

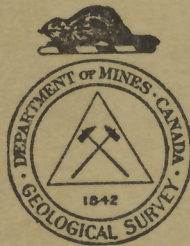
CANADA  
DEPARTMENT OF MINES  
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER  
GEOLOGICAL SURVEY  
W. H. COLLINS, DIRECTOR

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## Summary Report, 1924, Part B

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OTTAWA  
F. A. ACLAND  
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY  
1926

No 2077

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## SUMMARY REPORT, 1924, PART B

### OIL AND GAS PROSPECTS OF THE WAINWRIGHT-VERMILION AREA, ALBERTA

*By G. S. Hume*

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#### Illustration

Map. 2058. Wainwright-Vermilion area, Alberta..... In pocket

#### INTRODUCTION AND ACKNOWLEDGMENTS

In November, 1923, British Petroleum, Limited, struck a flow of oil in their No. 2 well, 5 miles north of Wainwright. A short report on this discovery, with a statement regarding other drilling, was issued in December, 1923, by the Geological Survey. At that time little was known of the details of the geological structure of the field, and in view of the importance of this discovery of petroleum the Geological Survey during the summer of 1924 undertook a regional study to investigate the conditions under which the petroleum occurs. With this intention the writer, assisted by R. H. Pegrum, spent from June 6 to September 25 in the field, and made a detailed study of a small area along Battle river in the vicinity of the oil wells and a less detailed study of a much larger area extending from the Canadian National railway to North Saskatchewan river and from the Alberta-Saskatchewan boundary as far west as Viking. In the detailed work a special levelling party under A. J. Childerhose, assisted by W. S. Yarwood, ran accurate level-lines to the various outcrops. The determination of the geological structure, as finally outlined, is to a large extent due to the careful and efficient work of the above-named assistants without whose enthusiastic co-operation the results that were achieved could not have been accomplished.

The geological section exposed along the banks of North Saskatchewan river from Edmonton to the Alberta-Saskatchewan boundary has been

reported upon by J. A. Allan.<sup>1</sup> This section was restudied, but the positions of the various outcrops, as indicated on the map accompanying this report, have been derived from manuscript maps and notes prepared by Dr. Allan.

In the field the writer had the co-operation of the various drilling companies, to whom he expresses his thanks. In an area such as the one studied, where outcrops are scarce, well logs must be relied on for much of the information. The rotary drill-cores taken by British Petroleum, Limited, are now in the care of the Borings Division of the Geological Survey, and the information derived from these cores and supplied to British Petroleum should be of decided advantage to that company in their search for oil. A very fine set of samples of sediments encountered in drilling with a standard rig has been received from J. O. Williams, Western Consolidated Oil Company, Limited, and also a number of samples from the rotary drillings of the Maple Leaf Oil Company. The records and drilling samples of the Imperial Oil Company are also in the care of the Borings Division. The information derived from well logs is considered confidential unless permission be granted for publication. In this way a great deal of data is accumulated which can be used to solve problems of importance and value to all drilling companies.

### PHYSICAL FEATURES

The Wainwright-Vermilion area is in east-central Alberta. The surface is for the most part flat or gently rolling and in a large measure reflects the horizontal character of the underlying rocks. Bedrock is largely concealed by deposits of glacial origin, the distribution of which has given certain parts of the area a hilly appearance and in which rocky ridges may occur. Groves of poplar trees occur throughout the whole area and frequently the south banks of the river and stream valleys are wooded, whereas the north banks are almost treeless. Farming and ranching are the chief industries, but although the soil is mostly rich and fertile, certain sections are too sandy for cultivation. Attempts to cultivate the sandy soil have in some cases ended in the abandonment of the farms; in other cases have partly destroyed the vegetation, thus assisting the formation of sand-dunes which are liable to migrate, and are thus a menace to good farm land in adjoining sections. The sandy soil in certain sections is due to weathering of the underlying soft sandstones and in many places the character of the underlying rock can be inferred from the surface materials.

In the north of this area, the flat prairie surface has been dissected by the wide and deep valley of North Saskatchewan river and in the south by Battle river, with a valley 200 to 300 feet below the general prairie level. Several coulées occupied by small streams joining Battle river are deep and steep-sided near the outlet, but a short distance away are much wider and less abrupt, and give only gentle relief to the prairie. Except near North Saskatchewan river, Vermilion River valley is nowhere very deep, the river itself flowing sluggishly, often in a poorly defined channel in which water weeds and reeds flourish.

<sup>1</sup> Allan, J. A., Geol. Surv., Can., Sum. Rept., 1917, pt. C, pp. 9-13.

Exposures of rock are almost wholly confined to the steep river banks, and consist entirely of Cretaceous rocks and mostly of hard sandstones belonging to several formations of this age. The scarcity of rock outcrops throughout this part of the plains area is a marked feature which makes geological interpretation of structure difficult and somewhat conjectural.

### STRATIGRAPHY

The following table descriptive of the formations within the Wainwright-Vermilion area is based in part on one prepared by S. E. Slipper.<sup>1</sup>

*Table of Formations*

			Formation	Thickness in feet	Description
Cretaceous	Montana group	Belly River series	Pale beds	About 500	Pale, incoherent, crossbedded sandstones, green clays, and sandstones. Indigo-coloured nodules and thin coal seams. Freshwater fossils
			Variegated beds	200	Interlayered sandstone and shale of various tints of green, brown, and yellow. Coal seams. Brackish water deposits
			Birch Lake formation	60 to 100	Massive, crossbedded, buff-coloured sandstone containing layers of harder sandstone. Some shale. Brackish water deposits
			Grizzly Bear formation	40 to 100	Dark blue to grey, marine shale containing ironstone and sandstone nodules. Some beds of yellow, incoherent sandstone
			Ribstone Creek formation	325	Greenish yellow, massive, soft sandstone at top with carbonaceous shale and coal. Light grey sandstone at base. Brackish water deposits
		Lower Pierre	Lea Park formation	700	Blue-grey shale. Contains nodules and selenite. Marine
	Colorado		Benton formation. (Not exposed in the Wainwright-Vermilion area)	800 to 900	Dark-coloured shale with some sandstone beds and sandy shale. Contains ironstone bands and some bentonite bands. Marine
	Lower Cretaceous		(Not exposed in the Wainwright-Vermilion area)	100 to 150	Sandstone beds with some dark shale. Coal seams. Continental deposits

#### *Erosional unconformity*

Devonian.....	(Not exposed)	?	Principally limestone
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<sup>1</sup> Slipper, S. E., Geol. Surv., Can., Sum. Rept., 1917, pt. C, p. 8.

The Cretaceous strata appear to belong to an unbroken sedimentary series. For this reason and because fossils are scarce, it is difficult or impossible sharply to divide succeeding formations, especially in the case of the Pale and Variegated beds. The difficulty is greatly increased by the lack of good exposures, the beds being as a rule quite soft and the outcrops, therefore, mostly small and in many places widely separated by covered intervals. In addition, lateral variations in character of the sedimentation make it difficult to correlate strata even for short distances. Most of the exposures are of hard beds of the Birch Lake and Ribstone Creek formations, and the contacts of successive formations are rarely seen. The positions of the boundary lines between the formations, as drawn on the map, are, therefore, mainly based on their calculated positions relative to the outcrops of the hard beds.

The name Pale beds was applied originally in southern Alberta to the top beds of the Belly River series; its use in the Wainwright-Vermilion area implies a correlation which has not yet been established, although the two groups of strata are lithologically similar and seem to occur at the same stratigraphic horizon. The use of the name Variegated beds is also objectionable on account of its descriptive nature. The two formations were not separated in the field and their names, in spite of various objections, have been retained because of their general use in the literature dealing with this area.

The Pale and Variegated beds in the Wainwright-Vermilion area probably belong to the Belly River series, but possibly represent only part of that series. The term Belly River series originated with Dawson<sup>1</sup> and was applied by him to strata exposed in southern Alberta, where he supposed the succession to be as follows:

Pierre shales  
Belly River series  
Lower dark shales

Dowling<sup>2</sup> has shown the succession to be as follows:

Marine shale (Montana)  
Pale beds (non-marine)  
Foremost beds (non-marine)  
Pakowki shale (marine)  
Milk River sandstone  
Marine shale (Colorado)

Dawson thought that the Pakowki shale was the same horizon as the Lower Marine shale (Colorado) and did not recognize the fact that the Milk River sandstone is under the Pakowki shale. However, since Dawson included the Milk River sandstone (Yellow beds) in the Belly River series, Dowling interpreted Dawson's Belly River series as including all strata below the top of the Pale beds and above the bottom of the Milk River sandstone.

The Milk River sandstone is provisionally correlated with the Eagle sandstone of Montana, which in part carries a marine fauna of Lower Pierre age. The Lea Park formation in the Wainwright-Vermilion area has been presumed to be of Lower Pierre age and hence the first marine transgression of the Montana sea in the south giving the Pakowki shales

<sup>1</sup> Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1882-3-4, p. 112 C.

<sup>2</sup> Dowling, D. B., "Southern Plains of Alberta", Geol. Surv., Can., Mem. 93, 1917.

may be, in part at least, equivalent to the Lea Park in the Wainwright-Vermilion area. Since the Pakowki formation has been included by Dowling in the Belly River series and the Lea Park is not included by Allan and Slipper<sup>1</sup> in the Belly River series it follows that there have been two distinct interpretations of the Belly River series in Alberta. It may be found advisable to restrict the Belly River in southern Alberta to the Pale and Foremost beds equivalent to the Judith River of Montana, but further field work is necessary to establish correlations between the section in southern Alberta and the section in the Wainwright-Vermilion area.

#### LEA PARK FORMATION

This formation, exposed only in the northeastern part of the Wainwright-Vermilion map-area, consists of shales and sandy shales in which *Baculites ovatus* Say is quite commonly found. It is undoubtedly marine and belongs to the Montana group. The thickness of this formation has been given by Slipper<sup>2</sup> as 700 feet and by Allan, who studied the North Saskatchewan River section, as considerably less. Since the Benton and Lea Park are both marine shales they are distinguishable only on the basis of fossils, which fact may account for the difference in the estimates of the thickness. From well records it would seem that the combined thickness of Lea Park and Benton is 1,500 to 1,600 feet.

#### RIBSTONE CREEK FORMATION

This formation was named from its outcrops on Ribstone creek in tps. 44 and 45, ranges 1 and 2, W. 4th mer. A typical section on sec. 31, tp. 44, range 1, is as follows:

	Feet
Grey shale.....	11
Soft yellow sand or sandstone, mostly fine grained and with some large concretions and thin layers of ironstone. Also some hard sandstone beds..	21
Light grey to light yellow sand.....	2
Hard sandstone.....	1
Grey and yellowish shale with marine fossils—Lea Park formation.....	42

The above section is only a small part of the Ribstone Creek formation, and, owing to the scarcity of outcrops and difficulties of correlation, no complete section could be compiled. The thickness and character of the whole formation can best be judged from drill-hole records. Hard sandstone beds form the majority of outcrops belonging to this formation and so nearly resemble the hard sandstone beds of the Birch Lake formation that the two have been frequently confused. It has now been definitely established that they are separated by a marine formation, certain hard layers of the Birch Lake formation being 210 to 240 feet higher stratigraphically than some hard sandstone beds of the Ribstone Creek formation. It seems probable also that this difference is greater in the south of the area studied than in the north, a fact which is accounted for by the thickening to the south of the Grizzly Bear marine member which separates them.

<sup>1</sup> Allan, J. A., and Slipper, S. E., Geol. Surv., Can., Sum. Rept., 1917, pt. C.

<sup>2</sup> Slipper, S. E., Geol. Surv., Can., Sum. Rept., 1917, pt. C, p. 8.

## GRIZZLY BEAR FORMATION

On the north bank of Battle river in sec. 4, tp. 46, range 3, W. 4th mer., the following section of the Grizzly Bear formation is exposed. It is the best section of this formation seen in the map-area.

	Feet
Black fissile shale.....	2
Covered.....	35
Shale, light grey when dry, dark when wet.....	22
Soft sand mixed with shale.....	12
Yellow shale.....	5
Soft yellow and greenish grey sand.....	16

There is considerable gypsum in thin flakes and crystals in this section. In a narrow zone in the yellow shale a pelecypod, *Tancredia americana*, was abundant, and in the soft yellow sand immediately under the shale a number of specimens of *Baculites ovatus* were collected.<sup>1</sup> The fossils conclusively demonstrate the marine origin of these shales.

About a mile west up Battle river from the above section, the 5-foot bed of yellow shale is again exposed and *Tancredia americana* occurs in some profusion. The section is as follows:

	Feet	Inches
Yellow shale with fossils.....	..	..
Grey sand.....	..	6
Concretionary sandstone band.....	..	6 to 8
Grey and yellow sand.....	14	..
Covered interval.....	..	..
Hard yellow sandstone forming a ledge in the river and probably having a thickness of about.....	8	..

The hard, yellow sandstone, 8 feet thick, is exposed 5 feet above the river level about 1 mile farther west. Since the Ribstone Creek formation is known elsewhere to contain a number of hard layers of sandstone it is possible that this 8-foot bed of sandstone should be included in that formation. However, no sharp division can be drawn between the two formations, since under marine conditions a sand was deposited as indicated by the stratum in which *Baculites ovatus* was found and there does not appear to be any break between this fossiliferous sand and the sandstones below that are included in the Ribstone Creek formation.

The 8-foot bed of hard sandstone rises above the river level to the west and the fall in the river is a few feet a mile, so that the rocks at this place must have a small easterly dip. To the east the dip is westerly, the Ribstone Creek beds being exposed high up on the river bank in ranges 1 and 2 on Ribstone creek. The Grizzly Bear beds in range 3 thus lie in a syncline and it is thought their total thickness may be nearly 100 feet. It is the writer's opinion that they thin to the northwest, since in the sections on North Saskatchewan river exposures of an apparently much-thinned marine shale hold the same position stratigraphically.

## BIRCH LAKE FORMATION

The type section for the Birch Lake formation is at Birch lake where hard sandstone beds of brownish and yellow colours are well exposed. In some places the sandstone contains considerable carbonaceous material

<sup>1</sup> Fossils identified by F. H. McLearn, Geol. Surv., Can.

represented by plant fragments, and toward the base of the formation there is an oyster bed as much as 3 feet thick in some places and almost entirely composed of oyster shells. On the north bank of Battle river, at Grattan No. 1 well, sec. 4, tp. 45, range 8, W. 4th mer., exposures of hard sandstone contain the following fossils:<sup>1</sup>

*Ostrea* sp.  
*Volsella* cf. *meeki* E. and S.  
*Anomia* sp.

These oyster beds were noted at other places, including the south-west corner of sec. 2, tp. 50, range 8, W. 4th mer.; sec. 1, tp. 46, range 5, W. 4th mer.; sec. 11, tp. 46, range 4, W. 4th mer.

From the second of these places *Ostrea subtrigonalis* E. and S., and from the third *O. subtrigonalis* and *O. patina* M. and H., were identified.

The oyster bed extends, apparently, over a wide area and is considered by the writer to be indicative of the change to brackish-water conditions following the marine transgression marked by Grizzly Bear shale deposition.

The Birch Lake formation contains some layers of hard sandstone which form the majority of the outcrops belonging to this formation and which for this reason and their persistence, with only slight alterations, over considerable distance, were used in determining the local structure.

#### VARIEGATED AND PALE BEDS

Although no division has been attempted here between the Pale and Variegated beds on account of the absence of a suitable dividing line there is some considerable difference in the lithology between the uppermost sediments of the Pale beds and the lowermost sediments of the Variegated beds. This difference is most evident in the colour, although the character of the sediments also differs. The most favourable sections in which to study these beds are near Hawkins along the Canadian National railway. From the character of the beds it is considered that these sections represent the Variegated beds rather than the Pale beds. A typical section, which includes only part of the total thickness, is as follows:

	Feet
Boulder clay.....	..
Light sandy shale.....	4
Dark and light grey shale.....	2.6
Dark shale.....	3
Clay ironstone band.....	1.4
Dark shale.....	4
Light grey sand.....	3
Yellowish shale.....	1.9
Sand, rusty colour.....	2
Light grey, sandy shale.....	4
Light-coloured sand.....	1
Dark grey shale.....	5
Sandy shale.....	8
Light yellow sand.....	1.4
Light yellow, sandy shale.....	1.5
Light yellow sand with carbonaceous material.....	1
Dark grey, carbonaceous shale.....	0.5
Chocolate brown shale with thin sand layers.....	5.5

<sup>1</sup> Fossils identified by F. H. McLearn, Geol. Surv., Can.

	Fee
Poorly defined coal seam.....	0.5
Chocolate shale.....	1.6
Grey, sandy shale with many plant fragments and small bits of coal.....	1.6
Yellow, non-bedded sand with thin laminae of carbonaceous material.....	2.7
Grey, sandy shale with coal fragments.....	4
Clay ironstone band.....	0.25
Dull grey shale.....	1.6
Light yellow, non-bedded sand with shale lenses.....	2.3
Shaly sand in thin layers.....	4.3
Light yellow, non-bedded sand.....	2.4

Below these beds—according to the writer's interpretation of other sections—there are 6 to 8 feet of sandy shales, below which there are beds almost entirely composed of sand, that belong to the Birch Lake formation.

Above the highest horizon of the foregoing section the beds become sandy, and it is believed that the very sandy soil of the country immediately east of Irma is due to the presence of these upper sandy beds near the surface. The same beds also form the sands exposed along the railway between Fabyan and the Battle River railway bridge. The coal seam noted in the above section outcrops in a number of places and by levelling it was found that the beds west of Hawkins have a gentle westerly dip. To the east of Hawkins, according to the elevations of the outcrops, the dip is more pronounced and easterly, so that it is believed the beds exposed in the railway-cuts near Hawkins belong to the Birch Lake formation, there lying in an anticline as shown on the map on the cross-section A-B. This interpretation of the structure supports the supposition that the country east of Irma is underlain by sandy strata of the same horizon as the sands which outcrop along the Canadian National railway between Fabyan and the Battle River bridge and that these beds belong to the Variegated beds.

## STRUCTURE

The regional structure of the Wainwright-Vermilion area has been presumed to be a terrace, that is, an area over which the beds are almost horizontal. In this area there is a slight departure from the horizontal, which gives a regional dip of a few feet a mile to the southwest and on which a number of minor folds are superimposed. The western edge of the supposed terrace structure lies outside the area studied and has been said to extend from Misty hills, south of Monitor, in a northwest direction, to west of the Viking gas field on the north. The eastern edge has not been defined and it is thought by Allan and Slipper that eastward the structure is monoclinical. If this be so, the supposed terrace structure is apparent only in the west and is represented only as a flattening of the dip east of the Alberta syncline.

Local structure can best be determined in this area by accurate levelling on known geological horizons. A line of accurate levels was carried from the Geodetic Survey precise level bench-mark on the Canadian National Railway bridge over Battle river, down Battle River valley to Buffalo coulée, and up Buffalo coulée to the Topographical Survey bench-mark on the northeast corner of sec. 36, tp. 47, range 9, W. 4th mer. In this

distance all outcrops whose stratigraphical position was known were levelled, with the result that Buffalo coulee was found to lie along the strike of the formations, whereas in a northeast and southwest direction the strata showed distinct undulations or small folds of an unsymmetrical nature, the eastern limb in those determined being steeper than the western limb. By this method of levelling three folds were found, one near Hawkins, one northeast of Fabyan, and one crossing Battle river near the corner of tps. 45 and 46, ranges 6 and 7, W. 4th mer.

#### HAWKINS FOLD

A section across the fold near Hawkins is represented on the map accompanying this report. As already stated in the discussion of the stratigraphy of the Pale and Variegated beds, this fold exposes Birch Lake sandstone along its axis, whereas on both flanks strata, considered to belong to the Pale and Variegated beds, occur. Grattan No. 1 well, on sec. 4, tp. 45, range 8, W. 4th mer., was drilled on the southwestern flank of the fold and "came in" as a gas well. Imperial No. 2 well on sec. 14, tp. 45, range 8, was drilled on the northeastern flank far down the dip of the fold and for this reason, it is believed, proved to be a dry hole. The crest of this fold is between the two wells and as Grattan No. 1 well gave gas without oil no reason exists for expecting oil to be present in this fold, although larger flows of gas than in Grattan No. 1 well might be obtained in wells drilled nearer the crest of the fold.

#### FABYAN FOLD

It is believed that a fold crosses Battle river northeast of Fabyan station. Results obtained by running lines of levels indicate that there are some variations both in the direction and amount of dip on township 45 along Battle river. Although the data are not all that could be desired the best interpretation indicates a fold with axis east of Imperial (Fabyan) No. 1 well on sec. 18, tp. 45, range 7. From Imperial (Fabyan) No. 1 well to Maple Leaf well on sec. 19, tp. 45, range 8, the dip is southwesterly. Imperial (Fabyan) No. 1 well has a capacity of about 10,000,000 cubic feet of gas a day. When the well is opened, oil, which accumulates when the well is closed, is first thrown out. The oil is followed by salt water until the accumulated supply of oil and water is exhausted. Any well drilled between Imperial No. 1 well and the crest of the fold may be expected to produce only gas, but if oil is present in the fold, it should be found farther down the flank of the fold than Imperial (Fabyan) No. 1 well. Maple Leaf No. 1 well is some distance down the dip from Imperial (Fabyan) No. 1 well and the chances of finding oil in commercial quantities in the oil horizon of Imperial No. 1 well depend: (1) on the presence of a quantity of oil in the fold; and (2) on the location being far enough up the dip to avoid the water which is likely to occur down the dip from the oil. Maple Leaf well No. 1 "came in" at a depth of 1,705 and 1,720 feet with a gas capacity of 2,500,000 cubic feet a day under a closed pressure of 700 pounds. Below this gas sand an oil sand is said to have been

penetrated, but has not been tested. The Maple Leaf well is not deep enough to reach the horizon that yields the heavy gas flow of Imperial (Fabyan) No. 1 well, below which the heavy oil in that well was encountered.

#### FOLD NEAR CORNER OF TOWNSHIPS 45 AND 46, RANGES 6 AND 7

Accurate levelling along Battle river on hard beds of the Birch Lake formation indicates that the strata dip southwest at the rate of a few feet to the mile on the western flank of the fold, and dip about 40 feet in half a mile on the eastern flank. The crest of the fold is rather flat, with the axis extending southeast-northwest. It is on this fold that British Petroleum's Nos. 1, 2, 4, and 5 wells are located. Nos. 2 and 4 wells are oil wells; No. 1 well contained shows of oil and considerable gas, but has been drowned out by a water sand; No. 5 well is now ready to "spud in".

#### OTHER FOLDS LOCATED BY RECONNAISSANCE STUDY

Outside the area in which accurate levelling was done, a number of folds were located, but their extent is not known. It is believed that an anticlinal fold exists between the mouth of Buffalo coulee and the mouth of Grizzly Bear coulee on Battle river, but as far as present data indicate, this fold is in the nature of a broad upwarp rather than a sharp anticline. The data on which this belief is based are as follows:

(1) An outcrop of Birch Lake sandstone at an elevation of approximately 2,100 feet on the Vermilion-Wainwright trail on the north side of Battle river near the line between tps. 46 and 47, range 6, W. 4th mer.

(2) An outcrop of Birch Lake sandstone in a quarry on Mr. Patterson's farm, N.W. sec. 24, tp. 47, range 6, W. 4th mer., at an elevation of approximately 2,150 feet.

(3) An outcrop of Ribstone Creek sandstone on Battle river near the mouth of Grizzly Bear coulee at an elevation of approximately 1,850 feet.

Thus between outcrops Nos. 1 and 2 there is a southwest dip of about 50 feet, and between outcrops Nos. 2 and 3 there is a northeast dip of about 70 feet. In this last calculation it is considered that the Ribstone Creek hard sandstone beds are separated from the hard sandstones of the Birch Lake formation by 230 feet. These elevations indicate a fold. This fold may extend northwest, for at Cummings school, S.E. sec. 10, tp. 48, range 7, W. 4th mer., hard beds of sandstone are reported to have been penetrated in a well drilled for water, the beds being found 10 feet below the surface or at an approximate elevation of 2,090 feet. These beds are considered to be Birch Lake sandstones, and if they belong to the same horizon as those that outcrop to the southwest on Buffalo coulee, a southwest dip of 60 feet in 6 or 7 miles is indicated. There are no outcrops to the northeast of Cummings which could serve to indicate the dip from Cummings northeastwards.

On Battle river, in range 3, there are exposures of Grizzly Bear shale lying in the axial part of a syncline with outcrops of Ribstone Creek sand-

stones at higher elevations on the limbs of the fold, as shown on the map. On the east side of the syncline the dip is sufficient to cause the strata to rise quickly to the east and it is almost certain that this dip continues nearly to the Alberta-Saskatchewan boundary. No geological work has been done east of the boundary in this area, but the regional dip is likely to be southeast, as is indicated by the results obtained by J. A. Allan<sup>1</sup> from his traverse of North Saskatchewan river east of the boundary. If, east of the boundary, the dip is in the same direction on Battle river as it is on North Saskatchewan river then it follows that an anticlinal axis lies somewhere near the Alberta-Saskatchewan boundary east of the syncline on Battle river, in range 3, west 4th mer. On the farm of Mr. Gartner, in N.W. sec. 24, tp. 46, range 1, W. 4th mer., in drilling for water in 1923 a flow of gas was struck at a depth of 290 feet. The gas has now been shut off by a half-inch pipe in order to secure water from a lower depth, but during the winter of 1923-24 sufficient gas was produced to supply Mr. Gartner with fuel. The flow of gas from this shallow well may have some significance in relation to the possible structure outlined above. The productive horizon of the Fabian area lies in this vicinity at a depth of from 1,700 to 1,800 feet and, if further investigations should indicate the existence of an anticlinal structure, drilling for oil and gas would be worth considering.

A fold, though possibly of only minor proportions, appears to be present on Vermilion river near the mouth of Deer creek. Outcrops of Ribstone Creek sandstone occur on the east bank of the river on the south of sec. 3, tp. 52, range 4, and on the east side of sec. 12, tp. 52, range 4, apparently at nearly the same elevation, but intervening outcrops of the same horizons appeared at a somewhat higher elevation than either of these. More field work with accurate levels is necessary before the structure can be properly outlined, but it may be of some significance that the fold apparently indicated here is on the strike in a northwest direction of the anticline that is presumed to exist on Battle river near the Saskatchewan boundary.

#### STRUCTURE AT BIRCH LAKE

The details of the structure near Birch lake have not been determined, but the writer wishes to draw attention to an error in interpretation in an earlier<sup>2</sup> report which may be responsible for much misunderstanding regarding this area. It was stated that "on Vermilion river, 3 miles below the mouth of Birch creek, there is an exposure of 40 feet of similar soft yellow sandstone (as on the north end of Birch lake) with large nodules or concretions of ferruginous sandstone throughout, but still doubtless belonging to the same band as that seen on Birch lake. As these two places differ in altitude 300 feet and are 15 miles apart the dip of the rocks is shown to be 20 feet to the mile to the east". The present writer is of the opinion that the rocks on Birch lake belong to the Birch Lake formation, whereas those on Vermilion river are considered to belong to the Ribstone Creek formation. Also, the Birch Lake outcrops are approximately 150

<sup>1</sup> Allan, J. A., Geol. Surv., Can., Sum. Rept., 1917, pt. C, pp. 9-13.  
<sup>2</sup> Tyrrell, J. B., Geol. Surv., Can., Ann. Rept., 1886, vol. II, p. 99 E.

feet higher than those on Vermilion river, instead of 300 feet as quoted. The stratigraphic difference between the outcrops of Birch Lake sandstone at Birch lake and the Ribstone Creek outcrops on Vermilion river is thought to be about 200 feet. The Ribstone Creek beds on Vermilion river outcrop at an elevation of approximately 1,960 feet and the elevation of Birch lake is 2,107 feet. From this it is manifest the dip is southwesterly instead of easterly as formerly thought and at the rate of about 50 feet in 15 miles. There is another outcrop of Birch Lake sandstone on Vermilion river west of Chailey at an approximate elevation of 2,150 feet. By using these three outcrops as the points of a triangle the amount of dip is calculated to be 45 feet in 12 miles and the direction south 65 degrees west. This result indicates that no anticlinal structure with an east and west axis exists at Birch lake as has generally been assumed.

The Talpey-Arnold well was drilled on the west side of Birch lake, and hard beds, believed to belong to the Birch Lake formation, were encountered at a depth of 112 feet, or at an elevation of 2,120 feet. This indicates that the southwesterly dip is continuous across Birch lake and there is no structure at the Talpey-Arnold well, at least in an east-west direction, which would be expected to cause any accumulation of oil and gas at that point. Only minor flows of gas and small showings of oil were encountered in the Talpey-Arnold well, but these are sufficient to indicate possibilities for oil and gas in this region if suitable structures can be located. Before a definite pronouncement regarding the nature of the structure in this area can be made more field work is necessary, as the structure in a north-south direction across Birch lake is unknown. To the west the Viking gas field is evidently located on an anticlinal fold on the western edge of the regional terrace structure. It is thought that between the Viking gas field and the Talpey-Arnold well a syncline is present, although the data on which this is based are rather meagre. There is, however, indication of easterly dips on the west side of the Viking gas field.

#### RELATION OF REGIONAL DRAINAGE PATTERN TO STRUCTURE

A glance at a map of the Wainwright-Vermilion area shows a drainage pattern that follows two main directions, the rivers and streams flowing mostly in a northeast or a southeast direction and, except for short distances, rarely in any other direction. It is unlikely that this pronounced stream pattern, which also characterizes surrounding areas, is a fortuitous occurrence, and it is probable that the southeast drainage is controlled by the alternation of soft and hard strata, since its direction corresponds to the regional strike of the formations. The northeast drainage lines are at right angles to the strike and the water flows against the regional dip. This being the case the northeastward-flowing streams are more irregular than the southeast drainage lines and there seems no reason to assume any structural control for drainage lines in a northeast direction.

The folds crossing Battle river at Hawkins, Fabyan, and in townships 45 and 46, ranges 6 and 7, have already been discussed. In the case of the Hawkins fold and the fold in townships 45 and 46, ranges 6 and 7, Battle river makes a decided southward bow with a less regular bow at the Fabyan

fold. It is believed that each of these bows in the river's course has been determined by the geological structure, the river tending to flow along the strike of the strata when it encounters a fold and again turning along the strike in an opposite direction as soon as it has passed over the main part of the fold, thus forming the bows. This connexion between bows in the river and the presence of folds may prove of considerable value in the search for further folds, although the conclusion that every large bend in the river is related to geological structure is not warranted, since the relationship depends on the river channel being preglacial in origin, as is discussed further under "Glacial Geology".

## ECONOMIC GEOLOGY

### *Wells Drilled in the Wainwright-Irma Area*

We location			Elevation	Company	Date drilled	Results
Range	Tp.	Sec.	Feet			
7	45	18	2,040.0	Imperial (Fabyan) No. 1.....	1921-23	Gas and oil
8	45	14	1,969.4	Imperial (Fabyan) No. 2.....	1923	Dry hole
8	45	4	1,942.3	Grattan No. 1.....	1914-5	Gas
7	45	36	2,187.1	British Petroleum No. 1.....	1922-3	Gas with oil showings
6	45	30	2,251.3	" No. 2.....	1923	Oil
6	45	29	2,304.3	" No. 3.....	1924	Showings of oil and gas
6	45	30	2,251.9	" No. 4.....	1924	Oil
6	45	31	2,320.3	" No. 5.....		Derrick erected
8	45	24	1,991.9	Maple Leaf No. 1.....	1924	Gas
8	45	24	1,937.3	" No. 2.....		Derrick erected
6	45	20	2,270.1	Western Consolidated No. 1.....	1924	Not complete
7	44	36	2,216.8	Wainwright Producers Syndicate...	1924	Not complete
6	45	22	.....	British Wainwright.....	.....	Derrick erected
9	45	28	2,252.1	Irma Oil Holdings.....	1924	Not complete

### RELATION OF OIL AND GAS ACCUMULATION TO STRUCTURE

Information obtained from the wells drilled in the vicinity of Wainwright and Fabyan renders it certain that the oil and gas are associated with anticlines or upwarps of the strata, and that little or no success is likely to attend wells drilled in synclines. In some fields lenticular sands produce accumulations of oil and gas similar to those produced by folds in other areas, but although the sands in the Wainwright area are in some degree lenticular any accumulations of oil and gas that have been found are definitely related to folds. It is known that British Petroleum Nos. 1, 2, 4, and 5 wells are located on an anticline and there seems no doubt that the oil in Nos. 2 and 4 wells is related to this folding. Should this be true No. 5 well ought to be an oil well if the sands that are productive in Nos. 2 and 4 wells are continuous and of the same character at No. 5 well as they are at Nos. 2 and 4. The width of the fold on which the British Petroleum wells are located is unknown because it is not known how far down the dip "edge" water will be encountered, but it would seem likely

from the presence of "bottom" water in No. 2 well that the width of the fold from which production of oil may be expected will not be large and may not be as much as one mile.

The probable presence of a fold northeast of Fabyan has already been indicated. The Imperial (Fabyan) No. 1 well is located on this supposed fold and is a gas well containing small quantities of oil. Any wells drilled east of this well nearer the crest of the fold may be expected to yield large quantities of gas with but little oil, whereas oil, if present in this fold, may be expected down the dip. Maple Leaf No. 1 well was drilled down the dip and, as now finished, has a daily capacity of 2,500,000 cubic feet of gas from a sand 1,705 to 1,720 feet in depth, but this is a higher horizon than the main gas flow of Imperial No. 1 well and still higher than the oil horizon in that well. It is possible that deeper drilling at the Maple Leaf location may yield oil, but it is also possible this location is too far down the dip, in which case only "edge" water will be found.

The cross-section A-B, reproduced on the accompanying map (No. 2058), shows the Hawkins fold and the positions of Grattan No. 1 and Imperial No. 2 wells with reference to the structure. Grattan No. 1 well is down the dip from the crest of the anticline and as it is a gas well it is unlikely that wells drilled nearer the crest will yield oil. If the writer's interpretation of this structure be correct, Imperial No. 2 well has been drilled in a syncline, which fact accounts for it being a dry hole. A study of the wells so far drilled in this area leads to the unavoidable conclusion that oil and gas occur in the anticlines, and that wells drilled off such structures are not likely to be successful. With this conclusion in mind an inquiry into the positions of other wells with respect to the structures would be valuable, but unfortunately, owing to the scarcity of outcrops, no definite statements can be made. A line of levels run along Buffalo coulee demonstrated that it followed the strike of the formation in a northwest and southeast direction. The anticlinal axes have undoubtedly much the same strike. If the axis of the fold at British Petroleum Nos. 1, 2, 4, and 5 wells be produced southeast it will pass near No. 3 British Petroleum, Western Consolidated, and British Wainwright locations. The writer has not enough data to show whether the fold extends sufficiently far to include all these locations.

If the axis of the Fabyan fold which yields such large quantities of gas at Imperial (Fabyan) well be produced southeast it will pass near Wainwright Producers Syndicate well on sec. 36, tp. 44, range 7. If the fold extends as far as this and if the sands are present and of the same character as near Fabyan, this well also should be a gas producer. The gas flow in the Wainwright Producers Syndicate may then be expected at depths between 1,880 and 1,900 feet and at 1,930 to 1,945 feet, this last horizon corresponding to that which yields the heavy flow of gas in the Imperial (Fabyan) No. 1 well.

How far the Hawkins fold extends in a northwest direction is unknown, owing to the lack of any outcrops in this direction, but if the fold does extend to the vicinity of Irma, the well of Irma Oil Holdings on sec. 28, tp. 45, range 9, should be on the western flank of the fold. The Grattan No. 1 well on the western flank of the fold gave a good flow of

gas, and the possibilities of the Irma Oil Holdings well, on the assumption that the fold extends so far, may be considered favourable for gas although the assumption of a northwest strike would bring the crest of the fold some distance east of the Irma Oil Holdings well. Since the Grattan No. 1 well is considerably down the dip on the western flank of the fold and gives only gas it is probable the fold contains little oil, but heavier gas flows may be expected in any wells drilled nearer the crest of the fold.

#### CHARACTER OF THE WAINWRIGHT OIL

The results of an analysis by the Fuel Testing Division, Mines Branch, of oil from No. 4 British Petroleums well, are as follows:

Specific gravity at 60° F.....	0.973
Degrees Baumé at 60° F.....	13.9

Distillation	Per cent	Sp. gr. at 60° F.
Water.....	7.4 (vol.)	.....
Up to 150° C. (Naphtha).....	.....	.....
150° C. to 300° C. (Illuminants).....	12.9 (vol.)	0.870
300° C. and up (Lubricants, etc.).....	68.2 (vol.)	0.897
Coke and residue oil.....	14.1 (wt.)	.....
Sulphur.....	1.98	.....

From this analysis it is evident that the oil as it comes from the well contains no gasoline. No cracking tests have been made in the Mines Branch laboratory to show what percentage of gasoline can be obtained or whether such a process would be practicable with this oil.

#### GLACIAL GEOLOGY

In Battle River valley, Vermilion River valley, and many places along North Saskatchewan River valley, glacial deposits are found as cut banks that are being eroded by these rivers, and rock outcrops occur at higher elevations on the valley sides. Obviously, the conclusion that these river valleys are, at least in part, preglacial, is quite justifiable, for the valleys must have been present in preglacial times to account for the deposition of glacial deposits in them. This also means that the postglacial drainage has in part been developed along preglacial valleys that were not obliterated by glacial debris.

One of the best sections of glacial material found on Battle river occurs in sec. 30, tp. 45, range 2, W. 4th mer., and is as follows, in descending order:

15 feet of boulder clay with granite and other boulders.

56 feet of stratified sands, clays, and gravels. Some of the layers are composed almost entirely of shale evidently derived from outcrops of Cretaceous shales that occur along this part of the river valley.

In the gravels are granite and gneiss pebbles up to 8 inches in diameter and many smaller quartzite pebbles. About 10 feet below the base of the boulder clay a band of sandy clay contains an abundance of freshwater shells belonging to the genera *Sphaerium* and *Valvata*.

Since boulder clay covers the section and since the stratified materials contain granite pebbles that must have been carried by the ice, it is evident that the stratified material is interglacial, or at least represents an interval between two advances of the ice-sheet, the first advance of which left no permanent evidence of boulder clay.

The top boulder clay contains granite pebbles that were derived probably from the Precambrian Shield to the east.

It has already been shown that the drainage in a southeast direction is in all likelihood structurally controlled, giving a trellis pattern to the drainage. Since a number of the valleys can be shown to be preglacial, it is probable that the structural control of the drainage is also preglacial, which would explain the close relationship between drainage and structure, as in the case of such minor folds as those crossing Battle river at Hawkins and at British Petroleum's location on tps. 45 and 46, ranges 6 and 7, where the river in each case makes a southward bow, evidently as a result of encountering a small fold.

