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DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1928, Part B

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OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1929

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BRÛLÉ MINES COAL AREA, ALBERTA

By B. R. MacKay

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Illustrations

INTRODUCTION

The field season of 1927 was spent in a detailed examination of the Brûlé Mines Coal area, situated on the Canadian National railway, 180 miles due west of Edmonton.

As a result of intensive prospecting carried on through the Yellowhead pass in 1910 in anticipation of the construction of the Grand Trunk Pacific railway, coal was discovered on Scovil creek 9,000 feet west of Brûlé lake. In 1911, shortly after the decision was reached to build the Canadian Northern railway also through the pass along a route on the north side of the river where these coal deposits are located, the property was acquired by the McKenzie and Mann interests who incorporated their holdings under the name of the Brûlé Coal Company, Limited. Mining operations were begun in the spring of 1914 and have continued, with few interruptions, to the present. In 1917, following the merger of the Grand Trunk Pacific and the Canadian Northern railways into the Canadian National Railway system, the property was acquired by the McIntyre Porcupine Mines, Limited, and the Temiskaming Mining Com-

[1]Legend of Plate III erroneously states that limestones are Mississippian.

pany, Limited, each holding a half interest, and the name of the company was changed to Blue Diamond Coal Company, Limited. The total production of the mines has amounted to 1,836,743 tons of coal. The maximum output was obtained during 1922 and 1923 when very many mine pillars of No. 3 seam workings were extracted and this part of the mine abandoned. During 1924 the mine was practically idle, insufficient coal being extracted for local plant requirements, with the result that the stock piles had to be drawn upon. Mining was renewed in 1925, but since then the quarterly output has never exceeded 37,000 tons as compared with the output the first quarter of 1922, which amounted to 102,000 tons. In fact, since the reopening of the mine in 1925, the encountering of structural difficulties and areas of dirty coal has so increased the cost of obtaining a marketable product that the company several times seriously considered discontinuing operations permanently. This action was finally decided upon, and on July 20, 1928, mining operations ceased, with the result that not only has a large amount of capital invested in plant equipment been wholly lost, but an industry and resource of value to the country has been greatly impaired (*See* Plate I).

The writer was instructed to make a detailed survey of the coal measures in the hope that the results would assist the operating company more intelligently to plan their development program, and would throw light upon coal problems elsewhere in the mountain regions of Alberta and British Columbia. The Blue Diamond Coal Company was particularly anxious to learn what the possibilities were that the seams then being developed extended in a mineable condition into the undeveloped ground northwest of Scovil creek, and whether adjacent areas presented any possibilities of containing commercial seams.

A map prepared by A. C. T. Sheppard, Topographical Division, Geological Survey, on a scale of 1 inch to 800 feet with a contour interval of 50 feet, served as a base for the geological mapping. The map was considerably extended by the writer so as to take in additional areas of economic and structural importance and it now embraces approximately 10·2 square miles.

The writer desires to record his indebtedness to Mr. D. H. Macdougall, Managing Director, Mr. O. N. Brown, Mr. C. Graham, and other officials of the Blue Diamond Coal Company, for the many favours received and assistance rendered during the course of the work, for supplying mine plans and bore-hole records, and for detailing two labourers for trenching to aid in tracing coal seams. Thanks are also due the company for permitting the publication of considerable private information. Much of the old mine workings had been abandoned; it was, therefore, impossible to procure first-hand information in that part, and the structure of the coal seams as shown in Figures 1 and 2 and on transverse sections CD, is based on sections prepared with the assistance of Mr. O. N. Brown, General Manager, after a careful study of all the mine plans.

Messrs. I. W. Jones, F. Foreman, J. B. Bocock, and H. Hainstock were attached to the party as student assistants and each performed the duties assigned him in an efficient manner.

PREVIOUS WORK

In 1910 D. B. Dowling examined the coal fields of Jasper park, which embraces the Pocahontas and the Brûlé fields, and his results are given in the Summary Report for that year. The only coal seam then opened was a $9\frac{1}{2}$-foot seam on Scovil creek (apparently the Dickson prospect), which was sampled and analysed, but mention is made of a later discovery of three other seams measuring 10, 12, and 15 feet respectively. Dowling revisited the field in 1911 and records a 12-foot seam on the hill slope toward Brûlé lake, and a thin seam and a 5-foot seam on the upper part of Scovil creek at what is now known as the Bartholemew prospect.

In 1916 J. M. MacVicar examined the foothills coal areas north of the Grand Trunk Pacific railway. In the Summary Report for that year he gives a stratigraphic section of the coal measures on the property of the Brûlé Lake Coal Company furnished him by the company. More recent field work, however, has shown the recorded section to be inaccurate. Supplementary data pertaining to the stratigraphy and structure of the coal areas northwest of Brûlé lake are given by J. MacVicar in the Summary Reports for 1919 and 1923.

In 1922, 1923, and 1924 John A. Allan and R. L. Rutherford geologically surveyed the Foothills Belt from Saskatchewan river northwest to Athabaska river. Their results are contained in Reports 6, 9, and 11 of the Scientific and Industrial Research Council, Alberta, of which Report No. 11 by Rutherford deals with the area lying to the east of Athabaska river opposite Brûlé Mines coal area.

In 1924 James McEvoy examined Smoky River coal field, Alberta, for the Dominion Fuel Board, and in his report reference is made to the coal deposits at Brûlé.

The method of mining the deposit at Brûlé is described by Wm. G. Heeley, a mine manager of the Blue Diamond Coal Company, in two papers appearing in the Transactions of the Canadian Mining Institute for 1924 and 1925.

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GENERAL CHARACTER OF MAP-AREA

The Brûlé Mines map-area lies on the outer or eastern slope of the front range of the Rocky mountains and marks the junction of the rolling wooded foothills to the east and the high, rugged mountain country to the west. It is situated immediately west of the northern end of Brûlé lake, an expansion of Athabaska river, 7 miles long and ½ to 1 mile wide. The area rises from river level at an elevation of 3,226 feet with a gentle slope of 5 degrees to 6 degrees to an elevation of approximately 3,600 feet which marks the base of the mountain (*See* Plate II). Here there is an abrupt increase in slope to about 22 degrees which continues to near the crest of a northwesterly trending anticlinal ridge that attains its maximum elevation within the map-area, 5,909 feet, on Scovil peak 2 miles distant from the lake. Just beyond the southwestern corner of the map-area rise the precipitous Palæozoic cliffs of Boule range which mark the fault scarp of the Rocky Mountain overthrust here trending north 40 degrees west astronomic. The foothill area bordering the mountain is traversed by four easterly flowing streams, three of which, during pre-Glacial time, deeply incised their valleys in the soft Cretaceous sediments and gave to the upland a maturely dissected appearance. At this time the relief was at least 500 feet greater than at present.

During the Glacial period the whole map-area appears to have been covered by an ice-sheet, and a large glacier moved northward down the valley of Athabaska river, rounding off and polishing the valley spurs of Bullrush mountain. Although no glacial striæ or foreign boulders were observed on the summit of Scovil mountain, its smoothed surface points to it having been completely overridden. Numerous, large, limestone erratics, up to 15 feet in diameter, occur in the glacial drift on the hill-slope in front of the mountains. In the lowlands, and in the transverse valleys, the glacial drift is several hundred feet thick, and consists of boulders of local origin firmly cemented in a calcareous rock flour. On the hill-slopes in the vicinity of the mine and to the west of Scovil creek, trenching has proved the drift in places to be more than 20 feet thick. A large terminal moraine, deposited by the Athabaska River glacier, several miles to the east of the map-area, appears to have completely dammed the river, forming an extensive valley lake, approximately 2 miles wide and 60 miles long, which stood at least 350 feet higher than the present river level. Local evidence of this lake is presented by the wave-cut cliffs which occur on sandstone outcrops between Brewster creek and Oldhouse creek at an elevation of 3,500 feet, and by the deposits of stratified gravel and silt which cover bedrock and glacial drift to an elevation of about 3,540 feet. That most of this alluvium was deposited by the tributary streams that entered the lake is indicated by the four prominent coalescing alluvial fans that form the lowland and whose outlines are clearly shown by their topography and by the lobate form of the western shoreline of Brûlé lake. The alluvial fan of Supply creek reaches lakewards to 3,500 feet from the eastern shore. Bore-hole 37, sunk at a point between the fans of Supply and Scovil creeks, half a mile distant from the lake shore and at an elevation of 3,360 feet, reached a depth of 492 feet without encountering bedrock, thus indicating the great amount of filling that has taken place. The tributary streams which supplied this material have in places completely cut through the firmly cemented boulder clay, exposing on one side or other of their channels rock shoulders of the preglacial valley spurs. As Athabaska river lowered its channel through the drift filling it assumed in places a different course and exposed a few miles east of the map-area a rock barrier which retarded erosion of the post-glacial channel and caused the superficial deposits along its banks upstream to be carved into a series of immature terraces. These are not so well developed, however, on the west side of Athabaska river as they are on the east. The most pronounced terrace within the map-area is the one lying 2,500 feet east of the mine tipple at an elevation of 3,400 feet. This terrace marks the upper limit of conspicuous deposits of fine grey silt which contain several thin marl beds carrying numerous freshwater shells. These shells are similar to those now found in the river and indicate a climate comparable with the present. Recent stream floods have in places cut channels into these glacial fans, re-sorted the gravels and built upon them secondary fans and deltas, making it almost impossible to distinguish the fluvioglacial deposits from those of recent origin. A number of small alluvial cones and fans are also to be found at the mouths of the smaller valleys cut in the hill-slope.

The greater part of the map-area is covered with a new forest growth consisting largely of jackpine which has sprung up on the dry, burnt soil left by the fires that swept through the district about one hundred years ago. Patches of old growth of spruce and balsam are to be found in the swamp areas and on the northern slopes of the hills and in the higher valleys which escaped these fires. Poplar is found in the flats and along the base of the hills, whereas alder and willow occur sparingly throughout the area, except on the patches that are still covered by a mass of deadfall.

A large assortment of game is present in the area, being protected throughout the year by the regulations governing Jasper park. Black bears are very abundant and pay frequent visits to the town. Mountain goats are plentiful and were frequently seen grazing on the grassy slopes at the base of the cliff of Boule range. Bighorn sheep are sparingly found on the limestone range: mule deer were frequently observed on the grassy willow-covered flats bordering the railway track. Moose, caribou, and elk were not encountered, but are reported from the area. Rabbits are numerous; porcupine, mink, beaver, muskrat, squirrel, and chipmunk are also present. Ptarmigan and Franklin grouse, commonly known as the foolhen, geese, and ducks were the most common game birds observed. Whitefish and trout inhabit Brûlé lake.

GENERAL GEOLOGY

General Statement

All the solid rocks exposed within the map-area are of Cretaceous age, with the exception of possibly 90 feet of strata outcropping as a small "window" in the gorge of Brown creek at the crest of the anticline, which may be of Jurassic age. Palæozoic rocks forming Boule mountain and overthrust upon Lower Cretaceous measures occur within a few hundred feet of the south corner of the map-area (*See* Plate III) and these, with Triassic and Jurassic sediments, outcrop 8 miles southeast of Brûlé on the northern slope of Folding mountain and undoubtedly underlie the outcropping strata of the map-area.

The Cretaceous rocks present embrace sediments of Lower Cretaceous and Upper Cretaceous age. The Lower Cretaceous strata, which have generally been referred to as the Kootenay, consist of continental deposits of sandstone, shale, conglomerate, and coal, and the Upper Cretaceous rocks of marine shales. The various formations are practically identical with those of Mountain Park district 40 miles southeast, and some of the formations have been traced from one area to the other. The intensely folded and faulted character of the Cretaceous strata at Brûlé makes impossible an accurate determination of the thickness of most of the formations.

Table of Formations

			Approximate thickness, feet	Character
Quaternary......		Recent and Pleistocene	0-500+	Stream gravels and sand; fluvioglacial gravels and sands; lacustrine silts and marls; boulder clay and erratics
Upper Cretaceous	Colorado.......	Blackstone.....	1,700±	Dark fissile marine shales with occasional sandy clay concretions
Lower Cretaceous	(Kootenay group of various authors)	Luscar (may contain some Mountain Park formation)	1,950±	Sandstones, shales, and coal seams
		Cadomin conglomerate	25±	Massive conglomerate composed of chert, quartzite, and quartz pebbles
		Nikanassin (May contain some Jurassic beds)	1,200±	Thin-bedded, fine-grained, ripple-marked sandstones and hard, dark shales

Description of Formations

LOWER CRETACEOUS

The term Kootenay has been used to designate a group of continental strata stratigraphically above the marine Jurassic and below the marine Colorado beds; the term has also been used to designate only a part of the group of continental strata. The term Kootenay (also spelt Kootanie) was first proposed by Sir William Dawson[1] for the plant-bearing Lower Cretaceous strata in the Rocky mountains south of Bow river. Eventually the Kootenay in that region came to be defined as the coal-bearing Lower Cretaceous strata that rest on the Jurassic and are overlain by the plant-bearing Blairmore beds. Thus, south of Bow river the term Kootenay has a distinct age significance. On the assumption that the Lower Cretaceous coal deposits, which extend along the front of the Rocky mountains from the International Boundary to Smoky river, were all of the same horizon, the name Kootenay has been applied to the coal-bearing measures of these fields as they were successively described. During the summer of 1927 a large and representative collection of the flora of the coal-bearing beds of the Luscar formation of Brûlé area was made and the study of these by W. A. Bell points to them being of Blairmore rather than Kootenay age. It appears best, therefore, until more evidence is obtained as to the age relationship of these northern coal-bearing beds, to discontinue the use of the name "Kootenay."

In Brûlé area the Lower Cretaceous strata are divided into three formations, the Nikanassin formation below, the Cadomin conglomerate, and the Luscar formation above. A still higher mapable unit named the Mountain Park formation was made use of in Mountain Park district to designate hard, olive-green, non-coal-bearing shales and sandstones and conglomerate overlying the Luscar (coal-bearing) formation and which previously had been wrongly designated as being the "Dakota" formation. These beds, if present at Brûlé, have lost their characteristic greenish hue and ridge-forming character and are included with the Luscar formation.

Nikanassin Formation

The lowermost strata exposed within the map-area consist of a series of interbedded continental deposits of grey, brown-weathering sandstones and dark and sandy shales. The sandstones are fine-grained, hard, thin-bedded, slabby, and ripple-marked. The shales are in places carbonaceous and show many irregular markings which appear to be worm tracks. Although several, small, coaly streaks and seams were noted in the formation, no seams of commercial thickness have yet been discovered; with this exception these beds agree closely in lithological character with those lying above the conglomerate. As these strata correspond in stratigraphical position and lithological character with the

[1]Proc. and Trans., Roy. Soc. of Canada, vol. 3, pt. IV, pp. 1-22 (1886).

lowermost of the Lower Cretaceous formations of Mountain Park district, designated the Nikanassin formation, it is proposed to use the same name in Brûlé area.

This formation underlies a belt of territory averaging a half mile in width extending along the northwestern border of the map-area and occupying the crest of the major anticline. Owing to the heavy blanket of drift and forest cover outcrops are relatively few and are confined largely to summits, rock cliffs, and gorges. Nowhere is it possible to obtain a complete section of the formation, as the upper part of the formation is concealed. The most nearly complete section obtainable occurs on Brown creek and has a measured thickness of 1,046 feet. This is as follows:

Section of Nikanassin Formation on Brown Creek

(In descending order)

Character of beds	Thickness of beds
Thin-bedded, sandy shale	10
Thick-bedded, hard, brown sandstone	55
Grey shale with sandy beds	6
Brown weathering sandstone with shale partings	2
Dark, fissile shales	9
Hard, massive sandstones	7
Dark shale	5
Hard, thin-bedded sandstone	3
Black, fissile shale	2
Hard, thin-bedded sandstone, beds 1 inch to 3 inches thick	4
Dark shale with sandy streaks	5
Hard, brown, weathering sandstone	2
Black shale	6
Thin-bedded, grey sandstone and shaly sandstone	15
Dark, sandy shale with carbonaceous bands	8
Hard, brown sandstone, beds about 6 inches	18
Thin-bedded, dark, sandy shale	2
Hard, brown sandstone	2
Grey, sandy shale	30
Thin-bedded, shaly sandstone	7
Brown shale	2
Brown, shaly sandstone with shale partings	36
Dark, sandy shale	28
Hard, grey sandstone	8
Concealed interval	28
Hard, massive, brown-weathering sandstone	15
Dark grey, sandy shale	4
Thin-bedded (2-inch beds) sandstone	14
Sandy shale and shaly sandstone	14
Thin-bedded sandstone	3
Grey, sandy shale	2
Light brown-weathering, hard sandstone	31
Brown, sandy shale	3
Hard, brown-weathering sandstone	43
Dark carbonaceous shale with thin beds and lenses of sandstone up to 2 feet thick	200
Thin-bedded sandstone	10
Shale	4
Sandstone	3
Dark shale with thin sandstone beds	23
Reddish, brown-weathering sandstone with thin shale partings	30
Shale	2
Sandstone	3
Shale	4
Sandstone	3

Section of Nikannassin Formation on Brown Creek—Continued
(In descending order)

Character of beds	Thickness of beds
Shale	5
Thin-bedded sandstone	15
Shale	1
Medium-bedded sandstone	20
Dark shale with sandstone lenses	12
Sandstone	2
Shale	20
Sandstone	55
Shale	5
Sandstone	1
Shale and sandstone	9
Sandstone	6
Shale	5
Medium-bedded sandstone	17
Dark grey shale	22
Dark grey, coarse-grained, medium-bedded sandstone	35
Brownish black shale	24
Sandstone	1
Shale	1
Sandstone	1
Brownish black shale	5
Grey sandstone	7
Dark shale	4
Sandstone	2
Dark shale with several beds of sandstone up to 1 foot thick	60
	1,046

The lowermost 92 feet of this section may be Jurassic in age as the beds are similar in appearance to the uppermost Jurassic beds exposed on Folding mountain 8 miles southeast of Brûlé Mines area.

Cadomin Conglomerate

The most conspicuous member of the Lower Cretaceous sediments in Brûlé Mines coal area is a massive conglomerate which on account of its greater resistance to weathering stands out above the surrounding beds. This bed varies in thickness from 5 to 70 feet and averages 25 feet. It is composed of flattened and well-rounded pebbles of black, white, and green chert, white and grey quartzite, and quartz, which range in diameter from ¼ inch to over 3 inches. The pebbles are firmly cemented in a coarse, sandy matrix which in parts of the bed forms conspicuous lenses.

This conglomerate was mapped by the writer in Mountain Park district, 40 miles southeast of Brûlé, where it was traced instrumentally along its numerous sinuosities for a distance of 70 miles through Mountain Park, Cardinal River, and Cadomin map-areas. From the fact that the conglomerate is well exposed in the railway cutting and on the hill-slopes at Cadomin it was designated the Cadomin conglomerate. The conglomerate has also been traced intermittently by Rutherford from Cadomin area northwestward along the strike to Folding mountain 8 miles southeast of Brûlé Mines area.

Within the map-area the conglomerate outcrops along the eastern flank of the major anticline. Where not exposed, the member may be absent as a result of overthrust faulting, or it may be present but concealed beneath the heavy covering of drift and soil that occurs on the lower valley slopes, and lowland. The most southerly outcrop noted occurs on the east slope of Errington hill at an elevation of 4,000 feet and the bed is traceable for 1,500 feet northwestward to where it becomes obscured. It reappears in the channel of Supply creek and has a continuous outcrop for 4,000 feet to about 1,000 feet beyond the crest of Brûlé hill at an elevation of 4,800 feet. The abrupt termination of the conglomerate at this latter locality is believed to be due to a westward dipping thrust fault which has caused the conglomerate north of the fault to be offset to the west and at a lower elevation where its position is obscured by the heavy covering of glacial drift. The only indication of the presence of the conglomerate in place between the last-mentioned location and the next observed outcrop on the north slope of Scovil creek 5,000 feet to the northwest at an elevation of 5,050 feet, is a small exposure of a 6-foot conglomerate bed outcropping on the north side of Scovil Creek channel in line with the main conglomerate band. Although this bed is considerably thinner than the main conglomerate, its lithological character points to it being the same bed. Assuming such to be the case the assumed position of the conglomerate between the two main outcrops has been indicated on the map by projecting the outcrop on Scovil creek, in both directions, in accordance with the strike and dips of the adjacent beds, until it is truncated by an assumed fault which trends northwest-southeast and which truncates the main conglomerate outcrop on the east slope of Scovil hill. Beginning again on the east slope of Scovil peak, at an elevation of 5,050 feet, the conglomerate is traceable for a distance of 3,000 feet northwesterly to where it terminates sharply at an elevation of 4,900 feet. From here, outcrops fail over an interval of 1,500 feet along the strike to where, at an elevation of 4,400 feet, what is thought to be the same conglomerate bed reappears for a distance of a few hundred feet. Throughout its course the conglomerate dips from 40 degrees east to 155 degrees (overturned) west.

North of Scovil creek and 1,000 feet east of the main conglomerate band, there occurs a second outcrop of conglomerate. This outcrop commences about 500 feet north of the creek, runs for a few hundred feet northwesterly, and then makes a pronounced bend eastward and northward and continues for a distance of approximately 5,000 feet northwestward parallelling the main conglomerate band. At its southeastern extremity the conglomerate dips 85 degrees northeast; in the hook-like bend it dips 160 degrees west (overturned) and along the remaining distance it dips from 115 degrees west (overturned) to 90 degrees east. At its northwestern end a small, triangular mass of conglomerate dipping 30 degrees east occurs, which appears to be a faulted fragment from the main outcrop. The abrupt termination of the conglomerate at both ends suggests that the outcrop is bordered by faults.

No exposures of conglomerate were observed in the glacial-drift-covered, lower part of Oldhouse creek, the existence and assumed position of the conglomerate as shown on the map being inferred from the general structure of the beds and the position of the coal horizon and the Luscar-Blackstone contact.

The majority of pebbles of the Cadomin conglomerate are flattened by transport into ovoids and show numerous percussion marks obtained from impact in transit. A goodly proportion of the pebbles are of a sub-angular outline, this shape having been undoubtedly caused by the pebbles breaking in transit and a new erosion surface being formed on the irregular fracture faces.

There appears to be no marked gradation in the size of the pebbles from the bottom to top of the formation, but the bedding of the deposit is generally easily detectable from the sub-parallel attitude of the longer dimensions of the pebbles.

The pebbles, and the enclosing sandy matrix which consists of the same three types of rock—quartzite, chert, and quartz—and which makes up about 30 per cent of the formation, are so firmly cemented and partly recrystallized that joint fractures developed by subsequent folding cut straight through the pebbles and matrix alike rather than free the pebbles from the enclosing matrix. Two systems of joints have been developed in the conglomerate. These lie normal to the bedding plane and to one another and cause the conglomerate to break up into numerous, small, sub-rectangular blocks. The more prominent of these is a closely spaced jointing which parallels the strike of the bed and which in places produces a conspicuous sheeting structure apt to be mistaken for bedding.

The fault planes are invariably characterized by a white, highly polished, slickensided surface, the ripple-mark-like gouges of which show numerous small, hair-like striations parallel to the direction of movement and asymmetrical checks lying in a transverse direction.

The contact between the conglomerate and the underlying beds is of the nature of a disconformity, there being evidence, in a number of places, such as the removal of 3 feet of the underlying beds within a distance of 30 feet, of erosion of the beds prior to the deposition of the conglomerate.

This conglomerate not only persists throughout this northern part of the province, but it is identical in lithological character and physiographic expression with the conglomerate bed that marks the base of the Blairmore in the Crowsnest Pass area and which has been traced 120 miles northward. There remains along the strike a gap of 80 miles between Saskatchewan and Bow rivers in which the position of the conglomerate, if present, has still to be determined. Because of the persistence of this member over the two extensive areas mapped and because of flora evidence indicating a Lower Blairmore age for the overlying coal measures at Brûlé, it is believed detailed work in the unmapped interval will prove the conglomerate bed to be traceable from Crowsnest pass northward to beyond Brûlé Mines area and to mark throughout the base of the Blairmore formation.

The source of the conglomerate pebbles is believed to be the thick, hard quartzite and chert formation of Mississippian age, which now caps the mountain ranges to the west extending from beyond Smoky river southeasterly to the International Boundary. During late Palæozoic and early Mesozoic times this area, capped by Mississippian rocks, is thought to have formed a land area of low relief, on the weathered surface of which a mantle of coarse, residual chert, quartzite, and quartz boulders was being formed by the disintegration of the beds. Early in Lower Cretaceous time this land area appears to have been subjected to a further rapid uplift accompanied by a rejuvenation of the streams. These streams carried off this coarse, residual rubble, rounded and striated the boulders in transit, and deposited them in the form of a series of coalescing alluvial fans.

Luscar Formation

Overlying the massive conglomerate just described and extending upward to the base of the marine shales which are thought to be of Colorado age, is a series of dark grey, sandy shales and grey sandstones containing the commercial coal seams of the area and a few thin beds and lenses of fine conglomerate. Shales make up 60 per cent of the formation. Lithologically and stratigraphically, this formation corresponds to the Luscar formation of Mountain Park district, although there is a possibility that the uppermost part in Brûlé area may represent strata that in the Mountain Park area compose the Mountain Park formation. On Brazeau river the Mountain Park formation is 825 feet thick, but on McLeod river it is only 400 feet thick at Mountain Park, at Cadomin 330 feet thick, and at Luscar 320 feet thick. If this rapid northward thinning continues it is probable that little, if any, of the Mountain Park formation is present in Brûlé Mines area. If it is, the beds have entirely lost their ridge-forming character and their characteristic greenish colour.

Within the map-area the most continuous exposures of the Luscar formation occur on Scovil creek where they form a broad band on the flank of the major anticlinal fold of the area. The character of the formation as a whole is known, but the intense folding and faulting to which the measures have been subjected preclude obtaining any accurate determination of its total thickness.

The formation is also exposed on the east flank of the major syncline, on Oldhouse creek and at a number of localities east of Brewster creek, and it undoubtedly underlies the eastern part of the map-area. Confirmatory data as to the character of the upper part of the formation were obtained by two bore-holes, No. 39 sunk on Brewster creek and No. 40 located 1,200 feet farther east, but the presence of several crushed and faulted zones here also made impossible any accurate measuring of the section pierced. The contact between the Luscar formation and the overlying Colorado shales was pierced in bore-hole No. 39 at a depth of 490 feet and several small coal seams were penetrated between this horizon and a depth of 980 feet at which depth the bore-hole terminated. In bore-hole No. 40 drilling began at what is believed to be approximately the horizon at which drilling ceased in hole No. 40 and the drilling was continued to the coal horizon. Assuming that no extensive faulting has taken place and that at most only a small interval exists between the bottom strata of bore-hole No. 39 and the tops beds encountered in bore-hole No. 40, the commercial coal horizon containing seams No. 2 and No. 3 lies approximately 900 feet stratigraphically below the top of the formation.

No definite data are at hand indicating the thickness of the strata between the coal horizon and the Cadomin massive conglomerate bed. On Scovil creek the interval between the coal bed of the Bartholomew prospect which is thought to be seam No. 3, and an outcrop of conglomerate which is taken to be part of the main conglomerate band, is only 270 feet, whereas south of this creek, but where folding is more pronounced, this interval appears to be considerably greater, approximately 700 feet. This stratigraphic interval in the neighbouring field at Pocahontas on the opposite flank of the Palæozoic anticline, 10 miles to the southwest, was determined to be 530 feet, whereas in Cadomin area the writer found the commercial coal seams to be about 900 feet above the conglomerate and Rutherford determined them to be 700 feet above the conglomerate. Assuming this interval in Brûlé Mines area to be approximately 700 feet the thickness of the whole formation would be 1,950 feet, made up of:

	Feet
Upper sandstones and shales	900
Coal-bearing horizon	350
Underlying sandstones and shales	700
	1,950

A collection of fossil plants from the rock dump from seams No. 2 and No. 3 was submitted to W. A. Bell, who has furnished the following statement:

"The plant remains are mainly imprints of stems and leaves preserved in a blackish grey, argillo-arenaceous shale. Some of the imprints have a highly polished slickensided surface. Of a total of 22 species, 13 are ferns, 8 are gymnosperms, and 1 a liverwort. The following species occur:

Marchantites blairmorensis Berry	not rare
Coniopteris n. sp.	very common
Coniopteris ? n. sp.	very rare
Cladophlebis virginiensis (Fontaine)	common
Cladophlebis distans Fontaine	rare
Cladophlebis cf. *heterophylla* Fontaine	very rare
Cladophlebis martiniana (Dawson)	rare
Cladophlebis n. sp.	rare
Sagenopteris mclearni Berry	rather common
Sagenopteris cf. *nervosa* Fontaine	rather rare
Acrostichopteris n. sp.	very common
Sphenopteris (Coniopteris?) sp.	rare
Sphenopteris cordai Schenk	rather rare
Sphenopteris n. sp.	rather rare
Ginkgoites arcticus (Heer)	rather rare
Nilsonia orientalis (Heer)	rather rare
Pterophyllum montanense (Fontaine)	very common
Pterophyllum arcticum (Goeppert)	rather rare
Zamites sp.	very rare
Podozamites lanceolatus (Lindley and Hutton)	rare
Elatocladus smittiana (Heer)	common
Athrotaxopsis grandis Fontaine	common

Of the above species, four, viz., *Marchantites blairmorensis, Cladophlebis distans, Sagenopteris mclearni,* and *Athrotaxopsis grandis,* are typical Lower Blairmore forms. Of the remainder, the following four species occur in both Lower Blairmore and Canadian Kootenay floras: *Cladophlebis virginiensis, Ginkgoites arcticus, Pterophyllum arcticum, Podozamites lanceolatus,* but these, with the exception of *Cladophlebis virginiensis,* are rare in the present flora as also in the Lower Blairmore. *Nilsonia orientalis* is a cosmopolitan "form species" that ranges upwards from Jurassic floras. *Sagenopteris* cf. *nervosa* is perhaps identical with Fontaine's species from the Shasta beds of California. *Sphenopteris cordai* is a Wealden form of Germany not hitherto reported in North American early Cretaceous floras. The conclusion from the general assemblage of species and relative abundance of individuals is that the flora is of Lower Blairmore rather than Kootenay age."

UPPER CRETACEOUS

Blackstone Formation

The youngest solid rock formation exposed within Brûlé Mines map-area is a series of thin, fissile, black shales with a few, thin, dark, fine-grained sandstone beds and lenses, and an occasional ferruginous sandstone or sandy shale concretion ranging up to 1 foot in diameter. The sandstone beds are generally less than 1 inch thick, and the shales make up more than 90 per cent of the formation. No fossils were found, but on lithological character and stratigraphic position the formation is correlated with the marine Blackstone formation, which is well exposed at Leyland on McLeod river, and on Brazeau river and a number of its tributaries to the southeast. This marine formation occurs in Bighorn area, where it was originally mapped and named by G. S. Malloch.[1] It has been traced by Rutherford[2] from this area northwestward to the vicinity of Brûlé lake, and has been mapped by the writer in Mountain Park, Cadomin, Cardinal River, and Lovett map-areas.

Exposures of the formation within the map-area are confined to three localities, Scovil creek, Oldhouse creek, and Brewster creek, but at none of these localities does the outcrop exceed 1,000 feet in width. On Scovil creek the conformable relationship between the Colorado and the underlying, coal-bearing Luscar measures is apparent, the one formation grading so imperceptibly into the other that the exact line of separation is a matter of choice. The base of the Colorado formation was here assumed to be where the first comparatively thick sandstone bed appears. The beds are overturned and dip 70 degrees southwest. On Oldhouse creek the actual contact between the Blackstone and Luscar beds is concealed by alluvium, but the shales close to the base are exposed. These have a general dip of 36 degrees to 30 degrees southwest, with some minor crumbling and at least one prominent fault zone. On Brewster creek the beds dip 55 degrees to 60 degrees southwest. The base of the formation is not exposed, but an inclined diamond drill hole put down on this creek passed into the underlying formation at a depth of 490 feet, indicating that the contact of the two formations lies approximately 500 feet east of the creek in the vicinity of the drill hole.

[1] "Bighorn Coal Basin, Alberta"; Geol. Surv., Canada, Mem. No. 9 E.
[2] Reports Nos. 6, 9, and 11, Sci. and Ind. Research Council, Alberta.

The distribution of the exposures and the attitudes of the beds, together with the strike of outcrops of the adjacent formation, indicate that the Blackstone formation is here folded into a tightly compressed, gently, south-eastwardly plunging synclinal basin, whose western limb is overturned or vertical throughout. The basin underlain by the Blackstone formation has an approximate width on Oldhouse creek of 3,500 feet and in the vicinity of Scovil creek of 4,500 feet. Owing to the paucity of exposures the position of the western boundary of the basin is indefinite, its assumed position, as shown on the map, being obtained by projecting the Scovil Creek contact northwestward and southwestward parallel to the strikes indicated by the relatively few outcrops. The best section of these rocks in the area is that furnished by the outcrops and bore-holes on Brewster creek. This section is less than 1,200 feet in thickness, but the total thickness of the formation must be at least 1,700 feet. No reason exists for supposing any higher member of the Colorado group to be present.

QUATERNARY

Glacial

Boulder clay, composed mainly of a compact, bluish grey, calcareous rock floor in which are firmly embedded boulders of limestone, shale, sandstone, and conglomerate, apparently all of nearby or local origin, covers most of the map-area. This deposit varies in thickness from a thin veneer on the uplands to several hundreds of feet in the lowlands and transverse valleys. In upper Scovil creek the deposit has been trenched to a depth of almost a hundred feet. Large glacial erratics of limestone and conglomerate, the largest observed measuring 20 feet by 12 feet by 15 feet, occur on the hill-slope immediately west and north-west of Brûlé Mines, the limestone erratics having been derived from the limestone range lying to the west of the map-area and those of conglomerate from the Cadomin conglomerate.

Gravels, sands, marls, and silts also referable to the Glacial period overlie the boulder clay in the lowlands, forming a belt 2,000 to 4,500 feet in width along the western border of Brûlé lake. These represent deposits that were laid down in a large glacial lake which stood approximately 350 feet above the present lake level. Where the four main streams within the map-area entered the lake they built prominent alluvial fans, the configuration of which is clearly shown by the lobate form of the contours and the shoreline of Brûlé lake. The interfan areas of the lowlands are characterized by extensive deposits of fine silt and marl. The fluvioglacial deposits in the lower parts of Scovil creek, Supply creek, and Brown creek have been partly reworked by flood action, so that it is difficult in places to distinguish between the fluvio-glacial deposits and more recently built deltas.

Recent

In the vicinity of the Brûlé Lake shoreline the sands and silts have been re-sorted by wind action and built into sand-dunes. On the opposite side of the lake the sand-dunes topography is much more prominently developed. At Park Gate on the abandoned Grand Trunk Pacific grade which lies just within the eastern corner of the map-area, the road-bed and telephone poles have been buried to a depth of 10 feet by deposits of loess.

Small deposits of calcareous sinter or tufa are being deposited on the hill-slopes at Brûlé by streams which, percolating beneath the moss, dissolve calcium carbonate from the impervious boulder clay.

STRUCTURAL GEOLOGY

Brûlé Mines coal area is characterized by a series of folds and thrust fault blocks trending northwestward parallel to the Rocky Mountain front. Boule range, elevation 7,230 feet, bordering the basin on the west, is mainly a block of Palæozoic strata thrust northeastward over Cretaceous measures (*See* Plate III). The fault plane is exposed at intervals over a distance of more than a mile in the cliff facing Brûlé station. The fault there strikes northwest, dips 40 degrees west astronomical, and along it overturned Devonian limestone rests on severely crushed Nikanassin shales that dip westerly at high angles.

The major structural features within the map-area are: an anticlinal fold in Lower Cretaceous and, probably, Jurassic rocks; an open, southeastward-plunging syncline floored with Upper Cretaceous shales, the synclinal axis lying approximately 6,500 feet east of the anticlinal axis; and an intervening fault zone in the Lower Cretaceous coal-bearing formation.

