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

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1931, Part B

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OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1932

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NOTE. Part B of the Summary Report formerly included reports relating to the provinces of Manitoba, Saskatchewan, and Alberta, and to the part of the North West Territories lying north of these provinces. It now contains only reports that deal with the southern and western parts of this region underlain chiefly by Palæozoic and later formations. Part C is a new part comprising reports that relate to the northern and eastern portions of the same region, which are underlain chiefly by Precambrian formations. What has hitherto been called Part C is now Part D. It relates to the provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, and Nova Scotia, and to the part of the North West Territories lying north of these provinces and east of Hudson bay.

THE MESOZOIC-PALÆOZOIC CONTACT AND ASSOCIATED SEDIMENTS, CROWSNEST DISTRICT, ALBERTA AND BRITISH COLUMBIA

By B. R. MacKay

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Illustrations

INTRODUCTION

Operations carried on in the Turner Valley and other oil fields in Alberta have demonstrated that oil occurs in both Mesozoic and Palæozoic measures, and that one of the most important of these horizons is at or near the Mesozoic-Palæozoic contact. At all the oil-producing localities this contact is deeply buried beneath younger formations, so that data pertaining to its character are meagre. Drilling results in Turner valley and elsewhere have shown, however, that the formations change in lithological character within comparatively short distances, and, since formations present in certain localities are wanting a few miles distant, that a disconformity representing a great interval of time occurs at the Mesozoic-Palæozoic contact. There are also indications that disconformities may exist at other horizons.

With the object of gradually accumulating data pertaining to the nature and extent of any unconformities that exist, and the changes in thicknesses and lithological character of the associated sediments that take place the writer was directed, in conjunction with his main investigations, to examine the Mesozoic-Palæozoic contact in Crowsnest district. Three student assistants, H. N. Hainstock, N. H. Fraser, and R. Thompson, rendered able assistance in this work, the first mentioned being given charge when the writer was engaged in other field investigations.

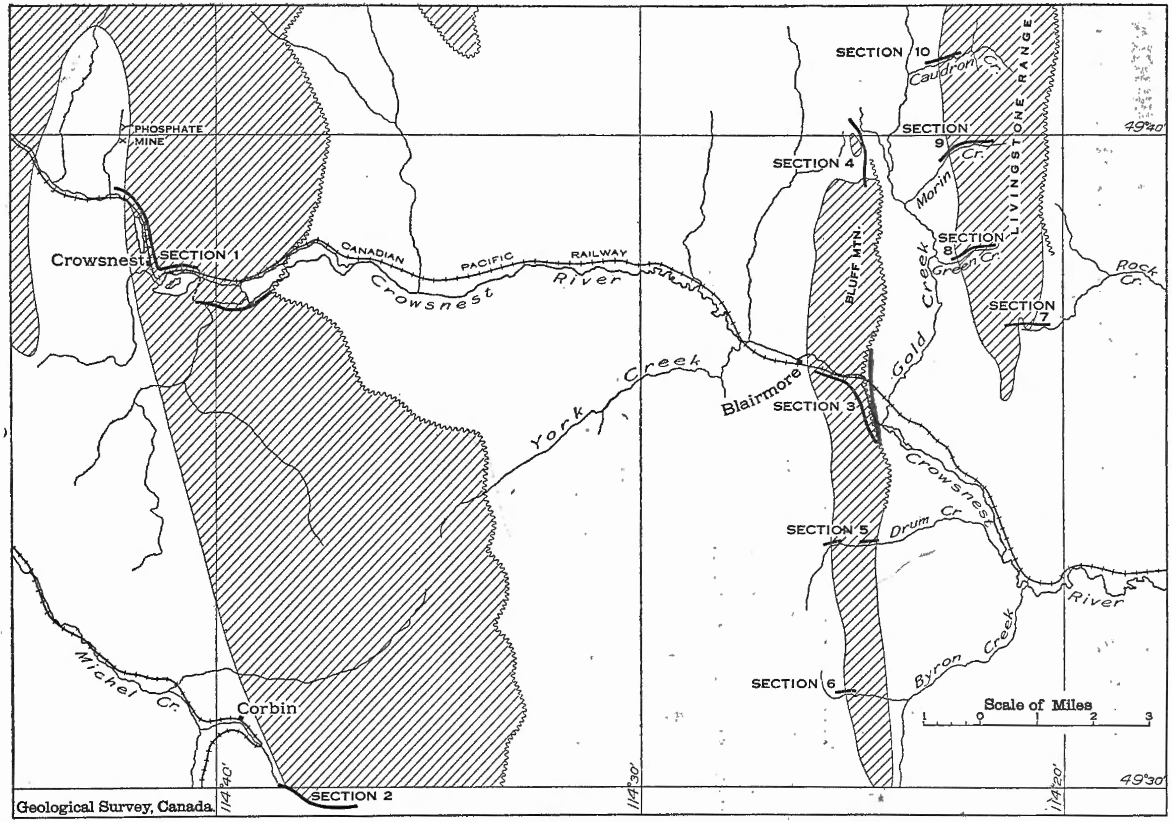

Figure 1. Index map of Crownest district, Alberta and British Columbia, showing position of sections measured and areas occupied by Palæozoic strata (shown by pattern of ruling).

The positions of the sections examined are indicated on the accompanying index map, Figure 1. From this it will be observed that east of Blairmore are two northerly-trending Palæozoic areas, here designated, respectively, the Livingstone range and the Blairmore inlier. The strata of both areas lie in asymmetrical anticlinal folds, the axial planes of which dip steeply to the west. The eastern flank of each of these anticlines over most of its length is defined by westerly dipping strike faults of pronounced displacement, along which the Palæozoic rocks have been thrust eastward over Mesozoic sediments, but near the plunging ends of the folds the normal Palæozoic-Mesozoic contact emerges and gradually swings away from the fault planes. At these localities and on the western flank of each of the folds the Mesozoic rocks lie in normal contact with the underlying Palæozoic sediments, but owing to the cover of alluvium and boulder clay the actual contact is visible at only a few places. Complete columnar sections of the sediments below the contact were obtained at four widely spaced localities on each of the Palæozoic inliers, and sufficient of the overlying Jurassic and Lower Cretaceous sediments were observed to be certain of the character and thicknesses of these formations.

About 10 miles west of Blairmore occurs the crest of the Rocky mountains. This range in the vicinity of Crowsnest pass is 3½ miles in width and consists of westerly dipping Palæozoic strata. These measures on the east side of the crest of the range are terminated by a pronounced low-angle, westerly dipping fault plane along which they have been thrust eastward for many miles, so that they now rest on Upper Cretaceous sediments. Westward from the fault progressively younger Palæozoic sediments appear forming an almost uninterrupted section of apparently conformable beds having a uniform westerly dip of from 65 to 40 degrees and with no evidence of pronounced thrust faulting. To the west the Palæozoic rocks disappear beneath the Mesozoic beds of the Fernie coal basin. A complete columnar section of the Palæozoic sediments exposed in this part of the pass was obtained. A supplementary section was also obtained on the west flank of Flathead range at Corbin, 12 miles south of the pass.