## LOGS OF WELLS

### *Imperial<sup>1</sup> (Fabyan) No. 1 Well*

Elevation: 2,040 feet

Location: Sec. 18, tp. 45, range 7

Method of drilling: Standard rig

	Feet
Sand, light grey.....	0 to 30
Shale, dark grey, argillaceous with sand.....	30 to 100
Shale, light bluish grey, soft, plastic, with some small sandy streaks.....	100 to 130
As above, with hard sandstone bed.....	130 to 140
Sandstone, light grey, soft, with dark shale.....	140 to 150
Shale and soft sandstone, dark blue and light grey.....	150 to 160
Shale, light blue and light grey, greyish blue, with hard grey sandstone.....	160 to 170
Shale, light and dark blue, black and soft grey sand.....	170 to 180
Shale, blue, brown, and carbonaceous.....	180 to 190
Sandstone (5 feet thick), hard, light grey.....	190 to 200
Shale, soft, light bluish grey, plastic without grit.....	200 to 220
Shale, somewhat sandy, light grey, with few small coal fragments..	220 to 240
Shale, light bluish grey, soft, plastic.....	240 to 280
Shale as above with some grit.....	280 to 300
Shale, very light greyish blue, soft, plastic, no grit.....	300 to 340
Shale, as above, with one 18-inch hard sandstone bed.....	340 to 350
Shale, light greyish blue, plastic, tough.....	350 to 680
Shale, as above, with one sandy streak.....	680 to 700
Shale, greyish and brown iron-stained, soft, plastic, becoming sandy and thin, brownish hard sandstone layer at 715 feet. Showing of oil and gas at 710 feet.....	700 to 720
Shale, light greenish blue, soft, plastic.....	720 to 880
Shale, as above, small bits of coal.....	880 to 900
Shale, light greenish blue, soft, plastic.....	900 to 1,050
Shale, light blue and dark with fine-grained sandstone and pyrite crystals.....	1,050 to 1,060
Shale, light greenish blue, soft, plastic.....	1,060 to 1,240
Shale as above, in part brownish.....	1,240 to 1,260
Shale as above with hard sandstone streak. Small gas flow.....	1,260 to 1,300
Shale, blue to grey, plastic.....	1,300 to 1,600
Shale, plastic, with soft, white, fine-grained sand.....	1,600 to 1,620
Shale, dark greyish blue, soft. Show of oil and gas.....	1,620 to 1,640
Shale, light greenish blue.....	1,640 to 1,660

<sup>1</sup> Log supplied by Imperial Oil Co., Ltd.

	Feet
Shale, light greyish blue. Fair show of gas.....	1,660 to 1,680
Shale, dark greenish blue with some hard streaks.....	1,680 to 1,720
Shale, dark, sandy.....	1,720 to 1,726
Hard shell (may be an ironstone band).....	1,726 to 1,727
Shale, sandy—gas from 1,720 to 1,732 feet.....	1,727 to 1,732
Shale, blue.....	1,732 to 1,800
Shale, light greyish blue.....	1,800 to 1,830
Shale, as above, slightly calcareous.....	1,830 to 1,840
Shale, dark grey to blue, calcareous. Big flow of gas at 1,870 feet. Gave 10,000,000 cub. ft.....	1,840 to 1,870
Missing.....	1,880 to 1,884
Shale, light grey with stains of petroleum, slightly calcareous.....	1,884 to 1,887
Shale, grey, very hard, arenaceous and calcareous.....	1,887 to 1,889
Shale, light grey, soft, resembles talc, slightly calcareous. Heavy black oil at 1,892 feet.....	1,889 to 1,893
Limestone, hard, grey, thin streak with some dark shale.....	1,893 to 1,895
Sandstone very hard; dark grey and black to brown conglomerate.....	1,895 to 1,907
Sand, greyish brown, fine-grained, calcareous.....	1,907 to 1,940
Shale, dark grey to blue, soft, arenaceous. Oil shows at 1,934 to 1,947 feet.....	1,940 to 1,950
Sand, brown, very fine.....	1,950 to 1,960
Shale, dark blue, hard, with some fine brown sand. Show of oil at 1,962 feet.....	1,960 to 1,970
Shale, light grey to blue, with a little sand and coal.....	1,970 to 1,980
Shale, as above, no coal.....	1,980 to 2,000
Shale, as above, little coal.....	2,000 to 2,010
Sand, greyish brown, some carbonaceous shale.....	2,010 to 2,060
Limestone, sandy, dark grey.....	2,060 to 2,070
Limestone, dark grey, considerable pyrite.....	2,070 to 2,080
As above, small coal fragments. Show of oil at 2,086 feet.....	2,080 to 2,100
Limestone, sandy, with pyrite.....	2,100 to 2,110
Shale, carbonaceous, with coal and pyrite.....	2,110 to 2,120
Shale, blue grey, hard.....	2,120 to 2,130
Shale, carbonaceous and calcareous.....	2,130 to 2,140
Shale, pale green.....	2,140 to 2,150
Shale, dark grey, calcareous.....	2,150 to 2,160
Limestone, grey.....	2,160 to 2,170
Limestone, light grey, and greenish grey shale.....	2,170 to 2,180
Limestone, brownish.....	2,180 to 2,190
Limestone, brown and grey. Show of oil at 2,198 and at 2,225 feet.....	2,190 to 2,320
Limestone, bluish.....	2,320 to 2,330
Limestone, blue grey.....	2,330 to 2,470
Sandstone, calcareous, fine-grained.....	2,470 to 2,480
Limestone, arenaceous.....	2,480 to 2,500
Limestone, brown.....	2,500 to 2,510
Limestone, arenaceous.....	2,510 to 2,530
Sandstone, calcareous.....	2,530 to 2,540
Limestone, arenaceous.....	2,540 to 2,550
Limestone, grey to brown.....	2,550 to 2,600
Limestone, sandy, pale yellow.....	2,600 to 2,630
Limestone, slightly arenaceous.....	2,630 to 2,640
Limestone, bluish.....	2,640 to 2,660
Limestone, brown.....	2,660 to 2,690
Limestone, brown, arenaceous.....	2,690 to 2,710
Limestone, blue grey.....	2,710 to 2,730

This well is now capped, the closed pressure being about 650 pounds a square inch. When the valve is opened a dark brown oil emulsion is shot into the air, followed by salt water. After a few minutes flow the well clears itself of oil and water and gives only gas. The well is thus a gas well and has a capacity of about 10,000,000 cubic feet a day. According to R. T. Elworthy, Mines Branch, Ottawa, this gas has no gasoline content. An analysis of the oil is published in Bulletin 616 A, Mines Branch, under the title "Natural Gas in Alberta", by R. T. Elworthy.

*Maple Leaf No. 1 Well<sup>1</sup>*

Elevation: 1,992 feet

Location: L.S.D. 1, sec. 24, tp. 45, range 8

Drilled by: Edmonton Gas and Development Company

Method of drilling: Rotary rig

	Feet	
Surface materials.....	0 to	10
Shale, blue and yellow.....	10 to	56
Sandstone, grey.....	56 to	59
Concretionary.....	59 to	70
Sand, grey.....	70 to	175
Sand, brown.....	175 to	190
Shale, brown and blue.....	190 to	240
Shale, slate coloured.....	240 to	260
Shale, grey.....	260 to	350
Ironstone band overlain by hard coal, slightly saline artesian water flow, with gas.....	350 to	352
Shale, slate coloured.....	352 to	364
Ironstone, with bits of coal.....	364 to	367
Shale, with sand lenses.....	367 to	530
Shale, slate coloured.....	530 to	592
Sandstone, grey.....	592 to	595
Shale, sandy.....	595 to	705
Shale, brown, sandy. Oil and gas showing at 708 feet.....	705 to	740
Shale, sandy, grey.....	740 to	764
Shale, slate coloured.....	764 to	775
Shale, sandy, grey, in part carbonaceous.....	775 to	970
Same as above. Gas shows.....	970 to	1,090
Shale, dark.....	1,090 to	1,135
Lime, brown. (May be ironstone band in part).....	1,135 to	1,145
Shale, dark. Gas at 1,257 feet.....	1,145 to	1,267
Shales, dark, with hard bands (ironstone).....	1,267 to	1,280
Shales, dark, with hard bands (ironstone). Gas at 1,287 feet.....	1,280 to	1,450
Shale, black, and gypsum.....	1,450 to	1,495
Ironstone band.....	1,495 to	1,500
Shale, sandy.....	1,500 to	1,504
Shale, slaty, with iron pyrites.....	1,504 to	1,611
Shale, slaty coloured, with thin hard bands (probably ironstone). Gas.....	1,611 to	1,635
Shale. Gas at 1,705 and 1,720 feet.....	1,635 to	1,750
Shale, with oil sand.....	1,750 to	1,776

*British Petroleum No. 1 Well<sup>2</sup>*

Elevation: 2,187 feet

Location: L.S. 1, sec. 36, tp. 45, range 7, W. 4th mer.

Drilled by: Edmonton Gas and Development Company

Method of drilling: Rotary rig

	Feet	
Surface material.....	1 to	32
Clay, blue.....	32 to	99
Sandstone, hard. (Represents part of Birch Lake sandstone).....	99 to	103
Water sand, hard packed, dark blue, giving over 150 bbls. water per day.....	103 to	150
Shale, grey.....	150 to	200
Sand, blue.....	200 to	205
Shale.....	205 to	275
Sandstone, hard.....	275 to	277
Water sand.....	277 to	282
Shales, hard, sandy, with streaks of hard sand.....	282 to	320
Shale, grey, sandy.....	320 to	380
Shale, hard, grey, sandy.....	380 to	400

<sup>1</sup> Log supplied by Edmonton Gas and Development Company and published by permission of Maple Leaf Oil Co.<sup>2</sup> Published by permission of British Petroleum Ltd., by whom the log was supplied.

	Feet
Shale, hard, sandy.....	400 to 403
Lime, light brown. (Probably ironstone band).....	403 to 410
Water sand, dark.....	410 to 415
Shale, hard, grey, sandy.....	415 to 430
Water sand.....	430 to 440
Shale, grey.....	440 to 570
Sand, light grey.....	570 to 583
Shale, light grey.....	583 to 650
Shale, grey, sandy.....	650 to 720
Shale, hard, coarse, sandy, grey.....	720 to 860
Shell, lime. (Probably ironstone band).....	860 to 861
Shale, hard, sandy, many hard streaks, pyrites.....	861 to 1,065
Lime, light brown. (Probably ironstone band).....	1,065 to 1,070
Shale, sandy grey, with hard streaks.....	1,070 to 1,095
Shale, grey, sandy.....	1,095 to 1,170
Shale, black.....	1,170 to 1,220
Shale, hard, sandy, with pyrites.....	1,220 to 1,260
Sand and shale, layers of.....	1,260 to 1,270
Same as above with hard streaks.....	1,270 to 1,380
Shale, dark grey.....	1,380 to 1,470
Shale, light grey.....	1,470 to 1,490
Shale, hard, black.....	1,490 to 1,500
Limestone. (Probably ironstone band).....	1,500 to 1,503
Shales, grey.....	1,503 to 1,550
Shale, brittle.....	1,550 to 1,600
Shales, sandy.....	1,600 to 1,620
Shale, hard, black.....	1,620 to 1,660
Shale and lime streaks. (Probably ironstone streaks).....	1,660 to 1,680
Limestone, hard, brown. (Probably ironstone).....	1,680 to 1,681
Sandy beds with gas.....	1,681 to 1,682
Limestone, hard, brown. (Probably ironstone).....	1,682 to 1,683
Sand and shale, good gas flow, probably about 3,000,000 cub. ft. a day.....	1,683 to 1,686
Limestone, very hard with pyrites. (Probably ironstone band).....	1,686 to 1,688
Shale with small hard streaks.....	1,688 to 1,745
Limestone, brown. (Probably ironstone band).....	1,745 to 1,747
Shale, bluish.....	1,747 to 1,765
Limestone, hard. (Probably ironstone band).....	1,765 to 1,767
Shale, black, carbonaceous.....	1,767 to 1,776
Limestone, hard. (Probably ironstone band). (Gives petroleum test with chloroform).....	1,776 to 1,777
Shale, black, carbonaceous—petroleum test.....	1,777 to 1,785
Shale, hard. Gas showings 1,745 to 1,786 feet.....	1,785 to 1,786
Shale, black, carbonaceous.....	1,786 to 1,795
Limestone. (Probably ironstone band).....	1,795 to 1,796
Shale, brittle. Gas.....	1,796 to 1,808
Limestone, hard. (Probably ironstone band).....	1,808 to 1,809
Shale, black. Gas.....	1,809 to 1,844
Limestone. (Probably ironstone band).....	1,844 to 1,846
Shale.....	1,846 to 1,883
Shale, with gypsum.....	1,883 to 1,905
Limestone, hard. (Probably ironstone band).....	1,905 to 1,907
Shale, light blue.....	1,907 to 1,928
Shale, with fine-grained sand. Oil showing.....	1,928 to 1,930
Shale, some sand.....	1,930 to 1,950
Conglomeratic bed, soft.....	1,950 to 1,952
Shale, soft, blue.....	1,952 to 1,960
Limestone, brown, with shale partings. (The limestone is probably ironstone bands).....	1,960 to 1,964
Same as above. Gas showings 1,890 to 1,975 feet.....	1,964 to 1,966
Shale, hard and gritty. Salt water.....	1,966 to 1,975
Sandstone, grey.....	1,975 to 1,980
Shale, hard, brown.....	1,980 to 1,990
Lime, blue.....	1,990 to 2,000
Shale, hard, showing tar material.....	2,000 to 2,010
Shale, tough, gummy, carrying about 6,000,000 cub. ft. gas.....	2,010 to 2,015
Lime, blue, black on top, very hard and gritty.....	2,015 to 2,017

NORZ. The bands called lime or limestone in this log are probably all ironstone bands. It was found that hard layers in British Petroleum No. 3 well were ironstone bands, although in some cases they superficially resembled limestone. In this area very little, if any, limestone is to be expected in the Cretaceous, to which age all the strata penetrated in this well belong. The ironstone bands give little or no effervescence when treated with an acid.

*British Petroleum No. 3 Well*

Elevation: 2,304.3 feet

Location: L.S. 4, sec. 29, tp. 45, range 6, W. 4th mer.

Method of drilling: Rotary rig with core barrel used for part of log

	Feet	
Surface material.....	0	to 130
Shale, dark grey.....	130	to 210
Sandstone, with hard layer on top.....	210	to 230
Shale, soft, grey.....	230	to 251
Sandstone, hard, grey.....	251	to 285
Shale, sand, grey.....	285	to 302
Shale, grey, sticky, sandy in part.....	302	to 343
Shale, grey.....	343	to 370
Shale, blue.....	370	to 383
Sandstone, hard, grey.....	383	to 386
Shale, coal fragments.....	386	to 412
Shale, grey, hard.....	412	to 479
Sandstone, hard.....	479	to 480
Shale, blue, soft.....	480	to 501
Limestone, hard. (Probably ironstone bands or sandstone)...	501	to 504
Shale, grey.....	504	to 507
Limestone, hard. (Probably ironstone bands).....	507	to 509
Shale, sandy, dark grey.....	509	to 580
Shale, grey, soft.....	580	to 588
Limestone, blue. (Probably ironstone).....	588	to 589
Shale, blue.....	589	to 624
Shale, blue, hard.....	624	to 784
Shale, grey, hard.....	784	to 897
Limestone, hard. (Probably ironstone band).....	897	to 898
Shale, grey, soft.....	898	to 997
Shale, blue.....	997	to 1,045
Shale, blue, hard.....	1,045	to 1,073
Limestone. (Probably ironstone band).....	1,073	to 1,074
Shale, grey, hard.....	1,074	to 1,189
Shale, sandy, grey.....	1,189	to 1,239
Shale, black, pyrite.....	1,239	to 1,277
Shale, black, hard streaks.....	1,277	to 1,300
Shale, black, sandy. Gas.....	1,300	to 1,352
Shale, black, soft.....	1,352	to 1,427
Shale, sandy, dark grey. Gas.....	1,427	to 1,481
Shale, black, hard and soft alternating.....	1,481	to 1,657
Shale, dark grey. Glauconitic sand, 1,800 to 1,804 feet.....	1,657	to 1,804
Limestone. (Probably ironstone band).....	1,804	to 1,804.5
Shale, black, sandy.....	1,804.5	to 1,820
Shale, sandy, with pyrite.....	1,820	to 1,836
Shale, black, hard.....	1,836	to 1,838
Limestone, hard. (Probably ironstone band).....	1,838	to 1,838.5
Shale, grey, hard.....	1,838.5	to 1,852
Lime, sandy, hard, grey.....	1,852	to 1,852.5
Shale, black.....	1,852.5	to 1,879
Lime, sandy, hard.....	1,879	to 1,879.5
Shale, black, soft.....	1,879.5	to 1,895
Sand, hard.....	1,895	to 1,896
Shale, black, hard.....	1,896	to 1,903
Shale, black, sandy.....	1,903	to 1,931
Sand, blue grey, hard.....	1,931	to 1,931.5
Shale, sandy, black.....	1,931.5	to 1,939
Sand, brown, soft, with shale partings. All saturated with oil.		
Gas.....	1,939	to 1,942
Shale, sandy, soft, brown, containing oil and gas.....	1,942	to 1,953
Sand, brown, soft, saturated with oil and gas.....	1,953	to 1,956
Shale, black, sandy layers.....	1,956	to 2,008
Lime, grey, soft. (Probably ironstone band).....	2,008	to 2,009
Shale, hard, dark.....	2,009	to 2,021
Lime, grey, very hard. (Probably ironstone band).....	2,021	to 2,022
Shale, black, hard.....	2,022	to 2,038.5
Lime, grey, hard. (Probably ironstone band).....	2,038.5	to 2,039.5
Shale, black.....	2,039.5	to 2,056

	Feet	
Sand, coarse, white, soft. Bentonite band.....	2,056	to 2,058
Shale, black.....	2,058	to 2,074
Sand, blue.....	2,074	to 2,075
Shale, black.....	2,075	to 2,085
Shale, with streaks of soft, brown sand impregnated with oil.		
Gas.....	2,085	to 2,093
Shale, black, hard.....	2,093	to 2,096
Lime, grey, hard, with pyrite. (Probably ironstone bands)...	2,096	to 2,096-5
Shale.....	2,096-5	to 2,098
Sand, soft, brown, impregnated with oil. Gas.....	2,098	to 2,106
Shale, sandy. Oil and gas.....	2,106	to 2,109
Sand, brown, soft. Oil and gas.....	2,109	to 2,111
Shale, brown, sandy.....	2,111	to 2,113
Shale, brown, sandy.....	2,113	to 2,118
Sand, showing oil.....	2,118	to 2,120
Sand, hard, showing oil.....	2,120	to 2,151
Sand, hard, shale partings.....	2,151	to 2,152
Shale, grey.....	2,152	to 2,155
Shale, grey, with some sandy streaks.....	2,155	to 2,157
Sand, hard, coarse.....	2,157	to 2,158
Shale, grey, sandy.....	2,158	to 2,160
Shale, grey, sticky.....	2,160	to 2,161
Sand, hard and coarse, grey.....	2,161	to 2,165
Sand, grey, with streaks of asphaltic material.....	2,165	to 2,166
Shale, brown, with streaks of asphaltic material.....	2,166	to 2,171
Shale, grey, sandy.....	2,171	to 2,178
Asphaltic material.....	2,178	to 2,183
Shale, grey, sandy, asphaltic material.....	2,183	to 2,188
Sand, hard, coarse.....	2,188	to 2,190
Sand, grey, with streaks of shale.....	2,190	to 2,200
Shale, grey.....	2,200	to 2,208
Coal.....	2,208	to 2,217
Shale, sticky, grey.....	2,217	to 2,222
Shale, black, with sand partings. Oil and gas.....	2,222	to 2,223-8
Lime. (A part of this was tested by the Borings Division, Geological Survey, showing it to be ironstone).....	2,223-8	to 2,224-8

NOTE. The glauconitic horizon at 1,800 to 1,904 feet in this well correlates with a similar horizon at 1,684 to 1,688 feet in No. 1 B.P. well and at about 1,705 feet in Maple Leaf No. 1 well.  
For further notes on this well between depths of 1,300 to 2,086 feet see report by E. D. Ingall, Borings Division.

### *Talpey-Arnold Well, Birch Lake*

Elevation: 14 feet above Birch lake or 2,121 feet

Location: Sec. 14, tp. 50, range 12, W. 4th mer.

Method of drilling: Standard rig

	Feet	
Clay.....	0	to 75
Shale, grey, sandy.....	82	to 112
Shell, hard.....	112	to 114
Shale, dark grey.....	114	to 123
Shell, hard.....	123	to 125
Shale, blue.....	125	to 200
Shale, brown.....	200	to 250
Sand.....	250	to 285
Shale, brown sand.....	285	to 350
Water.....		350
Shale, brown.....	350	to 400
Sand. Gas, 200,000 cub. ft.....	400	to 402
Shale, blue.....	402	to 430
Shale, blue.....	430	to 500
Sand, caving.....	500	to 505
Shale, grey.....	505	to 518
Shale, sandy, grey.....	518	to 548
Shale, sandy.....	548	to 560
Shale, sandy.....	560	to 575
Shell, hard.....	...	570

	Feet
Shale, blue.....	575 to 770
Shell, hard.....	764
Shale, brown.....	770 to 1,040
Shale, black.....	1,040 to 1,215
Shell, hard.....	1,215 to 1,235
Shale, black.....	1,235 to 1,305
Shell, hard.....	1,305 to 1,325
Shale.....	1,325 to 1,345
Shale.....	1,345 to 1,360
Shell, hard.....	1,355
Shale, black.....	1,360 to 1,420
Shale.....	1,420 to 1,440
Sand, hard.....	1,440 to 1,460
Shale, black.....	1,460 to 1,560
Shell, hard.....	1,560
Shale, sandy.....	1,560 to 1,620
Shale, black.....	1,620 to 1,660
Shale, caving.....	1,660 to 1,760
Shale, black.....	1,760 to 1,870
Shale, caving.....	1,870 to 2,000
Shale, hard.....	2,000 to 2,018
Gas, 500,000 cub. ft.....	2,018
Sand, brown.....	2,018 to 2,030
Sand, fine, grey, shale caving, show of oil.....	2,030 to 2,040
Sand, fine, grey, shale caving, show of oil.....	2,040 to 2,050
Sandstone, grey, coarse, showing of oil.....	2,050 to 2,070
Sandstone, fine, grey, finer than above.....	2,070 to 2,090
Sandstone, fine, grey, shale caving, also sandy shale.....	2,090 to 2,100
Sandstone, darker grey, fine.....	2,100 to 2,120
Sandstone, grey, brown shale, show of oil.....	2,120 to 2,140
Shell, hard.....	2,140 to 2,142
Sand, salt water in bottom.....	2,142 to 2,190
Shale, blue.....	2,190 to 2,208
Sand, with brown oil emulsion.....	2,208 to 2,215
Sand.....	2,215 to 2,240
Sand, very hard.....	2,240 to 2,250
Coal.....	2,250 to 2,254
Shell, lime.....	2,254 to 2,257
Sand, with salt water.....	2,257 to 2,268
Sand, showing oil and gas.....	2,268 to 2,272
Shell, hard.....	2,272 to 2,275
Sand, showing gas.....	2,275 to 2,285
Shale, sandy.....	2,285 to 2,290
Shell, lime, hard.....	2,290 to 2,292
Sand, showing oil and gas.....	2,292 to 2,298
Shale, containing coal.....	2,298 to 2,305
Shell, lime, hard.....	2,305 to 2,310
Shale, sandy.....	2,310 to 2,320
Shell, lime, hard.....	2,320 to 2,322
Sand, showing oil and gas, salt water and tar.....	2,322 to 2,335
Shell, hard.....	2,335 to 2,338
Shale, blue.....	2,338 to 2,359
Shell, hard, iron pyrite.....	2,359 to 2,365
Shale, brown, with coarse sand.....	2,365 to 2,367
Shale, black, sandy.....	2,367 to 2,385
Coal, very hard.....	2,385 to 2,388
Shale, black.....	2,388 to 2,395
Shell, hard, iron pyrite.....	2,395 to 2,401
Sand, hard, with gas.....	2,401 to 2,404
Sand, salt water.....	2,404 to 2,407
Shale, grey.....	2,407 to 2,411

# WAPAWEKKA AND DESCHAMBAULT LAKES AREA, SASKATCHEWAN

*By J. S. DeLury*

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## Illustration

Map 2078 (two parts). Wapawekka and Deschambault Lakes area, northern  
Saskatchewan.....In pocket.

## INTRODUCTION

During the summers of 1923 and 1924 the area embracing Wapawekka and Deschambault lakes, Saskatchewan, was studied and mapped. Therefore only a reconnaissance survey had been made by McInnes,<sup>1</sup> in 1910, of Pelican, Deschambault, Bigstone, and Limestone lakes and their intervening travel routes, and in 1909 of Wapawekka lake. The mineral resources of Wapawekka lake were investigated by Worcester<sup>2</sup> in 1921.

In the compilation of the map accompanying this report, surveys made by McInnes of much of the shoreline of Wapawekka lake and of Ballantyne bay were used, as well as his maps of Bigstone and Limestone lakes, and the intervening Grassberry river. To supplement the information obtained from the shores and islands of surveyed waterways, trips were made across country at intervals of about one mile. Rock outcrops, lakes, and other features met on these inland excursions were located by means of pace and compass measurements. The map-area embraces a region about 75 miles long from west to east and 25 miles from north to south.

Messrs. G. M. Brownell and J. E. Maynard, student assistants in both seasons, and Mr. C. A. Merritt, in the latter season, gave very efficient aid in carrying on the work of the survey. It is a pleasure, too, to acknowledge the many courtesies which were shown the party by Messrs. A. J. Jan and A. Neilson, of Pelican Narrows, by Mr. H. M. S. Cotter, of Cumberland House, and by Keeler Bros., who were prospecting in the district.

Wapawekka-Deschambault Lakes area lies in the northern part of the drainage basin of Saskatchewan river, approximately between 103° and 105° longitude and 54° 40' and 55° latitude. It is accessible from the

<sup>1</sup> McInnes, W., "Lac La Ronge District, Saskatchewan"; Geol. Surv., Can., Sum. Rept., 1909, pp. 151-157. "The Basins of Nelson and Churchill Rivers"; Geol. Surv., Can., Mem. 30.

<sup>2</sup> Worcester, W. G., "Reconnaissance Survey of Part of Northern Saskatchewan". Manuscript copy of unpublished report made to the Minister of Labour and Industries, Regina, Saskatchewan, 1921.

east by means of two canoe routes, both leading from Saskatchewan river, and from the west by another by way of Montreal river and La Ronge lake. Steamers ascend Saskatchewan river from The Pas, Manitoba, to Cumberland House on Cumberland lake, and to Sturgeon Landing on Sturgeon lake. The more direct canoe route leads through Cumberland lake and Grassberry river to Bigstone lake in the southeastern part of the map-area. A longer route begins at Sturgeon Landing, from which point the map-area is reached by ascending Sturgeon-weir river to Pelican lake. The Grassberry route is the poorer one during most seasons. Heavily loaded canoes have to be dragged over the stream bottom owing to the shallowness of the water. Though there are many objections to the Sturgeon-weir route, chiefly on account of its swift waters and greater length, it is regarded as the better means of access, owing to the abundance of water.

The country along these routes is very thinly peopled. Except for a few fishermen's summer quarters at the west end of Cumberland lake, there are no settlements or habitations on the Grassberry route. A few families of Indians live on Sturgeon-weir river between Beaver and Mirond lakes. The most important settlement near the district is Pelican Narrows, on Pelican lake, a few miles to the northeast of the map-area. Here are three trading posts, a Roman Catholic mission and school, and twenty or thirty families of Indians. There are also some small settlements on La Ronge lake.

The only inhabitants of the map-area are five or six families of Indians on Deschambault lake and two or three on Wapawekka lake. They appear to occupy their cabins for only part of the year. A few small potato patches on Deschambault and Pelican lakes demonstrate that hardy vegetables can be grown in the district. The chief food of the natives is fish, which is supplemented by game and the supplies obtained from traders in exchange for the winter's catch of fur.

Among the fur-bearing animals seen by members of the party, were brown and black bears, foxes, wolves, mink, and beaver. Other common varieties are trapped. There was a serious shortage of muskrats in this district and to the southeast of it during both seasons. Moose, deer, and caribou are scarce except in the central part of the area, near Oskikebuk lake, where they are probably less hunted. Small game was scarce during both field seasons. During the summer, pelicans and cormorants are very numerous on Deschambault lake. The large lakes are well stocked with pike, pickerel, lake trout, whitefish, etc.

The plant life is much like that of the Lake of the Woods country in Ontario, indicating similar temperature and moisture, though the growing season is much shorter in the north. The chief forest trees are spruce, aspen, jackpine, and birch. Small tamarack is found here and there in the swamps. About half of the land area has been invaded by forest fires within a time so recent that the later growth—chiefly aspens—is still small. Of the unburned area, a considerable part is not adapted to the growth of large trees, being occupied by muskeg swamps or bare rocks. No extensive tract of good timber was seen, though there are considerable areas untouched by recent fires, in which there are many small patches of

good timber, each a few acres in extent. These are separated by poor or barren areas, in general of greater extent. Many of these small patches show a thick growth of spruce trees with diameters between 10 and 20 inches. Large jackpine are common, but as a rule are widely scattered. Birches and aspens are less than 10 inches in diameter. By far the most promising forest growth is in the vicinity of Wapawekka hills (known locally as Bear hills) where there are considerable areas and long strips, commonly along the stream courses, of excellent spruce forest. Fires have made inroads into many of these in recent years. Some of the largest spruces are over 4 feet in diameter and unusually tall. Large areas on the flanks of the hills are occupied by light growths of small jackpine, and many large, undrained areas have nothing but swamp growths of small spruce. During their seasons, blueberries, raspberries, cranberries, and saskatoons may be gathered in many places.

The only waterpower of any considerable importance is that on Grand Rapids river. Here the waters of Deschambault lake debouch through a river 4 miles long into Pelican lake. The total fall is approximately 35 feet, distributed over most of the length of the river. The greater part of the fall, however, is in the upper stretches. Where the water leaves Deschambault lake there is a drop in a short distance of at least 13 feet. Considerable water is always flowing, but only some development calling for power in the immediate vicinity would justify its utilization. There is a descent of over 175 feet from Wapawekka lake to Deschambault lake, but the limited flow and the absence of a noteworthy fall along any single stretch do not offer promising conditions for power development.

## TOPOGRAPHICAL FEATURES

The map-area lies in the northern part of the Saskatchewan River drainage basin, a short distance to the south of the divide which separates it from the basin of Churchill river. A small southeastern part of the area drains rather directly into the Saskatchewan through Grassberry river, but the greater part drains into the same river by a more circuitous course through Pelican lake and Sturgeon-weir river. The district lies on the southwestern margin of the Canadian Shield.

The land surface of the different parts of the map-area is estimated to lie between a minimum of about 1,000 feet and a maximum of 1,900 feet above sea-level.

Precambrian rocks underlie the greater part of the area and this part shows the characteristic surface features of the Canadian Shield, namely, an abundance of lakes and a low general relief with a very rugged surface. Low, rounded hills and ridges of bare Precambrian rocks, or of rock covered by a thin mantle of soil and vegetation, alternate with shallow depressions in which the rocks are hidden by a varying thickness of glacial drift, by muskeg and swamp, and not uncommonly by lakes. Flat-lying limestones of Ordovician age underlie a small area in the southeastern part of the district. Here the surface is comparatively flat and even; depressions are shallow and lakes are few. Some parts of the limestone country, particularly near its margin, are drift-covered and poorly drained.

On the east and west sides of Bigstone and Limestone lakes, on Grassberry river, and on the east side of Ballantyne bay, beds of limestone rise in abrupt escarpments to heights between 20 and 50 feet. Similar escarpments are found elsewhere along the limestone margin, but more commonly there appears a series of step-like terraces, which occupy a wide band and are no doubt due to a well-developed bedding in the limestone. In such cases the margin of the formation is covered by surficial deposits, and it may be impossible to fix the boundary between limestone and Precambrian within an error of half a mile. This is especially true of the country west of Ballantyne bay, where swamps and other surficial deposits cover a belt several miles wide.

Flat-lying sandstones and shales of Cretaceous age occupy the southwestern part of the area. From Deschambault lake on the east and Wapawekka lake on the north, there is a gradual ascent of 200 to 300 feet to the base of Wapawekka hills, where there is a sharp rise to a plateau forming the top of the hills. The plateau is estimated to be about 600 feet above Wapawekka lake. It is deeply dissected by steep ravines along its margin. Probably most of this dissection followed closely the retreat of the Pleistocene ice-sheet. The hills are now heavily wooded and erosion is not rapid. The Cretaceous area differs notably from the other parts of the district in the absence of lakes; only a few small ponds are scattered over the surface.

The numerous lakes are of two general types: those occupying unfilled parts of swamps in drift-covered areas, and those with rock rims. The first-named lakes are numerous, but mostly small; they are found in Precambrian and Ordovician areas, and the few ponds found above the Cretaceous are of this type. All of the larger, and many of the smaller, lakes belong to the second class. They are in most cases irregular in outline and commonly have many islands. Almost all of the streams are interrupted by numerous rapids and falls. Where the streams are at all navigable for canoes, their courses and tributary lakes were surveyed. The streams which flow from Wapawekka hills are largely unnavigable, and access to the Cretaceous area is consequently difficult. The upper waters of Oskikebuk river may be ascended in a light canoe to a point several miles from the base of the hills, but this is accomplished only with great difficulty.

Deschambault lake has two outlets through which its waters are drained into Pelican lake. The greater part of the water runs through Grand Rapids river, but a small part is always trickling through a creek lying a little north of the main river and near the 10-chain and 6-chain portages between the two lakes.

## GEOLOGY

Rocks of Precambrian age outcrop prominently in all parts of the region except south of a line crossing the north ends of Bigstone and Limestone lakes and of Ballantyne bay, and also to the south of Wapawekka lake. In the former area these rocks are covered by flat-lying beds of Ordovician limestone, and the latter is occupied by undisturbed

Cretaceous sediments. These three major groups of rocks are so different lithologically that they offer no special difficulty in mapping, except in some cases where the margins of the Ordovician and Cretaceous beds are hidden by surficial deposits.

A large part of the area underlain by Precambrian and Ordovician rocks is occupied by lakes and ponds, and over the remaining part a great deal of the bedrock is hidden by glacial drift and muskeg. Though there are not many large areas in which the rock is entirely covered, outcrops are as a rule small and scarce. Probably not over one-tenth of the region shows good exposures of bedrock. The rocks available for study are mainly on the shores and islands of lakes, and on a few of the higher ridges and hills. Outcrops of Cretaceous rocks are rare. This formation is largely covered by a thick mantle of glacial drift. Only on the south shore of the west part of Wapawekka lake, where in a few places the sandstone forming the base of the Cretaceous rises in steep bluffs to heights of 40 to 50 feet, and in a few places along the cut-banks of streams, is it possible to view these rocks.

The Precambrian part of the region is occupied by a complexly inter-banded series of schists and gneisses. The schists appear most commonly as long and relatively narrow bands or lenticular areas surrounded by gneisses and, more rarely, massive granitoid rocks. The schists are most abundant in areas of lower relief and are, therefore, commonly covered. Their best exposures are on shores and islands. The Precambrian presents an almost endless variety of metamorphic rocks whose relations are not easily determined on account of their extreme metamorphism and because their contacts generally lie in valleys and depressions occupied by glacial drift, swamp, or lakes. Two major groups of Precambrian rocks are readily distinguished. One group includes the schists, which are typically fine in grain and dark in colour. The second major group includes mostly granitoid plutonic intrusives, which are in the main of coarse grain and gneissic structure. Most of these gneisses have an acid composition, are light in colour, and commonly show intrusive relations to the schists.

A detailed study of the schists indicates that some are deformed sediments, and that the others were surface volcanics. Both groups are now steeply tilted. A conglomerate member of the sedimentary schists is made up largely of fragments of the older volcanics, and it is presumed that the sediments formerly overlaid the volcanics. For purposes of description the schists are, therefore, divided into two groups; an older volcanic group, and a later one of sedimentary origin. There is no evidence of a great structural break and of plutonic intrusion between the times of formation of the two groups of schists.

The bulk of the gneisses and other plutonics of the region intrude the schists, but there is some ground for the conclusion that an older series is also present. In many places, and particularly near areas of schist, there is found a great variety of gneisses, which form comparatively small outcrops, were not found intruding the schists, and do not sufficiently resemble the other abundant intrusive gneisses to be related to them. These rocks are believed to be part of the floor on which the volcanics

rested. Boulders of many similar types of granitoid rocks appear in the conglomerate member of the sedimentary schists.

The more widely-occurring gneisses belong to relatively few types and are intrusive in the schists. These gneisses, as well as the schists, are intruded by massive acid granites and pegmatites, which are judged to be members of a separate batholithic intrusion, rather than later invasions of differentiates from the batholith which produced the gneisses.

The data available do not permit a subdivision of either the Ordovician or the Cretaceous formations, but point to an orderly sequence of deposition in each of the periods. The mantle rocks of the region are mainly the several types of glacial drift which were formed by the Pleistocene ice-sheets. Recent deposits are of little significance.

### *Table of Formations*

Quaternary	Recent	Swamp, river, and lake deposits. Clay, sand, gravel, and peat.
	Pleistocene	Glacial drift. Boulder clay, eskers, etc.
Mesozoic	Cretaceous	Shale and sandstone. Lignite and oil-shale.

### *Disconformity*

Paleozoic	Ordovician	Dolomitic limestone and basal sandstone of Trenton age.
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### *Great unconformity*

Precambrian		Massive granite, pegmatite dykes. Rarer gneissic varieties.
		<i>Igneous contact</i>
		Acid, intermediate, and a few basic plutonic intrusives. Mainly gneisses.
		<i>Igneous contact</i>
		Slates, biotite-schists with local development of meta-crysts of garnet, staurolite, cordierite, andalusite, and sillimanite, and a basal conglomerate. Sedimentary.
		Basic, intermediate, and acid schists and fine-grained gneisses of volcanic origin. Agglomerates (pyroclastic?).
		<i>Implied great unconformity</i>
		Gneissic, granitoid, and pegmatitic plutonic rocks of many types. Possibly older than the volcanic and sedimentary schists.

## GNEISSES, ETC., POSSIBLY OLDER THAN THE SCHISTS

This group includes a variety of gneissic and massive granitoid rocks which in no place were found to be intrusive into the schists. As contacts are commonly hidden, the failure to find intrusive relationships for these rocks is alone an insufficient basis for making a separate group of them. There are other grounds, however, for making such a group. In many places, and particularly near outcrops of volcanic schist, there is a diversity of granitoid rock types that differ lithologically from the typical gneisses which intrude the schists. They are as a rule in relatively small masses, and many different kinds outcrop together in small areas. A microscopic examination of a typical example of these gneisses shows that it had a history different from that of the supposedly later gneisses; it has been much more shattered and recrystallized. On the whole it and the associated gneisses are more metamorphosed than those gneissic and granitic rocks known to intrude the schists. Moreover, the conglomerate member of the sedimentary schists contains numerous boulders of granitoid rocks. This demonstrates that plutonic rocks were present somewhere in the region before the schists were deposited. Among the boulders in the conglomerate are some that strongly resemble the supposedly older gneisses.

The gneisses which, for the reasons given above, are thought possibly to be the oldest rocks in the map-area, are plutonic. The more common members are gneissic granites, pegmatites, and aplites. They are probably present in many localities, but were noted more particularly in three areas, one of which lies west of Tulabi lake and south of eastern Deschambault lake, one south of Piney lake, and another west of Sausage lake. In all three localities they are in close association with areas of schist, particularly with those of volcanic origin. Two types of gneiss will be described briefly; both occur in the first-mentioned area. These two rocks, among many others in the group, bear a striking resemblance to boulders in the conglomerate member of the group of sedimentary schists.