The anticline is the northwestward continuation of the anticline that attains its maximum elevation in Folding mountain, 6 miles south of Athabaska river. Its axis lies approximately 1,000 feet within the southwestern border of the map-area and parallels the fault scarp of Boule mountain which is 2,000 feet farther west. The anticline is asymmetrical, having a gently dipping southwesterly limb and a steeply dipping, crenulated northeasterly limb. On Brown creek, at the southern end of the field, the crest of the anticline is characterized by numerous, asymmetrical, secondary folds each with a gentle dip on the west and a steep dip on the east (*See* Plate IV). North of Supply creek the secondary folds become less pronounced and the shortening is largely taken up by minor strike faults, which cause a slight offsetting of the beds. North of Scovil hill the axis of the anticline appears to be offset approximately 500 feet to the northeast by a fault which crosses the summit with a southeasterly direction. How far to the southeast the fault extends has not been determined owing to the glacial drift which conceals most of the bedrock, but the fault is thought to coincide with a fault crossing Scovil creek about 500 feet upstream from the Bartholomew prospect, and which extends southeast along the eastern limb of the anticline truncating the conglomerate at the northern slope of Brûlé hill.

The middle part of the map-area is occupied by a broad, southeasterly trending, asymmetrical syncline having in places a steeply inclined, overturned, western limb and a steeply dipping eastern limb. Blackstone shales occupy the trough of this fold and the coal-bearing Luscar formation forms both flanks. On Oldhouse creek the belt of Blackstone shales is approximately 3,500 feet wide, whereas in the vicinity of Scovil creek it is 4,800 feet in width, indicating that the syncline has a gentle plunge to the southeast. The strata of the western limb are best exposed on Scovil creek where the Blackstone shales and the upper part of the Luscar beds are overturned and dip from 60 to 80 degrees west. The beds in the eastern limb are exposed on and east of Brewster creek, and on Oldhouse creek. On Brewster creek the Blackstone shales dip from 40 degrees to 65 degrees west, whereas the Luscar measures farther east show more moderate dips, progressively decreasing to about 15 degrees west at the most easterly outcrop 1,800 feet northeast of the contact. On Oldhouse creek the Blackstone beds dip from 40 degrees to 50 degrees west and the Luscar beds average about 35 degrees west. Occasional faults occur in the strata and the dips of the beds in their immediate vicinity are considerably steeper.

The coal-bearing, Luscar measures occupying the area between the major anticline and syncline are folded and faulted in a complicated manner. In the vicinity of Brûlé town they form a syncline and anticline which have a gentle northwestward plunge as far, at least, as the vicinity of Scovil creek. This structure is partly expressed on the map by the sinuous course of the outcrop of seams No. 2 and No. 3 and is more clearly portrayed in structure section CD in which the attitude of the coal seams is based on mine plans. These secondary folds show the same asymmetrical structure as do the major folds; the syncline has a vertical or slightly overturned western limb and a gently dipping eastern limb, and the complementary anticline to the east has a gently dipping western limb, a sharp crest, and a steeply dipping, to overturned, eastern limb. This limb is cut off by a thrust fault which dips from 20 degrees to 40 degrees west.

The measures east of the mine tipple are much more severely crushed than those in the belt occupied by the mine workings, and appear to be mashed and repeated by a series of strike thrust faults. Most of this area is concealed by a thick deposit of boulder clay and alluvium, making it impossible to accurately determine the structure of the bedrock or to correlate the fragments of the several seams that have been located by bore-holes or exposed by prospect pits.

During the summer of 1927, coal measures were discovered east of Brewster creek and it is hoped that the results of the drilling carried on in this section will aid in the correlation of the several prospects opened up on the western limb of the syncline.

Some conception of the complicated structure of the area may be obtained from the arrangement of the outcrops of the massive, Cadomin conglomerate as indicated by the corrugated outcrop immediately north of Brûlé Hill peak, by the truncation and offsetting of the conglomerate bands, by the duplication of the conglomerate on the east slope of Scovil hill, and especially by the hook-like form and apparently overturned attitude of the most easterly conglomerate outcrop. Considering only the dip of the conglomerate and associated beds, the parallelism of the two conglomerate bands and their alinement with that of coal seams No. 2 and No. 3 on the east slope of Brûlé hill, the simplest and most plausible interpretation of the latter structural feature appears to be that the conglomerate bands form the limbs of a faulted southeasterly-plunging synclinal basin which is represented also by the configuration of the outcrops of the overlying coal seams. If such were the case we must assume that the complementary anticline which should lie between the outer conglomerate band and the Luscar-Blackstone contact has been completely faulted out and that that part of the synclinal basin north of Scovil creek has been faulted up several hundred feet along some southeasterly trending dislocation plane with respect to the part of the basin lying south of Scovil creek. There should also occur the same sequence of sediments and coal seams from the conglomerate toward the centre of the trough and any crossbedding in evidence on the limbs of the basin should indicate that the top of the beds lies towards the axis of the fold. A search for this confirmatory evidence on the outer limb of the basin yielded only negative results. The bulk of the field evidence strongly supports the interpretation that the more eastern conglomerate and associated beds are overturned and form a wedge-shaped fault block which has been thrust southeasterly from the main conglomerate belt into younger sediments. This block is bounded by two converging steeply inclined faults. One of these faults appears to cross Oldhouse creek about 300 feet above the cabin, truncates the main conglomerate band 400 feet southeast of the creek, angles southeasterly across the coal-bearing measures to near the eastern extremity of the second conglomerate band, and crosses Scovil creek 250 feet below the Bartholomew prospects to continue southeastward into the mine workings. The other fault appears to cross Oldhouse creek 150 feet below the cabin, cuts across the northwestern end of the eastern conglomerate band, and continues southeastward about 100 feet northeast of this conglomerate band to truncate it at its southeastern extremity, crosses Scovil creek 500 feet below the Bartholomew prospect, and, apparently, merges with the first described fault approximately 1,000 feet southeast of Scovil creek and within the synclinal basin. Owing to the heavy mantle of glacial drift the positions of these faults cannot be traced accurately, but their assumed positions as indicated on the map agree closely with the structural data available. Several similar thrust faults occur in the beds, especially at the Dickson prospect and farther down Scovil creek, but the paucity of outcrops forbids the structure being more accurately defined than as shown on the structure sections.

Lacking exposures, the assumed position of the base of the Blackstone shale on the west limb of the major syncline is projected from the exposure on Scovil creek northwestward in a gently curved line.

COAL DEPOSITS

The coals of Brûlé Mines area are of bituminous and semi-bituminous rank and resemble in appearance the coals of Mountain Park district, but are considerably softer. The commercial coal seams so far discovered are confined to the strata overlying the Cadomin conglomerate, only a few, thin, non-commercial seams being found in the underlying beds. These coal-bearing beds extend as a belt along the east flank of the Brûlé-Scovil anticline and during the past summer have been shown to reappear 1½ miles to the northeast of the mine workings on the opposite or eastern limb of an open, southeastward plunging syncline. These seams doubtlessly can be traced northwestward around the head of this syncline which apparently terminates near the headwaters of Solomon creek about 3 miles beyond the map-area.

Prospecting in the area has been extremely difficult and expensive owing to the thick mantle of boulder clay, alluvium, and forest growth that conceals the bedrock. Furthermore, the severe crushing and faulting to which the beds have been subjected makes it impossible to project accurately for any great distance the structural data obtained in any prospect pit. Even the Cadomin conglomerate which marks the base of the coal-bearing beds, although outcropping over most of the length of the map-area, is of much less value as a horizon marker than it might be, because, owing to the intense folding and faulting, it has been found impossible to determine at all accurately the stratigraphic interval between the conglomerate and the commercial seams. On the slope of Brûlé hill the stratigraphic interval between the conglomerate and seam No. 3, as indicated by their respective outcrops, is estimated at approximately 700 feet, whereas on Scovil creek and farther north on the eastern slope of Scovil creek, the interval between the conglomerate and what is believed to be seam No. 3 is approximately 300 feet. In the Bighorn field, 75 miles southeast of Brûlé, G. S. Malloch[1] located the lowest commercial coal seam at 1,275 feet above the conglomerate. In the Cadomin-Luscar area, 30 miles southeast of Brûlé, the writer determined the interval to be approximately 1,100 feet; on Folding mountain, 8 miles southeast of Brûlé, R. L. Rutherford[2] determined the interval to be 700 feet; and at Pocahontas 10 miles southwest of Brûlé the writer determined it to be 530 feet and at Miette on the opposite or north side of Athabaska river it is estimated at approximately 425 feet.[3] There appears, therefore, to be a progressive northward and possibly a westward thinning of the sediments between the conglomerate and the coal horizon, so that at Brûlé, seam No. 3 probably does not lie much over 700 feet above the conglomerate. Until more drilling data are obtained it will be impossible to determine this interval more accurately.

At least six coal seams are known to occur in Brûlé Mines area and there may be more. The average thickness of these and the approximate thickness of the separating measures as obtained from drilling and development work at the mine are as given below in descending order.

[1]Malloch, G. S.: "Bighorn Coal Basin"; Geol. Surv., Canada, Mem. 9-E, pp. 24-25.
[2]Rutherford, R. L.: Sci. and Ind. Res. Council, Alberta, Rept. 11, p. 36.
[3]Mine Records.

Strata to top of Luscar formation, approximately 900 feet

	Feet	Feet
Seam No. 1	5½	
Rock		100
Seam No. 2	5	
Rock		35
Coal seam	1½	
Rock		192
Coal seam No. 3	9	
Rock		50
Coal seam No. 4	3½	
Rock		72
Coal seam No. 5	1	
Strata to top of Cadomin conglomerate, 700 feet		

Only three of the above listed seams are of sufficient thickness to have been mined. These occur within an interval of 310 feet and are designated locally as seams No. 1, No. 2, and No. 3. Seams No. 2 and No. 3 are the main producers, having yielded to date approximately 1,800,000 tons. Seam No. 1 has been mined only to the extent of a tunnel 1,100 feet long having been driven along it. The seams and associated measures vary greatly in thickness from place to place, so that their thicknesses as obtained from drilling on the east limb of the syncline may be found to differ considerably from the measurements given above. The varying thicknesses are due, in a large measure, to the intense folding which has caused the clean coal and the incompetent shale beds to flow away from the limbs and form swells at the bends of the folds or be forced into fracture planes or zones of dislocation. The extent of this variation in the case of seams No. 2 and No. 3 and the separating beds is shown in Figures 1 and 2.

Seam No. 1 averages 5½ feet in thickness and outcrops 700 feet north of the mine tipple. An adit has been driven in the seam for 1,100 feet to where the seam has been pinched out by a strike fault. The seam strikes north 56 degrees west. At the adit mouth it is overturned, dipping 140 degrees southwest, 300 feet in from the mouth of the adit the seam stands vertically and a couple of hundred feet beyond it assumes a normal dip of 45 degrees northeast, which dip it retains to the end of the tunnel. The seam has a sandy shale foot-wall and a shaly roof. From the fact that the seam has approximately the same thickness and similar walls as seam No. 2 and that the measures are greatly deformed it was considered that No. 1 seam might be a segment of No. 2 seam repeated by strike faulting. Its stratigraphic position with reference to seam No. 2 and its parallelism to it in strike and dip as far as mined, support the view that No. 1 is a separate seam lying approximately 150 feet stratigraphically above seam No. 2. Conclusive evidence as to whether this is so will undoubtedly be forthcoming shortly through the drilling now being carried on in the northern limb of the syncline east of Brewster creek.

The coal of seam No. 2 is of bituminous rank and is the best grade of coal mined in the area, as may be seen from the analyses, on a following page. A bench of so-called "grey" coal 1½-3 feet thick occurs in the lower part of the seam, is very pure, and makes excellent coke. No. 2 seam varies in thickness from 3½ to 9 feet and has an average thickness of 5 feet.

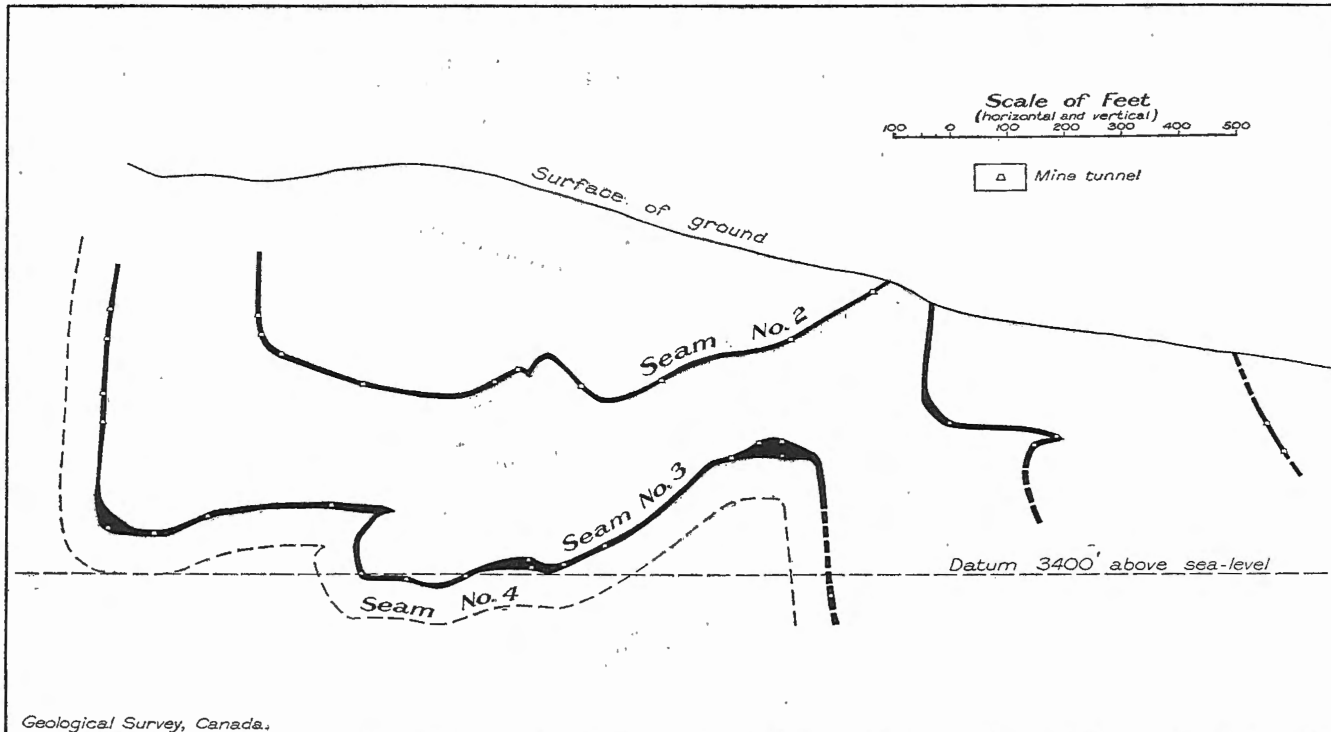

FIGURE 1. Vertical section through mine workings 450 feet northwest of vertical section CD.

The details of a section of No. 2 seam in the high level on the counter between raises 36 and 37, are as follows:

Sandstone roof

	Feet	Inches
Coal		8
Brown clay		2
Hard grey shale		4
Grey coal	2	10
"Black jack"	2	
Shale floor		

The upper 8-inch bench is of interbedded layers of dull and bright coal and streaks of shaly material. The dull coal appears to be more pronounced toward the bottom of the layer. The underlying bench of so-called "grey coal" consists of layers and lenses, ranging from thin lenticles up to bands three-quarters of an inch thick, of a shiny, jet black coal which breaks with a conchoidal fracture, separated by layers up to one inch thick of a fine, granular, dull, porous coal. This dull coal when examined in detail was found to be made up of innumerable, small, thin lenses and fragments of bright coal separated by a granular porous material, in which is also embedded an occasional lens of a soft, dull, porous powdery substance. Thin sections of the coal layers examined under the microscope show the lenses and fragments of bright coal to exhibit the characteristic structure of wood and the dull coal to be composed of a granular groundmass of resinous matter and decomposed vegetation in which are embedded still smaller splinters of the bright coal, along with the soft, powdery substance, which appears opaque under the microscope and consists of natural charcoal commonly designated "mother of coal."

Beneath this bench is a 2-foot layer of a soft, glistening, black, schistose, impure coal or carbonaceous shale locally designated "Black jack." This material, though resembling coal in appearance, runs so high in ash and low in volatile matter that it is worthless as a fuel. It is so incoherent that with the least handling it falls away into a powdery, flake-like mass in which the only remaining pieces of any size consist of a few, thin, hard, slickensided pellets or small, sandy nodules which apparently have been formed by the rearrangement of the coarser arenaceous material in the coal seam during movement.

Another section of seam No. 2 taken on No. 2 high level a short distance away from the above section, is as follows:

Shaly sandstone roof

	Feet	Inches
Bright coal		11
Carbonaceous clay		2
Hard grey coal	2	
Bright coal	1	
Stratum of sandstone niggerheads		3
Bright coal	1	6
"Black jack" or carbonaceous shale	3	
Shale floor		

The seam has been mined by means of a number of adits and slopes located on its eastern outcrop and an area approximately 1,400 feet wide and ½ mile in length may be considered as largely worked out.

Proximate Analyses of Coal Samples from Brûlé Mines Area, Alberta
(Analysed by Mines Branch with exception of Bartholomew sample which was analysed by J. O'Sullivan, Vancouver)

Lab. No.	—	Form of analysis	Moisture	V.M.	F.C.	Ash	S	Heating value: Calories	Heating value: B.T.U's	F.R.	Coking prop.
4234	No. 2 seam run of mine (Collected by B. R. MacKay, 1927)	A	1·2	21·1	64·5	13·2	0·5	7,405	13330	3·05	F.G.
		B		21·4	65·2	13·4	0·5	7,490	13480		
4235	No. 2 seam lump coal (Collected by B. R. MacKay, 1927)	A	1·0	26·8	60·8	11·4	0·5	7,465	13440	2·25	Good
		B		27·1	61·4	11·5	0·5	7,540	13580		
4236	No. 3 seam run of mine (Collected by B. R. MacKay, 1927)	A	1·4	18·2	61·6	18·8	0·4	6,835	12300	3·40	Poor
		B		18·5	62·5	19·0	0·4	6,930	12480		
4237	No. 3 seam lump coal (Collected by B. R. MacKay, 1927)	A	0·9	19·7	67·3	12·1	0·5	7,540	13580	3·40	Good
		B		19·9	67·9	12·2	0·5	7,610	13700		
4238	Lump grey coal, seam No. 2 (Collected by B. R. MacKay, 1927)	A	0·9	26·3	63·2	9·6	0·5	7,680	13820	2·40	Good
		B		26·5	63·8	9·7	0·5	7,750	13940		
1219	No. 2 seam north (Collected by Fire Ranger, 1917)	A	0·5	21·3	67·0	11·2	....	....	....	3·15	Good
		B		21·4	67·3	11·3					
1220	No. 4 S. slope No. 3 seam (Collected by Fire Ranger, 1917)	A	0·9	16·5	65·0	16·9	....	....	....	3·90	Fair
		B		16·6	66·3	17·1					
1221	Tipple sample (Collected by Fire Ranger, 1917)	A	0·5	18·6	67·4	13·5	....	....	....	3·60	Good
		B		18·7	67·7	13·6					
889	Bartholomew prospect (Collected by J. MacVicar, 1916)	A	2·2	15·3	63·8	18·7	....	....	....	4·15	Poor
		B		15·6	65·3	19·1					
603	Blue Diamond Coal Co. mine (old) (Collected by Fire Ranger, 1915)	A	0·7	20·5	63·0	15·8	....	....	....	3·10	Poor
		B		20·6	63·5	15·9					
	Bartholomew prospect (Collected by M. Bartholomew, 1911)	A	0·5	19·0	73·5	6·0	1·0	....	....	3·80	
	Dickson prospect (Collected by D. B. Dowling, 1910)	A	1·09	17·88	56·95	24·08	....	....	....	3·19	Good
		B									

A=As received. B=Air dried basis.

There still remains, mostly undeveloped, approximately 2,000 feet of the northwestward continuation of this progressively narrowing belt before the severely faulted ground is encountered. A few years ago an inclined rock tunnel was driven between seam No. 2 and seam No. 3, 226 feet stratigraphically below, which allows all the coal mined from No. 2 seam being extracted by the main slope situated at the tipple. A certain part of the western vertical limb was mined, but work was discontinued due to the seam becoming very dirty and being pinched down to a width of 2½ feet. A short distance above this location the vertical limb was found to be displaced northward a distance of a hundred feet by a southwestward dipping, low angle thrust fault.

Seam No. 3 was the first to be opened and has been the most extensively worked seam in the area. It averages 9 feet in thickness and is enclosed in shale walls. Owing to the extremely soft character of the coal and surrounding rock, the seam varies greatly in thickness, there being bulges on the axis of the anticline up to 35 feet thick and corresponding pinches on the limbs. Where fractures in the roof occur the coal has been forced into these, giving the impression that the seam splits up into several seams (*See* Figure 2). It is so soft that with the exception of the 2-foot layer of grey coal very little lump is obtained in mining. Where hard layers occur in the seam they are generally found to be attributed to the presence of impurities in the form of sandy bands termed "bone" beds, or large, arenaceous nodules designated as niggerheads. Analyses (*See* table of analyses) show the coal to be considerably lower in volatile matter and higher in ash than the coal of seam No. 2. It has also a higher fuel ratio and poorer coking qualities, being of semi-bituminous rank. These differences in quality and rank of seams Nos. 2 and 3 are due, presumably, to differences in their original composition rather than to any difference in degree of metamorphism to which they have been subjected as they are separated by an interval of only 226 feet.

Seam No. 3 was largely mined by means of a series of adits and slopes driven into the coal at the most accessible points along the eastern outcropping rim of the basin, but in recent years all the coal mined has been extracted through the main slope situated at the tipple. An area 1,300 feet wide and 1 mile long has been largely mined out and the workings now reach to within 750 feet of Scovil creek. A considerable part of the western vertical limb rising over 400 feet above the trough of the basin was mined by means of two adits and two counter tunnels carried in on the level from the hill-slope with angle workings between them, but the soft nature of the coal and of the enclosing shale wall-rocks, causing pinches in the seam and dirtiness in the coal, made the obtaining of a commercial product too expensive, so that the mining of vertical or steeply inclined parts of the seam was abandoned. Even in the flat-lying areas certain parts of the seam contain so many dirty streaks and niggerheads that selective mining had to be carried on to obtain a marketable product.

During the past field season an attempt was made to trace the vertical limb of this seam from the line of caves at the township line northwestward across the shoulder of Brûlé hill, but proved unsuccessful due to the severely faulted and crushed condition of the measures encountered

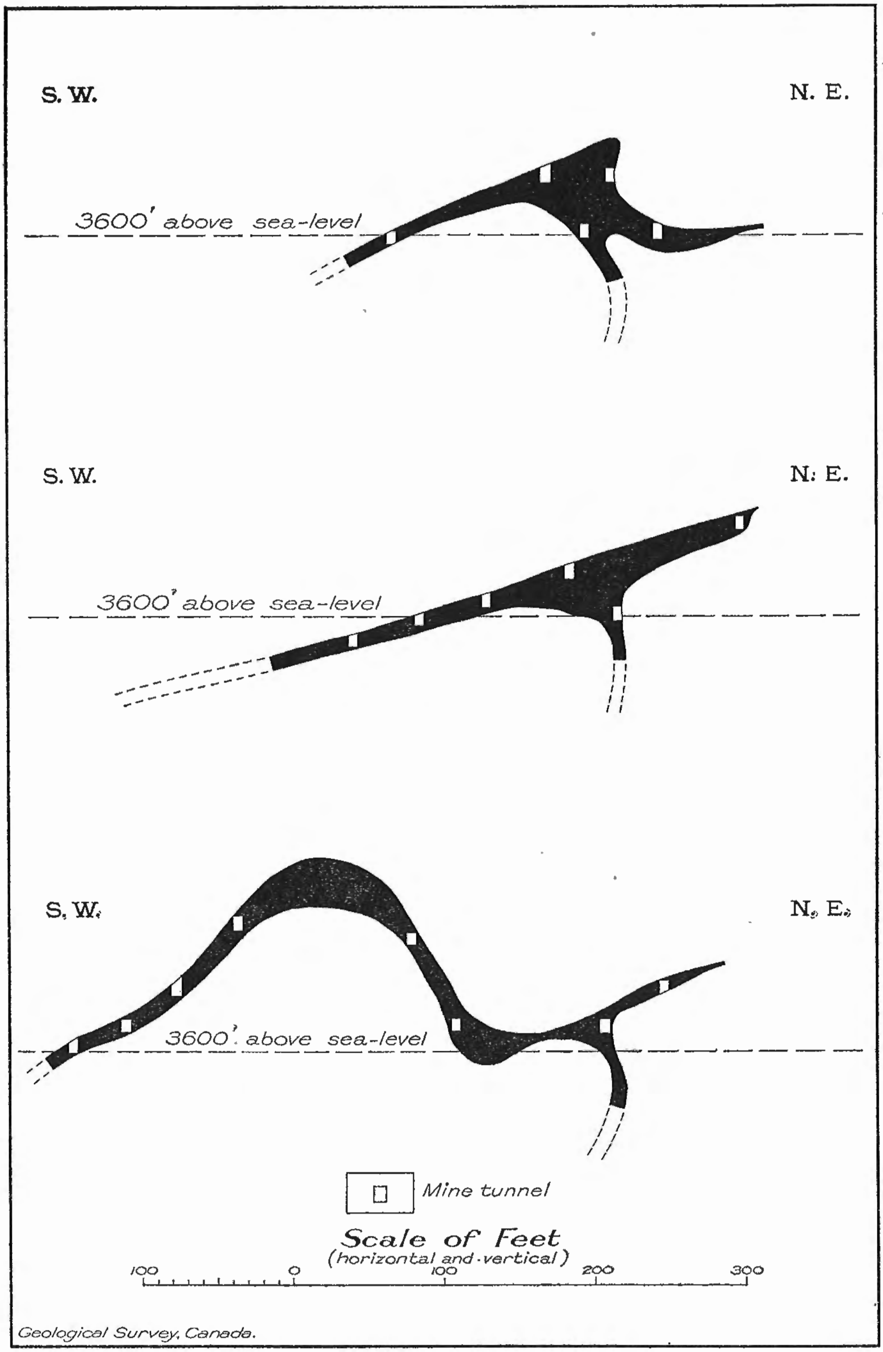

FIGURE 2. Southwest-northeast vertical sections of crest of anticline in No. 1 and No. 2 south mines.

at an elevation of 4,500 feet. Several prospects opened up to the north of the township line showed the seams to stand practically vertical, and to be offset approximately 100 feet to the north of the line of caves by presumably the same westward-dipping, low angle fault that displaced seam No. 2.

Seam No. 4 averages 3½ feet in thickness and lies approximately 50 feet below seam No. 3. No attempt has been made to mine the seam, but it has been opened up in depth by a rock tunnel driven from seam No. 3 and on the surface by several prospects. Its position has also been determined in a number of the bore-holes.

The Dickson prospect is located near the apex of a faulted anticline 5,000 feet northwest of the mine tipple on the north bank of Scovil creek at an elevation of 3,845 feet. This is thought to be the first seam discovered in the area and the one which was sampled by Dowling in 1910. As the slope is full of water no examination of the seam underground could be made. The slope is said to have been driven down the seam, 9½ feet in thickness, for a distance of about 100 feet, when operations were discontinued as a result of encountering a fault. The seam is overlain by a 35-foot bed of medium-bedded sandstone which at the slope mouth strikes north 145 degrees east and dips 28 degrees east. A few feet south of the slope the seam is cut off on the crest of the anticline by a steeply dipping, southeasterly trending fault. The thickness of the seam, its low volatile matter, and its high ash content (*See* table of analyses) suggest that the Dickson prospect is on seam No. 3. The roof of seam No. 3, however, is shale and the thick medium-bedded sandstone roof of the Dickson prospect favours it more likely being seam No. 1.

The Bartholemew prospects are 3,500 feet west-northwest of the Brûlé mine tipple, on the north bank of Scovil creek at an elevation of 4,000 feet, being 1,800 feet upstream from the Dickson prospect. Two seams were discovered at this locality in the autumn of 1910, a 9-foot seam and a 2-foot seam, 38 feet stratigraphically below. Little work has been done on them except to drive a short prospect tunnel and sample the seams. The seams strike north 135 degrees east and dip 85 degrees northeast.

The section in descending order, is as follows:

	Feet
Shaly sandstone	12
Coal soft appears to be seam No. 3	8
Shaly sandstone	6
Shale	2
Hard sandstone	6
Carbonaceous shale	1
Sandstone	6
Carbonaceous shale	10
Brown, shaly sandstone	7
Coal, appears to be seam No. 4	2
Shale	2
Sandstone	2

A fault trending north 20 degrees east and dipping 40 degrees east cuts across the measures, causing the top of the 8-foot seam to be displaced about 4 feet to the west. On chemical composition, physical character, thickness, and stratigraphic position, the 8-foot seam is correlated with seam No. 3 which in the mine workings 750 feet distant is vertical and lies directly along the line of strike. Such being the case, the 2-foot seam lying 38 feet stratigraphically below, may be correlated with No. 4 coal seam.

Two similar seams, with correspondingly separating measures, have been opened up in prospects located 2,000 feet along the strike to the northwest, at an elevation of about 5,000 feet, and are believed to be the same seams.

Three other noteworthy prospects have been opened north of the present workings and are designated locally as prospect A, prospect B, and prospect C.

Prospect A lies on the abandoned power-line, 1,800 feet southeast of the Dickson prospect, at an elevation of 3,945 feet. A pit about 15 feet deep was sunk in a coal seam which at the top of the pit has a width of about 10 feet and at the base of the pit a width of 6 feet. The seam strikes north 50 degrees west, its sandy shale hanging-wall dips 63 degrees southwest and its shale floor dips 55 degrees southwest to 47 degrees southwest, with several fault steps. The seam consists of thin benches of hard, bright coal, splint, and lustreless, soft, impure coal with streaks of grey shale, the whole running about 22 per cent ash. Discarding about 2 feet of the shaly streaks, the ash content is reduced to 13½ per cent. This seam has the appearance of being seam No. 3, and the pit was apparently sunk near the crest of the fold where the seam is above normal thickness. It is offset only a slight distance south from the seam opened up at the Dickson prospect, which is thought to be seam No. 3. About 200 feet east of this pit a second pit has been sunk, but caving prevented any examination of the seam, consequently it is not known whether the prospect is sunk on the northern limb of seam No. 3 or on the underlying seam No. 4.

Prospect B is located about 300 feet southeast of prospect A at an elevation of 3,850 feet. Here a seam 11 feet 4 inches wide was opened up, striking north 45 degrees west and dipping 63 degrees southwest. This seam has a shaly floor and a sandy shale hanging-wall, and consists of thin bands of hard, bright coal and soft, impure coal with clayey streaks, the seams averaging about 22 per cent ash. On its thickness, physical appearance, chemical analysis, and alinement it is thought to be seam No. 3 and to form the southeastward continuation of the seam opened up in prospect A.

Prospect C is located 1,900 feet north-northwest of the mine tipple, at an elevation of 3,760 feet. The pit is sunk on what appears to be the crest of a fold and though the seam was exposed across a width of 20 feet 2 inches, insufficient sinking was done to determine its thickness, beyond that it is at least 3 feet thick. The southern wall strikes north 49 degrees west and dips 22 degrees southwest and the northern wall strikes north 52 degrees west and dips 85 degrees northeast. The seam consists of alternate layers of hard and soft coal with clayey streaks and analyses 22 per cent ash. Four hundred feet southeast of prospect C a trench 400 feet long was dug in an attempt to locate the eastern continuation of what was supposed to be a thick seam, but only a 2-foot seam was discovered directly on the strike of the northern wall. This seam has sandstone walls striking northwest and dipping 62 degrees east. It is presumably the same seam as opened up in prospect C, the southern limb of the fold having probably been cut off by a strike fault. From the thickness and structure of the seam and the position of prospect C relative to prospects A and B on seam No. 3, prospect C is believed to be located on seam No. 4.

Two thin coal seams have been uncovered on the lower part of Oldhouse creek on the north bank of the stream. The Roscoe prospect lies about 350 feet below the mouth of a creek coming in from the west on section 28. The seam dips vertically and lies on the southern limb and a few feet from the centre of a tightly squeezed, southwestward plunging, compressed syncline. Sixty feet southwest, a fault cuts across the measures, trending north 125 degrees east and dipping about 60 degrees southwest, whereas the beds on the south side of the fault strike north 130 degrees east and dip 50 degrees southwest. The western prospect lies about 60 feet below the junction of the creeks. Here a seam 2 feet thick, striking north 140 degrees east and dipping 48 degrees southwest, and which may prove to be a segment of the same seam, was opened up by a small prospect tunnel. Due to the thinness of the seams and the folding and faulting of the measures in their vicinity these seams have no commercial value in themselves, but they are of importance in indicating the approximate position of the coal horizon which has been proved by the bore-holes recently put down north of Brewster creek, a mile to the southeast.

ECONOMIC POSSIBILITIES

The total production of the Brûlé mines amounts to 1,836,743 tons, almost all of which has been derived from the synclinal basins of seams No. 2 and No. 3, lying to the west of the mine tipple and extending from the outcrops of those seams northwesterly to within 700 feet of Scovil creek. The withdrawal of the mine pillars has left most of the mine in an inaccessible condition, so that all the commercially recoverable coal within this area may be said to have been extracted. Although there still remains a considerable tonnage of unmined coal on the vertical limbs bordering the basins, the several attempts so far made to extract it on the western limbs of the syncline have proved unprofitable, owing to the soft nature of the coal and enclosing measures resulting in pinches of the seam and in an insufficiently pure product. No attempt has been made to mine the vertical seams at and to the east of the mine tipple below adit level, but doubtless comparable structural and physical conditions will be found to exist there also. The steeply inclined and crushed condition of the seams exposed in prospects A, B, and C, and of the measures on Scovil creek at and to the east of Dickson prospect, holds forth little hope of the existence of favourable mining conditions on the area east of the present mine working.

For the same reasons the highly inclined coal seams uncovered at the Bartholomew prospect on Scovil creek and in the pits located near the crest of the spurs of Scovil hill 2,000 and 4,000 feet farther northwest along the strike are considered to offer too small a chance of profitable extraction to warrant any heavy expenditure in their exploitation.

As regards the belt lying beyond Scovil creek and to the east of the outer conglomerate band, although the seams doubtless occur in it the heavy mantle of boulder clay, forest growth, and moss cover makes impossible any approximation being made of their position. The absence of any evidence of coal in place and the highly inclined attitude of the relatively few rock exposures that occur on Scovil creek below the Dickson prospect and on the eastern slope of Scovil hill suggest that folding and faulting have been at least as equally effective in this zone as in the southern part of the belt. The thrust faulting may be such as to totally obscure all evidence of coal at the surface. The drift cover, which is in places 20 feet thick, makes trench prospecting slow and expensive and the position of the seams can be determined most economically by diamond drilling, even though this will prove fairly costly. The unfavourable structural conditions evidenced in the few outcrops that exist and the impurity of the coal where mined have so far deterred such an expensive prospecting program being undertaken.

During 1927 the geological investigation confirmed by drilling on the part of the company revealed the fact that the coal measures reappear $1\frac{1}{2}$ miles to the northeast of the camp, where they outcrop over a belt about $\frac{1}{2}$ mile in width, trending in a northwesterly direction along the eastern limb of the synclinal basin. A moderately inclined, southwesterly dipping seam had previously been uncovered on Oldhouse creek at what is designated the Roscoe prospect. The stratigraphic position of this seam with reference to the top of the formation outcropping 1,900 feet upstream indicated it to be close to the main coal horizon. One and one-half miles to the southeast of this prospect the existence of the coal horizon was proved by a series of bore-holes put down by the Blue Diamond Coal Company to the north of Brewster creek, but no data as to the thickness or quality of the several seams encountered are at hand. Although evidence of considerable folding and crushing of the measures was found both on Oldhouse creek and in the bore-hole cores the structural conditions of this limb are believed to be much more favourable to the economic extraction of coal than is the coal elsewhere along the western limb. The relatively low relief of this belt allows of little coal lying above adit level.

Time did not permit of the examination of the northwesterly extension of the belt beyond Oldhouse creek, but the configuration of the synclinal basin within the map-area suggests that the coal horizon in all probability continues its northwesterly course for a distance of at least 3 miles and then curves westward around the head of the basin to join with that of the western limb. The possibility of the existence of favourable structural conditions in this area entitles it to a detailed examination.