The strata exposed in the part of Crowsnest district examined have a maximum thickness of 22,000 feet. They comprise marine, freshwater, and volcanic sediments which are grouped into two main divisions, Palæozoic and Mesozoic.

The Palæozoic sediments comprise limestones, cherts, and quartzites of Devonian, Mississippian, and Pennsylvanian ages, having a maximum total thickness of almost 10,000 feet in the Crowsnest section. The Palæozoic succession in the district was first studied by Dawson, but on account of their rather limited economic importance the Palæozoic sediments have not received in recent years anything like the attention given to the Mesozoic succession, due principally to the presence of coal in the latter. The Mesozoic succession was divided by Leach into six formations which in descending order are: Fernie of Jurassic age; Kootenay and Blairmore of Lower Cretaceous age; and Crowsnest volcanics, Benton, and Allison of Upper Cretaceous age. In 1915 Rose completed the mapping of Blairmore area, determined the thicknesses and general character of the Mesozoic formations, and showed by a battery of structure sections the general structure of the region. His results are presented largely on the geological map of Blairmore area and in his two summary reports on the area, 1915 and 1916; a comprehensive study of the Mesozoic palæontology of the Blairmore region was made by McLearn[1] in 1915.

The Mesozoic formations of Crowsnest district, British Columbia, were studied and reported upon by McEvoy in 1902. Parts of the area have received supplementary studies by other officers of the Survey whose results in the form of reports, maps, and sections appear in more recent publications of the Geological Survey.

During the past eight years the demand for phosphate ore by the Consolidated Mining and Smelting Company has resulted in their investigating the commercial possibilities of phosphate deposits in the Rocky mountains. In this program the phosphate deposits of Crowsnest district, which appear to be the most important, are receiving special attention. There is a tendency to correlate these deposits with those of Banff area to the north and with those of the western United States all of which are presumably of Pennsylvanian age. Fossils occurring in the phosphate deposits of Crowsnest district, however, place these deposits as undoubtedly Mesozoic and most likely lower Jurassic in age. Near Crow's Nest station there occur between the phosphate and the Rocky Mountain Quartzite, 350 feet of sandstones and shaly quartzite in which no fossils have been found, and which because of their lithological resemblance to the Spray River beds of Banff area, are temporarily classed as Triassic.

The stratigraphic succession in Crowsnest district with the thicknesses of each formation in the Crowsnest section and the Alberta section, is given in the accompanying table.

Table of Formations

Age	Formation	Thickness in feet	
		Crowsnest	Blairmore
Upper Cretaceous	Allison		2,500–3,000
	Benton		3,250
	Crowsnest Volcanics		1,100
Lower Cretaceous	Blairmore	6,000+	2,100–3,000
	Kootenay	3,500	400–650
Jurassic	Fernie	3,000	750–900
Triassic (?)		350	0
Pennsylvanian	Rocky Mountain Quartzite	1,118	340
Mississippian	Rundle	4,988	1,623
	Banff shale	1,070	540
Devonian	Minnewanka	2,626	182

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[1] McLearn, F. H.: "Mesozoic Palæontology of Blairmore Region"; Geol. Surv., Canada, Mus. Bull. 58 (1929).

CONCLUSIONS

(1) The thickness of the Crowsnest section agrees closely with that obtained by Dawson in 1885 and by Warren in 1927. The apparent absence of pronounced faulting in the section would indicate that the thickness of the Palæozoic beds obtained, 9,802 feet, approaches very closely to the true thickness.

(2) No evidence was obtainable within the sections examined as to the amount of eastward thinning of the Devonian beds, but a remarkable eastward thinning was found to exist in the case of the Banff shale, the Rundle formation, the Rocky Mountain Quartzite, the possibly Triassic beds, the Fernie formation, the Kootenay formation, and the Blairmore formation.

(3) The only rocks observed in the sections examined that were likely to be source rocks of oil, are bituminous sediments at or near the base of the Jurassic formation. In most cases these bituminous rocks are closely associated with a phosphate deposit.

(4) Numerous fossils, found in this phosphate horizon at three widely spaced localities, i.e., Crowsnest lake, and White Sulphur on the Corbin highway, B.C., and the Rock Creek section north of Bellevue, Alta., indicate the age of the deposit to be Mesozoic and most probably lower Jurassic. These deposits are, therefore, younger than those of Banff area and most of the phosphate deposits of the Western States, which occur in the Rocky Mountain Quartzite formation of Pennsylvanian age.

(5) The phosphate deposits at Crowsnest lake are the only ones observed that are of sufficient thickness to be of economic value. These are, however, appreciably lower in phosphatic acid content than are the deposits of the Western States from which the Consolidated Mining and Smelting Company derive their phosphate ore, and are, therefore, not being developed at present.

(6) The coal deposits of the Kootenay formation in Crowsnest district yield considerable gas (methane) and some of the coals show, by the presence of small, circular, thin, iridescent films of oil along closely spaced joint planes, that they contain oily matter in small amounts.

(7) The sections revealed two erosional unconformities. The lower lies at the Palæozoic-Mesozoic contact at which beds of Pennsylvanian age directly underlie sediments probably of lower Jurassic age. The second unconformity occurs in Lower Cretaceous sediments. Here at least 20 feet of Kootenay beds have been in places removed prior to the laying down of a massive conglomerate which marks the base of the Blairmore formation.

DETAILED DESCRIPTION OF FORMATIONS

Introduction

By far the most complete of the geological sections is the one exposed in Crowsnest pass where this major transverse valley cuts through the limestones of the Rocky mountains. This section is considered the type section of the Palæozoic formations of the district. It was first measured by Dawson[1] who obtained a total apparent thickness of 9,610 feet. Dawson found no evidence of faulting or folding in the section, but the thickness was so greatly in excess of what he had observed elsewhere in the Rockies that he was of the opinion that the great thickness was due to a repetition of beds caused by compressed folding or thrust faulting or by both. On the assumption that such hypothetical folding did occur he suggested that the true thickness was probably in the neighbourhood of 3,575 feet. In 1927 Warren[2] studied this section and the Palæozoic section at Blairmore and correlated the formations with those in Banff area. He obtained for the Crowsnest section a total thickness of 8,950 feet exclusive of several hundred feet of the lowermost exposed beds which he purposely omitted. He found no evidence of pronounced faulting or folding and on the basis of fossils collected through the section he was of the view that there was no repetition of beds in the section. The writer remeasured this section from the lowermost Devonian beds exposed at the fault plane, westward and upward to the basal Jurassic beds. The total thickness of strata measured was 10,152 feet, of which 9,802 belong to the Palæozoic formations. Slight faulting and small drag-folds were noted to occur at several horizons, both in the lowermost exposed Devonian sediments and in the Rundle formation, but no appreciable duplication of beds could be detected. There are several concealed intervals in the section where faulting might be present, but lacking direct evidence of repetition of beds the writer is of the opinion that the measurements of the formations as obtained approach very closely to their true thicknesses.