A greenish grey, very gneissic rock outcrops in a narrow band running north and south about midway between Tulabi lake and the southern part of Grand Rapids river. It shows in thin section: quartz (25 per cent), orthoclase (25 per cent), microcline (5 per cent), acid plagioclase (35 per cent), and biotite (10 per cent) partly altered to chlorite. Some of the quartz is secondary and the feldspars show considerable alteration to sericite and kaolinite. The rock has been much mashed. The constituent minerals are broken, and there is pronounced undulatory extinction in quartz and feldspars. The rock has been strengthened by recrystallization after its mashing, which is more pronounced than in any of the supposedly younger gneisses examined. A similar, though coarser, rock occurs a short distance south of Piney lake.

In an area 2 or 3 miles southwest of the outlet of Deschambault lake there are numerous small outcrops of pegmatite gneiss. This is a coarse, whitish weathering, very feldspathic pegmatite with a pronounced gneissic structure. This pegmatite weathers differently from the prevailing pegmatites of the region, which generally assume pink and red tints.

North of the eastern half of Wapawekka lake, particularly within a mile west of Sausage lake, there are outcrops of many varieties of gneiss which probably should be placed with the group of presumably older gneisses. Among these is a gneissic aplite very similar in appearance to boulders of aplite found in the conglomerate member of the schistose series.

#### SCHISTS AND GNEISSES OF VOLCANIC ORIGIN

This group is a series of schists and fine-grained gneisses mainly if not entirely volcanic. All have been subjected to intense metamorphism and their original structures and textures have been largely lost. That they are mainly of volcanic origin is suggested by their fineness of grain, their occurrence in bands resembling a succession of lava flows of different compositions, the appearance in one area of typical pillow structure, by residual textures such as characterize porphyries, and, finally, by the presence among them of volcanic agglomerates. Moreover, the mineral compositions of the various schists correspond to a series of lavas, including acid, basic, and intermediate varieties. Some members may be related rocks of intrusive character.

Though the schists as a whole are easily distinguished from the other rocks of the region, certain outcrops of volcanic schists resemble those of sedimentary origin, and members of the two schist families may resemble each other so closely that it is impossible to distinguish them with certainty. Textural criteria are of little value, for all have been more or less recrystallized. Mineral compositions, and in particular relative quantities of constituent minerals, are often characteristic of one group or the other. Probably the most useful single criterion for distinguishing the two types of schist in the more doubtful cases is the range of composition shown by plagioclase in any particular rock. Little secondary plagioclase has been developed during metamorphism and primary plagioclase should have a greater range of composition in an average sediment than in an igneous rock.

The volcanic schists show a difference of grain, which indicates that some were originally felsitic and others porphyritic in texture. All have been more or less recrystallized and exhibit a schistose or gneissic structure. Structural relations show that in general the basic lavas were laid down first. Acid and intermediate varieties are not so abundant; their field relations show that they largely followed the basic lavas and only exceptionally are interbedded with them. The basal conglomerate of the sedimentary series which, it is thought, overlies the lavas, was found at many places to rest on the more acid volcanic rocks, and it typically has a greater content of acid and intermediate than of basic volcanics.

The more basic members of the volcanic group are well exposed on many of the islands and on the shore of eastern Wapawekka lake, on the west and southeast arms of Deschambault lake, and along the eastern part of the northern boundary of the map-area. They are more commonly distributed throughout the district and are more abundant than acid varieties and members of the sedimentary group. In one locality, 3 miles

south of the middle of Brownell lake, a basic lava has retained a fairly distinct pillow structure. At several places on Wapawekka lake, notably on a point  $1\frac{1}{2}$  miles northeast of Signal point, and on one of the larger islands off the north shore opposite Russell bay, agglomerates of volcanic origin outcrop. They are basic and are interbedded with basic lavas. Basic schists with "augen" structures appear on several islands between the two localities last mentioned. These schists where weathered have pitted surfaces. The "augen" structures bear some resemblance to amygdaloidal structures, but the "eyes" are, probably, squeezed phenocrysts of plagioclase, which have altered to various mixtures of calcite, epidote, zoisite, and quartz. The "eyes" with abundant calcite weather out readily and leave a pitted surface on the rock. Among the commoner varieties of basic schist belonging to the series are fine-grained, silicified, and rather massive black rocks, greenish black felted hornblende schists of fine or medium grain, and some very coarse hornblende schists. The last named are commonly developed near the contacts with intrusive rocks, and the relatively coarse grain may be a result of intense contact metamorphism. Other outcrops of coarse hornblende schist may represent altered intrusives associated with the basic lavas.

The typical hornblende schists which are regarded as altered basalts are of one general type. They have 40 to 70 per cent hornblende. Besides accessories such as ilmenite, sphene, magnetite, and pyrite, the remainder of the rock is made up mainly of labradorite and its alteration products, calcite, zoisite, and epidote. Great variations are found from place to place in the extent to which the plagioclase of the schist has gone over into these minerals. At most places very little of the original plagioclase has escaped such alteration, but at others most of it is still fresh. The coarser and less abundant hornblende schists have the same mineral composition as the ones just described.

Schists derived from intermediate lavas are not so common. Bands of them are found on Wapawekka lake and on the northwest arm of Deschambault lake. They include many of the varieties that are most likely to be confused with schistose sediments. They are mostly dark grey or dark brown, the common colours of the sedimentary schists. There are indications of a fairly complete series from acid to basic lavas. The most apparent mineralogical change in the corresponding schists is that from prominent hornblende in basic members to biotite in the intermediate kinds. Biotite in turn gradually gives way to muscovite in the more acid schists.

One of the schists with intermediate composition is noteworthy. It is a member of a series of rock bands which are interpreted as being a succession of lava flows and which occur in eastern Wapawekka lake on the middle island of a group of three which almost bridge the lake opposite Russell bay. It is a dark grey rock with a texture that suggests a metamorphosed porphyry. It is highly schistose but has relicts of phenocrysts. Ferromagnesian minerals make up about one-third of the rock. Hornblende, biotite, and chlorite are present in the proportions of 3 : 2 : 1. Mashed labradorite crystals make up about 5 per cent and andesine in the matrix 30 per cent. Orthoclase and quartz in about equal quantity

form the bulk of the remainder of the schist. Calcite and zoisite are noteworthy secondary minerals and apatite and magnetite are accessory. The rock must have been largely recrystallized, for there is a marked parallelism of the ferromagnesian mineral grains.

Some schists which are believed to have been porphyritic acid lavas outcrop on the islands and on the north shore of eastern Wapawekka lake, particularly near Snake island. They have a structure which is best described as gneissic rather than schistose. A typical one, light grey in colour, is made up of, approximately, boitite (20 per cent), a little muscovite, quartz (30 per cent), and altered feldspar, mostly orthoclase (50 per cent). The feldspar is much changed to sericite and kaolin. There are relicts of mashed orthoclase phenocrysts.

The rocks of the series which are probably altered acid felsites, appear in the same Wapawekka area, also on the long portage from the east end of Wapawekka lake, and in many small outcrops in other parts of the region. They are light grey to pale red and have generally a more massive structure than the other schists. A common variety outcrops in a small bay on the north shore of Wapawekka lake, north of Snake island. It is a pale red, massive rock, fine in grain, and resembling a quartzite except for the presence of relatively coarse grains of quartz which resemble phenocrysts. In this section it is found to be composed of quartz (35 per cent), orthoclase (30 per cent), acid plagioclase (25 per cent), muscovite, and a little biotite. The feldspars are slightly sericitized. The larger grains of quartz have outlines that suggest that they were phenocrysts. The rock is no doubt a fine-grained quartz-porphyry, only slightly metamorphosed. Large blocks and many smaller rounded fragments of the same rock are found in the conglomerate member of the sedimentary schists.

The volcanic schists are followed by the schistose sediments without any great structural break. The schistose structures of the two schist groups are parallel, and the bedding, in both volcanics and sediments, is also roughly parallel. In eastern Wapawekka Lake district, where the relations between the two schist groups are best exposed, the dips are to the north at angles varying from almost vertical to as low as 45 degrees. The strikes are roughly parallel to the shore of Wapawekka lake.

#### SCHISTS OF SEDIMENTARY ORIGIN

The group of sedimentary schists includes a conglomerate member which is probably basal, a great variety of biotite schists, and a slate. They are younger than the volcanic schists, for the conglomerate is made up largely of boulders of volcanics and was found in structures that show that it was laid down on the volcanics. The biotite schists have lost all the original structures and textures of sedimentary rock. They vary little in appearance except in grain. The degree of coarseness of grain may be in part due to an inheritance of the grain of the original sediment, and in part to recrystallization. Normally, the schistose structure is highly developed; its strikes and dips are well defined and uniform for considerable distances. Twisted and contorted schists occur. Locally,

small and large metacrysts appear, giving the schist more or less pronounced, knotted and porphyroblastic textures. The slate member is so called on account of its highly developed cleavage and fine grain. Faint suggestions of bedding are found in the slate, but the conglomerate is the only member of the series that gives a definite clue to the attitude of the sedimentary beds. This member is everywhere steeply tilted and is roughly parallel to the bedding displayed by the volcanics.

The sedimentary schists are generally in close association with those of volcanic origin. Outcrops of the latter are more numerous, though it is probable that the sedimentary varieties are more common than might be supposed, for they are mostly in places of low relief, and, therefore, are largely hidden by drift, lakes, and swamps. The more prominent areas of the sedimentary schists are in and near the basin of eastern Deschambault lake, in a band crossing Deschambault channel, on the north shore of eastern Wapawekka lake, and in a belt traversing Brownell lake.

The conglomerate member was found in only a few, widely separated outcrops. Everywhere it has the same general appearance. The fragments which make up the bulk of the rock are generally well rounded and are plainly waterworn. The least resistant of them have been squeezed into thin sheets which in many cases wrap around the more resistant pebbles and boulders. As a rule the fragments vary in size from small pebbles to large boulders a foot or more in diameter. On the north shore of Wapawekka lake, huge blocks of a felsite are included. In all of the conglomerate outcrops, the greater number of fragments appear to have been derived from the volcanics. Other abundant boulders and pebbles are representative of plutonic rocks of many kinds, some of which are believed to have been derived from the supposedly older group of gneisses already described. The matrix of the conglomerate can not everywhere be distinguished from the squeezed fragments themselves. In general, the matrix resembles the typical biotite schist of the sedimentary schist series. Near the mouth of Hidden bay on Deschambault lake, and also on the north shore of Wapawekka lake near Snake island, the steeply-dipping conglomerate passes, in a direction away from the volcanics, into a rock which is coarser and more quartzose than the typical biotite schists. It has probably been derived from coarse clastic materials; examined in thin section it is found to contain large, mashed fragments of quartz adjacent to areas rich in hornblende. This rock is a transitional type from conglomerate to typical schist and was probably made up mainly of small fragments of many kinds of rock. On Brownell lake the conglomerate member of a tilted group of schists overlies schistose volcanics and changes upward into a staurolite schist containing boulders, and above this, farther across the strike, is a wide band of garnet and staurolite schist. On the north shore of Wapawekka lake, near Snake island, the conglomerate contains huge angular and subangular blocks, 20 feet or more in diameter, of a red rhyolite member of the volcanics.

Biotite schists are by far the most abundant rocks of the sedimentary group. They vary in grain from fine to coarse. The different mineral grains of the rock can generally be distinguished with the naked eye. In

many varieties biotite is the most conspicuous mineral in hand specimens, owing to the show that it makes along the cleavage planes of the schist. The rock is typically dark brown or greyish brown. Locally, there is a prominence of metacrysts. The common ones in approximate order of abundance are: garnet, staurolite, cordierite, andalusite, and sillimanite.

In the typical biotite schist, as well as in the matrix of porphyroblastic varieties, biotite makes up from 15 per cent to 40 per cent of the rock, most commonly about 25 per cent. Quartz occurs in amount between 15 per cent and 60 per cent, usually about 45 per cent. Feldspars vary inversely with quartz and make up the bulk of the remainder of the rock. Muscovite is common in small quantity and may make up as much as 10 per cent or more of the schist. Chlorite is also common in small amount, and occasionally it is abundant and biotite is absent. Common accessories are apatite and zircon. Tourmaline is rarer as grains. Magnetite and other iron oxides appear as grains and as irregular patches associated with biotite. Pyrite and pyrrhotite are not uncommon, but are generally in minute quantity. Ilmenite, sphene, and leucoxene are comparatively rare. The basic feldspars show partial or almost complete alterations to calcite, zoisite, and epidote, and the acid ones to sericite and kaolinite, but in some schists all feldspars are remarkably fresh.

Of the schists which show a development of metacrysts, the garnetiferous varieties occur most widely. Others show staurolite, and cordierite with included needles of sillimanite. Schists with andalusite occur in only one area. As contacts of plutonic intrusives are approached the development of metacrysts in the schist is generally more pronounced, but there are some exceptions to this rule and apparent proximity to contacts is not the sole determining factor in metacryst growth. Local factors may be original chemical and mineral composition, and the porosity of the rock. All the schists have been subjected to an intense dynamic metamorphism which has resulted in their prevailing schistose structure. Locally, contact metamorphism was produced in them by intrusions of plutonic masses.

The sediments are believed to have been made up of varying amounts of quartz, potash and soda-lime feldspars, rock fragments, ferromagnesian minerals, and probably argillaceous materials, with common accessories such as apatite, zircon, and iron oxides.

Biotite, muscovite, and chlorite were formed under dynamic metamorphic conditions. A pronounced schistosity was developed, and these minerals in nearly all cases show an orientation with this structure. The schistosity and the recrystallization of sedimentary materials to form micas seem to have no special connexion with igneous contacts, but are common in the sedimentary schists throughout the region. Marking a more pronounced metamorphism, is a widespread development of garnet crystals in the biotite schist. The crystals are rarely more than a quarter of an inch in diameter. They are especially numerous near igneous contacts, but they also appear at many other places. The garnets, some of which have good outlines and others poor, have numerous inclusions of angular and rounded grains of quartz. These are probably the same grains as the original sediment. Garnets are also commonly present in the schists

that hold staurolite and cordierite. Bands of schist rich in garnets are interbanded with others carrying staurolite, giving a suggestion that the original sediments varied somewhat in composition from bed to bed. Sillimanite needles appear as inclusions in cordierite and in quartz. Inclusions of quartz, probably grains of the original sediments, are numerous in most of the staurolite crystals.

In certain schists andalusite crystals are abundantly developed. Crystals of staurolite, cordierite, and andalusite are found intergrown. Andalusite is generally later than staurolite; crystals of the latter appear as inclusions in the former. Cordierite is in part earlier than, in part contemporaneous with, and also later than, andalusite. The andalusite schists occur in only one locality, west of Grand Rapids river. The slaty member of the sedimentary schist group is also found only in this locality. The slate, which is rich in alumina, is found near the andalusite rocks, which were formed, probably, from the slaty member. The andalusite crystals were disrupted at a later stage during which the schists containing them were contorted and more or less recrystallized.

In some schists, sillimanite occurs as small, needle-like inclusions in cordierite. It also occurs in large masses, commonly formed at the expense of andalusite, and also in long, blade-like crystals which are formed independently of earlier andalusite. The schists showing abundant sillimanite are exceptional. In them the sillimanite appears as columnar bladed masses, cylindrical in form with tapering ends, and in forms which show conclusively that the mineral is pseudomorphic after andalusite. These pseudomorphs and knots in some outcrops form as much as one-quarter of the mass of the schist. They are comparable to the andalusites in size, being 3 inches or more long and over 1 inch thick. In thin section the knots are found to be made up of both bladed sillimanite and the fibrous form known as fibrolite, together with thin sheets of biotite interspersed between the blades and some recrystallized quartz and secondary albite.

In some instances andalusite schist has been broken by rock movements, and recrystallization has followed with the development of such minerals as cordierite, sillimanite, and albite. The last mineral has many inclusions of schist materials, among them quartz, biotite, and andalusite. This recrystallization of albite and the appearance of tourmaline rods in the schist indicate that materials such as soda and boron were introduced. Andalusite is unstable at high temperatures and its transition to sillimanite indicates that the temperature was very high.

In some bands of mica schist on the east shore of eastern Deschambault lake, there is a prominent development of "eyes." The typical "eyes" are symmetrical, lenticular bodies half an inch or more in length and a quarter of an inch or more thick. They are fairly uniform in size and are distributed rather evenly throughout the schist, two or three appearing on each square inch of rock surface. Their long axes are parallel to the schistosity. The white "eyes" show very prominently against the background of dark brown schist and resemble squeezed pebbles of quartz. In thin section they are found to be composed of a mixture of quartz and cordierite, both containing numerous inclusions of sillimanite needles and

grading into the fibrolite variety of that mineral. The cordierite of the "eyes" is very unstable and shows alterations, in some instances almost complete, into a variety of materials. Some of the alteration products resemble sericite and chlorite. Others are almost white, grey, and brown materials, and still other products of cordierite alteration appear in thin section as isotropic areas with low relief and a clear yellow colour.

With increasing metamorphism, recrystallized quartz is more and more in evidence. The greater the metamorphism, the more difficult it is to detect the original quartz of the sediment. That some of it is primary even in advanced stages, is suggested by the numerous inclusions of angular and rounded quartz grains in such metacrysts as garnet, staurolite, cordierite, and andalusite. No definite secondary feldspar was observed in thin sections except some large crystals of albite which formed with, and perhaps at the expense of, andalusite, in the more intensely metamorphosed rocks. This secondary albite shows numerous inclusions of quartz and biotite.

The two chief factors that determined the kind and quantity of metacrysts were the degree of intensity of metamorphism and the composition of the original sediment. It is believed that materials were present in nearly all of the original sediments for the formation of all kinds of metacrysts. Intense contact metamorphism causes the development of metacrysts with relatively simple compositions, such as andalusite and sillimanite. Complex silicates such as garnet grow under less intense conditions where the solution and migration of material within the schist is not facilitated, and a metacryst such as garnet embodies in its mass much of the material of the schist that originally occupied the space of the developed crystal. Similarly, intense metamorphism favours solution and migration and makes possible a metacryst of simple composition such as andalusite.

The variations in abundance of the different metacrysts give some indication of the corresponding variations in composition of the original sediments. Garnet commonly makes up less than 5 per cent of the containing schist, but exceptionally amounts to 20 per cent. Staurolite is sparingly distributed through some rocks, but in others makes up about one-third of the mass; its abundance indicates an exceptionally high iron content in the original sediment. Andalusite is not widely distributed but is abundant in an area west of Grand Rapids river, where it commonly forms as much as 25 per cent of the schist. Sillimanite is also abundant in this area and is widely distributed elsewhere, but in relatively small quantity. The prominence of all of these metacrysts, and particularly of the latter two, indicates a high content of argillaceous material in the sediments from which they were formed. This is suggested also by the proximity of an area of slates to the schists, which are particularly rich in andalusite and sillimanite. Evidently in this area the sediments were fine grained and contained abundant alumina. Cordierite is also prominent in these rocks. Its similarity in thin section to quartz and feldspar, which are nearly always associated with it, makes its detection difficult, and estimates of its quantity of doubtful value. The cordierite is uncoloured and rarely gives a hint of its more characteristic properties, such as twinning and pleochroic haloes around zircon inclusions. The refractive indices of the cordierite

of this region are typically lower than those of quartz, but there is sufficient variation to make its detection difficult, even when the mineral is immersed in a series of refractive index oils.

The slate member of the sedimentary schists appears in only one locality, north of the Grand Rapids area of andalusite schist, near the 10-chain portage leading out of Deschambault lake. The slate is in a band about 300 or 400 feet wide and close to andalusite schist. The slate member appears to grade into andalusite schist both westerly across the strike of the rock and southerly along the strike. It may be a variety of the same type of rock which produced the porphyroblastic rocks of the vicinity. The slate is more remote from igneous intrusives than most of the latter rocks and seems to owe its character to dynamic rather than to contact effects. The slates are nearly vertical in attitude and strike about north. They are very fine grained and have a well-developed cleavage. There is a slight suggestion of bedding in them, due to bands of different colour, but as these bands are closely parallel to the rock cleavage, they may be the result of metamorphic influences. In colour the slates are dark grey to almost black. They are made up approximately of quartz (50 per cent), which is in very fine grains and resembles fragments of sedimentary origin, similar grains of feldspar (10 per cent), and varying quantities of chlorite, biotite, and sericite totalling about 30 per cent. There are some other very fine materials not easily diagnosed, among them opaque specks which are probably iron oxides. Many of the feldspar grains show alterations. Some of the slates have a spotted appearance due to the development of darker areas which commonly show crude hexagonal or long rectangular outlines on the cleavage faces of the rock. The spots have dimensions between half an inch and an inch and seem to have little depth across the cleavage of the rock. When the slate is examined in thin section, no great difference is apparent between the spotted area and the rest of the rock, except that a chloritic material is more evident in the spots. Mr. Geo. Brownell has made a chemical analysis of the material of the spots and of the adjacent slate. The results are tabulated below. To permit a better comparison of the two materials, the results are recalculated to a basis of 100 per cent, after eliminating losses on ignition. The spots show a marked segregation of alumina and magnesia and an increase of iron and potash as compared with the normal slate, and a corresponding lower amount of silica and soda.

	Material of spots in slate	Material of slate
SiO <sub>2</sub> .....	57.39	83.43
Al <sub>2</sub> O <sub>3</sub> .....	28.01	6.72
Fe oxides.....	6.12	4.48
CaO.....	1.02	0.98
MgO.....	4.23	1.50
Na <sub>2</sub> O.....	1.18	1.78
K <sub>2</sub> O.....	2.05	1.11
Total.....	100.00	100.00

## GNEISSES AND GRANITOID INTRUSIVES

This group includes a variety of gneisses which together occupy the greater part of the Precambrian part of the map-area. The group embraces all the intrusive rocks younger than the schists, except what appears to be a later granite and pegmatite. The gneisses are evidently parts of great batholithic intrusions which accompanied the folding and recrystallization into schists of the volcanics and sediments. They are typically gneissic in structure, but they grade in a few places into fairly massive granitoid types not easily distinguished in the field from the still younger intrusives. The gneisses vary considerably in composition from place to place. These variations probably resulted from a differentiation at depth before intrusion and possibly to a lesser extent from the assimilation of intruded rocks.

In some outcrops the gneissic structure appears to be trachitoid, but more commonly the structure is due to dynamic metamorphism suffered after solidification. Augen structures, fracturing of quartz and feldspar, bending of biotite grains and feldspar crystals, and pronounced undulatory extinctions are characteristic. The great bulk of the gneisses are fairly acid rocks, chiefly quartz monzonite and quartz diorite rocks with granitoid textures. In colour they vary from dark grey to light grey; pink and red tints are less common. The common and acid varieties show a mineral composition of quartz (20 per cent to 40 per cent), orthoclase (20 per cent to 40 per cent), andesine and oligoclase (10 per cent to 40 per cent), biotite (5 per cent to 20 per cent), hornblende (0 per cent to 5 per cent), and commonly a little primary muscovite. Apatite, magnetite, and zircon are common accessories. Sphene is rare. Little or no microcline is found in the bulk of the gneisses. The rocks vary somewhat in their alterations, some of which are magmatic and hydrothermal and others are the results of weathering. Among the secondary minerals is chlorite, which is exceptionally the most abundant ferromagnesian mineral in the gneiss. Sericite, kaolinite, zoisite, epidote, leucoxene, and iron oxides are common secondary minerals which vary in quantity in different outcrops.

A more basic gneiss is exposed prominently near the south end of Deschambault channel, farther west on the north shore of Ballantyne bay, and on the south side of eastern Wapawekka lake. It is believed to be a basic differentiate from the same magma that produced the acid gneisses. It appears to grade into the acid gneiss and to be a relatively small marginal part of the main body of intrusive gneiss. This basic gneiss varies in grain from medium to coarse and in colour from almost black to dark grey. Two specimens taken near the north shore of Ballantyne bay illustrate its variation in mineral composition. One of these shows, approximately, andesine (45 per cent), orthoclase (20 per cent), quartz (15 per cent), biotite (20 per cent), and accessory magnetite and apatite. The more basic of the two specimens shows labradorite (50 per cent), orthoclase (15 per cent), little or no quartz, hornblende (30 per cent), biotite (5 per cent), and accessories like those of the other rock. All gradations between these two varieties and between them and the acid

gneisses are found, and probably all are differentiates from the same magma. All common members of granitoid rock families from granite to gabbro appear among the gneisses.

In a large area south of the west arm of Deschambault lake, and in another area north of western Wapawekka lake, there are many outcrops of an acid gneiss that is essentially the same as the more typical gneiss, except that microcline appears in quantity varying from 5 per cent to 20 per cent of the rock. The gneiss, because of the microcline, appears similar to the younger granite yet to be described, but in other respects it resembles the widespread gneisses and is, therefore, placed with them. Basic hornblende gneisses, probably diorites and gabbros, are abundantly exposed north of the western part of the west arm of Deschambault lake. In this locality some gneisses appear to have intrusive relations to others and it is possible that some of the latter are members of the supposedly older group of intrusives, older than the schists.

Certain fairly massive granites occur on Tower island, Deschambault lake, and in its vicinity. These resemble the younger granite in structure, but they weather to light grey and white and not to pink and red, the prevailing tints of the younger granite. Mineralogically these granites resemble the acid gneisses and they are tentatively placed in that group. In the same general vicinity there are pegmatites, which similarly may be associated with the group of gneisses rather than with still later intrusives. Near the east end of Wapawekka lake, on the south shore, there is a massive red granite which is very similar in appearance to the younger granite.

At a few points on eastern Wapawekka lake and on Brownell lake massive dyke rocks outcrop. These dykes are probably between 20 and 50 feet wide in most places. They appear only in intrusive relationship with schists. This relation and their coarse porphyritic textures suggest that they were formed as deep hypabyssal intrusions, which were the forerunners of the main injections of gneiss, and that they are probably differentiates from the same magma. The dykes are in most cases associated with contacts of conglomerate and volcanic schist. These contacts evidently provided lines of weakness which determined the loci of the dykes. The dyke rocks are typically massive, but at some places have gneissic structure. There are two distinct kinds of dyke-rocks; one will be referred to as the hornblende dyke-rock, the other as the feldspar-porphyry dyke-rock.

The hornblende dyke-rock, as represented in an exposure near the portage from Wapawekka to Cliff lake, appears massive and is very coarse in grain. The bulk of the rock is made up of hornblende crystals which are stout and uniformly about a half inch long. These crystals are surrounded by a fine-grained matrix of epidote, zoisite, calcite, and biotite. Outcrops of the same rock occur on small islands and on the south shore of Wapawekka lake, immediately east of Snake island. In most of these outcrops there are signs of shattering and shearing as well as of a development of secondary minerals. Near the south shore in this locality the hornblende rock is completely altered to a soapstone, consisting of a mixture of talc,

chlorite, and other secondary micas, together with other minerals in lesser quantity, notably iron ochres. Pipestone is a local name for the eastern part of Wapawekka lake, due no doubt to the use of this rock by the natives for the manufacture of tobacco pipes. The increasing alteration shown by the hornblende rock as it approaches the level of the Cretaceous floor is very good evidence that the soapstone or pipestone was formed by ordinary weathering processes. This weathering took place at a time antedating the encroachment of the Cretaceous sea. The feldspar-porphry dyke-rock was found intruding the schists at two places: on the south shore of western Brownell lake where a dyke splits a conglomerate bed, and on the north shore of Wapawekka lake, east of Cliff lake, where it forms a little off-shore island and has an inclusion of conglomerate. In neither place could the width of the dykes be measured; they are probably about 50 feet wide. The rock is massive to slightly gneissic. Large, reddish-weathering feldspar crystals make up about one-quarter of the rock and are surrounded by a fine-grained, dark-coloured matrix. The phenocrysts are of labradorite and are uniformly about three-quarters of an inch long. The matrix consists of plagioclase (10 per cent), more sodic than the phenocrysts which have a well-defined zonal structure, orthoclase (10 per cent), quartz (10 per cent), hornblende (30 per cent), biotite (30 per cent), and a little accessory zircon.

#### LATER GRANITE AND PEGMATITE

This group includes massive acid granites and pegmatites which intrude not only the schists but also the previously described, widely spread gneisses. The group is not extensively exposed and outcrops are confined to the eastern part of the map-area near Deschambault lake. The larger outcrops of granite are confined to the extreme eastern part of this local area. Pegmatites appear farther west, but beyond the west side of Deschambault lake there are few traces of even these. The wide distribution of the pegmatites as compared with the massive granite suggests the presence of a subjacent batholith of this age underlying at least the eastern part of the map-area.

The pegmatites appear in dykes from 10 to 40 feet in width or even more. They intrude all other Precambrian formations, usually parallel to the schistosity of the enclosing rocks, but at some places they cut across this earlier structure. The minerals of the pegmatite are similar to those of the associated granite. The bulk of the dykes is made up of acid feldspar. Quartz, biotite, and muscovite vary greatly in their relative quantities, as well as in their total, as compared with the content of feldspar. Tourmaline is the most common accessory constituent of the pegmatite. It occurs in long, black prisms, some of which are over one inch in thickness. Magnetite occurs, but is much less common as an accessory.

The typical later granite is a massive rock with a variety of grain; fine, coarse, and medium. It commonly is pale pink or pale red, rarely white or grey. Gneissic structures are usually not apparent. The areas in which it outcrops are small as compared with those of the older gneisses. As in the case with the pegmatites, the intrusive masses of granite generally

conform with the schistosity of the rocks which they intrude, but in other places, as in the vicinity of Tulabi lake, the granite cuts across the strike. The typical granite shows an approximate mineral composition of quartz (25 per cent to 35 per cent), orthoclase (10 per cent to 25 per cent), microcline (15 per cent to 40 per cent), acid plagioclase (10 per cent to 15 per cent), biotite (5 per cent to 15 per cent), and a little muscovite; hornblende is wanting. Accessories are few and scarce as compared with those in the gneisses. Zircon is generally apparent and in biotite shows the characteristic haloes. A little apatite is also accessory, but practically no magnetite. Typically the rock is very fresh, though iron stains, kaolinite, and some sericite occur as alterations in feldspars. There is little evidence of fracturing in the minerals. Undulatory extinctions of quartz and feldspar, so pronounced in the older gneisses, are either not apparent or are very inconspicuous. In the granite other differences are noted in the comparative scarcity of accessory minerals and the abundance of microcline in the granite as compared with the older gneisses.

#### STRUCTURE

The Precambrian of the region is largely a complexly interbanded series of schists and gneisses in which the schists appear most commonly in long and relatively narrow bands, or small, lenticular areas, surrounded by intrusive plutonic rocks, mostly gneisses. At a few places the schists occupy wider areas, notably in the basin of eastern Deschambault lake and also south of Brownell lake. In following the gneisses across the prevailing strikes of the formations it is found that they vary greatly from place to place. The gneissic structures are in general closely parallel to those of the included and intruded schists. Not infrequently two different gneisses are found on opposite sides of a band of schist. The gneissic and schistose structures of all rocks are nearly everywhere parallel to the larger features, as represented by prominent bands of different formations and the contacts between them.

The prevailing strikes of the different bands of rocks and of their parallel gneissic and schistose structures are approximately east in the western half of the area. In the central part the strikes turn and assume in a comparatively short distance a southeasterly direction, and finally in the eastern area the bands and the same structures strike south. There are many local variations in strike. Dips also vary locally and the variation is great in a regional sense. The prevailing dip in the vicinity of Wapawekka lake is to the north at angles between 30 and 80 degrees, with an average of about 45 degrees. As the strikes change to the southeast in the central region, the prevailing dip is to the northeast. Dips become very nearly vertical as the eastern area is approached; here the rocks are either vertical or dip at high angles both to the east and west.

There is no evidence of any great geological break between the laying down of lavas and sediments. It is possible that the two groups of rocks are more or less interbedded. No intrusive rock can be said to intrude either the volcanic or the sedimentary group and not both. The two schist series

are involved in the same structures and are closely associated in their outcrops. Where contacts of the two formations can be observed, it is obvious that the conglomerate was laid down on volcanics. The original bedding structures of the two groups are roughly parallel.

Almost all the areas of gneiss include small bands and inclusions of schist, and many of the schist areas have small tongues of plutonic intrusives. The gneisses and schists show lit-par-lit injections at many places near their contacts. The relations of the principal bands of gneiss and schist when viewed in a regional way, correspond to interbanding on a large scale. The obvious conclusion from these structures and relations is that the gneiss intrusions accompanied a mountain-folding movement in which the overlying formations were squeezed into isoclinal folds. The major bodies of gneiss intruded the anticlines and smaller masses were injected into the synclinal parts of the folds. The present schist areas are the outcrops of synclinal remnants of old mountain ranges. The volcanics and sediments suffered a dynamic metamorphism from the mountain-folding movements and a contact metamorphism from the intrusion of gneisses.

In the vicinity of the basin of eastern Deschambault lake, particularly along the south shore, there are many signs of an east-west movement that produced drag-folding, local crumpling, and many sudden changes of strike and dip in the schists. The drag-folding indicates that the southern part of the country moved west relatively to the northern part. The relative abundance of schists to the north of this line suggests also that the southern part moved relatively upward. The eastern Deschambault basin, and especially the south shore, is no doubt a topographic expression of this disturbance. It is probable that this movement accompanied a crustal warping that was associated with the intrusion of the younger granite. This granite appears most abundantly in the vicinity of this zone of movement. Some bands of the granite and dykes of related pegmatite cut across old gneissic and schistose structures.

There is some evidence that the Precambrian rocks have suffered their deformations only at great depth. There is no evidence of any structure of shallow origin, except, of course, the earlier minor structures of volcanics and sediments. Faults, even of small size, are absent. Great movements and dislocations have taken place, but adjustments in the rocks were accomplished by bending, folding, and crumpling without breaking. Evidently the rocks were in the zone of flowage during their periods of deformation. The intrusive rocks are all of kinds that are formed at great depth. Though there is some fracturing of the minerals of the gneisses, the feldspars show a tendency to bend rather than to break. All these features indicate that there was a vast thickness of rock overlying the present known volcanics and sediments before the period of mountain-folding and intrusion. A long period of erosion was, therefore, necessary to subdue the old mountain ranges to the floor later occupied by an Ordovician sea.

## ORDOVICIAN

Formations of Ordovician age, consisting of limestone beds and a basal sandstone member, are confined to the southeastern part of the region. The northern margin of the beds is near the northern parts of Bigstone and Limestone lakes and of Ballantyne bay, and the formation is continuous except for one small outlier which is separated from the main area by Grassberry river. East of Ballantyne bay the Ordovician margin is fairly closely located, but west of the bay its position—owing to a wide covering of drift and swamp—can only be inferred. The relation of Ordovician and later Cretaceous beds to the west is obscure for the same reason. Ordovician beds are the only Palæozoic representatives in the region.

The best exposures of limestone appear in escarpments on the east and west sides of Bigstone and Limestone lakes and on some intervening stretches of Grassberry river. Another prominent escarpment, and the only one which shows the basal sandstone member, appears on the northeast shore of Ballantyne bay. A few low escarpments are exposed in the country inland from the larger lakes, but typically the margin is hidden under surficial deposits. Commonly the limestone rises above the covered margin to the north in a series of step-like terraces which no doubt correspond to its prominent bedding planes. Many of these terraces are covered to some extent by surface debris, and in places by swamps. At other places the escarpment is disrupted. Great blocks of limestone have been wedged away from the main body, by expansion of joint fissures, and lie tumbled over in all attitudes along the margins of escarpments.

The basal sandstone member was found in only one locality—on the northeast shore of Ballantyne bay. Here it underlies beds of limestone not far from outcrops of Precambrian gneiss. The thickness of the sandstone in this outcrop is about 15 feet, estimated from differences in levels of the limestone base and the adjacent Precambrian floor. The sandstone is particularly friable owing to the very small amount of cementing material. It consists almost entirely of pure white quartz sand, the larger grains of which are well rounded, the smaller angular to subangular. Its nature suggests a mature weathering of the underlying Precambrian rocks from which it was, probably, derived. This interpretation is supported by the highly weathered condition of the nearest Precambrian rock, which is a gneiss so highly kaolinized that it is easily crumbled in the hand, and is widely different in this respect from the fresh, glaciated gneiss a short distance to the north. No pronounced structures are apparent in the sandstone, except an horizontal bedding with a little variation in coarseness of grain from bed to bed. A close examination of the sandstone revealed no fossils. The probability is strong that the sandstone was at one time cemented and that the cement was removed by circulating waters, in which case any calcareous fossils that may have been present were probably removed by solution.

The Precambrian floor was maturely weathered and eroded before being invaded by the Ordovician sea. It no doubt had some irregularities,

so that it is reasonable to expect that the basal sandstone varies somewhat in thickness. Depressions in the floor would have greater thicknesses of sand laid down on them than would elevations. All escarpments save one have the basal member hidden, and the occurrences of sandstone can only be inferred from the abundant loose sands of similar nature that occur with the drift in the vicinity. In no place can the sand be of great thickness and the 15-foot section probably gives a good idea of the order of thickness of the bed.

The Ordovician limestone resembles the typical dolomites of similar age which are so well exposed to the east in many parts of Saskatchewan and Manitoba. The highest escarpments are only 40 or 50 feet above the adjacent Precambrian floor. The limestone is well bedded and the beds appear to be generally horizontal. Slight local dips are apparent, but there is nothing to indicate any uniform regional dip, except possibly in the attitude of the Precambrian floor. The floor of the Ordovician is about 30 feet or more lower on Bigstone than on Limestone lake, and at least 200 feet lower than the Cretaceous floor on Wapawekka lake, where there are no Ordovician beds. The dip of the floor is, therefore, of the grade of 4 or 5 feet to the mile in a southeasterly direction. Whether this dip is due in part to an upwarping of the western region or whether it is largely the initial dip of the floor, could not be ascertained. The occurrence of hills and ridges of fresh Precambrian rocks close to and higher than the base of Ordovician formations suggests that there are local irregularities in the floor or that it has considerable dip to the south.

The limestone has a well-developed bedding. The beds are commonly thin, most of them only a few inches, but some rather more, and a few are as much as 2 or 3 feet. The rock is typically solid and non-porous, except where post-glacial solution has pitted the surface. A crude mottling is commonly apparent. The colour varies from buff to yellow tints and is rarely almost white. The mottlings are yellowish brown. The limestone has been largely dolomitized and recrystallized. A fairly typical specimen shows a content of roughly 55 parts of calcium carbonate to 32 parts magnesium carbonate and 13 parts of ferruginous and argillaceous matter.

No well-preserved fossils were found in the limestones. At many points fair specimens of *Receptaculites oweni* are numerous. Poorly preserved fossils suggestive of compound corals, algæ, and stromatoporoids are common enough, but they are unsatisfactory as specimens. The presence of *Receptaculites oweni* is in itself fairly characteristic of Trenton age and this agrees with the interpretation<sup>1</sup> that has been made of fossils collected by McInnes on Ballantyne bay.