SOUTHERN SASKATCHEWAN

By F. H. McLearn

CONTENTS

INTRODUCTION

A study of the stratigraphy and structure, and the preparation of a geological map of southern Saskatchewan were begun by the Geological Survey in 1927[1] and continued in 1928. The following parts of the Cypress, Wood Mountain, and Willowbunch topographic surveys sheets, assigned to the writer, were examined in 1928: Frenchman river from near Whitemud to Val Marie, a part of the southwest border of Pinto plateau, and, in a preliminary way, the country around Twelvemile lake. A reconnaissance trip across southern Saskatchewan was made with C. M. Sternberg, which resulted in the discovery of several new and important fossil dinosaur localities. The fossils from them, together with the fossils obtained from localities found by the writer's party, are listed in the following pages. Two conferences held in the field with P. S. Warren proved most helpful. In the field O. L. Backman, Edward Leith, A. F. Matheson, and A. Pentland gave very satisfactory assistance. In the office F. J. Fraser continued the study of the petrography of the sandstones, C. M. Sternberg identified the fossil vertebrates, and W. A. Bell examined the fossil plants.

STRATIGRAPHY

Economic purposes alone are sufficient to demand a detailed study of the stratigraphy of southern Saskatchewan, for a solution of the stratigraphy is prerequisite to all determination of structure, which in turn must precede all inferences of oil and gas possibilities. After two years of field study, as evidence of progress, it is possible to enumerate some additions to our knowledge of the stratigraphy; an erosional unconformity has been

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, pp. 21–43, map (1928). Fraser, F. J.: Appendix No. 1 (to above report) pt. B, pp. 44–53 (1928).

found at the base of the Ravenscrag formation in Eastend area;[1] the Lance age of the basal Ravenscrag in Eastend area has been determined; the Lance age of the beds that occupy the stratigraphic position of the Whitemud beds down Frenchman river, where the Whitemud beds are absent, has been established; the Lance age of at least a part of phase B of the Basal sandstone has been determined; it has been found that the Whitemud type of sandstones and clays is present at more than one horizon; it has been found that the Whitemud sandstones have certain peculiarities of heavy mineral composition concomitant with their alteration; a theory of local or intraregional origin of the Whitemud clays has been advanced, but not proved. On the other hand, a number of, as yet, unsolved stratigraphic problems have arisen; the age of the Eastend or true Whitemud beds and of phase A of the Basal sandstones underlying them is not yet known and consequently the erosional unconformity at the top of the Whitemud in Eastend area cannot yet be evaluated; the relation of the beds of Lance age which occupy the stratigraphic position of the Whitemud beds, where they disappear down Frenchman river, to the Whitemud beds, is not proved, although it is thought that they are of a later age, and, therefore, the probable extension of the erosional unconformity, at the top of the Whitemud, down Frenchman river, cannot yet be firmly established; the hypothesis of a post-Whitemud age of phase B of the Basal sandstones has yet to be proved or disproved; the determined age of the Upper Ravenscrag is only based on plant and non-marine invertebrate evidence and would be better established if diagnostic vertebrate remains, e.g., mammals, could be found; it has yet to be determined whether the Whitemud beds of the Willows, Big Muddy, and other eastern localities are of the same age as, or later than, those of Eastend; the problem of the direction of source of the Whitemud sediments has yet to be proved.

BEARPAW

Exposures of the upper part of the Bearpaw are found on the lower slopes and bottom of the valley of Frenchman river in townships 4 and 5 and ranges 18 and 19. At the very top are dark shales containing very few fossils, including a poor specimen of *Baculites*. Below this and near river-level in range 18 and the western part of range 17 are greenish, massive sandstone and thin-bedded sandstone and shale.

East of Mule creek the Bearpaw underlies more and more of the valley sides owing to the eastward regional slope of the land and the downcutting of the river. Between Mule and Bates creeks the top of the Bearpaw consists of dark shale, arenaceous shale, some sandy layers, a peculiar yellowish green clay layer, crystals of selenite, and, more rarely, spherical masses of fibrous and stellate gypsum. Fossils are rare in the top of the Bearpaw here and include the following marine invertebrates, *Baculites* cf. *grandis*

[1]In Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 31, in comparing this unconformity with one described by Allan and Sanderson in Red Deer river, it is stated that the Paskapoo is post-Lance and post-Fort Union. As the exact position of the Paskapoo mammal fauna, dated by Simpson of about Clark Fork or late Palæocene age, is not known, this sweeping statement of the age of the Paskapoo is withdrawn. If the dated mammal fauna is in the middle or upper part of the Paskapoo the lower part of the formation may possibly be of some earlier age. Anyway, the writer has no right to consider it all late Palæocene and post-Lance, etc., without more evidence. As the age of the Whitemud is yet unsolved it is not advisable to say that the Edmonton is "probably" pre-Whitemud.

Hall and Meek, *Goniomya americana* Meek and Hayden, *Yoldia,* and the wood-borer *Martesia.* Below the dark shale and at about river-level are about 15 feet of fine sandstone with some shale layers and concretions. In places the beds are thin, 2 inches or so. In the concretions the following marine invertebrates were found: *Dentalium, Protocardium, ?Linearia,* and *Lingula.*

Between Bates and Warholes creeks the upper part consists of dark shale with selenite crystals and is followed below by a sandy zone and yet farther down by dark shale. In about sec. 33, tp. 5, range 16, W. 3rd mer. and northwest of the '76 ranch on the north side of the river the sandy phase is thick and consists of sandstone, some shale, and fossiliferous concretions enclosing the marine invertebrates *Scaphites nodosus* var. cf. var. *plenus* Meek, *S. nodosus* var., *Nautilus* sp., *Haminea, Nucula, Lucina, Inoceramus barabini* Morton, etc. On the opposite and south bank of the river the section is similar and there a sandy phase of the Bearpaw yields *Baculites* cf. *grandis* Hall and Meek and *Yoldia.* Yet farther east and on the north slope of the valley the sandy phase yielded *Scaphites nodosus* var. cf. var. *plenus* Meek. On the south slope of the valley, south of McGuire's ranch, in about sec. 19, tp. 5, range 15, W. 3rd mer., the Bearpaw consists of dark shale above, with some layers of light-coloured clay shale, followed below by sandstone with concretions and a 1-foot bed of greenish silt at the top. Below this are dark shales to river-level. In the sandy phase and in the shale immediately over it, a marine crustacean and specimens of *Baculites compressus* Say were found.

From the mouth of Warholes creek downstream more and more of the dark shale below the sandy phase is exposed. On the south side of the valley in about sec. 10, tp. 5, range 15, W. 3rd mer., dark shale with concretions yield *Baculites compressus* Say, *B. ovatus* Say?, *Inoceramus barabini* Morton, *Scaphites* cf. *subglobosus* Whiteaves, etc. On the north side of the Frenchman and on the east side of Hoff valley, between sec. 2, tp. 5, range 14, W. 3rd mer., and sec. 28, tp. 5, range 14, W. 3rd mer., dark shales yielded *Baculites compressus* Say, *Scaphites* cf. *subglobosus* Whiteaves, *Inoceramus barabini* Morton, and other shells. On the west side of Hoff valley in sec. 7, tp. 5, range 14, W. 3rd mer., dark shale yielded *Baculites compressus* Say, *Discoscaphites,* etc.

South and east of Val Marie in the valley of the Frenchman and its tributaries the Bearpaw underlies a broad area. In sec. 2, tp. 4, range 12, W. 3rd mer., dark shale yielded the following: *Baculites compressus* Say, *Scaphites* cf. *subglobosus* Whiteaves, *Inoceramus,* and other shells. In about sec. 32, tp. 3, range 11, W. 3rd mer., *Baculites* was found in dark shale with selenite crystals and concretions. In the above descriptions, *Scaphites* is used in the broad sense.

BASAL SANDSTONES

The sediments directly over the Bearpaw shales in the area examined in 1928 vary considerably, but fall into three principal classes which may be tentatively designated: phase A, or the yellow superfine sandstones and shales; phase B, or the greenish yellow to dark green, massive sandstones; and phase C, or the very fine, white, high quartz-bearing sandstone. The exact relation of the beds of these phases to one another is as yet unsolved and they are merely tentatively classed together because of their like stratigraphic position.

The yellow superfine sandstones and shales of phase A are identical with those over the Bearpaw in Eastend area described last year as the yellow sandstones,[1] and are a continuation of them. In the area studied in 1928 they are present on both sides of Frenchman valley from the southeast corner of Eastend area[2] to about sec. 17, tp. 5, range 19, W. 3rd mer. They consist above chiefly of massive, yellow, very fine or superfine sandstones and silts with flat concretions and below of thin beds of the same sandstone with dark grey or greenish shales and arenaceous shales. Many of the sandstones and silts are slightly dolomitic. They underlie the Eastend Whitemud beds everywhere in the southeastern part of Cypress hills and persist only a very short distance beyond where the Whitemud beds disappear down Frenchman river. Similar sandstones and shales underlie the Whitemud beds where they reappear on the southwest border of Pinto plateau in sec. 26, tp. 3, range 10, W. 3rd mer., and secs. 34 and 35, tp. 3, range 10, W. 3rd mer.

The beds of phase A appear to be conformable with the Bearpaw below, showing a gradation in sediments, and are also conformable with the Whitemud beds above. No fossils have been found in them, except in transition beds to the Bearpaw, and their age is unknown. They are, of course, pre-Whitemud, are not later than Lance, and are equivalent in time to Lance, Edmonton, or Foxhills. But to be called Foxhills, in the strict sense, it is presumed that they would have to be of marine origin and of pre-Lance but not pre-Edmonton age.

A more common phase in the area examined in 1928 is the massive, yellowish green or dark green, medium sandstone which resembles the dark green sandstone[3] at the base of the Ravenscrag formation in Eastend area. Down Frenchman river it first appears at about sec. 17, tp. 5, range 19, W. 3rd mer., and continues eastward on the north side of the valley to Warholes valley and beyond. It is also present on the west border of Pinto plateau. A sandstone overlies the Bearpaw shales at Twelvemile lake, but as it underlies Whitemud it is probably not the same sandstone and may be of earlier age. The rock of phase B is commonly a massive, medium to fine, dark green or yellowish green sandstone with hard, flat ledges and crossbedding on a large scale. It is mostly non-calcareous and non-dolomitic. The hard ledges in places are light grey in colour and have a calcareous cement. The component grains consist of quartz, feldspar, dark argillite, "chert," etc., and the heavy mineral suite includes in varying amounts zircon, tourmaline, rutile, sphene, biotite, apatite, garnet, epidote, and hornblende. The heavy mineral suite resembles that of the dark green sandstone at the base of the Ravenscrag in Eastend area, particularly in the presence of hornblende. The presence of apatite, garnet, and epidote points to the

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 25 (1928).
[2]Map 212A, Cypress Hills, Geol. Surv., Canada, Sum. Rept. 1927, pt. B (in pocket).
[3]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, p. 32 (1928).

small amount of chemical alteration that this sandstone has undergone. The thickness is commonly from 45 to 65 feet, where measured last summer, but is locally much less. In many places the upper part is of finer grain and exhibits a gradation up into the silty shales or clay shales of the overlying zone, hereafter designated the Lower (Lance) part of the Ravenscrag formation. A conformable relation with the overlying beds is further indicated by replacement of the top part laterally by the clay shale, etc., of the overlying zone and the consequent rise and fall stratigraphically of the contact. In a few places it passes into fine-grained, yellowish sandstone and even into fine sandstone and shale, but characteristically it is a massive, medium to fine sandstone. Fossils are very rare. From the very top, in about the northwest corner of sec. 35, tp. 5, range 17, W. 3rd mer., the following were collected on the surface of the basal sandstone and were so situated that they could only have come from the top of the Basal sandstone. The fossils collected include a dorsal vertebra of *Triceratops,* a fragment of crest of a horned dinosaur, a vertebra of a champsosaur, a fragment of turtle, and a fragment of crocodile. This is a non-marine reptilian fauna and its age is interpreted by Sternberg as Lance. At this place the top of the Basal sandstone appears to come high stratigraphically. In about the southeast corner of sec. 31, tp. 5, range 17, W. 3rd mer., at the very bottom of this member in a basal shale phase under the massive sandstone and directly over the Bearpaw shale, selenite crystals, fossilized wood, and fragments of the rib of an herbivorous dinosaur were found; this fossil lot, of course, does not admit of dating. Considering the Lance age of the one datable lot of fossils in this sandstone and in many places its apparent conformability with the overlying beds of Lance age, it is probable that at least in places this phase of the Basal sandstone is of Lance age. Its relation to the Whitemud and phase A of the Basal sandstone is not yet known. It nowhere underlies the Whitemud and only appears where the Whitemud beds disappear. If the Whitemud and phase A are pre-Lance then the phase B is later. Unfortunately, where the sandstones of phase B take the place of those of phase A, the outcrops so far studied do not reveal the nature of the change, i.e., whether there is merely lateral gradation of one into the other or whether there is an erosional unconformity present. If the basal part of the Lower Ravenscrag, the part that occupies the stratigraphic position of the Whitemud, is of post-Whitemud age then a part at least of phase B is post-Whitemud, for in places at least the strata of the basal Ravenscrag and phase B are conformable. If the strata of phase B are post Whitemud, then they should rest with erosional unconformity on the Bearpaw or at least should not show at the contact a gradation in sediment down into the Bearpaw. The Basal sandstone is probably waterlaid and as far as the evidence goes, non-marine; at least, the few fossils found in it are non-marine.

In a part of the area there is a third or C phase of the Basal sandstone, lying south of an area where phase B is present, occupying as far as known the same stratigraphic position. It was seen to overlie the Bearpaw on both sides of Frenchman valley from a little east of Bates valley to near Warholes valley; the boundary between the two phases runs on the north side of Frenchman valley approximately through the north part of sec. 5, tp. 6, range 16, W. 3rd mer., the north-central part of sec. 10, tp. 6, range 16, W. 3rd mer., and the southern part of sec. 12, tp. 6, range 16, W. 3rd mer. It consists principally of fine to superfine (or silt) light grey to white sandstone, weathering mostly white in colour, but in places, yellowish. Three samples examined are of from very fine sandstone to superfine sandstone or silt grade and consist chiefly of quartz grains. The heavy mineral suite is restricted and includes zircon, tourmaline, apatite, garnet, and anatase, but all are not present in the one sample. It is in part massive and homogeneous, but contains in places very thin, leaf-like bands of clay or black to brown plant detritus and thicker layers of clay or clay shale. It is crossbedded on a small scale, due apparently to wave or current work and contains flat ironstone concretions. There is a 6-inch or less seam of lignite near its top and in places a very thin, coaly or carbonaceous layer about 6 feet below the seam. Southward down the '76 and other tributary valleys of the Frenchman the sandstone of phase B disappears and has its stratigraphic position taken by those of phase C, but the actual contact is not visible and it has not yet been determined whether or not one phase passes gradually into the other and consequently whether or not they were laid down contemporaneously. In one place it is known that sandstone of phase C overlies the lower part of sandstone of phase B. It has not yet been found in higher members of the local stratigraphic column and nothing has so far been found to overlie it; the evidence, therefore, of its stratigraphic position, is not yet complete. No fossils have so far been found in it in the area studied by the writer, but P. S. Warren reports[1] that a sandstone of similar lithology and stratigraphic position on Notukeu creek contains fossil leaves.

WHITEMUD

There are undoubtedly two distinct Whitemud zones, and very possibly a third at least, in southern Saskatchewan. One in the Eastend area, Whitemud in the strict sense, is of either lower Lance or pre-Lance age and consists chiefly of medium to fine kaolinized sandstones and semi-refractory clays. The probably coeval Whitemud of Twelvemile lake is similarly overlain by the Lower Ravenscrag with similar erosional unconformity in places. Another zone, high in the Buff or third division of the Ravenscrag, west of Willowbunch, must be of Palæocene age and consists chiefly of very fine sediments, including semi-refractory clay. The Whitemud of Big Muddy valley apparently lies in the middle or second division of the Ravenscrag, but its exact stratigraphic position needs yet to be proved; this applies also to the Whitemud of Willows and other eastern localities with their coarser sandstones and refractory and semi-refractory clays.

The Whitemud beds may be followed a short distance down Frenchman valley, off the southeast corner of the Cypress Hills map-area[2] to dis-

[1]Personal communication.
[2]Geol. Surv., Canada, Sum. Rept. 1927, Map 212 A.

appear at about sec. 19, tp. 5, range 19, W. 3rd mer., on the northeast side of the valley and at about a corresponding position on the southwest side. In sec. 25, tp. 5, range 20, W. 3rd mer., the Whitemud sandstone is about 25 feet thick and overlies very fine, yellow sandstone or coase silt of phase A of the Basal sandstone. The lower part consists of greenish, fine sandstone weathering yellow in patches, streaks, layers, or yellow spots and is greenish white on the surface. The upper part consists of greenish grey, finer sandstone with some yellow streaks and patches and bluish clay patches. Immediately over the Whitemud sandstone the following section was measured in an artificial section:

	Feet	Inches
Green sandstone	3	0
Grey shale	0	3
Green sandstone	0	2
Grey shale	1	2
Brown, carbonaceous, arenaceous shale	1	0
Dark shale	1	0

It is probable that the three lowest beds should be assigned to the Whitemud formation and the three highest to the basal Ravenscrag. The lithology of these three highest beds is similar to those of the basal Ravenscrag, the dinosaur fauna appears just over them, and there appears to be some indication of an erosional interval between the lower and upper three beds of the above section. For a short distance southeastward along the valleyside the section is about as described above. Then the massive, Whitemud, kaolinized sandstone thickens to about 70 feet, but in a very short distance it abruptly thins to about 25 feet as before. At this place the Whitemud sandstone has the form of a mound with the dark green sandstone of the basal Ravenscrag on the top and on both sides of it. Yet a little farther along the valleyside and near the boundary between ranges 19 and 20, W. 3rd mer., township 5, the Whitemud sandstone is about 30 feet thick, overlies very fine yellow sandstone or coarse silt of phase A of the Basal sandstone, consists below of fine, greenish, silty sandstone and above of partly kaolinized grey sandstone. Over this are clay of the Whitemud type, dark shales, dark grey and brown, arenaceous shale, green sandstone, and greenish shale. The last two are probably of the basal Ravenscrag. Yet a little farther southeast along the same side of the valley, in sec. 7, tp. 5, range 19, W. 3rd mer., at a small coulée extending southward into the main valley, the Whitemud sandstone, approximately 20 to 25 feet thick and underlain by sandstone of phase A of the Basal sandstone, is abruptly cut off and its stratigraphic position is taken by yellow and yellowish green, fine sandstone with large concretions, presumably of the Lower Ravenscrag. For some distance along the valleyside there are no Whitemud sediments, their stratigraphic position being occupied by greenish and yellow sandstone, etc. In the eastern part of sec. 7, tp. 5, range 19, W. 3rd mer., the Whitemud extends a short distance. It is nearly 70 feet thick and consists of fine, greenish sandstone weathering white on the surface, and is underlain by very fine, yellowish sandstone with large, slab-like concretions of phase A of the Basal sandstone. It is overlain by dark grey, greenish, etc., clays and shales and a 6-foot bed of greenish yellow sandstone. A little southeast of this the Whitemud disappears abruptly, its stratigraphic position being occupied by the shales, clays, and sandstones of the Lower Ravenscrag. The contact is a very abrupt one and on a slope of about 30 degrees. No more Whitemud was found down Frenchman river, its stratigraphic position continuing to be occupied by the beds of the Lower Ravenscrag.

On the west slope of Pinto plateau the Whitemud is present at one locality. In sec. 35, tp. 3, range 10, W. 3rd mer., there are 13 to 15 feet of grey, partly kaolinized, micaceous sandstone overlain by 4 feet of hard, grey clay-shale and fine, yellow sandstone and underlain by yellowish and grey superfine sandstone, silt, etc., and light and dark grey shales resembling those of phase A of the Basal sandstone in Eastend area. Whitemud sediments are also present in a coulée northwest of Horsethief Guide, in approximately sec. 21, tp. 4, range 10, W. 3rd mer.

At Twelvemile lake a beginning was made of the study of the Whitemud beds there. They are fairly thick in places and either directly overlie the Bearpaw shales or more commonly are separated from them by massive, greenish, or yellowish sandstone and thin-bedded sandstone and shale.

The exact age of the Whitemud beds is not known. No fossils have yet been found in them. The beds that occupy their stratigraphic position down Frenchman river are of Lance age, but they are probably of somewhat later time. The Whitemud may be early Lance, Edmonton, or some intervening age.

Data on the Whitemud sediments additional to that furnished in a previous report[1] can now be given. About eighty samples of Whitemud sandstones and silts alone have been examined by F. J. Fraser. That apatite, garnet, and epidote are absent in the Whitemud or are in much smaller proportion than in the sandstones and silts of the other formations is amply confirmed. These three minerals are absent in almost all the Whitemud silt samples and almost all Whitemud sandstone samples containing more than 30 per cent of sediment of clay grade. One or two, or all three of these minerals, are present in nearly all Whitemud sandstone samples containing 20 per cent or less of sediment of clay grade. On the whole, the presence of these minerals in the Whitemud beds appears to be roughly inversely proportional to the amount of clay grade in the sediments and possibly to the amount of decomposition that they have undergone. Anatase is very characteristic of the Whitemud sediments and is probably a decomposition product. Very few of the Whitemud sandstones or silts are calcareous or dolomitic, whereas many of the sediments of phase A of the Basal sandstone and of the Upper Ravenscrag are. It is also to be noted that until the Whitemud beds of the east

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, pp. 26, 38.

and west are correlated it is useless to base any conclusions on variation in grain of the sediments, for obviously it is the grain of sediments of the same age that must be compared[1]. For this reason the determination of the source of the Whitemud sediments must be postponed.

LOWER RAVENSCRAG

It is interesting to find that beds containing the Lance dinosaur fauna are not confined to Rocky creek in the southern part of Wood mountain, but can also be recognized in Cypress hills and adjacent country. In Eastend area the basal part of the Ravenscrag below the No. 1 coal seam is found to contain this fauna, as also the beds occupying the stratigraphic position of the Whitemud beds where they disappear, down Frenchman river below Whitemud. A part at least of the sandstone of phase B of the Basal sandstone is of Lance age and eventually it, or parts of it, may have to be included in the Lower Ravenscrag. Some of the beds classed in a former report as part of phase E of the Whitemud formation in Eastend area[2] are identical with those here included tentatively in the Lower Ravenscrag, i.e. with those occupying the stratigraphic position of the Whitemud where it disappears or is only a few feet thick. This applies to beds north of Southfork and in the southeastern corner of Cypress Hills map-area.[3] The thickness of the Lower Ravenscrag will thus vary according to whether it merely includes the beds between the Whitemud beds and the first coal seam of the Ravenscrag, or in addition the beds occupying the stratigraphic position of the Whitemud beds where they disappear.

Just off the Cypress Hills map-area on the northeast side of Frenchman valley, in sec. 25, tp. 5, range 20, W. 3 mer., the contact between the Whitemud and Lower Ravenscrag is drawn a few feet above the top of the Whitemud sandstone, the first layers of green sandstone being placed in the Lower Ravenscrag as noted on a previous page. The Lower Ravenscrag is here over 75 feet thick and consists of yellowish and greenish and dark grey clay-shales and shales and some greenish sandstone; it contains the following reptilian fossils ranging from a little above the base to within about 5 feet of the No. 1 coal seam: fragments of crest of horned dinosaur, phalanx of carnivorous dinosaur, right ilium of *Champsosaurus,* and fragment of carapace of Trionychid turtle. The section remains much the same along the valley side for a short distance to where the lower part of the shales and clays and sandstones pass into massive green sandstone. In a small coulée the contact of this massive green sandstone with the underlying Whitemud sandstone rises abruptly and the thickness of the Lower Ravenscrag consequently thins abruptly. Beyond this the contact rapidly falls again and the Lower Ravenscrag thickens, at the expense of the Whitemud sandstone, which becomes much thinner. At this place the bottom of the massive green sandstone contains the neural spine of a duckbill dinosaur. The contact

[1]The variations in grain of the Whitemud sandstones and the variations in degree of refractoriness of the Whitemud clays, cited by some authors as evidence of the direction of the source of the Whitemud sediments, are as much stratigraphic or vertical as geographic or lateral variations. The lateral variations need to be restudied in the light of the new correlations of the various Whitemud zones.

[2]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, pp. 28, 39.

[3]Geol. Surv., Canada, Sum. Rept. 1927, Map 212A.

here and in the vicinity of the above small coulée is evidently that of an erosional unconformity. The green sandstone cuts down across the Whitemud sandstone at steep angles, leaving a high and comparatively narrow ridge of the same. A little farther along the valley side in township 5, and near the boundary between ranges 19 and 20, W. 3rd mer., Lower Ravenscrag is of about the same thickness; its lower part occupies the stratigraphic position of the Whitemud sandstone in the ridge which projects up into the green sandstone in the small coulée described above; it consists of green sandstones, clay shales, etc. Yet farther along the same side of the valley at another coulée, in sec. 7, tp. 5, range 19, W. 3rd mer., the lower contact cuts abruptly downward, so that the Whitemud entirely disappears and the Lower Ravenscrag is much thickened at the expense of the Whitemud. It consists here in its lower part, i.e. at the horizon of the Whitemud beds, of fine and coarse, greenish and yellowish sandstones with concretions; above, it consists of greenish yellow clay-shale, sandstone, etc. In its higher part at this locality the following vertebrate fossils were found: occipital condyle, section of crest and centrum of vertebra of the horned dinosaur *Triceratops*. For some distance along the valley side the Lower Ravenscrag is fairly thick as it continues to extend down below the horizon of the Whitemud, there being no Whitemud present; it consists here in the lower part of greenish and yellowish sandstone, etc. Yet farther along the valley side and in the eastern part of sec. 7, tp. 5, range 19, W. 3rd mer., where the Whitemud sandstone, etc., is present for a short distance along the bank, the Lower Ravenscrag is thin. As stated on a previous page, the kaolinized sandstone of the Whitemud is overlain by dark grey and greenish clays and shales and a 6-foot bed of greenish yellow sandstone. The sandstone at least should be included in the Lower Ravenscrag. A few hundred feet beyond, the basal contact with the Whitemud beds is very marked and extends down at a pronounced slope. The Whitemud beds disappear and chocolate grey, greenish, and yellowish shales and clay shales and some greenish sandstone take their place. The actual contact is an abrupt one, there being no gradation of the one sediment into the other and no interfingering of layers. The beds taking the place of the Whitemud beds were found to contain the fragmentary remains of a part of a large Triceratops-like dinosaur. In the next exposure the Lower Ravenscrag consists of blue-green, yellowish, dark grey, chocolate clay shales and some green sandstone. It is underlain by sandstone and shale of phase A of the Basal sandstone. There is no Whitemud here. A little farther down the valley side the massive green sandstone of phase B of the Basal sandstone appears. From this locality down Frenchman valley where beds of this horizon are present they consist of 125 feet, more or less, of light and dark green or bluish green, yellow or yellowish green, dark grey clay shales and shales, and green and yellow sandstones. A layer of light green or light bluish green clay shale in the lower part is very prominent in the cliffs for a long way down the valley. A thick bed of greenish or yellowish sandstone occurs in places near the middle of the Lower Ravenscrag. Smaller sandstone layers are also present, but none is very persistent. There is also in places a thick sandstone bed near the top. Underlying all is the massive sandstone of phase B of the Basal sandstone. A typical section taken from the southeast corner of sec. 15, tp. 5, range 19, W. 3rd mer., is as follows:

	Feet	Inches
Greyish green and yellowish green clay shale, superfine sandstone, etc.	20	
Green sandstone	3	
Grey, greenish grey, yellowish green shale, clay shales	30	
Crossbedded, massive, green sandstone, large, hard ledges	50	
Yellowish green, pale greenish blue, dark mostly yellowish, and chocolate clay shale with dinosaur remains	15	
Light greenish clay	1	6
Yellowish clay shale	1	0
Chocolate green clay shale	3	0

The beds of this section are underlain by coarse greenish sandstone of phase B of the Basal sandstone and are overlain by No. 1 seam of the Ravenscrag formation. The dinosaur remains mentioned in the above section include the nasal horn core of the large horned dinosaur *Triceratops*. Fossils were found also in other localities. Thus in sec. 1, tp. 5, range 19, W. 3rd mer., on the north side of the valley, in the middle of the Lower Ravenscrag, part of the anterior caudal vertebra of the duck-billed dinosaur *Thespesius* was found. In about the northwest corner of sec. 32, tp. 4, range 18, W. 3rd mer., in the green sandstone in the middle of the Lower Ravenscrag and in clay shales just under it, *Unio* and the caudal vertebra of a duckbill dinosaur were found. In about the southeast corner of sec. 5, tp. 5, range 18, W. 3rd mer., just above a green sandstone in the middle of the Lower Ravenscrag, the fragment of a limb bone and rib of an herbivorous dinosaur were collected.

The only occurrence[1] of fossils east of Mule creek in this member of the Ravenscrag is that of a bone fragment, probably of dinosaur, which is in the lower part of the Lower Ravenscrag, on Pinto plateau, at about sec. 27, tp. 4, range 11, W. 3rd mer. Where there are no fossils this member can be traced by means of its characteristic lithology and by its relation to the Bearpaw, etc., below.

The Lower Ravenscrag is probably largely non-marine. Only non-marine fossils have been found in it. The age is Lance or Hell Creek, and is based largely on the occurrence of the large, *Triceratops*-like horned dinosaur remains.

UPPER RAVENSCRAG

The Upper Ravenscrag[2] is tentatively defined to include the upper and greater part of the Ravenscrag formation from about the first coal seam up, i.e., the part above the beds containing the Lance dinosaur fauna.

[1]Dinosaur fragments have recently been collected by Sternberg in the Lower Ravenscrag of Twelve-mile lake.

[2]The Ravenscrag, in places at least, including its type locality, consists of three divisions: a lower part of greenish and grey sandstones and silts and sombre yellowish and greenish weathering plastic clay shales and containing the Lance dinosaur fauna; a middle and much thicker part of somewhat similar lithology, but with coal seams and so far as known without dinosaur remains; an upper part of fine silts and shales chiefly, with coal seams and weathering prevailingly buff in colour. The first division is herein tentatively designated Lower Ravenscrag, the second and third divisions can be mapped separately with considerable difficulty and are herein tentatively grouped together as Upper Ravenscrag. If the separate mapping of the second and third divisions proves practicable it may be desirable to recognize all three divisions as Lower, Middle, and Upper Ravenscrag or it may be necessary to introduce new member or formation names for them and possibly Estevan can be salvaged for one of these names.

Down Frenchman river, off Cypress Hills map-area,[1] only the lowest part is exposed at the tops of the cliffs, but up Mule, Gunns, and Bates creeks much more of it underlies the hillsides. The lower part underlies the higher part of Horsethief Guide in the southwest part of Pinto plateau and good sections of considerable thickness are found farther east at the east end of Twelvemile lake and in Hay Meadow Creek valley.

The Upper Ravenscrag consists commonly of very fine sandstones, silts, clays, and clay shales. Coarser sandstones of fine or medium grade are present in places. Grey, greenish, yellowish, and buff colours are characteristic of the lower part. All these colours are present in the upper part, but buff predominates. A number of coal seams are present. Many of the sandstones and silts are calcareous or dolomitic. At Horsethief Guide and in Hay Meadow Creek valley a thin zone of fine sandstone and clay of Whitemud type is present at a considerably higher horizon or horizons than the Whitemud beds along Twelvemile lake.

Fragments of bone of the reptile *Champsosaurus*, fragments of the carapace of a turtle, and scales of the fish *Lepisosteus* are about the only vertebrates present. Last year plants were collected in Eastend area and were dated about Fort Union or early Tertiary by W. A. Bell, who studied them. This year the following were collected on Mule creek and identified by W. A. Bell.

Trochodendroides 2 n.sp.
Populus cf. *xantholithensis* Knowlton
Cocculus haydenianus Ward

Bell notes that "the two species of *Trochodendroides* may be compared with *Trochodendroides arctica* (Heer) Berry and *Populus amblyrhyncha* Ward. They, along with *Populus* cf. *xanolithensis* Knowlton, represent a type of leaf common in, and rather characteristic of, the early Tertiary. *Cocculus haydenianus* has been reported from both the Fort Union and Lance." It is most desirable that mammal remains be found in the Upper Ravenscrag, for they admit of exact dating. No dinosaur remains have yet been found above the first coal seam in localities examined by the writer's party. The dinosaurs may have been extinct by Upper Ravenscrag time. That being so, the Upper Ravenscrag may be the equivalent of the Tullock and other Palæocene formations of southern Montana or of the Puerco of Colorado and New Mexico, but mammal remains are necessary for the correlation with the latter.

It is interesting to note that the beds mapped[2] by Davis at the east end of Twelvemile lake as Estevan do not underlie the Whitemud beds along Twelvemile lake, but overlie them. They evidently belong to the first and second divisions of the Ravenscrag. The sombre beds of Rocky creek, in the southern part of Wood Mountain plateau, mapped by Davis as Estevan, belong to the Lower Ravenscrag. Most of the beds of the eastern half of southern Saskatchewan, mapped as Estevan by Davis, belong to parts of either the first or second division of the Ravenscrag or

[1] Geol. Surv., Canada, Sum. Rept. 1927, pt. B, Map 212A (in pocket).
[2] Mines Branch, Dept. of Mines, Canada, "Report on the Clay Resources of Southern Saskatchewan," Map 468, p. 6 (1918).

to both. The beds mapped as Ravenscrag by Davis at the east end of Twelvemile lake and at other localities, probably, in eastern south Saskatchewan, actually belong to the third or Buff division of the Ravenscrag.

CYPRESS HILLS

About 10 feet of conglomerate and sandstone are exposed on the southwest border of Pinto plateau, near Horsethief Guide, in sec. 1, tp. 4, range 10, W. 3rd mer., and are correlated with the Cypress Hills on the basis of the composition of the pebbles. The lowest exposure is a 4-foot bed of conglomerate consisting of pebbles of quartzite, chert, quartz vein material, grit, etc. Presumably they were derived from the Precambrian and Palæozoic terrains of the Rocky mountains. The matrix of coarse sand is in fairly large proportion. The average size of the pebbles is about $\frac{7}{8}$ inch, but quite a few are from 2 to $2\frac{1}{2}$ inches in diameter and the largest observed is $7\frac{1}{2}$ inches. The size of pebbles is smaller than farther west in Cypress hills. The bed of conglomerate is overlain by sandstone having a few pebbles scattered through it. This sandstone is of medium to almost coarse grade and consists of angular grains of quartz, chert, and a small amount of feldspar.

The beds of this formation at the above locality rest on massive, yellow-green sandstone of the lower part of the Upper Ravenscrag. The actual contact was not seen. No fossils were found at this locality.

STRUCTURE

As the determination of the structure is so dependent on an understanding of the stratigraphy and, as noted in preceding sections under stratigraphy, there yet remain a number of unsolved stratigraphic problems, a full account of the structure of the area studied in 1928 cannot yet be given. A few remarks on the general structure are offered, however. From Whitemud down Frenchman river to where the river turns to the east, the general attitude of the strata in the direction of the section cut by the river is about horizontal. On the eastward stretch the strata are a little higher, i.e., there is a slight upwarping. From Mule to Warholes creek there is some variation in the altitude of the strata due to slight and irregular warping, and on the whole the elevation is a little higher than below Whitemud. In Pinto plateau the elevation of the strata is even a little higher than in the vicinity of Warholes creek and there is some warping, up and down. There is no eastward regional dip from Whitemud to Pinto plateau, rather a slight rise eastward.

In the vicinity of Twelvemile lake the structure is such that there is a dip eastward in the direction of the section exposed along the lake.

ECONOMIC GEOLOGY

It seems best to postpone a diagnosis of oil and gas possibilities until the stratigraphic and structural studies are completed. When the surface structure is established it will be necessary to consider to what extent it will persist in depth and whether it is on a scale, or has closure, favourable to oil and gas accumulation. Even if structural conditions are favourable, unless more pronounced folding is met with than is at present known, at best only heavy oil can be anticipated.

Because extensive technological tests of Saskatchewan clays are being made at the University of Saskatchewan little attention is here devoted to this aspect of the study of the clays. Whenever work is completed, however, it will be possible to furnish considerable information on the distribution of the clays and much detail of their occurrence. A few fusion tests were made in the Ceramics laboratory of the Mines Branch, of samples collected in 1928, and were reported on by J. G. Phillips. As the fusion test alone does not indicate the commercial value of a clay only a summary of the results need be given. Several samples of Upper Ravenscrag clay from Horsethief Guide and Hay Meadow creek gave cones of from 14 to 18½. These fall within the range of cones of semi-refractory clays, but the clays examined cannot be so designated on the basis of this test alone. A sample from the small clay parting in the No. 1 coal seam, northwest of Eastend, yielded a cone of 13. Ten samples of clay and clay shales of the Lower Ravenscrag were disappointing and yielded cones only from 2 to 8. Although these tests are not conclusive they indicate that the Upper Ravenscrag in places may yield clays of some value and is at least worthy of search. The parting in the No. 1 coal seam will also bear investigation.