The Crowsnest section follows the main highway throughout. It begins at the fault scarp at the eastern end of Crowsnest lake and terminates at what is known as the phosphate mine owned by the Consolidated Mining and Smelting Company and located 2½ miles north and a little west of Crow's Nest station. The main highway runs along the south side of the valley from the eastern end of Crowsnest lake west to a point a mile east of Crow's Nest station. There it crosses over to the north side of the valley and continues along this side for 4½ miles to the junction of Michel and Alexander creeks. Wherever concealed intervals occur in this section an attempt was made to complete the sequence of beds from correlated outcrops on the opposite side of the valley.

The Crowsnest Pass section has been chosen as the type section and in the following account of the various formations, each formation as it appears in the Crowsnest Pass section is first described, and this is followed by a description of the same formation as it occurs in the other sections examined. By following this procedure it is believed that the changes in the character and thicknesses of the formations and the nature of the Palæozoic-Mesozoic contact will be more apparent than if each section were described separately.

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[1] Dawson, G. M.: Geol. Surv., Canada, Ann. Rept., vol. I, pt B, pp. 70–73 (1886).
[2] Warren, P. S.: Roy. Soc. of Canada, vol. XXII, sec. IV, pp. 109–119 (1928).

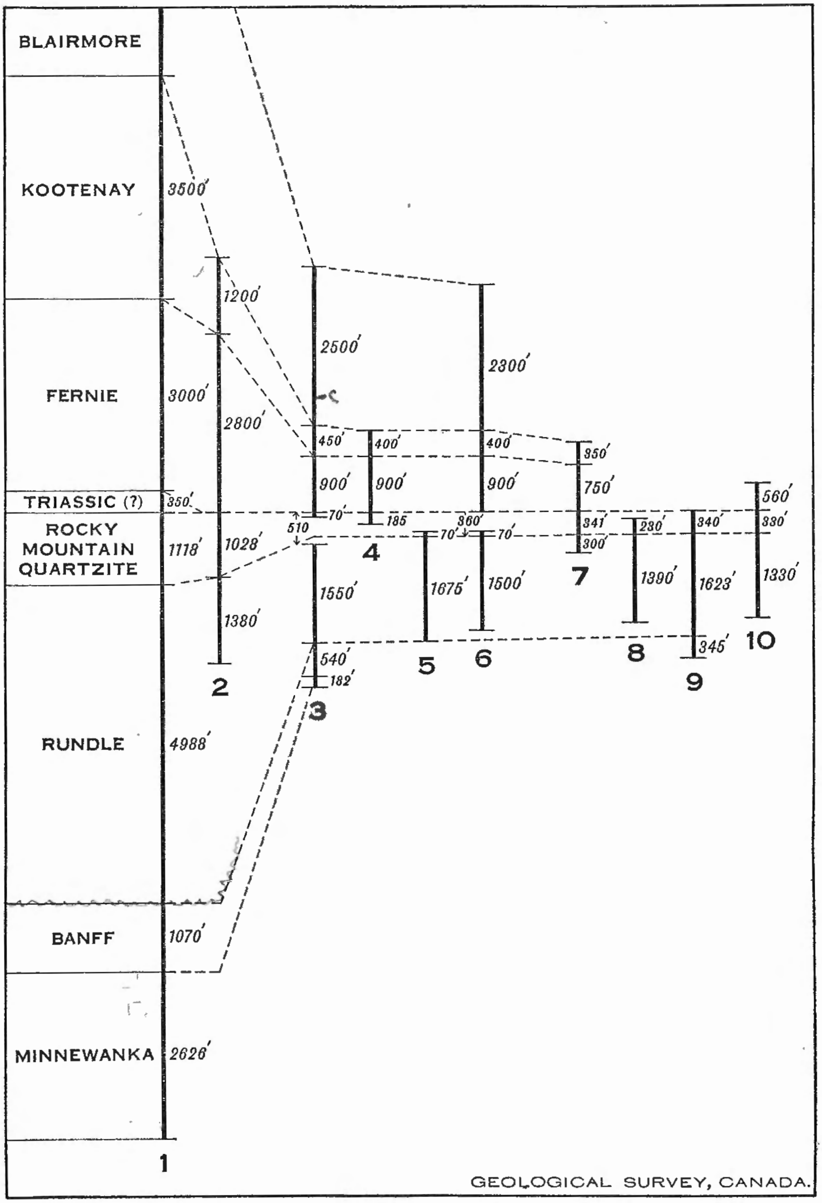

Figure 2. Diagram illustrating correlation of formations in measured sections *(See* Figure 1 for positions of sections). 1, Crownest pass, B.C.; 2, Corbin, B.C.; 3, Blairmore, Alta.; 4, Grassy mountain, Alta.; 5, Drum creek, Alta.; 6, Byron creek, Alta.; 7, Rock creek, Alta.; 8, Green creek, Alta.; 9, Morin creek, Alta.; 10, Caudron creek, Alta.

Minnewanka Formation

CROWSNEST PASS SECTION

Extending from the base of the exposed section at the fault plane at Crowsnest lake, westward, and stratigraphically upward for a thickness of 2,665 feet, is a series of thin and massive bedded limestones of Devonian age. The greater part of this section has been correlated by Warren with the Minnewanka formation of Banff area, and hence it may be designated by the same name. On account of the possibility of repetition of beds by faulting Warren did not include in his section the lowermost 550 feet of exposed beds. The complete section is as follows.

Section of the Minnewanka at Crowsnest Pass

Overlying formation—Banff shale	Thickness Feet
Soft, earthy, black, brown-weathering, thinly bedded shale	15
Concealed, largely dark and buff-grey, calcareous shale	30
Brown, massive, bedded, buff-grey weathering limestone	96
Dark, black, massive bedded, finely crystalline limestone weathering dark grey with brown patches	790
Brown, finely crystalline, dark grey-weathering limestone	95
Thinly bedded, finely crystalline, dark grey limestone weathering buff	24
Brown, finely crystalline, buff-weathering limestone	180
Finely crystalline, light brownish buff-weathering limestone with nodules of chert	15
Finely crystalline, buff-weathering limestone	12
Coarsely granular, light grey limestone	65
Concealed	120
Massive-bedded, light brownish weathering, black limestone	156
Black, finely crystalline, buff-weathering limestone with 2-inch bands and nodules of hard, black limestone	12
Massive and thin-bedded, black limestone weathering reddish brown	62
Finely bedded, black, brownish grey-weathering limestone containing brachiopods and gasteropods	30
Massive, black limestone weathering light grey and buff	147
Concealed (probably same as above)	225
Black, thinly bedded, jointed, brown-weathering limestone containing a few lenses of black chert	57
Black, rough weathering, porous limestone	8
Finely crystalline, black limestone weathering grey	57
Black, finely crystalline limestone weathering grey and containing a little chert	48
Concealed	53
Finely crystalline, light creamy grey-weathering dark limestone with a few bands and lenses of chert	24
Light creamy grey, crystalline limestone weathering buff	133
Dark grey, hard, massive, buff-weathering, finely crystalline limestone	100
Finely crystalline, light brown-weathering, dark grey limestone containing bands and lenses of buff-weathering, grey chert	72
Total exposed thickness	2,626

Fault plane.