#### CRETACEOUS

Rocks of Cretaceous age occupy a single large area in the southwestern part of the region. They consist of horizontal beds of sandstone and shale. Near its margin the formation is thin and covered by glacial drift, so that at most places there is difficulty in defining its exact boundary. An escarpment of basal Cretaceous beds forms a considerable

<sup>1</sup> McInnes, Wm., "The Basins of Nelson and Churchill Rivers", Geol. Surv., Can., Mem. 30, p. 61, 1913.

stretch of the southeast shore of western Wapawekka lake. The shoreline here marks approximately the level of the Cretaceous floor. The central part of the Cretaceous area is occupied by the Wapawekka hills, which form a plateau about 600 feet above the level of Wapawekka lake. At some places the plateau ends abruptly in steep slopes with a descent of 200 to 300 feet. At others the margin of the plateau is dissected by steep valleys into sharp ridges and isolated peaks. These forms are, probably, the result of a rapid post-Glacial erosion. From the bases of the steep slopes of the hills, there is a gradual descent of 300 feet or more to Wapawekka lake on the north, to Precambrian areas lying to the northeast, and Ordovician to the east. The thickness of the formation accordingly varies from a few feet on the margin to 300 or 400 feet at the base of the hills and to a maximum estimated to be about 600 feet in the plateau area itself.

The Cretaceous area is largely forested and covered by varying thicknesses of glacial drift. Outcrops of its beds are, consequently, few. The only good exposures are on the shore of Wapawekka lake, and some others of very limited vertical extent in the cut-banks of creeks that traverse the area. The general information gathered from these scattered outcrops of different vertical horizons is to the effect that the Cretaceous beds are largely arenaceous in the lower half; that the higher they are the more argillaceous material they carry; and that the upper parts appearing only in and near the plateau area, are mainly argillaceous. No fossils were found in any of the outcrops, so that the ages of the beds can only be conjectured. It has been the custom in the northwest to correlate the basal Cretaceous sandstone provisionally with the Dakota formation. These sandstones, though appearing to form a continuous unit at the base of the Cretaceous, were formed at different times at different places. The higher beds exposed in this region, consisting mainly of shales, could probably be best correlated on lithological grounds with Niobrara and perhaps higher beds of western Manitoba and adjacent parts of Saskatchewan.

Owing to the wide drift-covered areas that occur along the Cretaceous margin, the relations between Ordovician and Cretaceous beds are nowhere apparent. It is presumed that the Ordovician beds extend far enough west of Ballantyne bay to be overlaid in a certain area by Cretaceous beds. The basal sandstone probably lies directly on Precambrian rocks in the western area, though in no place are the two formations found in contact. Outcrops of the two formations are closest together near Signal point, on the east side of western Wapawekka lake. Fresh Precambrian diorite gneiss forms the point, and about a half-mile south of it, at the water's edge, there is a flat-lying, brown, ferruginous sandstone. The Precambrian outcrop rises about 30 feet above the level of the lake, an elevation which suggests either a pronounced dip to the south of the base of the Cretaceous or a considerable local irregularity in the Precambrian floor. In this connexion it is probable, too, that Signal point lost some thickness of Precambrian rock during glaciation. The gneiss here is very fresh, though elsewhere in the district there is much evidence that the pre-Cretaceous floor was maturely weathered.

The brown sandstone on the shore south of Signal point is probably an outcrop of the basal bed of the Cretaceous. It resembles very much the bottom bed of the Ordovician (Winnipeg) sandstone which occurs on lake Winnipeg, hence the possibility of its being a remnant of Ordovician formation. However, the weight of evidence, based chiefly on location, places it more definitely with the Cretaceous. It is made up of rather coarse grains of quartz cemented by limonite, the cement forming about 20 per cent of the rock. The grains are well rounded and the lack of minerals other than quartz among the grains shows that mature weathering antedated the approach of Cretaceous seas.

Southwest of Signal point on Wapawekka lake, and about a mile or more northeast of the mouth of Muddy creek, there is a good exposure of some of the lower beds of Cretaceous sandstone. The rocks outcrop here in an escarpment, the base of which is concealed by a miscellaneous assortment of Precambrian boulders which have been shoved up on the shore by the ice of the lake. The cliff is 40 to 50 feet above the shore and shows in the lower part 30 to 40 feet of white quartz sandstone. Some crossbedding is made apparent by differences of grain in the sandstones. The rock is coarse to fine in texture and is made up exclusively of quartz sand. Most of this sandstone is snow-white. The quartz grains are exceptionally well rounded. The rounding of the grains, as well as the unusual purity of the sandstone, may be due to the reworking by waves and other erosional agents of an Ordovician basal sand which may have covered the area at one time. Landslips and other surface disturbances have spoiled the outcrops in this vicinity and have disguised the original structures. There are some signs in the tops of the cliffs of an overlying, grey, fine-grained, argillaceous sandstone and a still higher bed of darker grey calcareous sandstone. Crushing by Pleistocene ice-sheets has doubtless contributed to the disturbances of original structures on the faces of these outcrops. The hard white sandstone, with a crushing strength of from 6,000 to 7,000 pounds to the square inch, is traced laterally into loose sands of the same nature. It is almost certain that this lateral variation in the beds is due to crushing by ice and not to local cementation. There are many signs, too, of a reworking of the upper beds of these outcrops by fluvio-glacial agencies. McInnes mentions the occurrence of a thin seam of lignite in these sandstones. At the present time the lignite is hidden, but there are many signs of carbonaceous materials in the disrupted faces of the cliffs.

About a mile up Muddy creek from Wapawekka lake and in a cut bank of the stream, there is an outcrop of Cretaceous beds. The base of the section exposed here is estimated to be about 60 feet above the base of the Cretaceous formation. This outcrop exposes the following beds in succession from top to bottom:

	Feet
Loose sand.....	19
Friable grey sandstone.....	15
Interbedded yellow and grey sandstones with shale.....	5
Interbedded shale and sandstone.....	5
Interbedded yellow and grey sandstones.....	5
Grey sandstone with a thin seam of clay ironstone at the base.....	2
Crossbedded white and light grey sandstone.....	20

Another section of Cretaceous rocks is exposed on the creek east of Muddy creek. It is estimated to be about 200 feet above the level of Wapawekka lake and the base of the formation, and is about 3 miles south of the lake. Here are exposed 15 feet of soft, grey, Cretaceous sandstone with a covering of 20 feet or more of boulder clay.

On the headwaters of a branch of Oskikebuk river, which flows eastward from the north side of Wapawekka hills, and at an elevation of over 400 feet above Wapawekka lake, there is an exposure of shale 20 feet thick. It is a thin-bedded, very fine-grained, light grey shale, cemented into a hard rock, though containing no carbonates. On the face of the outcrop it weathers into thin, flat, angular fragments of the beds. Included in this shale are several thin and irregular bands, from 1 inch to 3 inches thick, of clay ironstone, which is partly weathered into limonite. In all the higher stream-beds fragments of similar shale and ironstone are prevalent, indicating that these are probably the prominent formations in the upper parts of the Cretaceous of the region.

Worcester<sup>1</sup> reports on a section which was exposed by excavating on the shore of Wapawekka lake in the summer of 1921. The section is described as showing, from top to bottom:

	Feet	Inches
Crossbedded yellow sandstone.....	8	0
White sandstone.....	14	0
Lignite.....	2	10
Sandy coal.....	0	6
Yellow sandstone.....	1	6
White sandstone.....	14	0
Talus-covered base.		

The same writer also describes a section which is probably on the same branch of Oskikebuk river as the one already mentioned, and is, therefore, about 400 feet above the base of the Cretaceous. This section is described as showing, from top to bottom:

	Feet
Fine, grey, flaky shale.....	8
Carbonaceous shale, black and sulphurous.....	15
Oil-shale (the bottom not exposed).....	5

#### PLEISTOCENE

On its northward retreat the ice-sheet left its usual deposit of drift. Along the limestone escarpment and the margin of the Cretaceous, sand is the most prominent constituent of surficial deposits. Elsewhere, boulders and boulder clay prevail. Most of the scattered boulders of the region correspond to members of neighbouring Precambrian formations. Limestone fragments similar to those of local Ordovician beds are found as far north as the south end of Pelican lake and as far west and north as Snake island on Wapawekka lake. Here and there throughout the district are more or less prominent eskers. The greatest known thicknesses of drift are on the northern slopes of Wapawekka hills to the shore of Wapawekka lake. In this locality boulder clay is commonly between 20 and 30 feet deep.

<sup>1</sup> Worcester, W. G., "Reconnaissance Survey of Part of Northern Saskatchewan". Manuscript copy of unpublished report made to the Minister of Labour and Industries, Regina, Saskatchewan, 1921.

Though the Pleistocene ice-sheets were no doubt the chief agents that gave the country its present topographic features, it is difficult to form any very definite conclusion regarding the thickness of rock removed from the region by the glaciers. The nature of the pre-Ordovician floor has a bearing on this problem. This floor is commonly regarded as having been a peneplain. In the wearing down of a country to a peneplain it is expected that underlying rocks will be deeply weathered. There is good evidence that the Precambrian rocks in the floor were maturely weathered. Close to the basal sandstone of the Ordovician on the northeast shore of Ballantyne bay, there is, as already mentioned, an outcrop of highly kaolinized granite gneiss, so much weathered that it is possible to crumble it in the hand. It is presumed that such a weathered floor was general throughout the region and that there was sufficient ice-erosion to remove all signs of weathering except where Precambrian rocks were protected by later sedimentary beds. Precambrian outcrops are conspicuously fresh except where they approach the margins of limestone beds in the eastern area of Cretaceous beds of the western area. On Wapawekka lake mature, pre-Cretaceous weathering is conspicuous in many places, but these are invariably in the most southerly outcrops. It is nevertheless very doubtful whether the pre-Ordovician and pre-Cretaceous floors were base-levelled to a stage comparable to the present Precambrian surface as it was left by the ice-sheets. It appears probable that considerable thicknesses of Precambrian rocks were removed by the ice from the northern part of the area.

The direction of ice-movement, as ascertained from measurements of numerous glacial striæ found in the region, was a few degrees west of south. In the vicinity of Deschambault lake the common direction indicated is south 14 degrees west. In the central area, near Brownell lake, the general direction is south 16 degrees west. Farther west, around Wapawekka lake, the direction is south 24 degrees west. There is, therefore, some evidence of a systematic variation across the district. It is probable that part of this variation is due to the proximity of Wapawekka hills, which appear to have slightly deflected the ice to either side of them.

#### RECENT

There are no signs of any prominent topographic changes subsequent to the retreat of the Pleistocene ice-sheets. Probably a little rapid erosion took place on the sides of Wapawekka hills immediately following the retreat of the ice and before the country was forested. The streams of most of the area follow rock-bottomed courses and erosion is not appreciable. Similarly there are no important river deposits. There is some evidence that Deschambault lake at one time had an elevation 20 or more feet above its present level. On the west side of Ballantyne bay there is a wave-cut shore showing 10 to 15 feet of loosely consolidated sands, which were evidently formed when the lake was at a higher level. The beds of sand are in broad, undulating waves. They show, at all depths, fragments of charcoal and other signs of vegetation, which suggest a recent, or at least post-Glacial age, for them. There is further evidence in the numerous, flat, covered areas surrounding Deschambault lake in this vicinity, that much

of the country was once under water. The conclusion that the lake was at one time higher was substantiated by the finding of pot-holes near the head of the falls at the outlet of Deschambault lake. The pot-holes are several feet above the present level of the lake and could have been formed only when the lake was at a considerably higher level. It is possible that the lake-level was changed by the wearing away of glacial debris which formerly kept it at a higher level.

The only other post-Glacial phenomena worthy of mention are the extensive development of ice-shoved boulder shores, the filling of swamp areas with peat and other organic deposits, and the general forestation of the region.

## ECONOMIC GEOLOGY

The Precambrian rocks of the region failed to show in their outcrops any noteworthy metalliferous deposits. Traces of chalcopyrite, pyrite, and pyrrhotite, in veinlets and small quartz stringers and disseminated through the rock, are found in schists and gneisses, usually near igneous contacts. The injection type of intrusion, which is the prevailing one for the gneisses of the region, is not regarded as being the most favourable kind for developing concentrations of ore-minerals. On this account the most favourable area for prospecting in the region is the one along the northern boundary of the eastern area, where the rocks are more massive than elsewhere. Gold is reported to occur in association with arsenopyrite in the vicinity of Neilson lake, north of the area under review. Traces of molybdenite are found outside of the district in contact-metamorphic rocks on an island north of the narrows in Pelican lake.

The lignite reported to occur in Cretaceous sandstone on the south shore of Wapawekka lake is now hidden under a considerable thickness of surface debris. It was investigated by McInnes and his description<sup>1</sup> is quoted:

"In the white quartz sands and sandstones, exposed in cliffs on the south shore of Wapawekka lake, a bed of lignite occurs, varying in thickness from 4 feet 1 inch (with a sandy 6-inch parting in the middle) to 2 feet 5 inches of fairly clean lignite. The seam lies about horizontal, and was traced in a longitudinal direction for a distance of  $3\frac{1}{4}$  miles, following the windings of the shore, thinning out westerly, or being represented by very dirty lignite or highly carbonaceous beds of sand; and not traceable farther easterly, owing to the higher encroachment of talus on the scarped face of the cliffs.

A proximate analysis, by fast coking, of a sample of this lignite, made by F. G. Wait of the Mines Branch, Department of Mines, gave the following results:

	Per cent
Moisture.....	11.23
Volatile combustible matter.....	30.97
Fixed carbon.....	34.80
Ash.....	23.00
	100.00

<sup>1</sup> McInnes, W., Geol. Surv., Can., Sum. Rept., 1909, p. 156.

The seam is at its best at the extreme southwesterly point of the bay, where it attains both its greatest thickness and greatest purity. North-eastward and northwestward along the shore it deteriorates both in size and purity; hence, there is a reasonable probability that in the country farther south, back from the lake, where it is not exposed, the seam may be better."

Worcester<sup>1</sup> sampled the oil-shale occurring in a section exposed on a tributary of Oskikebuk river, as already quoted in this report. The oil-shale is in the higher shales of the Cretaceous formation as exposed in the region and only the upper 5 feet of the oil-bearing member was available for sampling. Worcester supplies the results of an analysis of the shale, made in Saskatchewan University:

Oil per ton of shale.....	7½ gal.
Gas per ton of shale.....	1,893 cub. ft.
Ammonium sulphate per ton of shale.....	10½ lbs.

The purity of the quartz sand and sandstone found at the bases of Ordovician and Cretaceous formations, suggests the possibility of their use for the manufacture of glass or for other purposes which require pure silica. McInnes<sup>2</sup> reports an analysis made of some of the sand by H. A. Leverin of the Mines Branch, as follows:

Silica.....	98.60
Iron oxide and alumina.....	1.20
Other impurities.....	0.20
	<hr/> 100.00

This analysis was of loose sand at the base of the Cretaceous on Wapawekka lake. It is believed that the hard sandstone beds in the same vicinity are purer than the sample analysed. The basal sandstone of the Ordovician is not so free from impurities as that of the Cretaceous.

The dolomitic limestones of Ordovician areas and shales of Cretaceous formations offer no immediate possibilities of being used for structural or any other purposes, owing to their distances from any large market and the lack of a local demand. Peat does not appear to be present in noteworthy amount on the surface of the country and even if it is present in quantity, the time for its utilization is remote.

<sup>1</sup> Worcester, W. G., "Reconnaissance Survey of Part of Northern Saskatchewan". Manuscript copy of unpublished report made to the Minister of Labour and Industries, Regina, Sask., 1921.

<sup>2</sup> McInnes, Wm., Geol. Surv., Can., Sum. Rept., 1909, p. 157.

# GEOLOGY AND MINERAL DEPOSITS OF OISEAU RIVER MAP-AREA, MANITOBA

*By J. F. Wright*

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## INTRODUCTION

An area of Precambrian lavas and sediments along Oiseau valley has been known for over thirty years, but not until the autumn of 1920, when nickel-copper-bearing sulphides were discovered in these rocks about 3 miles west of Oiseau lake, did it attract attention as a prospecting area. Prospecting has been active each summer since the original discovery, and copper and nickel-bearing sulphides have been discovered at numerous points in an area extending from  $\frac{1}{2}$  to 3 miles north of Oiseau river and from Oiseau lake to the east end of lac du Bonnet, a distance of about 20 miles. A favourable feature of this prospecting area is its nearness to transportation and the sources of electrical power.

## LOCATION AND ACCESSIBILITY

The west side of Oiseau River map-area is 70 miles northeast of Winnipeg. The southern edge is about 90 miles north of the International Boundary; the Ontario boundary crosses the east end. Over half of the area mapped has been subdivided and includes the northern half of township 15, and townships 16 and 17 of ranges 13, 14, 15, 16, and 17 east of the principal meridian.

The map-area is a rectangle 30 miles east and west and 15 miles north and south and covers about 450 square miles. Any point in it is easily accessible from Winnipeg. The route is by Canadian Pacific railway to Lac du Bonnet, thence to Bird River settlement by motor boat,

and finally by canoe up Oiseau river to points in the northern half of the area. Localities in the southern half can be reached by the City of Winnipeg railway from Lac du Bonnet to Pointe du Bois, and thence up Winnipeg river by motor boat or canoe. Winnipeg river from Pointe du Bois to the Ontario boundary is navigable for small motor boats when the water is high.

#### BASE MAP, FIELD WORK, AND ACKNOWLEDGMENTS

The base map of Oiseau River map-area (No. 2059) has been compiled from subdivision plans and the Manitoba-Ontario boundary surveys by the Topographical Survey Branch of the Department of the Interior; from waterpower surveys of Winnipeg river by the Dominion Water Power Branch of the same Department; and from telemeter traverses by the writer in 1924. The mineral claim surveys are by H. G. Beresford, D.L.S. The geology has been compiled from closed pace and compass traverses made by the writer and assistants during three weeks of the field season of 1923 and from June 1 to October 1, 1924.

In order to make the geological map accompanying this report as useful as possible to prospectors and others visiting the area, an attempt has been made to indicate the positions of observed outcrops and drift-covered areas. The drift-covered areas (shown by black stipple over colour representing assumed underlying bedrock) are extended only one-eighth of a mile on each side of the traverse line. Beyond this the assumed bedrock is shown by the appropriate colour without stipple, although it may also be drift-covered. Bedrock is represented as being continuously exposed in the large granite areas and though this may not always be the case it holds true of many areas, as forest fires have completely burned the moss and trees and any remaining soil has been washed from the rock ridges into small, irregularly outlined depressions. In mapping, it is always necessary to generalize somewhat, and, therefore, there are included in the areas of outcrop along traverse lines some patches of drift too small to be conveniently shown on the map. However, with these exceptions, the geological map shows the position and extent of the observed outcrops.

The many courtesies extended the party by the local residents and others interested in the progress of the work are gratefully acknowledged. The field assistants, R. A. Shatford, Donald Brise, and Leonard Greer, completed the work assigned them in a satisfactory manner. The writer is especially indebted to the Manitoba Copper Company of the Wad Syndicate, and the Devlin Mining and Development Company, for the assay results and geological information kindly placed at his disposal.

#### GENERAL HISTORY

Oiseau River map-area was crossed by the early explorers of western Canada, for until 1886 Winnipeg river, in spite of navigation difficulties, formed a link in the main water route west from lake Superior to lake Winnipeg and the northwest. This route was discovered in 1689 and about 1800 Sir Alexander Mackenzie described the numerous falls and portages between lake of the Woods and lake Winnipeg.

The original inhabitants of the area were Cree Indians and until recently the Hudson's Bay Company had a trading post on Windigo island in lac du Bonnet. Active development of the natural resources of the area may be said to have commenced only about 1900, when the Winnipeg General Power Company began to plan a large hydroelectric development on Pinawa channel. The Winnipeg Electric Railway Company completed this development in 1906 and in 1908 the city of Winnipeg began the construction of a railway from Lac du Bonnet to Pointe du Bois. In 1911 their large power plant at Pointe du Bois and the transmission line to Winnipeg were completed<sup>1</sup> (Plate I).

The history of prospecting in Oiseau River map-area dates from 1895, when several prospectors from western Ontario visited the area. Information kindly supplied by Mr. J. C. Webber, mining recorder, Winnipeg, indicates that in 1897 there was considerable activity in the district and that a number of Winnipeg business men had organized the Lac du Bonnet Development and Manufacturing Company to develop a number of the prospects. The first prospectors were searching for gold and silver, and sunk a number of shallow pits and shafts, but evidently had no great success, for the area was soon abandoned. It was not until the autumn of 1920 that active prospecting was revived, and since that date the nickel and copper sulphide bodies have been discovered. The details of the history of the individual deposits are given in the section of this report dealing with the mineral prospects.

Pointe du Bois and Bird River are the only settlements and post offices in the map-area. About fifteen families live at Pointe du Bois and are employed in the maintenance of the City of Winnipeg Power Plant, Railway and Transmission line. A few small patches of clay that lie between the extensive rock outcrops are the only parts cultivated. From 1908 to 1916 some twenty families from Latvia settled along the valley flat of Oiseau river between its outlet into lac du Bonnet and the first falls about 5 miles upstream, and along the east and south shore of the lake. These thrifty people have cleared the best land bordering the river and lake and have built fairly comfortable homes from the timber. They farm and prospect in the summer months and trap or cut wood in the winter.

#### PREVIOUS GEOLOGICAL WORK AND BIBLIOGRAPHY

The area adjacent the west end of lac du Bonnet was first geologically explored in 1890 by J. B. Tyrrell who, following the custom of that time, called the sediments along Oiseau river Huronian. In 1912, E. S. Moore and R. C. Wallace geologically explored Oiseau river from its mouth to near its headwaters, in Ontario. In Moore's report the sediments were called Wanipigow series and were correlated with sediments found along Wanipigow and Manigotagan valleys from 25 to 50 miles to the north. Moore put the Wanipigow series, tentatively, in the Huronian. In 1916, R. C. Wallace examined Winnipeg river between Pointe du Bois and the Ontario boundary. In 1921, H. C. Cooke studied the geology and mineral

<sup>1</sup> Johnston, J. T., "Winnipeg River Power and Storage Investigations", Water Resources Paper No. 3, vol. 1, 1915, pp. 137-160.

deposits of a small area west of Oiseau lake, and in the same year E. M. Burwash studied the geology of the eastern end of the map-area in connexion with the Manitoba-Ontario boundary survey. From the above summary it will be seen that, previous to the commencement of the present investigation, geological information of Oiseau valley was based either upon reconnaissance traverses or studies of small local areas.

Following are the more important reports dealing with the geology of the map-area:

- Burwash, E. M.,—"The Pre-Cambrian of Western Patricia", *Jour. of Geol.*, vol. 30, 1922, pp. 397-400. "Geology of the Ontario-Manitoba Boundary from Winnipeg River to Bloodvein River", *Ontario Dept. of Mines*, vol. XXII, pt. II, 1923, pp. 1-48.
- Camsell, Charles,—"Geology of the Winnipeg River Basin", *Water Resources Paper No. 3*, vol. 1, 1915, pp. 341-346.
- Cooke, H. C.,—"Geology and Mineral Resources of Rice Lake and Oiseau River Areas, Manitoba", *Geol. Surv., Can., Sum. Rept.*, 1921, pt. C.
- Moore, E. S.,—"Region East of the South End of Lake Winnipeg", *Geol. Surv., Can., Sum. Rept.*, 1912, pp. 262-270.
- Tyrell, J. B., and Dowling, D. B.,—"East Shore of Lake Winnipeg and Adjacent Parts of Manitoba and Keewatin", *Geol. Surv., Can., Ann. Rept.*, vol. XI, pt. G, 1900, pp. 80-82 G.
- Wallace, R. C.,—"Area Between Red River and Eastern Boundary of Manitoba, and Between Winnipeg River and National Transcontinental Railway, Manitoba", *Geol. Surv., Can., Sum. Rept.*, 1916, pp. 175-178.
- Wright, J. F.,—"Oiseau and Maskwa Copper and Copper-nickel Deposits, southeastern Manitoba", *Bull. Can. Inst. of Min. and Met.*, 1925, pp. 220-231.

## GENERAL CHARACTER OF THE MAP-AREA

### TOPOGRAPHY

Oiseau River map-area lies just within the southwestern rim of the extensive Canadian Shield, which occupies nearly all of east-central Canada. The topographical features of this great shield, wherever studied, are markedly similar, the most remarkable feature being the even surface of low relief (Plate I) extending over such a tremendous area and truncating such different rocks and structures. In southeastern Manitoba this plain-like surface slopes slightly to the southwest, and about 15 miles southwest of Oiseau River map-area is overlapped by nearly flat-lying, early Palæozoic sediments.

Although the general appearance of the surface is plain-like, in detail it is not smooth, but is broken by numerous irregularly shaped depressions, which are partly filled by muskeg, stratified clay, and glacial drift, or are occupied by lakes. The elevation of lac du Bonnet, at the west side of the map-area, is 820 feet above sea-level and that of Shinewater lake, near the east side, is 1,134 feet; the elevation of all the other lakes in the area is between these two extremes. The depressions have a general east-west strike and the relief is seldom over 125 feet, the average elevation of the hilltops being about 1,000 feet above sea-level. The difference in relief is not so great towards the west as in the east, for north of lac du Bonnet the highest ridge noted rises only 65 feet above the lake-level, whereas north of Davidson lake, on the Ontario boundary, an elevation of 125 feet above the lake-level was noted.

Terraces cut in the drift about 850 feet above sea-level were seen in the cleared areas along Oiseau river between lac du Bonnet and the

first portage. Possibly there are other terraces above these, but if so, they are obscured by the heavily wooded, rocky areas. The base of these terraces is about 20 feet above the level of Oiseau river, and they were cut, probably, during a late stage of post-Glacial Lake Agassiz.

#### DRAINAGE

The whole map-area lies in the drainage basin of Winnipeg river, which enters the southeast corner and flows north for 6 miles, then turns west, southwest, and south for 16 miles. The river in this distance does not follow a well-defined valley nor does it do so anywhere along its whole course of 160 miles from lake of the Woods to lake Winnipeg, but, instead, flows between the rock ridges and from one depression to another in a winding course trending northwest. The profile of the river is not that of a well-graded stream, but consists of a series of nearly flat stretches representing lake expansions and short steep drops at the points where the river descends over rapids and by falls from one basin to the next. Where the river crosses areas underlain by granitic rocks the shoreline of the lake expansions is very irregular, and there are numerous bays, but where the country rock is lava or sediments, as is the case east of Lamprey falls, the lake-like feature is not so noticeable, for the river is narrower and flows in a general straight course parallel to the strike of the beds. The absence of a well-defined valley, the ungraded profile, and the general irregular shoreline all indicate that Winnipeg river is post-Glacial in age and does not follow an old preglacial drainage course.

The northern half of the map-area is drained by Oiseau river and its tributaries. This river rises in Ontario and flows south and west to Oiseau lake and from there in a fairly straight course, a little south of west, to lac du Bonnet, which is one of the typical lake-like expansions of Winnipeg river. From Oiseau lake to lac du Bonnet, Oiseau river flows near the middle of a broad depression, and follows the strike of the sedimentary beds. In this distance it has incised a channel in the stratified clays which partly fill the hollows between the rock ridges along this general depression, and bedrock is exposed in only a few places or where the channel crosses a rock ridge at right angles.

The tributary drainage of Winnipeg and Oiseau rivers is not well developed, and many of the swamps and muskegs of the map-area are not, or are only partly, drained. Starr creek, in the northeast corner of the map-area, and Peterson creek, which is just north of—and flows in a general parallel direction to—Oiseau river, are the two largest tributary streams in this area. A noticeable feature is the abundance of lakes in the eastern end of the map-area and their absence in the lower and poorly drained western end. This difference may possibly be explained by the fact that in the western half of the area stratified clay, deposited in Lake Agassiz, occupies most of the depressions in the surface, and the lakes there occupy the relatively small depressions in the depositional clay flats. Such clay areas are absent, or are very thin, in the higher eastern part of the area, where many of the depressions are occupied by lakes in the fashion so characteristic of the Canadian Shield.

## FORESTS AND WATERPOWER

It is estimated that about one-half the area of Oiseau River map-area is covered with green woods; the other half has been swept by very severe forest fires within recent years. Most of the burned area is underlain by granitic rocks, and the thin moss that once covered the hill tops and slopes was burned and the remaining soil has been eroded, so that bare rock is now exposed over wide areas. In the depressions where the soil was originally thicker there frequently is a thick growth of bushes, and such areas, combined with the many windfalls, make traversing in burned country difficult. About 25 square miles of timber in the southeastern corner of the map-area, and several square miles of timbered ground east of Bernic lake, were burned in the summer of 1924.

The most extensive area of green woods is along the valley of Oiseau river between lac du Bonnet and Oiseau lake. Another quite extensive area south of Winnipeg river and east of Lamprey falls has recently been lumbered. The timber area along Oiseau river was studied by Mr. R. S. Carman, forest engineer of the Dominion Forest Service, and the following information about the forests of this area is extracted from Mr. Carman's unpublished report, a copy of which was kindly furnished the writer by the Dominion Forestry Branch.

Mr. Carman examined 72,209 acres of average timber land extending east from the east end of lac du Bonnet. About 35 per cent of this area was timbered with trees of commercial sizes, 18 per cent carried young growth of black spruce under 6 inches in diameter, and the remaining 47 per cent was practically valueless for timber reserves. The most important trees are jackpine, poplar, spruce, balsam, and tamarack. The jackpine cover about 28 per cent of the timbered area and in about one-half this area the trees are under 4 inches, and seldom are over 10 to 14 inches in diameter. The jackpine grow on the poor, sandy slopes, but in the valleys where the soil has more clay, the forest is a mixture of jackpine, spruce, and balsam. The poplar grows in the well-drained, sandy loam slopes, which are the best soils of the area. Poplar groves with trees averaging from 6 to 9 inches in diameter and about 50 feet in height occur at various places along Oiseau river. In such poplar areas the thick hazel underbrush makes walking difficult and also shades the ground so that spruce or jackpine trees cannot grow. The black spruce of most of the swamps is too small to be of commercial value. A few large, scattered spruce and poplar trees were noted along the edges of the swamps, and probably they are remnants of forest fires which swept this whole area about seventy-five years ago. Mr. Carman concludes that the average timber of the area is chiefly valuable for pulpwood and that the timbered parts will average about 4 cords an acre. Also, in many parts of the area the wooded patches are so scattered and the country is so rough that it will require a very large logging-road mileage for the small amount of pulpwood available.

The Dominion Water Power Branch has studied and reported on the waterpower resources of Winnipeg river in great detail.<sup>1</sup> This investigation showed that there are nine natural power sites along this river between lake Winnipeg and the Ontario boundary, and it is estimated that with a regulated minimum flow of 20,000 cubic feet a second, the nine sites could produce 418,000 horsepower in terms of 24-hour continuous power. Three of the nine sites are now developed; the one farthest up the river is at Pointe du Bois, where the City of Winnipeg Municipal plant (Plate 1) has a developed output of 65,000 horsepower of electrical energy. The construction of the dams raised the water about 6 feet and nearly flooded Lamprey falls about 8 miles upstream. The total area of this pond is about 6,500 acres. The two other developments are at Pinawa (30,000 horsepower developed) about 3 miles west of the area, and at Great falls (capable of developing 168,000 horsepower), about 10 miles to the west of the area. The developments are in advance of the local demand and cheap electrical energy will be at once available to develop ore-bodies that may be found in Oiseau River map-area.

## GENERAL GEOLOGY

### GENERAL SUMMARY AND TABLE OF FORMATIONS

In Oiseau River map-area, as in most areas within the southwestern rim of the Canadian Shield, the geological formations are divisible into a very recent group of unconsolidated gravel, sand, and clay, and a very old group of metamorphosed sediments, lavas, and of deep-seated intrusives. The recent unconsolidated materials were deposited during and immediately after the retreat of the late Pleistocene ice-sheet, and they partly cover or, in some quite large areas, completely cover, the older underlying solid rocks.

The bedrock group is Precambrian and can be divided petrographically and structurally into two main divisions, the older of which consists of a thick series of sediments and lavas, and the younger of deep-seated intrusives (peridotites to granite) which cut the lavas and sediments. The sediments are quartzose, and originally were argillaceous and ashy sandstone. The lavas are intermediate in composition—trachytes and andesites. In places the sediments and lavas are interbedded and form one apparently unbroken series. However, in some localities sedimentary types predominate, and in others volcanics are the most abundant, and in such cases it is difficult to determine their age relations. These rocks also vary considerably as regards the degree of metamorphism exhibited and all variations ranging from slightly metamorphosed to highly metamorphosed schists were noted. The beds now stand vertically or dip steeply and this, combined with their metamorphic character and the presence of large drift-covered areas, makes it almost impossible to determine positively the detailed structural geology of the map-area.

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<sup>1</sup> Water Resources Paper No. 3, vol. 1, 1915.

The plutonic rocks cut the lavas and sediments as dykes, bosses, and batholiths, and vary in mineral composition from basic to acidic. For the most part they are massive, although outcrops of gneissic granite were noted. A microscopic study of thin sections of the basic varieties furnishes evidence of much chemical alteration and granulation. Fairly acidic microcline granite almost surrounds the volcanic-sedimentary series, and along a considerable part of the contact zone there are numerous inclusions of sediments or lavas in the granite, and many small bosses and dykes of granite cutting the sediments. Also, within areas of sediments and lavas, there are intrusive masses of basic to intermediate rocks. The basic intrusives are cut by the granite.

The following is a summarized tabular statement of the geological formations and their sequence as determined in Oiseau River map-area.

Quaternary	Post-Glacial	Stratified Lake Agassiz clay and sand
	Glacial	Gravel, sand, boulders, and boulder clay.
<i>Great unconformity</i>		
Precambrian	Plutonic intrusives	Pegmatite
		Microcline-granite and granite gneiss (pegmatite cuts oligoclase-granite, and microcline-granite grades into oligoclase-granite)
		Oligoclase-granite and granodiorite (relations not determined)
		Diorite, syenite, granodiorite porphyry, and quartz porphyry (relations not determined)
		Gabbro and amphibolite (cut by microcline-granite)
	<i>Intrusive contact</i>	
	Sedimentary-Volcanic complex	Arkose, quartzite, and greywacke apparently conformable with trachyte, dacite, and andesite. Beds of chert, quartzite, slate, metargillite, and various tuffs are locally interbedded with the above groups. Quartz-mica schist with local conglomerate beds.

#### SEDIMENTARY-VOLCANIC COMPLEX

##### *General Distribution and Basis of Subdivision*

Small intrusive bodies of gabbro, granite, etc., are so common throughout the sedimentary-volcanic complex that it is impracticable to outline the areal extent of the rocks of this complex in detail. Sediments and lavas constitute the prevailing rock, however, throughout the part of Oiseau River basin included within the map-area. Also, an area of lava, with a thin quartzite bed, outcrops along Winnipeg river for about 10 miles east from Lamprey falls.

In areal mapping an effort was made to separate the sedimentary rocks from those of volcanic origin. In many cases this was easily done, as the sediments showed bedding or other distinct evidence of their origin and the

lavas were ellipsoidal or else had the typical texture and composition of extrusives. But where metamorphosed tuffaceous materials and lava flows are intimately interbedded, as in the northwestern corners of township 17, range 15, or the southwest part of township 16, range 16, it is very difficult in the field, and even after a microscopic study of thin sections, to differentiate the water-sorted materials from true lava, and, therefore, in mapping such areas it is more than likely that some bands of lava were included in the sedimentary group and vice versa. Also, certain amphibolite schists included in the volcanic group may represent schistified, medium-grained, basic intrusives and vice versa, although it is believed that most of the intrusive masses of any considerable size are represented on the map.

The sediments have been divided into three groups on the basis of lithology and degree of metamorphism. In the northeast corner of the map-area the sediments outcrop as long bands in the granite and are recrystallized to typical mica schists similar to the mica schists along the valley of Manigotagan river to the north and English river to the east. The sediments along Oiseau valley consist of tuffaceous materials interbedded with the lavas and of massive, thick-bedded arkose, greywacke with some metargillite, and slate. The later group of sediments appear to be conformable with the lavas and tuffs, but the relations of the sediments and lavas along Oiseau valley to the mica schists could not be determined.

### *Petrography*

*Quartz-mica Schist and Conglomerate.* Quartz-mica schists with thin conglomerate lenses and beds outcrop in the eastern end of the map-area, and are typically exposed in the basins of Lucky, Flanders, Ryerson, and Davidson lakes. These rocks are medium to fine grained, light grey to dark grey weathering. All are essentially composed of quartz and mica, and evidently are metamorphic sandstones, which originally contained varying amounts of argillaceous material. Veinlets of quartz, small pegmatite dykes, and bosses of granite cut them, and in places typical lit par lit gneisses have developed. These rocks have already been described in some detail more or less parallel. No orthoclase feldspar was definitely determined, although some grains of a cloudy, untwinned feldspar are probably orthoclase. Microcline and plagioclase, ranging from albite to oligoclase, were noted in most of the thin sections. Titanite partly altered to a dark greyish material, resembling leucoxene, occurs as small grains and is characteristic of the thin sections studied. One or two thin sections

The several thin sections of representative specimens of the mica schist that were studied under the microscope were found to be remarkably uniform in mineral composition and texture. They consist of a mosaic of small, rounded and angular, irregularly outlined grains of quartz and feldspar with abundant flakes of green and brown biotite, with their longer axes oriented more or less parallel. No orthoclase feldspar was definitely determined, although some grains of a cloudy, untwinned feldspar are probably orthoclase. Microcline and plagioclase, ranging from albite to oligoclase, were noted in most of the thin sections. Titanite partly altered to a dark greyish material, resembling leucoxene, occurs as small grains and is characteristic of the thin sections studied. One or two thin sections

<sup>1</sup> Ontario Dept. of Mines, vol. XXXII, pt. II, 1923, pp. 9-10.

contain abundant calcite, and others contain abundant garnet. The surface of some outcrops, notably on the southwest shore of Lucky lake, weather rough, with many small, dark brownish protuberances which consist of many small crystals or flakes of brown biotite cemented in a quartz matrix. Many of the quartz and feldspar grains contain inclusions of biotite and show evidence of recrystallization.

Interbedded conglomerate lenses and beds outcrop at several localities. The longest uninterrupted bed noted was between Flanders, Lucky, and Summerhill lakes. This bed varies from 5 to 200 feet in width and was noted at intervals along the general northwest strike for about  $1\frac{1}{2}$  miles. The boulders are embedded in a matrix of quartz-mica schist, and are rounded or lens-shaped, with their longer axis parallel to the strike of the bed. Boulders up to 1 foot in diameter were noted, but the most abundant are rounded pebbles from 1 inch to 3 inches in diameter. Only white granite and dark, vitreous quartz pebbles and boulders were noted in any of the conglomerate lenses studied. Conglomerates also outcrop west of Davidson lake and these and all the other conglomerate outcrops noted were similar to, but less extensive than, the one described from west of Flanders lake. In several cases conglomerate beds were noted to grade gradually along the strike into mica schists with few or no pebbles.

*Quartzite, Arkose, and Greywacke.* Long parallel ridges of thick-bedded quartzose sediments outcrop north and south of Oiseau river between the east end of lac du Bonnet and Oiseau lake. Due to their resistance to erosion these quartzose rocks are by far the most abundant type of sediment outcropping in the map-area. They vary from white or light grey to dark grey or nearly black. The quartzite is thick bedded and massive; the greywacke is as a whole thinner bedded and in a number of observed localities is well laminated. The arkose-like sediments were noted only locally, and in one or two cases showed poorly developed crossbedding and contained a few small quartz pebbles.

