. Cumming, District Manager, Keewatin District, Hudson's Bay Company, Winnipeg.

The Hudson's Bay Company has been trading at their present site continuously since 1864, and this has been one of the best fur posts within Keewatin district. Fisher, lynx, martin, otter, red fox, and muskrat are the important fur-bearing animals sought. In recent years this area has been trapped intensively, consequently the fur-bearing animals are becoming scarcer, and the present trapping ground of some of the Indians is approximately 100 miles distant from the post. In the summer, moose and caribou are scarce and hard to get, but excellent white fish and trout are abundant in almost all parts of Island lake.

The timber on a number of the large islands in Island lake will be a valuable resource. A few of the islands seem never to have been swept by forest fires, their present forest represents the original forest of the district. On such islands the trees are closely spaced, almost all are spruce varying from 2 inches to 8 inches in diameter, from 25 to 50 feet in height, and without limbs for from 15 to 25 feet from the ground. A few very large spruce were noted, one measured 42 inches in diameter, but bore limbs from the ground up.

The original forest of much of the country north and south of Island lake has been burned, and the small jackpine, poplar, balsam-fir, and spruce trees of these areas will not be of commercial value for many years to come. Large stretches of country have been swept by forest fires within the last fifteen years, and the traversing of such areas is difficult on account of the many windfalls and thick underbrush.

The mineral resources of the area will be discussed in the section of this report dealing with the economic geology.

## GENERAL CHARACTER OF THE AREA

### TOPOGRAPHY

Island Lake area is within the Canadian Shield and exhibits, in general, the topographical features of this great region. The surface has a flat appearance when viewed from any of the higher hills, but, in traversing the country, a series of low ridges with complementary swampy valleys are crossed. The maximum relief noted was 200 feet and in much of the area the average height of the hills above the adjacent lake level or valley bottom is estimated at from 50 to 75 feet. Most of the ridges trend in a general east-west direction, parallel the regional structure of the underlying rocks. In many parts of the area the surface is hummocky, as depressions break the continuity of the ridges at intervals of from a quarter to a half mile along the strike. The surface of the larger islands within the lake exhibits the same hummocky character as the country north and south of the lake. In wooded areas small, flat outcrops of bedrock are abundant along the north side and top of the ridges, and, in areas swept by severe forest fires, bedrock is exposed almost continuously, except in the low, swampy depressions.

The most prominent hill in the area extends northeast-southwest along the east side of DuSault bay and Cordeau lake. This hill is about 6 miles long, and an aneroid traverse from near the foot of DuSault bay indicated a height of 200 feet above the lake level. No rock outcrops were noted along the route traversed, the hill, evidently, is of glacial drift, and, possibly, is a moraine.

### GLACIATION AND GLACIAL DEPOSITS

The polished rock surfaces and the thin deposits of boulders and unstratified clay indicate that Island Lake area has been crossed by a continental ice-sheet. A study of the glacial striæ shows that the ice movement was from the north-northeast, the strike of the striæ varying from south 10 degrees to south 45 degrees west, astronomic. No regularity in the changing strike of the glacial striæ is apparent from east to west across the area, as on closely adjacent outcrops striæ were noted that varied in strike as much as 25 degrees. Two sets of striæ were noted at only one place, namely, the large outcrop at the end of a point on the south shore of Benson bay near its east end. Here an older set of striæ strikes south 10 degrees west, and a younger set, south 45 degrees west astronomic. The variation in strike of the striæ throughout the area is apparently due to local movements of the bottom layers of the ice-sheet in passing over and around the rock hummocks. At the locality where the two sets of striæ were seen, the earlier ice moved approximately south along the east side of a rock ridge, whereas the later movement was southwest across the ridge.

As the ice-sheet retreated deposits of boulders, clay, sand, and gravel were left scattered irregularly over the surface in the form of terminal moraines, ground moraine, and kames. On the islands and along the shore of Island lake the drift is thin and is confined to the valleys and the south side of the southward-facing hills. Boulder beaches are characteristic of the south shore of many of the islands and of parts of the southward-facing main shore, whereas, along the northward-facing shore, rock outcrops are abundant and there is little drift. South and southwest of the lake, drift deposits are fairly widespread, and several isolated drift ridges, trending from east of north to northwest, were noted within a narrow area extending northwest for 25 miles from Cordeau lake. These north and northwestward-trending ridges probably represent a poorly developed terminal moraine, and if so, indicate a halt in the retreat of the ice-front just south and west of the basin of Island lake.

Sections of the glacial deposits are exposed at only a few places along the lake shore or along creeks and rivers. Much of the drift is boulder clay, and in the sections examined is not water-sorted. A few sections showed irregularly stratified sand and gravel and represent kame-like deposits or outwash materials. Boulders are scattered abundantly over the surface, all the rock types of the area are represented, together with a comparatively few, small, rounded boulders of Palæozoic limestone and sandstone, probably from the area of Palæozoic strata southwest of Hudson bay, and 150 to 200 miles to the northeast. A few small boulders of iron ore—banded hematite, jasper, and chert—also were noted, the source of these boulders is evidently from some area to the north or northeast and within the Precambrian. No stratified post-Glacial lake clays were noted within Island Lake area. Stratified clays formed in post-Glacial Lake Agassiz are widespread to the northwest along Hayes and Nelson rivers, and their absence from Island Lake area indicates that this area was covered by the ice-sheet until after Lake Agassiz was drained.

No evidence was noted within Island Lake area of more than one ice invasion. A study of the glacial features of north-central Canada, however, indicates a more complex glacial history[1] for the area, and that the Keewatin ice-sheet, moving from the northwest, probably also covered the area. The last ice-sheet, moving from the north-northeast, is thought to have been a part of the great Labradorean glacier that covered a large part of eastern Canada. This last or Labradorean ice invasion destroyed, in this local area, any easily recognizable traces of the earlier ice-sheets.

## DRAINAGE

Island Lake area is within the drainage basin of Hayes river and the drainage is to the northeast to Hudson bay by Island Lake river, Gods lake, Gods, Shamattawa, and Hayes rivers. The lake has two outlets, both at the northwest end. The main outlet is 6½ miles northeast of the Hudson's Bay Company post and is on the usual canoe route to Gods lake. The second outlet is at the north end of Chapin bay, 6 miles east of the first outlet. The two rivers are reported to unite before Gods lake is reached. A number of lakes within the Canadian Shield have two outlets on the same side, and this feature is interpreted as due to a coincidence of level of two depressions on the rim of the lake basin and not to recent tilting of the land.[2]

Several fairly large rivers enter Island lake from the south, one river flows from the west, and two from the east. The streams from the north are all small as the northeast and northwest shores of the lake are just south of a height of land; York and Angling lakes, 1 and 2 miles, respectively, north of the northeast corner, drain to the north into Hayes river, and the lakes north of Collins bay on the northwest drain west and northeast. The rivers of the area are characteristic of those of the Canadian Shield in general, and consist of lake-like expansions connected by narrow stretches with boulder runs, rapids, and waterfalls.

## ISLAND LAKE BASIN AND ITS ORIGIN

Island lake is so named from the vast number of islands, 3,475 of which were examined and are shown on the accompanying map. A number of other lakes within the Canadian Shield are characterized by numerous islands, distributed in groups with intervening large stretches of open water, but in the case of Island lake the islands are distributed uniformly

[1] Tyrrell, J. B.: "Glaciation of North-Central Canada"; Jour. Geol., vol. VI, pp. 152-160 (1908).
[2] Bowman, Isaiah: "Forest Physiography", p. 564 (1911).

throughout the whole area of the lake, and in this respect it resembles the northern half of Lake of the Woods[1] and also lake Timagami, which, although much smaller in size of islands, contains 1,300 islands.[2]

Cochrane[3] has compared, appropriately, the general form of Island lake to that of the human stomach. In detail the shoreline is for the most part exceedingly irregular, due to numerous branching bays, extending from the west and east ends and from the south shores of the main central body of the lake. The trend of the longer axis of the lake is nearly east-west and the greatest length, from the west end of Collins bay to the east end of Sagawitchewan bay, is approximately 70 miles. The main body of the lake is 45 miles long and varies in width from 9 to 13 miles, the north and south shores are parallel approximately, and curve gently to the south to near the west end, where there is an abrupt turn north to the outlet.

The largest of the many bays indenting the shoreline is Cochrane bay, extending eastward 11 miles from Linklater island and decreasing in width from 4 miles to ½ mile. The shoreline of this bay is fairly straight and follows closely the contact between granite, outcropping on the mainland, and sediments outcropping on the points and islands within the bay. The long direction of the narrow bays from the east and west end of the lake is parallel the strike of the bedding or schistosity of the underlying sedimentary and volcanic rocks, and apparently the form of these bays is controlled by the presence of strata or lava flows more easily eroded than the adjacent members of the series, which outcrop as low ridges along their north and south shores. The south shore of the lake is exceptionally irregular due to numerous branching bays within granite and granite-gneiss, whereas the north shore, from Cochrane bay eastward, is fairly regular and follows the strike of thick, massive, sedimentary beds and lava flows, or the contact between granite and sediments or lavas.

The islands within the lake vary in size from mere rocky islets to masses of land many acres in extent. During the summer of 1927 the water-level of the lake was low, and many low, flat, rocky islets were not mapped, as when the water is very high these would be shoals; possibly a few of the islets mapped may be covered at times of exceptionally high water. Among the large islands are: Cochrane and Linklater islands, each 6 miles long with an average width of over 1 mile; Jubilee and Confederation islands 7½ and 8½ miles long, respectively; and Whiteway island 5½ miles long. Islands underlain by granite have an irregular shoreline and shape, whereas islands underlain by sediments and lavas, with the exception of the north shore of Jubilee island, have fairly straight shores, are much longer than they are wide, and locally are distributed in line, following the trend of a particular sedimentary bed or lava flow. The islands rise above the water-level of the lake in a fashion similar to that of the small rock outcrops and ridges above the general level of the drift of the surrounding country.

---

[1] Lawson, A. C.: "Lake of the Woods Region"; Geol. Surv., Canada, Ann. Rept., vol. I, pt. CC, pp. 15 (1886).
[2] Barlow, A. E.: "Geology and Natural Resources of Nipissing and Timiskaming Map-sheet"; Geol. Surv., Canada, No. 962, p. 268 I (1907).
[3] Geol. Surv., Canada, Rept. of Prog. 1878-79, pt. C, p. 31.