Down Frenchman river only the lower beds of the Upper Ravenscrag are exposed and they are at the tops of the cliffs on the valleysides. Therefore, in most places, only the bottom seam can be examined in natural exposures. From sec. 25, tp. 5, range 20, W. 3rd mer., to about sec. 1, tp. 5, range 19, W. 3rd mer., on the north side of the valley, the lowest or No. 1 seam maintains a fairly uniform character. It consists of:

	Feet
Black carbonaceous shale with lignite streak	0·3 to 1·2
Yellowish green clay shale	0·5 to 0·7
Lignite or lignite and shaly lignite	0·9 to 1·4

On the north side of the valley in the vicinity of secs. 4 and 5, tp. 5, range 18, W. 3rd mer., only a little black carbonaceous shale with some lignite streaks was found at the horizon of this seam. In the vicinity of the northwest corner of sec. 19, tp. 4, range 18, W. 3rd mer., on the south side of the valley, the hill appears to be high enough to carry this seam, but the horizon of it is occupied by massive, green, crossbedded sandstone.

On the lower part of Mule and Gunn creeks and along the north side of Frenchman valley east of Gunn creek, the bottom seam outcrops near the top of the valley sides and up these creeks comes nearer to the valley bottom because of the rise of the creeks in that direction. In this part of the area the seam varies considerably. It is fairly good in sec. 10, tp. 6, range 17, W. 3rd mer., and consists of:

	Feet
Brown and black carbonaceous shale and some lignite	2·1
Light greenish yellow, silty clay	0·8
Lignite	2·5

In sec. 2, tp. 6, range 17, W. 3rd mer., the following section was measured:

	Feet
Lignite, etc.	3·0
Yellowish green, micaceous silty clay	0·6
Lignite	1·0

On Mule creek in about sec. 12, tp. 6, range 18, W. 3rd mer., the lower or bottom seam consists of :

	Feet
Carbonaceous shale	1·0
Grey shale	2·0
Coaly shale with layers of lignite	2·0
Brown shale	0·5
Lignite	2·0

Above this is a higher seam consisting of 3·0 feet of poor lignite. Coal is also found on Bates creek at two horizons apparently.

In the vicinity of Warholes creek the horizon of the bottom seam is just below the plateau level and it is difficult to locate it there. A burnt shale outcrop in sec. 22, tp. 6, range 15, W. 3rd mer., may indicate the former presence of the bottom seam at this locality. In sec. 3, tp. 6, range 15, W. 3rd mer., on the east side of Warholes creek, part of a seam was uncovered in a slight slumped area on the border of the plateau. It consists of:

	Feet
Lignite	2·5
Grey, hard shale	6·6
Fine, grey sandstone	2·0
Lignite with brown clay parting in the middle	2·5

At Horsethief Guide in sec. 11, tp. 4, range 10, W. 3rd mer., the first or bottom seam of the Ravenscrag is very thin. At a locality on the west side of the ridge it measured as follows:

	Feet
Lignite	0·5
Clay	0·8
Lignite	0·3

The lignite bed in phase C of the Basal sandstone is 0·5 feet or less in thickness.

APPENDIX I

By F. J. Fraser

Additional Notes on the Petrography of the Sediments

The minerals described in the previous report omitted sphene which had not then been identified. Sphene grains identified in these samples may be roughly equidimensional showing good crystal faces, or irregular fragments showing traces of crystal faces; their colour is faint brown yellow, lustre adamantine, and by reason of their high refractive index, the lustre is very distinct even in plane polarized light. Globular inclusions are common. Under crossed nicols, grains do not extinguish, but show anomalous polarization colours, amongst which metallic blues predominate. The biaxial interference figures of such grains are good, show high dispersion, and are optically positive in character. The positive identification of grains identified has depended on the above properties.

In the samples already reported on, sphene has been found only in six concentrates, and exclusive of Whitemud samples, occurs in fourteen concentrates from twenty-seven samples collected in 1927. Out of seventy-four samples collected in 1928 and already examined, nineteen contain sphene. At the time of writing, the total number of samples examined is 184; work is proceeding on the remaining 72 samples.

REINDEER LAKE AREA, SASKATCHEWAN AND MANITOBA

By C. H. Stockwell

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Illustrations

INTRODUCTION

Reindeer lake was geologically explored in 1896 by D. B. Dowling who acted as assistant to J. B. Tyrrell.[1] Since that time his work has been quoted by William McInnes,[2] but no more geological work was done until the summer of 1928 when the writer examined and geologically mapped the area. In this work G. W. Ward, J. A. Retty, and D. M. Phillpotts acted as assistants and gave very satisfactory service. Many thanks are due to Mr. C. H. E. Stewart and Mr. P. E. Hopkins, both of the Reindeer Lake Syndicate, Limited, for information and maps placed at the writer's disposal.

A topographical map of Reindeer Lake area, published by the Topographical Survey of Canada, was used as a base for the geology and found to be very satisfactory, only slight alterations having to be made on the map which accompanies this report. Geological work was confined almost entirely to the shoreline and where rock exposures are easily accessible and exceptionally good, especially when the water-level in the lake is below normal as was the case in the summer of 1928.

Reindeer lake lies on the boundary line between northern Saskatchewan and Manitoba, the greater part of it being on the Saskatchewan side. The southern end of the lake is at latitude 56° 15′ and the northern end at 58° 10′. The total area mapped is approximately 3,500 square miles, much of which is underlain by water.

During the summer months the lake is usually reached by way of The Pas, Manitoba, the first part of the journey being made on the Ross Navigation Company's river boat westward along Saskatchewan river and over

[1]Geol. Surv., Canada, Ann. Rept., vol. VIII, pt. D, p. 950.
[2]"The Basins of Nelson and Churchill Rivers"; Geol. Surv., Canada, Mem. 30 (1913).

Cumberland and Sturgeon lakes to Sturgeon Landing. The second part is made by canoe in a general northerly direction by way of Sturgeon-weir river, Mirond lake, Pelican lake, Wood lake to Churchill river, thence down the Churchill for a short distance, and up Reindeer river to the southern end of Reindeer lake. The total distance by canoe is 220 miles and the trip can be made with loaded canoes in about ten days. There are eighteen portages, but most of them are quite short and their total length is only 2 miles. This route is shown on maps of The Pas Mineral Belt and Reindeer Lake area issued by the Topographical Survey of Canada. Alternative routes are from Prince Albert, Saskatchewan, via Montreal lake, lac La Ronge, Churchill river, and Reindeer river, or from The Pas via Kississing lake, and northwesterly, over a route which is partly unmapped, to Wapus river on Reindeer lake. Up to the present time two winter routes have been in use, one from Prince Albert to Southend and the other from The Pas to Wapus river, but when the railway from The Pas to Kississing lake has been completed a shorter winter road from the end of the railway to Wapus river will be used.

There are three trading posts and Indian villages on the lake, Brochet, Southend, and Wapus river. At Brochet, which is the largest village, the majority of the inhabitants are Chipewyan Indians, and at Southend they belong to the Cree tribe. Wapus river is important as the end of the winter road from The Pas, but only a few Indians live there.

GENERAL CHARACTER OF THE DISTRICT

TOPOGRAPHY

Reindeer lake lies in the great Canadian Shield and the physical features of the surrounding country are similar to those at many other places in this great area. At Reindeer lake, flat-topped rock hills and ridges rise 70 to 150 feet above the level of the lake, or 1,220 to 1,300 feet above sea-level, since the lake-level, according to the Topographical Survey's map, is 1,150 feet above sea-level. A few hills rise to nearly 200 feet above the lake, but the relief is for the most part low.

The lake, which is 144 miles in length in a direction slightly east of north and 30 miles wide at its widest point, has a very irregular shoreline due to numerous, long, irregular-shaped bays and projecting points, which generally trend parallel to the gneissic structure or jointing of the underlying rocks. The total length of the shoreline, neglecting small, unmapped irregularities, is 1,300 miles. Many irregular-shaped islands, about 3,700 in all, both large and small, occur widely scattered or in closely spaced groups, and are so numerous and well distributed that only rarely are these open stretches of water more than 3 miles across.

A large proportion of the shoreline on both mainland and islands is rock which rises from the water as gently sloping, glaciated surfaces or as vertical cliffs; other portions consist of sand, gravel, boulder, or swamp.

The country is timbered with small spruce, pine, tamarack, birch, and poplar generally less than 6 inches in diameter, and in many places has been burnt over.

GLACIAL AND RECENT GEOLOGY

During the Pleistocene period the area was covered by a continental ice-sheet which moved in a southwesterly direction. Glacial striæ are well preserved in many places and most commonly strike from south 20 degrees west to south 30 degrees west, parallel to the long direction of the lake. On the east side of the lake strikes are slightly more westerly, usually between south 30 degrees west and south 40 degrees west, suggesting that the latter is the regional direction of ice motion and that the lake basin deflected the ice slightly more southerly. Minor topographical irregularities had no appreciable effect on the direction of motion. The ice apparently came from the Keewatin ice centre west of Hudson bay and there is no evidence to show that the lake was ever overridden by ice from any other direction. The work of the ice was chiefly erosional on northeasterly facing slopes where the rocks have been smoothed off to gently sloping surfaces. Southwestern slopes, as well as depressions, are more commonly covered with glacial drift. Consequently the best rock exposures are more frequently to be found on northeasterly facing shorelines. Locally, large hills appear to be composed entirely of glacial drift and at other places sand and gravel have been deposited with typical morainal topography. During the last stages of the ice local sand outwash deposits were formed and these in part are pitted with kettle-holes formed by the melting of ice blocks.

Since the retreat of the ice-sheet, time has been too short for any important amount of erosion to have taken place. Glacial striæ are still well preserved on many rock surfaces, particularly on granitic rocks. The surfaces of easily weathered basic gneisses have been roughened and pitted to some extent by solution and calcareous beds in sediments have been dissolved to a depth of a few inches. Glacial deposits above the high water level of the lake are practically as the ice left them.

The chief changes in Recent time have been the reworking of glacial deposits by the action of waves and ice along the shoreline of the lake. Unsorted glacial deposits left by the ice have been sorted by wave action and shore currents so that the deposits along the shoreline now consist in many places of either boulders, gravel, or sand rather than a mixture of these materials. Shore erosion has not been confined to a line along the present level of the shore, for there is evidence to show that in post-Glacial time the lake has stood at a higher level than at present and that it has since gradually subsided and worked over the deposits as it fell. This is shown by the presence of beaches, usually in sandy material, at a number of places above the present lake-level. At one locality they were studied in detail. A series of sand beaches occur in steps on a gently sloping hillside. The highest beach-line is at an elevation of 37 feet above the present level of the lake, above it there is an uneroded, pitted outwash plain. The highest beach-line is slightly above the edge of a large kettle-hole and the kettle-hole has not been filled with sand, from which it is concluded that the hole was filled with ice when the water-level of the lake was at its highest and consequently that the highest water-level occurred immediately following the glacial period. Such beaches are not of common occurrence, having been observed at only ten localities, all the beaches are apparently the result of reworking of glacial deposits. Many of the beaches, especially the lower, more recent, and best preserved ones, are in the form of ridges of sand, gravel, or boulders up to 2 feet in diameter, the material possibly having been pushed up by shore ice (*See* Plate VA).

GENERAL GEOLOGY

GENERAL STATEMENT

The consolidated rocks are all Precambrian and are divisible into four groups which in the order of age are old metamorphosed sediments and volcanics, basic intrusives, granitic intrusive, and diabase. The sediments, volcanics, and basic intrusives are so intimately associated with granitic material that they must be mapped together as a complex, but it is also possible to map large areas of granitic rocks separately. For purposes of description, however, the rocks may be dealt with in the order of age.

Table of Formations

Younger basic intrusive	Diabase
Granitic intrusives	Pegmatite, aplite, and pegmatitic granite Granodiorite Quartz diorite Granitic gneisses and oligoclase quartz-diorite gneiss
Older basic intrusives	Amphibolite (metamorphosed peridotite, pyroxenite, hypersthenite, and gabbro) and diorite
Sediments and volcanics	Biotite schist and gneisses, quartzite, impure limestone, muscovite schist, anthophyllite schist, iron formation, hornblende schists (metamorphosed sediment, andesite, basalt, augitite, and tuff), amphibolite

SEDIMENTS AND VOLCANICS

The greater part of the southern half of the lake is underlain by schists and gneisses which have been so completely metamorphosed and recrystallized that, over large areas, their origin is difficult or impossible to determine with certainty. However, at many localities bedding planes are well preserved, thin beds of biotite schists, of various shades of grey and sizes of grain, alternating with beds of quartzite and hornblende schist, which undoubtedly indicates sedimentary origin. Thin-bedded limestones, undoubted sediments, are also present. Since the large areas of schists and gneisses in which bedding is not present are otherwise similar lithologically, and closely associated with these undoubted sediments, the whole is considered to be of sedimentary origin. Conglomerate as far as known is entirely absent. Volcanic structures are of rare occurrence, but are present locally in the form of much compressed pillows showing the presence of lavas, which, however, are in much less quantity than the sediments. The volcanics are interbedded with sediments and there is no evidence of unconformity between them; the whole is considered to be a single, thick, sedimentary-volcanic series.

Biotite Schist and Gneisses

Biotite schist, and coarser-grained phases which may be called biotite gneiss, are by far the most common type of sediment. The biotite schist is light to dark grey and fine to medium grained, with well-developed schistose or gneissic structure due to parallel orientation of biotite flakes. In thin section under the microscope it is seen to consist dominantly of quartz, feldspar, and biotite. The minerals vary in average size of grain from $\frac{1}{4}$ mm. to 1 mm. in diameter and vary in proportions at different localities and in different beds at the same locality. The feldspar varies widely in composition; in some specimens both orthoclase and oligoclase are present, either the one or the other predominating; in others the only feldspar present is plagioclase, generally untwinned, and varying in different specimens from oligoclase to andesine and labradorite in composition. Biotite, in brown, strongly pleochroic plates, is the characteristic and usually only ferromagnesian mineral present, although locally, in type intermediate between biotite schist and hornblende schist, hornblende is also present. Frequently there is a small amount of magnetite, apatite, epidote, and sericite, the last being an alteration product of plagioclase; pyrrhotite and pyrite are commonly present in small quantity and locally are developed abundantly; in one specimen examined there is a small amount of calcite interstitial to the other minerals. Garnets are of common occurrence and are in many cases developed in great numbers, and at several localities metacrysts of muscovite are present and give the rock a coarse, spotted appearance. Rosiwal measurements on two of the thin sections gave quartz as 44 and 47 per cent of the rock; such a high percentage of quartz in association with plagioclase as basic as andesine and labradorite is abnormal for an igneous rock and is additional evidence for sedimentary origin. In most types recrystallization has been complete, the minerals being interlocked, biotite plates being oriented with their long axes parallel to one another, and none of the minerals, except the quartz, showing undulatory extinction. In some specimens, where recrystallization has not progressed to such a complete stage, feldspar shows strain shadows and has been rounded by granulation, biotite flakes form bands bending around them, and quartz has been much deformed and drawn out. The schist, although forming large areas comparatively free from injected granitic material, is characteristically much granitized as described in a paragraph in the description of the granitic rocks.

Of less certain origin are grey and pink gneisses with a granitic appearance. These are of quite common occurrence and both igneous (granitic) and sedimentary material are probably represented, although in the majority of cases it is difficult or impossible to distinguish the one from the other. At one locality (5 miles southwest of survey post M 38) pink and grey gneisses were observed to alternate across the strike with, and grade into, glassy quartzite and biotite schist, giving the appearance of coarse bedding and suggesting sedimentary origin. Under the microscope the gneiss is found to consist of interlocking grains, with an average diameter of about 1½ mm. of quartz (forming 48 per cent of the rock) and oligoclase (38 per cent) with brown biotite in plates oriented approximately parallel to one another and subordinate amounts of microcline, orthoclase, muscovite, and apatite. The glassy quartzite, into which the gneiss shows a gradual gradation, consists dominantly of quartz, 68 per cent, and labradorite, 28 per cent, with subordinate amounts of biotite, with random orientations, and also muscovite, calcite, apatite, magnetite, and pyrite.

At a number of localities similar gneisses have scattered lens-shaped masses of sillimanite up to ½ inch in length. Under the microscope these are seen to consist of closely packed masses of acicular crystals (fibrolite variety) in quartz and feldspar. The origin of this gneiss is uncertain, but at one locality at least it is associated with bands of sedimentary amphibolite, described later. There is no evidence indicating that the gneiss intrudes the amphibolite, but it appears to be interbedded with it, which suggests a sedimentary origin for the sillimanite-bearing gneiss.

Quartzite

As has already been mentioned quartzite occurs as thin beds in association with biotite schist and other schists. It is, however, most abundantly developed on a large island 4 miles east of M 37 and extending in a belt, up to 2 miles in width, for a distance of 10 miles southwest by west through several islands to the mainland. It is rather fine-grained, grey to pale pink, and characteristically massive over considerable distances, without evidence of bedding, and having the appearance of a fine-grained granite. The sedimentary origin is shown, however, by the presence, locally, of distinct bedding planes, individual beds only a few inches thick were traced for as much as 100 feet along the strike. In places the quartzite grades into biotite schist which is identical in appearance with the common type of sediment already described. In thin section under the microscope the typical massive grey quartzite with an average grain size of about ½ mm. is seen to consist of interlocking grains of quartz, 40 per cent, and feldspar 48 per cent, including microcline, orthoclase, and albite-oligoclase with subordinate amounts of greenish, strongly pleochroic biotite, some calcite, as an alteration product of feldspar and also interstitial to the other minerals, suggesting that it is an original constituent, with scattered grains of magnetite, titanite, apatite, and muscovite. Locally, garnets are developed in considerable numbers. The quartz shows strain shadows, but the other minerals do not, the compression having been relieved by recrystallization. Biotite has random orientations and does not give the rock a schistose or gneissic structure. A 3-inch bed of greywacke in this quartzite consists dominantly of oligoclase, 59 per cent, with some microcline, 17 per cent; biotite, 24 per cent, is much more abundant than in the typical quartzite and is in plates oriented parallel to one another and quartz is absent. A 3-inch calcareous bed traced for 50 feet along the strike consists dominantly of quartz (36 per cent) and oligoclase (32 per cent); there is a considerable amount of calcite (12 per cent) interstitial to the other minerals and both green augite and green hornblende have been secondarily developed; orthoclase, microcline, titanite, apatite, and epidote are present in negligible quantity.

Impure Limestone

Limestone forms a very small part of the sedimentary series, having been observed at only four localities, namely, 2 miles southwest of M 37; 3 miles north-northeast of M 38 on the islands and on the mainland to the southwest of the islands; ½ mile southeast of K 30; and at M 8. It has a maximum observed thickness of only 10 feet and is thin bedded with individual beds of alternating calcareous and quartzitic material ¼ to 6 inches in thickness made conspicuous by differential weathering. It is not known whether these isolated occurrences form a single horizon in the sedimentary series or occur at several horizons, but the latter seems to be more probable and the beds are likely discontinuous, thin, lenticular masses. The limy beds occur in association with quartzite and biotite schists and are more complexly folded than the associated rocks. In thin section under the microscope some beds, white to grey in colour, are found to be dominantly calcite in which are scattered grains of quartz, plagioclase (oligoclase and oligoclase-andesine), microcline, and orthoclase. The quartz is in rounded grains with pronounced undulatory extinction and is an original constituent of the sediment. The feldspars, where surrounded by calcite, are also frequently rounded but not strained and may be original constituents, but in places feldspar grains are in contact with one another and are interlocked, indicating that they are recrystallization products. In some of the beds secondary minerals are extensively developed and form up to 75 per cent of the rock. These secondary minerals are colourless diopside, pale green actinolite, dark green hornblende, zoisite, and small amounts of muscovite and biotite. Accessory constituents are apatite, pyrite, and titanite, the last occurring in rounded grains.

At a locality 3 miles north-northeast of M 38, there was observed a much contorted gneiss overlying limestone. It consists chiefly of bytownite, colourless pyroxene (probably diopside), and dark green hornblende, the last two minerals occurring in alternating, discontinuous, dark and light coloured bands up to one inch in thickness. The feldspar is partly altered to zoisite and there are small amounts of titanite, in rounded grains, and calcite. The rock is probably a much metamorphosed impure limestone. A similar banded gneiss also occurs on the northwest shore of a small lake 6 miles northeast of K 33.

Scapolite-bearing rocks were observed at two localities. One of these is 1½ miles northeast of K 37 where the rock occurs along the northeast sides of two small islands forming a band about a mile in length. It is a medium to coarse-grained rock weathering to a rough surface.

When examined in thin section under the microscope it is found to consist dominantly of green monoclinic pyroxene and scapolite, both of which are fresh. Wedges of brown pleochroic titanite are plentiful and there are small amounts of quartz, red garnet, pyrrhotite, dark green hornblende, calcite, and zoisite. The scapolite, which is white in colour, has $N_o=1 \cdot 585$ and $N_e=1 \cdot 550$ giving its composition as Ma 35 : Me 65 which according to the classification used by Winchell[1] is the variety known as mizzonite. The rock was not studied in detail in the field, so that its origin is doubtful, but since mizzonite is developed most commonly in metamorphosed limestones, the rock probably has this origin. At the other locality (2 miles south 20 degrees east from K 37) there is an exposure of fine-grained, grey to green rock with irregular-shaped patches of black hornblende. Under the microscope the green variety is seen to consist of scapolite, considerably altered to chloritic material and calcite, and monoclinic pyroxene, with small amounts of basic plagioclase, hornblende, apatite, magnetite, titanite, sericite, zoisite, and a bright green isotropic mineral, probably spinel. The origin of this rock is unknown.

Muscovite Schist

This rock is of rare occurrence, having been noted at only one locality (1 mile south of M 37) where it occurs as thin beds alternating with dark grey biotite schist and is apparently of sedimentary origin. In thin section under the microscope it is found to consist of quartz, oligoclase, much of which is untwinned, and muscovite in flakes oriented parallel to one another, giving the rock a schistose structure.

Anthophyllite Schist

This rock is of uncommon occurrence. At one locality (3 miles north 15 degrees east from M 7), it occurs as a thin bed in sediments which vary across the strike from biotite schist to hornblende schist and quartzite. Under the microscope the rock, which is apparently of sedimentary origin, is seen to consist of brown, strongly pleochroic biotite and andesine (Ab 62 : An 38) and a large number of pale brown, anthophyllite crystals with their long axes parallel to one another, giving the rock a schistose structure. At another locality (4½ miles north 5 degrees west from M 36) a similar rock associated with garnetiferous biotite schists consists of quartz, andesine (Ab 64: An 36), anthophyllite, biotite, and small amounts of red garnet, magnetite, pyrrhotite, and chalcopyrite.

Iron Formation

This rock was noted at one locality on a small island 6 miles southeast of M 33. It occurs as a bed about 10 feet in width in association with biotite and hornblende schists and consists of alternating bands of magnetite, quartz, and hornblende with a development of red garnets in some layers.

[1] "Elements of Optical Mineralogy," Part II, John Wiley and Sons, 1927.

Hornblende Schists

Hornblende schists are present in considerable quantity and quite widely distributed, but are in much less amount than the biotite schist and gneiss. Although it is not possible to determine its origin at every locality where it was observed, hornblende schist no doubt includes both sedimentary and volcanic material.

It is found interbedded with, and grading into, biotite schist and quartzite in such a manner as to show undoubtedly its sedimentary origin. It is dark grey to black in colour and schistose due to parallel orientation of hornblende crystals. Thin sections of two specimens examined show the rock to be made up largely of plagioclase (andesine, comprising 56 per cent of the rock, in one case, and labradorite, 20 per cent, in the other) and dark green hornblende (25 per cent and 50 per cent). The plagioclase is both twinned and untwinned. There are smaller amounts of quartz (14 per cent and 10 per cent), biotite, magnetite, titanite, and augite, the last being much altered to hornblende. Calcite, chlorite, and epidote are present in small amount as alteration products.

Positive evidence indicating volcanic origin of any of the rocks in the area is rare. However, at one locality very much compressed pillow structure is present, showing that at least some lavas are present. On the west shore of Numabin bay 4 miles north-northwest from K 33 there is a belt of hornblende schist one mile in width in which dark-coloured bands form much elongated, oval-shaped outlines unlike the parallel banding of sedimentary rocks and undoubtedly represent much compressed pillows. One of these, which is typical, measures 5 feet in length and is only 4 inches in width, a ratio of length to width of 15:1, indicating a large amount of compresssion since the normal ratio in uncompressed pillows is approximately 2:1. The bands are thickened at the ends of the pillows and the rock in the central part of each oval is lighter coloured and coarser grained than that near the borders. Under the microscope the rock is seen to consist largely of secondary green hornblende crystals oriented with their long axes parallel to one another; the remainder is augite and labradorite (Ab 45: An 55) with small amounts of titanite, epidote, and pyrite. Such a composition suggests that the rock was originally a basalt, the minerals now present in the rock, however, are largely recrystallization products.

At another locality (3 miles south of M 33) poorly developed pillows were seen in a fine to medium-grained, dark green, massive rock consisting almost entirely of augite and pale green actinolite, the latter mineral being an alteration product of the augite. Magnetite occurs as specks in the augite and there are small amounts of pyrrhotite and secondary calcite. The rock appears to have been originally essentially all augite and the pillow structure shows it to be a lava flow. Where this rock is cut by pegmatite dykes it is altered for a distance of 3 inches from the contact to a bright green rock consisting almost entirely of actinolite in short, interlocking crystals without parallel arrangement, only a few remnants of augite remaining.

The largest area of lava occurs as a belt 12 miles long and varying from ½ to 1 mile in width. It was observed at a locality 2 miles southwest by west of M 37 and from there the belt strikes north 75 degrees east passing immediately south of M 37, continuing through the islands 2 miles south of M 36 and ending against a granodiorite intrusion 3 miles southwest of M 1. On its northern side it is bordered by quartz diorite along the eastern part and by granodiorite along the western, and on the southern side by sediments. The rock is dark grey to greenish, fine grained or dense, schistose or massive. No volcanic structures were observed, but its basic character and absence of bedding indicate that it is of igneous origin and the general fine grain suggests an extrusive origin. A representative specimen, examined in thin section, consists dominantly of dark green secondary hornblende in crystals oriented parallel to one another, giving the rock a cleavage; oligoclase, partly altered to sericite, is the chief remaining constituent and titanite is accessory. A specimen collected at the contact with quartz diorite is similar except that the plagioclase is andesine and augite is present in addition to hornblende. This belt of rock apparently approaches andesite in composition.

Other hornblende schists which are probably lavas occur along the east shore of a small lake 5 miles northwest by west from M 36, on the northwest side of the island on which M 36 is located, and small outcrops occur at other localities. A specimen from one of these places has phenocrysts of hornblende rounded by granulation and lying in a schistose groundmass of hornblende and andesine with accessory titanite.

Associated with the lavas are small amounts of thinly bedded hornblende schists which are probably recrystallized tuffs. A representative specimen of this rock consists of hornblende and plagioclase in about equal proportions, the former being in crystals oriented with their long axes parallel to one another; magnetite is accessory.

Sedimentary Amphibolite

The origin of linearly-arranged lenticular masses of amphibolite, which are fully described in the following paragraph, is uncertain in many instances. At one locality (1¾ miles south 40 degrees west of M 38) such amphibolite masses, occurring in sillimanite-bearing gneiss, appear to be basic sediments. It is a medium-grained, black rock consisting of hornblende to the extent of about half of the rock, the remainder being quartz and labradorite in about equal proportions with accessory magnetite, a composition unusual for igneous rocks and suggesting sedimentary origin.

OLDER BASIC INTRUSIVES

Older basic intrusives include chiefly amphibolite, usually in small, discontinuous sills, small amounts of serpentinized basic rocks, and areas of diorite. These rocks are younger than the sedimentary volcanic series which they intrude.

Amphibolite

Black, medium to coarse-grained, amphibolite, usually without schistose structure, occurs in many places throughout the areas mapped as a sedimentary-igneous complex. It is not important quantitatively, however, for it is present only in small masses. The rock, although in places occurring in masses up to 300 feet across, usually forms thin sills parallel to the foliation of the enclosing schists or gneisses and usually not more than a foot or two in width. It is never continuous for any great distance along the strike, but is pinched out by the sediments and continues again farther along the strike. Most commonly this pinching is very marked and the amphibolite remains as a series of irregular, lens-shaped masses in alinement with one another, with the foliation of the sediments paralleling the border of the lenses. These lenses, which probably at one time formed a continuous band, are separated from one another in extreme cases by as much as 15 feet. In most cases intrusive relationships are not seen and the amphibolite has three possible origins; either it is a basic sedimentary layer, a thin lava flow, or a sill. Other evidence has then to be relied upon such as high quartz content in association with basic feldspar suggesting sedimentary origin as in the case already described in the previous paragraph on sedimentary amphibolite. In other cases the absence of quartz or the presence of a mineral such as olivine suggest igneous origin and the coarse grain of the rock is taken to indicate its intrusive rather than extrusive origin. Locally, field evidence such as crosscutting relationships clearly show intrusive nature of at least some of the rock.

An amphibolite occurring as sill-shaped masses in sedimentary schists in the north arm of Paskwachi bay, was found, when examined in thin section under the microscope, to contain a considerable amount of coarse-grained olivine, much altered along irregular fractures to green and brown serpentine and magnetite. In addition there is a small amount of colourless hypersthene. The rock, however, consists largely of fresh, pale green pargasite (optically positive) and in places there are patches of interlocking crystals of brown biotite; magnetite and pyrrhotite are accessory. The presence of olivine indicates that the rock is undoubtedly of igneous origin and was originally apparently a peridotite, the pargasite, biotite, and serpentine being of secondary origin.

Not far from this locality on the south shore of Steeprock point, another mass of amphibolite, 200 feet in diameter, consists dominantly of green pargasite occurring as a secondary development as crystals scattered through hypersthene crystals averaging about 3 mm. in length, which are pleochroic from pale brown to colourless; there are small amounts of biotite, magnetite, pyrrhotite, and a bright green isotropic mineral probably spinel. The original rock was probably essentially all hypersthene and the rock would then be called hypersthenite. The outcrop is cut in many directions by white pegmatite dykes a few feet in thickness, and for a distance of 1 foot from their walls the amphibolite is contact metamorphosed to a blacker rock which weathers more easily. Under the microscope this contact phase is seen to consist entirely of two minerals, pale greenish hornblende and brown biotite. The biotite is more abundant than in the normal rock and the hornblende is similar to the pargasite except that it is optically negative.

Amphibolite occurs along the mineralized zone of the Brown mineral claim described later. It consists dominantly of dark green hornblende and labradorite partly altered to sericite; there is some unstrained quartz which is probably of secondary introduction. The composition of the rock suggests that it was originally gabbro.

At another locality, 6 miles south 65 degrees east from M 5, a specimen of amphibolite, with the typical lenticular arrangement in sedimentary schists, is composed largely of dark green hornblende; a small amount of basic plagioclase almost completely altered to sericite is also present and titanite and apatite are accessory. This rock is also probably a metamorphosed gabbro.

Another type of rock, without the lenticular arrangement of many of the amphibolites, may be termed a serpentine-actinolite schist, but because of the abundance of actinolite may still be classed with the amphibolites. It was observed at three localities, namely, in Numabin bay at three places near the northern edge of the sediments, on a small island $4\frac{3}{4}$ miles east of M 37, and at the south shore of the bay south of K 38. It occurs as sill-shaped masses usually not more than 50 feet in thickness, but at one locality 300 feet thick. Individual occurrences were not traced for more than one-half mile along the strike, but they are probably much longer. The rock is characterized by a yellow, knotted appearance on the weathered surface, the knots, $\frac{1}{8}$ to 1 inch in size, being black and dense on a fresh surface, and the groundmass consists of green crystalline material. Under the microscope it is found that antigorite, which is pale brown to greenish in colour, along with abundant magnetite, is the most abundant material in the black, dense knots, and actinolite, which is pale green to colourless (green in hand specimen), is the chief constituent of the crystalline portions. Colourless chlorite occurs in fair amount in association with antigorite and is partly altered to calcite. This chlorite is optically positive with a small optic-angle and with $Nm=1 \cdot 585$ approximately, agreeing closely with the variety sheridanite.[1] There are also small amounts of brown and green chlorite and a green isotropic mineral probably spinel. Usually these are the only minerals present and they are apparently all of secondary development. In some specimens examined, however, there are remnants of olivine and augite, almost completely altered to antigorite and chlorite, which are presumably original constituents of the rock, suggesting that it approached pyroxenite and peridotite in composition.

Diorite

This rock is developed most abundantly along the northwestern shore of the lake, where it occurs as large inclusions up to several miles across in a large, granodiorite batholith occupying the whole of the northern part of the lake. It is commonly dark grey and rather fine-grained, locally with small phenocrysts of feldspar. At one locality it is lighter grey and

[1] Jour. Washington Acad. Sci., vol. XII, p. 239 (1922). Am. Jour. Sci., vol. IV, 34, p. 475 (1912).

granitoid. The diorite consists essentially of andesine and dark constituents in about equal proportion, the latter being dark green hornblende with less amounts of biotite and in one case remnants of augite altered to hornblende; magnetite and apatite are accessories. At one locality the rock has been altered by granitic solutions along cracks with an introduction of orthoclase and an alteration of the original constituents to sericite, chlorite, epidote, and pyrite. Diorite is not plentiful within the sedimentary-igneous complex, but a hornblende-oligoclase diorite was seen at one locality.

GRANITIC INTRUSIVES

As has already been mentioned, granitic rocks occur as batholiths and stocks which are large enough to be shown on the accompanying map, and also as small intrusions, usually sills, occurring within the area mapped as a sedimentary-igneous complex. Most of the latter intrusions are gneissic and in many cases are difficult or impossible to distinguish from sedimentary gneisses. In addition much of the sedimentary schist has been so intimately injected and permeated by granite and pegmatite (granitization) that it is impossible to separate the two on any scale of mapping. The granitic rocks include various types such as granitic gneisses, oligoclase quartz-diorite gneiss, quartz diorite, granodiorite, pegmatitic granite, pegmatite, and aplite; each of which is described below.

There is abundant evidence to show that the granitic rocks are all younger than the sediments, volcanics, and older basic intrusives, for these rocks at many places occur as inclusions in, and are much injected by dykes and sills of, the granitic rocks. The relationship between the various types of granitic intrusives, although clear in some cases, is generally obscure. Thus, an intrusive of quartz diorite at Priest point, M 36 and vicinity, is clearly older than granodiorite, and quartz diorite of other localities grades into and is contemporaneous with granodiorite, but the relationships of the granitic gneisses to oligoclase-quartz-diorite gneiss or the relationships of either of these to quartz diorite or granodiorite are not definitely known. White pegmatitic granite is closely associated and contemporaneous with white pegmatite and both of these are clearly younger than granitic gneisses and oligoclase-quartz-diorite gneiss, and pink pegmatite is present as a late differentiate of quartz diorite and granodiorite. The relationship, however, between pink pegmatite and white pegmatite is less certain, for they are not usually found in contact with one another; however, some pink pegmatites carry a considerable amount of white feldspar and some white ones carry a small amount of pink feldspar, suggesting that there is a gradation from one to the other and that they are contemporaneous. In the absence of any definite evidence to the contrary, it is concluded that all of the granitic intrusives, although some are older than others, probably belong to one period of igneous activity. An alternative hypothesis is that there are two main periods of granitic intrusion, an earlier intrusion of granitic gneisses and oligoclase-quartz-diorite gneiss with a late white pegmatite phase, followed by a later intrusion of quartz diorite and granodiorite with a late pink pegmatite phase.

Granitic Gneisses

Gneisses with a granitic appearance are widely distributed throughout the southern half of the lake which has been mapped as a sedimentary-igneous complex. Some of these gneisses are probably of sedimentary origin, as already described; in many exposures it is difficult or impossible to determine their origin, but at some localities the gneisses are clearly granitic intrusives as shown by the fact that they contain angular inclusions of the older sediments, volcanics, or basic intrusives, occur as dykes and sills, cutting these rocks, and locally are associated with pegmatite clearly derived from them. The granitic gneisses vary in composition from granite to granodiorite and quartz diorite and are usually strongly foliated.