Ridges of typical fine-grained, white to dark grey, glassy-looking quartzite outcrop along the northern side of sections 19 and 20, range 15, township 17. In thin section this quartzite consists of interlocking, fairly uniformly sized quartz grains with some shreds of white mica and chlorite. A few of the quartz grains are broken and granulated, but this thin section as a whole shows little evidence of intense deformation. Many outcrops of these massive quartzose rocks show angular and rounded fragments of bluish quartz and a few white feldspar grains in a fine to medium-grained, typical, glassy-looking quartzite. A thin section of this type of sediment outcropping about 3,000 feet south of the west end of Oiseau lake shows, in addition to the large angular quartz and albite-oligoelase grains, many small flakes of brown biotite and some muscovite, tourmaline, magnetite, and calcite. The larger quartz and feldspar grains are fractured and their edges are granulated. Minute dust inclusions are abundant in the quartz and some of the fracture-planes are stained with limonite.

Quartzite and white quartz-sericite-garnet schist outcrop at a number of places along and south of Winnipeg river for about 8 miles east from a point about  $1\frac{1}{2}$  miles east of Lamprey falls. Here the sediments are interbedded with pillow lava, and one bed of quartzose sediments from 50 to

500 feet thick was traced fairly continuously for over 3 miles along the strike. Where this sedimentary bed first crosses Winnipeg river east of Lamprey falls, it is a white, finely laminated sandstone, slightly sheared and with an abundance of white mica along the shearing planes. To the east this rock becomes a glassy typical quartzite. South from Winnipeg river sedimentary beds similar in appearance and thickness to the one outcropping along the river were noted at several localities. Away from the river the rocks are not well exposed but the few observed outcrops and dips suggest that the lavas and sediments lie in closely compressed, small folds.

About one mile northeast of the east end of lac du Bonnet there are a number of outcrops of gritty-looking sediments that might be taken for quartz porphyries, except that the fresh, unweathered surface is laminated. A thin section of this rock is similar in texture and mineral composition to the quartzite described from south of Oiseau lake. Light grey, dense beds of greywacke were noted on many of the traverses. In thin section such beds contain, besides angular and rounded quartz and feldspar grains, considerable greenish, chloritic-looking material and calcite. Interbedded with the greywacke are fine-grained, clayey beds containing abundant red garnets.

*Metargillite, Slate, Chert, and Tuff.* Numerous outcrops of the above-named rocks were noted along Oiseau valley, and are believed to represent beds of clayey and ashy materials that are interbedded with the thick quartzite beds. In the regional deformation which the volcanic-sedimentary complex has undergone, these incompetent beds have been in many places schistified, and slaty cleavage is frequently well developed. These softer and more schistose rocks are best exposed along the lake shores or on the sides of ridges formed by more resistant quartzite beds or lava flows.

A band of argillite-like sediments was noted about 2 miles north of Lamprey falls. These are fine grained, laminated, dark grey to black rocks, which in thin section consist of an aggregate of small, rounded to subangular, quartz grains, with abundant small flakes of green biotite and a few grains of microcline, hornblende, a cloudy untwinned feldspar possibly orthoclase, epidote, calcite, and titanite. Associated with the argillaceous bed from which the above specimen was collected are sandy beds, and along the strike to the east these sediments are apparently represented by the quartz-sericite-garnet schist and quartzite on Winnipeg river already described.

Along the line between sections 20 and 21, range 15, township 17, and just north of Oiseau river several beds of spotted, finely laminated, fine-grained, dark grey or brownish metargillite were noted. Some outcrops show an imperfectly developed slaty cleavage; at others there is a tendency towards recrystallization of the clayey constituents and the development of mica schist. The evenness in the size and shape of the quartz grains in the thin sections of this metargillite is noticeable. The small brown spots and the brownish colour are evidently due to abundance of brown biotite and its segregation in small bunches. Along the strike, metargillite was noted to grade gradually into black fissile slate.

Many thin beds of typical chert, closely associated in distribution with the quartzite and quartzose tuff, were noted within the area underlain by sediments. The chert is light grey to dark grey or black and is generally dense and glassy, although some outcrops show faint lamination markings and others are traversed by minute veinlets of white quartz or feldspar. A thin section of a specimen of the dark chert outcropping along the north shore of lac du Bonnet and about  $1\frac{1}{2}$  miles northeast of the mouth of Oiseau river is seen under the microscope to consist of a microcrystalline aggregate of quartz, with large bunches of calcite, small flakes of biotite and white mica, many small pyrite cubes, and a few specks of magnetite. The minerals are fresh and locally are fractured and the fracture-planes are filled with vein quartz or white mica.

Glassy or ashy-looking rocks outcrop at various places in sections 25, 26, 27, 28, 29, 30, and 31, range 15, township 17. They vary noticeably in appearance within short distances, and appear to grade imperceptibly into chert, quartzite, greywacke, and, possibly, rhyolite. Many of these rocks closely resemble quartz porphyry or rhyolite, but in places they are distinctly bedded, crossbedded, or laminated, and, therefore, they represent water-sorted materials.

In the middle of section 29, range 15, township 17, there are many outcrops of dark grey to black rhyolite tuff containing numerous, rounded and angular, smoky-coloured quartz grains in a finely laminated, glassy groundmass. The smoky or bluish quartz grains from  $\frac{1}{16}$  to  $\frac{1}{8}$  inch in length stand out slightly on the weathered rock surface. In thin section they are fractured and the fracture zones are filled with the groundmass material, which apparently has been squeezed into the cracks during the deformation of the rock. Also, the groundmass material is arranged in lines which bend around the corners of the large, square-shaped quartz grains or phenocrysts forming on a small scale a typical "eye" structure. Rows of minute dust inclusions parallel to the fracture-planes are abundant in these large quartz grains. The groundmass is similar in appearance to the thin section of the chert, and consists of minute quartz grains with abundant feldspar, biotite, and some chlorite. Tourmaline was noted in all the thin sections of this type of rhyolite tuff.

Numerous beds of dark grey sediments were noted south of the west half of Oiseau lake, and west down Oiseau river for 7 miles. Along the south shore of Oiseau lake the surface of some outcrops weathers irregularly, owing to the thin, ashy beds being less resistant than the alternating more quartzose beds. A thin section of a specimen collected from a representative bed of these greyish rocks from near the west end of Oiseau lake consists of a background of small quartz fragments, untwinned feldspar, and brown biotite in which there are a few large oligoclase crystals containing small quartz inclusions. The hornblende is acicular and is either in long, individual grains or is bunched in radiating groups. Along the line between sections 22 and 23, range 15, township 17, a greyish rock of similar appearance contains long, black specks of hornblende, and a thin section of this rock contains about 40 per cent of green, highly pleochroic hornblende. Hornblende was not noted in the biotite schists and only sparingly in the metargillite; the abundant hornblende combined with the large proportion of feldspar in these fine-grained rocks suggests that they are largely composed of volcanic ash.

Agglomerate beds, associated with tuffs and lavas, were noted at only three localities, and in each case were thin and of only local extent. They consist of lighter-coloured, angular fragments up to 4 inches in length in a darker, slightly schistose groundmass. The limited occurrence, so far as is known, of such rocks, is a noticeable feature of the sedimentary-volcanic complex of Oiseau River map-area as contrasted with analogous complexes in Beresford Lake area 20 miles to the north or Lake of the Woods area 25 miles to the south.

*Andesite, Trachyte, Dacite, and Chlorite Schist.* Lavas of intermediate composition outcrop in three main belts in Oiseau River map-area. The southern belt is along Winnipeg river east of Lamprey falls; the middle belt, averaging about  $1\frac{1}{2}$  miles in width, extends 10 miles east and west from the middle of Bernic lake; and the northern belt, averaging about 1 mile in width, extends almost unbroken from the west end of Oiseau lake to the northeast corner of lac du Bonnet. The rocks of this group are green where schistified, but the prevailing type is dark grey to black, and is massive. In a number of places ellipsoidal structure is well developed and this feature with the uniform fine grain of the rocks over wide areas is the only noted evidence indicating volcanic origin.

A thin section of a specimen of typical medium-grained, ellipsoidal andesite from an island in Winnipeg river, section 32, range 16, township 16, shows a somewhat trachytic texture, in that the hornblende and feldspar are arranged in alternating parallel bands possibly corresponding to flow streams of the nearly consolidated lava. Lath-shaped, light to deep green, highly pleochroic hornblende, and brown biotite apparently secondary after hornblende, occupy about 60 per cent of the area of the thin section. Between the hornblende bands are parallel rows of small grains of andesine, mostly untwinned, but some grains show typical plagioclase twinning. There is also some feldspar with an index of refraction less than Canada balsam, which is possibly orthoclase. Irregularly shaped magnetite grains and pyrite cubes are quite abundant. Some of the hornblende is partly altered to chloritic-looking material, but the minerals as a whole are fresh, as would be expected from a specimen formed in a massive and glacially polished surface.

Besides the sediments previously described associated with the lavas along Winnipeg river there are other thinner and more local beds of clay-like material and red garnet. In some beds the clay-like rock has been broken into small, angular fragments cemented together by similar clay-like material. The weathered surfaces of other beds have peculiar worm-like markings. These beds alternate with others estimated to be three-quarters garnet, in red crystals under  $\frac{1}{2}$  inch in size, and set in a quartz matrix. One garnet bed about 6 feet in width and 250 feet long was noted on the south shore of Winnipeg river, section 29, range 16, township 16. Red garnets were also noted in the interstices of the pillow lava flow exposed on the west end of the large island in Winnipeg river, section 24, range 16, township 16. Here both the red garnets and the pillows are sharply outlined on the weathered surface; the ashy-like part weathers more quickly than either the garnet, or rock of the pillow. It is possible that those peculiar occurrences of red garnet are

due to the recrystallization of fine volcanic ash or clayey material that was deposited in local basins on top of the lava flows, or contemporaneously with the extrusion of the lava.

Thin sections of the andesite from north of Bernic lake and Oiseau river are all similar in texture, mineral composition, and mineral alteration to the Winnipeg River occurrence. A thin section from the north shore of Bernic lake contains a plagioclase of the andesine-labradorite series and is a little more basic than the average andesite. In other thin sections there is considerable secondary quartz, and in others there is also considerable calcite and chlorite. A thin section of typical dacite from about one mile north of Bernic lake, section 14, range 15, township 17, contains considerable quartz, oligoclase-andesine, hornblende, and biotite, the two last minerals being present in about equal proportions. Many of the copper prospects of the map-area occur in the northern andesite belt and the specimens collected near the various prospects will be described in more detail in the section of this report dealing with the mineral occurrences.

At a number of localities, especially in the middle and southwest part of range 16, township 17, outcrops of massive, fine-grained, feldspar-rich rocks were noted, these, in some places look like porphyritic lava, and in other places resemble more closely the quartzose tuffs from sections 29, 30, and 31, range 15, township 17. These rocks are similar in origin and composition to rocks that have been described under the general term of leptites by the Swedish and Finnish Precambrian geologists.<sup>1</sup> They may represent either lava flows or consolidated volcanic-ash material, but as it is difficult to determine the origin of such rocks, even after detailed microscopical study, they have been for the most part mapped with the lavas. The several representative specimens collected for detailed study were found to be fairly uniform in texture and mineral composition. One from about 2,000 feet west of the southwest corner of Osis lake is a trachyte porphyry. It is dark grey with white phenocrysts of oligoclase. The matrix is a structureless mass of obscure feldspar material, quartz, biotite, and minor amounts of calcite, magnetite, and titanite. A thin section of a specimen from about one mile east of Osis lake shows a distinctly schistose rock in which bands of biotite alternate with quartz and feldspar bands. A few hornblende crystals, together with zoisite, titanite, magnetite, and apatite, are present.

Chlorite schists derived from dacites and andesites were noted at a few localities. These are greenish to black rocks, which when examined in thin section under the microscope are found to consist of granulated quartz and feldspar, actinolite, chlorite, calcite, pyrite, epidote, and leucoxene. An exposure of this chloritic schist along the section line between sections 29 and 30, range 15, township 17, and 2 miles north of Oiseau river, is peculiar in that it contains lenses and seams of calcite. It is possible that this calcite originally filled amygdules in other small cavities in the lava, and that it has been drawn into narrow bands and small lens-shaped masses when the rock was deformed, but outcrops were noted where the planes of schistosity are cut by quartz and calcite veinlets, the materials of which were plainly introduced later than the deformation.

<sup>1</sup> Holmes, Arthur, "The Nomenclature of Petrology", May, 1920.

### *Structural Features*

*Folding.* The various formations of the sedimentary-volcanic complex have been folded along a general east-west axis, but the large drift-covered areas, the absence of recognizable horizon-markers, and the variations of the rocks across the strike make it difficult to trace these folds in detail. Along the shores of Davidson lake the mica schists are well exposed and to the north of the lake all the beds dip from 40 to 70 degrees north, but south of the lake the dip is from 30 to 60 degrees south. A small anticline, striking about east-west, crosses this lake, and conglomerate lenses and beds outcrop along the axis of this fold. To the west, along the projected strike of the axis of this anticline, is a long, tongue-shaped mass of granite, and the beds to the north and south dip away from the centre of the granite body. South of the large granite mass between Davidson and Ryerson lakes the quartz-mica schists all dip to the south. However, in the basin of Lucky lake and to the northwest from Ryerson lake along the strike of the beds the mica schist and a conglomerate bed northeast of Lucky lake dip to the southwest, and to the southwest of the lake the dip is the reverse, forming a small syncline. The conglomerate bed between Lucky and Flanders lakes was not found on the southwest limb of the fold. This may be due to the conglomerate bed ending down the dip, as the conglomerate of the mica schist series is intraformational and the beds are discontinuous along the strike.

The andesite area with a thin quartzose bed, east of Lamprey falls, is folded into an anticline and syncline within  $2\frac{1}{2}$  miles across the strike. In section 29, range 16, township 16, quartzose sediments dip to the north and are followed to the south by 3,000 feet of andesite lava. Along the south side of the andesite a similar bed of quartzose sediments dips 75 degrees south. This bed is followed to the south by 2,500 feet of andesite and again outcrops, dipping 65 degrees to the north with granite to the south. The quartzose sediments are white or light grey and exposed widths of the bed vary from 100 to 600 feet. The central occurrence of the three is exposed at various places for 7 miles to the east along the strike. To the east the andesite thins so that the central and southern quartzose beds are about 500 feet apart, and here the structure is definitely synclinal.

The various members of the sedimentary-volcanic complex between the granite areas respectively north and south of Oiseau river are interpreted as forming the north limb of a broad syncline. The evidence supporting such an interpretation may be summarized as follows: The beds north of Oiseau river and between Oiseau lake and Bird River post office dip from 70 to 85 degrees south. Cooke concluded that just west of Oiseau lake the beds were not overturned<sup>1</sup> and in the extended areal mapping no evidence of overturning of the beds was noted, except west of Bird River post office, where the same beds that to the east, dip south, are vertical, and on the northwest shore of lac du Bonnet where the greywacke sediments dip 75 degrees to the north. South of Oiseau river the lavas and sediments dip to the south, except locally around masses

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1921, pt. C, p. 7 C.

of intrusives where the beds dip away from the intrusive bodies. The beds east of Shatford lake, also, dip to the north at angles of from 50 to 90 degrees and away from the granite mass between Shatford lake and Winnipeg river. The parallelism of the direction of the strike of the beds and of the schistosity to the contacts of the intrusive masses is noticeable in this area, as in other areas of pre-granite rocks in south-eastern Manitoba. However, the prevailing regional dip of the lavas and sediments along Oiseau valley is southward and the simplest interpretation is that these rocks represent the remnant of the north limb of a large syncline, whose axis, now occupied by intrusives, lay somewhere between Bernic lake and Winnipeg river.

It is interesting to note in this connexion that the structure of the mica schist and interbedded sedimentary-volcanic series along Manigotagan valley, 20 miles to the north, is also interpreted as synclinal<sup>1</sup>. There, the regional dip is to the north and, as in Oiseau area, the mica schists outcrop between the granite and the sedimentary-volcanic series. The country between these two areas was crossed at two places by the writer. The rock exposed is pink and grey granite, some areas of which contain abundant long, narrow inclusions of black and grey schist. The distribution and dip of the mica schists and interbedded sedimentary-volcanic series north and south of this granite mass suggest that the granitic magma intruded along a broad upfolded arch of these sediments and lavas, possibly with a number of minor folds. The comparatively flat top part of this arch has been eroded and only the steeply dipping beds along its flanks remain. Such an interpretation of the broad regional structure puts the mica schists below and, therefore, older than the interbedded sedimentary-volcanic series.

*Faulting.* No field evidence of large faults was noted. There has been local minor faulting and schistifying at a few places, and such deformed zones are locally mineralized. They will be described in detail in the section relating to the individual mineral deposits.

#### *Internal Relations*

No evidence of an erosional or structural break between different formations of the sedimentary-volcanic complex has been noted in any part of the map-area. In the northern half of range 15, township 17, and in the central part of range 16, township 17, tuffaceous sediments and lavas are definitely interbedded. The thin sedimentary bed outcropping along Winnipeg river is also interbedded with andesite flows. The thick-bedded arkose and greywacke sediments in the western end of the area dip and strike parallel to the lavas and interbedded sediment and there is no basal conglomerate or other evidence of an erosion interval between the two formations. The succession of events, from oldest to youngest, in Oiseau River area as represented by the strata described in the preceding sections may be summarized as follows: (1) a period of clayey and sandy sedimentation represented by the quartz-mica schists; (2) a period of vulcanism and sedimentation represented by the andesites and interbedded tuffs, cherts, and grits; (3) a period of sedimentation represented by the arkose, greywacke, and slate.

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1923, pt. B, pp. 95-97.

*External Relations*

The members of the sedimentary-volcanic complex represent the oldest rocks noted in the map-area, and they are cut by all the known intrusives. In most cases the evidence of intrusion is plain, as the beds are either cut off along the strike or are bent to conform to the general strike of the contact of the intrusive mass. In some places, and especially along the granite-mica schist contact, the line of contact is indefinite, for approaching the granite mass granite dykes cutting the sediments become more abundant, and finally an area of granite full of inclusions of sediments is entered, the contact zone being a mile or more wide.

*Comparison of Sedimentary-Volcanic Complex with Lithologically and Structurally Similar Groups in Nearby Areas*

By far the largest part of the explored area of the Canadian Shield in southeastern Manitoba and adjacent parts of western Ontario is underlain by pink to grey microcline-granite. This granite at four or five localities surrounds large areas of pre-granite schists (sediments and lavas) and the schist series of Oiseau River valley is fairly representative of the rocks of such areas in general. Besides the main bodies of schist, long, narrow inclusions of schist are abundant in the granite for a considerable distance in every direction from the large areas of sediments and lavas. It is believed that the granite consolidated in very extensive bodies with comparatively even upper surfaces, and that the remnants of pre-granite rocks represent the limbs or troughs of major synclinal folds that escaped assimilation by the intruding magma. The granite mass has been eroded deeply enough to destroy the direct connexion of those downfolded basins with each other and, therefore, a precise, well-proved correlation of the pre-granite formations of the different basins is probably impossible.

The largest and best-known areas of pre-granite sediments and lavas in this general region are the Lake of the Woods basin, Oiseau valley to the north, Beresford Lake area still farther north along Manigotagan river, Red Lake and English River basins to the east of the Beresford and Oiseau areas respectively, and Rainy Lake basin southeast of lake of the Woods. The following table indicates the pre-granite geological sequence as established by the geologists working in these areas.

Lake of the Woods <sup>1</sup> 1885	Oiseau river <sup>2</sup> 1924	Beresford lake <sup>3</sup> 1923	Rainy river <sup>4</sup> 1887	Rainy river <sup>5</sup> 1913	English river <sup>6</sup> 1922	Red lake <sup>7</sup> 1923
	Quartzose sediments			Seine quartzose sediments Laurentian granite		Timiskaming quartzose sediments
Keewatin lavas with some sediments and intrusives	Volcanics with sedi- mentary materials	Lavas with some sediments	Keewatin lavas with sediments	Keewatin lavas with some sediments and intrusives		Keewatin lavas with some sediments
	Mica schists	Quartzose sediments Mica schists	Couchiching sedi- ments (mica schists)	Couchiching sedi- ments (mica schists)	Sedimentary gneiss with some intru- sives	

<sup>1</sup> Lawson, A. C., "Lake of the Woods Region", Geol. Surv., Can., Ann. Rept., 1885, vol. I, pt. CC.

<sup>2</sup> This report.

<sup>3</sup> Wright, J. F., "Geology and Mineral Deposits of the Northern Part of Beresford Lake Map-area, Southeast Manitoba", Geol. Surv., Can., Sum. Rept., 1923, pt. B, pp. 86-97.

<sup>4</sup> Lawson, A. C., "Rainy Lake Region", Geol. Surv., Can., Ann. Rept., 1887, vol. III, pt. F.

<sup>5</sup> Lawson, A. C., "The Archean Geology of Rainy Lake Re-studied", Geol. Surv., Can., Mem., 40, 1913.

<sup>6</sup> Bruce, E. L., "Geology of the Upper Part of English River Valley", Ont. Dept. of Mines, vol. XXXIII, pt. 4, 1924.

<sup>7</sup> Bruce, E. L., "Geology of the Basin of Red Lake, District of Patricia", Ont. Dept. of Mines, vol. XXXIII, pt. 4, 1924, pp. 12-30.

This table shows that two or even three distinct series of rocks of pre-granite age have been recognized. In some areas the oldest series is sedimentary in origin and is represented by various biotite schists and garnet gneisses which originally were clayey sediments. Inclusions of such rocks are fairly widespread in the granite throughout this region. This series was first recognized and described by Lawson in 1887 from the Rainy Lake basin and was called Couchiching, subsequently altered to Couchiching. Lithologically similar rocks occur along Manigotagan, Oiseau, and English River valleys.

The second series is widespread, but is more variable in composition than the lower series and consists of interbedded lavas and sediments, in some areas the lavas predominating and in others the sediments. The term Keewatin, or in one instance<sup>1</sup> Rice Lake, has been applied to this series. The term Keewatin was first defined and applied to the assemblage as occurring within the basin of lake of the Woods by Lawson in 1885, and on page 49 CC of his report Keewatin time is defined as a period of "an extremely rapid process of deposition of intimately associated, and often alternating, volcanic ejectamenta (both flows and tuffs) and aqueous sedimentation, the material for which was derived partly from the volcanic products and partly from more siliceous or acidic rocks which seem to have constituted the original floor or trough." It is plain that the Keewatin series as originally defined contained considerable sedimentary material.

This table also shows that Lawson, when he restudied the Rainy Lake area in 1913, recognized amongst the strata he called Keewatin in 1887 a younger sedimentary series which he named Seine series and which consists of a basal conglomerate with a thick overlying group of quartzose and other sediments. The redefined Keewatin of this area, though largely composed of volcanic strata, still includes closely associated quartzose and schistose sediments. A part of the so-called Keewatin of Lake of the Woods area may belong to the Seine series and it is not impossible that some of the quartzose sediments of Oiseau River area may be equivalent to the Seine series. In Beresford Lake area a group of quartzose sediments underlain by a basal conglomerate at the east side of the area are indicated in the table as lying between the possible equivalents of the Couchiching and Keewatin. It may be possible that some of Lawson's Seine series belong in this horizon. The Seine rocks are for the most part of continental origin and, therefore, likely to be variable in composition, thickness, and possibly in stratigraphic position, from area to area. Such an origin renders this series rather unsatisfactory for correlation purposes. However, the marked unconformity at the base of the Seine, as outlined by Lawson, should afford a fair basis for correlation purposes in this geological region unless the pre-Seine interval is represented to the west by a period of continuous or nearly continuous deposition, as has already been suggested by Burwash.<sup>2</sup> It may be that in the western part of this geological region the important time break is at the base of the quartzose series

<sup>1</sup> Moore, E. S., Geol. Surv., Can., Sum. Rept., 1912, pp. 262-70.

<sup>2</sup> Jour. Geol., vol. XXX, July-Aug., 1922, p. 400.

lying between the mica schists thought to be equivalent to Couchiching and the Rice Lake or interbedded sedimentary-volcanic series thought to be equivalent to Keewatin.

It was within Lake of the Woods area, near the centre of this south-eastern Manitoba-western Ontario geological region of the Canadian Shield, that Lawson in 1885 studied these pre-granite lavas and sediments in some detail, and first enunciated such important principles of Precambrian geology. Considerable work has been done in areas north and east of this original Lake of the Woods area since Lawson completed his studies, and the following is a summary statement of the pre-granite succession of sediments and lavas of this geological region as known at present.

General character of strata		Series name
Quartzose sediments with conglomerate	A time of continental sedimentation in a low-lying land to the west with higher land to the east	Seine in the east, Wanipigow in west
In the east, granite intrusion, folding, and a structural and erosional unconformity. In the west, no structural break and apparently continuous deposition		
Lavas with interbedded tuffs and sediments, in part reworked tuffaceous matter, in part clastic, but all such as might occur within a vast volcanic assemblage	A time of vulcanism largely under terrestrial conditions, the water-sorted materials being deposited in local depressions developed on the surface of the lava fields	Rice Lake in the west; Keewatin was proposed for this series in 1885
No structural break represented in the east, but along Manigotagan valley the lava-tuff assemblage is separated from the mica schist series by quartzose sediments with a basal conglomerate		
Sediments Quartz-mica schist, garnet gneiss, and local conglomeratic beds	A time during which well-sorted sandy-clayey materials were deposited over a wide area. The composition of the sediments is such as would result from the erosion of a large granite area	Couchiching
Base nowhere exposed		

#### PLUTONIC INTRUSIVES

##### *General Character and Distribution*

Plutonic or deep-seated intrusive rocks outcrop over slightly more than one-half of Oiseau River map-area. These intrusives vary considerably in appearance and mineral composition, but greyish to pink, medium-grained microcline-granite is by far the most abundant type, and almost completely surrounds the map-area. The volcanic-sedimentary complex, already described, is bounded on all sides by the microcline-granite mass. The sediments and lavas are also cut by a group of intrusives in the form of dykes, bosses, and small batholith-like masses ranging from basic to intermediate in composition and frequently porphyritic in texture. Some of the areas of gabbro are known to be older than the surrounding granite, but the relative ages of the different members of this intrusive group are for the most part inferred.

In areal mapping the intrusive rocks were grouped on the basis of mineral composition into: (1) basic, (2) intermediate, and (3) acidic. The basic group is represented by peridotite and gabbro outcropping for the most part north of Oiseau river. The intermediate group includes boss- and batholith-like masses of diorite, granodiorite, and quartz and feldspar porphyries which outcrop between Oiseau and Winnipeg rivers. The acidic group has been divided into two main divisions characterized by oligoclase and microcline feldspars, respectively. A wide belt of oligoclase-granite extends from Pointe du Bois eastward to near the Ontario boundary. Pink to grey microcline-granite is by far the most abundant single rock type outcropping within the map-area.

### *Petrography*

*Peridotite.* South of the granite contact and between the northwest corner of Oiseau lake and the Cup Anderson mineral claim, L 246-124, there are a number of outcrops of a massive, fine to medium-grained, black to reddish-brown weathering rock. Some of the weathered outcrops of this rock show markings somewhat similar to poorly developed pillows and also features suggesting the flow structure frequently noted in basaltic lava. These characters and the uniform texture and appearance of the rocks suggest that they may be basic extrusives belonging to the sedimentary volcanic complex. The contact between peridotite and lavas or sediments was not seen. However, when studied in thin sections under the microscope, the rocks were seen to be markedly different in mineral composition and type of mineral alteration from any of the nearby lavas, and to resemble more closely ultra-basic intrusives. The five thin sections of this black basic rock are almost identical in general appearance and degree of alteration of the minerals. Although the rock appears massive and fairly fresh in the outcrops, the thin sections show that the original minerals have been almost completely altered to a fibrous, felty mass of colourless, light green to slightly yellowish, non-pleochroic material resembling tremolite and serpentine. The typical augite interference colour and right-angled cleavage are still recognizable in the centre of a few of the larger masses of altered material, and a few areas of a material with a bluish interference colour and abundant specks of magnetite, resemble the serpentine-like alteration products of olivine. A few irregularly outlined areas of a mineral with good amphibole cleavage, probably uraltite, were noted in the centre of some of the fibrous altered masses. No feldspar or feldspar alteration products were noted in any of the thin sections. Magnetite in small grains within the altered ferromagnesian minerals and small grains of ilmenite were seen. Also, magnetite, or some dark-coloured, dust-like material, possibly ilmenite, makes a number of the weathered aggregates of ferromagnesian minerals almost opaque. Noticeable features of this rock are the absence of fresh minerals, the great abundance of amphibole-like alteration material, the abundant magnetite, the absence of feldspar, and the uniformity of mineral composition and alteration wherever studied.

A representative sample was collected for chemical and petrographic study from the outcrop of peridotite on the Martin mineral claim, L 174-124. In hand specimen the rock appears perfectly fresh and massive, but in thin section no trace of any of the original minerals was noted and an aggregate of tremolite, serpentine, uraltite, chlorite, and magnetite remains. This thin section contains a little more magnetite than one or two of the other thin sections studied. No trace of augite or olivine was noted, but a few brownish coloured areas show excellent amphibole cleavage.

A chemical analysis of this peridotite, made by A. Sadler in the chemical laboratory of the Mines Branch, Department of Mines, is given below in column (1). For comparison, in column (2) is presented the analysis of a somewhat similarly altered Precambrian peridotite from Ophir lake, Marquette region, Michigan,<sup>1</sup> and in column (3) is the average of seven analyses of amphibole peridotites.<sup>2</sup>

	(1)	(2)	(3)
SiO <sub>2</sub> .....	42.88	39.37	40.91
Al <sub>2</sub> O <sub>3</sub> .....	3.54	4.47	5.00
Fe <sub>2</sub> O <sub>3</sub> .....	10.38	4.96	4.64
FeO.....	4.90	9.13	7.97
MgO.....	25.13	26.53	30.82
CaO.....	6.50	3.70	4.41
Na <sub>2</sub> O.....	none	0.50	0.58
K <sub>2</sub> O.....	none	0.26	0.36
H <sub>2</sub> O+.....	5.36	7.08	} 4.56
H <sub>2</sub> O-.....	0.44	0.87	
CO <sub>2</sub> .....	trace	1.23	.....
P <sub>2</sub> O <sub>5</sub> .....	.....	0.17	.....
TiO <sub>2</sub> .....	0.29	0.66	0.65
MnO.....	.....	0.12	.....
Ni.....	0.12	.....	.....
Cu.....	none	.....	.....
	99.54	99.26	100.00

No attempt has been made to calculate the norm of the Oiseau River peridotite because little trace of the primary minerals exists and the secondary minerals noted indicate that complex chemical reactions have been involved in their formation. However, alumina is regarded as rather stable under metamorphic conditions and the low per cent of Al<sub>2</sub>O<sub>3</sub> at once indicates that this rock was not originally a norite, olivine-norite, or any differentiate in situ from a norite or gabbro magma. The absence of Na<sub>2</sub>O and K<sub>2</sub>O indicates that the Al<sub>2</sub>O<sub>3</sub> must be accounted for in the ferromagnesian minerals. The per cent of CaO is too low for pyroxene-rich rocks such as pyroxenites, websterites, etc. Amphibole rather than augite or olivine was undoubtedly the abundant primary mineral of this peridotite and the composition is, as the table shows, near that of an amphibole peridotite.

*Hornblendite.* Two small bodies of hornblendite outcrop along the mineralized zones in the Chance and Devlin mineral claims, L 166 and L 177.

<sup>1</sup> Van Hise, C. R., and Bayley, W. S., U.S. Geol. Surv., Ann. Rept., 1893-94, p. 511.

<sup>2</sup> Daly, R. A., "Igneous Rocks and Their Origin," p. 29.

The outcrop near the west end of the Chance claim is exposed by the two shafts at this point and is at least 125 feet long. It is bordered by a zone of peridotite in which are veinlets and bunches of hornblende with sulphides. The hornblende mass on the Devlin claim is near the west side of the claim and, as exposed by the prospect pits, is at least 3 feet wide and 100 feet long. The hornblende has developed as individual crystals up to one inch in length. Some of the hornblende is deep green and is characteristically pleochroic, whereas other long, lath-shaped crystals are nearly colourless and only slightly pleochroic. Some of this amphibole has a slightly brownish pleochroism. Associated with this hornblendite are nickel-bearing sulphides which clearly replace the hornblende (Plate II).

*Hornblende Gabbro.* Numerous dyke-shaped masses of amphibole gabbro cut the sedimentary-volcanic series between the west end of Oiseau lake and the east end of lac du Bonnet, and between Oiseau river and the granite contact on the north. These rocks are all similar in appearance and in them dark grey or white, shining crystals of feldspar and green to black hornblende are recognizable. A few small areas of a variety more acidic than the usual type occur within or near the edges of some gabbro masses, and are described on succeeding pages of this report. Although the rock has undoubtedly been subjected to compression it generally shows little or no gneissic structure except along a few shear zones 5 or 10 feet wide where the gabbro has been converted to a light green, in many cases reddish stained, chlorite-saussurite schist.

Under the microscope the texture of the gabbro is seen to show a diabasic tendency, the hornblende and accessories having formed later than the feldspars. The mineral composition of this gabbro is fairly simple and uniform and consists of plagioclase feldspar varying from 40 to 70 per cent, and hornblende with its alteration products varying from 20 to 60 per cent of the volume of the rock. In most thin sections the plagioclase is labradorite ( $Ab_{45} An_{55}$ ), with a mean index of refraction, as determined by the immersion method, of about 1.560. A slightly more acidic plagioclase, belonging to the andesite-labradorite series, was noted in several thin sections. The plagioclase grains are lath-shaped and up to 5 millimetres long. Some crystals show undulatory extinction, others are bent and, locally, the crystals are broken and the cracks are filled with veinlets of actinolite or uralite-like material. Inclusions of hornblende needles are abundant in some crystals and others are flesh coloured, due to kaolin-like alteration products or to dust-like material. Small areas of some of the labradorite individuals are altered to sericite-like material and a few grains of epidote were also noted in such areas.

The hornblende is a light green, highly pleochroic variety and occurs either in single compact grains or, more commonly, in aggregates. It has frayed ends, and some masses have a bleached appearance, and brown biotite and magnetite are developed along the cleavage planes. Locally the hornblende is altered to a weakly pleochroic material and magnetite. Some of the magnetite is titaniferous, as the grains around the edges weather to a material white in reflected light, which resembles leucoxene.

Brown and green biotite in small flakes are associated with the hornblende in a few of the thin sections. Some of it is evidently primary, but some flakes may be secondary. Apatite needles occur included in the hornblende and plagioclase. No augite was found, nor is there any evidence to suggest that the abundant hornblende is secondary after augite. The minerals of these rocks are fresh and unaltered as compared with those of the peridotite.

*Granitic and Coarse-grained Phases in Gabbro.* In a few places the hornblende gabbro varies in mineral composition and texture from the average type described above. Both acidic and basic types are developed locally, as well as coarse-grained, feldspar-rich types. The only known example of an acidic phase occurs along the south edge of the gabbro hill extending nearly parallel to, and just north of, the south line of section 28, range 15, township 17. Here a white, aplite-looking band less than 50 feet wide is exposed for about 1,500 feet along the foot of the hill. The contact between this aplite-like band and the slaty and cherty sediments outcropping about 250 feet to the south is drift covered, but the contact to the north with the gabbro is well exposed on the side of the hill, and is very clearly seen to be a gradational one; the granitic material grades northward and abruptly within a distance of 15 feet, into typical, medium-grained, hornblende gabbro.

A suite of three thin sections prepared from specimens collected from south to north across this acidic border zone have the mineral compositions given below, as determined by Rosiwal microscopic methods.

	No. 76	No. 77	No. 78
Quartz.....	33	10	.....
Oligoclase.....	40	55	.....
Andesine-oligoclase.....			40
Hornblende.....	10	25	50
Calcite.....	12	3	5
Titanite.....	3	5	2
Other accessories.....	2	2	3
	100	100	100

No. 76 from south edge of exposure; aplite-like material.

No. 77 from 30 feet north of No. 76; dioritic-looking.

No. 78 from 15 feet north of No. 77; typical gabbro.

The rock at the southern edge of the exposure, and represented by specimen 76, is a white, fine-grained aplite that somewhat resembles, in general appearance, the quartzite beds to the south. A thin section (No. 76) consists of crenulated, interlocking grains of quartz and plagioclase feldspar with abundant calcite and titanite. The plagioclase has an index of refraction slightly greater than Canada balsam and is probably oligoclase. No orthoclase was noted. All the quartz has abundant dust-like inclusions and the amphibole is practically gone to chlorite and carbonate. The texture of this rock is not that of a normal igneous rock, but rather of an assimilated rock. The rock 30 feet northward (specimen No. 77)

is medium grained and dioritic-looking, and consists of interlocking oligoclase and quartz grains with altered hornblende and abundant titanite. The texture is not markedly different from that of specimen No. 76, although 15 feet farther north the rock as illustrated by specimen No. 78 shows the typical lath-shaped plagioclase individuals and gabbro texture. The andesine-oligoclase contains actinolite needles, and some crystals are flesh coloured, just as was noted in the normal gabbro. A noticeable feature is the abundant calcite, some of it with rhombohedral cleavage and good crystal forms.

Such local granitic facies as the one just described have been frequently noted and described as occurring around the edges of gabbro masses in various ways such as may result from gravitative differentiation, assimilation of slaty sediments, squeezing of acidic material from interstices of nearly consolidated magma, or later intrusion of an acidic magma along contact zones. Cooke has described this particular acidic band as due to gravitative differentiation, the heavier minerals having sunk toward the north to the supposed bottom of the body which he considered to be a sill.<sup>1</sup> If such gravitative settling took place, it is peculiar that titanite, specific gravity of 3.4 to 3.5, equally as heavy as augite, did not also sink. As far as known, granitic border zones such as the above are of only local distribution around the gabbro masses of Oiseau River map-area. In other areas microgranite<sup>2</sup> is known to have formed locally along gabbro-slate contacts by hydrothermal alteration without gravitative differentiation. The texture of the material represented by the two thin sections described is not that of normal igneous rock or differentiate, but is the characteristic texture of assimilation products as illustrated and described by W. H. Collins.<sup>3</sup> Such a local occurrence of granitic material along a gabbro contact does not in the writer's opinion prove gravitative differentiation in situ nor that the intrusive is a sill. The texture and character of this particular occurrence rather suggest that it originated from a slight digestion of slaty and cherty material by the gabbro magma.

Another interesting feature of some gabbro outcrops is the white weathering areas composed of large feldspar crystals with hornblende filling the interstices between the feldspar crystals. Some such masses are only a foot in diameter, but others 100 feet long were noted. Outcrops of this coarse gabbro were seen only on top, or near the top, of gabbro hills, although not all gabbro hills showed this feature. The feldspar crystals are from  $\frac{1}{4}$  to 2 inches long and are between oligoclase and andesine in composition, that is, are only very slightly more acidic than the average feldspar of the normal gabbro. The hornblende is the common, unaltered, highly pleochroic variety, and it crystallized later than the plagioclase. No other minerals were noted in this coarse-grained gabbro or diorite. The origin of such masses is not clear, but it is possible that such local masses so much coarser-grained and richer in feldspar than the surrounding average gabbro, represent segregations somewhat like pegmatite segregations in granite.

<sup>1</sup> Geol. Surv., Can., Sum. Rept., pt. C, 1921, p. 15.

<sup>2</sup> Barrell, J., "Geology of the Marysville Mining District, Montana", Prof. Paper No. 57, U.S. Geol. Surv., 1908, p. 48.

<sup>3</sup> "Onaping Map-area", Geol. Surv., Can., Mem. 95, 1918, pp. 53-62.