The soundings completed to date have not been extensive enough to determine the average depth of water in the lake, but the few soundings made indicate that certain parts are exceptionally deep and that there are no extensive very shallow areas. Mr. T. Wass, a local trader, told the writer that a series of carefully made soundings across Cochrane bay, just east of Cochrane island, showed that at this point the water increased in depth gradually from 6 to 36 feet, suddenly from 36 to 100 feet, and gradually from 100 feet to a maximum of 240 feet, and then decreased in depth at about the same rate as it had increased. A series of soundings made by the writer at various points along the southward curving shore west from monument N58 indicated an average depth of water of over 150 feet. The depth of the southern part of the lake basin is not so great as that of the north, as the soundings made at numerous points indicated a depth of water varying from 30 to 110 feet. Over most of the lake, with the exception of the small, shallow reefs, the water is comparatively deep to within a few feet of the shore, and almost any point could be reached by small tug and barge. Marshy tracts of shore are few and small, and shallow sandy or shingle beaches are rare and of small extent.

An important factor in determining the shape and outline of Island lake was the marked unequal resistance to erosion of the underlying rocks, due to their variation in composition and structural features. Granite and granite-gneiss outcrop extensively north and south of the lake, and a long, narrow band of sediments and lavas extends through the central part from the west to east ends. The granite is fairly uniform in texture and mineral composition over wide areas, but the degree of development of jointing and gneissic structure varies greatly from point to point, and in many cases these structures have facilitated erosion, and thereby controlled the location and irregular outline of the many bays along the south shore. The lava flows and sedimentary strata, in contrast with the fairly uniform granitic rocks, vary markedly in mineral composition and degree of schistosity within short distances transverse the strike of the flows and beds, and, on this account, were more easily eroded along certain zones than others. Thus the resulting surface would be naturally more uneven, and the average relief somewhat greater, in the area of sediments and lavas, than in the surrounding granite.

During the Glacial period one, and possibly several, ice-sheets crossed the basin of Island lake. The last ice invasion was from the north-northeast and nearly at right angles to the long direction of the lake basin. These glaciers removed from the surface the weathered materials, and locally some solid rock, although glacial erosion, in the writer's opinion, was only a minor factor in the formation of the lake basin, a more important glacial feature being the quantity and mode of distribution of the glacial deposits. The mantle of glacial drift deposited within the basin of Island lake by the last ice-sheet was comparatively thin, consequently the original uneven pre-Glacial surface was not obliterated. Lawson[1] has noted that the drift deposits are thin and scarce in the northern half of Lake of the Woods, where the shoreline is irregu-

[1] "Lake of the Woods Region"; Geol. Surv., Canada, Ann. Rept., vol. I, pt. CC, p. 15 (1886).

lar and islands are numerous. Undoubtedly many of the more shallow depressions between islands or between islands and mainland would have been filled locally, if the drift mantle had been thicker or more unevenly distributed, and instead of a single lake, with a very irregular shoreline and numerous islands, many small basins would have been formed and occupied by lakes in a fashion so characteristic of most areas within the Canadian Shield.

To sum up: the basin of Island lake is interpreted as a remnant of a broad depression eroded in the area underlain by metamorphic sediments and lavas at a period in pre-Glacial time when the land stood slightly higher than at present. Some beds of the volcanic and sedimentary strata eroded much faster than others and a very uneven surface resulted. During the Glacial period the advancing ice-sheet carried away practically all the decomposed materials from the surface, and possibly deepened locally this depression by removing fresh rock. As the last ice-sheet retreated the drift deposits left in this particular area were thin, consequently the irregularities of the original surface were only slightly smoothed out by glacial deposition. Water accumulated in this broad depression and the level of the two outlets or lowest points on the rim was slightly below the general level of the many hummocks on the surface of the depression, consequently they formed the many islands dotting the surface of the lake.

## GENERAL GEOLOGY

### GENERAL STATEMENT

The known bedrock of Island Lake area is Precambrian and is divided structurally into five main groups. The oldest group is a complex of volcanic and sedimentary strata, in places interbedded, but in some localities only sediments or only lavas are present. The rocks of this group are metamorphosed, and locally chlorite and carbonate schists have developed. The average dip of the beds is steep and locally small anticlinal and synclinal folds developed on major folds. Extensive areas of sediments and lavas lithologically similar to those of the basal group of Island Lake area are known at a number of other localities within the basin of Hayes river, and the name Hayes River group is proposed for this basal group of sediments, volcanic flows with interbanded sediments, and volcanic flows and tuffs.

In Island Lake area a younger series of sediments was deposited on an erosion surface of the Hayes River group. Pebbles of the main rock types of the Hayes River group are abundant in the basal conglomerate of this younger series of coarse clastic sediments, which are folded into a broad syncline within the volcanic members of the Hayes River group. Sediments younger than the Hayes River volcanics have not been recognized elsewhere in northeastern Manitoba, and it is proposed to designate these younger sediments the Island Lake series.

Members of the Hayes River group are cut by a few dykes and sills of a fine to medium-grained diorite and gabbro older than more widespread granite and granite-gneiss which also intrude the Hayes River group. Granite was not found in contact with the Island Lake series, but this series is assumed to be older than the granite. Although granite boulders and pebbles are abundant in the conglomerate of both the Hayes River group and the Island Lake series, no field evidence was found proving the presence of granite of more than one age. Numerous small dykes and lenticular bodies of granite porphyry intrude the Hayes River group and are interpreted as upward projections from the roof of a granite body below, and to be of about the same age as the widespread granite of the area. Pegmatite and aplite dykes cut the grey phases of the granite and small quartz veins were noted along schistose zones in the lavas and sediments. Dykes of massive diabase cut the Hayes River group and the granite, and are the youngest rocks recognized in the area.

The various rocks recognized in the field may be grouped and tabulated, in descending order with respect to age, as follows:

*Table of Formations*

| | |
|---|---|
| Younger basic intrusives | Diabase |
| *Intrusive Contact* | |
| Granitic intrusives | Pegmatite and aplite<br>Granite, granite-gneiss, quartz diorite, and quartz gabbro<br>Granite porphyry |
| *Intrusive Contact* | |
| Older basic intrusives | Diorite and gabbro |
| *Intrusive Contact* | |
| Island Lake series | Quartzite, grit, and conglomerate |
| *Unconformity* | |
| Hayes River group | Volcanics, including andesite, dacite, and derived chlorite and carbonate schists<br>Volcanics with interbedded sediments, including andesite, dacite, tuff, slate, and cherty quartzite<br>Sediments, including slate, greywacke, quartzite, and conglomerate |

## HAYES RIVER GROUP

### *Lithological Character*

The Hayes River group embraces a complex of surficial rocks, and, for the purpose of description, may be subdivided lithologically into four classes: (1) clastic sediments, including greywacke, quartzite, and conglomerate; (2) fine-grained, laminated sediments, including cherty quartzite and slate; (3) lava flows, including dacite and andesite and derived schists; and (4) tuffs interbanded with the lava flows.

### *Greywacke, Quartzite, and Conglomerate*

Sediments of this class outcrop on Cochrane island, on the small islands within Cochrane bay, and on the mainland east and west from Garden Hill Indian reserve. The rocks are grey to dark grey, and all have been mashed and the minerals partly recrystallized. The microscopic examination of thin sections of greywacke, quartzite, and the matrix of the conglomerate shows all to consist of both rounded and angular fragments of quartz and of feldspar, in a fine-grained matrix of these minerals along with varying proportions of biotite, chlorite, sericite, calcite, magnetite, and pyrite. The larger quartz grains show undulating extinction, are intersected by small cracks, and contain dust-like inclusions. The plagioclase feldspar shows albite twinning and ranges in composition from albite to oligoclase. Only a very few grains of orthoclase were recognized. The feldspars are fresh in appearance, but contain many minute inclusions.

Greywacke is typically exposed along the north side of Cochrane island and along the shore at points east and west of Garden Hill reserve. Bedding is usually well developed; coarse, light grey beds varying in thickness from 2 to 18 inches alternate with thin, dark grey, fine-grained, micaceous beds, or with grey, cherty-appearing beds. The coarser beds are lenticular and crossbedding is locally developed; the beds of finer materials continue long distances along the strike with uniform width and appearance. Along the south shore of Chapin bay, beds of quartz-feldspar-biotite-garnet schist alternate with the greywacke. Under the microscope the typical greywacke is seen to consist of sand grains, and these rocks were originally sandstone, carrying variable proportions of feldspar and clayey materials.

The quartzite beds are best developed along the north shore of Jubilee island and on the islands in Cochrane bay, south and east of Cochrane island. The rocks are massive and the beds vary from 6 inches to 3 feet in thickness, and locally are separated by thin beds of greywacke or slate, which show fracture cleavage. Some of the thin beds show a change in texture gradually from a relatively coarse, typical quartzite at the bottom to a very fine, cherty quartzite at the top of the bed. A thin section of a specimen from one of the thick, massive quartzite beds shows fair-sized grains of quartz and a few grains of plagioclase, near oligoclase in composition. The periphery of these grains has been shattered; the interstices between the grains are filled by quartz, untwinned feldspar, calcite, epidote, and chlorite. The minerals are fresh, many of the larger feldspars contain inclusions, and in one thin section brown biotite is abundant. The larger grains are angular in shape and only a few show the rounded outlines typical of water-sorted sands.

Conglomerate occurs associated with the greywacke and quartzite at various horizons and grades upward, downward, and along the strike into sediments of finer texture. These conglomerates have been deposited as lenticular beds of various lengths and thicknesses, the most persistent bed noted follows closely the water edge along the north shore of Cochrane island, and varies from 5 to 35 feet in thickness. The matrix of this bed is greywacke, in places fine-grained, almost black, and with a slaty cleavage. The pebbles and boulders are all waterworn, they range from less than 1 inch to over 1 foot in diameter, and are predominantly granite, but pebbles of quartzite, white quartz, chert, flint, and a dark dioritic rock are also represented among them.

A considerable thickness of conglomerate is exposed north of Island lake along the east line of Garden Hill reserve. Here the matrix is a sheared greywacke, the pebbles are of granite and all are small. In certain beds the pebbles are squeezed into lenticular forms whose longest axis parallels the strike of the schistosity of the groundmass. The feldspathic and clayey material of the matrix has been converted in great part into the micaceous minerals sericite and chlorite. Outcrops of conglomerate on the small bay 1 mile east of Garden Hill settlement show few granite pebbles, white quartz, chert, and black quartzite pebbles greatly predominate, and here the matrix is slate. Observations at a number of other localities indicate that in conglomerate beds with a slaty matrix the proportion of granite pebbles is much less than it is in the beds with a greywacke or arkose matrix.

A fringe of conglomerate outcrops at intervals along the south shore of Cochrane bay and closely adjacent islands for a distance of 1 mile west and 2½ miles east of monument M 87. This conglomerate is interbedded with quartzite, arkose, and greywacke. The boulders and pebbles are well-rounded and up to 3 feet in diameter, but the larger number are under 1 foot in diameter. They are mostly granite of a dark grey, slightly porphyritic variety. A few pebbles of white quartz and of dark quartzite were noted also. These conglomerate beds are exceptionally lenticular, grading within short distances, both at right angles to and along the strike, into arkose, quartzite, or greywacke. A similar quartzite-conglomerate horizon was noted along the south shore of Cochrane island near the west end.