Granite gneiss occurs on the west shore of the lake at its southern end for miles both north and south of the outlet of Little Deer river. It is grey to pinkish and is very strongly foliated parallel to the structure of the surrounding sedimentary rocks. Under the microscope a typical light grey phase is found to have the composition of granite; orthoclase and a subordinate amount of oligoclase are present and both are much altered to sericite; quartz occurs in bands of interlocking crystals and shows marked strain shadows; there are also bands of biotite flakes oriented parallel to one another and much altered to chlorite; in addition some hornblende is present and titanite is accessory. Other portions of the same mass are darker in colour and approach quartz diorite in composition.

Grey, intrusive gneisses, probably granodiorite in composition, occur as small sills along the shoreline southwest and northeast of K 33. Sills and large masses of grey gneiss, probably of igneous origin and about granodiorite in composition, occur also at many other places such as at M 34, at a number of places on the shores of Paskwachi bay, on Wepusko river, along the shoreline and islands extending for a distance of 4 miles north and one mile south of M 32, and at other localities.

A fine-grained, grey dyke rock, having much the appearance of sedimentary biotite schist, was seen to be intrusive into sediments, volcanics, and amphibolite at a few localities. It is much cut by white pegmatite and appears to be the same age as the granitic gneisses with which it is probably closely related.

Oligoclase-Quartz-Diorite Gneiss

This rock, with local more acidic and more basic phases, occurs in small amount at several localities as detailed below and is of special interest because of its relation to the mineral deposit on the Brown mineral claim, as described in the section on "Economic Geology," and because of its copper content at other localities. In the field the gneiss usually has a foliation due to segregation of biotite in broad bands, although it does not show cataclastic structure in any marked degree. The rock is characterized by an iron-stained, weathered, surface and outer layer 1 to 3 inches deep, due to the weathering of sulphides which are disseminated through the rock. The characteristic sulphide is pyrrhotite, which is apparently an original constituent of the rock, for it is always present, is fairly uniformly disseminated, and occurs disseminated in the intruded rocks close to the contacts of the gneiss where, however, it occurs in irregularly distributed patches. At some places a small amount of chalcopyrite is associated with the pyrrhotite and is also apparently an original constituent. Graphite also occurs locally in small flakes scattered through the gneiss as well as in the intruded rocks nearby. The feldspar in the rock has a grey, greenish, or bluish colour, a characteristic, together with the content of sulphides or graphite, by which the rock may be recognized in the field.

On the western shore of the north arm of Paskwachi bay, at a point 2 miles northeast of the mineral deposits on the Brown mineral claim, this gneiss occurs as a number of sills intruding sedimentary schists and amphibolite over a width of ½ mile across the strike. A typical specimen examined under the microscope consists dominantly of oligoclase (Ab 87: An 13) and quartz. There is a small amount of biotite, pyrrhotite, graphite, and accessory apatite. Associated pegmatite dykes are composed of greenish oligoclase and quartz with a small amount of pyrrhotite. The whole is cut by unmineralized white pegmatites.

In the mineralized zone on the Brown mineral claim, pegmatitic and granitic stringers consist of quartz and greenish plagioclase. This is described in detail in the description of the mineral deposit.

Small amounts of the gneiss and associated pegmatites, both containing disseminated pyrrhotite, occur in sediments on the small point of land at M 8 and along the shoreline just to the south and continuing for a distance of 1 mile westerly from M 8.

At a locality 1¾ miles south of M 33 there is another iron-stained sill of this gneiss about 100 feet in width, intruded into sedimentary schists. The gneiss contains disseminated pyrrhotite, chalycopyrite, and a small amount of graphite. These minerals are also present to a less extent in the intruded rocks. The gneiss is again cut by white, unmineralized pegmatites in which the feldspar is microcline, which, however, are iron stained on the surface due to transfer of iron from the gneiss by means of surface waters. A thin section of a medium-grained, grey variety of the gneiss shows the rock to be dominantly oligoclase and quartz with some biotite, a small amount of orthoclase, and accessory apatite and magnetite. A lighter coloured, fine-grained variety is similar except that orthoclase is present in about the same quantity as oligoclase and the rock is, therefore, granodiorite.

At a locality 4½ miles north 5 degrees west of M 36, sills of greenish gneiss up to 3 feet in width and many small stringers of the same material cut anthophyllite schist and biotite schist in which garnets up to 2 inches in diameter have been developed. The feldspar is greenish plagioclase varying in composition from oligoclase-andesine to andesine and is associated with quartz, a small amount of biotite, and disseminated pyrrhotite and chalcopyrite, the sulphides occurring in both schists and the intruding gneiss, but being somewhat more abundant in the former.

At another locality, 3 miles west of M 35, a band of the gneiss about 200 feet in width contains disseminated pyrrhotite and is similar to the others except that the feldspar in this case is labradorite.

In addition the bluish feldspar gneiss carrying pyrrhotite was observed at several other localities.

Quartz Diorite

Of special interest because it is the source of copper mineralization, although nothing of commercial interest has been found, is an intrusion of dark grey, rather coarse-grained, gneissic to massive quartz diorite, generally uniform in composition and appearance and forming a mass extending over a length of 16 miles from Priest point southwesterly as far as the east shore of the large bay 7 miles west of M 36. It is bounded on the south and southwest sides by a belt of volcanics and sediments and on the northwest side by sediments and pinkish granodiorite. The same type of rock, and no doubt the same intrusive mass in depth, occurs again on the south side of this sedimentary belt, and occurs in a mass elongated in an east-west direction extending for 3 miles east of M 36, where it is cut off by pink granodiorite and extends southwesterly from M 36 for a distance of 4 miles and is again cut off by pink granodiorite; on the south side it is bordered by a belt of hornblende schist which occurs along the northern part of a large sedimentary area to the south. The quartz diorite where in contact with sediments and volcanics contains angular inclusions of these rocks and sends dykelets into them and is, therefore, younger. Where in contact with granodiorite, it occurs as angular inclusions in and is cut by dykes of the latter and is, therefore, older than it. Under the microscope a typical specimen of this quartz diorite collected at M 36 is found to consist dominantly of oligoclase-andesine (Ab 70: An 30); there are considerable amounts of strained quartz and the ferromagnesian constituents, hornblende and biotite, the former being somewhat more abundant than the latter; accessories are magnetite, apatite, and titanite.

Other quartz diorite intrusives in the area grade into and are contemporaneous with granodiorite. They are generally lighter grey than the older type just described and somewhat gneissic. This quartz diorite forms the major portions of the granitic intrusive south and east of M2 and also of the irregular-shaped intrusive east of Malcolm island and in Whitesand bay. Two typical specimens examined in thin section under the microscope were found to consist chiefly of andesine (Ab 65: An 35); quartz is quite plentiful and, of the ferromagnesian constituents, biotite is more abundant than hornblende; there is a subordinate amount of orthoclase and accessories are magnetite, apatite, and titanite. Portions of these masses are pinkish in colour and approach granodiorite in composition.

Granodiorite

The most abundant intrusive rock in the area is granodiorite, pink or light grey in colour and typically either massive or only slightly gneissic, although portions have well-developed foliation. It forms the granitic intrusion across the northern end of Numabin bay, the small, oval-shaped mass at M 1, several other small intrusions in the sedimentary-igneous complex, some of which are shown on the map, and the largest granitic mass in the area covering nearly half of the lake at its northern end. Thin sections of representative specimens of the granodiorite of the smaller masses in the southern part of the lake show the rock to be composed of oligoclase (Ab 80: An 20), orthoclase, and quartz as the chief constituents, the oligoclase being present in about the same quantity as orthoclase. Biotite is the characteristic ferromagnesian constituent, although at some localities hornblende is also present and at one locality there is a subordinate amount of muscovite; accessories are magnetite, apatite, and titanite.

The large batholith, extending for at least 70 miles in a northeasterly direction and over a known width of 35 miles, at the northern part of the lake, is generally pink in colour, coarse-grained, and porphyritic, with feldspar phenocrysts usually about ½ inch in length and with a maximum observed length of 2 inches. At some places the phenocrysts are very numerous and closely packed together and at other places are entirely absent over fairly large areas. It is generally massive, although locally it is strongly gneissic with the phenocrysts oriented with their long directions parallel to one another. A thin section of a characteristic specimen shows large phenocrysts of orthoclase in a granitic groundmass of oligoclase, orthoclase, quartz, and biotite; accessories are magnetite, apatite, and titanite, the last in some specimens being in wedge-shaped crystals as much as ¼ inch in length; part of the oligoclase is graphically intergrown with quartz, forming what is known as myrmekite. Locally, especially on the islands just west of Porcupine point, there is a darker grey phase in which phenocrysts are only sparsely distributed. This phase contains hornblende in addition to biotite and due to the subordinate amount of orthoclase approaches quartz diorite in composition.

Pegmatitic Granite and Granitization

As has already been mentioned, the metamorphosed sediments, particularly the biotite schist and to a less extent the volcanics, amphibolites, and some of the granitic gneisses, over large areas, have been much injected and permeated in a very intricate manner by white, granitic rocks. Portions of these rocks are almost free from this injected material, but in many places it forms a considerable proportion of the rock and in some areas over 50 per cent is granitic material. These white granitic rocks usually occur as small, irregular-shaped stringers usually injected parallel to the schistosity of the intruded rocks, forming injection gneisses but also crossing the structure at all angles. The stringers, which at many places form a series of lenticular masses, are not in sharp contact with the schist, but there is a complete gradation from the one to the other and scattered individuals of introduced feldspar occur throughout the schist, suggesting that the granitic material was very fluid at the time of injection (Plate V B). A series of three thin sections, taken from a typical locality at the south end of the lake showing the gradation from biotite schist to granitic stringers, was examined under the microscope. The fresh biotite schist shows quartz much strained and drawn out into bands, oligoclase in grains that are strained and rounded by granulation, biotite in wavy, contorted bands bending around oligoclase grains, and a small amount of garnet. The partly granitized schist is similar, except that orthoclase is present as large crystals as well as oligoclase, the total feldspars forming a large proportion of the rock, and biotite is partly altered to chlorite. A specimen of the granite, which appears to be almost completely replaced schist, consists of large, rounded crystals of orthoclase, forming about 50 per cent of the rock, in a groundmass of contorted, crushed quartz with biotite and muscovite, in bands bending around the orthoclase grains; cracks in the orthoclase are also filled with these minerals; chlorite is abundant as an alteration product of biotite. Granitization of the biotite schist in this case is the result of introduction of much orthoclase, and probably oligoclase also, with some muscovite and the alteration of biotite to chlorite; there has been considerable compression subsequent to or during the period of granitization. At another locality the schist occurs as elongated inclusions in coarse, white, pegmatitic granite composed of microcline, quartz, and biotite. Surrounding the inclusions is a broad zone of hybrid rock apparently formed by the partial replacement of schist by granite or by a reaction between the two. This hybrid rock has the composition of quartz diorite, being composed dominantly of closely spaced euhedral crystals of oligoclase which are surrounded by a mixture of quartz and biotite, both of which show strain shadows; microcline is subordinate, and at places garnets are abundant.

At some places quite large masses of white pegmatitic or aplitic granitic rocks occur quite free from the intruded schists. One of these examined in thin section was found to have the composition of granodiorite, being composed essentially of oligoclase, orthoclase, microcline, quartz, and a small amount of biotite and garnet. At another locality a large mass has crystals of white microcline graphic granite up to a foot in diameter lying in an aplitic garnet-bearing groundmass of oligoclase and quartz. Near the north end of Malcolm island white granitic rock is composed of oligoclase, quartz, and a small amount of biotite and is accordingly an oligoclase quartz diorite.

Pegmatite and Aplite

Pegmatite dykes and sills, both pink and white in colour, are very numerous in the area. They are usually from 1 foot or less to 10 feet in thickness, but in places are as much as 100 feet thick. The white, pegmatitic granite described in the previous paragraphs grades into white pegmatite and is contemporaneous with it and the pegmatite has granitized the schist in the same way as the granite has done. White pegmatite is confined in its occurrence, except for a few dykes cutting quartz diorite, to the areas mapped as a sedimentary-igneous complex and cuts sediments, volcanics, older basic intrusives, granitic gneisses, and oligoclase-quartz-diorite gneiss. Pink pegmatite dykes are most abundant in areas of quartz diorite, granodiorite, and granitic gneisses, where they occur as segregations grading into the granitic rocks or as sharp-walled dykes cutting them; they are also present in the intruded rocks along the borders of these intrusives and elsewhere. Large areas within the porphyritic granodiorite batholith at the northern end of the lake are almost free from pegmatite.

The minerals in the dykes are usually only the common rock-forming ones such as quartz, pink and white microcline, orthoclase, albite, oligoclase, biotite, and muscovite; common accessories are garnet and magnetite. Locally, titanite, blue and green apatite, hornblende, black tourmaline, pyrite, pyrrhotite, graphite, tantalite, and polycrase (?) are also present. The feldspar occurs in crystals up to 2 feet in cross-section, usually lying in a coarse, granitic groundmass and in places is intergrown with quartz forming graphic granite, or potash feldspar is intergrown with albite forming perthite. Quartz is present as irregular-shaped pockets filling spaces between feldspar crystals or in a granitic mixture; in some dykes it is concentrated in the central part but more commonly is distributed throughout its width. Biotite, which is much more plentiful than muscovite, is locally present as thin plates as much as 1½ feet across, but usually much smaller. A black, vitreous mineral, with properties similar to the mineral polycrase, occurs sparingly as small, tabular-shaped crystals in pegmatite dykes 1 mile southeast of M 7. Fragments of this material examined under the microscope were found to be isotropic with a brownish green colour and an index of 1·675. At another locality a similar mineral with an index of 1·650 occurs in small grains in white pegmatite, cracks up to 6 inches in length in the pegmatite radiating out from each grain. The proportions of the different minerals vary considerably in different dykes and in different parts of the same dyke, but feldspar usually predominates, although in places quartz is very abundant and some dykes are entirely of quartz.

Fine-grained, pink, aplite dykes, composed of microcline, albite, and quartz, occur at many places cutting the porphyritic granodiorite batholith at the northern end of the lake.

Contact metamorphic effects of pegmatite on amphibolite and volcanic schist have already been described where augite lava has been altered to actinolite and a hypersthene-pargarite rock has been changed to a hornblende-biotite rock. In addition biotite schist is somewhat affected, the schist being coarser grained and containing more biotite along the contacts of pegmatite. In the majority of cases, however, there is little or no contact metamorphism of any of the rocks by pegmatite.

YOUNGER BASIC INTRUSIVES

Diabase

Near the northern end of Numabin bay an intrusion of diabase, forming high hills with dip slopes to the northwest, cuts granodiorite and its associated pegmatite dykes as well as inclusions of schist and amphibolite in the granodiorite and is, therefore, the youngest consolidated rock in the region. The diabase is in the form of a sill, since it is intruded for the most part parallel to the gneissic structure of the granodiorite, which is anticlinal at this locality. The opening along which the sill was intruded was in general a simple and regular fracture, but locally the intrusion is somewhat irregular, the contact being jagged, stringers of diabase projecting out into the intruded rocks, and the diabase including broken fragments of the intruded rocks. The sill, which is about 50 feet in thickness and has been traced along the strike for a distance of 6 miles, strikes northeasterly over the greater part of its length and dips from 25 degrees to 45 degrees to the northwest. At its southern end it swings easterly around the nose of the anticlinal structure, but here lies almost flat and cuts across the structure. Contact metamorphic effects of the diabase on the intruded rock are slight, the contact being very sharp and the grey granodiorite being changed to a slight greenish colour within a distance of only an inch from the contact. The sill has well-developed columnar jointing, the columns being normal to the contacts; at one locality the joints were observed to continue across the contact into the underlying granodiorite. As may be easily observed on the dip slope of the sill the columns, in cross-section, are circular in shape with diameters averaging 5 to 10 feet and with a maximum of 15 feet. Less well-developed radial cracks are also present in each column.

The diabase, which weathers to a dark brown colour in sharp contrast to the nearly white granodiorite, varies greatly in size of grain across the strike. At both the upper and lower contacts it is chilled for a distance of 3 inches to 1 foot from the contact, to a dense, black rock containing a few small, scattered phenocrysts of plagioclase; the rock is so fine grained that it is almost isotropic under the microscope. Toward the central part of the sill it gradually becomes coarser grained, until in the upper central part, where the grain is the largest, crystals are up to 1 cm. in length and locally there are areas in which individuals are as much as 2½ cm. in length.

There is also a variation in composition across the strike, the central part, which is also lighter coloured, being more acidic than the borders. A specimen collected at a distance of 20 feet from the bottom of the sill is representative of the medium-grained and most common type, and probably represents fairly closely the average composition of the sill. In thin section under the microscope it is seen to consist chiefly of labradorite and augite in about equal proportions. The feldspar is lath-shaped and commonly penetrates augite crystals, giving the rock an ophitic or diabasic texture. Filling wedge-shaped interstices between these crystals is a small amount of graphic granite, a mixture of quartz and orthoclase, associated with sericitic material, hornblende, and a small amount of biotite. Hornblende is also present to a slight extent as an alteration product of augite, particularly along the edges of the latter. Magnetite is quite abundant as graphic-shaped growths associated with the ferromagnesian constituents. In addition there is a small amount of a tabular mineral, possibly hypersthene, but which is almost completely altered to greenish serpentine, a mineral that also occurs sparingly as veinlets cutting across all the other minerals of the rock. As compared with this dominant type, a specimen of the very coarse diabase from the upper central part of the sill has a somewhat larger proportion of plagioclase as compared with augite, and graphic granite with associated biotite and hornblende is much more plentiful. A specimen collected at a distance of 1 foot from the foot-wall is similar to the dominant type except that graphic granite is absent. Contrary to expectations there is very little difference in the composition of the plagioclase from different places across the strike, but the plagioclase forming the phenocrysts in the chilled phase and in the finer-grained diabase near the border is somewhat more basic, being labradorite (Ab 35: An 65), than the plagioclase in the remainder of the sill which is labradorite (Ab 42: An 58).

Late differentiates of the diabase include aplitic stringers and quartz-calcite veinlets. The aplitic stringers, which are reddish coloured and about one inch in width, were observed cutting medium-grained diabase at one locality; they are much more acidic than the diabase and consist of a fine-grained mixture of orthoclase, quartz, hornblende, and accessory magnetite, approximating in composition the graphic granite with associated ferromagnesian constituents filling interstitial spaces in the diabase.

The quartz-calcite veinlets are present in many of the circular joint cracks of the diabase and much less commonly in the radial cracks as well; they are more abundant near the hanging-wall than near the foot-wall and are apparently absent from the central part of the sill. They also occur to a less extent cutting the intruded granodiorite and schists at both contacts and at the hanging-wall side were observed in the country rock as much as ¾ of a mile from the diabase. These veinlets, which are only from ¼ to 1 inch in width, consist of comb quartz along the borders and calcite, associated in places with a few grains of chalcopyrite, along the centre. Both the diabase and the granodiorite are altered for a distance of 3 inches on each side of the veins to a soft, easily weathered, sericitic material. Pyrite occurs locally as thin films cutting the dense, chilled border phases of the diabase and across the contact into the granodiorite.

A comb-quartz calcite vein was also seen on the south shore of Wepusko bay 2 miles northeast of the outlet of Wepusko river. This vein, except for the absence of chalcopyrite, is entirely similar to the veins in and near the diabase and since it is also younger than biotite schist and pink pegmatite, which it cuts, is undoubtedly to be correlated with those veins and suggests that diabase may also occur somewhere in the vicinity, although none was observed.

CORRELATION

The sedimentary schists and gneisses of Reindeer lake are similar lithologically and are probably to be correlated with the Kisseynew gneisses of the Amisk-Athapapuskow Lake district of northern Manitoba,[1] with the sedimentary gneisses at Kississing lake examined in 1928 by J. F. Wright,[2] and with the Lac La Ronge series described by William McInnes.[3]

During the journey into Reindeer lake, from Amisk lake, via Pelican narrows, Churchill and Reindeer rivers, much of the country crossed was seen to be composed of metamorphosed sedimentary material entirely similar to that at Reindeer lake and to be correlated with it.

[1]Bruce, E. L.: Geol. Surv., Canada, Mem. 105 (1918).
[2]See pages 78-84 (this volume).
[3]Geol. Surv., Canada, Sum. Rept. 1909, pp. 151-157; Geol. Surv., Canada, Mem. 30, pp. 47-49 (1913).

The volcanic material, which is associated with sediments at Reindeer lake, is somewhat similar to the Amisk series of the Amisk-Athapapuskow Lake district[1] and should probably be correlated with it.

The diabase may be of the same age as a diabase cutting Athabaska sandstones on Cree lake 160 miles west of Reindeer lake,[2] and of the more abundant diabase far to the north such as has been found to cut Athabaska sandstone at Dubawnt lake and vicinity.[3] It may be of the age of the diabase at Great Slave lake.[4]

STRUCTURAL GEOLOGY

Secondary schistose and gneissic structures developed by compression and recrystallization are present everywhere in the old sediments and volcanics and the strike and dip are easily observed. As a result of numerous observations the strike of these structures is found to be very irregular, forming broad or sharp curves and locally minute crenulations. In a broad way the trend is generally northeasterly and, although dips are in all directions, the great majority are toward the northwest. The angle of dip varies at different localities from 15 degrees to vertical, the majority being from 40 degrees to 70 degrees. Where these rocks are intruded by granitic rocks their schistose or gneissic structure parallels in a general way the borders of the intrusives. Within the granitic intrusives, gneissic structure is also usually developed to some extent and is well developed in the granitic gneisses; these structures in general also parallel the borders of the intrusives and trend chiefly in a northeasterly direction. Locally, as along the contact between granodiorite and sediments at the south side of Porcupine point, the structure of the sediments meets the contact of the intrusive at a small angle. Schistose structure is entirely absent from the diabase.

Because of the intensive development of these secondary structures and extensive granitization, much of the original bedding of the sediments has been obliterated and consequently the attitude of the bedding, although observed at many localities, cannot always be determined and the folding, which is evidently complex, cannot be solved except over small areas. Another factor contributing to this difficulty is the absence of any well-defined beds that could be used as horizon markers. Wherever observed the bedding planes are parallel to the secondary schistose or gneissic structures. Locally there are small areas in which anticlinal folding may be observed, such as across the point of mainland 2 miles southwest of M 37, where a small anticline with minor drag folding on the limbs can be observed. On a large scale an anticlinal fold is also present on the shores and islands of Numabin bay. A generalized diagram showing the trend of schistose and gneissic structures, and also bedding where observed, is shown on the geological map accompanying this report.

Faulting was observed at several localities, but only on a small scale, and is apparently a very minor structural feature of the district.

[1]Bruce, E. L.: Geol. Surv., Canada, Mem. 105 (1918).
[2]Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol. VIII, pt. D, pp. 18 and 42 (1897).
[3]Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol. IX, pt. F, pp. 1-218 (1898).
[4]Lausen, Carl: Can. Min. and Met. Bull., pp. 388-389 (Feb. 1929).

ECONOMIC GEOLOGY

Early in September, 1927, a zinc-copper deposit was staked on the shore of Paskwachi bay almost on the boundary line between Saskatchewan and Manitoba. In December of the same year a number of other prospectors visited the district and staked additional claims in the vicinity of the original discovery. During the summer of 1928 still other prospectors visited the deposit and a few of them searched along other parts of the lake shore and islands with the hope of finding other deposits, but, as far as known to the writer, nothing more of economic interest has been discovered. This, however, should not be discouraging, for the lake is very large and it would take a number of years to examine in detail even the easily accessible exposures along the water's edge and much longer to examine the very large unprospected areas inland.

BROWN MINERAL CLAIMS

Early in September, 1927, the zinc-copper deposit on the western shore of Paskwachi bay was staked by John Highway, the original discoverer, E. L. Brown, and John Drybrough. A number of claims were staked on the deposit and in its vicinity, those on the deposit being called the Brown mineral claims.

These claims are owned by the Reindeer Lake Syndicate, Limited, of which Mr. P. E. Hopkins, 406-9 Bank of Hamilton building, Toronto, is president. During the summer of 1928 this syndicate sent a party of men, in charge of Mr. C. H. E. Stewart, to determine the value and extent of the deposit. A total of eight diamond drill holes were put down, two of which were abandoned before bedrock was reached. By means of these holes and surface trenching the mineralized zone has been traced for a distance of 800 feet along the strike. Values, as determined by assays of drill cores, were found to be present over widths varying from 1 foot to 23 feet and are chiefly in zinc with lesser amounts of copper and still smaller amounts of lead, silver, and gold. The zone strikes east-west and dips 40 per cent to the north, paralleling the gneissic structure of the country rock.

The rocks in the vicinity of the deposit are chiefly grey gneisses and schist which are generally much injected by white pegmatitic granite and pegmatite; in addition there are a few bands of amphibolite and small areas of granitic rocks also cut by white pegmatite. Immediately at the deposit a band of dark, coarse-grained amphibolite, varying in width from 5 to 10 feet and locally pinching out altogether, lies between grey gneisses. The ore minerals occur chiefly in the amphibolite and to a less extent in the gneisses adjacent to it.

The least mineralized amphibolite is seen under the microscope to consist dominantly of pale green hornblende, with lesser amounts of augite, labradorite, apatite, quartz, and sulphides. The hornblende, although partly altered to chlorite, is generally fresh and unstrained and appears to be of secondary development; the augite is partly altered to hornblende and calcite and labradorite is much altered to sericite and cut by stringers of chloritic material; the quartz is fresh and unstrained and it, as well as the sulphides, which in places occur as stringers cutting hornblende crystals, appears to be of secondary introduction. It is difficult to determine the origin of this amphibolite with any degree of certainty, but its basic character suggests that it is igneous (gabbro in composition) rather than a sedimentary layer and its attitude to the gneisses indicates that it is a sill.

A thin section of the gneiss on the foot-wall side of the amphibolite consists dominantly of quartz and labradorite with considerable amounts of hornblende and biotite in crystals oriented with their long axes parallel to one another, a composition that is abnormal for igneous rocks and suggestive of sedimentary origin. Other coarser-grained gneisses have a granitic appearance, the feldspar is chiefly orthoclase, and the rock may be of igneous origin.

In places the amphibolite is cut by small stringers of granitic and pegmatitic material composed of quartz and greenish-coloured plagioclase varying greatly in composition from oligoclase, through andesine and labradorite, to bytownite. As well as occurring in small stringers this material is present as irregular-shaped masses impregnating and replacing the amphibolite. In addition to these types of rock there are, in the mineralized zone, numerous small stringers of white microcline pegmatite.

The minerals present in the deposit are pyrrhotite, pyrite, sphalerite, chalcopyrite, galena, quartz, garnet, and graphite. Pyrrhotite is more plentiful than pyrite and both iron sulphides, taken together, are more abundant than the copper, zinc, and lead sulphides. Sphalerite is present in larger quantity than chalcopyrite and galena is the least abundant of the sulphides. Only a few small flakes of graphite were noted and garnets are not abundant, but quartz is quite plentiful. The sulphides occur chiefly in the amphibolite, but are also present in the gneisses adjacent to it, and are distributed irregularly in grains and patches which have replaced these rocks. They are usually accompanied by quartz and where sulphides are most abundant quartz is also plentiful. Accompanying the mineralization were solutions that altered the plagioclase of the amphibolite to sericite and the augite to chlorite and calcite.

The stringers and irregular-shaped masses of granitic and pegmatitic rock composed of greenish plagioclase and quartz, already mentioned, afford a clue to the source of the mineralizing solutions. This rock in part contains the sulphides and in part occurs as unmineralized stringers cutting sulphide-bearing amphibolite, the two facts together suggesting that it is essentially contemporaneous with the mineralizing solutions, and that both of them probably came from the same source. Since the feldspar of this rock has the same appearance as the feldspar of the oligoclase quartz diorite gneiss and associated pegmatites which, as already described, also contains pyrrhotite and locally chalcopyrite and graphite, it is probable that this gneiss, the greenish feldspar rock in the mineralized zone, and the mineralization are all closely related. The nearest outcrop of the oligoclase quartz diorite gneiss is 2 miles northeast of the deposit and the mineralization, and associated greenish feldspar rock on the Brown mineral claim is probably an offshoot from this or a similar gneiss which may possibly be present beneath the deposit. As has been previously stated the oligoclase quartz diorite gneiss is older than unmineralized white microcline pegmatite dykes which cut it, and the mineralization on the Brown mineral claim is accordingly also believed to be older than white pegmatite which occurs at the deposit and is unmineralized but has not been observed, because of poor exposures, to cut the mineralized zone.

The fact that the greenish feldspar stringers, which are later than the amphibolite, are mineralized, shows undoubtedly that the mineralization is subsequent to and not related in origin to the amphibolite. The fact that the mineralization occurs chiefly in amphibolite may be due to a precipitating action of this basic rock on the acidic ore solutions.

MINERALIZATION AT OTHER LOCALITIES

In addition to the mineralization on the Brown mineral claim, there are small amounts of chalcopyrite at several other localities, which although of no commercial interest in itself, indicates that at least some mineralization is present and that larger deposits also possibly occur; a consideration of its origin should accordingly be of value to prospectors who consider it worth while to make further search for economic deposits in this area.

Mineralization is clearly related in origin to at least three types of rock, the oligoclase quartz diorite gneiss, the quartz diorite in the vicinity of Priest point and M 36, and the diabase. A fourth type, the widespread granodiorite and associated quartz diorite, probably also has mineralization associated with it in origin.

The oligoclase-quartz-diorite gneiss, the distribution and characteristics of which have already been described under the heading of general geology, always contains scattered grains of pyrrhotite and, in places, chalcopyrite also. The facts that these minerals also occur in the intruded schists adjacent to the gneiss and that they are here present with a less uniform distribution than in the gneiss indicate strongly that the gneiss is the source of the mineralization. As already explained, the deposit on the Brown mineral claim is probably related in origin to this gneiss.

The quartz diorite which has been described as occupying a large area at Priest point, M 36 and vicinity, has small amounts of chalcopyrite associated with it at two localities, namely, 2 miles northeast of M 36 and 1 mile south of M 36. At the first locality, on the southwest shore of an island, pyrrhotite, pyrite, and a few specks of chalcopyrite occur in schists close to the contact of the intruding quartz diorite. At a point a few hundred feet away from the contact there are many, small, irregular-shaped lenses of quartz diorite and quartz, the one grading into the other, in much contorted black hornblende schist which has been altered at the contacts of these lenses to a green pyroxene rock. Most of the lenses are barren of sulphides, but some of them contain small amounts of chalcopyrite disseminated in the quartz diorite or occurring as small veinlets at the outer edges of the quartz, and also occurring to some extent in the adjacent schists. At the second of these localities, on the north side of an island, where quartz diorite is in contact with schist, stringers and dykes of the quartz diorite cut schist. Chalcopyrite occurs in small quantity disseminated in the stringers and also in the intruded rocks adjacent to them. This association of chalcopyrite with small off-shoots from the main mass of quartz diorite, together with the fact that small specks of chalcopyrite were observed at one locality within the main mass of quartz diorite, undoubtedly indicates that this rock is the source of the chalcopyrite.

In addition there are many large and small pyrrhotite replacement bodies occurring at numerous places within the areas mapped as sedimentary-igneous complex. These are so numerous that many could not be examined in detail and their origin is for the most part obscure. Many of them may be related to the oligoclase quartz diorite gneiss, or the quartz diorite of Priest point, M 36 and vicinity, and others may be related to the large areas of granodiorite and its associated quartz diorite. All of the pyrrhotite bodies examined were found to contain, as far as could be determined with a hand lens, only iron sulphides, chiefly pyrrhotite and lesser amounts of pyrite. Polished surfaces of specimens from two localities were examined under the microscope. One of these is of nearly massive pyrrhotite from the south shore of the west arm of Numabin bay, 6 miles northwest of K 33, a part of the lake where iron sulphides are particularly abundant. It was found to contain, in addition to pyrrhotite, a very small amount of chalcopyrite. The other specimen is from a band of biotite schist, 2 miles north of M 2, which has been heavily impregnated with pyrrhotite and pyrite for a length of at least one mile. A typical specimen of this was found, when examined under the microscope, to contain a small amount of sphalerite and chalcopyrite in addition to pyrrhotite and pyrite. The presence of small amounts of chalcopyrite or sphalerite in these iron sulphide deposits, which for the most part are evidently not of commercial value, suggests that they should not be entirely overlooked, however, for concentrations of valuable minerals may possibly occur in them.

Locally white and pink pegmatite dykes, which are the youngest phases of the granitic intrusives, contain a considerable amount of pyrite, but they are generally unmineralized and are not of economic interest.

Much younger than any of this mineralization is that related to the diabase which has already been described under the heading of "General Geology."

SUGGESTIONS TO PROSPECTORS

Although mineralization may have originated from still other sources than those mentioned in the previous section, it would seem advisable, in prospecting this area, to search for deposits in sediments, volcanics, or amphibolite in the vicinity of exposures of oligoclase quartz diorite gneiss, or of the quartz diorite intrusive at Priest point, M 36 and vicinity, the distribution of which has been described. It would also be advisable to examine closely the extensive iron sulphide replacement bodies with the hope of finding parts in which valuable minerals are concentrated. In addition, the diabase and the intruded rocks adjacent to it should be prospected. The oligoclase quartz diorite gneiss or the quartz diorites themselves, although they are the source of the mineralization, are not likely to contain, within themselves, economic minerals in sufficient concentration to be of interest, and the large areas of granodiorite and associated quartz diorite likewise would not be expected to be mineralized except in proximity to the diabase.

KISSISSING LAKE AREA, MANITOBA

By J. F. Wright

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Illustrations

INTRODUCTION

The search for mineral deposits in northern Manitoba has been in progress at intervals during the past fifteen years. The first deposits discovered were gold-bearing quartz veins, but, up to the present, these have not proved to be important commercially. In 1915, the Flin Flon and Mandy copper-zinc deposits were discovered in Athapapuskow Lake area, and since then the district has attracted attention as a base-metal field. The prospecting activities gradually worked northward from Athapapuskow area, and, early in 1923, deposits of copper-zinc sulphides were staked in the basin of Kississing lake, approximately 40 miles northeast of the Flin Flon deposit. The more important of these deposits is the Sherritt-Gordon, which is now being explored and developed, and will be producing early in 1931, or possibly late in 1930. The mineral deposits previously discovered in northern Manitoba are in the volcanic rocks (greenstones), whereas many of the deposits of Kississing Lake area are in sedimentary gneisses, and for this reason the geology of the area has especial interest. Also, the occurrence of a commercial sulphide body in this series of ancient sedimentary gneisses has encouraged thorough exploration of the large areas of these rocks in the district.

The first geological exploration of Kississing lake was in 1899, when D. B. Dowling[1] passed down Kississing river and across Kississing lake en route from Athapapuskow lake to Churchill river. Outcrops of grey and black hornblende and biotite-garnet gneisses were recognized, also intrusive granite and pegmatite. This complex was mapped as Laurentian. The geology and mineral deposits of Athapapuskow and Wekusko areas to the south and southeast of Kississing area were studied by Bruce[2]

[1] Geol. Surv., Canada, Ann. Rept., vol. XII, pt. A, pp. 110-112 (1902), and vol. XIII, pt. FF, pp. 34-39 (1903).

[2] "Amisk-Athapapuskow Lake District"; Geol. Surv., Canada, Mem. 105 (1918).

and Alcock[1], and the writer's work of last summer continued this geological exploration northward. The topographical base used was a part of the Kississing sheet, issued in June, 1928, by the Topographical Survey of Canada. In the field work the writer was ably assisted by Messrs. A. W. Derby, O. B. Gwillam, J. A. Syme, and, for the last two months, by R. P. Quinn. Thanks are due Mr. E. L. Brown, Mr. Geo. M. Thorpe, Mr. A. B. Carson, Mr. H. J. Carmichael, Mr. R. C. Mackeg, Mr. W. A. Rae, and Messrs. Durie and Akers for courtesies extended the party.

In summer, Kississing Lake area is easily accessible by canoe from Cranberry Portage on the Canadian National branch line from The Pas to Flinflon. The trip from Cranberry Portage takes from 1½ to 3 days, depending upon the load carried. The route follows Pineroot river and the chain of lakes north from the west side of the north arm of Athapapuskow lake. The longest portage is three-quarters of a mile, and crosses the height of land north of Wabishkok lake between the drainage south to Saskatchewan river and north to Churchill river. Throughout most of 1928, Western Canada Airways operated a passenger, mail, express, and freight service to the area, from either Cranberry Portage or The Pas. Late in the summer of 1929, a railway will be completed from Cranberry Portage, on the Flin Flon branch line, to the Sherritt-Gordon deposit, on the east side of Kississing lake.