Underlying sediments—Allison formation, Upper Cretaceous

OTHER SECTIONS

The only other locality at which rocks of Devonian age were observed to outcrop is the landslide scarp forming the eastern face of Turtle mountain at Frank, Alberta. The structure of the mountain here is that of a tightly squeezed, asymmetrical anticline with a fault of rather large displacement cutting along the eastern side of the fold a few hundred feet below the anticlinal axis. The beds forming the core of this anticline, which outcrops on the landslide scarp about 1,500 feet above the base of the mountain, are considered to be Devonian in age. This zone is thought to comprise the uppermost 182 feet of the Devonian. It consists of a lower 132 feet of brownish, coarse limestone which weathers to a buff grey, and an upper 50-foot bed of dark brown to black-weathering, calcareous shale. The beds immediately overlying the Devonian consist of massive, dark grey to black, buff-weathering limestones which contain numerous chert bands and nodules and are considered as forming the basal beds of the Banff formation.

The presence of a Devonian horizon in the fault scarp section was established in 1903 by McConnell and Brock[1] who collected two corals, one from the crushed zone and the other from the slide rock beneath. These corals were determined by Lambe to be *Diphyphyllum arundinaceum* Billings, and *Acrophyllum oneidaense* Billings.

GENERAL REMARKS

The impervious character of the Minnewanka formation where it occurs in the Crowsnest Pass section suggests little possibility of oil occurring in it. The only two horizons at all suggestive of source rocks of oil are the 8-foot thick, black-weathering, porous limestone bed 500 feet above the base of the exposed section, and the 15-foot thick, soft, earthy, black, brown-weathering shale at the top of the formation. Both these rocks were tested for oil, but gave no indications. It is of interest to note that what appears to be the same shale horizon has been pierced in three of the deeper wells sunk in the more gently folded areas in southern Alberta and that here it has given slight indications of oil. It would appear, therefore, that accumulation of oil from this horizon can be expected only in territory where it is much more strongly developed than here shown.

The black shale zone is in all probability the black shale horizon which Warren places as the lower member of the Banff shale formation of Mississippian age. A similar black shale zone underlies the Carboniferous limestone in the plains area, in which have been found Devonian fossils. On the basis of this the zone is considered by the oil geologists as marking the closing stage of Devonian sedimentation, at which time there was an upwarping of the land area and a widespread deposition of black carbonaceous muds. Lacking fossil evidence to the contrary the writer has placed this bed as the uppermost of the Devonian formation.

Banff Shales

CROWSNEST PASS SECTION

Overlying the Devonian sediments conformably is a thickness of 1,070 feet of dark brown and black, buff-weathering limestones containing nodules and lenses of chert throughout all except the uppermost 50 feet of the formation. Warren correlates this group of beds, because of their

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[1] McConnell, R. G., and Brock, R. W.: "Report of the Great Landslide at Frank, Alta., 1903"; Dept. of Interior, Ann. Rept., pt. VIII (1903).

similar lithological character and stratigraphic position, with the middle and upper members of the Banff shale formation at Banff, so the same formation name is here used. The detailed section is as follows:

Overlying formation—Rundle	Thickness Feet
Thick-bedded, brown, semi-granular, light grey-weathering limestone	50
Dark brown to black, buff-weathering limestone with bands, lenses, and nodules of black chert; the chert is more widely spaced in the upper 92 feet and becomes more granular toward the top	592
Very fine-bedded, buff-weathering, dark grey limestone containing bands and lenses of chert	225
Fine, compact, black limestone containing lenses and bands of black chert and weathering buff; the upper 90 feet of this zone is concealed	203
Total thickness	1,070

OTHER SECTIONS

At only one other locality was a complete section of the Banff formation obtained. This was on the landslide scarp on the east slope of Turtle mountain at Frank. The base of the formation is here clearly discernible traversing the scarp a few hundred feet above the fault plane. A section similar except that the lower hundred feet of the formation is concealed by talus and alluvium, occurs on the slope of Bluff mountain on the north side of the valley. The section obtained on Turtle mountain is as follows.

Overlying formation—Rundle limestone	Thickness Feet
Light buff-weathering, brownish grey, hard, crystalline, medium and massive bedded limestone	240
Massive bedded, finely crystalline, buff-weathering, brownish grey limestone becoming finer bedded toward the top and bluish in colour; has a strong odour of hydrogen sulphide	100
Dark brown to black, fine-grained limestone with layers of black chert from ½ inch to 3 inches; both weather to a creamy white tint	200
Total thickness	540

What is considered to be the uppermost 345 feet of the Banff formation is exposed in the heart of the Livingstone Range fold on Morin creek. The section is as follows.

Overlying formation—Rundle	Thickness Feet
Hard, shaly, grey limestone with small lenses and nodules of white-weathering chert	30
Fine-grained, crystalline, dark grey limestone with lenses and beds of creamy white-weathering chert ranging up to 3 inches in thickness, and lying 1 to 3 inches apart	105
Shaly, coarsely granular, brown-weathering limestone with abundant crinoid columns	15
Coarsely crystalline, brownish grey limestone	10
Finely bedded limestone with thin laminæ of chert	2
Massive, coarsely granular, grey, pitted limestone	15
Coarsely granular, porous, crumbly weathering, grey limestone containing crinoid columns and giving off the odour of hydrogen sulphide	10
Porous, pitted, light grey, crystalline limestone	18
Soft, granular, shaly, thin-bedded limestone	10
Massive, coarsely granular, grey limestone in beds 2 to 15 feet thick, the coarser beds are porous and contain abundant crinoid columns	130
Total exposed thickness	345

GENERAL REMARKS

None of the Banff formation sections examined contain beds that offer any possibility of being source rocks of oil, although the presence in some of them of chert and hydrogen sulphide suggests stagnant water conditions. The formation shows only slight differences in lithological character in the several sections examined, but there is a remarkable eastward thinning in the formation as indicated by the difference in thickness on Turtle mountain and at Crowsnest lake.

Rundle Formation

CROWSNEST PASS SECTION

The Banff shale is overlain without any apparent break by a thick series of massive, coarse and finely crystalline limestones which are predominately grey in colour and weather to white, grey, and buff tints. The series has a total thickness of 4,988 feet. Distributed through it are beds containing nodules, lenses, and irregular bands of chert ranging up to 3 inches in thickness. The chert is predominately white or grey, but there is an occasional bed of black chert. Certain beds are highly fossiliferous from top to bottom, the prevailing fauna comprising crinoids, corals, brachiopods, and fenestelloid bryozoans. Although no systematic collecting was attempted by the writer, fossils were obtained from several widely distributed zones. On the basis of these most of the formation was placed by the Palæontological Division as Mississippian in age, but the uppermost beds were found to carry Pennsylvanian fauna. Warren collected from several horizons in this section and on the diagnostic characters of the fauna correlated the formation with the Rundle formation of Banff area.