Along the north shore of Red Sucker lake, northeast of Island lake, a large area is underlain by dark grey, fine-grained sediments that originally were greywacke, but are recrystallized for the most part to dark micaceous rocks, which are locally schistose. A few outcrops show the original bedding planes distinctly, and some of the more massive beds are impure quartzites and are only slightly recrystallized. No outcrops of conglomerate, cherty quartzite, or slate so characteristic of the sedimentary series on Island lake were noted. In thin section under the microscope the important constituents of the mica schists are angular and rounded grains of quartz, green biotite, green hornblende, and oligoclase feldspar. The general strike of the beds is approximately east and west, and the dips are steep. There has been some close folding, as both northward and southward dips were noted, but outcrops are scarce for long stretches along the lake shore and little detail of the structure of this area of sediments was obtained from a hurried examination of the lake shore. Pegmatite and aplite dykes cutting the sediments are locally abundant.

### *Cherty Quartzite and Slate*

Members of this group are interbanded at various horizons with the sediments described in the preceding paragraphs, and also with the lavas to be described in the next section of this report. At many places the massive, thickly bedded quartzite and greywacke grade into more thinly bedded types of finer and more even-grained fabric. The beds of the fine-textured sediments vary in thickness from a fraction of an inch to several feet, and lamination lines are well developed in many outcrops. Many of the thin beds of these sediments are metamorphosed to either quartz-sericite or quartz-chlorite schists, and locally are strikingly drag-folded.

Cherty quartzite is the field name given to certain bedded, fine-grained to dense, siliceous rocks with a cherty appearance, that outcrop with typical features along the north shore of Confederation island. Here is exposed a thickness of at least 1,000 feet of such siliceous rocks, the coarser-grained beds of which are dark quartzite with a glassy appearance, and with which are interbedded thin beds of typical chert and beds gradational in texture between the typical quartzite and chert. The beds are up to 1 foot in thickness, and are not lenticular, for a series of a dozen or more alternating beds were followed 6,000 feet along the strike without any marked change in their appearance or thickness.

In thin section the cherty appearing beds are seen under the microscope to consist of a microgranular aggregate of quartz, abundant small shreds of white mica, some chlorite, and a few small grains of pyrite and magnetite. The glassy, quartzitic beds consist of a matrix of microgranular quartz throughout which are scattered angular grains, averaging 0·013 inches in diameter, of quartz and a twinned plagioclase. Shreds of sericite and chlorite are abundant and are arranged in parallel lines across the thin section. An unusual feature of the thin sections of these very fine-grained quartzose rocks is the presence of numerous rounded areas, up to 0·15 inch in diameter, consisting of hornblende, plagioclase, epidote, and calcite. These areas have sharp outlines against the quartzose matrix and are arranged at intervals along zones wherein the quartz is of slightly coarser fabric than the average of the thin section. Lavas outcrop both north and south of this cherty quartzite horizon, and the nodular bodies represented in thin sections by the areas rich in ferromagnesian minerals, are interpreted as fragments of volcanic rock deposited contemporaneously with the fine-grained sand.

Black, very fine-grained rocks, generally characterized by slaty cleavage, are exposed at numerous places along the shore and on the adjacent islands east for 8 miles from Garden Hill settlement, and west to near the southwest corner of Cochrane island. In many outcrops of these rocks, thin, dark grey, more quartzose beds alternate with black, dense beds, or dark magnetite-rich lamina alternate with greenish grey chert or dark cherty slate layers. The cleavage of the slaty beds parallels the bedding. Associated with the distinctly bedded types is a considerable thickness of a fine-grained black rock with poorly developed cleavage, and without trace of bedding or other evidence of origin, but probably also representing thick beds of argillaceous materials. Microscopic examination of thin sections with high magnification shows that the slates are made up of very small quartz and feldspar grains like the other sediments of the group, but the slates contain a much higher percentage of greenish grey, chloritic-looking material. Quartz-chlorite schists are locally developed and many of the thin cherty and iron-rich beds are minutely folded and crinkled. Differences in original composition account for the bedding and variation in appearance of the slaty beds, the schistose and drag-folded beds resulted from local deformation of the thin beds during folding.

### *Andesite, Dacite, and Derived Schists*

Rocks that were undoubtedly volcanic flows are abundant in Island Lake area. They are typically developed on the east shore of Fleet point, on the south end of Linklater island, along the south shore of Confederation island, on Whiteway island and the mainland to the north, and along Sagawitchewan bay. The volcanic rocks are characteristically grey to black, fine-grained, and massive, except locally where chlorite-schist is developed along shear zones. Although massive in appearance these lavas contain considerable quantities of the secondary minerals, chlorite, actinolite, carbonate, and epidote. Possibly there was a considerable range in composition of the unaltered rocks, but the microscopic study of thin sections of specimens from typical exposures indicates types of medium basicity, probably andesite and dacite in composition originally. Pillow structure is well developed in many exposures, but scoriaceous lava was observed only at a few localities.

A specimen of what was judged to represent the typical massive andesite of the area, and was collected from near the southeast corner of Linklater island, shows under the microscope a felty aggregate of feldspar and hornblende, together with a few flakes of biotite. Most of the feldspar is kaolinized or has been recrystallized to albite, containing abundant small inclusions, and only a few lath-shaped fresh crystals of andesine remain. The hornblende is in part gone to chlorite and epidote; the biotite flakes are fresh and highly pleochroic. No quartz was recognized in the thin section. To the west along the south shore of Collins bay, however, a number of flows of black lava show small phenocrysts of smoky quartz on the light grey, weathered surface. In thin section these lavas consist of oligoclase and orthoclase feldspar, quartz, and green biotite. The feldspar is partly altered to calcite and sericite. The texture is slightly porphyritic, the larger quartz and feldspar phenocrysts average in length about 0·06 of an inch. The quartz of these black lavas is undoubtedly primary, and, therefore, they are probably near dacite in composition.

Volcanic rocks outcrop extensively along Sagawitchewan bay and westward. At a few localities they show excellent pillow structure, some of the pillows noted were 10 feet long. On the point north of the long, narrow entrance to Sagawitchewan bay some of the pillows are flattened markedly on the south side, and others show scoriaceous lava on the north side and around the ends. Areas of lava without pillows are irregularly distributed throughout the pillow lava. On the islands and point southwest of Loonfoot island, however, the lavas are exceptionally massive and free from pillow structure or interbanded stratified tuffaceous materials. A study of thin sections of the lavas from this locality shows no evidence of flow structure and the rock consists largely of an aggregate of small grains of kaolinized feldspar, shreds and fibrous bunches of actinolite and chlorite. A few clear grains of a twinned plagioclase, near andesine in composition, are present, also some untwinned feldspar, possibly albite, and a few grains of calcite.

The microscopic study of thin sections of the volcanics from the small islands northwest of Loonfoot island shows that here the black lavas all contain a large percentage of carbonates and that exceptional carbonated types are developed locally. The thin sections of the massive-appearing black lava show almost all the feldspar gone to calcite and the ferromagnesian minerals to actinolite, chlorite, epidote, and magnetite. Associated with these black lavas are grey rocks that weather with an irregular pitted surface and are cut by very small granitic dykes and carbonate veins. A thin section of this type consists of over three-quarters carbonates, the remaining minerals being a colourless mica, possibly muscovite, some chlorite, and magnetite grains. It is not easy by microscopic study to ascertain the composition of the carbonates; however, the most abundant carbonate present is probably ankerite, as the brownish-coloured weathered surface of some outcrops suggests an iron-bearing carbonate, and chemical tests indicate the presence of abundant magnesium in the rock. Dolomite and siderite may also be present as the exact composition of these carbonates cannot be determined without a more detailed chemical study.

Carbonated rocks have been described in association with the lavas from a number of areas in Ontario, and it is generally agreed that such rocks represent lavas wherein the primary minerals have been replaced by carbonates and other secondary minerals. In Red Lake area, approximately 170 miles to the south, many of the volcanic rocks contain considerable carbonate and here the field and microscopic evidence agree that the carbonates have developed as end products of the alteration of basic rocks, and this alteration is believed to have been produced by certain quartz porphyry intrusives.[1] Almost all the thin sections of the volcanic rocks of Island Lake area show the feldspars partly altered to calcite, and the gabbro, diorite, and quartz porphyry intrusives also contain carbonates. At most localities, however, the alteration of the original minerals to carbonates has not reached the advanced stage it has in the area northeast of Loonfoot island, and especially in the narrow area between the granite on the east and the younger sediments on the west. Rusty weathering carbonate veins are developed in the slates, tuffs, and schistose volcanics along the shore and on the islands east from Garden Hill settlement, but here the country rock is not so extensively replaced by carbonates. In both these localities numerous small intrusive dykes of quartz porphyry and aplitic granite are abundant, and the solutions forming the carbonate veins and causing the intense alteration of the rocks in these localities are believed to have originated from the magma that formed the numerous, small, granitic dykes. For some areas the evidence strongly supports the view that the carbonation is caused by heated carbonated waters that accompanied the successive volcanic eruptions[2] and it is noteworthy in this connexion that the most widespread type of alteration of the volcanics of Island Lake area is that of the feldspars to calcite, and that the iron and magnesium-bearing carbonates are only locally developed and occur along zones where intrusives are abundant. The widespread occurrence of the calcite type as compared with the local distribution of the iron and magnesium carbonates, suggests that there may have been two periods of carbonation: the first a widespread alteration of the feldspar of the lavas to calcite caused by heated waters given off during the volcanic eruption; the second a more local but intense introduction of carbonates along schistified zones immediately preceding or accompanying the intrusion of the granite magma.

Andesite lava outcrops at seven places on the north shore of Red Sucker lake west of the large north bay leading to the outlet of the lake. The lavas are black, fine-grained rocks showing pillow structure. A few outcrops of bedded tuff were noted associated with the lavas. In thin section the feldspar of the specimen of lava collected is andesine, in part granulated and recrystallized to an untwinned feldspar, probably albite. The hornblende is a deep green, highly pleochroic variety, in part altered to chloritic material. Little or no calcite is present in the thin section examined. The age relations of the lava to the mica schists are unknown.