*Relations between Gabbro and Peridotite.* At no place were gabbro and peridotite seen in contact, for wherever the two types approach each other, they are separated by a drift-covered depression. Cooke described the gabbro as forming a single very long sill and the peridotite as the basic or bottom edge of the sill, and, therefore, formed by gravitative differentiation in situ.<sup>1</sup> Such an explanation demands that the peridotite should follow the bottom of the sill or the present exposed north side of the gabbro mass. The point was carefully investigated by the present writer, and it was found that on the Martin mineral claim peridotite occurs as a long, narrow mass in the andesite of the schistose sedimentary-volcanic complex with no known gabbro nearby, the main gabbro mass being over one-quarter of a mile to the south, with andesite lava exposed in the intervening area. It seems to the writer that such an occurrence disproves the theory that the peridotite originated through gravitative differentiation in situ from the gabbro magma. The relation between peridotite and gabbro assumed by the writer is that the peridotite and gabbro masses represent sills or dykes of basic magma that were intruded separately into the sedimentary-volcanic complex, but very probably at about the same time.

*Relations between Basic Group and Granite.* Gabbro and granite were seen in contact at two localities, and in one case the granite definitely cuts across the gabbro mass and, therefore, is younger. Peridotite and granite were not seen in contact. The best locality noted by the writer at which to study the granite-gabbro contact is near the centre of section 1, range 14, township 17, where a long gabbro mass about 1,000 feet wide and striking parallel to the lava flows is cut off by granite, just as is the andesite on each side of it. Blocks of gabbro with sharp outlines (Plate III) occur within the granite, and small outcrops of gabbro were noted in the granite for 2 miles to the west along the projected strike of the gabbro mass. The contact between granite and gabbro is not sharp or knife-like, but rather there appears to be a zone 25 feet or thereabouts in width within which gabbro has been added to the granite, and quartz from the granite to the gabbro.

The contact zone between granite and gabbro is fairly well exposed a short distance north of Oiseau lake at a place about 1 mile from the west end of the lake. The area, about 100 feet wide, between where gabbro outcrops on the south and granite on the north, was carefully searched, but no outcrop was noted where granite could be said definitely to cut gabbro, or vice versa. A thin section of an outcrop of dioritic-looking rock from along this zone between gabbro and granite contains considerably more hornblende than the granite, and abundant quartz and oligoclase. Large areas of untwinned and only slightly altered feldspar contain inclusions of biotite, hornblende, and lath-shaped areas of feldspar, some of which are badly altered. The general appearance and texture of the rock along this granite-gabbro contact suggest that the gabbro has been partly re-fused, impregnated by granitic solutions, and recrystallized as a hybrid rock.

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<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1921, pt. C, pp. 14 to 17.

Gabbro and granite are separated on the Wento mineral claim L 241-124 by about 150 feet of andesite lava. Prospect pits along the gabbro-andesite contact expose a fine-grained, chilled gabbro against the andesite. About 5 feet south of this contact the gabbro is cut by small, irregular-shaped stringers of aplite, which possibly originated from the granite about 100 feet to the north. Along the road about 1,000 feet north of the Wento prospect pits, an outcrop of gabbro is sheared and impregnated with quartz and some sulphide. Although the granite contact is not exposed, it must be a few feet to the west of this outcrop and the mineralized quartz is believed to have originated from the granite magma.

At a number of localities outcrops of gabbro and diorite occur within the large granite areas. Unfortunately the contact of these masses of basic rocks with the surrounding granite is seldom exposed and in such cases it was impossible to demonstrate absolutely whether the gabbro or the diorite represents basic segregations of the granitic magma, inclusions of older rocks, or basic dykes cutting the granite. But along the west shore of Winnipeg river, 100 feet south of Geodetic Survey bench-mark 22K, in section 9, range 17, township 17, the contact between diorite and granite is exposed and dykes from the granite cut the diorite; and gabbro inclusions were noted in the granite in section 1, range 14, township 17, and in section 33, range 15, township 17. Since the basic rocks of the above-described two localities are inclusions in the granite, it is reasonable to conclude that nearby outcrops of similar rock also belong to inclusions, especially since hornblende-gabbro, similar to that of Oiseau area, has been described as being older than the granite at a number of localities in southeastern Manitoba and western Ontario. In Maskwa River area, 15 miles to the northwest, the gabbro with associated copper-nickel deposits is, as stated by Cooke,<sup>1</sup> definitely older than the granite. In Beresford Lake area, 25 miles to the north, small gabbro masses are also older than the granite.<sup>2</sup> In Rainy River area, large sill-like masses of hornblende-gabbro intrude the Keewatin, are confined to areas of the Keewatin, and were clearly injected into these rocks prior to their deformation.<sup>3</sup>

*Mode of Occurrence of Gabbro.* The gabbro masses are long and narrow, and their longer axes are parallel to the strike of the neighbouring sediments and lavas, with the exception of the body on section 28, range 15, township 17, where the gabbro cuts across the strike of the lavas and sediments. The gabbro shows chilled contacts against the lavas and is clearly intrusive, but it is difficult to determine whether the intrusion preceded or followed the folding of these rocks. The gabbro locally is sheared and schistified and this phenomenon, combined with the localized distribution of the gabbro bodies within the area of lavas along and just south of the granite contact, suggests that the gabbro magma intruded this general horizon prior to the folding. In the Rainy River area referred to above, the gabbro magma was intruded before the lavas were deformed, as the gabbro masses have undergone the same general deformation that affected the rocks of the volcanic series.

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1921, pt. C, p. 21.

<sup>2</sup> Geol. Surv., Can., Sum. Rept., 1923, pt. B, p. 97.

<sup>3</sup> Lawson, A. C., "Archean Geology of Rainy Lake Re-studied", Geol. Surv., Can., Mem. 40, 1913, p. 38.

Cooke,<sup>1</sup> on the basis of a brief preliminary study of a small part of the map-area, concluded that the gabbro mass west of Oiseau lake was younger than the granite and had formed as a sill 5 miles long and varying from 500 to 6,000 feet in thickness. The more extended mapping of the writer has demonstrated, as outlined in the preceding section, that the gabbro is older than at least some of the granite. Also, detailed mapping proves that this assumed sill consists of two or, probably, three separate bodies, since in the northwest quarter of section 25, range 15, township 17, the granite contact extends south to Oiseau river and the gabbro body to the east of the granite is not connected on the surface with that to the west. That the gabbro mass in section 26, range 15, township 17, is connected with the one in section 28 to the west is not known, as the intervening area is drift covered. Outcrops are fairly abundant in areas underlain by gabbro, and the absence of outcrops in this particular area, combined with the fact that the gabbro mass in section 28 is rapidly thinning to the east and is not directly in line with the last outcrops in section 27, suggests that these two masses may not be connected as was supposed.

Evidence advanced by Cooke supporting the theory that the gabbro mass was intruded as a sill when the lavas and sediments were horizontal or only gently folded, was the occurrence of basic rock and sulphides along the north side, or supposed bottom, of the mass, and the narrow band of acidic rock at one place along the south contact. More extended study has definitely proved that the basic rock is an amphibole-peridotite and that its distribution and composition are such that it cannot be a gravitative differentiate in situ from the gabbro to the south. Further work has also shown that the sulphides are not confined to the north edge of the body, but, as in the case of the Wento deposit, occur also along the south side. The sedimentary-volcanic complex has been steeply folded and, as indicated by the many masses of the volcanics lying in the granite with attitudes paralleling those of the large area of volcanics and sediments south of the granite contact, the folding of these rocks clearly antedated or accompanied the granite invasion and, therefore, gabbro sills subjected to gravitative differentiation could not have been intruded into them later than granite intrusion. However, since the gabbro is now believed to be older and not younger than the granite, it is possible that, under these conditions, the gabbro bodies did form as sills within the sedimentary-volcanic complex. Even if this be the case, the writer has found no evidence suggesting that gravitative differentiation in situ was operative on a large scale within these comparatively small bodies.

*Diorite, Quartz Diorite, and Granodiorite.* Several elongated, boss-shaped masses of dark grey or black, medium-grained intrusives outcrop west of Bernic lake. These rocks vary considerably in composition from place to place, and outcrops of grey granite were noted within the areas. The specimens of the darker rocks collected from such areas for detailed study prove to be diorites or granodiorites. A thin section of black, medium-grained, massive diorite, from near the southwest corner of section 17, range 15, township 17, was measured by the Rosiwal method,

<sup>1</sup> Geol. Surv., Can., Sum. Rept., 1921, pt. C, p. 20.

and since the minerals were all easily determinable and the rock is fairly homogeneous, the percentages given below yield a rather exact idea of the mineral composition of the rock.

Andesine.....	40
Orthoclase.....	10
Hornblende.....	30
Biotite.....	15
Quartz.....	3
Accessories.....	2
	<hr/> 100

The plagioclase individuals are zoned with central parts of andesine and edges of oligoclase-andesine or some member of that series. In places the feldspar grains are slightly altered to sericite and zoisite. There are a few cloudy grains of an untwinned feldspar with an index less than Canada balsam; these grains probably are orthoclase. Green hornblende is abundant and is highly pleochroic in deep green to yellowish tones. The biotite is brown, highly pleochroic, and has the typical "bird's-eye maple" appearance. Quartz is only sparingly present in this thin section, but a thin section of a specimen about 1,000 feet to the south contained about 15 per cent quartz. The minerals appear fresh except for the orthoclase which is slightly altered to kaolin-like material and contains inclusions of hornblende needles. A few of the feldspar grains are granulated and cracked, but the thin section does not suggest that these rocks have been severely deformed.

*Granodiorite Porphyry and Quartz Porphyry.* A large, roughly lens-shaped body of porphyritic rock, ranging in composition from granodiorite to granite, occurs north of Winnipeg river in the northern half of township 16, range 16, and extends about half-way across the adjoining ranges on the east and west. The rocks are characteristically fine to medium grained, light grey to dark grey, and have white feldspar phenocrysts or dark quartz phenocrysts sharply contrasting with the greenish grey weathering, fine-grained groundmass. Along the north shore of Winnipeg river, well-developed parallel joint-planes, dipping at about 45 degrees, divide the rock into layers from 6 inches to 2½ feet thick, which, at a distance, give the outcrop the appearance of a bedded quartzose sediment. About ½ mile north of Winnipeg river, along the line between ranges 16 and 17, are exposures of a rock the groundmass of which is dense to fine grained, and the phenocrysts are fairly uniform in size and average about ¼ inch in length. Along the north side of the mass the contrast between the size of grains of the groundmass and that of the phenocrysts is not so noticeable, the groundmass being medium grained and the phenocrysts no longer markedly noticeable; in fact some outcrops are typical, medium-grained granodiorite or oligoclase-granite. Inclusions of lavas and sediments were noted along the hill-tops, and the intrusive character of the rock is quite clear at many places along the northern contact.

A thin section of the typical porphyry, from north of Winnipeg river near where the line between ranges 16 and 17 crosses the river, consists of a microcrystalline groundmass of quartz, orthoclase, microcline, oligoclase-albite, and brown biotite. The phenocrysts are orthoclase with

excellent carlsbad twinning, and smaller plagioclase individuals. The phenocrysts are fractured and have their corners rounded, and the biotite and other minerals of the groundmass are arranged in parallel lines which bend around the phenocrysts. In thin sections from near the eastern end of the mass the plagioclase is near oligoclase and is present in about the same proportion as orthoclase and microcline combined. The per cent of quartz in these rocks is estimated to be about 20 per cent; brown biotite and hornblende form about 25 per cent and are present in about equal proportions.

An interesting feature of this intrusive mass is presented by outcrops that show numerous lens-shaped masses of quartz lying in a fine-grained porphyritic groundmass. One of the most characteristic examples occurs near the southwest corner of section 25, range 16, township 16, and is illustrated in Plate IV. There, areas of typical porphyry 100 feet or more long and 25 feet wide contain closely-spaced quartz lenses, from 4 inches up to 2 feet long, with their longer axes oriented in a general east-west direction parallel to the longer dimension of the intrusive body and to the foliation lines of the porphyritic groundmass. The areas in which the quartz bodies are abundant are rather sharply defined, as outside such areas only a few quartz lenses occur although, along the general strike, small quartz lenses in places occur intermittently until the next main area is reached, which may be only 100 feet or so distant. A thin section of the quartz of one of the lenses showed numerous grains of quartz which have the texture and general appearance of vein quartz. In places the quartz is stretched so as to resemble lenticular veinlets 4 or 5 inches long. The quartz lenses have been fractured by two sets of joints about at 45 degrees to each other, the strike of the major set being north 15 degrees west. There has been no movement along these joint-planes and they suggest north-south compression at about right angles to the longer axes of the intrusive body. The flow-lines of the porphyritic groundmass bend around the quartz lenses, indicating that the quartz of the lenses had consolidated before the porphyritic groundmass. The silica to make these lenses may have resulted from the assimilation by the magma of quartzose foreign material, possibly a bed of quartzite.

*Relations between Diorite, Quartz Diorite, and Granodiorite, and Granodiorite Porphyry and Quartz Porphyry.* As stated in the previous sections, diorite, quartz diorite, and granodiorite collectively form roughly lens-shaped bodies of variable composition, and granodiorite porphyry and quartz porphyry form a single, larger body. These intrusive bodies do not come in contact with one another. They occur as boss-shaped or long, lens-shaped masses confined to the areas of the schist complex and frequently include small fragments of this group. In each separate mass the mineral composition of the rock varies somewhat from place to place and the porphyritic texture of large areas of the rock indicates that it cooled suddenly. It is suggested that this group of rocks, slightly more basic than granite, and porphyritic in texture, may represent local upward migrations of a magma which presently gave rise to the more extensive granite masses and that, therefore, they belong to the same plutonic period as the widespread oligoclase and microcline-granite.

*Oligoclase-granite.* A belt, from 1 to 2 miles wide, of grey, medium to coarse-grained, granitic rock extends in a general east-west direction through Pointe du Bois and ends to the east near the Ontario boundary. In places the rock is slightly porphyritic, and gneissoid phases were also noted, but by far the most abundant type is even grained and massive. Typical examples of the intrusive are exposed in the quarry just west of Pointe du Bois, where it is massive, jointed, and cut by pegmatite dykes. The mineral composition of two representative thin sections of this rock were measured by the Rosiwal method and are given below:

	(1)	(2)
Quartz.....	18	15
Oligoclase-albite.....	30	0
Oligoclase.....	0	50
Orthoclase.....	0	15
Microperthite.....	30	0
Microcline.....	12	0
Micropegmatite.....	3	0
Biotite.....	5	17
Allanite and other accessories.....	2	3
	100	100

(1) From quarry west of Pointe du Bois, section 35, range 14, township 15.

(2) From west shore of Winnipeg river, section 16, range 17, township 16.

In thin section all the minerals are fairly fresh, the edges of the larger feldspars are granulated, and some of the crystals are fractured. A thin section of a specimen from the south shore of Winnipeg river, along the line between sections 28 and 29, range 16, township 16, shows the quartz and feldspar with strain shadows, and considerable of the quartz and orthoclase is micrographically intergrown. This thin section also contains considerable calcite. Potash feldspar is slightly more abundant than plagioclase, but in one thin section the two feldspars are present in about equal proportions. A noticeable feature of this rock in all the thin sections studied is the presence of allanite (orthite) in prisms, rods, and grains. The mineral is colourless to light green or brownish, the interference colour is very similar to that of epidote, the extinction angle is about 35 degrees, and the relief is high. Other accessory minerals noted are epidote, white mica, magnetite, and zircon.

*Microcline-granite.* A pink or white, massive or locally slightly gneissic, medium to coarse-grained granite, generally containing abundant microcline, is the most widespread single type of rock in Oiseau River map-area. It outcrops almost continuously around the edges of the map-area and wherever studied was fairly uniform in composition and texture. However, locally, there are segregations of coarse-grained, more acidic, pegmatitic material, but such areas are irregular in outline and never extend over 200 or 300 feet in any direction. No pegmatite was noted cutting this granite in dyke form, as was the case with the oligoclase-granite.

The following three mineral analyses made by the Rosiwal method are thought to be fairly representative of the composition of this intrusive.

	(1)	(2)	(3)
Quartz.....	18	25	30
Microperthite.....	25	15	3
Micropegmatite.....	5	0	5
Microcline.....	30	40	20
Orthoclase.....	10	5	15
Albite.....	4	5	15
Biotite.....	5	8	10
Accessories.....	1	2	2
	98	100	100

(1) Pink granite from south side of section 27, range 15, township 15.

(2) Pink granite from west side of Shinewater lake near crossing of Manitoba-Ontario boundary.

(3) Pink granite from section 31, range 13, township 17.

Microcline and quartz are the two most abundant minerals present in the thin sections. The microcline occurs in large crystals or granular aggregates and has been fractured, and shows slight alteration to kaolin along a few of the fracture and twinning planes. Inclusions of quartz and albite are abundant in some of the large microcline grains. Spindle-like intergrowths of orthoclase and albite are well developed and in most thin sections some of the interstices between the large grains are filled with quartz and orthoclase with typical micropegmatite texture. The biotite occurs in small flakes more or less segregated in bunches. Accessory minerals are scarce and consist of magnetite, a few flakes of muscovite, and a few small zircon crystals. All the minerals are on the whole fresh and unaltered.

*Pegmatite.* Dykes of pegmatite occur abundantly along the contact zone of the oligoclase-granite and the microcline-granite. They cut the oligoclase-granite, but in the microcline-granite the pegmatite occurs as segregations and not as true dykes. Pegmatite dykes are abundant west of Pointe du Bois and at various places along Winnipeg river. The dykes vary from 1 foot to 100 feet in width. None of them was traced any great distance along the strike. In many places they strike nearly north and south or at right angles to the contact zone of the oligoclase- and microcline-granites. West of Pointe du Bois the dykes strike from north 20 degrees east to north 45 degrees east, which is the same direction as the major jointing of the oligoclase-granite.

The pegmatite is very simple in mineral composition. Pink microcline and quartz are the most abundant minerals. In many places the quartz and microcline are intergrown, but dykes were noted in which the quartz is segregated in bunches. Some white feldspar, probably albite, some biotite, muscovite, molybdenite, black tourmalines, cassiterite, beryl, lepidolite, and spodumene were the only accessory minerals noted. It should be pointed out, however, that no special search was made for rare

minerals characteristic of pegmatites and that the flat nature of the outcrops of pegmatite do not afford much opportunity to examine fresh surfaces without blasting. A pegmatite mass rich in lithium-bearing minerals was discovered near the north side of lot 17, range 16, township 16, in the summer of 1924, and is described in an appendix to this report.

*Relations Between Oligoclase-granite and Microcline-granite.* The contact between oligoclase-granite and microcline-granite is not sharp and definite, but rather as though between the two granites there lay a zone of variable width up to  $1\frac{1}{2}$  miles, in which the two types were intermixed. Along traverses crossing this contact zone where the rocks are not well exposed, one outcrop may be typical pink granite and the next grey granite. The nature of the contact between these two types is excellently shown along the east shore of Winnipeg river and on the adjacent islands in sections 4, 9, and 16, range 17, township 16. There, in passing from grey oligoclase-granite on the north to pink microcline-granite on the south, the first outcrops over a width of 2,000 feet consist of grey oligoclase-granite, with only a very small amount of pink feldspar, cut by numerous pegmatite dykes. These outcrops are succeeded by a zone from 2,000 to 3,000 feet broad in which the two granites are intimately intermixed in about equal amounts. In the next 2,000 feet the pink microcline-granite predominates, but some grey granite is present. This zone of intermixed granite has a width of from 6,000 to 8,000 feet and only beyond its edges may the rock be definitely mapped as oligoclase or microcline-granite, as the case may be. The contact is definitely a gradational one and on the map the boundary between the two types has been drawn along the middle of this zone.

Pegmatite dykes cut the oligoclase-granite, but in the microcline-granite all the pegmatite noted occurs as coarse-grained segregations with gradational indefinite boundaries. It is believed that the pegmatite originated from the microcline-granite magma, and that the dykes definitely cutting the oligoclase-granite indicate that the oligoclase-granite consolidated as a border facies of the granitic magma whose interior consolidated at a later stage and is now represented by the microcline-granite.

*Post-Granite Basic Dykes.* Diabase dykes later than the granite are not abundant in Oiseau River map-area. Near the west end of Oiseau lake a basic dyke 1 foot wide and exposed for about 10 feet along the strike cuts the granite. Another, black, fine-grained diabase dyke, about  $1\frac{1}{2}$  feet wide and exposed over a length of 20 feet, cuts the lava on the south shore of an island in Winnipeg river in section 24, range 16, township 16. The diabase dykes in this area, as elsewhere in southeastern Manitoba, are, apparently, not numerous or long, and seem to be only sporadically developed. They are, so far as known, the youngest rock in the area.

#### GLACIAL AND POST-GLACIAL DEPOSITS

Glacial and post-glacial deposits are widespread, but for the most part are thin, though locally they reach a thickness of 100 to 200 feet. The glacial deposits consist of boulders, gravel, sand, and some boulder clay, and were deposited from a continental ice-sheet that retreated

towards the northeast. No evidence was found of more than one ice advance, but in upper Whitemouth River area some 30 miles to the south, W. A. Johnston has secured evidence of the existence of two till sheets and two advances of the ice, the older from the northeast, and the younger from the northwest.<sup>1</sup> In Oiseau River map-area all the glacial striae noted were made by an ice-sheet moving from the northeast, and no limestone boulders or other evidence of a younger ice-sheet from the northwest were noted. However, owing to the presence of the post-glacial stratified clays that cover the drift in most of the map-area, and to the thick forest growth, it is difficult, except on the lake shores, to obtain much information about the character of the glacial deposits. Some of the deposits consist of roughly stratified gravel and sand, evidently of fluvioglacial origin. This material may take the form of small hills elongated in a general northwest-southeast direction and somewhat resembling small moraines. Such a series of gravel hills cross the City of Winnipeg railway about 6 miles west of Pointe du Bois where there are large gravel pits, from which material was taken for concrete construction work and ballast along the railway.

The post-glacial deposits consist of uniformly stratified silts and clays laid down in Lake Agassiz, and Recent swamp and lake deposits of muck and peat. The stratified deposits of Lake Agassiz are widespread, but in most places are thin, rarely exceeding 20 feet; the thickest deposit noted measured about 50 feet, as recorded by the diamond drilling on the Cup Anderson mineral claim. Along Oiseau valley these deposits have in some cases filled the minor inequalities of the underlying surface. Some of the clays are greyish and when wet are very sticky, but are not silty in character. Sandy and silty clays were also noted. In the higher areas back from Oiseau river, thin deposits of stratified sand were noted at a few places, and in such areas granite boulders are abundant, the finer materials having been washed from the hills into the depressions. Except for the terraces along Oiseau river and just east of lac du Bonnet, no evidence of shorelines of Lake Agassiz was noted. The areas underlain by clay and silty clay are the only agriculture lands of value within the map-area, and such areas are generally heavily forested and difficult to bring under cultivation.

## ECONOMIC GEOLOGY

*Since this report was written, a lithium-bearing deposit has been found 10 miles northeast of Pointe du Bois. This occurrence is described on pages 100 to 104 of this report.*

The known mineral deposits of possible future economic importance, within the map-area, are the copper and nickel-bearing sulphide bodies north of Oiseau river. In this locality most of the development work to date has been done on the Wento-Cup Anderson group of claims controlled by the Manitoba Copper Company of the Wad Syndicate, and on the Devlin-Chance group controlled by the Devlin Mining and Development

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<sup>1</sup> Geol. Surv., Can., Mem. 128, 1921, p. 27.

Company, Limited. The other mineral occurrences within the map-area are developed by only one or two shallow prospect pits or trenches and include showings of chalcopyrite, pyrite, arsenopyrite, and molybdenite.

To date the important mineral occurrences within Oiseau River map-area have been found north of Oiseau river in the belt of andesite lava and tuffaceous sediments extending from the west end of Oiseau lake to the northwest corner of the east end of lac du Bonnet. The areal association of some of these deposits with dykes and bosses of peridotite and gabbro cutting the lavas is noticeable and suggests that such deposits and the basic rocks are connected in origin. Other mineral occurrences are a long distance from known outcrops of the basic intrusives and are more closely related to the granite-andesite contact, which suggests that the area adjacent to this contact, as well as the areas of peridotite and gabbro, should be carefully examined by prospectors. South of Oiseau river, sulphides are known to occur in only a few localities, although no extensive prospecting has been attempted in this part of the map-area. The location of the more important prospects examined by the writer is shown by a symbol and a number on the geological map (No. 2059) and the corresponding numbers are placed in parentheses after the heading under which the prospect is described in the following text.

The known mineral deposits occur in fracture and shear zones in the andesite lavas and tuffaceous sediments, or along schistified zones following the contacts between these two classes of rocks or between them and peridotite, gabbro, and granite. Along these schistose zones magnetite, pyrrhotite, pentlandite, chalcopyrite, chalmersite, pyrite, arsenopyrite, sphalerite, and galena have been deposited as dyke-like injections, impregnations, and as replacements of the schistified country rock. The gangue minerals are hornblende, tremolite, actinolite, chlorite, brown biotite, sericite, epidote, carbonate, and quartz. Secondary copper and nickel minerals are of no great importance, although malachite and native copper are sparingly present at a few localities.

Classified on the basis of sulphides present the nickel and copper occurrences may be arranged in the following three groups: (1) deposits of pyrrhotite, pentlandite, and chalcopyrite in which nickel is the important metal and which are represented by some of the Devlin-Chance occurrences; (2) deposits of chalmersite, chalcopyrite, pyrrhotite, and pyrite in which copper is the important metal and which are represented by the Wento occurrence; (3) deposits of chalcopyrite with minor amounts of sphalerite and galena and which are represented by the Cup Anderson deposit.

The nickel-bearing deposits of group (1) occur in shear zones in andesite lava, along the andesite-peridotite and andesite-granite contact, but never more than 300 feet from the peridotite masses. The ore consists of small lenses of pyrrhotite, pentlandite, and chalcopyrite, of hornblende masses carrying nickeliferous sulphides, and of schistified andesite with scattered veinlets and small aggregates of these sulphides. It is doubtful if such deposits, even if they should prove to be large, could be worked at a profit in the near future in competition with the Sudbury deposits where "the nickel deposits are so large that so far as this and the succeeding generation are concerned they may be considered to be inexhaustible."<sup>1</sup>

<sup>1</sup> Burrows, A. G., Bull. Can. Inst. Min. and Met., April, 1925, p. 366.

The second group contains no nickel or only a very small trace, but magnetic chalcopyrite or chalmersite is the characteristic mineral. Such deposits outcrop along or close to the gabbro-andesite contact. The ore consists either of schistified andesite lava impregnated with chalmersite and chalcopyrite as lens-shaped masses up to 20 feet long, of lava containing veinlets and aggregates of these minerals, or of sulphide-bearing, hornblende-rich phases of the gabbro. Large masses of magnetite and pyrrhotite, also, occur along the Wento mineralized zone. The ore of this deposit contains titanium, some silver, and a trace of gold.

The third group is represented by disseminated replacement deposits in andesite and tuffs adjacent to the granite contact. The characteristic sulphides are chalcopyrite, sphalerite, and galena; pyrrhotite and chalmersite are absent or only very sparingly present. Where the wall-rock is andesite it has been altered to a chlorite-sericite-epidote schist and, locally, considerable quartz has been added, apparently at the same time as the chalcopyrite. The ore-body consists of schistified and altered andesite and acid tuff carrying veinlets, and irregularly outlined small areas of chalcopyrite, frequently with minor amounts of sphalerite and galena. Economically this type of deposit is believed to be the most important occurring in the map-area. The development work completed is insufficient to determine whether large tonnages of ore are present along any single mineralized zone. The deposits are known to be lens-shaped and the widespread, thick clay deposits and the large alder swamps and muskegs along the andesite belt north of Oiseau river and just south of the granite contact make prospecting difficult and development work expensive. A light drilling equipment capable of sinking a hole through from 50 to 200 feet of drift and taking a core to a depth of 10 to 100 feet in the bedrock will probably be found the most economical and satisfactory equipment wherewith systematically to prospect this area. A very favourable feature is the proximity of the mineralized area to the railway, and the large electrical plant of the Manitoba Power Company at Great falls on Winnipeg river.

The information available at the time of the writer's examinations does not warrant positive statements and conclusions as to the origin and extent of these deposits. However, the presence of nickel-bearing sulphides among the minerals of the first group, as outlined above, indicates that the primary mineralization of such deposits was associated with an ultra-basic rock. Segregations of nickel-pyrrhotite in norite and peridotite occur at a number of localities in Canada, and in Norway thirty-seven separate bodies of norite and peridotite are known to be accompanied by nickel-pyrrhotite.<sup>1</sup> Clarke, in the "Data of Geochemistry", has the following to say about the origin of nickel ores: "In one respect all the ores of nickel seem to agree. Their magmatic associate is always a subsilicic rock, such as norite, peridotite, or in some cases diabase or diorite. In no case are they clearly shown to have originated from persilicic magmas."<sup>2</sup> The limitation of the nickel-bearing sulphides of Oiseau River area to the vicinity of small masses of peridotite strongly suggests a connexion in origin with these basic rocks.

<sup>1</sup> Vogt, J. H. L., "Nickel in Igneous Rocks", Econ. Geol., vol. XVIII, 1923, p. 334.

<sup>2</sup> U.S. Geol. Surv., Bull. 770, 1924, p. 712.

The absence of nickel-bearing sulphides in the deposits represented by the second and third groups indicates that possibly the mineralizing solutions in these cases had a different source. The abundant titaniferous magnetite and chalmersite associated with the ore at the Wento deposits indicate a basic rather than an acidic magma, since the copper ores containing chalmersite at Fierro, New Mexico,<sup>1</sup> and Prince William sound, Alaska,<sup>2</sup> are directly associated with basic intrusives, such as diorite and gabbro. The source of the sulphides at the Wento deposit is attributed to a basic magma, possibly represented by the nearby hornblende-gabbro.

The occurrences represented by the third group of sulphides are typical replacement deposits in andesite lava and quartzose tuffs. The occurrence of a quartz vein carrying some chalcopryrite, along one of the schistified mineralized zones, and of bunches of chalcopryrite and quartz in the schistose andesite, indicates that the mineralizing solutions were acidic; also, the confinement of this type of deposit to shear zones in the andesite belt just south of the granite contact suggests that the mineralizing solutions were residual from a magma represented by the nearby granite.

All three groups of deposits occur along sheared zones that originated before or during the period of plutonic intrusion. The mineralization is later than the regional metamorphism of the lavas and sediments, and later than the consolidation of the intrusives. Some of the chalcopryrite mineralization on the Devlin claims is later than the granite, and this led Burwash to conclude that the deposition of the sulphides was due to heated residual solutions from the granite magma, the sulphide content of which, by a process of assimilation, was partly derived from the nearby basic rock containing accessory sulphides. Under this view, the sulphide bodies, therefore, represent a concentration of the accessories of the basic rock by the solutions from the granite magma.<sup>3</sup> It is well established that igneous magmas may incorporate considerable quantities of foreign material by a method of reactive solution and reactive precipitation.<sup>4</sup> In Oiseau River area the residual solutions from the granite would carry both nickel and copper if the granite magma north of the peridotite and gabbro masses had absorbed much of these rocks and their local segregations of nickel and copper-bearing sulphides. The nickeliferous hornblende rock near the peridotite masses is interpreted as the primary sulphide ore. The sulphides of the broad sheared zones in the andesitic lavas, even near the peridotite masses, assay over three times more copper than nickel, whereas in the hornblende rock the reverse is the case. Such copper and nickel-bearing sulphides of the sheared zones in the andesitic lavas are interpreted as representing mineralization by the residual solutions following the granite intrusion. Such an interpretation would explain the presence of nickel-bearing sulphides later than the granite, but with no basic intrusives younger than the granite. This interpretation of the

<sup>1</sup> Schwartz, G. M., "Chalmersite at Fierro, New Mexico, with a note on Its Occurrence at Parry Sound Ontario", *Econ. Geol.*, vol. XVIII, No. 3, 1923, pp. 220-77.

<sup>2</sup> Johnson, Bertrand L., "Preliminary Note on the Occurrence of Chalmersite,  $\text{CuFeS}_2$ , in the Ore Deposits of Prince William Sound, Alaska", *Econ. Geol.*, vol. XII, 1917, pp. 519-25.

<sup>3</sup> Burwash, E. M., "Geology of the Ontario-Manitoba Boundary, Winnipeg River to Bloodvein River, 1921", *Ont. Dept. of Mines*, vol. XXXII, pt. II, 1923, pp. 19-20.

<sup>4</sup> Bowen, N. L., "Behaviour of Inclusions in Igneous Magmas", *Jour. Geol.*, vol. 30, 1922, pp. 513-570.

available evidence requires two periods of mineralization, the first associated with the intrusion and consolidation of the basic magma, and the second following or accompanying the granite intrusion. The deposits formed in the first period were nearly destroyed by the assimilation processes of the later granitic magma.

#### DESCRIPTIONS OF PROSPECTS

##### *Devlin (4) and Chance (5)*<sup>1</sup>

(See also Figure 1)

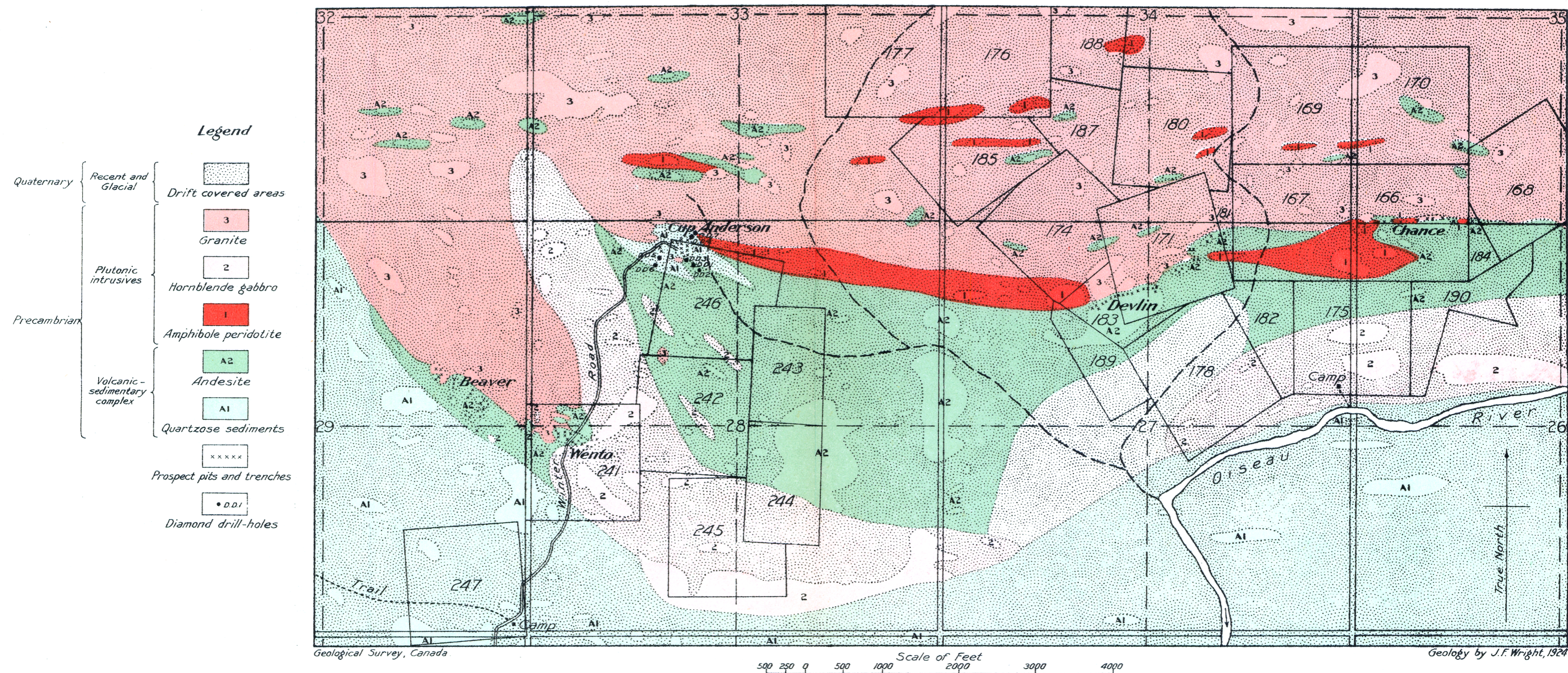
The Devlin and Chance are two of a group of some twenty claims staked in 1920 by Messrs. J. D. Devlin and William Ainslie. They are controlled by the Devlin Mining and Development Company, Limited, which in 1921 sank four shallow shafts and dug about twenty-five shallow trenches on mineralized zones on two of the claims—the Devlin and the Chance—which are situated, respectively, near the north side of sections 26 and 27, range 15, township 17, about  $\frac{1}{2}$  mile north of Oiseau river, and  $2\frac{1}{2}$  miles west of Oiseau lake.

In the general vicinity, bedrock is largely concealed by drift, in places very thick, so that it is difficult to determine the areal distribution of the various formations. The group of claims is located in the neighbourhood of the southern edge of a broad area of granite. The granite contact follows a general east-west course with minor irregularities and, south of it, lies a band of andesitic lava invaded by elongated bodies of peridotite and of gabbro. The strike of the volcanic rocks, of the schistosity locally developed in them, of the granite contacts, and of the longer axes of the basic intrusives is approximately parallel.

Two areas of mineralization have been discovered, one on the Chance and the other on the Devlin claim 2,000 feet to the west. The mineralized areas lie in the andesite lava along, or close to, the granite contact. A narrow peridotite body extends westward from about 150 feet north of the west end of the mineralized area on the Devlin claim, and a second body, which lies to the east, is thought to be continuous with an area of peridotite exposed on the eastward part of the Chance claim. About 1,000 feet south of the Chance mineralized zone are exposures of an extensive body of gabbro.

The western sulphide occurrence on this group is in the southwestern part of the Devlin claim, and extends westward about 300 feet across the adjoining Martin fractional claim. The mineralized zone is along the granite-andesite contact and is exposed along the strike for about 800 feet with a width varying from 2 feet to 75 feet. In this zone the andesite with an interbedded chert layer is schistified and jointed. The sulphide-bearing part of this zone consists of two lenses of massive pyrrhotite and one of hornblendite carrying abundant pyrrhotite. These lenses vary from 2 inches to 2 or 3 feet in width and from 15 to 100 feet in length. The schistified rock for distances up to 5 feet from these sulphide-rich lenses

<sup>1</sup> The numbers following the names of the mineral properties are the symbols employed on the accompanying map (No. 2059) to indicate the situation of the properties.



To accompany report by J.F. Wright, in Summary Report, Part B, 1924.

FIGURE 1. Part of Oiseau River mineralized area, township 17, range 15, east of principal meridian, southeast Manitoba.

is impregnated with small pockets and spots of pyrrhotite and chalcopyrite. Much of the remaining schistified rock, as exposed by the trenches, is limonite-stained, but sulphides are only sparingly distributed throughout the fresh rock. Pyrrhotite is the most abundant sulphide in this mineralized zone; a partial analysis of a fresh specimen of this sulphide by A. Sadler, chemist, Mines Branch, is as follows:

Nickel.....	0.27 per cent
Copper.....	0.17 "
Silver.....	0.08 oz. a ton of 2,000 lbs.
Gold.....	None

This analysis shows the pyrrhotite to be nickel-bearing. Assays, kindly furnished the writer by the Devlin Mining and Development Company, Limited, of ten channel samples from this mineralized zone, taken by Mr. C. H. Hitchcock, at intervals of about 75 feet and across a width of from 3 to 7.5 feet, averaged about 1.0 per cent copper and 0.50 per cent nickel. Pentlandite was absent and the nickel content is due to the abundant nickeliferous pyrrhotite.