Only two horizons are at all suggestive of oil: they are two dark grey, massive limestone beds that occur near the top of the section. The lower is a 65-foot bed of finely crystalline limestone containing a few lenses and nodules of chert. It has a strong petroliferous odour. The upper horizon lies 170 feet from the top of the formation and is a 40-foot bed of dark grey, fine-grained limestone which contains *zaphrentis* and other corals, and with a petroliferous odour.

This section of the Rundle formation is as follows.

Overlying formation—Rocky Mountain Quartzite	Thickness Feet
Light grey, finely crystalline, compact limestone with bands and nodules of grey chert	170
Dark grey to black, fine-grained limestone containing corals and having a petroliferous odour	40
Fine-grained, dark grey, creamy-weathering limestone with bands of chert ½ to 2 inches wide	110
Interbedded, brown-weathering, shaly limestone and dark grey, fine-grained limestone containing chert nodules	20
Concealed interval	150
Dark grey, massive bedded, finely crystalline limestone with a few lenses and nodules of chert; has a petroliferous odour	65
Concealed interval	550
Dark grey, finely crystalline, creamy weathering limestone with black chert nodules	156
Concealed interval	200
Dark grey, fine-grained limestone	100
Concealed interval	60

	Thickness Feet
Light and dark grey, buff-weathering limestone	70
Concealed interval	220
Dark grey limestone with black chert beds	40
Dark grey, creamy-weathering limestone	115
Concealed interval	408
Light grey, finely crystalline limestone containing grey chert lenses and nodules	85
Coarse, granular, grey limestone	80
Interbedded finely crystalline and coarse, granular, grey limestone, fossiliferous	31
Coarse, granular, grey limestone; fossiliferous near centre	120
Interbedded, finely crystalline and coarse, granular, grey, buff-weathering limestone	64
Coarse, granular, grey limestone weathering light grey	70
Coarse, granular, grey, white-weathering limestone	120
Concealed interval, largely coarse, granular limestone	70
Brownish, fine-grained limestone containing chert bands and lenses; fossiliferous	160
Finely crystalline and coarse, granular, dark grey limestone with crinoid stems in upper beds and chert lenses and nodules in lower	24
Dark grey to brown, coarse, granular limestones with crinoid stems	80
Concealed interval	60
Fine-grained, brownish, white-weathering limestone containing nodules of grey chert	105
Coarse, brownish grey, massive bedded, granular limestone	108
Buff weathering, finely crystalline, brown limestone with grey chert	18
Coarse, granular, grey limestone	105
Finely crystalline, light grey, buff-weathering limestone	25
Coarse, granular, dark grey-weathering, brownish limestone with crinoid stems	213
Finely crystalline, brownish limestone with grey chert lenses and nodules	50
Coarse, granular, grey, massive bedded limestone with crinoid columns	115
Finely crystalline, brown limestone, light grey-weathering with grey to black chert bands 2 inches thick	35
Coarse, granular, grey-weathering, brownish grey limestone	44
Finely crystalline, brown, much jointed, white-weathering limestone	110
White, creamy-weathering calcite	2
Finely crystalline, massive bedded, grey limestone containing bands and lenses of grey chert 2 inches thick	120
Coarse, granular, grey limestone	56
Finely crystalline, cream-weathering, dark brown limestone	2
Coarse, granular, grey limestone with crinoid stems	100
Coarse, granular, massive, grey limestone with stringers and nodules of white-weathering, grey chert	11
Medium coarse, granular, grey limestone with bands and lenses of grey chert up to 3 inches thick	170
Very coarse, soft, granular, grey limestone; fossiliferous	8
Buff-weathering, coarse, granular, light brown limestone with a few bands of grey chert	120
Hard, finely crystalline, buff-weathering, brown limestone with fine layers of buff-weathering chert	3
Massive bedded, buff limestone with small bands of buff-weathering, grey chert	30
Total thickness of formation	4,988

OTHER SECTIONS

In only one of the other nine sections measured was a complete thickness of the Rundle formation obtained; but in two others only small parts of the formation were concealed. On the western flank of Flathead range at Corbin, 12 miles south of Crowsnest pass, a detailed section was carried from the top of the formation down through a thickness of 1,380 feet and an additional 500 feet or more of the underlying beds were observed to outcrop on an inaccessible cliff. The total thickness of the formation there in all probability approximates closely to that of the type section at Crowsnest pass.

In the Alberta areas a complete section was obtained on Morin creek in the Livingstone range and two almost complete sections in the Blairmore inlier. The Morin Creek section measured 1,623 feet and in addition there was measured 345 feet of shaly limestone beds which are believed to belong to the upper part of the underlying Banff shale formation. This is indicated by a correlation of the beds in this section with those exposed on the landslide scarp of Turtle mountain. The thickness of the Rundle formation there is about one-third the thickness of the formation in the Crowsnest section. The details of this section are given below. The Rundle formation exhibits such slight variation in character in the several Alberta sections that the Morin Creek section may be taken as representing them all. A partial section carried from the base of the formation exposed on the fault scarp of Turtle and Bluff mountains, upward to near the top of the formation, measured 1,550 feet. The uppermost beds were concealed by alluvium which floors the valley of Crowsnest river. Farther south on the western slope of the Blairmore inlier, on Drum and Byron creeks, sections were carried from the top of the formation downward as far as possible into the heart of the fold. The Drum Creek section measured 1,675 feet and the lowermost beds exposed are believed to lie within a few feet of the base of the formation. The Byron Creek section measured 1,500 feet.

Section of Rundle Formation on Morin Creek, near Lille, Alberta

	Thickness Feet
Overlying formation—Rocky Mountain Quartzite	
Concealed interval	100
Massive, dark grey, hard, finely crystalline limestone containing brachiopods	90
Concealed interval, largely fine-grained, light grey limestone	135
Hard, jointed, finely crystalline limestone	12
Concealed interval, largely finely crystalline and slabby limestone	65
Grey limestone with lenses and nodules of chert	3
Hard, fine-grained, light grey limestone	20
Light grey, creamy-weathering, finely crystalline limestone	2
Concealed interval, largely finely granular, crystalline limestone	13
Finely crystalline limestone with thin layers of chert	5
Finely crystalline limestone	25
Coarsely granular limestone	2
Hard, finely crystalline, and dark grey limestone with thin layers and stringers of chert	12
Concealed interval, largely coarsely crystalline limestone	180
Coarsely crystalline, in beds 2 feet thick	20
Hard, finely crystalline limestone with layers and lenses of black chert $\frac{1}{16}$ inch to 2 inches in thickness spaced 1 to 3 inches apart	10
Shaly, quartzitic, brown-weathering limestone containing numerous small brachiopods	15
Coarse, granular limestone	2
Shaly, quartzitic limestone with layers and lenses of chert	19
Massive, sandy limestone showing crossbedding and containing small brachiopods	4
Shaly, brown-weathering, quartzitic limestone	10
Thin-bedded, brownish, grey-weathering, finely crystalline limestone with a few chert nodules	85
Finely granular, light-weathering limestone with small nodules and veinlets of black chert in joint planes	10
Coarsely granular limestone	25
Hard, fine-grained, dark-weathering limestone with numerous lenses and thin layers of chert	50
Massive, coarsely crystalline, light grey-weathering limestone with large masses of white chert	25