GENERAL CHARACTER OF THE AREA

TOPOGRAPHY

During a part of the summer of 1928, a preliminary geological reconnaissance was completed of the main canoe routes and adjoining country of parts of an area of about 1,600 square miles, extending eastward from the 102nd meridian and northward from the 18th base-line (approximately latitude 55 degrees). Lakes are fairly abundant throughout most of this area, consequently most parts can be reached for prospecting or geological work by the use of light canoes. Kississing (or Cold) lake is the largest lake and occupies about half of an area 25 miles square, in the centre of the map-area. This lake has a very long shoreline, due to many long points with intervening irregularly outlined bays. Rock exposures are generally abundant adjacent the lakes, and an examination of the rocks exposed along the shoreline and a mile or so inland gives a fairly representative idea of the general character and structure of the geological formations of the district. Also, the presence of numerous lakes a mile or over in length, facilitates preliminary development work, for hydro-airplanes can land near the mineral prospects with supplies and equipment. During the summer of 1928, light diamond drills were moved from one prospect to another by hydro-airplanes.

The country inland from the lakes is rough and hilly in part of the area, whereas other large sections are flat and swampy. The map-area is just north of a height of land, and, therefore, most of the streams are

[1] "The Reed-Wekusko Map-area"; Geol. Surv., Canada, Mem. 119 (1920).

small, and large sections are poorly drained. The average elevation of the surface is nearly 1,050 feet above sea-level, and the hills rise from 25 to 225 feet above the adjoining swamp or lake-level. A large area west of Kississing lake to Mari lake is generally flat and swampy, with few lakes and poor drainage. This part of the map-area has not yet been prospected or geologically examined in any detail. Also, north of Fay lake there is a very large, swampy area, one partly flooded muskeg being several miles in extent. The country north and east of Kississing lake is hilly, and bedrock is well exposed, the swamps, though numerous, are on the average small and seldom reach a mile in width. Sedimentary and volcanic rocks of pre-granite age generally outcrop along the lake shores, whereas inland the rocks of surficial origin are cut by deep-seated granitic intrusive as sills, bosses, and large batholith-like masses.

GLACIATION AND GLACIAL DEPOSITS

In late Pleistocene time, Kississing Lake area was crossed by the Keewatin ice-sheet, moving from east of north to west of south. Records of glaciations earlier than this last advance and retreat of the ice-sheet were not observed. Almost everywhere the exposed rocks are fresh, and the surface of the outcrops is polished and grooved. The strike of the glacial striæ varies from south 5 degrees east to south 45 degrees west, the average strike being about south 25 degrees west.

The deposits left by the retreating ice-sheet consist of boulders, boulder clay, and stratified sand and gravel. Most of the drift is typical ground moraine material. The water-sorted sand and gravel are irregularly bedded, and are typical outwash material. Sand-plains are present; these were formed by waters, laden with fine débris, flowing from the ice field. In some depressions stratified clay and sand overlie the glacial drift. These younger deposits probably were formed by streams carrying clay and silt from the ice-sheet into small, temporary lakes formed by ice barriers and rock ridges. Probably lake Agassiz was largely drained before the ice retreated from Kississing Lake area, and no evidence was noted to suggest that any very extensive post-Glacial lake covered the area.

NATURAL RESOURCES OTHER THAN MINERALS

Previous to the commencement of active mining in 1926, the fur-bearing animals were the only resource of the area being exploited. For many years a few Indian trappers visited the area during the winter months, but no settlement or reserve was ever established on the lake, the Indians coming either from Sturgeon Landing and Cumberland House to the south or Pukatawagan to the north. In parts of the area there still remain a few game animals, and during the summer a few moose and caribou were seen, also deer in the vicinity of Kipahigan lake. Ducks were fairly abundant on some of the lakes, and partridge were exceptionally plentiful in the autumn.

Large tracts of country surrounding Kississing lake have been swept by forest fires at intervals during the past fifteen years. The forest fires last summer were numerous and large, and much forested country was burned over. Only small stands of spruce of commercial size remain, and in the summer of 1928, Sherritt-Gordon Mines, Limited, had to bring timber for mining purposes and camps from near the west side of Kississing lake, about 30 miles away from the mine. In the future, most of the timber for mining purposes will be brought from outside.

No large waterpower sites are present in the area mapped. As the area lies just north of a height of land, the streams are small and, during dry seasons, their volume is slight. One or two of the small falls on Kississing river, north of Kississing lake, could be developed to yield a small horsepower, provided the level of Kississing lake is raised several feet, to ensure a uniform flow of water down the river throughout the year. Approximately 40 miles north of Kississing lake on Churchill river, however, there are a number of falls that could be utilized to supply all power necessary in mining for a number of years to come. Only preliminary surveys of these power sites have yet been made, but at Bloodstone falls, 50 miles in an air-line north and west of the Sherritt-Gordon mine, there is a head of 20 feet, and approximately 42,400 horsepower at 80 per cent efficiency could be developed.[1]

Small areas of soil are suitable for agriculture, and as mining activities expand in the area, some of the land undoubtedly will be cleared and cultivated. A few patches of land have been cleared within the past two years, and during the summer of 1928, potatoes, cabbage, and other vegetables were grown successfully on islands in Kississing lake. Frost killed most of the vegetables in gardens on the mainland, but when larger areas of forest surrounding the cultivated areas are cleared, the frost probably will not be so severe during summer months.

GENERAL GEOLOGY

The bedrock of Kississing Lake area is of Precambrian age and the groups of rocks recognized are lava flows with interbedded sediments, a thick series of quartzose sediments, small bodies of basic intrusive rocks, many sills and dykes of granite, aplite, and pegmatite, and large batholith-like bodies of granite. Most of the rocks older than the granite are much metamorphosed, and are, for the most part, gneisses and schists. The more abundant rock types may be grouped as follows.

[1]Atwood, C. H.: "Water-Powers in Manitoba"; Water Resources Paper No. 56, Dept. of Interior, Ottawa, 1926, p. 18.

Table of Formations

Granitic intrusives	Pegmatite and aplite Granite and granite-gneiss
Basic intrusives	Peridotite, gabbro, and diorite
Intrusive contact	
Kisseynew sedimentary gneisses	Granitized sediments Hornblende-bearing garnet gneiss Quartz-biotite-garnet gneiss Gneissic quartzite
Conformable contact	
Amisk lavas and sediments	Andesite, dacite, tuff, greywacke, arkose, and derived chlorite and sericite schists and gneisses

AMISK LAVAS AND INTERBEDDED SEDIMENTS

Distribution and Lithological Character. South and east of Kisseynew lake, lavas outcrop and these rocks represent a continuation of the Amisk series north from Amisk-Athapapuskow Lake district. The lavas are black, fine-grained, either massive or schistose rocks. Only a few outcrops show pillow structure or other evidence of volcanic origin. In thin section the massive, black lava consists essentially of a plagioclase, near andesine in composition, and hornblende, and, therefore, is andesite. Green biotite is fairly abundant in some thin sections. The schistose lava contains, in addition to a few grains of hornblende and plagioclase, a great abundance of chlorite, and some biotite, quartz, calcite, and epidote. Associated with the lavas are beds of a very fine-grained, laminated rock, representing water-sorted, presumably andesitic, volcanic materials. Some outcrops within the area of lavas are dark grey, micaceous rocks containing red garnets; others are light grey, laminated, siliceous rocks, near chert in mineral composition and texture. In a few places the bedded rocks associated with the lava flows are metamorphosed to schists and gneisses.

Lavas occur associated with sediments in the basin of Nokomis lake and northward to Walton lake. Here, the lavas are dark grey to black rocks ranging from dacite to andesite in mineral composition. Both massive and schistose types are present. Locally poorly developed pillows were noted. In thin sections under the microscope, the minerals are in part altered to chlorite, carbonate, and epidote. In places north of Nokomis lake, the lavas form only a minor proportion of the group, fine to medium-grained greywacke and arkose being much more abundant. Many outcrops of the sediments show bedding exceptionally well, dark, fine-grained beds from 2 to 10 inches thick alternating with coarser grained beds of arkose from 6 inches to 2 or 3 feet thick. The abundant minerals of these sediments are quartz, biotite, microcline, plagioclase, hornblende, and garnet. Some of the quartz grains are rounded, others are subangular. The mineral grains of the arkose beds show little evidence of granulation. Many beds are schistose, and through metamorphism a variety of grey to black quartz-mica-garnet and quartz-hornblende-biotite-mica-garnet and quartz-hornblende-biotite schists and gneisses have been developed along parallel zones with intervening beds of more massive sediments or lavas.

General Structure and Age Relations. The schistosity and bedding of the Amisk lavas and sediments south and east of Kisseynew lake trend from east to northeast, and their dip is from 70 to 85 degrees north and northwest. Along the south shore of Weldon bay, at the east end of Kisseynew lake, the Amisk lavas and sediments are followed to the north by the Kisseynew sedimentary gneisses without evidence of a stratigraphic break. The gneisses overlie stratigraphically the Amisk volcanic group. The contact between the two groups is a transitional one, for there is a zone, from one-half to a mile in width, along the contact between the two groups of strata, wherein quartzose sediments and lava flows alternate, the lava beds toward the north becoming narrower and finally disappearing. The Amisk lavas are cut by large, batholith-like masses of granite and by a few aplite and pegmatite dykes.

The bedding and schistosity of the sediments and lavas from south of Nokomis lake north to Walton lake, strike from north to northwest and the dip from 40 to 80 degrees to the east and northeast. The area of these rocks examined is surrounded by intrusive granite, and, therefore, their relations to the Kisseynew gneisses and the Amisk series are unknown. The sediments and lavas at Nokomis lake, however, may belong to the Amisk group, as mapped by E. L. Bruce, at Elbow lake approximately 15 miles directly south. The possibility must also be considered that these strata may correspond to a part of the Wekusko group of lavas, gneisses, and schists described by F. J. Alcock in the Reed-Wekusko map-area, the northwest corner of which is approximately 20 miles southeast of Nokomis lake. The Kisseynew group of gneisses as developed north of Kisseynew lake and in the basin of Kississing lake is not known to contain intercalated lava flows.

KISSEYNEW SEDIMENTARY GNEISSES

General Character and Distribution. The complex of quartzose sedimentary gneisses and intimately intermixed granitic intrusives, outcropping in the basin of Kisseynew lake, were named the Kisseynew gneisses by E. L. Bruce.[1] The field work of last summer has shown that these gneisses are widespread north of Kisseynew lake, and in the basin of Kississing lake. Field evidence clearly indicates that a large proportion of these gneisses was originally sandstone, impure sandstone, and clayey arkose. These sediments have been extensively invaded by granitic intrusives, and many outcrops show intimate mixtures of granite and sediment. The sediments varied considerably in mineral content from bed to bed, and this variation, combined with varying degrees of recrystallization and intensities of regional and contact metamorphism, has resulted in the

[1] "Amisk-Athapapuskow Lake District"; Geol. Surv., Canada, Mem. 105, pp. 27-30 (1918).

production of a great variety of gneisses, some beds of which are distinguished with difficulty from intrusive rocks. A great range in the appearance and mineral make-up of the gneiss is visible within short distances in a few localities, consequently in mapping such areas it has been necessary to generalize, for to represent each lithological unit would require a map on a very large scale. In other parts of the area, however, the sedimentary gneisses show only minor textural and mineralogical variations, and present a monotonous succession of grey quartz-mica-garnet gneisses cut by numerous sills of granite and dykes of pegmatite.

Sedimentary gneisses outcrop from points 5 and 10 miles east of Kississing lake westward to the edge of the map-area, and from Kisseynew lake northward to a few miles north of Kississing lake. East of Kississing lake, the sedimentary strata are terminated by a large granite body, occupying the southeast corner of the map-area and extending southward. East of this granite body, in the basin of Nokomis lake, volcanic rocks occur with the sediments, and have been mentioned in the discussion of the Amisk group. A few miles north of Kississing lake the sediments are gradually replaced by granite and granite-gneiss, which become the predominant rocks. Westward of Kississing lake to Kipahigan and Mari lakes, sedimentary gneisses, so far as is known, are the predominant rocks. At many points throughout this large area, as in the vicinity of Bartlett lake, the continuity of the sedimentary gneisses is broken for short distances by boss-like and other small granite bodies. Thus the Kisseynew gneisses are the predominant rocks of pre-granite age in the map-area, and these gneisses are believed to extend over considerable areas in the part of Saskatchewan lying immediately west of the map-area.

Lithological Character. As already indicated, a considerable variety of metamorphic sedimentary rocks are included within this group. Of this complex, only types judged to be the most abundant or such as were most commonly encountered in examining mineral prospects, have been selected for brief description.

Gneissic quartzite is a fairly common member and is considered to represent sandstone beds. The quartzites are now medium-grained, light-grey, slightly foliated, bedded, quartz-rich rocks. They outcrop prominently along the tops of many rock ridges. Bands or zones of these rocks are seldom more than 1,000 feet wide, and are associated with fine-grained, more micaceous, garnet-bearing strata. Many outcrops show bedding, now represented by light-grey, fine-grained layers, from 2 inches to 5 inches wide, alternating with slightly coarser-grained, lighter-coloured, quartz-rich beds, from 6 inches to 3 or 4 feet wide. In the more massive, thick beds, the micaceous minerals are somewhat segregated in narrow bands, believed to represent original stratification. In thin section under the microscope, the gneissic quartzite is seen to consist of an aggregate of interlocking, large and small, subangular quartz grains, with some microcline, plagioclase, biotite, and a white mica. Some beds also contain a few small, red garnets, but, as a rule, red garnets are not present in the more quartzose gneisses.

Quartz-biotite-garnet gneiss is a very widespread, abundant member of the Kisseynew group, and is interpreted as representing impure sandstone. The typical quartz-mica-garnet gneisses are fine to medium-grained, greyish rocks, which show bedding represented by repeated variations of the relative amounts of quartz and mica in alternating layers. These gneisses are fairly uniform in appearance throughout the map-area. Under the microscope they are seen to consist of angular quartz and feldspar grains, with abundant flakes of brown and green biotite. The biotite flakes are oriented, for the most part, with their long axes parallel, and in the thin sections are grouped in narrow bands, the intervening areas being occupied by quartz and feldspar grains, accompanied by only a few small biotite flakes with random orientation. The most abundant feldspar is a plagioclase, near oligoclase in composition; only a few grains of orthoclase and microcline are present in the four thin sections examined. Some specimens contain hornblende in addition to biotite. All thin sections show reddish garnet, in small subangular crystals with inclusions of small, round quartz, feldspar, and mica grains and flakes. The wavy extinction and fractured character of many of the quartz and feldspar grains indicate that the rocks have been subjected to considerable pressure, either since or at the time they were recrystallized. The minerals are only slightly altered to secondary products.

Hornblende-bearing garnet gneiss locally outcrops as bands associated with the gneisses already described. These gneisses are grey to black, medium to coarse-grained rocks, some of which have the appearance of quartz diorite-gneiss. Many outcrops contain abundant small crystals of red garnet; in a few outcrops garnets up to 2 inches in diameter are present. Many outcrops show banding, representing remnants of the original bedded structure. These dark, hornblende-bearing gneisses outcrop north of the Sherritt-Gordon deposit, and are fairly abundant from there north to Found and Cree lakes, also north of Sherlett lake, between Sherlett and Molly lakes, on the northwest side of Kipahigan lake, and at numerous other localities. These black gneisses occur adjacent to a number of the sulphide bodies and form the hanging-wall of the Sherritt-Gordon deposit. The hornblende-bearing garnet gneisses are believed to represent clayey arkose beds.

The five thin sections of these gneisses studied microscopically, show large and small, angular to subangular grains of plagioclase, quartz, and garnet, and abundant long crystals of amphibole. The plagioclase varies in composition from oligoclase to near labradorite. In two specimens the plagioclase is andesine. Albite is also present sparingly in one specimen. Some orthoclase was recognized, but potash feldspar is not abundant. The amphibole is a deep green, highly pleochroic variety. Most of it is hornblende, but some of it has optical properties near those of actinolite. The garnet grains and crystals are cracked and hold abundant inclusions of quartz, feldspar, hornblende, and biotite. Small flakes of green and brown biotite are present in three thin sections. The outlines of many of the larger grains are crenated, and hornblende crystals cut across or into plagioclase and quartz grains and vice versa. Inclusions of one mineral within another are abundant, the hornblende containing round grains of quartz and feldspar, and many of the larger plagioclase and hornblende crystals hold clusters of small, round, quartz grains. The relative proportion and size of the mineral grains vary greatly in the same thin section, for areas of large crystals of feldspar may have as neighbours a mosaic of small quartz, mica, and hornblende grains. A thin section, of which over a third of the area was estimated to be quartz, carries abundant andesine and hornblende, a mineral association unusual for an igneous rock. The quartz and feldspar grains are slightly granulated, but the minerals are only slightly altered to chlorite, epidote, and kaolinite.

The relics of bedding shown in many outcrops of these hornblende-bearing garnet gneisses are the most convincing evidence that they are recrystallized sediments, and not intrusive quartz diorites and gabbros. Their bedded character is well shown just north of the west shaft of the Sherritt-Gordon, where layers of dark, hornblende gneiss alternate with lighter-coloured beds richer in quartz and feldspar. The weathered surfaces of some outcrops along the shore of Sherlett lake present a ribbed appearance, due to the hard quartz-feldspar beds resisting erosion, whereas intervening beds containing a larger percentage of hornblende and biotite have weathered to form long, narrow, parallel depressions. It is hard to conceive that, in so many outcrops over so wide an area, the different minerals of an igneous rock could become arranged in alternating layers, so as to give the bedded appearance now visible. Furthermore, the hornblende-bearing gneisses alternate with the quartz-mica gneisses of undoubted sedimentary origin without the sharp contacts they should show if they represented recrystallized lava flows or metamorphosed intrusive bodies. These conditions and the presence of abundant red garnet of the same variety as is found in the sedimentary gneisses indicate a sedimentary rather than an igneous origin for these gneisses. No lava flows or other rocks that might be considered to represent highly metamorphosed lavas were noted amongst the Kisseynew gneisses in the basin of Kississing lake. Small bodies of basic intrusives, however, are present, but, if the field outcrops of these are large, they can be differentiated from the hornblende gneisses by their compact, massive, or only slightly schistose appearance.

Granitized gneisses have been developed over wide areas by the invasion of the Kisseynew sediments by granitic materials. A common feature is the presence of small lenses of granite distributed along the bedding or foliation planes of the gneiss, with no apparent granitic layers connecting one lens with another. In a few outcrops, this type of injection was seen developed on such a scale as to give the gneiss the appearance of a conglomerate. Other outcrops show long, narrow, parallel bands of grey or black gneiss alternating with others of granite, giving the typical lit-par-lit gneiss. In other outcrops the granitic material, instead of having been injected along planes, has penetrated the sediment itself, and formed a hybrid rock or impregnation gneiss. In some places this process, combined with recrystallization, has gone so far that the bedding and other structural features of the sediment have almost been obliterated. This is especially true of some beds of the hornblende-bearing and quartzite gneisses. Such beds may be only a few hundred feet wide, and may have the normal gneisses in each side. If traced along their strike these more massive granitic beds usually pass into bedded types. In places adjacent to the granite bodies, the original sediment has been so thoroughly impregnated by the invading granitic materials that over fairly large areas a rock type has resulted which shows a banded structure, but equally resembles a sedimentary gneiss or an intrusive granite-gneiss. These are usually greyish to slightly pinkish, fine to medium-grained rocks. Traverses across the structure of these rocks show that in some places they pass rather abruptly into normal granite on one side, and gradually grade into normal sedimentary gneiss on the other side. In other places the granitized gneisses pass into normal gneisses on both sides, and this would seem to indicate the presence of granite bodies at no great depth below. In the field it was found impossible to classify individual outcrops of these complex gneisses without studying sections across their structure.

General Structural Features of the Kisseynew Gneisses. The reconnaissance geological survey of Kississing area did not allow determining precisely the structure of the Kisseynew sediments. The recrystallized, foliated character of the strata and the absence of definite, easily recognizable horizons within the series, such as conglomerate or iron formation beds, make structural determinations difficult. Also, it was not possible to establish any method of determining the top and bottom of the highly metamorphosed beds. General observations indicate, however, that in parts of the area away from the larger granite bodies, the sedimentary gneisses lie in a series of open, rather than close, folds. The strata adjacent to the large granite bodies are more complexly folded, especially along the east border of the area of Kisseynew gneisses, and apparently here one or more overturned folds have developed.

A prominent structural feature of the Kisseynew sediments is their gneissoid and locally schistose character. This is the result of the recrystallization or partial recrystallization of the sediments under pressure. All observations of outcrops showing both bedding and foliation indicate that these two structures are parallel. The strata everywhere show the gneissoid structure, but not to the same degree. The usual results are the recrystallization of the original materials of the sediments with the resultant formation of new minerals amongst which, biotite, hornblende, red garnet, and plagioclase feldspar are the more abundant. These minerals are developed in different proportions in alternating beds and many of the individual grains lie with their longer directions parallel, giving the sediments their characteristic foliated appearance. Some beds dipping only 10 degrees show this foliated structure as well developed as do beds dipping 40 or 60 degrees. No staurolite, cyanite, or other such minerals were noted in the gneisses.

Many observations were made of the strike and dip of foliation and bedding of the gneisses, and on the geological map accompanying this report the pattern of the areas underlain by the Kisseynew gneisses has been designed to show in a general way the dip and trend of the strata. In the central, southern, and western parts of the map-area, the dip of the beds is low, ranging from 10 to 50 degrees. Locally, dips of from 50 to 90 degrees were noted, but are unusual. In these parts of the area, low dips in opposite directions are commonly encountered in traversing the strata transverse to their strike. Along the east side of the area of Kisseynew gneisses, the trend of bedding and foliation is from north to northwest; along the south side, the trend, proceeding from east to west, swings from northeast to east to northwest; and along the west side the prevailing trend is north. Thus, lines showing the general trend of the gneisses form roughly a horseshoe-shaped figure. There are, however, local variations to the general trends outlined in the preceding sentences and shown on the accompanying map, due to numerous small folds. The major structure is interpreted as a synclinorium, the axis of which trends north to northwest across Kississing lake. A number of small folds are developed on both the east and west limbs of this major structure, but the axes of these minor folds were only approximately located at a few points.

In the area surrounding the Sherritt-Gordon deposit, some detailed field work was done to determine, if possible, the detailed structure of the sedimentary gneisses of this locality as an aid in interpreting the structure along which the ore-body is located. In this part of the area, the general trend of the foliation and bedding of the gneisses is northwest, and the prevailing dip is from 40 to 90 degrees to the northeast. A fairly prominent ridge of gneissic quartzite outcrops adjacent the Sherritt-Gordon ore-body and this was followed as an horizon marker. From the west shaft, just east of the bay of Camp lake, westward for slightly over half a mile, the trend of the bedding of the quartzite is from north 40 to north 20 degrees west, and the dip is from 45 to 55 degrees northeast. Northward from the north end of Camp lake for about 3 miles, the strike is approximately north, and the dip from 50 to 75 degrees eastward. The strike of the quartzite then commences to swing to the east, and, in the vicinity of Sing Sing lake, the dip changes from an easterly direction to a north or reverse direction. At the east end of Sing Sing lake, the strike of the bedding and foliation is nearly east and west, and the dip varies from 40 to 60 degrees to the north. It was impossible to trace definitely this quartzite horizon southeast of Sing Sing lake, because of the discontinuous nature of the outcrops. The general trend of the beds here is nearly southeast.

From the west shaft eastward, the trend of the bedding of the quartzite is fairly uniformly southeast to just east of the foot of Sherlett lake, where the strike gradually swings more to the east and the dip also changes from about 45 degrees northeast through vertical to 75 degrees south. East of the east shaft, the strike of the quartzite is approximately east and west and continues to swing to the northeast. Just south of Sherlett lake, the strike of the quartzite is approximately north and the dip is approximately 45 degrees east. Northwest of Sherlett lake to near Cree lake, the trend of the foliation is nearly northwest, and the dip northeast. Eastward from Cree lake the foliation and bedding appear to swing to the east, and around to the southeast again, thus paralleling the strike and dip of the beds that extend east and southeast from the east end of Sing Sing lake.

The field work already completed indicates that an unusual structure is developed in the gneisses surrounding the Sherritt-Gordon deposit, and observations made in other parts of the map-area did not disclose the presence of other similar structures. The outward dips around the ends of the major structure, as on Sing Sing lake, indicate an anticlinal nature, and possibly the structure may be an anticlinal fold with one limb overturned. Although enough detailed information is not yet available to warrant a definite statement of the nature of the Sherritt-Gordon structure, the suggestion is tentatively advanced that the ore-body is along a part of a large drag fold developed on the limb of an overturned anticline. The fact that the deposit is along an unusual structure suggests that the search for additional deposits in the sedimentary gneisses should be guided to some extent at least by a study of the structure of the strata.

BASIC INTRUSIVES, INCLUDING PERIDOTITE, GABBRO, AND DIORITE

A few bodies of basic rock, intrusive into the Kisseynew gneisses, were noted. With these will also be described some small outcrops of fairly basic rock whose origin and age relations are unknown. Along Kississing river, about a mile north of Kississing lake, a small, black dyke of dioritic composition cuts quartz-mica gneiss. The black dyke rock is cut by pegmatite. At the northwest side of Kipahigan lake, just south of the long, narrow outlet, a dyke-like body of gabbro shows a chilled intrusive contact against the gneiss. The gabbro is sheared and the sheared zone is cut by a small dyke of pegmatitic quartz. Near the north end of Cree lake there are a number of outcrops of a black, massive, coarse-grained rock consisting almost entirely of ferromagnesian minerals. The contact of this basic rock with the gneiss was not seen. A number of small bodies of basic rock occur along both the Sherritt-Gordon and the Smith-Pride mineralized zones, but the origin and age relations of these rocks are not apparent from their small exposures.

The basic rock from Cree lake is especially interesting in that the original minerals were olivine, augite, and probably hornblende and biotite. No trace of feldspar can be recognized in the specimens studied microscopically. The original minerals are in part altered to serpentine, chlorite, carbonate, and magnetite. The hornblende and biotite also may be secondary after augite or other minerals. The rock is undoubtedly of igneous origin and belongs to the peridotite family. In Flinflon area Alcock[1] recognized basic intrusives of somewhat similar type, and older than the granite. The larger outcrops of these basic rocks are readily recognized in the field by their coarse, granular, black appearance. A few of the outcrops weather reddish or brownish. Some outcrops of this medium-grained peridotite contain patches wherein garnets are present. These garnets are apparently identical with those in the adjacent sedimentary gneisses.

A few small bodies of black rock occurring along or adjacent the Sherritt-Gordon sulphide body are fairly massive in appearance, and some of these may be basic intrusives. In the gneissic quartzite foot-wall of the

[1]Geol. Surv., Canada, Sum. Rept. 1922, pt. C, pp. 16–17.

Sherritt-Gordon deposit, these rocks form dyke-like bodies, from 6 inches to 3 feet in width, and from 10 to several hundred feet in length. They are composed of large crystals of amphibole and small grains of quartz. These small bodies do not show chilled contacts against the gneiss, and everywhere they were examined, they parallel, approximately, the bedding and foliation of the gneiss. They have an unusual mineral composition for an igneous rock, and may represent recrystallized thin beds or lenses of clayey material.

A number of outcrops of the hanging-wall of the Sherritt-Gordon deposit are more massive and of coarser grain than the hornblende-bearing garnet gneiss. These rocks, without the banded structure of the sedimentary gneiss, outcrop at intervals from 400 to 1,600 feet west of the east shaft, and also along the hill south of the west shaft. In thin section under the microscope, they consist of a plagioclase, between andesine and labradorite in composition, hornblende, actinolite, augite, quartz, titanite, and titaniferous magnetite. The plagioclase and hornblende are in large crystals, and are the most abundant minerals. In texture these rocks closely resemble the hornblende-bearing garnet gneisses. They differ from them in that they contain a more basic plagioclase, some augite, less quartz, and do not show the banded structure. The contact of the bodies of the more massive looking rock with the sedimentary gneiss is nowhere exposed, but these rocks will soon be encountered underground from the Sherritt-Gordon east shaft, and then their origin and their age relations with the gneiss should be apparent.

At the Smith-Pride, some medium-grained, black rocks are exposed in prospect pits and trenches. The surface outcrops are grey, quartz-mica gneiss, dipping about 25 degrees to the east. The black rocks are covered by drift, except where they are exposed by trenching and there are much jointed and are decomposed along their contacts with the gneiss. A microscopic study of three thin sections shows the rocks to be composed of hornblende and actinolite, in part altered to chlorite. Carbonate, quartz, and magnetite are abundant. Some augite and tremolite are also present, but only a few large crystals of plagioclase, near andesine, occur in the thin sections. These black rocks appear to form narrow, sill-like bodies lying between beds of quartz-mica gneiss. Pyrrhotite, chalcopyrite, and sphalerite are present in the black rock, as veinlets in the silicates, and as grains and small patches distributed throughout the rock.

GRANITIC INTRUSIVES

Granitic intrusives are abundant in the map-area, and occur as long, narrow sills between beds of sedimentary gneiss, as large, batholith-like bodies, and as dykes of aplite and pegmatite. All the granite bodies noted intrude either the Amisk volcanics or the Kisseynew sedimentary gneisses. Small areas of gneiss traversed by narrow, parallel dykes of granite, and other masses of highly granitized sediments, lie in, and present sharp contacts with, granite. These granitized gneisses were clearly produced before they were included by the magma at the level exposed. No evidence was noted to indicate whether the granitization of the engulfed blocks was caused by the invasion of an older granite, large bodies of which were not recognized in the area, or by an earlier stage of the invasion of the granite magma in which the blocks of highly metamorphosed rock now lie. The granite is cut locally by dykes of pegmatite.

Sills and Other Small Bodies of Granite

Small intrusive bodies of granite are abundant in almost every part of the area underlain by the Kisseynew sedimentary gneisses. Though a few granite and pegmatite bodies were found cutting members of the Amisk group, these intrusives are not nearly so numerous in the areas of volcanic rocks as in areas underlain by the sedimentary gneisses. The sills of granite vary in size from stringers less than a foot wide to bodies 2,500 feet wide and 7 or 8 miles long. The long, narrow bodies follow the dip and strike of bedding and foliation of the gneisses. On the south shore of the north bay in the east side of Collins point, narrow sills of granite follow the gentle curve of the enclosing strata. No small dykes were noted extending from the granite sills into the adjoining gneiss. The intrusive rock adjacent the gneiss is slightly finer grained than in the centre of a body, but chilled, glassy contacts were not observed. The contacts of the narrow granite bodies are sharp and definite against the sedimentary gneiss. The rocks of the sills are even grained, no porphyritic phases were noted. The rock of only a few of the numerous granite sills was studied microscopically, the minerals of the thin sections examined being fresh but slightly granulated. Quartz, microcline, orthoclase, albite-oligoclase, biotite, and hornblende are the abundant minerals. No evidence of differentiation into a basic and acidic facies was noted in any of the granite sills. Time was not available to map the numerous granite sills, but the pattern of the map accompanying this report shows, by broken lines, where these intrusives are especially abundant in the area underlain by the Kisseynew gneisses.

A number of bodies of granite, somewhat larger than the sills, cut the Kisseynew gneisses in the southwest corner of the map-area and especially from the middle of Kisseynew lake westward to Mari lake. Fairly large granite bodies are also developed in the southwest corner of Kississing lake, on the west side of Kipahigan lake, and in the vicinity of Bartlett lake. A few of these granite bodies are shown on the geological map. Both massive and gneissoid granites were noted in most of these small bodies; the granites are somewhat variable in appearance, in the same body, and the rocks of closely adjoining bodies also differ markedly in appearance. A body of massive, pink granite may have as a neighbour a mass of dark, micaceous, gneissic granite. The pink granites carry abundant microcline and little biotite, whereas the grey granites contain considerable hornblende biotite, micropegmatite, and little or no microcline. Some of the dark grey granite carries red garnet, and in these outcrops small, schlieren-like areas of grey to black mica-garnet gneiss are recognizable. It is possible that the red garnets and the marked variation in colour and mineral content, shown by some of these granite masses, are due to the incorporation of some of the sedimentary gneiss by the magma. No evidence of sulphide mineralization was noted in the country rock adjacent any of the medium-sized granite bodies, although small quartz veins are developed north of the west end of Kisseynew lake in the vicinity of Florence and Mari lakes.

The outline of the granite body on the point west of Kississing post office was mapped in some detail. This mass follows the strike of the sedimentary gneiss, and from south to north becomes narrower and curves around to the east, paralleling the sedimentary strata. The rocks along the contact zone of this granite body are no more deformed than elsewhere, and the granite itself does not show signs of severe deformation, as it should if the mass were folded into its present curved outline after consolidation. This granite mass appears to be laccolith-like in shape, and was probably intruded either during or following the folding of the gneissic strata.

Batholith-like Bodies of Granite

Parts of two large batholith-like masses of granite are present in the map-area. One of these lies north of Kississing lake and was examined at various points from Derby lake northwest to Crow lake. The other large granite body outcrops in the southeast corner of the map-area, and represents the northward continuation of the Kaminis granite of Athapapuskow Lake region. The granite of the larger masses locally shows gneissic structure, or in places is porphyritic, or is coarse-grained and pegmatitic, or fine, evenly granular, almost aplitic in texture. The composition of the larger granite bodies has not been studied in detail, but varieties ranging from acid granite to granodiorite and syenite were observed. The granite of the body north of Kississing lake is, typically, grey and of medium grain. In thin sections under the microscope the minerals are seen to be granulated, indicating that the rock has undergone some deformation since or during the time of consolidation. So far as observed, the minerals of the Kaminis granite to the south are not so badly granulated as are those of this granite. Some specimens of the granite north of Kississing lake carry considerable hornblende, others have an abundance of muscovite. Microperthite and micropegmatite are present with the muscovite. Along the south border of this mass, inclusions of sedimentary gneisses are locally abundant, and red garnets are an abundant accessory mineral of the granite adjacent to these inclusions. The microscopic study of a thin section of a specimen of fresh, pink granite from the west shore of Derby lake shows the minerals practically all altered to green, chloritic, and brownish grey, kaolinitic, materials. This is unusual, for the minerals of the other thin sections were fresh or only very slightly altered to the secondary minerals chlorite, epidote, and kaolinite.

Dykes of Aplite and Pegmatite

Dykes of pink aplite are fairly abundant in the Kisseynew gneisses from the north end of Bartlett lake southwest to Kisseynew lake and in the area several miles east of these lakes. The aplite is pink and is massive, except in one dyke east of Weldon bay, where several outcrops of an aplite dyke are a white mica schist. Two aplite dykes were each traced for several miles along their strike. Most of the dykes, however, are discontinuous, the dyke pinching out and a thousand feet or more along the strike another dyke being developed. East of Bartlett lake, some bodies of pink granite of pegmatitic texture have aplitic border phases. At no place was aplite seen in contact with pegmatite. No aplite dykes were seen in the north nor towards the west side of the map-area; these dykes are confined to an area northwest of the large, batholith-like body of Kaminis granite.

Pegmatite dykes are equally as numerous in the Kisseynew gneisses as are the granite sills. The bodies of pegmatite, however, are on the average much smaller, and are more irregular in shape than the granitic sills. The pegmatite cuts the gneiss with sharp, definite contacts and effected no noticeable contact action on the older rocks. Many dykes parallel the dip and strike of the bedding and foliation of the enclosing gneiss, but a few cut across both the dip and strike of the gneisses. A few pegmatite stringers, from 1 inch to 4 inches in width, follow, in every detail, the small drag folds in the sedimentary gneisses. The rock of these irregular-shaped dykes is unfractured, so far as could be determined from an examination of their outcrops. A few dykes are present along mineralized zones of sheared and highly jointed gneiss. Some of these dykes are massive, and others have been fractured and schisted along their contacts with the schistose gneiss.

The pegmatites range in colour from white through pink to dark grey. The most abundant variety is a light pinkish, microcline-quartz rock of irregular grain size. The white pegmatites contain abundant albite. Biotite and muscovite, in flakes up to an inch in diameter, are present in a few of the pink and white dykes. In a few dykes a greenish microcline is an abundant mineral. A dyke along the Sherritt-Gordon ore zone, about 2,200 feet west of the east shaft, contains a dark plagioclase, near labradorite in composition. Other dykes along this ore zone contain, in addition to quartz and microcline, an abundance of a greenish plagioclase, between oligoclase and andesine in composition. A few narrow dykes of black, mica pegmatite were also noted near the southeast end of the Sherritt-Gordon ore zone. No evidence was noted to suggest that these various types of pegmatite differ in age from the normal microcline pegmatites, and it is concluded that all the different pegmatites are facies of the same magma. From an economic viewpoint, it is interesting that sphalerite is proportionately more abundant where the oligoclase-andesine pegmatites are developed along a mineralized zone.