### *Tuffs*

At various horizons within the lavas, greenish to black stratified rocks were recognized and in the field were interpreted as beds of tuffaceous materials. These rocks are fine-grained except locally where medium-grained, grey, gritty, and agglomeratic types are developed. Tuffs outcrop along the shore of a number of the islands of the chain of long, narrow

[1] Bruce, E. L.: Ont. Dept. Mines, vol. XXXVI, pt. III, pp. 13-15 (1927).
[2] Collins, W. H., Quirke, T. T., Thomson, Ellis: "Michipicoten Iron Ranges"; Geol. Surv., Canada, Mem. 147, p. 32 (1926).

islands 3 miles south of monument N 58, and on a number of the islands north and south of this group. Here some outcrops show excellently the bedded character of the tuffs, the different beds weathering to tints of greenish grey, reddish, and purplish. The central part of the islands is underlain by typical andesite lava and the stratified beds are clearly interbanded with the volcanics.

Under the microscope all thin sections of the tuffaceous rocks are similar in appearance and, as in the case of the lavas, are characterized by abundant secondary minerals. A thin section of the typically bedded tuff from the east end of the large island southwest of Savage island shows the rock to consist of abundant calcite and chlorite, angular grains of twinned plagioclase, some quartz, zoisite, and pyrite. A thin section cut transverse to the bedding shows that the carbonate and shreds of chlorite are distributed in parallel layers, with a larger percentage of quartz and feldspar in the intervening areas. Many of the feldspar grains are altered to kaolinitic-like material and the few fresh grains contain abundant small inclusions. The few quartz grains are fresh in appearance and their distribution in veinlets or grouped around clusters of zoisite, suggests for them a secondary origin. These tuffs are associated with andesite lavas and probably originally were andesitic in composition. They have undergone secondary alteration similar to that of the nearby lava.

### *Structure and Age Relations*

The lavas and sediments of the Hayes River group are closely folded and the details of the structure have not been determined. The general strike of the now deeply truncated fold is west or locally northwest.

The axis of a broad anticlinal fold, striking east, crosses Linklater island about 2 miles from its north end, and swings southeast towards Garden Hill reserve. South of Cochrane bay a large, tongue-shaped mass of granite has been intruded along the projected eastward continuation of this fold. Coarse, clastic sediments outcrop along the axis of this fold, and volcanics and interbanded sediments are typically developed on its south limb. On the islands in Cochrane bay, the sediments are closely folded into several minor anticlinal and synclinal folds. This minor folding is well shown on the east end of Cochrane island, where, within one-half mile transverse the strike, a conglomerate bed between two beds of greywacke is folded into two synclines with an intervening anticline. The gradual change in texture within many of the thin quartzite beds, from relatively coarse quartzite at the bottom to fine-grained cherty quartzite at the top, shows that south of Garden Hill Indian reserve the south-dipping beds are not overturned, and, therefore, successively younger strata and lava flows are crossed from north to south. The field evidence indicates that the quartzose sediments outcropping on the islands in Cochrane bay are stratigraphically below the sediments and lavas south of Garden Hill Indian reserve.

East of Confederation island definite horizon markers were not found within the volcanics whereby it would be possible to determine definitely their structure. The dip and strike of the schistose cleavage of the lavas and of the bedding of the tuffs show, however, that the volcanics are complexly folded. East of Pickerel narrows the dip of the schistosity of the lavas is to the north and away from the granite mass, and farther east along the north shore the prevailing dip is southward, although northward dips were also noted. On the south side of the lake, just west of the entrance to Sagawitchewan bay, the dip of the schistose cleavage is to the north, but farther west and south of Savage and Sinclair islands the belt of volcanics and interbanded tuff is narrow and apparently here these rocks are closely folded. The broad structure of the volcanic complex in the eastern half of the area is interpreted as synclinal, with minor folds on both the north and south limbs.

## ISLAND LAKE SERIES

### *Distribution*

A series of coarse, clastic sediments, younger than the Hayes River group of volcanics and sediments outcrops on the islands within the east-central part of Island lake. The sediments of this younger group are typically exposed on Sinclair and Savage islands, and on the islands to the east for 5 miles. The area underlain by this series of sediments is roughly oval in outline and is approximately 10 miles in length, with a maximum width of 3 miles.

### *Lithological Character*

The sediments of this younger series are massive, thick-bedded conglomerate, grit, and quartzite, with a few thin beds of greywacke and at one locality some slate. These sediments vary greatly in lithological character from point to point and the beds are lenticular. Conglomerate outcrops, however, predominate in a narrow belt along the border of the area underlain by the younger sediments, and the quartzite and grit outcrop on the islands in the central part of this area. The conglomerate beds vary in thickness from less than a foot to 12 or 15 feet, and the thicker beds nowhere definitely show stratification lines, although in a few places a faintly expressed parallel alignment of the pebbles can be observed. All the pebbles and boulders are rounded and the majority of them are small, averaging about 2 inches in diameter, although some beds contain many pebbles up to 6 inches in diameter, and a few boulders up to 1½ feet in diameter. The larger pebbles and boulders are of granite; small pebbles of andesite, green schist, quartzite, white quartz, feldspar porphyry, jasper, and iron formation are abundantly present. Some outcrops of conglomerate near the andesite and just west of Loonfoot islands carry abundant large pebbles and andesite of the Hayes River group. The matrix of the conglomerate on Sinclair islands is arkose and grit and here the pebbles of some beds are estimated to form three-quarters of the rock. Some outcrops show the pebbles distributed in bunches, and in several places three or more pebbles were noted in contact with each other. In the conglomerate outcropping along the south border of the area underlain by the younger sediments the pebbles are not so numerous, and are, on the average, of smaller size than they are in the conglomerate along the north border, also here the matrix is dark greywacke instead of grit. Thin beds of grit, greywacke, and quartzite are interbedded with the conglomerate, and on a small island 2½ miles northeast of Sinclair islands, two thin beds of slate were noted in the conglomerate, apparently near the base of the series.

The quartzite and grit are light grey rocks consisting of angular and subangular grains of quartz, a few bits of feldspar, and shreds of sericite mica. They are massive, thick-bedded, and the beds seldom show lamination lines or crossbedding. Here and there lenses and thin beds of conglomeratic material are present and grit beds were noted that graded into dark, fine-grained greywacke. The outcrops of the quartzite and grit are uniform in appearance and form hills and low bridges paralleling the strike of the beds.

*Structure and Age Relations*

The absence of distinct bedding planes in some of the outcrops of conglomerate and grit makes it difficult at most points to determine the angle of dip, but many observations of the strike and dip of the thinner beds show clearly that the strata are folded into a syncline within the volcanics. All the dips noted along the outer rim of this area of sediments are towards the centre of the area, and the angle of dip is from 35 to 60 degrees. The strike of the beds also roughly parallels the outline of the area underlain by these sediments, and around the northeast corner is approximately at right angles to that of the schistosity of the volcanics. The average dip of the younger strata is about 40 degrees, whereas the dip within the Hayes River group is generally 70 degrees or over. The presence of abundant pebbles of members of the Hayes River group in the basal conglomerate, combined with the discordance in structure between the two groups, indicates clearly that the coarse, clastic strata were deposited on an eroded surface of the volcanics and possibly within a broad, shallow depression.

The sediments of the Island Lake series were not seen in contact with granite, and, therefore, the age relations of this series of strata to the granitic intrusives of the area are not definitely known. The abundant large boulders of granite in the basal conglomerate indicate a granite area nearby at the time of deposition, but the field work failed to locate outcrops of this granite. Small veinlets of white quartz were noted cutting the conglomerate and quartzite beds on a small island just west of the entrance to Sagawitchewan bay, and since quartz veins are generally assumed to be closely associated in origin with periods of granitic intrusion, the presence of these small veins favours the assumption that the Island Lake series is older than at least some of the granite outcropping in the area.

In lithological character some of the conglomerate of the younger series resembles closely the conglomerate outcropping as a fringe along the south shore of Cochrane bay just east and west of monument M 87. However, the conglomerate at this latter point differs from the younger conglomerate in the absence, so far as observed, of boulders of andesite, jasper, and iron formation. For this reason the conglomerate and interbedded quartzite along the shore of Cochrane bay are thought to represent a phase of the greywacke conglomerate typically developed to the north and west and definitely older than the volcanics. The conglomerate along the shore of Cochrane bay is cut by granite, the intrusive relations of the granite being well shown on the east end of the long island just northwest of station M 87.

## OLDER BASIC INTRUSIVES

### *Occurrence and Age Relations*

Associated with the volcanic members of the Hayes River group are numerous, small bodies of a dark green to black, medium-grained rock, with the mineral composition of diorite and gabbro. The outcrops of these rocks indicate that they form long, narrow bodies, generally less than 400 feet in width, only one mass was noted with a width as great as 1,000 feet. These intrusives are not distinguished on the accompanying map, as time was not available to map accurately their areal extent.

Where exposed, the contact of the medium-grained, basic rocks shows intrusive relationships with the fine-grained, black lavas. A few, long, narrow masses of similar-appearing rocks were also noted within the sediments associated with the lavas, and, although the contact of these with the sediments was not seen at any of the localities examined, their coarse grain suggests an intrusive rather than an effusive origin. Inclusions of diorite and gabbro are abundant in the granite locally and on the west shore of Linklater island a dyke of granite cuts the diorite. The distribution of these basic intrusives indicates that they are intimately associated in origin with the volcanic rocks, possibly representing dykes or sills formed during the period of the extrusion of the lavas.

### *Lithological Character*

Several fairly large bodies of diorite outcrop on the southeast corner of Linklater island and to the west on Fleet point. The rock is medium-grained and massive, except where locally sheared. The outcrops weather black and except for their coarser grain are similar in appearance to some outcrops of the andesite lava. In thin section the minerals of the diorites are seen to be altered to an aggregate of chlorite, saussurite, epidote, calcite, quartz, leucoxene, and only remnants of a few of the larger crystals of andesine and hornblende remain. A thin section of a schistose phase of this diorite shows little trace of the original minerals of this rock and consists of needles and radiating fibrous aggregates of actinolite, without parallel orientation and embedded in a matrix of small grains of secondary feldspar, calcite, and quartz. A few small grains of hornblende were noted and chlorite, pyrite, and leucoxene are abundant.

The minerals in the thin section of the diorite within the sediments, on the north shore of Confederation island, are altered, and only a few grains of the original twinned andesine remain. Most of the feldspar is untwinned, appears to be albite, and probably is a recrystallization product. This diorite contains, besides feldspar, a considerable amount of brown biotite, titaniferous magnetite, leucoxene, and chlorite, probably secondary after hornblende.

A number of outcrops of gabbro were noted within the lavas along the south and east shore of Whiteway island. These rocks are massive, medium to coarse-grained, and locally weather reddish brown. Here the contact zone between a coarse-grained gabbro dyke and a lava flow is sheared and impregnated with white quartz. A thin section of what was judged to be the least altered and also the most basic phase of these intrusives, shows a large percentage of the secondary minerals actinolite, chlorite, calcite, epidote, and leucoxene. The feldspar is between andesine and labradorite, and both hornblende and augite are present. A few grains of secondary quartz are also present. Numerous outcrops of a similar-looking gabbro were also noted on the long, narrow island southeast of Confederation island and at the east end of the lake, one mile south of the entrance to Sagawitchewan bay. In the thin sections of specimens from these localities hornblende is abundant and the feldspar is labradorite, although largely altered to saussurite and small grains of an untwinned feldspar, probably albite. The hornblende is in part altered to actinolite and chlorite.