	Thickness Feet
Fine-grained, light grey-weathering, crystalline limestone	35
Finely granular, light-grey weathering limestone with thin lenses of chert	60
Medium granular, light grey-weathering, thin-bedded, closely jointed limestone	35
Fine and coarse granular, light grey-weathering limestone	95
Hard, finely granular limestone with few thin lenses of chert	10
Fine-grained, closely jointed limestone having a rubbly structure	40
Hard, fine-grained, light-weathering limestone with thin streaks of creamy white-weathering chert	12
Concealed interval, largely soft, shaly limestone with bands of fine and coarse, granular limestone	130
Finely crystalline, light grey-weathering limestone	20
Coarse, granular, shaly, thin-bedded, light grey-weathering limestone	25
Massive, coarsely granular, light grey-weathering limestone containing numerous brachiopods	12
Soft, shaly, crossbedded limestone	15
Soft, coarsely granular limestone	15
Hard, fine-grained limestone	5
Soft, coarsely granular limestone	30
Fine-grained limestone	8
Soft, coarsely granular limestone containing numerous brachiopods and crinoid columns	6
Massive, coarse and finely granular limestone	12
Hard, fine-grained, light grey limestone with numerous corals near base	16
Soft, coarsely granular, thin-bedded, grey limestone	8
Hard, grey limestone with thin beds and lenses of chert	13
Hard, grey, shaly limestone with few chert nodules	15
Soft, coarsely crystalline, massive limestone with odour of hydrogen sulphide	8
Coarsely granular, light grey-weathering limestone	3
Hard, grey, finely crystalline limestone with numerous nodules of chert and few fossils	7
Grey, coarsely crystalline limestone with abundant nodules of cream-weathering chert and beds containing abundant crinoid columns, small brachiopods, and cup corals	25
Massive, crystalline, dark grey limestone with closely spaced, rectangular jointing normal to bedding and with few nodules of creamy-weathering chert; contains numerous crinoid columns and corals and has a metallic ring when struck with a hammer	24
Total thickness	1,623

GENERAL REMARKS

The Rundle formation consists of interbedded, finely crystalline, coarsely granular, and cherty limestones, many of which are dolomitic in character. Numerous fossiliferous horizons occur throughout the formation, and in this respect it is in marked contrast with the immediate underlying Banff shale formation in which fossils appear to be confined to a few horizons. An horizon abounding in corals and crinoid columns occurs near the base of the Rundle. Fossils were collected from a number of widely spaced horizons in several of the sections, and in all sections examined the conspicuous fossiliferous horizons were recorded. By means of these fossil horizons, chert beds, and limestone beds strongly impregnated with hydrogen sulphide, the different sections were correlated.

The abundant chert distributed through the formation in nodules, irregular-shaped lenses, thin beds, and laminæ, is thought to have been formed from colloidal silica derived from the land areas, and finally precipitated as gell-masses in the zone where the fresh land waters gave way to marine waters. The cherty beds indicate shallow water conditions and the chert-free limestones deep water conditions. The beds in the Alberta section appear to be considerably thinner than those in the Crowsnest section, which would suggest that the waters in which they were deposited were shallower.

The Rundle formation contains many beds that are heavily impregnated with hydrogen sulphide, which at Frank give rise to prominent sulphur springs. In none of the Rundle sections examined, however, were any beds observed that were likely to be source rocks for oil, and only a few of the coarsely granular limestones present appear to be sufficiently porous to serve as reservoir rocks. The finely crystalline and cherty limestone beds are, moreover, too impervious to permit of any migration of oil.

Rocky Mountain Quartzite

CROWSNEST PASS SECTION

Overlying the Rundle formation without any apparent break is a series of light grey, fine-grained, buff and brown-weathering quartzites measuring 1,118 feet in thickness. In the lower 900 feet of the formation no chert occurs, but it is quite conspicuously developed in the uppermost 200 feet. The formation is devoid of fossils, but on lithological character and stratigraphic position it is correlated with the Rocky Mountain Quartzite of Banff area and is presumably of Pennsylvanian age. The Crowsnest Pass section of the Rocky Mountain Quartzite is as follows.

Overlying formation—Triassic? formation	Thickness Feet
Hard, light grey quartzite with bluish-weathering, large nodules of grey chert	54
Hard, buffish-weathering, light grey quartzite	51
Light grey, massive-bedded, buff-weathering quartzite, with nodules of blue chert	12
Light buff to grey-weathering, massive bedded, hard, compact, grey quartzite	68
Pinkish grey quartzite containing nodules of bluish chert	10
Light grey-weathering, pinkish grey quartzite, jointed	180
Hard, grey quartzite weathering brown and black	160
Pinkish brown, grey-weathering quartzite	84
Concealed interval	450
Light grey, fine-grained, brown-weathering quartzite containing large grey and black chert nodules up to 18 inches in diameter and beds of grey chert up to 3 inches in thickness	41
Soft, light yellowish brown, fine-grained, limy shale	2
Grey, fine-grained, limy quartzite with a few chert nodules	6
Total thickness	1,118

OTHER SECTIONS

The Rocky Mountain Quartzite formation was examined at eight other localities, one 12 miles south of Crow's Nest at Corbin, B.C., and seven about 15 miles east in Alberta. The thickest of the Alberta sections is only about a quarter as thick as those in British Columbia.

The Rocky Mountain Quartzite section at Corbin measured 1,028 feet in thickness. It is as follows.

Overlying formation—erosional contact with Fernie formation	Thickness Feet
Thin, slabby, light brown, medium-bedded, coarse-grained quartzite....	240
Light grey-weathering, pinkish grey, coarse quartzite....................	316
Grey, pink-weathering, massive quartzite..............................	108
Fairly coarse, buff, grey-weathering quartzite..........................	250
Pinkish grey quartzite..	24
Buff-weathering quartzite with lower foot pitted.........................	3
Coarse, light buff and grey quartzite..................................	26
Very fine-grained, light buff quartzite with lenses and nodules of purple, black, and grey chert...	45
Light brownish, grey quartzite containing a little white chert...........	16
Total thickness......................................	1,028

The Rocky Mountain Quartzite beds observed on the Blairmore inlier consist of the lowermost 70 feet of the formation, the upper part being concealed by boulder clay or alluvium. These sections are on the valley slopes of Drum and Byron creeks and are made up largely of pinkish quartzite.

In the Livingstone range most of the Rocky Mountain Quartzite formation is exposed. It is considered here to embrace the whole series of beds lying between the uppermost observed beds of the Rundle formation and the thin conglomerate which is taken as marking the base of the Jurassic. The maximum thickness present is estimated at 341 feet. Sections of the formation were measured on the valley slopes of Rock creek, Green creek, Morin creek, and Caudron creek, but in every case, either the bottom or the top of the formation was concealed. Certain definite horizons, such as a characteristic porous quartzite bed observed in all the sections, made possible a correlation of these sections and a determination of the thickness of the formation which is believed to be accurate. The type section of the formation in Blairmore area is that exposed on the valley slopes of Rock creek. It consists of the following.