The pegmatites have not been examined carefully for accessory or rare earth minerals. It may be that with future detailed work a variety of such minerals will be found, including rare-earth minerals, gemstones, lithia-bearing, and other suites of minerals associated with pegmatites in other districts. Red garnet, magnetite, pyrite, pyrrhotite, and chalcopyrite were noted as accessory minerals in a number of dykes.

ECONOMIC GEOLOGY

The known mineral occurrences of economic importance in Kississing Lake area are deposits of copper and zinc sulphides associated with iron sulphides. The sulphide bodies carry low values in gold and silver, but so far as known they are not commercially valuable for their content of precious metals alone. The sulphide bodies occur along zones of sheared and brecciated rock within the sedimentary gneisses. In the granitic intrusives only very narrow zones of sheared rock were noted, and small quartz veins are present along a few of these.

Previous to the discovery of the Sherritt-Gordon deposit, most of the prospecting activities in northern Manitoba had been confined to the areas of volcanic and intercalated sedimentary strata (greenstones) and, in the Athapapuskow Lake area, the Flin Flon, Mandy, Baker-Patton, and other sulphide bodies are in this series. These sulphide bodies are very similar in general character and origin to those in the sedimentary gneisses of Kississing area. However, one difference between the sulphide bodies of these two adjoining areas is that pyrite is the abundant iron sulphide present in the deposits of Athapapuskow Lake area, whereas pyrrhotite is the characteristic sulphide of the deposits in Kississing Lake area. Gold-bearing quartz veins have also been discovered in the volcanic rocks, but up to the present no gold-bearing veins of promise have been located in the sedimentary gneisses of Kississing Lake area. The discovery of sulphide bodies carrying commercial quantities of copper and zinc in highly metamorphosed sedimentary gneisses has greatly enlarged the area of favourable prospecting ground in northern Manitoba and Saskatchewan.

GENERAL FEATURES OF COPPER-ZINC DEPOSITS

Distribution. In Kississing Lake area, the Sherritt-Gordon is the most important known deposit and the majority of the other known copper-zinc occurrences of the map-area lie in a rectangular area about 10 miles wide and extending northwest for about 25 miles from just southeast of the Sherritt-Gordon. The concentration of the mineral discoveries in this area may only mean that more detailed prospecting has been done in the small area surrounding the Sherritt-Gordon than elsewhere. During 1928, prospects with showings of copper-zinc sulphides were discovered to the east of this area, in the vicinity of Elken and Walton lakes, but little surface work had been completed here, and this section, though largely staked, has been only hurriedly prospected. In the northwest corner of the map-area, some prospecting was done near Kipahigan lake, and here copper-zinc sulphides also occur sparingly. In the late autumn of 1928, showings of iron and copper sulphides were located in the vicinity of Fay and Vamp lakes, along the south side of the map-area.

Character of the Deposits. The sulphide bodies lie in the Kisseynew sedimentary gneisses, consisting of gneissic quartzite, quartz-mica-garnet gneiss, and hornblende-garnet gneiss. The deposits are along zones of highly jointed and sheared rock, generally located along the contact between two different kinds of gneiss. The Sherritt-Gordon ore-body, for example, is for the most part within gneissic quartzite, adjacent a bed of black hornblende-garnet gneiss. Sills of granite occur a short distance away from many of the sulphide-bearing zones, but granite was not noted along the mineralized zones. Pegmatite dykes do occur along the sulphide-bearing zones. A few of these dykes carry small grains of pyrite, pyrrhotite, and chalcopyrite. At the Sherritt-Gordon, fractured pegmatite carries veinlets and irregular stringers of pyrrhotite and chalcopyrite

The zones of sheared rock follow closely the dip and strike of the beds of sedimentary gneiss. At the east end of the Sherritt-Gordon deposit, the zone of schistose gneiss and its contained sulphide lenses follow the same horizon, even though its dip steepens from 45 degrees through vertical to a steep reverse direction, and the strike changes 25 degrees within a distance of 1,000 feet. This would seem to indicate that this zone of sheared and brecciated rock originated either before or during the complex folding of the gneisses. In width these zones vary considerably along their strike, as also does the degree of deformation, for trenches along a number of the sulphide-bearing zones indicate that highly schistose rock passes within a few hundred feet along the strike into a zone of alternating bands of massive and schistose rock. The metal-bearing materials entered these zones of crushed and sheared rock, and the sulphides were deposited along joint-planes and in the schistose rock. The sulphide bodies thus consist of sheared and brecciated rock, carrying varying proportions of sulphides in veinlets, small lenses of massive sulphide, and small grains and patches distributed irregularly throughout the rock. In crosscuts, the Sherritt-Gordon sulphide today shows clearly a banded structure, due to beds of gneissic quartzite carrying sulphides along joint-planes, alternating either with beds of highly schistose rock carrying abundant sulphides evenly distributed, or layers of massive sulphide with little included rock or silicate minerals. The outer limits of sulphide mineralization are not sharp and definite, and the outline of the ore-bodies will be determined by the presence of commercial quantities of copper and zinc sulphides, rather than by some definite hanging and foot-wall rock.

The abundant sulphides of the deposit are pyrrhotite, sphalerite, and chalcopyrite. Pyrite and magnetite are present only sparingly. The pyrite occurs as isolated cubes up to $\frac{1}{4}$ inch across, and as narrow stringers and lenses within the pyrrhotite. Some of the pyrite cubes have been fractured and penetrated by pyrrhotite. Small spheres, composed of crystals of pyrite with curved faces, are present in some of the massive pyrrhotite. A white iron sulphide occurs as a coating along joint-planes crossing lenses of massive sulphide and country rock.

Of the abundant sulphides the pyrrhotite was deposited first and was followed by sphalerite and chalcopyrite. These three sulphides evidently belong to the same phase of mineralization. The pyrrhotite is massive with coarse, granular structure, and is a dark bronze variety. It is cut by a few veinlets of sphalerite and chalcopyrite, and also occurs as inclusions in these minerals. If exposed to moist air the pyrrhotite oxidizes rapidly, and, for this reason, it may be found advantageous to mill the ore as fast as it is broken. The sphalerite is black, in polished surfaces under reflected light it is exceptionally dark, and probably is the iron-bearing variety of zinc sulphide known as marmatite. The chalcopyrite is coarse granular and some of it is slightly magnetic, and, therefore, is chalmersite. In polished surfaces, the chalmersite is lighter in colour than the chalcopyrite, and the two minerals appear to be intimately intergrown. Needle-like veinlets of chalcopyrite cross grains of sphalerite, and chalcopyrite surrounds a few small grains of sphalerite. Many sulphide bodies contain only pyrrhotite, and others carry only a very small quantity of chalcopyrite or sphalerite with the pyrrhotite. The proportion of both the chalcopyrite and sphalerite present with the pyrrhotite varies greatly in the same deposit.

The more abundant silicate minerals of the sulphide bodies are quartz, biotite, hornblende, actinolite, feldspar, garnet, chlorite, and sericite. These are, with the exception of chlorite and sericite, the characteristic minerals of the sedimentary gneisses, but, in the sulphide-bearing zones, these minerals are much more fractured and granulated than they are in the gneiss outside the mineralized zone. Three of the thin sections of sulphide-bearing rock from the Sherritt-Gordon deposit contain a few crystals of augite and tremolite. These latter minerals were not noted in thin sections of gneiss from outside the sulphide bodies. Their distribution and quantity in the sulphide body are not known. It may be that the augite and tremolite were formed at any early stage of the period of mineralization.

All thin sections of the mineralized rock contain small quantities of epidote, zoisite, and carbonate. The silicate minerals, however, were only slightly altered to secondary minerals during the deposition of the sulphides. Green hornblende and biotite are altered to chlorite and colourless mica, respectively, for only a fraction of an inch from veinlets of sulphides. Small crystals of unaltered hornblende and biotite are surrounded by sulphides. There apparently was no widespread chloritization or silicification of the gneiss before or during the mineralization. The sulphides penetrate the fresh or slightly altered feldspar and other silicates as veinlets along cracks and cleavage planes, and inclusions of silicates, including garnet, are present in the sulphides. Small shreds and flakes of chlorite, sericite, epidote, and carbonate are also included in sulphides. Elliptical grains of quartz, surrounded by pyrrhotite, and penetrated by veinlets of this sulphide, are characteristic of some of the Sherritt-Gordon ore. Light-coloured, vein-like quartz is also present in the lenses of massive sulphides, as small, irregularly outlined patches. Pyrrhotite is cut by narrow, vein-like masses of quartz on the 125-foot level of the Sherritt-Gordon east orebody. At the Sherritt-Gordon, beds of gneiss and sulphide lenses have been jointed and displaced several inches after the mineralization. The sulphides have been for the most part leached from the upper part of the deposits by circulating waters, and a porous limonite-stained capping overlies many of the sulphide bodies.

Origin of the Deposits. The method of origin and the source of the iron, copper, and zinc sulphides are interesting problems on which direct evidence is meagre. The marked similarity in the general features of the deposits examined, together with the wide distribution of the mineralization, would seem to indicate an origin from some deep-seated source. As the sulphide bodies have been only very slightly deformed, it is evident that the mineralization followed the recrystallization, granitization, and folding of the gneisses in which the deposits are contained.

The banded structure of the sulphide bodies, their indefinite contacts with the country rock, the character of the sulphite bodies, consisting, as they do, of gneiss and schist impregnated by sulphides, the inclusions of small, irregularly outlined remnants of country rock and of quartz grains in the massive sulphides, indicate that the sulphide bodies were formed by replacement. That this replacement was of zones, wherein the rocks were sheared and brecciated before the ore materials entered, is indicated by the inclusions of highly schistose gneiss in the massive sulphides and also by the distribution of the lenses and irregular-shaped bodies of massive sulphides along beds of highly sheared rock between layers of more massive gneiss. Massive pegmatite is present along some zones of highly sheared gneiss. Along the Sherrit-Gordon deposit, however, some of the pegmatite is jointed and the border of one dyke has been sheared, and sulphides are present in this sheared pegmatite. The jointed, massive pegmatite is cut by veinlets of sulphide along the joint-planes. The comparatively small amount of shearing of the pegmatite as compared with that of the enclosing gneiss would seem to indicate that the main deformation that formed the zones of sheared and brecciated rock took place before the pegmatites were intruded. Since these zones of sheared and brecciated rock follow so closely the dip and strike of the strata, even around the ends of folds, it would appear that the zones the sulphides replaced originated during the folding of the strata, rather than by regional deformation after the beds were folded to their present position.

The veinlets of sulphides cutting both jointed and schistose pegmatite indicate that the mineralization is later than the pegmatites. However, the presence of sulphides, including pyrrhotite, chalcopyrite, and pyrite as accessory minerals in some of the pegmatite dykes, is suggestive of a common source for the pegmatites and the ore materials. Pegmatites are considered to represent portions of a granite magma that escaped into the roof rocks during or after the crystallization of the main granite mass. Furthermore, the presence of considerable quartz, of vein or pegmatitic character, in small masses and grains between the sulphides, or as veinlets cutting the sulphides, indicates a siliceous character of the end phase of the ore materials, and strongly suggests a granitic magma as their source. The absence near the deposits, so far as is known, of unmetamorphosed intrusives, of comparable age with the deposits, other than granite and pegmatite, the presence of accessory sulphides in some pegmatites, and of residual vein quartz in and cutting the sulphide ore are the evidences that the materials forming the sulphides originated from a granitic magma, probably at a late stage of its crystallization.

Oxidation of Sulphide Bodies. The upper part of many of the sulphide bodies is oxidized, there remaining a capping of porous rock stained by limonite. These cappings vary in colour from lemon-yellow through orange and brownish tints to brick red. The colour of many cappings is yellowish, with patches of orange and red. Little information is yet available as to the maximum depth of the oxidation. That the depth varies considerably in different deposits and from point to point along the same sulphide body, is indicated by the existence of fresh or only slightly oxidized sulphides in some trenches, whereas in nearby trenches or pits no traces of fresh sulphides are present within 20 feet of the surface. In crosscuts on the 125-foot level of the Sherritt-Gordon east sulphide body, the pyrrhotite is oxidized along joint-planes. Along the crosscut on the 125-foot level north from the east shaft, an elliptical outlined cavity, about 2 feet wide, was encountered in the sulphide body. This opening extends upward at least 6 feet, and probably continues to the surface. It is interpreted as a water channel, formed by the solution of the sulphides. So far as is known, the oxidation does not extend below the 250-foot level, and the depth will probably be found to vary from 10 feet to 250 feet.

In trenches exposing the capping of the Sherritt-Gordon and some other deposits, the oxidized materials are overlain with sharp contacts by glacial drift without limonite stains. In some trenches the drift above the capping is limonite stained. In two places where deep pits have been sunk into the capping of the Sherritt-Gordon west deposit, the oxidation extends at least 10 and 16 feet, respectively, below the glacial drift. The drift consists of boulder clay and irregularly stratified sand and gravel, and at the two points studied in detail is 6 and 9 feet thick, respectively. This relation of the drift to the capping clearly indicates that some pre-Glacial oxidized materials remain. The sulphide bodies naturally would weather deeper than the enclosing gneiss, because of the fractured condition of the contained gneiss and the ease with which sulphides weather, as compared with the silicate minerals of the adjacent gneiss. The advancing ice-sheets carried away practically all the weathered rock, but apparently glacial scour was not, in a few places, at least, intense enough to remove the adjoining fresh gneiss down to the bottom limit of the oxidation of sulphide bodies.

During oxidation, soluble copper and zinc sulphates were formed from chalcopyrite and sphalerite, by the oxygenated groundwater. These soluble sulphates naturally were carried downward towards the level of permanent groundwater, where reducing conditions generally exist. The sulphide bodies carried only small quantities of carbonates, hence only traces of the green and blue copper carbonates, malachite and azurite, were deposited in the cappings. No evidence was noted of deposits of jaspery or kaolinitic materials. A few specks of native copper have been found, but, so far as observed, no rich secondary copper ore was formed near the bottom of the oxidized zones, and it must be concluded that the copper and zinc-bearing solutions never reached to where reducing conditions operate, but rather migrated laterally along joints and other openings in the wall-rock, finally reaching the surface again; thus the copper and zinc, instead of being concentrated by precipitation within the mineralized zone, were widely scattered.

Many sulphide bodies of the district are barren or practically barren of chalcopyrite and sphalerite. It is thus an important economic problem to distinguish by the character of the capping and without too much deep trenching, the deposits that at depth are likely to carry chalcopyrite in addition to pyrrhotite and pyrite. The presence of sphalerite is not so important, for without considerable chalcopyrite, a deposit is not at present of commercial value, unless the sphalerite is very abundant and the body is very large. The Sherritt-Gordon capping is probably typical of the oxidized zones of the district, and its exposures were studied in some detail. In this capping the schistose rock from which the sulphides were leached contains many small, irregularly outlined cavities, and a few cavities over a quarter of an inch across. In places, and especially near the west end of the deposit, where the dip is nearly 45 degrees, the hanging-wall has slumped so that the oxidized zone, where exposed, is considerably narrower than the sulphide body below. In such exposures no large cavities are present. Many of the cavities contain no limonite; others carry limonite in fine grains coating the walls, especially in the corners or in small embayments along the wall. The schistose rock surrounding the cavities is stained with limonite, but apparently was not altered during the leaching. The limonite is typically of yellowish colour, though orange and brick red limonites are present. Where chalcopyrite is present, there are, in addition to these usual limonites, small streaks and irregularly outlined patches of a maroon limonite with a slight purplish sheen, and, in a trench just west of the east shaft, a dark brown limonite occurs. A maroon limonite is also present in a few cavities of the capping exposed in this trench. The results of underground work and diamond drilling indicate a good-grade copper ore beneath this capping. The limonite found where only pyrrhotite and pyrite are present, is of yellow, orange, and deep red colours. Though time did not permit a detailed and extensive enough study of the cappings to warrant general conclusions, nevertheless the results of the few observations made seem to indicate quite definitely that the presence of small quantities of limonite of maroon to purplish tints is a reliable indicator of some copper below. It cannot be definitely stated, however, that a sulphide body does not carry chalcopyrite, even though limonite of these unusual colours is absent from the capping. The presence of a maroon limonite in the capping should greatly encourage some exploration of the sulphide body below.

Sherritt-Gordon Deposits (1) and (2)[1]

History and Development. Information regarding the discovery of the Sherritt-Gordon deposit is meagre. For a number of years previous to 1922, a white trapper lived in a cabin at the rapids between Camp and Sherlett lakes, and it is believed that he had located one or two leached outcrops of the deposit.[2] This trapper did little or no work on the deposit, and did not record any mining claims. A skeleton found during surface exploration along the deposit is presumed to be the remains of this trapper.

[1]Figures refer to mineral localities indicated on the geological map accompanying this report.

[2]Historical data kindly supplied the writer by Mr. E. L. Brown, Superintendent of the Sherritt-Gordon mine, and by Mr. C. F. Spence, from the records of the Dominion Lands Administration, Department of the Interior, Ottawa.

An Indian by the name of Phillip Sherlett is reported to have staked the first mining claims on the deposit, although the title to these claims was not held in his name. For several years, Sherlett continued each year to do a little assessment work, but finally his claims lapsed, due to the failure of his partner to record the assessment work, although it had been done. In the meantime, white trappers and prospectors had staked claims adjoining Sherlett's ground, but all these claims were dropped, except the few held by Carl Sherritt and Dave Burke. Sherritt and his partner Madole restaked Sherlett's ground, and in September, 1924, had a group of some sixteen mining claims. In 1924 and 1925, Sherritt and associates held the group for option at a price of $250,000. Representatives of a number of mining companies examined the deposit, but the option was not taken. Little surface work had been done, and, due to the leached character of the upper part of the deposit, little could be learned of the value of the ore from a surface examination. Also, the deposit was approximately 70 miles in an airline from the railway, and in highly metamorphosed gneisses, not known elsewhere in the Canadian Shield to carry commercial ore-bodies of copper and zinc sulphides.

In October, 1925, the group of mining claims was optioned from Carl Sherritt by Mr. J. P. Gordon, and this option was assigned from Mr. Gordon to Mr. E. P. Earle. Work was commenced at once by Messrs. Earle and Fasken, with Mr. W. Lee Heidenreich in charge. Camps were built, and some 5,000 feet of diamond drilling, in twenty-eight holes, was completed. It was reported that this work indicated some 450,000 tons of ore, averaging 2·86 per cent copper, 3·3 per cent zinc, and less than $1 in combined gold and silver. Messrs. Earle and Fasken, after spending some $68,000 in development work, tried to get a new option, with better terms, but failed, and, in September, 1926, dropped their option. In the meantime representatives of Messrs. Earle and Fasken had staked eleven mineral claims, two fractions, and purchased one claim, and, on dropping the option, they endeavoured to retain five of these acquired claims. This was contrary to the terms of the agreement, and the courts returned these claims to the group, which now included some forty mining claims.

Early in October, 1926, the Victoria Syndicate, Limited, became interested in the group, and their representative, Mr. E. L. Brown, took charge of the property. This company dropped their option in December, 1926. In February, 1927, Mr. J. L. Agnew and associates optioned the property, but they relinquished their option in the early summer of 1927, without having done any work. In the summer of 1927, Mr. E. L. Brown interested Mr. Robert Jowsey in the possibilities of the deposit, and he in turn interested Toronto mining men, and Sherritt-Gordon Mines, Limited, was organized. On July 26, 1927, all interest in the group of mining claims was assigned by Carl Sherritt to Mr. J. P. Gordon, who, on the same date, assigned the property to the recently organized company. Sherritt-Gordon Mines, Limited, is capitalized at 6,000,000 shares of $1 par value. The head office of the company is in Toronto.

In the autumn of 1927, Sherritt-Gordon Mines, Limited, commenced development work, and within ten months some sixty diamond drill holes were put down to intersect the ore zone at from 125 to 400 feet below the surface, with several holes to depths of 500, 700, and 1,000 feet. These holes were spaced at intervals of about 250 feet along a distance of 4,400 feet from the east end and 6,200 feet from the north end of the deposit. At a few places three or four holes were drilled from the same point. This work indicated two deposits, referred to as the east and west deposits respectively. The interval of about 3,000 feet along the strike between the two deposits has not been explored.

During the winter of 1928, two surface mining plants, capable of developing the deposit to the 1,000-foot level, were brought in, and early in the spring, work was commenced on two shafts, approximately 7,000 feet apart. Early in the summer, the east shaft had reached the 250-foot level, and lateral work was commenced on the 125 and 250-foot levels. In the early autumn, lateral work was commenced on the 375-foot level from the west shaft. A third main shaft, inclined, was commenced, in the winter of 1929, near the north end of the west deposit, and approximately 3,000 feet northwest of the central shaft. Steam engines are used for hoisting, and Diesel driven horizontal compressors for compressed air. The cost of fuel for the latter engines is estimated at less than $150 per horsepower year, against approximately $300 per horsepower year for a steam plant fired by wood. A pilot mill will be in operation during the summer of 1929, to determine the flow sheets for a concentrator, a 1,500-ton unit of which will be built in the near future.

Geology. The bedrock exposed adjacent the ore-body consists of Kisseynew sedimentary gneisses, small outcrops of black, fairly basic rock whose origin is unknown, and granite and pegmatite cutting the sedimentary gneisses. The distribution of the larger outcrops of these rocks is shown on the plan (Figure 3) accompanying this report. The writer is indebted to the engineering staff of the Sherritt-Gordon mine for most of the topographic base of this plan.

The foot-wall is gneissic quartzite except at the east where this rock forms the hanging-wall. A few hundred feet away from the deposit, quartz-mica gneiss is interbedded with the gneissic quartzite. The hanging-wall, except at the east end, is hornblende-bearing garnet gneiss. A few outcrops adjacent to the sulphide body do not show the bedded structure so characteristic of much of the gneiss, and may represent intrusive bodies, near quartz-gabbro in composition. Two sills of granite, varying from 25 to 400 feet in width, occur in the hanging-wall gneiss, one just north of the east end of the east sulphide body, and the other east and north of the north end of the west sulphide body. A fairly large granite body outcrops just east of Lost lake, approximately 3,600 feet north of the middle of the east deposit, and another on the point in Kississing lake, 2,300 feet west of the north end of the west deposit. A tongue-like body of granite, widening southward, lies just west of Molly lake and is within 7,000 feet of the east shaft. The granite of all these bodies is of medium grain, and grey to slightly pinkish.

Small dykes of pegmatite are abundant both along the fractured and sheared zone containing the sulphides and in the hanging-wall. East of the east shaft, pegmatite is abundant in the gneissic quartzite. Many of these dykes parallel the dip and strike of the enclosing gneisses, but a few cross the beds. A pegmatite dyke, exposed about 1,200 feet west of the east shaft, cuts the hanging-wall gneiss nearly at right angles to the strike of the foliation, but at its intersection with the brecciated and sheared zone curves east and follows this zone. Many of the pegmatite dykes are the normal, white to pink, microcline-bearing pegmatite so abundant in the map-area. A few dykes exposed in the underground works are unusual types in the area, and carry considerable plagioclase, ranging from oligoclase to labradorite in composition, and other minerals not common in the normal pegmatites. Where these unusual pegmatites occur, as just east of the east shaft, sphalerite is the abundant sulphide. So far as observed, the bodies of these unusual pegmatites are narrow, varying in width from 6 inches to 10 feet, and they are also discontinuous along the strike. The diamond drill intersections show that many small bodies of pegmatite and granite are present in the hanging-wall throughout the area drilled.

The general structure of the sedimentary gneisses in the vicinity of the Sherritt-Gordon deposit has been outlined in the section of this report dealing with the general structure of the Kisseynew gneisses. It was there suggested that possibly the deposit is along a part of a large drag fold, developed in the southwest limb of an overturned anticline.

Description of the Deposit. The capping of the Sherritt-Gordon sulphide body has been exposed by trenching at five localities along the strike, where the drift cover was comparatively thin. Sulphides were exposed in only a few of the thirty-eight trenches and pits dug, as the walls of most surface workings had slumped. A study of the rocks as exposed in these trenches, however, indicates that the sulphide body is for the most part in the gneissic quartzite; in only a few trenches does the hornblende-bearing garnet gneiss show evidence of having been heavily mineralized.

The capping of the west ore-body has been traced by trenching for some 2,700 feet along the total distance of 6,200 feet of the mineralized sheared and fractured zone traced by diamond drilling. The strike, proceeding eastward from the north end, gradually swings from south 20 degrees east to south 40 degrees east. The dip is approximately 45 degrees eastward. Diamond drill intersections, 700 feet below the surface south of Wood lake, indicate that here the dip has flattened some in depth. The sulphide body on the 375-foot level, just west of the west shaft, is reported to show widths of from 22 to 30 feet, averaging 2·3 per cent copper and 3 per cent zinc. The assays of diamond drill cores indicate a higher copper content at the north end of this deposit and an inclined shaft is now being sunk to develop this body of copper ore.

The capping of the east ore-body is exposed for 2,600 feet of the 4,400 feet along which the mineralization has been indicated by diamond drilling. The strike of this deposit, proceeding from west to east, gradually changes from south 55 degrees east to east and west. The dip changes from 45 degrees northeast through vertical to nearly 70 degrees south. By the early winter of 1929, some 1,600 feet of drifting had been completed from the east shaft on the 125-foot level and crosscuts along this distance are reported to indicate widths of ore from 14 to 50 feet, averaging 3·25 per cent copper, 7 per cent zinc, and approximately $1 in combined gold and silver. Near its east end, this sulphide body is not so easily followed underground, due to the changing dip of the enclosing gneisses, as is the west ore-body where the dip and strike of the enclosing gneisses are more uniform.

The sulphide body, as exposed in the crosscuts, consists of jointed gneissic quartzite, quartz sericite schist, and some fairly basic rock carrying sulphides in veinlets, as specks distributed throughout some beds of rock, and as lenses of massive sulphides containing only small fragments and grains of hornblende, tremolite, quartz, and gneiss. The abundant sulphides are pyrrhotite, sphalerite, chalcopyrite, and chalmersite. Pyrite is also present. The sulphides are typically in large grains, with straight or only slightly curving boundaries, and are not intimately intergrown. The proportion of the various sulphides present varies considerably from point to point and, in some places, within short distances. Some pyrrhotite carries only small quantities of sphalerite and chalcopyrite. In parts of the sulphide body, chalcopyrite is more abundant than sphalerite and vice versa. The gold is apparently associated with the chalcopyrite, as assays of pyrrhotite and other sulphides show no gold or only a trace. The pyrrhotite is not known to carry nickel or platinum. Galena has not been noted in the sulphide body, though a few cubes and specks are present in the hanging-wall just south of the west shaft. No complete analysis is available of the average ore, nor of the individual sulphides.

Exploration of the sulphide bodies underground had just got under way in the late summer of 1928. This work and the diamond drilling are being advanced as far as possible under the present transportation conditions. The diamond drilling had not been intensive enough to warrant definite estimates of tonnages and grade of ore present in a deposit of this type. The assays of many diamond drill cores indicate ore, averaging slightly over 3 per cent copper across widths varying from 5 to 70 feet or more. It has been reported from the data available, that the average ore will probably hold nearly 3 per cent copper, 5 to 7 per cent zinc, and $1 per ton in combined gold and silver. The copper content will probably be slightly higher than the average of the Flin Flon ore-body, but the gold and silver are considerably lower. The deposit apparently is along a large structure, and the future possibilities seem promising.

OTHER MINERAL PROSPECTS OF THE MAP-AREA

Small prospect pits and shallow trenches have been dug at many points in the area, but many of these expose only limonite-stained, jointed, and schistose gneiss. A number of these workings were located during the mapping of the rocks, but undoubtedly many others are present, which were not thus encountered, for time did not permit a careful search of the hundreds of mining claims staked. In many parts of the area, the mining claims have been staked and recorded in such a manner that it is very hard to locate many of the groups. In the following paragraphs, the available information is given regarding the mineral prospects visited.

The approximate location of the main prospect pits on each of these groups is shown by figures on the accompanying geological map, and these figures are repeated below after the group name.

Smith-Pride Group (3)

This group comprises some twenty-five full and six fractional mineral claims, staked in July, 1927, by Messrs. Smith, Pride, and others. In the winter of 1928 these mineral claims were optioned by Mr. J. A. Callinan. A syndicate was organized to explore the ground, and Mr. G. M. Thorpe was in charge of the work. Camps were built, and by early summer some twenty-five shallow trenches and test pits had been dug at points where rusty cappings were present. Some 4,000 feet of diamond drilling was completed. A large prospect shaft was sunk to the 100-foot level.

The bedrock exposed consists of interbedded quartzite and quartz-mica-garnet gneiss, cut by dykes of pegmatite. The strike of the bedding and foliation of the gneiss varies from north 40 to 50 degrees west, and the dip from 20 to 24 degrees northeast. Across a depression west of the workings, the sedimentary gneisses are highly granitized. Narrow bodies of black, medium to coarse-grained rocks are exposed in a number of the prospect workings. These rocks appear to lie between the beds of quartz-mica gneiss; and their origin is unknown. The gneiss and the black rock have been fractured and sheared, and the zones so formed carry sphalerite, a little chalcopyrite, and, in one trench, some galena. No large commercial body of sulphide-bearing rock was indicated by the surface workings completed. The mineralization, however, is widespread and the ground has not yet been systematically explored.

Willsie Group (4)

This group includes some forty mineral claims extending from the southwest corner of Cree lake northward to and beyond Sing Sing lake. These claims were staked at intervals between 1925 and 1927, by the three Willsie brothers and associates. Considerable surface trenching was completed in 1927 along several cappings, and in the winter of 1928 the group was optioned by the Atlas Exploration Company. This company investigated the surface showings and in the summer of 1928 drilled a few shallow holes.

The bedrock exposed is gneissic quartzite, quartz-mica-garnet gneiss, and a few thin beds of hornblende-bearing garnet gneiss. These gneisses are cut by a few small sills of granite and dykes of pegmatite. At the south end of the property the gneiss strikes north and dips 55 degrees east. Proceeding northward, the dip steepens and the strike swings eastward, and, at the east end of Sing Sing lake, the dip is north and the strike from northeast to east. In the vicinity of the main prospect pits the rock is gneissic quartzite cut by pegmatite. A prospect shaft, sunk 23 feet, exposes a dyke-like mass of pegmatite, about 12 feet wide. This pegmatite carries large crystals of red garnet, probably of the same variety that occurs in small crystals in the gneisses. Near the middle of this pegmatitic body, there is an irregularly outlined mass of quartz. This quartz and the garnet pegmatite carry a little chalcopyrite, as veinlets and specks. Some sphalerite is also present. In the area between this shaft and the narrows between Sing Sing lake and the small lake to the south, some twenty-five trenches had been dug. These exposed fractured and sheared quartzose gneiss, but only a very small quantity of chalcopyrite was noted in a few of the trenches, the majority show only yellowish, rusty gneiss with no evidence of chalcopyrite. About 500 feet south of the prospect shaft, a mass of pegmatitic quartz is exposed in a trench. Some chalcopyrite is present in this quartz, but apparently the body is small. This pegmatitic rock, however, is interesting, as it carries considerable of an amethystine coloured quartz.

Cold Lake Group (5)

Early in the winter of 1928, Cold Lake Mines, Limited, was organized to take over several groups of mineral claims adjacent the holding of Sherritt-Gordon Mines, Limited. One of these groups is adjacent the north end of Camp lake, and in the early summer of 1928, some diamond drilling was done there. The rocks exposed are gneissic quartzite, and quartz-mica gneiss which farther south and east form the foot-wall of the Sherritt-Gordon deposit. It was thought by some that the Sherritt-Gordon deposit might be faulted westward near its north end. No field evidence, however, could be found to indicate such faulting. A sill of granite is developed in the hanging-wall gneiss, near the north end of the Sherritt-Gordon deposit, and here the dip of the beds commences to steepen, and there is little evidence of fracturing and shearing of the gneiss. It would appear that the fractured and sheared zone of gneiss containing the Sherritt-Gordon sulphide body gradually ends northward. One or more parallel, barren or practically barren pyrrhotite bodies are present in the foot-wall gneissic quartzite of the Sherritt-Gordon deposit.

Found Lake Group (6)

During the winter of 1928, Found Lake Ramon Syndicate acquired several groups of mineral claims in the map-area. The group on which this syndicate did most of their prospecting, in the summer of 1928, is just west of the southeast end of Found lake. The bedrock here is gneissic quartzite and quartz-mica and quartz-hornblende gneisses. The beds strike north 40 degrees west and dip 50 degrees northeast. Some beds are fine-grained, almost cherty in appearance, whereas others are black with poorly developed slaty cleavage. West of Found lake a considerable body of coarse-grained, hornblende-bearing garnet gneiss is developed. This rock is cut by granite, and in places is highly granitized.

The trenching on this group exposed a zone of sheared gneiss 100 feet wide, and carrying some pyrite and pyrrhotite across widths of 20 feet, and for 200 feet along the strike. No chalcopyrite or sphalerite was seen in the trenches. This sheared zone is located close to the lake level, and at the foot of a hill. On the hill to the southeast and along the strike, no definite continuous sheared zone could be located, there being several small areas wherein the rock was schistose and limonite stained. A few irregularly shaped, pegmatite bodies cut these rusty zones. No evidence of the presence of chalcopyrite was noted. In the late autumn of 1928, five diamond drill holes were put down on this property.

Cree Lake Group (7)

This group of some fourteen mineral claims covers the ground around the north end of Cree lake. The group was staked in 1927 by members of the Sherritt-Gordon staff. The claims were surveyed in the spring of 1928. Little surface work had been completed previous to August, 1928. The geology is interesting, as several masses of black, coarse-grained peridotite and quartz-gabbro are exposed on the lake shore. Quartzose sedimentary gneisses also outcrop. Small areas of basic rocks have been jointed and altered to a mass of serpentine, talc, and carbonate. White iron sulphide and white quartz are present along these altered zones. The rock of such zones might carry gold. Mr. D. C. Baar had done a little work on his Bonanza group, to the east of the Cree group. A fairly definite, narrow shear zone is exposed in the gneiss by two or three trenches, near the outlet of Cree lake. No evidence of chalcopyrite was noted in the few prospects pits visited.

Cananac Group (8)

This group includes some eighteen mining claims and was staked for Mr. Percy Hopkins in the autumn of 1927. In the winter of 1928, the group was sold to Manitoba Basin Mines, Limited. This company did considerable surface prospecting during the early summer of 1928, under the direction of Mr. George Downey. The rocks exposed include a few bodies of peridotite, black hornblende-quartz schist, quartzose gneiss and hornblende-bearing garnet gneiss. The strike and dip of the beds are variable, and a few drag folds, apparently, have developed. The details of these were not determined. Several large trenches and prospect pits were sunk to depths of 10 feet along rusty zones in sheared gneiss. Considerable pyrrhotite and pyrite were present, but chalcopyrite occurs only sparingly.

Elken Group (9)

Sphalerite and chalcopyrite were discovered near Elken lake by Phillip Sherlett, who later, in company with several members of the Sherritt-Gordon staff, staked this group of mining claims in February, 1928. The following spring surface work was commenced and during the summer five shallow holes were drilled. The bedrock is fine-grained, bedded quartzite, striking north 45 degrees east and dipping 42 degrees southeast. A slightly schistose zone, from 10 to 20 feet wide, was exposed by some twelve trenches, distributed over a distance of, approximately, 500 feet along the strike. This work was done along the side of a low ridge at the edge of a swamp, and the continuation of the sheared zone is drift-covered at both ends. The hanging-wall is quartzite. A coarse-grained, hornblende-rich, schistose rock outcrops in the foot-wall about 100 feet across a depression from the pits located farthest southwest. Some chalcopyrite and considerable sphalerite are distributed in small lenses throughout the jointed and schistose rock. The assays indicate that gold is also present at the surface. Prospect pits, along the trail about half a mile southwest of the Elken discovery, show traces of chalcopyrite and sphalerite with iron sulphides. In the winter of 1928, many mineral claims were staked in the area surrounding the Elken group, but the two localities mentioned were the only ones where prospect pits were seen.