## GRANITIC INTRUSIVES

### *Granite Porphyry*

*Distribution and Structural Relations.* Small dykes and lenticular bodies of granite porphyry of two types cut the lavas and sediments of Hayes River group. A type, in which quartz phenocrysts predominate, intrudes as small dykes along schistose zones within the volcanics and bedded tuffs east from Garden Hill Indian reserve and just west of Sagawitchewan bay. The quartz porphyries are generally schistose, but at a few places their contact is sharp and shows chilled edges or cuts at an angle the schistosity or bedding of the lava or tuff. Porphyry with feldspar phenocrysts outcrops in Jubilee and Confederation islands and on a few of the islands to the northeast to Linklater island. These porphyries occur as dykes or lenticular bodies cutting the sediments and lavas of Hayes River group and the gabbro intrusives. In the larger masses the porpyhyritic texture is not noticeable, the rock being an unevenly granular granite. The contact relations of the small porphyritic masses with granite were not seen, but the areas of rock with a porphyritic texture are thought to represent small upward projections from the roof of a granite mass below, and possibly were formed during an early stage of the period of granitic intrusion.

*Lithological Character.* The quartz porphyry is ash-grey to black, with abundant small phenocrysts of smoky quartz visible on the greenish grey, weathered surface. A thin section of a specimen from a porphyry mass outcropping along the lake shore 1 mile northeast of monument N 34 shows abundant, subangular quartz grains, and a few, small orthoclase and albite crystals in a schistose groundmass of sericite, chlorite, small angular grains of quartz and feldspar, and a few small areas of calcite. The quartz phenocrysts show undulatory extinction and their borders are granulated. Some quartz and feldspar are intergrown and a few small grains of pyrrhotite are associated with these areas. A grey porphyry from the south shore of Collins bay, 1½ miles west of monument W 96, contains phenocrysts of quartz and of partly altered orthoclase and albite oligoclase, in a groundmass of small grains of quartz and feldspar, green and brown biotite, sericite, and calcite. A thin section of quartz porphyry from one mile west of monument P 62 shows the minerals, except quartz, altered to calcite, chlorite, and kaolinite.

The feldspar porphyry is a massive-appearing, light grey rock with abundant feldspar phenocrysts and a few large crystals of black biotite and hornblende recognizable in the hand specimen. A thin section of a specimen from one of these porphyry bodies from near the bottom of the deep foot-shaped bay on the north side of Jubilee island shows the minerals of this rock badly altered to secondary products. Only the outline of the large feldspar phenocrysts and a few remnants of hornblende in the centre of large masses of chloritic-looking material can be seen. The feldspars are gone to kaolinite, calcite, sericite, and quartz. A few small grains of an untwinned feldspar are recognizable in the groundmass of secondary minerals, also a few grains of titanite, leucoxene, and magnetite. The study of the thin sections of both types of porphyry shows the minerals badly altered to secondary products, and in this respect these porphyries resemble the lavas and basic intrusives described in the foregoing sections of this report. The minerals of the granites are fairly fresh and the altered condition of the minerals of the small bodies of granite porphyry is the main reason for the belief that they are slightly older than the granite.

### *Granite and Granite-gneiss*

*Distribution.* Granitic intrusives are widespread in northeastern Manitoba; in Island Lake area they outcrop extensively around the edge of the area mapped. In fact the outline of the area studied was determined to a large extent by the size and shape of the area of pre-granite sediments and volcanics, which are more likely to be the ore-bearing formations of the district. The narrow areas of granite shown around the edges of the map-area are parts of granite masses, that are believed to extend miles beyond the edge of the map-area. At present the large granite areas offer little attraction to prospectors and are avoided. However, within these areas supposedly underlain by granite there may be fairly large areas of rocks of pre-granite age, and for this reason it is impossible without geological exploration to predict the localities in northeastern Manitoba wherein mineral deposits may or may not be expected to occur.

*Lithological Characters.* Massive, light grey and pink granite are the most characteristic types of the area, gneissic and dark basic phases are developed only locally. In texture all gradations from coarse to fine-grained exist and porphyritic varieties also occur sparingly. The composition varies from a very acidic granite to basic granite; and locally pegmatite and aplite dykes are numerous.

In the field work no outstanding characteristic of the granite of any particular part of the map-area was noted whereby to subdivide the granitic intrusives into groups for description and mapping. Some detailed work was done on the granite of small areas with this in mind, but it was soon found that all the lithological and structural features noted in the area studied could be duplicated at almost any locality within the granite. So far as could be determined all the granite cuts the Hayes River group. Since at present the granites cannot be subdivided either lithologically or structurally for description, it has been thought advisable to describe briefly the main features of the granite from the different parts of the area.

*Granite North of Collins and Chapin Bays.* In this locality the majority of the granite outcrops are of a pink variety, and dark grey varieties are only locally developed. The granite is massive except along the north shore of Chapin bay near the east end, where a dark, gneissic phase is developed. Pink pegmatite dykes and a few black diabase or lamprophyre dykes cut the pink granite of this area. The abundant mineral of the pink granite is microcline, which in thin section occurs as small and large, subangular grains showing the effects of pressure and granulation. Quartz and albite-oligoclase are present in about equal proportions; some microperthite and micropegmatite are also present; and a few small flakes of brown biotite is the only ferromagnesian mineral. The grey varieties of this granite contain abundant plagioclase ranging in composition from oligoclase to andesine and always carries hornblende in addition to green biotite. Also the dark basic varieties always contain abundant small grains of magnetite, pyrite, and titanite, whereas, with the exception of a few grains of titanite, these minerals are absent or only very sparingly present in the pink granites. The study of thin sections of the gneissic varieties shows the quartz and feldspar grains badly granulated and the mica shreds with parallel orientation and frayed ends. The gneiss structure was developed after the minerals had crystallized and the rock consolidated.

*Granite North and South of Mascinicap.* In this part of the area white and grey granite are the predominant types, and only a few outcrops of pink granite were noted. Inclusions of lava and quartz-biotite schist are abundant locally and in such areas gneissic phases are developed. The massive, grey granite is medium-grained and usually is slightly porphyritic. Both oligoclase and orthoclase feldspar are present and these minerals are slightly kaolinized. Biotite and hornblende are represented in all the thin sections examined, and wedge-shaped crystals of brownish titanite are characteristic of this granite. The gneissic phases show abundant microcline and micropegmatite, and the biotite and hornblende are in part altered to chloritic material. The plagioclase of these granite-gneisses is largely altered to zoisite, white mica, calcite, and quartz.

*Granite from Along South Shore East of Isbister River.* A characteristic feature of many outcrops of the pink and grey granite just east of Isbister river is the small, pale green coloured spots on its weathered surface. A thin section from an outcrop of this granite shows under the microscope abundant small crystals and irregular shaped grains of epidote, and the presence of this mineral in unusual quantity undoubtedly gives this granite the spotty green appearance. Some of the epidote is believed to be a primary constituent of this rock mass. The quartz of the light pink granite is clear and shows undulatory extinction. The orthoclase and oligoclase crystals are only slightly altered to kaolin and zoisite respectively. Biotite is more abundant than hornblende and these minerals are unaltered. The accessory minerals, besides the abundant epidote, are titanite, leucoxene, zircon, and apatite. The white to grey granite is very similar to the pink granite in mineral composition, except that in some thin sections hornblende is more abundant and epidote is only sparingly present. At many localities the foliated grey granite was seen to grade within 500 feet into massive, pink or grey granite. In this area black inclusions are locally abundant and small dykes of aplite, pegmatite, and diabase cut this granite.

Large areas of black, massive, medium to coarse-grained basic rock were noted within the granite along a zone varying from 1 to 3 miles in width and extending from Isbister river eastward to the east end of Benson bay. These areas of basic rock appear to pass with gradational contacts into the normal grey and pink granite. Inclusions of black lava are generally abundant in the granite adjacent to such areas of basic rock, and small dykes of pink aplite and medium-grained pegmatite cut the basic rocks. A thin section of a specimen from an outcrop of the black, medium-grained basic rock on the west side of Isbister river just above the second portage from Island lake is interesting in that augite and hypersthene are present. The feldspar is labradorite and is unaltered. The augite is in part altered to uralite and the hypersthene is fresh. Some of the augite is intergrown with the labradorite and biotite, giving the typical poikilitic texture. Quartz is present in small, angular grains between the labradorite and augite crystals. This rock is a hypersthene-bearing quartz gabbro. Thin sections from other outcrops of basic rock to the east do not carry hypersthene, but in these augite and hornblende are the abundant ferromagnesian minerals and the feldspar is between andesine and labradorite in composition. These areas of basic rock within the granite are interpreted as early basic phases of the granitic magma, possibly in part due to local digestion of basic pre-granite rocks.

A medium-grained quartz diorite is developed along the contact of the granite and andesite south of the entrance to Sagawitchewan bay. This rock weathers in a characteristic white and green mottled pattern, and in the thin section studied a partly saussuritized plagioclase, near andesine, forms a background in which is embedded frayed shreds of hornblende, chloritic-looking material, small grains of quartz, calcite, epidote, and titanite. The mineral grains are irregular in shape and orientation and contain abundant small inclusions. The contact relations of this rock with the granite are well exposed at the southeast corner of Island lake, 1½ miles southeast of monument P 74, where the dioritic rock grades gradually into grey granite to the south. No sections were found showing the relations of the quartz diorite with the andesite lava to the north. This basic contact phase of the granite is interpreted as an hybrid type, resulting from the reaction of the granite magma on the andesite lava and very probably formed in situ.

*Granite East and Northeast of Island Lake.* In this area granite outcrops extensively and it is uniform in appearance over wide areas. The grain is medium to coarse and the general colour light grey, although pink and dark grey varieties occur locally. The thin sections studied under the microscope show the plagioclase in the several specimens collected to vary in composition from oligoclase-albite to oligoclase, and orthoclase, microline, and microperthite are present. Biotite is the abundant ferromagnesian mineral, although a few grains of hornblende are always present. Few inclusions of older rocks are present in the granite of this area and gneissic phases are developed only locally. Granite outcrops along the canoe route northeast from Duck and Angling lakes to Red Sucker lake, a distance of about 20 miles. A large area of volcanic and sedimentary strata similar lithologically to the Hayes River group, outcrop north of this granite mass in the basin of Red Sucker lake.