Overlying formation—erosional contact with Fernie formation	Thickness Feet
Massive bedded, dark grey, reddish-weathering, coarse quartzite with nodules of grey and black chert....................................	30
Grey quartzite with bands of white chert ½ to ¾-inch thick, bedded........	12
Massive bedded, light grey, coarse, buff-weathering quartzite containing an occasional nodule of white chert................................	35
Massive, rough, honeycombed, grey quartzite..........................	4
Massive bedded, light grey quartzite weathering pinkish grey...........	15
Massive, grey quartzite with nodules and thin beds of white chert.......	20
Fine-grained, grey, limy quartzite......................................	25
Largely limy quartzite..	200
Total thickness......................................	341

GENERAL REMARKS

None of the Rocky Mountain Quartzite sections examined contains any beds at all likely to prove source rocks of oil, and with the exception of a pitted quartzite bed all are too firmly cemented to be oil reservoirs.

Triassic Formation

CROWSNEST PASS SECTION

Overlying the Rocky Mountain Quartzite in the Crowsnest section is a thickness of 350 feet of massive, brownish, sandy quartzites and thin, shaly sandstones. These beds are devoid of fossils and their age is doubtful. They differ in lithological character from the underlying quartzites, but lie conformably upon them with no appearance of an erosional contact. On their lithological resemblance to beds in the Spray formation of Banff area and their similar stratigraphic position, they are for the present correlated with them and placed in the Triassic. It is not improbable, however, that they represent the lowermost beds of the Fernie formation as they merge imperceptibly into the phosphatic beds which contain a lower Jurassic fauna.

At no other locality were beds of presumably Triassic age noted, and if such occur they have been grouped in with the Rocky Mountain Quartzite formation of Pennsylvanian age.

The section of the so-called Triassic beds occurring below the phosphate deposit at Crow's Nest is as follows.

Overlying formation—Fernie formation	Thickness Feet
Fine, brown, buff-weathering quartzite becoming greyish brown toward the top	250
Concealed interval, largely brownish, shaly sandstone and shaly quartzite	90
Massive, brownish, sandy quartzite becoming a black quartzite toward the top	10
Total thickness	350

Fernie Formation

CROWSNEST PASS SECTION

Overlying the so-called Triassic beds conformably in the Crowsnest Pass section and unconformably overlying the Rocky Mountain Quartzite in the other sections examined, occurs a thick series consisting largely of marine, black and grey shales. The base of the formation is characterized at some localities by a deposit of calcareous phosphate and at other localities by a basal conglomerate. The formation grades upward so imperceptibly into the overlying, freshwater, Lower Cretaceous Kootenay beds that it is difficult to draw the line where one formation ends and the other begins. At present the boundary between the Fernie and Kootenay formations is drawn at the base of the lowest, massive, sandstone bed. There are, however, beneath this massive bed a series of fine-grained, thin-bedded sandstones, and non-marine shales which record the transition from the estuarine conditions of the closing stage of the Jurassic to the freshwater sedimentation of the coal-bearing Lower Cretaceous formation. These beds have been referred to by McLearn as the "Passage Beds."

The Fernie formation forms the rim of the Crowsnest coal basin, but owing to the soft nature of these sediments they almost everywhere occupy areas of low relief, and are largely concealed by boulder clay and alluvium. No detailed complete section of the formation was obtained. Its thickness in the Crowsnest section is estimated at approximately 3,000 feet and this is checked by a series of measurements of the formation 10 miles south along the strike near Corbin, which gave a maximum thickness of 2,800 feet. Sufficient of the formation, however, was observed at both localities to be certain of its general character, and to establish the fact that the lithological character changes within comparatively short distances. A comparison of the sections in Crowsnest area with those of Blairmore area also indicates that the formation thins rapidly to the east, and that it presents varying unconformable relations with the underlying formations. The formation is fossiliferous throughout.

In the examination of the Jurassic beds of the district attention was mainly directed to the basal portion of the formation, as it presented evidence of being the most important zone of all the horizons examined with respect to oil possibilities. It contains what is believed to be both the main possible source rock of oil in the district and sands which would possibly serve as oil reservoirs.

The basal horizon of the Fernie in the Crowsnest Pass section is a phosphate deposit which appears to lie conformably upon the buff-weathering, brown quartzite of so-called Triassic age. This deposit has its greatest observed development at what is known as the Consolidated Mining and Smelting Company's phosphate mine, 1½ miles northwest of Crow's Nest station. The deposit has been opened up by a tunnel driven along the bed for over 3,000 feet. It varies in thickness from 2 to 15 feet, and is separated from the overlying greyish brown, marine shales by a soft layer of calcareous clay seldom more than 1 inch thick. The phosphate deposit is made up of two benches separated by a 2 to 4-inch layer of soft, dark grey shale. The upper bench, where measured, has a thickness of 3 feet 6 inches, and is composed largely of nodular phosphate in a groundmass of the same material. The majority of the nodular forms range from small, pea-like spheres to irregular, pear-shaped masses up to an inch in maximum diameter and 1½ inches in length. Some of the forms are disk-like in appearance and show on the upper surface as coiled spirals comprising several whorls. The largest of these forms observed was on the wall of the mine tunnel, but was so compact that it could not be removed. It had a diameter of 6 inches, and resembled closely an ammonite. It had three whorls, the individual coil being about an inch in width and standing about half an inch above the general surface. The lower bench where measured is 2 feet 6 inches in thickness and is composed of finer grained and more calcareous material in which in places an oolitic texture is developed.

The deposit is well exposed in an open-pit and prospect slope 1,000 feet south of the mine mouth. Here it has a thickness of 15 feet due to repetition of beds by several thrust faults of small displacement. The phosphate bed consists of a hard, black, calcareous rock which, traced along the strike, is found in places to be so diluted with sediment as to approach a quartzite or a shale. In the shale lenses are elongated concretions ranging up to 2 feet in length and 6 inches in diameter, composed of the same black, compact rock that makes up the shale bed. The calcareous rock is cut by thin veinlets of calcite, most of which start from the remains of calcareous organisms, principally Gryphæa, which were observed to be abundant in the deposit. These fossils were determined by McLearn to be of Jurassic age. The shales for at least 15 feet above the phosphate horizon are of a sandy nature. They are oil stained and give off a strong petroliferous odour. Samples of this shale tested in the laboratory confirm the presence of oil. The beds immediately above this zone are concealed by alluvium so that it was not possible to observe how much higher in the section the oil staining occurred.

This phosphate horizon has been prospected by the Consolidated Mining and Smelting Company at several widely spaced localities on the rim of the Fernie coal basin and at a number of isolated occurrences in Blairmore district, which will be referred to later. It is of interest to note here that a large ichthyosaurian marine reptile was found in what is believed to be the same horizon in the Fernie formation, on the opposite side of the Fernie coal basin, at a locality a mile north of Morrissey. The rock in which this fossil reptile occurs gives off when struck a strong odour of phosphorous similar to that obtained from the phosphate rocks at Crowsnest lake.