Three sheared zones occur in the andesite lava near the east side of the Devlin claim, L 171-124, and adjacent to where the granite contact makes a bend southward. One of these sheared zones crosses the east side-line of the Devlin claim at a point 130 feet south of the No. 2 post of the claim and strikes east-west, or parallel to the granite contact, for 300 feet. The andesite is not badly schistified and only locally carries bunches and stringers of pyrrhotite and chalcopyrite. An inspection of the trenches across this sheared zone indicates that at no place would the mineralized rock assay 1.0 per cent copper across a width of 3 feet or over.

The other two shear zones are about 400 feet west of the east side of the Devlin claim and are about 200 feet apart and strike about east-west. The northern of these shear zones is exposed for about 100 feet along the strike, and a shallow shaft has been sunk on it; the southern shear zone is exposed for 250 feet along the strike, and a shallow shaft has also been sunk near the east end of the exposed schistose rock. The width of the schistified rock as exposed varies from 2 to 15 feet. The schistose rock of both zones can be traced to the ends of tongue-like projections of the main granite and in the case of the southern zone the planes of schistosity bend around the end of the granite. The granite is not schistose, but is jointed, and the joint-planes contain chalcopyrite for distances up to 5 inches from the andesite-granite contact. The tongue-like projections of granite plainly intrude the shear zones, although it is possible that the shearing may have originated at an early stage in the granitic intrusion. The schistose rocks along these sheared zones have been sparingly mineralized with chalcopyrite. A channel sample by C. H. Hitchcock, across 3 feet of the schistose rock of the southern zone at a point 10 feet east of the granite, assayed 2.60 per cent copper. There is little available information about the copper content of these mineralized zones.

The eastern outcrop of mineralized rock on this group is along the location line of the Chance claim, L 166-124, about 1,800 feet east of the

occurrence last described. The bedrock between the two deposits is mostly drift covered. The mineralized zone extends east and west across the claim and lies a few feet south of the edge of the granite. At the west side of the claim the rock to the south of the mineralized zone is a black, fine to medium-grained peridotite. Andesite outcrops to the east of the peridotite at several places along the location line of the claim.

Two shafts about 150 feet apart, each from 20 to 30 feet deep, have been sunk near the west end of this mineralized zone. The rock on the dump is fine-grained basalt or peridotite with veinlets and bunches of hornblendite. Pyrrhotite, pentlandite, and chalmersite are associated with this hornblendite, which consists of hornblende crystals from  $\frac{1}{4}$  to  $1\frac{1}{2}$  inches long. Thin sections under the microscope (Plate II) show that the hornblende originally was a deep green, highly pleochroic variety, but that for the most part it has been bleached to a pale green or nearly colourless variety. The sulphides replace the bleached hornblende (See Plate II). A partial analysis of a specimen of this hornblende-bearing ore, by A. Sadler, chemist, Mines Branch, is given below under (I). Under (II) is an analysis of a sample of this pyrrhotite-pentlandite-bearing rock collected by William Martin, jun., and analysed by Ledoux and Company.<sup>1</sup>

—	(I)	(II)
	Per cent	Per cent
Insoluble siliceous matter.....		44.76
Alumina.....		1.50
Iron.....	12.46	28.50
Nickel.....	1.13	2.92
Copper.....	0.19	0.08
Cobalt.....		trace
Sulphur.....	1.90	
Silver.....	0.04 oz.	trace
Gold.....	none	trace
Platinum metals.....		none
Arsenic.....		1.50
Lead.....		0.03
Zinc.....		trace

Assays of representative samples of the ore exposed in the two shafts and supplied to the writer by the owners average 1.95 per cent nickel and 0.15 per cent copper. The high percentage of nickel in this rock as compared with the deposits in sheared andesite is noticeable. There is little definite information about the size or continuity of this sulphide body, but a rusty gossan zone is exposed by shallow trenches and pits at several places across the Chance claim. Near the east side of the claim there appear to be several small dykes of hornblendite and peridotite. To the east of the claim the drift is deep, but marked local attraction was noted at several places along the projected strike of this mineralized zone. Several small pits about 2,000 feet to the east of the Chance deposit exposed andesite lava, but there was little mineralization.

<sup>1</sup> McCann, W. S., "The Maskwa River Copper-Nickel Deposits, Southeastern Manitoba", Geol. Surv., Can., Sum. Rept., 1920, pt. C, p. 29.

## Wento (2)

(See also Figure 1)

The sulphide body on the Wento mineral claim, L 241-124, is situated about 300 feet east and 125 feet south of the  $\frac{1}{4}$ -section post on the west line of section 28, range 15, township 17. This deposit was discovered in October, 1920, by Messrs. Michael Osis and Joseph Drawson, of Bird River settlement. The mineral claim, with several others to the east of it, was optioned from Messrs. Peter and Michael Osis by Major T. C. Anderson of Winnipeg, in August, 1922. Later, Mr. H. A. Wentworth of Boston associated himself with Major Anderson, and in the spring and summer of 1923 quite extensive surface explorations were undertaken. In August, 1923, the Manitoba Copper Company was incorporated, and this company now controls the deposit, together with about 1,000 acres of surrounding ground.

The development work completed by September, 1924, consisted of some fifteen test pits and trenches, and a shaft 25 feet deep with about 20 feet of drifting. Around the original outcrop the drift is not thick, but about 300 feet to the east there is a thick gravel and boulder deposit resembling a small moraine, and to the northeast there is a small muskeg. The rocks exposed by the trenches are andesite or dacite lava with some more quartzose tuffaceous material. The lavas have been schistified and, for the most part, are altered to chlorite schist. They are cut by massive, medium-grained hornblende-gabbro, granite, and quartz porphyry. The gabbro near the pits has been only slightly granulated, but near the south side of the Wento claim it has been badly schistified across a width of about 6 feet and for at least several hundred feet along the strike. These sheared zones in the gabbro are only sparingly mineralized with chalcopyrite. The granite exposed to the north of the sulphide body is grey coloured, acidic, fine to medium grained, and is porphyritic along the contacts and in the small tongues projecting into the lavas. The granite and gabbro were not seen in contact at this point.

The Wento sulphide body consists of schistified andesite lava and tuff impregnated with sulphides which occur as lens-shaped masses of solid sulphide or in small stringers and bunches disseminated throughout the schistose rock. In addition to the mineralized andesite-tuff ore there are masses of hornblende-sulphide rock along the gabbro-andesite contact. The sulphides consist of pyrrhotite, chalmersite, chalcopyrite, and pyrite. The pyrrhotite occurs either intimately intermixed with the chalcopyrite and chalmersite or as small bunches of pure or nearly pure pyrrhotite. It is strongly magnetic, and another pale yellow sulphide, slightly lighter in colour than chalcopyrite, was noted to be magnetic also. A specimen of this latter mineral was submitted by Mr. H. A. Wentworth to Mr. M. N. Short, Economic Geology Laboratory, Harvard University, who determined it as chalmersite. Recently, considerable evidence has been submitted to prove the identity of chalmersite with cubanite.<sup>1</sup>

A number of specimens of the solid sulphide and the hornblende-sulphide ore were polished and studied by reflected light. The oldest

<sup>1</sup> Merwin, H. E., Lombard, R. H., Allen, E. T., "Cubanite: Identity with Chalmersite; Magnetic Properties", Amer. Min., vol. 8, No. 8, Aug., 1923, pp. 135-138.

minerals noted were a silicate (hornblende) and magnetite. The sulphides noted were pyrrhotite, chalmersite or cubanite, and chalcopyrite, which all appear to be contemporaneous in origin. They clearly are later than the hornblende. The chalmersite was very difficult to differentiate from pyrrhotite, except where the two are seen in contact and then the chalmersite is seen to be of a slightly lighter flesh colour and a little lower in relief. The chalcopyrite and chalmersite are in part intergrown. A partial analysis by A. Sadler, chemist, Mines Branch, of this intermixed hornblende-magnetite-sulphide ore gave the following:

Copper.....	21.40 per cent
Silver.....	4.34 ozs. per ton of 2,000 lbs.
Titanium oxide.....	0.44 per cent
Gold.....	trace
Nickel.....	trace
Cobalt.....	none

The mineralized rock on the Wento claim is exposed almost continuously for 300 feet east and west and from 5 to 100 feet north and south. In this area there are three post-mineral north-south fault-planes along which there has been from 5 to 25 feet of horizontal displacement. This deposit has been carefully sampled by the Manitoba Copper Company who have kindly supplied the assay results to the writer. Assays of samples from the bottom of the shaft and along the drift, in all across a width of 17 feet, averaged 5.2 per cent copper and 2.5 ounces of silver a ton. A mass of chalcopyrite and chalmersite 30 feet long and averaging 7 feet wide assayed 14 per cent copper and 3.2 ounces of silver a ton. However, much of the mineralized andesite and quartzose tuff assays less than 2 per cent copper, though by mixing high-grade and low-grade material a considerable tonnage of ore is available, which would average about 3 per cent copper and 2 or 3 ounces of silver a ton. No silver mineral has been detected in any of the specimens of the ore examined and it is very probable that the silver mineral is intergrown with the chalcopyrite.

Noteworthy features of the Wento deposit are the amount of oxidized material and the spherical aggregates of pyrite crystals. Locally, the pyrrhotite has been oxidized to limonite and hematite and the chalcopyrite reduced to native copper or stained brilliant blue and purple colours. These secondary processes are known to have extended 25 feet deep, and probably extended much deeper. The pyrite spheres vary from  $\frac{1}{4}$  inch to 3 or 4 inches in diameter and consist of pyrite cubes intergrown or cemented by massive iron sulphide. The faces of the pyrite cubes around the circumference of the sphere are bent to correspond to the outline of the sphere and are striated. These spheres occur within the solid sulphides and when the enclosing sulphide is broken the pyritic balls or spheres drop out. The surface of the spheres is slightly irregular, and the depressions are stained with limonite. These pyrite spheres are clearly of secondary origin, and may represent products of preglacial or post-glacial weathering. Recently, Professor Wallace<sup>1</sup> has described in some detail the secondary oxidation and reduction processes of the Flin Flon and

<sup>1</sup> Wallace, R. C., "Secondary Processes in Precambrian Ore-bodies", Trans. Roy. Soc., Can., vol. XVI, 1922, pp. 169-74.

Mandy copper deposits of northern Manitoba, and concludes that "the secondary processes are post-glacial in age" and that their "relative magnitude is due to the porous nature of the rock in which the disseminated sulphides occur." The thin drift cover and the post-mineral faulting and fracturing of the Wento sulphide body would facilitate post-glacial weathering, and this latter feature would also favour deep preglacial weathering. No evidence was found as to the time of the weathering of the Wento sulphide body.

*Cup Anderson (1)*

(See also Figure 1)

The Cup Anderson mineral claim, L 246-124, is situated near the middle of the north half of section 28, range 15, township 17; the sulphide body outcrops near the northwest corner of the claim. The original discovery was made by Mr. Joseph Thomas during the summer of 1923 and consisted of a small outcrop of chalcopyrite-bearing garnet schist. The Manitoba Copper Company at once staked this ground and in the autumn of 1923 and the winter of 1924 several test-pits, trenches, and seven shallow diamond-drill holes were completed. Diamond drilling was resumed during the winter of 1925.

Bedrock is poorly exposed on this claim. The drift, consisting of stratified clay and sand underlain by gravel and boulders, is about 100 feet thick within 200 feet south and east of the eastern trench. The rock exposed in the trenches crossing the sulphide body has been mapped as a quartzose, tuffaceous sediment, although some of it resembles quartz porphyry and rhyolite porphyry. However, outcrops of similar looking rock at nearby localities, where the rocks are not so badly fractured and metamorphosed, are laminated and crossbedded and are believed to represent water-deposited, but only slightly sorted, volcanic ash. At the Cup Anderson workings these rocks are dark grey to black. Small, rounded and angular grains of glassy and dark smoky quartz are readily recognizable in the dark, ashy-looking groundmass. More massive, thick, quartzose beds alternate with schistose, ashy beds which as a rule contain abundant red garnet. In thin section the quartzose beds consist of large, irregularly fractured, quartz grains in a fine-grained matrix of quartz, feldspar, hornblende, chlorite, brown biotite, sericite, and epidote with some chalcopyrite. Some of the chlorite has a deep blue interference colour and probably represents pennine. The abundant red garnets in the finer-grained, more schistose, beds indicate that there has been considerable recrystallization of this material, and it is believed that the groundmass of these rocks represents recrystallized volcanic ash. Chalcopyrite replaces garnet and, therefore, the mineralization followed the recrystallization and regional metamorphism.

No andesite lava is exposed in the workings, but No. 1 drill-hole penetrated about 100 feet of andesite with some tuffaceous material and andesite outcrops about 2,000 feet to the south and to the east. Black, massive, magnetite-rich peridotite outcrops from 300 to 500 feet east of the workings

along, and just north of, the north line of the claim, and massive hornblende-gabbro outcrops 800 feet to the southwest along the road. Granite outcrops about 300 feet to the northwest of the sulphide body, and a small, round mass of quartz occurs just south of the mineralized zone. About 1,000 feet directly north of the northwest corner of the claim, the rock is granite, with abundant andesite, gabbro, and basalt or peridotite inclusions.

The tuffaceous sediments exposed by the prospect pits have been badly jointed and schistified. The strike of the schistosity varies from north 60 degrees west in the eastern pits, to north 85 degrees west in the western pits, and the strike of the fracturing or jointing is about at right angles to the direction of schistifying. This difference in the strike of the schistosity and fracturing is a local feature, and is interpreted as due to a local bending southward of the granite contact as exposed about 300 feet west and along the projected strike of the schistosity. A few of the major fracture-planes are slickensided, and there has been some displacement, but no definite major fault-planes could be determined.

The sulphide body as exposed strikes and dips parallel to the schistosity of the enclosing rocks, and has an average strike of about north 80 degrees west and a vertical or high dip to the north. The commercial ore does not extend beyond the northwest corner of the claim, although the schistified and sparingly mineralized rock extends several hundred feet farther. About 200 feet to the east of the northwest corner of the claim the ore-body is well exposed for 200 feet along its strike by several trenches and pits. The diamond drilling completed in the winter of 1924 extended the ore-body another 200 feet to the east of the eastern prospect trench. Where exposed by the trenches the mineralized zone is up to 100 feet in width, but the average width of commercial ore throughout the 400 feet is probably between 25 and 40 feet. The possible continuance of this sulphide body eastward under the heavy drift and swamp is unknown.

The ore as exposed in the trenches consists of the quartzose tuff with chalcopyrite occurring either as veinlets along joint-planes or as bunches and nests in the schistified rock. None of the tested chalcopyrite was found to be magnetic and little or no pyrite or pyrrhotite was noted in any of the workings. The trenches have been carefully sampled by the Manitoba Copper Company, and their channel samples across 28.5 feet of the schistified rock of the trench, about 200 feet east of the northwest corner of the claim, averaged 3.8 per cent copper and 1.3 ounces of silver a ton. In a trench about 100 feet east of this the channel samples across 94 feet averaged 4.1 per cent copper and 1.4 ounces of silver a ton. Where the rock is more schistified there are high-grade streaks varying from 6 to 12 feet in width and averaging from 6.1 to 7.4 per cent copper and from 2 to 3 ounces of silver a ton. On each side of the main ore-body there is a large tonnage of jointed and slightly schistified quartzose tuff, which averages less than 1.5 per cent copper.

*Beaver-Diabase Group (3)*

(See also Figure 1)

The Beaver and Diabase mineral claims are unsurveyed and are situated immediately west of the Wento claim, in section 29, range 15, township 17. Copper sulphides were discovered on these claims by Mr. George Drawson in October, 1920, and in the autumn and winter of 1923-24 Mr. Drawson did considerable trenching and sank two or three shallow prospect pits in an effort to expose the mineralized zones. In July, 1924, this property was optioned by the Manitoba Copper Company.

The bedrock is a fine-grained, black andesite or dacite lava cut by granite. A small boss of gabbro occurs about 250 feet southeast of the mineralized zone, and quartzose tuffaceous sediments outcrop to the south and west. The andesite has been schistified locally. A thin section of a massive-looking specimen consisted of abundant hornblende, part of which is green and highly pleochroic, but most of which is bleached to a nearly colourless and only slightly pleochroic amphibole with considerable chlorite. No twinned plagioclase was recognizable and the hornblende lies in a background of untwinned feldspar and quartz. There are also a few specks of chalcopyrite, and considerable magnetite.

This andesite, as exposed by the prospect pits and trenches, has been locally schistified within an area 300 feet wide by 600 feet long and lying immediately south of the granite contact. One of the shear zones parallel to and near the granite contains considerable chalcopyrite distributed in small bunches and stringers. A trench across this shear zone also crosses a quartz vein 3 feet wide and containing some chalcopyrite. Sphalerite and galena, also, were noted in a prospect pit in a shear zone about 250 south of the granite contact. This shear zone strikes north 50 degrees west, and the sulphides and schistose rock are arranged in alternating bands. A selected specimen of this ore contains the following metals:

Copper.....	0.20 per cent
Lead.....	2.50 "
Zinc.....	6.10 "
Silver.....	3.40 ozs. a ton of 2,000 lbs.
Gold.....	0.06 oz.

*Osis Prospects (6)*

Copper and nickel-bearing sulphides were discovered in the summer of 1921 about 1,500 feet west of the northwest bay of Oiseau lake, by Mr. Michael Osis, and during the summers of 1922, 1923, and 1924 four prospect pits from 2 to 15 feet deep were sunk in the mineralized outcrops. In the autumn of 1924 several additional claims were staked to the east of these prospect pits. The exposed bedrock is peridotite which has been jointed. A few of the fracture-planes are mineralized with chalcopyrite and some pyrrhotite. Locally, this rock contains considerable magnetite. Granite is exposed about 300 feet to the north, but the interval between the prospect pits and the granite hills is heavily drift covered.

*Rex Group (9)*

The Rex group of claims were staked in 1921, but in 1923 they lapsed and the ground was re-staked in 1924 by Mr. C. G. Stewart as a part of the Silver Queen group. The original mineralized outcrop on the Rex group was just south of the northeast corner of section 36, range 14, township 17. The rock exposed here is tuffaceous grit with conglomeratic lenses and interbeds of andesite. These rocks have been jointed and slightly schistified. Two or three small chalcopyrite lenses from 2 inches to 1 foot wide and from 3 to 10 feet long are visible. Five prospect pits varying from 2 to 12 feet in depth have been sunk, but no sulphide body of any size or continuity was exposed.

*Hunter Group (10)*

The copper showing on the Hunter group, staked by Messrs. D. A. McLeod and Dan McDonald in January, 1924, is situated about one-half mile north of the showing on the Rex group and near the south side of section 1, range 14, township 18. Here the outcrop is a knob of andesite rising slightly above the swamp. About 100 feet west of the line between ranges 14 and 15, a trench about 25 feet long, 3 feet wide, and 3 feet deep, exposed about 20 feet of jointed andesite impregnated with chalcopyrite and a few specks of pyrrhotite, together with hornblende, red garnet, and quartz. Granite outcrops about 200 feet north of this prospect pit. Mineralized rock similar to that in the trench described above is exposed by a pit about 100 feet west. Also, on the Craten mineral claim about 2,000 feet east of the line between ranges 14 and 15, there are several small outcrops of schistified andesite which is chalcopyrite bearing. About a mile farther to the east of these occurrences, and across a large swamp, Messrs. Joe Thomas and Archie McDonald discovered chalcopyrite-bearing schist near the granite contact. The large, wet muskeg between these two discoveries makes prospecting by surface trenching almost impossible.

*Regal Group (11)*

This group of seven claims is situated in the west part of section 25, township 17, range 14. Most of the prospecting to date on the group has been done on Regal No. 2 claim and just east of the line between sections 25 and 26. The rock exposed by the prospect pits is andesite lava cut by gabbro a few hundred feet south. The mineralized rock is jointed andesite with stringers of chalcopyrite. Such rock is exposed at two points, about 150 feet apart, by two prospect pits about 4 and 6 feet deep, respectively. There is no definite continuous shear zone developed and no evidence of a commercial ore-body was noted. Silver-bearing calcite veins are reported from this vicinity, but they were not seen by the writer.

*National Group (12)*

The National group of nine claims is situated in sections 20, 21, 28, and 29, range 14, township 17. The group was staked in May, 1922, by Mr. E. L. Murray. The bedrock exposed is andesite lava cut by gabbro.

The gabbro has been sheared and the shear zones locally are sparingly mineralized with pyrrhotite and chalcopyrite. A number of scattered prospect pits were examined, but no commercial ore was noted at any locality visited on this group.

#### *Ross-Allison Group (13)*

This group is situated in sections 19 and 30, range 14, township 17, and the adjoining sections 24 and 25, range 13, township 17. The group was staked in the summer of 1923 by Messrs. J. W. Rathall and H. Smith. Most of the prospecting on this group was done near the southwest corner of section 30 and the southeast corner of section 25. The bedrock at these places is andesite lava cut by gabbro and granite. In section 30 two prospect pits expose jointed andesite sparingly mineralized with chalcopyrite. In section 25 the andesite just south of a gabbro mass has been slightly schistified and mineralized with chalcopyrite. All the mineralized rock seen at this locality was too low grade for an ore of copper.

#### *Anson Lake Group (14)*

Considerable prospecting was undertaken in the vicinity of Anson lake during the summers of 1923 and 1924. Drift is widespread in this area and the andesite and granite are exposed only by low, scattered outcrops. Several widely separated prospect pits were noted. Near the north-south line between sections 21 and 22 and near the north side of these sections, the andesite contains some chalcopyrite. Here the andesite is jointed across a width of from 2 to 5 feet and for at least 150 feet along the strike. Little systematic prospecting has been done in this locality.

#### *Muskrat (15)*

The Muskrat and adjacent claims in the south half of sections 21 and 22, range 13, township 17, were staked by Messrs. Edward and John Peterson in the autumn of 1923. The country rock is andesite cut by small dykes and stringers of porphyritic granite. The mineralized showing noted on the Muskrat claim is near the south side of sections 21 and 22 and along the north-south section line. Here a trench about 20 feet long and from 3 to 5 feet deep cuts across a jointed zone in the andesite, and some of the rock in the dump contains enough chalcopyrite to make an ore that would assay 4 or 5 per cent copper. This mineralized fracture zone is reported to have been traced several hundred feet to the east of this point.

#### *Gilmore-Hall Group (16)*

This group of claims is situated north of the northeast bay of the east end of lac du Bonnet, in sections 7 and 18, range 13, township 17. These claims were staked in the winter of 1924 by Messrs. R. More and D. A. McLeod. The bedrock of the south part of the group is greywacke sediments with andesite lava to the north. The lava and sediments dip steeply to the north and are cut by granite about three-fourths of a mile north of the shore of lac du Bonnet. Some thirty years ago a shaft was

sunk about 20 feet deep in the andesite lava at a point about 300 feet east of the west side of range 13, and 1,500 feet north of lac du Bonnet. At the surface there is little indication of fracturing or mineralization. At the bottom of the shaft there are some quartz and chalcopyrite, but no commercial copper ore was encountered. About one-half mile east of this point the andesite lava is slightly schistified at several places, but at no place was any commercial ore exposed by the prospecting completed at the end of September, 1924. However, the andesite is sheared and leanly mineralized with chalcopyrite at a number of places and this locality would seem a favourable one for prospecting.

#### *Rathall Iron Sulphide Deposit (7)*

An outcrop of rusty rock, about 3,500 feet south of the west end of Oiseau lake, was investigated by Mr. J. W. Rathall in the spring of 1922, and the fresh ore was found to be massive iron sulphide. The country rock here is a quartzose sediment striking about east and west and dipping about 80 degrees south. The outcrop containing the iron sulphide is at the foot of a hill to the south of which there is a wide, drift-covered area. The rusty zone has been traced about 300 feet along the strike, and the exposed width is about 5 feet. The sulphide body consists of schistified country rock with masses of nearly pure white pyrite. At present a deposit of iron sulphide in this vicinity is of little economic value, and only enough prospecting has been done on this sulphide body to determine that it is not an ore of copper. Several other sulphide gossan zones were noted south of Oiseau lake, but little is known of their value.

#### *Miller Arsenopyrite Prospect (8)*

In the summer of 1924 Mr. K. E. Miller located a small outcrop of arsenopyrite, about 300 feet south of the eastern end of Shatford lake, in the northwest quarter of section 33, range 15, township 16. This deposit is exposed at only one place, where there is a prospect pit about 3 feet deep. The bedrock is andesite cut by pegmatite and granite, and the main granite contact is only a few hundred feet south of the prospect pit, in which is exposed an arsenopyrite mass about 2 feet wide. The sheared andesite for 2 feet to the north of the massive sulphide body contains considerable quartz and some arsenopyrite. This deposit has not been traced along the strike, which apparently is north 70 degrees east.

#### *Zeemel Prospects (17)*

For several years Mr. F. Zeemel and associates have been prospecting for silver in section 33, range 13, township 16, just east of the east end of lac du Bonnet and south of Bird river. The country rock is greywacke sediments with interlayered slaty and conglomeratic beds. The beds strike east and west and dip vertically or steeply to the south, and, due to movement in folding, the rocks of the softer beds between the massive, thicker beds have been schistified. Two shafts, each about 20 feet deep, have been sunk along one of these schistified zones. A few calcite veins were encoun-

tered in the east shaft; a little galena was noted by the writer, but no silver-bearing minerals. An assay of a channel sample across the face of the shaft and about 10 feet from the surface gave only 0.8 ounce of silver a ton of 2,000 pounds. Near the bottom of the west shaft there is considerable quartz, and a channel sample across 2½ feet of the material assayed no gold and only 0.01 ounce of silver. There has been little or no mineralization in the exposed parts of any of these shear zones in the sediments. Pyrrhotite occurs along several of the shear zones just south of Oiseau river, and there are several patented claims along Bird river, and especially in section 3, range 13, township 17.

#### *Laurie Sulphide Prospect (18)*

In June, 1924, Mr. P. Laurie of Pointe du Bois discovered a few specks of cobalt bloom about one-half mile southwest of Winnipeg river near the west side of section 16, range 16, township 16. The bedrock is quartz-sericite schist included in granite. Two shallow trenches expose the quartzose sediment, which locally contains some pyrrhotite. A few specks of cobalt bloom were noted by the writer in the gossan material. A specimen of the fresh, massive, quartz-pyrrhotite-bearing rock tested qualitatively by Mr. E. Poitevin, Mineralogical Division, Geological Survey, gave no reaction for cobalt or nickel. Similar quartzose sediments outcropping about three-fourths of a mile southwest of the above locality are sheared, and impregnated with pyrrhotite, pyrite, and arsenopyrite. As far as could be learned none of the deposits here exposed contain metals of economic value.

#### *Lac du Bois Molybdenite Prospect (19)*

Molybdenite was noted as an accessory mineral in pegmatite at a number of localities west of Pointe du Bois. A shallow prospect pit has been sunk on one of these occurrences about 1 mile west of lac du Bois and ¼ mile north of the City of Winnipeg railway near the southern side of section 23, range 13, township 15. At this point there is a small inclusion of andesite lava in the granite, and there has been a concentration of molybdenite in a quartz-rich pegmatite which occurs along the andesite-granite contact. The general strike of the andesite inclusion is north 20 degrees east. The molybdenite occurs in small pockets and nests irregularly distributed along the contact for about 200 feet and across a width of from 2 inches to 1½ feet. Molybdenite in single flakes or small aggregates of flakes was noted at several nearby spots. However, only a very small amount of molybdenite was seen at this locality.

#### NON-METALLIC DEPOSITS

Feldspar and lithium-bearing minerals from the pegmatite dykes and garnets in the local garnet-rich beds of the sedimentary-volcanic complex are non-metallic resources of possible future economic value within the map-area. Pegmatite dykes outcrop abundantly west of Pointe du Bois and along Winnipeg river east of Lamprey falls. Pink feldspar

crystals up to 2 feet in length were noted in some of the pegmatite dykes along the east shore of Winnipeg river where the river turns south just west of the Manitoba-Ontario boundary. The quartz in some of these dykes is segregated in bunches and the quartz and feldspar could easily be separated by hand sorting. In a large percentage of the dykes noted, the feldspar crystals are under 1 foot in length and average from 1 to 2 inches. In such dykes the feldspar and quartz are intimately intergrown and, therefore, they are of no commercial value at present. A lithium-bearing pegmatite is described in the following appendix.

The garnet-rich rock outcrops along Winnipeg river, in sections 21 and 28, range 16, township 16. The garnet is a deep red variety and occurs in well-developed crystals up to  $\frac{1}{2}$  inch in diameter, although the average size is less than  $\frac{1}{4}$  inch. In places such garnet is estimated to form three-quarters of the rock. Two garnet beds noted were each about 6 feet wide and were exposed 200 to 250 feet along the strike, which is about east and west with the dip vertical or about 85 degrees to the south. A little quartz and pyrite are associated with the garnet, and the material cementing the garnet crystals is a fine, clayey material. The garnets of these beds may be valuable as a source of material suitable for the abrasive industry.

## APPENDIX

### *Lithium (20)*

In the summer of 1924 lepidolite, a lithium-bearing mica, was discovered in pegmatite, 10 miles northeast of Pointe du Bois, near the north side of lot 17, range 16, township 16. This locality was visited by the writer near the end of September, 1925. Pink pegmatite dykes are numerous in the district, but the prospectors were attracted by the peculiar lilac-coloured rock (massive lepidolite) occurring within this particular body of pegmatite, and outcropping over an area of several square feet near the foot of a small hill. The "Bear" and "Balsam" mineral claims were staked by Mr. R. G. O. Johnson along the strike of this outcrop, and in the winter of 1925, Mr. Johnson and Mr. G. E. Hoyt removed the thin overburden on the side of the hill and exposed the lithium-bearing pegmatite over an area 100 feet long and, on an average, 40 feet wide. They also blasted into this outcrop at several places and shipped sample specimens to various commercial laboratories. In the spring of 1925 the Silver Leaf Mining Syndicate (Canada), Limited, capitalized at £10,000, was incorporated by capitalists in Yorkshire, England. This syndicate has built camps and brought in considerable mining machinery (compressor, jack hammer drills, gasoline engines, etc.). A pole tram-line and a winter road, each about 3 miles long, have been constructed to the property from a point on Winnipeg river about one-half mile south of Lamprey falls. Large barges can be towed along Winnipeg river between the end of this tram-line and Pointe du Bois, a distance of about 7 miles. During the winter of 1925-26, it is proposed to ship a few carloads of the lithium-bearing rock to England for large-scale test treatment.

The bedrock exposed in the immediate vicinity of the lithium deposit is andesite and pegmatite. A band of pink granite outcrops about 850 feet north. Approximately 3,000 feet south is the north contact of a

granite mass that extends 20 miles or more south. The andesite forms a band which extends east 8 or 9 miles, but which, westward, is cut off by granite within a distance of 2,000 feet. An extensive spruce swamp, and the wooded nature of the country west of the deposit, make it almost impossible to locate definitely the contact between granite and andesite. The pegmatite intrudes the andesite and is exposed for 125 feet in a general

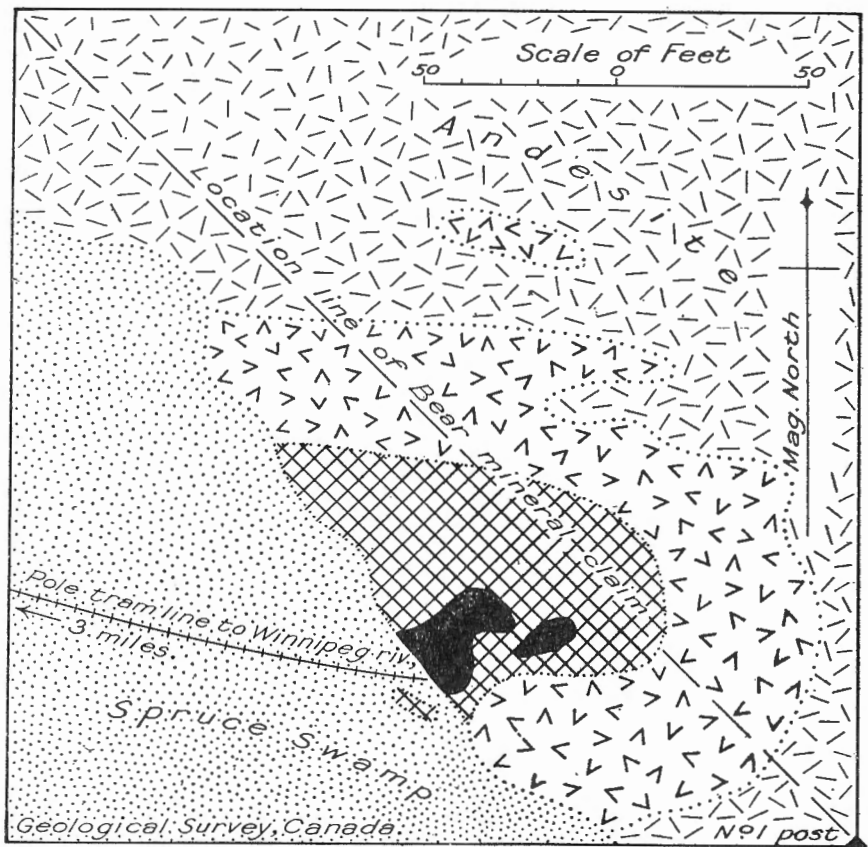


Figure 2. Plan of lithium-bearing minerals deposit, lot 17, range 16, township 16, southeastern Manitoba. The two areas shown in black are of massive lepidolite, the surrounding area represented by crossed lines is underlain by pegmatite carrying spodumene, montebrasite, and lepidolite, and the surrounding area represented by a V pattern is underlain by a pink pegmatite containing some lithium-bearing mica.

east-west direction and across an average width of 80 feet. The lithium-bearing minerals occur in pockets within the central part of this pegmatite outcrop (Figure 2).

The andesite north of the deposit is a fine-grained, massive, black rock, which locally shows poorly developed pillow structure. The rock in thin section under the microscope shows little evidence of the schistose

structure characteristic of much of the lava of this area, and consists of basic andesine, hornblende, magnetite, and some brown biotite. The andesite for a space of one foot from the pegmatite contact is coarser grained than the normal rock. A specimen of the andesite from a place 5 inches north of the north edge of the pegmatite showed under the microscope the same texture and minerals as the normal andesite, the only noticeable difference being the coarser grain. The contact of pegmatite and andesite is sharp and the sole contact metamorphic effect of the pegmatite magma was a recrystallization of the andesite for a few inches from the contact.

The pegmatite varies considerably in texture from the edge to the centre of the mass, and there is a zonal arrangement of the different minerals. The outer part, with a maximum width of 3 feet, is a pink or salmon-coloured, medium-grained, alkali granite. This evenly granular type gradually passes, inwardly, into a pink to flesh-coloured, uneven, grained rock, consisting of quartz, microcline, and minor amounts of a dark coloured mica. The quartz is irregularly distributed in small, white or slightly smoky, opaque masses. No graphic intergrowths of quartz and feldspar were seen. Microcline is by far the most abundant mineral and a few masses of it are 2 or 3 feet across. Under the microscope the microcline of the large masses shows excellent grating-structure and is crossed by narrow zones of small grains of an untwinned feldspar, probably orthoclase. A few small crystals of albite, and of orthoclase showing Carlsbad twinning, lie in the microcline. No lithium-bearing minerals were noted in either of the outer zones, with the possible exception of narrow veins of a dark crushed mica, which possibly may be lithium-bearing. However, within a varying distance, of from 20 to 50 feet from the walls, the unevenly granular rock type irregularly grades into a central body of white pegmatite, consisting principally of white alkali feldspar, spodumene, and montebrasite (identified by Mr. E. Poitevin), but with two lenses of massive lepidolite near the south side. The spodumene and montebrasite occur as pockets within the feldspar mass and it is estimated that they form about one-half of the rock. A few small pockets and veinlets of lepidolite occur with these minerals.

The spodumene is white or greyish white and occurs in cleavable masses, which fracture unevenly, and of which the parting planes have a somewhat pearly lustre. Mr. Poitevin, of the Mineralogical Division, reports that the indices of refraction agree very closely with those commonly given for spodumene. The montebrasite is white, with a slight greyish tint, and massive. It occurs in crystals up to one foot or more in cross-section, and certain faces show numerous lamellæ due to polysynthetic twinning. The mineral is very similar in appearance to feldspar, but can readily be differentiated by its greater specific gravity. Mr. Poitevin has determined the indices of refraction to be:  $\gamma$ , 1.620,  $\beta$ , 1.611, and  $\alpha$ , 1.600. In chemical composition, montebrasite is very like amblygonite but contains more hydroxyl and less sodium. The lepidolite occurs in small flakes, seldom as much as one-quarter inch in diameter, and some of which are white, whereas others have lilac and lavender tints. Mr. Poitevin reports that the mineral does not have the

accepted indices of lepidolite, but that it appears, from the little optical work done, to be intermediate in composition between ordinary lepidolite and a Madagascar lepidolite reported by Duparc.<sup>1</sup> In addition to the minerals described above, two small crystals of pale green beryl and some tantalite have been found at this locality. Tourmaline, cassiterite, and other minerals characteristic of such pegmatites have not yet been found, but, undoubtedly, as the deposit is developed, other minerals than those given above will be discovered.

The following table gives the results of partial chemical analyses of the two types of lithium-bearing rock from the Manitoba deposit, and, for comparison, the compositions of several lithium minerals mined as sources of lithia.

	I	II	III	IV	V
Alumina (Al <sub>2</sub> O <sub>3</sub> ).....	26.63	18.13	27.0	27.0	34.0
Lithia (Li <sub>2</sub> O).....	3.87	4.76	4.0	7.0	9.0
Soda (Na <sub>2</sub> O).....	1.80	0.28	.....	.....	.....
Potash (K <sub>2</sub> O).....	9.62	0.11	11.0	0.0	0.0
Iron (Fe <sub>2</sub> O <sub>3</sub> ).....	0.10	0.07	1.0	2.0	1.0
Fluorine.....	4.10	0.16	7.0	0.0	5.0
Phosphoric acid.....	traces	1.25	0.0	0.0	48.0

I. Sample of compact crystalline lepidolite from Manitoba. M. F. Connor, analyst.

II. Hand-picked sample judged to represent approximately the spodumene-bearing rock after 50 per cent gangue has been removed; from Manitoba. M. F. Connor, analyst.

III. Lepidolite.

IV. Spodumene.

V. Amblygonite.

Nos. III, IV, and V, are quoted from a report by Walderman T. Schaller on Lithium Minerals in Mineral Resources report, U.S.G.S., pt. 2, 1916, p. 11.

Owing to the variable character of the deposit, the only way to obtain a reliable sample is by mining and treating several carload lots.

Massive lepidolite rock, represented by analysis No. I in the above table, outcrops in two lenses. The larger lens is 30 feet long and has an average width of 15 feet; the smaller body is 18 feet long and averages about 10 feet in width. The weight of 11.5 cubic feet of this massive lepidolite is estimated to be one ton and, therefore, for each 10 feet that those two bodies extend in depth with the same horizontal dimensions, there are 540 tons of material of this general grade.