*Granite Between Cochrane Bay and Pickerel Narrows.* The granite of this area is massive and is typically grey in colour. The normal granite is medium-grained and is only locally coarse-grained and slightly porphyritic. Inclusions of the older rocks were noted only along the southern border of this granite mass. Basic contact phases are developed along the northern contact north of Garden Hill Indian reserve. Thin sections of the typical granite from this area show the following minerals: quartz, orthoclase, oligoclase, microperthite, biotite, hornblende, and a little magnetite. The edges of the feldspar crystals are granulated and the central area of a few of the oligoclase crystals is altered to saussurite.

*Granite on Red Sucker Lake.* Granite and granite-gneiss outcrop along the whole south shore of Red Sucker lake. The most widespread type is a medium-grained, grey granite consisting of quartz, orthoclase, oligoclase-albite, and green biotite. Locally a pinkish microcline-bearing granite is present, also a few outcrops of dark grey basic granite or granodiorite. Small pegmatite and aplite dykes are locally abundant cutting the granite. The granite intrudes the sediments and lavas outcropping along the north shore of the lake. Gneissic phases of the granite are not widespread and no lit-par-lit gneiss or large areas of granite containing inclusions of the older rocks were seen.

*Structural Relations*

As already stated wherever the relations of the granite to the Hayes River group were determined definitely the granite is intrusive. The relations of the granite to the Island Lake series is unknown, but presumably this series is also older than the granite. The abundant granite pebbles in the conglomerate of both the Hayes River group and the Island Lake series prove that granite was exposed in this area at the time of the deposition of these sediments. A study of thin sections of this older granite, as represented in the pebbles of the conglomerate, show that they are an acidic granite. The minerals are granulated and altered and the feldspars contain abundant inclusions of quartz and biotite, a feature uncommon in the thin sections of the younger granite. These features of the minerals of the granite from the pebbles may be of little use, however, in tracing them to their original source, as it is very probable that during the folding of the thick conglomerate beds the granitic pebbles would be severely squeezed and the minerals at this time would be granulated and in part recrystallized. The local variation in the mineral content of the granites is interpreted as due to differences produced either by assimilation or by differentiation. The basic contact phases described indicate assimilation at least locally and the aplite and pegmatite dykes cutting the granite show differentiation of the magma at a late stage. The only rocks of the area known to be younger than the granite are the dykes of olivine diabase, augite diabase, and fine-grained lamprophyre.

## YOUNGER BASIC INTRUSIVES

*Occurrence and Age*

Numerous dykes of black, medium-grained diabase were noted cutting the granite and the volcanics and sediments of the Hayes River group. The largest of these dykes noted is the one outcropping about a mile east of monument T 79. This dyke trends north 20 degrees east, varies from 50 to 500 feet in width, and was traced 7 miles along the strike. The outcrops of this dyke form a low ridge and on the island one mile northeast of monument T 79, the hill of black diabase is a prominent physiographic feature. Smaller dykes of diabase occur in the granite north and east of St. Theresa point, on the southwest side of Fleet point, and at a few localities along the shore west from the outlet of Island lake.

*Lithological Character*

The diabase is a massive, fine to medium-grained, black rock. The surface of a few outcrops is weathered brownish. In thin section under the microscope the minerals of the diabase are always fresh and by this feature the younger basic intrusives are easily distinguished from the older gabbro and diorite wherein the minerals are always badly altered. The thin sections consist of lath-shaped crystals of labradorite with the intervening area filled with olivine, augite, and a few grains of magnetite. A thin section from one of the smaller dykes contained no olivine, but showed abundant augite and some green hornblende. These dykes are similar in mineral composition and structural relations to the diabase dykes and sills so abundant in sections of northern Ontario.

## ECONOMIC GEOLOGY

Practically no prospecting has yet been undertaken in Island Lake area, and no mineral deposits of commercial value are known. The preceding description of the geology of the area, however, indicates areas of rocks similar to those wherein commercial mineral deposits have been discovered elsewhere within the Canadian Shield, consequently the area is one that should be prospected carefully. The bedrock is fairly well exposed and this feature will facilitate greatly the work of prospectors.

An examination of the geological maps of the important mining camps of Quebec, Ontario, and Manitoba shows that the gold and copper deposits of these areas are within the lavas and sediments of pre-granite age—Keewatin—and are connected in origin with intrusive rocks, in many cases granitic in composition. An opinion is also growing that the large and commercially valuable metalliferous deposits are associated with the small, rather quickly cooled intrusive bodies, and rarely occur along the contacts where erosion has gone deep, exposing great areas of granite. In Island Lake area intrusive bodies of both the small and large types are exposed and the Hayes River strata adjacent to the contacts with the granitic rocks should first of all be carefully prospected. Small, lenticular quartz veins were noted at many localities within shear zones in the volcanic members of the Hayes River group, and these quartz veins should be carefully examined to determine if they are gold-bearing. Some of the shear zones are mineralized with pyrite and chalcopyrite, but not in commercial quantities at the localities noted by the writer. The area that may contain valuable mineral deposits is a large one, and a great deal of intensive systematic prospecting will have to be done before the mineral possibilities of this district can be evaluated.

# DEEP BORINGS IN THE PRAIRIE PROVINCES AND NORTH WEST TERRITORIES

*By E. D. Ingall*

The Borings Division of the Geological Survey accumulates and studies records of borings made in any part of Canada, in order that the geological information thus rendered available may be utilized for the guidance of operators, and in geological research. The control of boring operations in the Prairie Provinces and the Northwest Territories is vested in the North West Territories and Yukon Branch of the Department of the Interior, which has legal power to enforce regulations and to collect well logs and samples from borings for gas or oil on lands controlled by the Federal Government. These samples are subsequently forwarded to the Borings Division, Geological Survey, for intensive study, chiefly with a view to obtaining more detailed knowledge of the geology in depth. Information is also gained directly from operators drilling for water supplies, etc.

The list given (Table I) presents in tabular form particulars of the records of borings in the Prairie Provinces added to the files of the Borings Division during 1927. Where need arose and time permitted, the series of cuttings from certain wells were intensively studied by laboratory methods and the results placed at the disposal of operators and geologists.

67538—6½

TABLE I

| Location | | | | | | Description | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LS. | Sec. | Tp. | Range | Mer. | At or near | Year drilled | Elevation above sea-level. Feet | Depth in feet covered by records | Yield | Number of samples received | |
| COUTTS-SWEETGRASS | | | | | | | | | | | |
| 5 | 32 | 1 | 11 | W. 4th.. | Coutts........ | 1924–25 | 3,275 | 2,580 | ........ | 138 | Imperial Oil Co., Dead Horse Coulée No. 2 |
| 13 | 8 | 1 | 12 | W. 4th.. | " ........ | 1925–27 | .......... | 3,650 | Gas..... | 248 | Imperial Oil Co., Erickson Coulée No. 1 |
| 2 | 4 | 1 | 15 | W. 4th.. | " ........ | 1927 | .......... | 3,430 | ........ | 128 | Urban Oil Co. No. 1 (formerly Moodie No. 1) |
| 7 | 9 | 3 | 15 | W. 4th.. | " ........ | 1927 | .......... | 285 | ........ | 10 | Ainsworth Oils No. 2 |
| 4 | 9 | 3 | 15 | W. 4th.. | " ........ | 1927 | .......... | 60 | ........ | 6 | Ainsworth Oils No. 3 |
| 14 | 21 | 4 | 18 | W. 4th.. | Warner....... | 1927 | .......... | 680 | ........ | 55 | Warner No. 1 |
| SKIFF | | | | | | | | | | | |
| 5 | 27 | 5 | 14 | W. 4th.. | Skiff.......... | 1927 | .......... | 3,170 | Oil..... | 302 | Imperial Devenish Petroleum |
| FOREMOST | | | | | | | | | | | |
| 6 | 31 | 5 | 10 | W. 4th.. | Foremost..... | 1926–27 | .......... | 1,050 | ........ | 104 | United Natural Gas No. 4 |
| 12 | 5 | 6 | 10 | W. 4th.. | " .... | 1926–27 | .......... | 2,235 | ........ | 213 | Canadian Western Light, Heat, and Power Co. (Foremost No. 8) |
| 4 | 24 | 6 | 11 | W. 4th.. | " .... | 1926–27 | .......... | 2,150 | ........ | 216 | Canadian Western Light, Heat, and Power Co. (Foremost No. 7) |
| CYPRESS HILLS | | | | | | | | | | | |
| 9 | 31 | 7 | 4 | W. 4th.. | Cypress hills.. | 1927 | .......... | 600 | ........ | 57 | Eagle Butte No. 1 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MEDICINE HAT | | | | | | |
| 4 | 6 | 13 | 5 | W. 4th.. | Crescent heights | 1924–26 | 2,220 | 3,940 | Gas..... | 50 | Roth and Faurot No. 1 |
| | 8 | 13 | 6 | W. 4th.. | Medicine Hat | 1926–27 | .......... | 3,150 | ........ | 258 | Roth and Faurot No. 2 |
| | | | | | BURDETT | | | | | | |
| | 8 | 11 | 11 | W. 4th.. | Burdett....... | 1926–27 | .......... | 4,060 | ........ | 415 | Imperial Oil Burdett No. 1 |
| | | | | | HERSCHEL | | | | | | |
| 16 | 4 | 31 | 17 | W. 3rd.. | Herschel...... | 1927 | .......... | 225 | ........ | 14 | Rosetown Lease Holding Development Co. No. 1 |
| | | | | | SIMPSON | | | | | | |
| 2 | 9 | 29 | 25 | W. 2nd.. | Simpson...... | 1927 | .......... | 1,055 | ........ | 69 | Simpson Oils Roycroft No. 1 |
| | | | | | ALTARIO | | | | | | |
| 5 | 13 | 33 | 2 | W. 4th.. | Altario....... | 1927 | .......... | 140 | ........ | 5 | Rosebud No. 1 |
| | | | | | VERA | | | | | | |
| | 23 | 41 | 24 | W. 3rd.. | Vera.......... | 1926–27 | .......... | 2,800 | ........ | 101 | Unity Valley No. 1 |
| | | | | | RIBSTONE | | | | | | |
| 3 | 16 | 45 | 1 | W. 4th.. | Ribstone...... | 1926–27 | .......... | 300 | ........ | 62 | Advance Ribstone No. 1 |
| | 5 | 45 | 1 | W. 4th.. | " .... | 1926–27 | .......... | 3,485 | ........ | 290 | Imperial Ribstone No. 1 |
| 1 | 1 | 46 | 1 | W. 4th.. | " .... | 1926–27 | .......... | 3,155 | ........ | 160 | Ribstone Oils No. 1 |