Three Finger Lake Group (10)

In the spring and summer of 1928 some surface prospecting was in progress southwest of Three Finger lake on several mining claims staked in 1927. The bedrock is quartz-mica gneiss, intruded by bodies of pegmatitic granite and dykes of pegmatite. Two narrow, irregularly outlined zones of jointed and sheared gneiss are exposed for 100 feet along their strike. Rusty cappings are exposed in all the pits. Some pyrite and pyrrhotite are present in the limonite-stained rock. In one pit chalcopyrite is present in small specks, evenly distributed across about 8 feet of sheared gneiss. This mineralized zone is drift covered along its strike. In the area between Three Finger and Kississing lakes, several cappings are exposed, but no evidence of chalcopyrite was noted at the localities examined. Mr. Jacob Cook, in December, 1927, staked the Gordon-Harriet group, adjacent to the northeast corner of Kississing lake, just east of the northeast corner of Big island. The gneiss is jointed and sheared at several points there, and these zones carry iron sulphide, but only very small amounts of chalcopyrite.

Crow Lake Group (11)

This group extends a mile or more along a contact zone between sedimentary gneiss and granite. The claims were staked in July, 1927, by Mr. W. Russick and associates. Quartz-mica gneiss and hornblende gneiss outcrop along the north part of the claims and granite along their south side. The general trend of the foliation of the gneiss is south 50 degrees west, and the dip 50 degrees northwest. Pegmatite dykes cut the sedimentary gneiss. In July, 1928, eight trenches had been dug along a distance of 3,000 feet. Sheared rusty gneiss was exposed in all these, and in two chalcopyrite and sphalerite are present in small quantities. The mineralized zone is for the most part heavily drift covered.

Collins Point Group (12)

Some surface work was done on a rusty zone in gneiss exposed on the east shore of Collins point. In the winter of 1928, Sherritt-Gordon Mines, Limited, optioned the property, and in the following summer did considerable surface work. The bedrock is quartz-mica gneiss, striking about east and west and dipping from 10 to 15 degrees north. Small bodies of granite and pegmatite are abundant along the shore, both north and south of the prospect pits. The large pits near the lake shore expose jointed and slightly schistose gneiss. Two layers of the more schistose rock, approximately 4 inches thick, and between beds of more massive gneiss, carry sphalerite. Some iron sulphide is present throughout the rock. Some surface work was done inland across a swamp and about 1,000 feet along the strike of the gneiss, but no continuous mineralized zone was located.

Yakusavych Island Group (13)

A rusty weathering zone of sheared gneiss is exposed at intervals on the east shore of Yakusavych island for over a mile along the strike. This was staked in 1925, and in the winter of 1928, Sherritt-Gordon Mines, Limited, optioned a group of some thirty mining claims on the northeast corner of the island. These claims were surveyed during the summer of 1928. The mineralized zone is exposed by trenches and prospect pits at four localities along its strike. Five shallow diamond drill holes were also put down.

The bedrock is quartzite and quartz-mica gneiss, striking north 40 degrees east and dipping 25 to 35 degrees northwest. On the hill, back from the lake shore, several sills of pink granite cut the sediments. At the locality where the diamond drilling was done, about halfway between the north and south ends of the island, the gneiss is sheared and jointed across widths of from 12 to 20 feet. Quartzite forms the hanging-wall and small bodies of massive pegmatite carrying greenish oligoclase or andesine are present in the zone of sheared gneiss. Some sphalerite is present in the schistose gneiss adjacent to this pegmatite. Pyrrhotite, pyrite, galena, and graphite were noted in nearby trenches. On the Cat and Loon claims some chalcopyrite and galena are present in the trenches. Iron sulphides are fairly abundant in a few trenches along this zone, but chalcopyrite apparently is not abundant.

Douglas Group (14)

In the spring of 1928, a few prospectors gradually worked eastward from Kississing lake, and in May, discoveries of chalcopyrite were made in the vicinity of Walton lake. In the early summer several groups of mining claims were staked there by Messrs. Douglas, McLellan, Martin, Caswell, Reid, and associates. The locality was visited in August, but time did not permit a detailed examination of the area. Only a very small amount of surface work had been completed on the discoveries.

The bedrock exposed in the vicinity of Walton lake is black to green lava flows, with interbedded grey layers of arkose, quartz-mica gneiss, and chloritic schists. The strike of the schistosity and bedding is from north to northwest and the dip from 40 to 60 degrees eastward. These strata are cut by sills of granite and aplite, and by a few dykes of pegmatite. Long, narrow bands of schistose rock are developed in both the volcanic and sedimentary members of the group. These weather rusty, and their outcrops were noted from the air in flying over the district during the early spring.

On the Douglas group, located southeast of Walton lake, chalcopyrite is present in two trenches, about 1,000 feet apart, and along one of those rusty zones where thin beds of the rock are highly schistose. The strike of this zone is north 20 degrees west, and the dip 45 degrees east. In the trench farthest north, thin beds of schistose mineralized rock alternate with layers of more massive rock, across a width of 60 feet. The foot-wall exposed in this trench is fine-grained granite and the hanging-wall andesite. The average copper content across commercial widths is low. Drift deposits are thick along the strike to the north. Several other of the sulphide-bearing zones nearby, and also north of Walton lake, are reported to carry some chalcopyrite, and this area would seem to warrant some further exploration.

DEEP BORINGS IN THE PRAIRIE PROVINCES

By D. C. Maddox

The Borings Division, Geological Survey, Canada, has for its aim the collection of the maximum amount possible of information relative to subsurface conditions as indicated by drilling operations. These conditions apply more especially to the nature of the rocks traversed and to the horizons at which oil, gas, or water are obtained, and also the character and yield of these products. The Borings Division is also interested in acquiring information relative to drilling operations in search for non-metallic minerals such as gypsum and salt and drillings for coal. The holes put down, generally with the use of the diamond drill, for determining the value of metalliferous deposits, are outside its province. Of the value of the work there can be no question. The work of the geologists in the field is definitely limited by the rock exposures available for examination, and information as to subsurface conditions obtained through drilling may be of great value in interpreting results of field work and in outlining structure. In areas as extensively drift covered as the western plains, outcrops are in general very few and far between and information as to the nature of the rock underlying the drift must be obtained in certain districts almost exclusively by drilling. In many cases information is not required until many years after the well is completed and the Borings Division, acting as a custodian of both samples and records, is able to supply the necessary data. Within the current year inquiries have been received for samples taken from wells drilled ten to twenty years ago, new and unexpected developments in the areas in which these wells are located having necessitated a re-examination of the samples. Recent advances in the comparatively new subject of sedimentation have resulted in the introduction of special methods for stratigraphic work, among these being the study of the heavy minerals contained in sediments, and the application of micropalæontology to them. Within the last few years the work of the Borings Division has been extended to include some of these more detailed methods and the samples remain available for future use should other detailed methods be evolved.

Water is a prime necessity for all organic growth and information as to where it may be obtained and as to the probable quality and quantity of it is of great interest to the community as a whole. With the increase in the density of population more water is required and sources previously available become useless owing to pollution. Every year the files of the Borings Division are augmented by the receipt of information relative to subsurface water conditions, which will become available for future use in replying to inquiries as to water supply.

The two chief methods employed in the work of the division are the collection of samples and of records. The samples are taken during the course of drilling, each sample representing a certain thickness of rock traversed, generally 5 or 10 feet; special bags are provided for this purpose, these being mailed, post free, to the division for examination and storage. Provision is made for the recording of information relative to water wells by the use of special report forms which include all important data as to the well. In certain of the provinces samples and records from wells drilled for oil and gas are collected by federal or provincial organizations before being sent to the Borings Division. In the western provinces this work is undertaken by the Northwest Territories and Yukon Branch of the Department of the Interior and thanks are due to the officials of the department for co-operation.

The large number of samples and records received and the large area covered by the work of the division necessitate the employment of the most efficient methods for the storage of samples, for the recording of the results of sample examination, and for the filing of records. In recent years these methods have been much improved by the adoption of standard laboratory report forms and standard log forms for wells, in which colour columns are used to express both the colour of the rocks and the lithological description. A card index system providing for the recording of all the essential information on the well has also been introduced. A system of standard maps mounted on heavy cardboard is being evolved, these maps being filed vertically in a special map case and well positions being plotted upon them. Ease of reference to information desired in reply to the numerous inquiries received is greatly aided by an efficient filing organization.

Co-operation, by an interchange of information, is provided with the various federal and provincial organizations that have direct dealings with the oil and gas operators. The exchange on the part of the Borings Division has usually taken the form of information as to the results of detailed examination of samples or of palæontological information on certain samples, for which purpose the expert advice of the palæontologists of the Geological Survey is available. The officials of several of the Federal Government departments not directly concerned with oil and gas have kindly assisted in the collection of data relating to water wells, as have also some of the Provincial Government officials. Messrs. Duff, Flint, and Company have also greatly assisted in the work by forwarding samples and records taken from wells which they were sinking for the railway companies during the construction of new branch lines.

Dr. Shutt of the Experimental Farm at Ottawa kindly provided much valuable information on water analysis.

It is earnestly to be hoped that Government officials of all departments, as well as private individuals, will do their best to aid the Borings Division in the collection of data of this nature. The field covered is so large that but little can be done with field work and personal interviews have in most cases to be replaced by the much less effective correspondence method. Wells are in many cases put down at geologically strategic points without the knowledge of the division and it is obviously essential that data should be recorded and samples taken at the time the well is being sunk.

Co-operation with drillers of water wells is established in parts of the United States of America by means of Government officials co-operating with the drillers in matters dealing with drilling problems and with water conservation. The Drillers' Association meetings which the Government geologist attends and at which he usually takes a prominent part form another method of co-operation. No drillers' associations on a large scale have been formed in Canada to date, but the principle of interesting the driller in the geological features of his work is at present receiving the attention of the division. A tentative scheme, involving the uses of two types of communications, the "General Principle" and the "Special Application" sheets addressed to the driller and dealing with some of the phases of his work, is under consideration. It is found in many instances that it is necessary to interest the driller in the geological features of his work or to be in a position to offer him advice on his drilling problems before he can be induced to send samples or records.

Drilling operations in the western provinces were much extended in 1928. Turner valley easily leads the list as to the number of new wells put down, the footage drilled, and the oil and gas produced. This remarkable field developed rapidly during the year.

In the Wainwright-Fabyan field some drilling was done, as also in the Ribstone field to the east of Wainwright. In Alberta many scattered wells were drilled, these ranging in position north and south from the Von Weymarn well in township 89 to the Pincher Creek district close to the International Boundary. In Saskatchewan work was done on some wells at or near Kenaston, Readlyn, Rosetown, Simpson, and Vera. In Manitoba but little seems to have been done. The number of samples received from wells drilled in the western provinces was 16,706, of which number 11,122 came from wells drilled in Turner valley. The tabulated list that follows shows the distribution of these samples in the various fields and wells.

Location					Description				Remarks
LS.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
					ACADIA VALLEY				
16	34	25	4	W. 4th...	1928	....	2,840	7	Fuego Oil Co. No. 1
					ATHABASKA RIVER				
10	32	96	10	W. 4th...	1928	....	349	47	International Bitumen No. 3
					BROOKS				
15	32	18	14	W. 4th...	1928	....	990	79	C.W.N.G.L.H.P. Co. Brooks No. 3
					CHIN COULÉE				
5	33	8	18	W. 4th....	1928	....	2,245	226	Lethalta Oil Ltd. No. 1
					CLEARWATER				
	21	89	3	W. 4th....	1928	....	495	54	Von Weymarn No. 1
SE ¼	10	89	9	W. 4th....	1928	....	1,003	49	Alberta Government salt well, Waterways
					CYPRESS HILLS				
9	31	7	4	W. 4th....	1928	3,263	3,070	189	Eagle Butte Oil Co. Ltd. No. 1

				DE WINTON					
1	22	21	1	W. 5th...	1928	....	4,500	323	Anglesey Lakeview No. 1
				DUNN					
14	10	43	3	W. 4th...	1928	2,080	1,850	93	London Ribstone Petroleum No. 1
				HIGH RIVER					
16	13	20	29	W. 4th....	1928	....	2,820	95	Ranchmen's Gas and Oil Co. No. 1
				HIGHWOOD					
3	36	18	3	W. 5th....	1928	4,074·4	3,626	30	Highwood No. 1
3	28	18	3	W. 5th	1928	....	100	9	Highwood Syndicate No. 1, Warner Oil Co.
				KENASTON					
16	18	29	2	W. 3rd....	1928	....	123	8	Big Six Oil Co. No. 3
				LESSER SLAVE LAKE					
	30	75	6	W. 5th....	1928	....	3,105	308	International Oils No. 2
				MILK RIVER					
1	30	2	16	W. 4th....	1928	....	51	10	A.P. Con. Test Exploration Co. No. 2
13	14	2	17	W. 4th....	1928	....	507	163	A.P. Con. Test Exploration Co. No. 3
4	1	1	17	W. 4th....	1928	....	304½	41	A.P. Con. Test Exploration Co. No. 8
4	4	2	12	W. 4th....	1928	....	660	83	Capital Oil and Gas Co., Ltd., No. 1
8	9	3	15	W. 4th....	1928	....	370	35	Commonwealth Petroleum No. 1
1	15	3	11	W. 4th....	1928	....	140	31	Geddes Bletcher Gayner No. 1
8	23	3	11	W. 4th....	1928	....	198	40	Geddes Bletcher Gayner No. 4
10	24	2	11	W. 4th....	1928	....	280	31	Madison No. 2
6	21	1	11	W. 4th....	1928	....	980	84	Range Oil and Gas Co. No. 2

Location					Description				Remarks
LS.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
					MORLEY RESERVE				
....	....	25	7	W. 5th....	1928	....	3,630 1,103	66 26	Gold Coin Oils, Ltd. Wabash No. 1
					PINCHER CREEK				
3	34	2	29	W. 4th....	1928	4,400	4,590	440	Alberta Gas and Fuel Co. No. 1
2	11	6	1	W. 5th....	1928	....	3,320	329	Alberta Gas and Fuel Co., Castle No. 1
16	14	4	30	W. 4th....	1928	....	1,260	127	Alberta Gas and Fuel Co., Drywood No. 1
4	7	6	1	W. 5th....	1928	....	855	8	Mount Royal No. 1
					READLYN				
11	7	8	27	W. 2nd....	1928	....	190	10	Ribstone Wainwright
					REDCLIFFE				
SW ¼	9	13	6	W. 4th....	1928	....	1,190	104	Redcliffe Pressed Brick Co. No. 2
					RIBSTONE				
3	16	45	1	W. 4th....	1928	1935	1,820	153	Meridian No. 1
1	1	46	1	W. 4th....	1928	1921	2,056	33	Ribstone Oils Co. No. 1
5	25	46	1	W. 4th....	1928	....	500	48	Ribstone Oils Co. No. 2

				ROSETOWN					
13	4	31	27	W. 3rd....	1928	....	2,031	146	Herschel No. 1
				SIMPSON					
2	9	29	25	W. 2nd....	1928	....	2,170	125	Simpson Oil Co., Roycroft No. 1
				SKIFF					
5	27	5	14	W. 4th....	1928	....	3,182	4	Devenish Petroleum
11	11	5	14	W. 4th....	1928	....	3,045	263	Devenish Petroleum No. 2
				SUFFIELD					
15	4	17	8	W. 4th....	1928	....	1,480	139	Ontario Alberta No. 1
				TURNER VALLEY					
16	19	19	2	W. 5th....	1928	4,229·8	2,680	262	Advance No. 5
4	5	20	2	W. 5th....	1928	3,985·7	6,600	57	British Dom. Oil and Development Co. No. 1
6	12	20	3	W. 5th....	1928	....	3,120	305	British Dom. Oil and Development Co. No. 2
2	1	20	3	W. 5th....	1928	4,015·5	5,615	242	Calmont No. 1
16	30	19	2	W. 5th....	1928	4,036	4,900	70	Dalhousie No. 5
10	13	20	3	W. 5th....	1928	4,056·2	5,027	55	Dalhousie No. 6
5	16	19	2	W. 5th....	1928	....	3,150	332	East Crest No. 1
SW. ¼	26	20	3	W. 5th....	1928	4,001·1	5,900	282	Foothills No. 1 (Millarville)
8	1	20	3	W. 5th....	1928	3,971·5	3,700	192	Foothills No. 2 (Dolomite No. 1)
4	3	21	3	W. 5th....	1928	....	1,940	117	Freehold No. 1
10	20	19	2	W. 5th....	1928	4,198·7	5,134	55	Home Oil Co. No. 1
14	20	19	2	W. 5th....	1928	4,204·6	5,050	286	Home Oil Co. No. 2 (Advance)
10	20	19	2	W. 5th....	1928	4,206·3	4,252	433	Home No. 3
N ½ 14	12	20	3	W. 5th....	1928	4,007·8	3,470	309	Illinois Alberta No. 2
16	1	20	3	W. 5th....	1928	4,012·5	3,910	118	McLeod Oil Co. No. 1
16	1	20	3	W. 5th....	1928	4,029	4,830	164	McLeod No. 3
16	1	20	3	W. 5th....	1928	4,007·0	3,780	314	McLeod No. 4
10	17	19	2	W. 5th....	1928	4,215·8	4,560	396	Mayland No. 1
8	22	20	3	W. 5th....	1928	....	2,980	302	Model No. 1
14	12	20	3	W. 5th....	1928	4,017·8	4,340	223	New McDougall Segur No. 2

TURNER VALLEY—*Continued*

Location					Description				Remarks
LS.	Sec.	Tp.	Range	Mer.	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	
S ½ 14	12	20	3	W. 5th....	1928	4,028	3,280	313	New McDougall Segur No. 3
4	6	21	2	W. 5th....	1928	3,872·9	2,190	11	New Valley No. 1
6	20	19	2	W. 5th....	1928	....	2,440	219	North West Associated No. 1
1	1	20	3	W. 5th....	1928	....	4,620	52	Okalta Oil Ltd.
9	1	20	3	W. 5th....	1928	3,979·1	3,060	5	Okalta Oil Ltd. No. 2
9	1	20	3	W. 5th....	1928	....	2,070	186	Okalta Oil Ltd. No. 3
16	1	20	3	W. 5th....	1928	4,001·3	3,630	117	Regent No. 1
16	31	19	2	W. 5th....	1928	4,000·0	4,260	105	Royalite No. 6
15	12	20	3	W. 5th....	1928	4,005·2	3,740	186	" 8
6	13	20	3	W. 5th...	1928	4,031·5	5,590	423	" 9
10	12	20	3	W. 5th ...	1928	4,010·0	3,120	190	" 10
10	12	20	3	W. 5th ...	1928	4,013·7	2,472	245	" 11
3	13	20	3	W. 5th....	1928	....	1,850	162	" 12
5	13	20	3	W. 5th....	1928	4,006·6	4,550	417	" 13
4	7	20	2	W. 5th....	1928	4,006·5	3,210	307	" 14
1	12	20	3	W. 5th....	1928	4,022·2	2,398	228	" 15
2	12	20	3	W. 5th....	1928	4,045·7	3,600	359	" 16
13	6	20	2	W. 5th ...	1928	....	3,625	368	" 17
15	12	20	3	W. 5th....	1928	....	3,440	318	" 18
5	6	20	2	W. 5th....	1928	....	1,970	167	" 19
7	12	20	3	W. 5th....	1928	....	2,095	194	" 20
10	12	20	3	W. 5th....	1928	....	2,250	412	" 22
1	34	20	3	W. 5th....	1928	3,986·6	4,660	207	Seneca Oils Ltd. No. 1
14	8	20	2	W. 5th....	1928	....	4,610	196	Sentinel Oils Ltd. No. 1
9	34	23	5	W. 5th....	1928	....	1,970	56	Signal Hill No. 2
12	13	20	3	W. 5th....	1928	4,060·1	4,880	30	Spooner Oils No. 1
14	13	20	3	W. 5th....	1928	....	5,000	497	Spooner Oils No. 2
7	27	20	3	W. 5th....	1928	4,040·5	2,980	129	Stockmen's No. 2B
2	24	20	3	W. 5th....	1928	....	4,780	429	United No. 4
11	13	20	3	W. 5th....	1928	4,031·4	4,843	80	Vulcan No. 2

				VERA					
	23	41	24	W. 3rd....	1928	....	2,925	5	Unity Valley No. 1
	23	41	24	W. 3rd....	1928	....	2,380	227	Unity Valley No. 2
				VIKING					
5	18	49	12	W. 4th....	1928	....	850	176	Hudson Bay Marland Oil Co. No. 1
				WAINWRIGHT-FABYAN					
8	24	45	8	W. 4th....	1928	....	1,770	74	Fabyan Petroleum No. 1
9	36	44	3	W. 4th....	1928	....	2,072	22	Interior Oil Co. No. 1
1	19	45	6	W. 4th....	1928	....	2,230	216	Sasko-Wainwright No. 1
15	36	44	7	W. 4th....	1928	....	480	40	Wainwells No. 2
9	36	44	7	W. 4th....	1928	....	2,020	171	Wainwells No. 3
				WILDCAT HILLS					
2	9	27	5	W. 5th....	1928	....	830	73	Frontier No. 1
				WARNER					
NW ¼	31	3	17	W. 4th....	1928	....	225	6	Warner Test
14	21	4	18	W. 4th....	1928	....	4,157	265	Warner No. 1, Gas Production and Transportation Co.
				MANITOBA					
10	30	22	17	W. 1st....	1928	....	1,488	71	W. J. Holmes
12	30	22	17	W. 1st....	1928	....	536	15	Mack Oil Co. Ltd. No. 1
....	45	33	1	W. 1st....	1928	....	232	19	R. J. McGuckin No. 1

LS.	Sec.	Tp.	Range	Mer.	At or near	Year drilled	Elevation above sea-level Feet	Depth in feet covered by records	Number of samples received	Remarks
		48	1	W. 1st..	Chemong....	1927	....	280	....	C. B. Jorge for McDonald Lumber Co.
	17	21	10	" ..	Alonsa.......	1928	....	66	....	W. Smith for W. Smith
	....	21	11	" ..	"	1928	....	87	....	W. Smith for W. Smith
	16	20	16	W. 2nd..	Regina.......	1926	....	288	....	W. H. Mauck for W. H. Mauck
	24	19	16	" ..	"	1926	....	183	....	" "
	20	32	18	" ..	Dafoe.......	1927	....	67	....	L. Meyer for N. Copeland
	5	17	20	" ..	Regina.......	1926	....	178	....	W. H. Mauck for W. H. Mauck
	8	17	20	" ..	"	1926	....	128	....	" "
	....	20	24	" ..	....	1928	....	50	5	M. Marno for W. Dickey
	9	29	25	" ..	Amazon......	1928	1,700	220	....	T. Townsend for M. Kennedy
	....	31	2	W. 3rd..	Alameda.....	1926	....	410	....	R. Davidson for W. H. McCaughy
	28	10	15	" ..	Admiral......	....	2,020	158	....	L. M. Young for L. Murrow
	5	11	15	" ..	Admiral	1923	3,040	162	....	L. M. Young for C. Hicks
	4	9	16	" ..	Scotsguard...	1922	3,000	272	....	L. M. Young for M. Burge
	5	9	16	" ..	" ...	1924	3,075	290	....	L. M. Young for H. Johnson
	25	10	17	" ..	" ...	1925	3,020	135	....	L. M. Young for O. Morin
	14	9	17	" ..	" ...	1925	3,000	128	....	L. M. Young for J. McKray
	13	9	17	" ..	" ...	1925	3,050	110	....	L. M. Young for J. Herners
	31	10	17	" ..	" ...	1925	3,020	136	....	L. M. Young for B. Askeldsen
	17	8	18	" ..	Shaunavon...	1921	3,020	106	....	L. M. Young for L. M. Young
	1	8	18	" ..	" ...	1923	....	227	....	L. M. Young for F. Moore
	17	8	18	" ..	" ...	1925	3,060	107	....	L. M. Young for J. Fennels
	17	8	18	" ..	" ...	1924	3,010	106	....	L. M. Young for Dr. Swanson
	7	9	18	" ..	" ...	....	3,050	179	....	L. M. Young for Dr. Swanson
	35	9	18	" ..	" ...	1925	3,070	236	....	L. M. Young for J. R. Taungstrum
	3	10	18	" ..	" ...	1923	3,030	255	....	L. M. Young for M. Blake
	10	10	18	" ..	" ...	1923	3,050	176	....	L. M. Young for N. Bigser
NE ¼	34	23	18	" ..	Tyner........	1928	....	291	23	Duff, Flint, and Co. for C.N.R. stockyard well No. 1
"	34	23	18	" ..	"	1928	....	269	27	Duff, Flint, and Co. for C.N.R. stockyard well No. 2
NW	26	24	19	" ..	Isham........	1928	....	232	21	Duff, Flint, and Co. for C.N.R. section house
NW ¼	26	24	19	" ..	Isham........	1928	....	275	8	Duff, Flint, and Co. for C.N.R. stockyard well No. 1
	12	51	21	" ..	Turtleford....	1928	....	....	....	J. H. Jones for J. H. Jones
	1	6	7	" ..	McCord......	1928	....	160	6	Duff, Flint, and Co. for C.P.R. well

	35	4	9	"	Mankota	1928	....	186	6	Duff, Flint, and Co. for C.P.R. well
	9	41	25	"	Rutland	1927	2,400	208	....	A. L. Stough for Rutland school
	9	41	25	"	"	1927	2,400	103	1	A. L. Stough for G. Ellis
SW	17	41	25	"	....	....	....	130	3	A. L. Stough for J. W. Brown
SW ¼	29	31	2	W. 4th	Esther	....	....	176	....	Duff, Flint, and Co. for C.N.R. section house well No. 1
"	29	31	2	"	"	....	....	151	12	Duff, Flint, and Co. for C.N.R. stockyard well No. 2
SE ¼	1	57	7	"	Elk Point	....	....	127	....	Duff, Flint, and Co. for C.N.R. depot No. 1 well
SE ¼	1	27	7	"	"	....	....	158	....	Duff, Flint, and Co. for C.N.R. stockyard well No. 2
NW ¼	27	57	8	"	Heenan	....	....	130	9	Duff, Flint, and Co. for C.N.R. stockyard well No. 1
SW ¼	27	57	8	"	"	....	....	134	....	Duff, Flint, and Co. for C.N.R. stockyard well No. 2
	....	36	11	"	Coronation	....	....	182	....	M. Mjolsness for town of Cornation
NW ¼	6	35	16	"	Byemoor	....	....	158	10	Duff, Flint, and Co. for C.N.R. section house well No. 1.
SW ¼	27	34	17	"	"	....	....	138	....	L. Byer for Soldier Settlement Board
NE ¼	17	37	24	"	Calgary	....	3,000	135	....	T. C. Gatenby for Soldier Settlement Board
	....	53	25	"	Edmonton	....	200	506	....	A. W. Huff for W. P. Huff and Sons
	32	52	24	"	"	....	....	326	....	H. A. McKen for N. Curtis
	32	52	24	"	"	....	....	123	....	H. A. McKen for W. Hober
	32	52	24	"	"	....	....	243	....	H. A. McKen for A. E. Jackson
	32	52	24	"	"	....	....	312	....	H. A. McKen for A. S. Matheson
	32	54	25	"	Volmer	....	....	425	....	H. A. McKen for D. Bard No. 1
	32	54	25	"	"	....	....	243	....	H. A. McKen for D. Bard No. 2.
	4	54	25	"	St. Albert	....	....	326	....	H. A. McKen for S. L. Dagsgard
	4	54	25	"	"	....	....	312	....	H. A. McKen for M. Kennedy
	4	54	25	"	"	....	....	383	....	H. A. McKen for Wm. Maloney
	....	....	....	....	Lake Johnston	....	....	180	17	Canadian Pacific Railway well

As regards laboratory work 4,424 samples were examined by the usual routine method. During the year 12,700 samples from wells in the western provinces were washed and bottled. As the interval from which samples are taken is in general 10 feet this number of samples would represent a section 127,000 feet, or about 24 miles, in thickness.

During 1928 Mr. F. J. Fraser continued the laboratory work started in 1927 on surface samples of rocks taken from southern Saskatchewan and brought in from the field by Mr. F. H. McLearn. Although this work forms no part of the routine operations of the Borings Division, the information and experience gained during its conduct are of considerable service to the division as offering a possible means of correlation that may be at some later date applied to well samples. Numerous slides containing heavy minerals obtained from material taken from well samples were made and filed.

Very few samples from water wells drilled in the western provinces were received or examined. This is explained by the fact that owing to the thick drift cover most of the water wells in this area are not of sufficient depth to reach the bedrock underlying the drift.

Field work for the Borings Division was undertaken by Mr. R. T. D. Wickenden. This work was a continuation of that of 1927 and involved the collection of surface samples from known horizons and of the collection of core samples from certain wells. These samples were disintegrated and examined for the presence of foraminifera. It is hoped that this method will ultimately prove of value for stratigraphic correlation, but the work has not yet been carried to the point where this is definitely proved. Mr. Wickenden is working with Dr. J. A. Cushman and has the benefit of the assistance and advice of this well-known expert on foraminifera.

In addition to the regular work of the division a number of samples were "split" and forwarded to persons desiring them and authorized by the owners of the wells to receive them. This work was undertaken in response to requests from oil well officials who desired to have these samples for examination. In all, 1,744 samples were so split and forwarded to persons requesting them. Mr. P. D. Moore, geologist of the Imperial Oil Company at Calgary, applied for and received many of these samples. It is a pleasure to acknowledge the co-operation of Mr. Moore and of other officers of the Imperial Oil Company in the supplying of information of great value to the division.

In 1928 the Borings Division received an inquiry from a large manufacturing concern as to the hardness of municipal water supply of the chief Canadian cities and towns. An attempt was made to obtain all information available on this point. In the case of the larger cities analyses of water supply were readily obtainable, but in the case of the smaller towns it was found that the analyses available were in general more of a bacteriological, than of a chemical, nature. In connexion with this inquiry an attempt was made to group all centres of population, concerning which we had any information relative to water supply, as occurring in one or other of certain areas, the limits of which were largely determined by geological conditions and political boundaries. A further subdivision within these areas was attempted by classifying sources of water supply under the headings of wells, springs, lakes, and rivers. There exists within most of these areas such a wide variation in conditions affecting water supply that the grouping must be regarded as purely tentative. Of the eleven main areas into which Canada was divided only two were of sufficient uniformity to provide reliable information, these being the Great Lakes area, including St. Lawrence and Ottawa rivers, and the area, or rather, areas underlain by the Precambrian and igneous rocks of all ages. The total population of the eleven areas is about 5,000,000, of this number about 3,000,000 reside in the two areas specifically referred to, but definite information was obtained of the chemical character of the water supply of only a very small proportion of this population. In the western provinces the scattered nature of the population rendered the collection of data rather difficult. Thanks are due to the Health Department of the provinces and to the waterworks engineers of many of the cities for co-operating in this work.

OTHER FIELD WORK

Geological

B. R. MacKay. Mr. MacKay made a detailed geological investigation of the north branch of Hay River coal area, Brûlé mining district, Alberta. A report and geological map are being prepared for publication.

C. S. Evans. Mr. Evans carried out a geological reconnaissance along the main rivers in the foothills region between Bow and Saskatchewan rivers, Alberta.

P. S. Warren. Mr. Warren investigated the geology of an area of about 12,000 square miles in southern Saskatchewan. This area is the northern part of a field embracing nearly the whole of southern Saskatchewan (and an adjoining part of Alberta) from the International Boundary north to latitude 52 degrees. The southern part of the field is being geologically studied by F. H. McLearn. When the whole area has been covered the results will be embodied in a map on a scale of 8 miles to 1 inch.

W. A. Johnston. Mr. Johnston continued the investigation of the surface geology, including the soils, of an area in southern Manitoba and southwestern Saskatchewan between latitudes 49 degrees and 52 degrees, and from the Ontario boundary to longitude 102 degrees.

S. R. Kirk. Mr. Kirk commenced a resurvey of the Palæozoic and Mesozoic strata of an area in southern Manitoba and southwestern Saskatchewan between latitudes 49 degrees and 52 degrees and from the Ontario boundary to longitude 102 degrees. The results of the work will be embodied in a geological map of the region on a scale of 8 miles to 1 inch.

Topographical

D. A. Nichols. Mr. Nichols completed the topographical survey of the west half of the Jumpingpound map-area, Alberta, latitude, 51° 00′ to 51° 15′, longitude 114° 30′ to 115° 00′, and commenced a topographical survey of the Wildcat Hills map-area, Alberta, latitude 51° 15′ to 51° 30′, longitude 114° 30′ to 115° 00′.

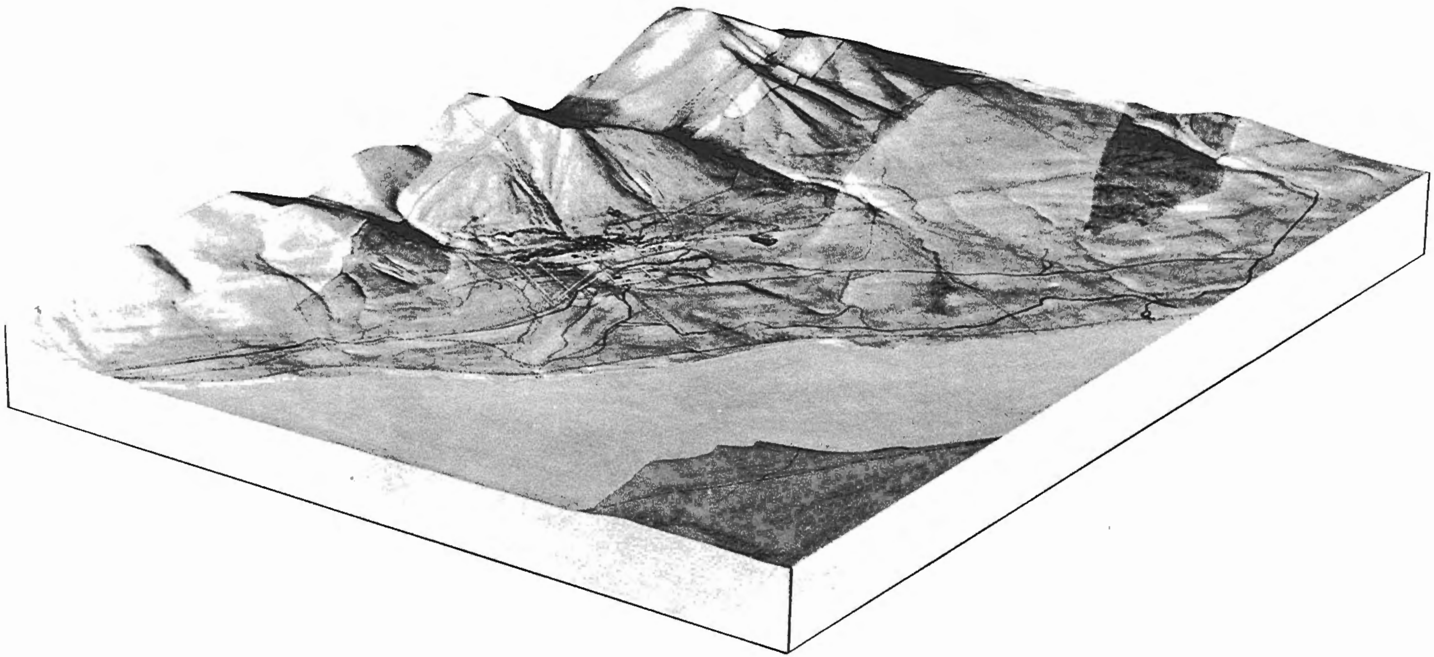
W. H. Miller. Mr. Miller completed the detailed topographical mapping of Thoreau Creek area, Alberta, and commenced the topographical mapping of Hay River map-area, Alberta.

R. C. McDonald. Mr. McDonald ran control surveys required for mapping, by aerial photography, Flinflon map-area, latitudes 54° 45′ to 55° 00′, longitude 101° 30′ to 102°, Manitoba and Saskatchewan. He also ran the control surveys required for the detailed mapping, by aerial photography, of Beresford Lake area, southeastern Manitoba.

Plate I

Brûlé townsite from hillside.

Plate II



Relief model of Brûlé Mines coal area, Alberta.

Mississippian limestones of Boule range overthrust on steeply inclined Lower Cretaceous sandstones and shales. Opposite Brûlé station.

Plate IV

Asymmetrical folds in Lower Cretaceous sediments on Brown creek, opposite Brûlé station.

A. Abandoned beach, Malcolm island, Reindeer lake.

B. Granitized biotite schist, Deep bay, Reindeer lake.

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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.