The spodumene-bearing rock, represented by analysis No. II in the above table, outcrops over an area averaging about 90 feet by 40 feet. This material will have to be hand-picked and it is estimated that only from one-third to one-half of it should be considered as a source of lithia. The estimated tonnage of this type of lithia ore is between 1,600 and 2,000 tons for each 10 feet in depth.

Lithium-bearing minerals occur as accessory constituents of pegmatite at a number of localities, as in Wakefield township, Quebec, where a white pegmatitic granite dyke contains large lepidolite flakes, and in

<sup>1</sup>"Mineralogie de Madagascar" by A. Lacroix, Tome I, p. 478.

Maine where many pegmatite dykes contain lithium-bearing minerals. At very few localities are such minerals the principal constituents of the pegmatite, the two noteworthy localities in the United States being in the Black Hills, South Dakota,<sup>1</sup> where either spodumene or amblygonite have been mined steadily since 1898, and in San Diego county, California, where lithium-bearing minerals have been mined since 1899, except between 1905 and 1915.<sup>2</sup>

The lithium deposit undoubtedly represents a phase of the pegmatitic magma in which there was a marked concentration of lithia, phosphate, and other minor constituents, which normally are absent or only sparingly present. These constituents are not essential components of the outer part of the body. This outer part—since it and the spodumene-bearing pegmatite are cut by veinlets of lepidolite—seems to have consolidated before the central part.<sup>3</sup>

It is not known whether the lithium-bearing pegmatite outcrop represents the east end of a pegmatite dyke or the east half of an oval-shaped mass. The zonal distribution of the different minerals suggests that the pegmatite body has an oval outline. In this connexion it is interesting to note that similar lithium-bearing pegmatite masses in the Black Hills region, South Dakota, have been demonstrated to be oval bodies, which widen downward.<sup>4</sup> If the Manitoba mass is oval shaped as surmised, the present exposed area represents about one-half the cross-section and, therefore, the estimated tonnages given above perhaps should be doubled. However, experience gained in the mining of deposits of mica, molybdenum, tungsten, lithia, etc., in pegmatite bodies has demonstrated that the valuable minerals in each case occur in large or small pockets erratically distributed through the pegmatite masses. In view of this fact, it is always advisable to determine that the valuable minerals are sufficiently abundant and sufficiently concentrated before purchasing expensive machinery for mining purposes. Other deposits like the one described above will probably be found in this area, because it is known that in regions characterized by the presence of pegmatites, these rocks have a tendency over quite wide areas to hold the same suite of minerals.<sup>5</sup> In southeastern Manitoba other pegmatite masses carrying small quantities of lithium-bearing minerals have been discovered near this deposit, and also 20 miles to the south, near Hawk lake, and 20 miles to the north, in Maskwa River area.

<sup>1</sup>Ziegler, Victor, "Lithia Deposits of the Black Hills", Eng. and Min. Jour., vol. 96, pp. 1053-1056, 1913.

<sup>2</sup>California Mineral Production for 1923, Bull. No. 94, Sept., 1924, p. 99.

<sup>3</sup>Since the above was written the author has read the interesting article on "The Genesis of Lithium Pegmatites" by Walderman T. Schaller in the Amer. Jour. Sc., vol. 10, fifth series, pp. 269-79, in which it is concluded that the lithium-bearing pegmatites "were at one time in their history solid graphic granite composed essentially only of microcline and quartz, from top to bottom, and that all the other minerals now present—albite, the micas, the garnets, the tourmalines, all the fluorine, phosphorus, water and lithium-bearing minerals—were not original crystallizations from a magma but were introduced later and are the result of replacement processes."

<sup>4</sup>Paige, Sydney, Central Black Hills Folio, No. 219, U.S.G.S., p. 30, 1925. Since this report went to press G. M. Schwartz, Economic Geology, Nov., 1925, "Geology of the Etta Spodumene Mine," writes: "Diamond-drill holes . . . indicate that the deposit closes in about 100 feet below. It seems unlikely that the pegmatite ends entirely at this depth."

<sup>5</sup>Bastin, E. S., "Pegmatites and Associated Rocks in Maine," Bull. No. 445, U.S.G.S., p. 43.

## DEEP BORINGS IN THE PRAIRIE PROVINCES AND NORTH-WEST TERRITORIES

*By E. D. Ingall<sup>1</sup>*

The Borings Division of the Geological Survey exists for the purpose of accumulating and studying records of borings made in any part of Canada, so that the information of a general geological character thus rendered available may be utilized both for the guidance of operators and in geological research, arriving at a fuller understanding of the strata in depth. The list given below presents in tabular form particulars of the records of borings in the Prairie Provinces added to the files of the Borings Division during 1924. These do not necessarily represent work done during that year, as the policy of many of the companies does not permit making these particulars known until their operations have been carried to a successful issue.

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<sup>1</sup> Information regarding boring records for Yukon and British Columbia will be found in Part A of the Geological Survey Summary Reports, and for eastern Canada in Part C.

## Records Received from the Prairie Provinces

## Turner Valley Group

LOCATION					DESCRIPTION					REMARKS			
Part	Section	Town-ship	Range	Meridian	At or near village, lake, river, etc.	Year made	Elev-ation (above sea-level) Feet	Total depth in feet	Yield	Charac-ter of water	To first rock Depth in feet	No. of samples received	(Local name, pool, district, name of drilling company, driller, casing, temperature, etc., etc.)
N.E. 1/4 S.E. 1/4	4	14	II	W. of 5th.	Rice creek...	1924	.....	600	.....	.....	.....	.....	Imp. Oil (Rice creek)
	29	14	II	"	Willow creek...	1919/24	.....	3,602	Gas	.....	.....	84	Imp. Oil No. 1
	31	19	II	"	Lineham.....	/24	.....	3,535	Gas	.....	134	29	Western Pacific Oil Co. No. 1
N.W. 1/4	6	20	II	"	Okotoks.....	1907/24	.....	3,924	Gas	.....	.....	125	Royalite No. 1
" "	6	20	II	"	"	1914/24	3,415	3,175	Gas	.....	54	231	" No. 2
	6	20	II	"	"	1921/24	3,911	2,840	Gas	.....	.....	265	" No. 3
	7	20	II	"	"	1923/24	.....	3,740	Gas	.....	.....	241	" No. 4

## Sweet Grass Group

29	1	XI	W. of 4th.	St. Kilda.....	1922/24	3,270	2,650	Gas	Fresh	.....	20	Canadian Oil Refinery (Rogers No. 1)
32	1	XI	"	.....	/24	.....	1,020	"	"	.....	.....	Northwest Co., Ltd. No. 2, Dead Horse coulee
5	1	XVI	"	.....	1922/24	3,545	2,700	"	Sulphur	.....	209	Imp. Oil, N.W. Co., Red coulee

## Wainwright-Irma Group

S.W. cor.	36	45	VII	W. of 4th.	Wainwright...	1924	2,188	2,107	Gas	Fresh	160	81	British Pet. No. 1
"	29	45	VI	"	"	1924	2,304	2,150	Oil	Salt..			British Pet. No. 3 (also 370 feet core samples)
"	30	45	VI	"	"	1924	2,251.5	2,036	Oil			12	British Pet. No. 4 (also 52 feet core samples)
"	20	45	VI	"	"	1924	2,270	807	Gas	Fresh...		61	Western Consolidated No. 1
"	24	45	VIII	"	Fabyan...	1924	1,992	1,776	Gas...	Saline...	10	46	Maple Leaf No. 1
"	18	45	VII	"	Grattan...	1921/24	2,040	2,730	"	"		182	Imp. Oil, Fabyan No. 1
"	14	45	VIII	"	"	1923/24	1,954	2,015	Oil	"	80		Imp. Oil, Grattan No. 2
"	28	45	IX	"	Irma...	1923/24	2,252	110	Gas			5	Irma Oil holdings
N.E....	19	44	IX	"	"	1924		180				10	Jas. Bell

## Medicine Hat Group

N.W. 4...	14	11	VI	W. of 4th.	Bullshead Sta.	1924		550	Gas	Saline...		15	Medicine Hat Pet. Co., No. 3
"	6	13	V	"	Crescent Heights	1924		1,118	Water	Fresh...			Roth, C. E., for city of Medicine Hat
"	12	13	VII	"	Redcliffe...	1924		784.5	Gas...		180		Geo. Worthy No. 1

## Pakowki Lake Group

S.W. 4...	10	5	VIII	W. of 4th.	Pakowki lake.	1922/24		2,900	Gas	Water			Thompson Oil Co., Sanctuary No. 1
"	6	7	IX	"	Nemiscam...	1924		680	Flowing water				Antelope Reserve (J. R. Fortune)

## Records Received from the Prairie Provinces—Continued

## Foremost Group

LOCATION						DESCRIPTION						REMARKS	
Part	Sec- tion	Town- ship	Range	Meridian	At or near village, lake, river, etc.	Year made	Elev- ation (above sea- level) Feet	Total depth in feet	Yield	Charac- ter of water	To first rock Depth in feet	No. of samples received	(Local name, pool, district, name of drilling company, driller, casing, temperature, etc., etc.)
S.E. 4...	1	6	XI	W. of 4th.	Foremost....	1923/24	3, 013	2, 191	Gas....	Mineral....	.....	.....	Canadian Western Natural Gas, Light, Heat, and Power Co. Nos. 1-4 (Foremost)
	29	5	X	"	"	1923/24	3, 001.8	2, 215	"	.....	.....	.....	
	36	5	XI	"	"	1923/24	2, 875.7	2, 070	"	.....	.....	.....	
	12	6	XI	"	"	1923/24	3, 070.8	2, 252	"	Fresh...	.....	.....	

## Barnwell Group

32	9	XVII	W. of 4th.	Barnwell....	1922/24	2,693.2	2,188	Gas....	.....	.....	.....	.....	C.W.N.G. L. H. and P. Co. No. 7 (Chin coulée)
29	9	XVII	"	"	"	1922/24	2,721	2,470	.....	.....	.....	.....	C.W.N.G. L. H. and P. Co. No. 8 (Chin coulée)

## Many Island Group

34	13	II	W. of 4th.	.....	1923/24	2,368	2,665	Gas....	Fresh....	.....	.....	47	Many Island Oil and Gas Co. (Drazen No. 1)
31	13	I	"	.....	1923/24	.....	1,315	"	.....	.....	89	.....	Can. American Oil and Gas

*Peace River Group*

24	85	XXI	W. of 5th.	Peace River...	1924	1,025	305	Salt...	.....	.....	Peace River Oil Co. No. 4
11	85	XXI	"	"	1923/24	1,140	2,940	.....	.....	.....	257 Can. Pet. Gas and Oil
23	74	XVII	"	High Prairie	1923/24	.....	2,205	Saline	.....	.....	Prairie Oils, Ltd. No. 1
17	89	IX	W. of 4th.	McMurray...	1924	.....	49	.....	24	.....	6 Alberta Salt Co. No. 2
26	80	XIII	W. of 6th.	Pouce-Coupé.	1921/24	.....	3,057	Gas...	.....	.....	302 Northwest Co. No. 1

S.E. 1/4...

*Fort Norman Group*

.....	40 miles	below	Norman..	Bosworth creek	1924	.....	975	Gas and oil	.....	.....	Imperial Oil Co. (Discovery No. 2)
.....	.....	.....	"	Bear island...	1923/24	.....	2,304	.....	.....	.....	212 Imperial Oil Co. ("D" Location)
.....	.....	.....	"	.....	1923/24	.....	1,705	.....	.....	.....	Imperial Oil Co. ("C" Location No. 1)
.....	.....	.....	"	.....	1923/24	.....	3,057	.....	.....	.....	478 Imperial Oil Co. ("C" Location No. 2)
.....	8 miles	below	"	Blue Fish creek	1921/24	.....	500	.....	30	.....	45 Imperial Oil Co. (Location B)

*Mafeking Group*

33	42	XXVI	W.P.M..	Mafeking.....	1923/24	.....	1,360	.....	.....	.....	22 Northern Manitoba Oil Co. No. 3
3	42	XXXVI	"	"	1923/24	1,063	977	Gas and oil shows	Fresh and brackish	.....	99 Porcupine Mountain Oil and Gas No. 2

*Pasquia Hills Well*

5	51	II	W. of 2nd.	Pasquia hills.	.....	.....	300	.....	.....	.....	27 Mann River Oil and Gas Co.
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*Records Received from the Prairie Provinces—Continued*  
*Luscar Group*

LOCATION					DESCRIPTION						REMARKS		
Part	Section	Township	Range	Meridian	At or near village, lake, river, etc.	Year made	Elevation (above sea-level) Feet	Total depth in feet	Yield	Character of water	To first rock Depth in feet	No. of samples received	(Local name, pool, district, name of drilling company, driller, casing, temperature, etc., etc.)
						1923/24	5,390	843			5		Luscar Colleries No. 1 (D.D. cores)
						1923/24	5,395	406			13		Luscar Colleries No. 2 (D.D. cores)
						1923/24	5,346	756					Luscar Colleries No. 3 (D.D. cores)
						1923/24	5,238	815					Luscar Colleries No. 4 (D.D. cores)
						1923/24	5,221	1,101					Luscar Colleries No. 5 (D.D. cores)
						1923/24	5,353	595			36		Luscar Colleries No. 6 (D.D. cores)
23	47	XXIV	W. of 5th.		Luscar mine.	1923/24	5,376	792	Bored for coal		57		Luscar Colleries No. 7 (D.D. cores)
						1923/24	5,352	683			8		Luscar Colleries No. 8 (D.D. cores)
						1923/24	5,449	463			15		Luscar Colleries No. 9 (D.D. cores)
						1923/24	5,355	557			20		Luscar Colleries No. 10 (D.D. cores)
						1923/24	5,355	457			5		Luscar Colleries No. 11 (D.D. cores)

## Other Borings

31	6	XXI	W. of 3rd.	Eastend.....	1924	3,000	1,245	Fresh...	.....	.....	Eastend Gas Co. No. 1
34	25	IV	W. of 4th.	Oven.....	1924	2,800	1,680	.....	.....	.....	Euego Oil Co. No. 1
3	49	XXI	W. of 5th.	Coalspur.....	1924	3,776-3	2,880	Gas....	.....	.....	Northwest Co. Coalspur No. 2
12	10	XXIV	W. of 4th.	Monarch.....	1920/24	3,092-6	2,813	Gas....	100	.....	C. W. N. G. L. H. and P. Co. No. 2
16	6	XIII	W. of 4th.	Skiff.....	1924	.....	702	.....	.....	.....	Fortune, J. R., for Geo. Privetziff
14	47	XXVII	W. of 4th.	.....	1924	2,450	1,175	.....	.....	.....	Mutual Oil and Gas Development Co.
14	50	XII	W. of 4th.	Birch lake....	1924	2,107	2,411	Gas....	.....	.....	United Dominion Petroleum No. 1

Most of the records listed are located in southern and central Alberta. The balance represent scattered borings in Alberta and some located at points along Peace River valley and in the vicinity of McMurray and Norman in the North West Territories, together with records from two borings which commenced in the Cretaceous close to its eastern escarpment in Manitoba and northern Saskatchewan. These wells along the eastern edge of the Cretaceous are of special interest as giving knowledge of the Cretaceous and of the underlying Palæozoic, in addition to that resulting from the chain of borings made in past years along the southerly extension of this escarpment. This series of well records also gives an interesting geological section beginning in the Benton shales and extending down through the basal Dakota sandstone for some depth into the underlying limestones, etc., of Devonian age. Through the acquisition in 1923 of a very complete set of samples from the boring at Winnipegosis put down by the Manitoba Government in 1921-22, the Palæozoic section was completed down to the old Precambrian sea bottom.

Apart from records accumulated, which were made out by the drillers or field geologists of the various companies, over 3,000 samples of drill cuttings were received from operators during the year. These were recorded and systematically filed away so as to be available for examination in connexion with geological studies in the future. Where need arose and time permitted, the series of cuttings from certain wells have been intensively studied by laboratory methods and the results placed at the disposal of the geologists in charge of the field work or of the operators. This intensive study of the cuttings from the sedimentary strata by microscopic and chemical methods is necessarily tedious and time-consuming and so can only be undertaken for specially selected wells. Furthermore, this research constituting a comparatively new branch of geological science, much time is consumed in working out methods experimentally. This matter is dealt with by Mr. D. C. Maddox of the division staff, who is entrusted with this phase of the work, and who reports as follows:

The location of geological horizons within the Great Plains region is rendered unusually difficult by the fact that the formations present a long succession of shales, with subordinate sandstones, in which neither the colour nor the lithology presents any marked differences or characteristics. The laboratory methods employed in these cases were of necessity much more detailed than those which were found serviceable in the eastern fields. The greater detail inevitably caused slower progress, and the use of certain tentative methods, the value of which could not be determined until the results from several wells were compared, also required considerable time.

The disintegration method, used on weighed charges of material, involved an optical examination of the sands left after screening the wet mud. It also included the identification when possible of the chief minerals, rocks, and fossils, as well as a very rough estimate of their relative abundance. Certain other mechanical tests, such as a rough comparison test of the volume of the disintegrated material, were made. A chemical test for the  $\text{SO}_4$  ion also formed a part of the routine method.

The value of a detailed examination of a sample depends upon the care with which that sample has been taken, and on its freedom from admixture with matter from above. This fact was kept in view in choosing material for detailed examination.

Core samples taken at certain critical horizons in British Petroleum's Wells Nos. 3 and 4, in the Irma-Wainwright field, were subjected to detailed examination. Eighty-five disintegration tests were made, and the cores were also subjected to a rigorous preliminary examination. Acid tests for the presence of carbonates were also made at close intervals. Among the results obtained by this work the following are of interest:

The location of a glauconite horizon in both wells. In both, the associations with microcrystalline pyrite and with an ironstone band were similar.

Numerous ironstone bands and bentonite layers were located. Although these might have proved of value for correlation purposes the very short length of samples from well No. 4 available for comparison with well No. 3, largely discounted their value.

An horizon high in foraminifera was located towards the base of well No. 3 and permanent mounts of a number of these fossils were made.

A calcareous horizon in the upper part of well No. 3 was located.

Three horizons containing a conglomeratic sandstone were located.

Numerous scales and other remains of fish were found, also shell fragments.

A graphic log showing the results was prepared.

Western Consolidated well No. 1 in the Irma-Wainwright field used a standard drill rig and sent samples for examination. A method generally similar to that used in the examination of the samples from the British Petroleum's well was followed in this work and a graphic log was prepared. The nature of the material naturally rendered the results of less value than in the case of the core samples.

Disintegration tests were undertaken on samples from the "Roger's Imperial" well in southern Alberta. Twenty samples in all were received and examined.

Drazan No. 1, the well of the Many Islands Oil and Gas Company, provided a series of samples, but as a rotary outfit was used in drilling the well, very little value could be attached to any results of their examination. However, a few bit and core barrel samples were included and were tested by the usual methods.

Some of the results of the examinations made as above described, of samples from the borings of the North Battleford Oil and Gas Company and from the British Petroleum's wells Nos. 3 and 4, follow:

## NORTH BATTLEFORD OIL AND GAS COMPANY

*Pasquia Hills, Section 5, Township 51, Range V, West of 2nd Meridian*

Feet	Feet	
Surface	to 50	Surface deposits
50	to 90	Dark grey shale
90	to 100	Brownish grey shale. Sand 10.5 per cent
100	to 200	Dark grey shale. Sand 2.5 per cent at base
200	to 210	Brownish grey shale
210	to 220	Light grey shale
220	to 230	Purplish brown shale
230	to 300	Light grey shale. Sand content: 230-240 feet less than 1 per cent 270-280 feet 1.6 per cent 290-300 feet 1.8 per cent
300		Ironstone band containing about 70 per cent of ferrous carbonate

*Results of Examination of Core Drill Samples From British  
Petroleum Limited Wells**By D. C. Maddox**Well No. 3, Section 29, Township 45, Range VI, West of 4th Meridian, Elevation  
2304.3 Feet*

Depth represented		Actual length	Sulphate reaction	
From	To			
Feet	Feet	Feet		
1,300	1,307	2.3	Decided	Grey, calcareous shale, white shell fragments at base.
1,307	1,314	Missing	.....	
1,314	1,321	2.9	Decided	Grey, mottled, calcareous shale, numerous shell fragments.
1,321	1,324	2.0	"	Grey, mottled, calcareous shale, small biotite flakes in upper part. Numerous shell fragments; small oyster shells at base.
1,324	1,328	3.3	"	Grey, mottled, calcareous shale. Very calcareous at centre with many shell fragments; thin oyster shells at base.
1,328	1,336	3.9	"	Grey, calcareous shale. Thin oyster shells near top. Fish scales in centre. A narrow band of <i> bentonite </i> near top.
1,336	1,344	8.0	Medium	Grey, mottled, calcareous shale. Thick shell fragments, probably <i> Inoceramus </i> , at centre.
1,344	1,352	4.5	Decided	Grey, mottled, calcareous shale. very highly calcareous horizon at centre. A cubic pyrite horizon near top.
1,352	1,711	Missing	.....	
1,711	1,716	3.5	Decided	Dark grey, non-calcareous shale. A few carbonaceous fragments at top. Numerous sand partings at close intervals.
1,726	1,744	6.75	Slight	Dark grey shale. <i> Bentonite </i> band at 5.5 feet containing biotite flakes. <i> Bentonitic </i> shale at top and near base. Much pyrite at 5-6 feet.
1,744	1,752	8.0	Slight	Dark grey shale.
1,748	1,756	8.0	"	Dark grey shale.
1,756	1,757	.....	.....	Dark grey shale.
1,757	1,766	3.5	.....	Dark grey shale, harder than normal. Sand partings at 1.5 and 2.8 feet. Fish scales in upper 0.5 feet.
1,766	1,776	Missing	.....	

## Well No. 3 (Continued)

Depth represented		Actual length	Sulphate reaction	
From	To			
Feet	Feet	Feet		
1,776	1,784	7.0	.....	Dark grey shale, harder than normal. <i>Bentonite</i> bands at 1.75 and 4.1 to 4.4 feet.
1,784	1,792	8.0	.....	Dark grey shale.
1,792	1,800	8.0	.....	Dark grey shale. Sand partings at 0.1, 5.3, 5.8, 6.3, 7.0 feet. Glauconite in rounded grains at 6.4 to 6.5 feet with quartz grains, fish remains, and a little pyrite. A few foraminifera at 4.0 feet.
1,800	1,806	5.0	.....	Dark grey shale. Ironstone? band at 3.2 to 3.5 feet. A glauconitic sandy horizon with microcrystalline pyrite just above this. Sand band at 1.8, 3.75, 4.1, 4.5 to 4.6 feet.
1,806	1,812	6.0	.....	Dark grey shale. Ironstone? band at 2.3 to 2.4 feet. Sand partings in lower 2.0 feet. Hard layer at top.
1,812	1,815	3.0	.....	Dark grey shale. Sand partings at frequent intervals throughout.
1,815	1,820	4.0	Trace	Dark grey shale. Ironstone bands at 0.1 to 0.3 feet. Closely spaced sandy partings at 1.7 to 4.0 feet.
1,820	1,828	Missing		
1,828	1,830	3.6	Decided	Dark grey shale. Sand partings at close intervals, especially in the upper 2.3 feet. Fish scale.
1,830	1,842	6.6	.....	Dark grey shale. Ironstone band at 6.2 feet.
1,842	1,844	1.15	.....	Dark grey shale. Sand partings at intervals.
1,844	1,852	7.7	Decided	Dark grey shale. Sand partings at 3.1, 6.2, and 6.8 feet.
1,852	1,860	7.4	.....	Dark grey shale. Ironstone band at top.
1,860	1,868	7.9	.....	Dark grey shale. Ironstone band at 4.6 to 4.8 feet.
1,868	1,876	8.0	.....	Dark grey shale. Ironstone band at top and at 4.5 feet.
1,876	1,886	7.5	.....	Dark grey shale. Ironstone band at 3.2 to 3.3 feet. At 2.2 feet some small, rounded, black pebbles with sharks teeth and vertebrae and jaw-bones, spines of bony fishes.
1,886	1,896	8.0	.....	Dark grey shale.
1,896	1,904	8.0	.....	Dark grey shale. Ironstone band at 1.1 to 1.6 feet and 2.2 feet.
1,904	1,912	8.0	.....	Dark grey shale. Ironstone bands at 0.6 to 0.8 feet and 4.3 to 4.4 feet.
1,912	1,921	8.0	.....	Dark grey shale.
1,921	1,931	7.5	.....	Dark grey sandy shale. Sand partings at frequent intervals throughout. Ironstone bands at 2.4 to 2.6 feet and 6.0 to 6.35 feet. Shaly sandstone with small black pebbles 7.4 to 7.6 feet.
1,931	1,939	8.0	.....	Dark grey shale, slightly sandy. Sand partings throughout, especially numerous at centre.
1,939	1,948	8.0	.....	1.8 to 2.55 feet very fine bituminous sand with shale partings. 2.55 to 4.1 feet shale with frequent sand partings, 4.1 to 5.0 feet bituminous sand, coarser than previous with shale partings becoming very shaly at base. Below 5.0 feet material very much broken up and difficult to decipher. An ironstone band at 6.4 feet.
1,948	1,957	8.0	Slight	Dark grey, sandy shale. Closely spaced sand partings in upper 3 feet; 3 to 5 feet very sandy with some small black pebbles. The upper 4 feet is bituminous. 5 to 8 feet sandy shale.
1,957	1,964	7.0	.....	Dark grey shale. A few widely spaced sand partings.
1,964	1,972	8.0	Slight	Dark grey shale. A sandy horizon at 4.5 to 6.5 feet.
1,972	1,978	8.0	.....	Dark grey shale. Ironstone bands at 4.4 to 4.5 feet.
1,978	1,986	8.0	.....	Dark grey shale. Numerous sand partings 2.0 to 3.0 feet.
1,986	1,994	8.0	.....	Dark grey shale. A few scattered sand partings. Shale rather bentonitic.

## Well No. 3 (Continued)

Depth Represented		Actual length	Sulphate reaction	
From	To			
Feet	Feet			
1,994	2,000	7.5	.....	Dark grey shale. A few scattered sand partings. Shale rather bentonitic.
2,000	2,007	7.0	.....	Dark grey shale. Sand band near top. Shale rather bentonitic.
2,007	2,018	7.0	.....	Dark grey shale. A few scattered sand partings. <i>Bentonite</i> band 2.45 to 2.7 feet.
2,018	2,021	2.2	.....	Dark grey shale. A few scattered sand partings. Ironstone band at 2.3 feet.
2,021	2,035	8.0	Trace	Dark grey shale. A few scattered sand partings. <i>Bentonite</i> band at 7.3 feet.
2,035	2,039	2.4	.....	Dark grey shale.
2,039	2,039.5	0.5	.....	Ironstone band.
2,039.5	2,044	5.6	.....	Dark grey shale with scattered sand partings. <i>Bentonite</i> band at 0.5 feet.
2,044	2,054	8.0	.....	Dark grey shale; many foraminifera.
2,054	2,064	7.5	.....	Dark grey shale; <i>bentonite</i> fragments in shale from 3.8 to 7.5 feet. Many foraminifera.
2,064	2,070	7.0	.....	Dark grey shale; many foraminifera.
2,070	2,080	4.9	Trace	Dark grey shale; ironstone band 1.0 to 1.7 feet.
2,080	2,086	2.7	.....	Black shale.

## Well No. 4, Section 30, Township 45, Range VI, West of 4th Meridian, Elevation 2251.9 Feet

1,712	1,722	8.0	Decided	Dark brownish grey, sandy shale. Numerous fish scales. Hard band 2.0 to 3.0 feet.
1,724	1,728	4.8	.....	Dark grey shale. Upper 3.2 feet sandy. <i>Bentonite</i> band 3.2 to 4.8 feet.
1,728	1,735	7.0	.....	Dark grey shale. Fish scales numerous at 0.7 to 0.8 and 5.8 feet.
1,735	1,742	3.2	.....	Dark grey shale.
1,741	1,749	7.2	Slight	Dark grey shale. Upper 1.5 feet sandy.
1,749	1,757	6.5	.....	Dark grey shale. Closely spaced sand partings in the upper 2.0 feet and more widely spaced partings in the lower part. Ironstone band 1.6 to 1.7 feet and immediately above this an horizon of very fine-grained glauconite associated with microcrystalline pyrite. (Compare with 1,800 to 1,806 in Well No. 3.)
1,757	1,759	1.5	.....	Dark grey shale with a few sand partings.
1,759	1,840	Missing	.....	
1,840	1,846	.....	Slight	Dark grey shale.

In the above "bentonitic shale" refers to shale containing sufficient colloidal matter to "jelly" in concentrations of about 1 in 5 of water. "Rather bentonitic shale" refers to shale which in a similar concentration expands sufficiently to absorb all the water, but does not "jelly".

## OTHER FIELD WORK

### *Geological*

M. Y. WILLIAMS. Mr. Williams continued a systematic resurvey of the geological succession, structure, and mineral resources of an area in southern Alberta and adjacent parts of Saskatchewan and British Columbia, extending from the International Boundary north to latitude  $52^{\circ}$  and from longitude  $109^{\circ}$  west to  $115^{\circ} 30'$ . This work was begun in 1923, jointly by Mr. Williams and the late E. J. Whittaker. During 1924, owing to the illness of Mr. Whittaker, his share was carried on by A. J. Childerhose.

B. R. MACKAY. Mr. MacKay commenced a detailed geological survey of the coal measures and associated strata in the vicinity of Mountain park, on the Canadian National railway in western Alberta. An area of 400 square miles was mapped, for publication on a scale of 1 inch to 1 mile. Publication of a report and maps is being withheld until the investigation has proceeded further, but hand-coloured geological plans of the coal measures are being prepared for the interim use of coal mining companies within the area.

B. ROSE. Mr. Rose completed the investigation and geological mapping of the coal deposits and related rock formations in Blairmore map-area, southwestern Alberta. A report upon this work and a revised issue of Blairmore map-sheet are now being prepared.

C. M. STERNBERG. Mr. Sternberg collected fossil remains of dinosaurs and other extinct vertebrate animals, from the bad lands of Red Deer river, Alberta. The following specimens were obtained.

Parts of vertebral column, limbs, and ribs of *Ornithomimus*.

Skull, dorsal vertebrae and ribs, and parts of limbs and tail of a new species of armoured dinosaur.

Part of skull of a horned dinosaur.

Part of skull of a species of *Edmontosaurus*.

Carapace and plastron of a turtle (*Basilemys*).

Skull of *Anchiceratops* sp., horns of *Anchiceratops ornatus*.

Most of a skull of *Thespesius* sp.

An elephant tooth and various fossil plants.

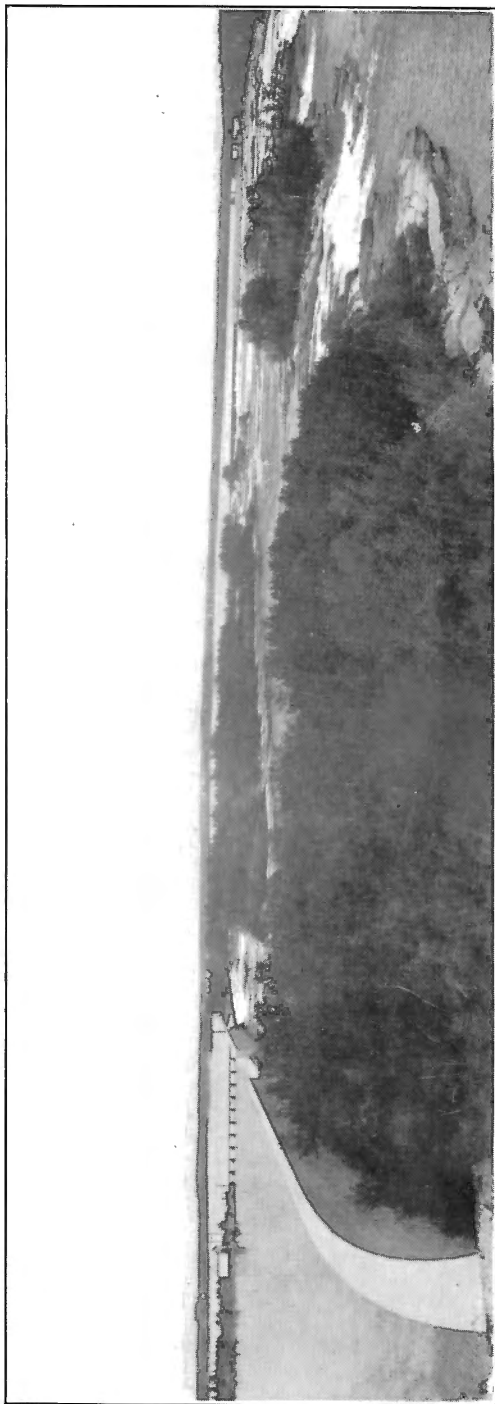
### *Topographical*

W. H. MILLER. Mr. Miller continued the topographical mapping of the coal-bearing district south and southeast of Mountain park, Alberta. In all, about 210 square miles were covered this year, and, together with the work carried out in 1921, an area of 360 square miles, lying between latitudes  $52^{\circ} 45'$  and  $53^{\circ} 00'$ , and longitudes  $117^{\circ} 00'$  and  $117^{\circ} 30'$ , is completed. About 90 square miles to the east and adjoining this area was also mapped.

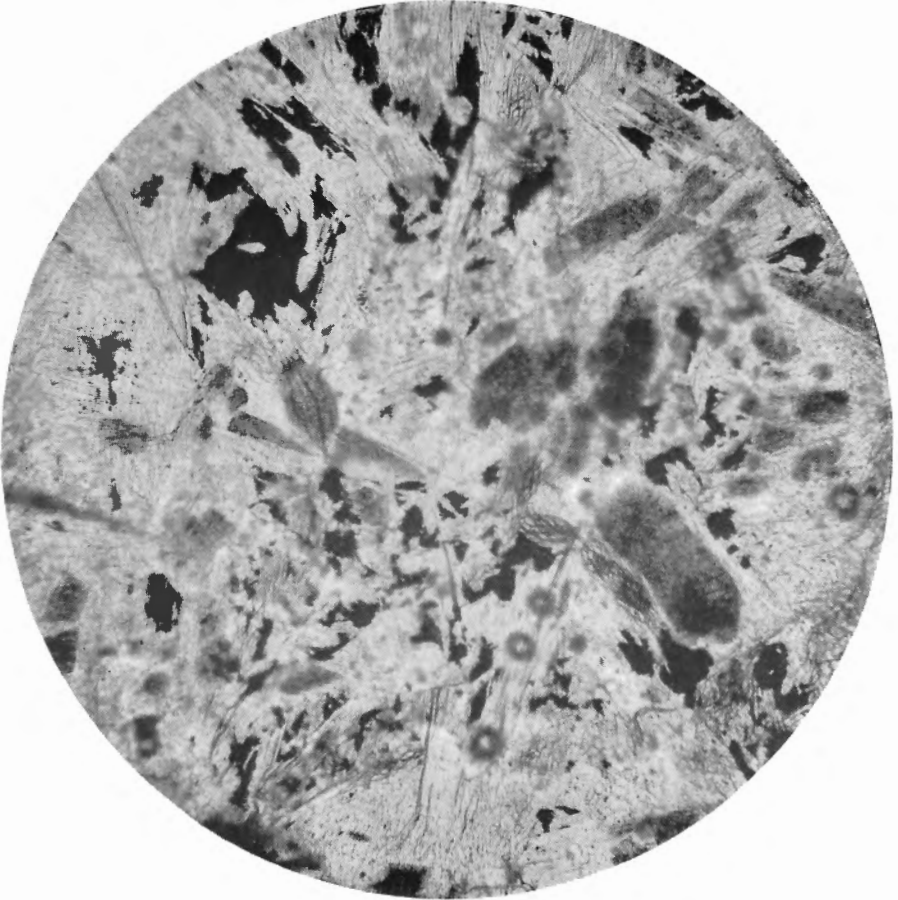
J. W. SPENCE, junior topographical engineer, had charge of a sub-party on this work.

R. C. MACDONALD. Mr. Macdonald made geographical control surveys for geographical and geological work, of an area in northern Manitoba, lying between latitudes  $54^{\circ} 00'$  and  $56^{\circ} 00'$ , and longitudes  $93^{\circ} 00'$  and  $96^{\circ} 00'$ . Approximately 1,100 miles of shoreline were mapped, based on a transit and micrometer traverse 590 miles in length. On account of the remoteness of the district and by reason of several, small, crooked streams that lay along the route surveyed, the mileage was not as large as in previous years. A portable radio receiving set was used for obtaining correct time, and many astronomical observations were taken. The position of Oxford House was determined in latitude and longitude by astronomic observations. One hundred and forty permanent posts were established along the route to serve as control for future work.

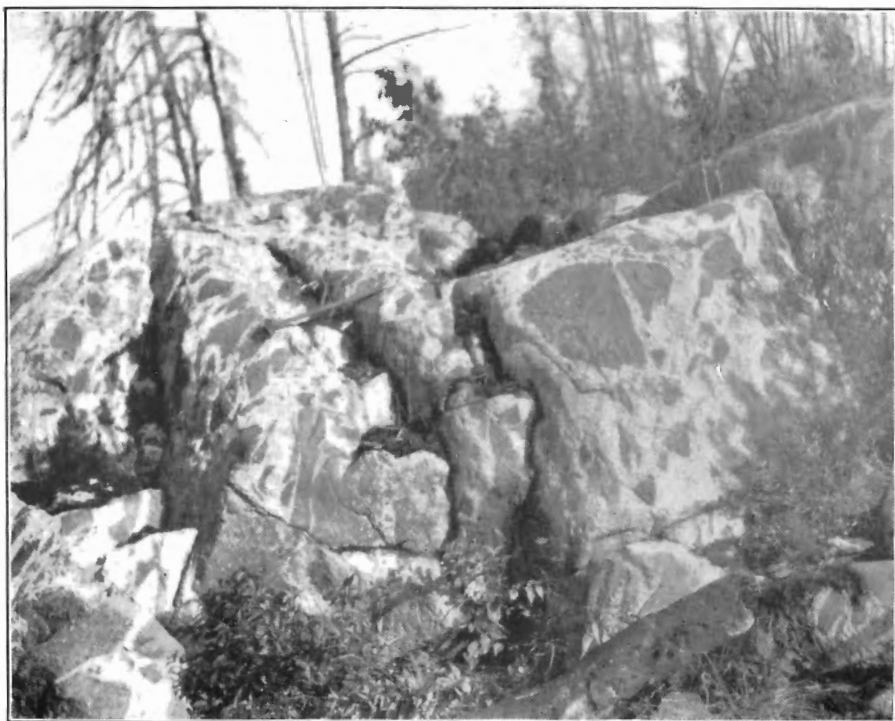
## PLATE I



General view looking north from the top of City of Winnipeg power plant, Pointe du Bois, shows even skyline, Winnipeg river flowing over a rock ridge from one basin to the next lower depression. (Pages 53, 57.)



Microphotograph of thin section of hornblendite from Chance claim; magnified 85 diameters. Light and dark grey mineral is hornblende, the dark grey areas are the central, green, unbleached parts of the crystals. Black areas are pyrrhotite or pentlandite which replaces the bleached hornblende. (Pages 73, 90.)



Inclusion of gabbro in granite, section 2, range 14, township 18. (Page 76.)

## PLATE IV



Lenses of quartz in granodiorite porphyry one-half mile north of Winnipeg river and near the southwest corner of section 25, range 16, township 16. (Page 80.)

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The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are three parts, A, B, and C. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.

C. T. Jones