TABLE I—*Continued*

| Location | | | | | | Description | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LS. | Sec. | Tp. | Range | Mer. | At or near | Year drilled | Elevation above sea-level. Feet | Depth in feet covered by records | Yield | Number of samples received | |
| | | | | | | WAINWRIGHT-FABYAN | | | | | |
| | 36 | 44 | 7 | W. 4th.. | Wainwright... | 1927 | .......... | 1,850 | ........ | 35 | Interior Oil Co. No. 1 |
| | | | | | | VIKING | | | | | |
| 1 | 18 | 49 | 12 | W. 4th.. | Viking........ | 1927 | .......... | 2,105 | Gas..... | 410 | North West Utilities Viking No. 13 |
| 4 | 4 | 49 | 12 | W. 4th.. | " ........ | 1927 | .......... | 2,195 | Gas..... | 438 | North West Utilities Viking No. 14 |
| 9 | 12 | 49 | 13 | W. 4th.. | " ........ | 1927 | 2,254 | 2,125 | ........ | 82 | North West Utilities Viking No. 12 |
| | | | | | | PINCHER CREEK | | | | | |
| 4 | 7 | 6 | 1 | W. 5th.. | Pincher Creek | 1927 | .......... | 775 | ........ | 140 | Mount Royal No. 1 |
| | | | | | | NANTON | | | | | |
| 13 | 4 | 14 | 2 | W. 5th.. | Nanton....... | 1924–26 | .......... | 5,740 | ........ | 84 | Imperial Oil Co. Rice Creek No. 2 |
| | | | | | | HIGH RIVER | | | | | |
| 16 | 13 | 20 | 29 | W. 4th.. | High River.. | 1926–27 | .......... | 1,870 | ........ | 222 | Ranchmen's Gas and Oil Co. No. 1 |

## TURNER VALLEY

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 30 | 19 | 2 | W. 5th.. | Turner Valley | 1926–27 | 4,035·6 | 4,530 | Oil..... | 430 | Dalhousie No. 5 |
| 11 | 20 | 19 | 2 | W. 5th.. | " | 1926–27 | 4,204·3 | 3,040 | ........ | 336 | Dallas No. 1 |
| 2 | 7 | 20 | 2 | W. 5th.. | " | 1926–27 | 3,903·0 | 5,320 | ........ | 208 | Great West No. 1 |
| 5 | 5 | 20 | 2 | W. 5th.. | " | 1926–27 | 3,992·8 | 4,280 | ........ | 105 | Big Chief No. 1 |
| 2 | 7 | 20 | 2 | W. 5th.. | " | 1926–27 | 3,901·0 | 4,730 | Gas and oil shows | 265 | Cooper Nanton Oils |
| 4 | 5 | 20 | 2 | W. 5th.. | " | 1926–27 | 3,985·9 | 6,040 | ........ | 224 | British Dominion Oil and Development Co. |
| 5 | 5 | 20 | 2 | W. 5th.. | " | 1926–27 | 3,985·4 | 3,000 | ........ | 180 | Highland Oil Co. No. 1 |
| 10 | 20 | 19 | 2 | W. 5th.. | " | 1926–27 | 4,198·6 | 4,560 | Oil..... | 345 | Home Oil Co. No 1 |
| 14 | 20 | 19 | 2 | W. 5th.. | " | 1926–27 | 4,204·4 | 2,140 | ........ | 78 | Home Oil Co. No. 2 |
| 13 | 7 | 20 | 2 | W. 5th.. | " | 1926–27 | 3,984·0 | 3,490 | ........ | 7 | Royalite No. 5 |
| 16 | 31 | 19 | 2 | W. 5th.. | " | 1926–27 | 4,000·0 | 3,095 | ........ | 9 | Royalite No. 6 |
| 3 | 13 | 20 | 3 | W. 5th . | " | 1926–27 | 4,012·5 | 3,870 | Wet gas | 375 | Royalite No. 7 |
| 4 | 18 | 20 | 2 | W. 5th.. | " | 1926–27 | 4,001·7 | 3,600 | ........ | 5 | Dalhousie No. 1 |
| 10 | 13 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,056·2 | 4,510 | ........ | 440 | Dalhousie No. 6 |
| 14 | 8 | 20 | 2 | W. 5th.. | " | 1926–27 | 3,857·9 | 2,700 | ........ | 246 | Sentinel Oil Co. |
| 4 | 6 | 21 | 2 | W. 5th.. | " | 1926–27 | 3,872·9 | 2,080 | ........ | 198 | New Valley Oil Co. No. 1 |
| | 20 | 19 | 2 | W. 5th.. | " | 1926–27 | .......... | 125 | ........ | 13 | Ainsworth No. 1 |
| 1 | 27 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,041·8 | 5,320 | Gas..... | 318 | Stockmen's Oil Co. |
| 2 | 1 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,015·5 | 4,090 | Oil..... | 259 | Calmont No. 1 |
| 1 | 1 | 20 | 3 | W. 5th.. | " | 1926–27 | 3,955·6 | 4,110 | Oil..... | 360 | Okalta Oils Ltd. |
| 8 | 1 | 20 | 3 | W. 5th.. | " | 1926–27 | 3,971·5 | 1,700 | ........ | 121 | Dolomite Oil Co. No. 1 |
| 16 | 1 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,004·7 | 4,330 | Wet gas | 135 | McLeod Oil Co. No. 2 |
| 1 | 3 | 20 | 3 | W. 5th.. | " | 1926 27 | .......... | 900 | ........ | 14 | New Black Diamond No. 1 |
| 12 | 13 | 20 | 3 | W. 5th.. | " | 1926–27 | .......... | 4,590 | ........ | 288 | Spooner Oils No. 1 |
| 14 | 12 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,017·6 | 2,140 | Oil..... | 212 | New McDougall Segur No. 2 |
| 14 | 12 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,013·3 | 2,490 | Oil..... | 248 | New McDougall Segur No. 1 |
| 16 | 1 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,001·3 | 2,600 | Oil..... | 222 | Regent No. 2 |
| 11 | 13 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,012·4 | 3,500 | Oil..... | 160 | Vulcan No. 1 |
| 1 | 34 | 20 | 3 | W. 5th.. | " | 1926–27 | 3,986·6 | 2,940 | ........ | 60 | Seneca Oils No. 1 |
| | SW.¼ 26 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,001·1 | 2,990 | ........ | 287 | Foothills No. 1 |
| 14 | 12 | 20 | 3 | W. 5th.. | " | 1926–27 | 4,012·5 | 1,052 | ........ | ........ | Illinois Alberta No. 2 |

## HIGHWOOD

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 36 | 18 | 3 | W. 5th.. | Highwood.... | 1926–27 | .......... | 3,340 | ........ | 314 | Imperial Highwood No. 1 |

## DE WINTON

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22 | 21 | 1 | W. 5th.. | De Winton.... | 1927 | .......... | 1,230 | ........ | 60 | Anglesey No. 1 |

TABLE I—*Continued*

| Location | | | | | | Description | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LS. | Sec. | Tp. | Range | Mer. | At or near | Year drilled | Elevation above sea-level. Feet | Depth in feet covered by records | Yield | Number of samples received | |
| **MOOSE MOUNTAIN** | | | | | | | | | | | |
| 9 | 34 | 23 | 5 | W. 5th.. | Moose Mountain | 1926–27 | .......... | 1,585 | ........ | 51 | Signal Hill No. 2 |
| **BOW RIVER** | | | | | | | | | | | |
| 15 | 12 | 25 | 5 | W. 5th.. | Bow river..... | 1925–27 | .......... | 5,230 | ........ | 249 | Imperial Oil Co., Bow River No. 1 |
| **MORLEY RESERVE** | | | | | | | | | | | |
| | | 25 | 7 | W. 5th.. | Morley reserve | 1927 | .......... | 2,910 | ........ | 265 | Gold Coin Oils Ltd. |
| | | | | | " | 1927 | .......... | 260 | ........ | 31 | Wabash |
| **OTHER BORINGS** | | | | | | | | | | | |
| 13 | 18 | 31 | 1 | W. 5th.. | Didsbury..... | 1927 | .......... | 250 | ........ | 12 | Delco Oil Co. |
| 4 | 32 | 42 | 25 | W. 4th.. | Ponoka....... | 1925 | 2,604 | 2,980 | Gas..... | 47 | Provincial Government well |
| | 36 | 53 | 4 | W. 4th.. | ............. | 1927 | .......... | 195 | ........ | 14 | Carrie W. Hill No. 2 |
| | 14 | 74 | 6 | W. 5th.. | Lesser Slave lake | 1926–27 | .......... | 2,845 | ........ | 312 | International Oils |
| 10 | 32 | 96 | 10 | W. 4th.. | McMurray.... | 1927 | .......... | 235 | ........ | 8 | International Bitumen No. 1A |
| | 34 | 107 | 8 | W. 5th.. | Fort Vermilion | 1925–27 | .......... | 715 | ........ | 62 | Black Rock Petroleum No. 2 |
| Near Bosworth creek | | | | | Mackenzie river | 1924–25 | .......... | 1,600 | Oil..... | 63 | Imperial Oil Discovery No. 2 |

MANITOBA

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 30 | 22 | 17 | W. 1st.. | .............. | 1927 | .......... | 448 | ........ | 18 | Mack Oil and Gas Co. Ltd. |
| 10 | 30 | 22 | 17 | W. 1st.. | Ochre River.. | 1927 | .......... | 1,485 | ........ | 72 | W. J. Holmes |
| 11 | 18 | 26 | 23 | W. 1st.. | Grandview... | 1927 | .......... | 100 | ........ | 10 | Irro No. 2 |
| 12 | 2 | 43 | 26 | W. 1st.. | Mafeking..... | 1925–27 | .......... | 1,630 | ........ | 160 | Edward Dougherty |
| 4 | 23 | 43 | 26 | W. 1st.. | " ..... | 1925–27 | .......... | 760 | ........ | 38 | Edward Dougherty |

SHALLOW WELLS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SE. 16 | 51 | 25 | W. 2nd. | Henribourg... | 1927 | .......... | 95 | ........ | 12 | C.N.R. well by Geo. Black |
| | 23 | 17 | 19 | W. 2nd. | Regina........ | 1927 | 1,905 | 187 | Water.. | ........ | Regina Waterworks No. 4 |
| | 23 | 17 | 19 | W. 2nd. | " ........ | 1927 | 1,905 | 125 | " .. | ........ | Regina Waterworks No. 6 |
| | 26 | 17 | 19 | W. 2nd. | " ........ | 1927 | 1,915 | 126 | " .. | ........ | Regina Waterworks No. 1 |
| | 26 | 17 | 19 | W. 2nd. | " ........ | 1927 | 1,910 | 190 | " .. | ........ | Regina Waterworks No. 2 |
| | 26 | 17 | 19 | W. 2nd. | " ........ | 1927 | 1,900 | 166 | " .. | ........ | Regina Waterworks No. 3 |
| | 26 | 17 | 19 | W. 2nd. | " ........ | 1927 | 1,902 | 232 | " .. | ........ | Regina Waterworks No. 5 |
| | 26 | 17 | 19 | W. 2nd. | " ........ | 1927 | 1,908 | 160 | " .. | ........ | Regina Waterworks No. 7 |
| | NE. 36 | 11 | 8 | W. 2nd. | Corning....... | 1927 | .......... | 221 | Dry.... | ........ | C.N.R. well by Duff, Flint, and Co. |
| | NW. 36 | 12 | 8 | W. 2nd. | Bemersyde... | 1927 | .......... | 128 | Water.. | ........ | C.N.R. well by Duff, Flint, and Co. |
| | SW. 29 | 31 | 2 | W. 2nd. | Esther........ | 1927 | .......... | 176 | " .. | ........ | C.N.R. well by Duff, Flint, and Co. |
| | 30 | 23 | 3 | W. 3rd.. | Grainland.... | 1927 | .......... | 110 | ........ | 11 | C.N.R. well by J. Connor |
| | SE. 30 | 22 | 4 | W. 3rd.. | Euclid........ | 1927 | .......... | 90 | ........ | 9 | C.N.R. well by J. Connor, driller |
| | SW. 10 | 25 | 5 | W. 3rd.. | Elbow........ | 1927 | .......... | 120 | ........ | 12 | C.N.R. well by J. Connor |
| | NW. 21 | 25 | 6 | W. 3rd.. | Longacre...... | 1927 | .......... | 200 | ........ | 20 | C.N.R. well by J. Connor |
| | 21 | 25 | 6 | W. 3rd.. | " ...... | 1927 | .......... | 100 | ........ | 10 | C.N.R. well by J. Connor |
| | NE. 7 | 14 | 7 | W. 3rd.. | Peebles...... | 1927 | .......... | 170 | Water.. | 15 | C.N.R. well |
| | NW. | 25 | 19 | W. 3rd.. | Witley........ | 1927 | .......... | 230 | " .. | 23 | C.N.R. well |
| | SE. 14 | 14 | 9 | W. 3rd.. | Scotsburg..... | 1927 | .......... | 55 | " .. | 7 | C.N.R. well |
| | SE. 1 | 15 | 10 | W. 3rd.. | Neidpath..... | 1927 | .......... | 225 | ........ | 32 | C.N.R. well by Duff, Flint, and Co. |
| | SE. 17 | 23 | 16 | W. 3rd.. | Whitebear.... | 1927 | .......... | 220 | ........ | 22 | C.N.R. well No. 1 by Duff, Flint, and Co. |
| | SE. 17 | 23 | 16 | W. 3rd.. | " .... | 1927 | .......... | 220 | ........ | 22 | C.N.R. well No. 2 by Duff, Flint, and Co. |
| | SE. 17 | 23 | 17 | W. 3rd.. | Lacadena..... | 1927 | .......... | 400 | ........ | 60 | C.N.R. well by E. Rigsby |
| | SW. 26 | 24 | 19 | W. 3rd.. | Isham........ | 1927 | .......... | 190 | ........ | 19 | C.N.R. well Stockyard, by E. Rigsby |
| | 4 | 40 | 19 | W. 3rd.. | Wilkie........ | 1927 | .......... | 215 | ........ | 10 | C.N.R. well, Jas. Douglas |
| | 17 | 37 | 19 | W. 3rd.. | Leipzig....... | 1927 | .......... | 420 | ........ | 22 | Notre Dame Convent, Jas. Douglas |
| | 8 | 31 | 14 | W. 4th.. | Hanna........ | 1927 | .......... | 120 | ........ | 12 | C.N.R. well by Duff, Flint, and Co. |
| | SE. 17 | 23 | 17 | W. 4th.. | Hanna........ | 1927 | .......... | 120 | ........ | 12 | C.N.R. well by E. Rigsby |
| | 32 | 31 | 2 | W. 4th.. | Esther........ | 1927 | .......... | 120 | ........ | 12 | C.N.R. well by J. Connor |
| | SE. 35 | 34 | 16 | W. 4th.. | Endiang...... | 1927 | .......... | 100 | ........ | 10 | C.N.R. well No. 3 by Du ff, Flint, and Co. |
| | SE. 35 | 34 | 16 | W. 4th.. | Endiang...... | 1927 | .......... | 130 | ........ | 13 | C.P.R. well No. 2 by Duff, Flint, and Co. |
| | SW. 35 | 34 | 16 | W. 4th.. | Endiang...... | 1927 | .......... | 140 | Water.. | 14 | C.P.R. well No. 1 by Duff, Flint, and Co. |

TABLE I—*Continued*

| Location | | | | | | Description | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LS. | Sec. | Tp. | Range | Mer. | At or near | Year drilled | Elevation above sea-level. Feet | Depth in feet covered by records | Yield | Number of samples received | |
| SHALLOW WELLS—*Continued* | | | | | | | | | | | |
| | NW. 6 | 35 | 16 | W. 4th.. | Byemoor..... | 1927 | .......... | 110 | ........ | 13 | C.N.R. well No. 1 by Duff, Flint, and Co. |
| | NW. 6 | 35 | 16 | W. 4th.. | " ..... | 1927 | .......... | 120 | ........ | 11 | C.N.R. well No. 2 by Duff, Flint, and Co. |
| | 2 | 47 | 20 | W. 4th.. | Camrose...... | 1927 | .......... | 150 | ........ | 8 | Camrose Townsite well by A. W. Duff |
| | SE. 38 | 33 | 15 | W. 4th.. | Scapa......... | 1927 | .......... | 122 | Water.. | ........ | C.N.R. well by A. W. Duff |
| | NE. 25 | 33 | 15 | W. 4th.. | " ........ | 1927 | .......... | 126 | " .. | ........ | C.N.R. well by A. W. Duff |
| | SE. 25 | 33 | 15 | W. 4th.. | Dowling...... | 1927 | .......... | 74 | " .. | ........ | C.N.R. well No. 1 by A. W. Duff |
| | SE. 25 | 33 | 15 | W. 4th.. | " ...... | 1927 | .......... | 76 | " .. | ........ | C.N.R. well No. 2 by A. W. Duff |

A total of 12,657 samples were received during the year from 101 borings.

As in past years, all the records received have been added to the systematic files of the Borings Division and form the basis of its activities in providing operators and other inquirers with information and reports on geological conditions probably to be encountered in boring in various districts. In every case great care is taken to safeguard private interests where information is requested that might be regarded as confidentially given. In these cases the sanction of the owner of the borings is asked or the inquirer is requested to communicate directly with those interested.

Apart from the efforts made to collect samples and all available data relating to deep borings for gas and oil, efforts are made to get in touch with drillers who are engaged in the business of boring for water supplies. Thanks to the courtesy of some of the larger firms, whose names are given in the tabulated statement, records from thirty-nine shallow wells were added to the files of the division. Sets of samples were also received from eighteen of these wells illustrative of the surface deposits penetrated and of the underlying bedrock where reached.

Considerable difficulty has always been encountered in this line of investigation as most of such borings are made by drillers operating locally, with whom it is difficult to get in touch and to maintain relationships. The solution of this problem may be arrived at by inaugurating in Canada a movement recently introduced in some of the states of the United States of America in which drillers' associations have been formed. Annual conventions are held at which problems of interest to drillers are discussed and where the members of the association can become familiar with the offerings of the manufacturers of drilling machinery exhibited by the manufacturers. The Borings Division of the Geological Survey could then perform more effectually its function of providing a central "clearing house" for well records and for their correlation and interpretation, and the utilization of the aggregate results for the guidance of future operations and in meeting the constant public demand for information.

The question of water supplies in the Prairie Provinces is a most difficult and important one and becomes more so as these provinces become more closely settled. The water required must, of course, be pure enough for domestic use and free enough from dissolved mineral salts to fit it for irrigation purposes and avoid the detrimental effect of accumulation of mineral salts in the soils when thus used. The water encountered in deep borings into the underlying rock formations is so frequently highly mineralized that the accumulations of rain water in the porous portions (gravels and sands) of the surface deposits has to be looked to in many districts. These, being in their nature very irregular in their distribution, the problem becomes one of making intensive local studies on the ground and the data it has been so far found possible for the division to acquire by correspondence are too scattered to give anything but general conclusions.

The following report of work done in the laboratory under his supervision is submitted by Mr. D. C. Maddox.

## LABORATORY REPORT

As a result of the recent great development of the oil and gas industry in the Prairie Provinces the great bulk of the samples received and examined by the Borings Division came from wells drilled in this area. During the year more than 7,000 samples were examined.

During 1927 the work of collecting foraminifera from cuttings from borings in the Cretaceous shales of the western provinces was chiefly done by Mr. R. T. D. Wickenden, a summer student temporarily attached to the Borings Division. Mr. Wickenden is specializing on work of this nature and on his return to Harvard University he undertook the study of these forms under Dr. J. A. Cushman. It is hoped that this work will ultimately prove to be of great assistance in recognizing various geological horizons.

During 1927 a study was commenced by F. J. Fraser of the heavy minerals characterizing the strata. One hundred and twenty-three slides were prepared. Few of the slides have been studied in detail but from the results of examination now in process, many interesting points are evolving. In the case of Turner Valley material, the slides already made represent mainly Benton shale residues, characterized by apatite, tourmaline, and zircon, with perhaps a more limited range of spherical and octahedral pyrite. Blairmore residues so far examined show garnet, and work in the near future should conform and limit the range of this mineral in pre-Benton strata. A few post-Benton residues have been separated and examined, and these invariably contain a much greater variety of minerals than the older beds. Epidote, garnet, and perhaps andalusite have been noted.

## OTHER FIELD WORK

*Geological*

E. M. KINDLE. Mr. Kindle geologically studied an area in the vicinity of Jasper park, Alberta.

B. R. MACKAY. Mr. MacKay made a detailed geological examination of the Brûlé Mines coal field.

W. A. JOHNSTON. Mr. Johnston geologically mapped the surface deposits of the areas covered by the Emerson, Virden, Turtle Mountain, and the greater part of the Winnipeg, sectional maps, southern Manitoba and southeastern Saskatchewan.

E. M. BURWASH. Mr. Burwash studied the geology in the vicinity of Cold lake, Manitoba.

C. H. STOCKWELL. Mr. Stockwell concluded an investigation of the lithia-bearing pegmatites and associated rocks of southeastern Manitoba and adjacent parts of Ontario. A memoir and a geological map are being prepared for publication.

*Topographical*

D. A. NICHOLS. Mr. Nichols completed the topographical survey of the east half of the Jumping Pound map-area, Alberta, and extended this mapping northwestward.

J. W. SPENCE. Mr. Spence completed the topographical survey of Turner Valley map-area and mapped part of Bragg Creek map-area, Alberta.

# INDEX