On the east side of the Corbin highway, 5·6 miles south of McGillivray station, the phosphate horizon has been opened up by a prospect tunnel. There the deposit has a thickness of only 18 inches. In it occur numerous Gryphæa similar to those found in the Crowsnest deposit. At Corbin no phosphate could be found and the base of the Fernie is characterized by a bed of conglomerate.

For a description of the Fernie formation at Corbin the reader is referred to a report on the Corbin Coal Field, British Columbia.[1]

OTHER SECTIONS

The best section obtained on the rim of the Blairmore inlier is that which is partly exposed in the cutting of an abandoned railway in the valley between Bluff and Grassy mountains. The series consists mainly of marine shales and sands with a 6-foot calcareous bed of grit lying 100 feet from the base, and a thin chert conglomerate at the base. This section was examined in detail by McLearn in 1914 and 1915 and forms his type section. Owing to faulting and an alluvium cover it is impossible to determine the exact thickness of the formation, but including McLearn's passage beds, estimated by him to be 180 feet in thickness, the total thickness of the formation is estimated at about 900 feet.

A detailed section of the lower part of the Fernie formation was obtained on the valley slopes of Rock creek. This section is of special interest as it shows the same association of petroliferous sands and phosphate beds and the presence in the phosphate of the same *Gryphæa* fauna as occur at Crowsnest lake. The section is as follows:

	Thickness	
	Feet	Inches
Fissile, fine-bedded, brown-weathering shale	26	
Light brown-weathering, dark grey, limy shale	1	
Dark brown, fissile shale with 1-inch bands of an ochre weathering shale.	12	
Light brown-weathering, calcareous shale	1	
Brown, fissile shale weathering rusty brown and black	14	
Dark grey, limy shale weathering light grey and rusty brown	1	
Dark brown, fissile shale weathering yellowish and black	30	
Dark grey, brownish weathering, hard, calcareous shale in beds 1 to 6 inches thick; has a bituminous odour	72	
Thin-bedded, hard, platy, blackish brown shale, iron stained in places and with a very strong petroliferous odour; belemnite horizon occurs 12 feet from the top	38	

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[1] MacKay, B. R.: Geol. Surv., Canada, Sum. Rept. 1930, pt. A, pp. 154-179.

	Thickness	
	Feet	Inches
Phosphate deposit; contains *Gryphæa* similar to those in Crowsnest deposit	1	3
Dark grey, massive quartzite, weathering light to yellowish grey and having a bituminous odour	4	
Thin-bedded, fine-grained, buff-weathering, limy shale	3	
Fairly massive, bedded, light grey-weathering, limy or quartzitic shale with petroliferous odour	9	
Thin-bedded, platy, reddish-weathering, grey, limy, or quartzitic shale	4	
Thin-bedded, blocky and platy, buff-weathering, grey, calcareous quartzite	19	
Massive bedded, light buff-weathering, limy quartzite with grey and buff markings on fresh fractures	5	
Buff-weathering, grey, calcareous quartzite	4	
Massive-bedded, buff-weathering, calcareous quartzite; has a petroliferous odour	3	
Conglomerate composed of irregular, angular fragments and pebbles of chert, quartzite, and limestone	2	
Total measured thickness	249	

GENERAL REMARKS

The basal part of the Fernie formation, especially where the phosphate beds are present, is sufficiently impregnated with oil to be stained dark and to give off a strong petroliferous odour. This horizon is the only important petroliferous zone observed in the numerous sections examined.

The close relationship between oil-impregnated sands and the presence of phosphate beds is not confined apparently to Crowsnest district. The same relationship appears to hold in Banff and Turner Valley areas, where both phosphate deposits and oil indications occur at a little lower stratigraphic horizon at or near the top of the uppermost Palæozoic sediments.

Kootenay Formation

The Fernie marine shales grade so imperceptibly upward into the freshwater, coal-bearing, Kootenay sediments of Lower Cretaceous age that it is impossible to determine where the Fernie stops and the Kootenay begins. This indicates that the change from marine to freshwater conditions proceeded without any interruption of sedimentation. The boundary between the two formations is commonly drawn at the base of the lowest massive sandstone bed. The Kootenay formation is of special economic importance in that it contains all the commercial coal seams of Lower Cretaceous age in the district. It was examined at several localities in both Blairmore area and Crowsnest area of British Columbia. In the former it was found to carry a maximum of five coal seams, and to vary in thickness from 400 feet at Hillcrest to about 600 feet at Coleman. It also varies considerably from place to place in the succession of strata and the thicknesses and positions of beds between coal seams. Part of the variation in thickness is due to erosion of the Kootenay sediments before the Blairmore formation was deposited, but most of it is attributed to variations in deposition. One of the best sections in Blairmore district is that which outcrops south of Crowsnest river at Blairmore. This section was measured by Rose in 1915 and is given here as illustrative of the nature and succession of the Kootenay sediments in the area. It is as follows.

	Thickness Feet
Overlying formation—Blairmore (conglomerate at base)	
No. 1 coal seam missing but present under the conglomerate 1½ miles to the north, where it has a thickness of 10 to 18 feet.................	
Massive, coarse-grained, and crossbedded, grey sandstone with prostrate fossil stems and bits of coal..	39
Coal, No. 2 seam..	15
Dark shale..	55
Sandstone, dark grey, crossbedded..	14
Shale, black, fissile with a few sandy layers............................	25
Coal, No. 3 seam..	2
Shale, black, sandy, and carbonaceous layers with little layers of coal....	81
Coal, No. 4 seam..	4
Black shale...	3
Coal..	2
Black shale...	3
Sandstone, coarse and crossbedded..	37
Shale and small coal seams..	70
Massive, grey sandstone, approximately..................................	100
Below is thin-bedded sandstone and shale assigned to the Fernie formation	
Total thickness..	450

The Kootenay formation in southeastern British Columbia has the same general character as in Blairmore area, but the beds are more massive and there is a larger percentage of sandstone and chert conglomerate in the formation and the coal seams are thicker and more numerous. In Flathead River basin and Elk River basin the formation has a thickness of 1,800 feet. At Sparwood the thickness is estimated at 2,050 feet and at the southwestern extremity of the basin it is over 4,000 feet. The sediments include an average of twenty-three coal seams having a total thickness of 170 feet. A section measured by the writer at Coal creek approached the maximum thickness. The formation there consists of grey and brown sandstones, carbonaceous shales, lenses and beds of chert conglomerate, and coal seams. The conglomerate beds range up to 20 feet in thickness.

GENERAL REMARKS

The freshwater character of the Kootenay sediments prohibits the possibility of their containing important source rocks of oil. Porous sandstone beds admirably suited for reservoir sands occur throughout the formation. Although there appears no possibility of obtaining oil in commercial quantities from the Kootenay formation in this region it is of interest to note that the coal seams contain considerable gas and other volatile hydrocarbons. Thus considerable quantities of methane gas have been issuing continuously for several years from a bore-hole at Hillcrest station put down by the Hillcrest collieries. This tapped the uppermost coal seam of the Kootenay measures lying at the Blairmore-Kootenay contact at a depth of 1,100 feet. The gas issues in such quantity that it can be lighted a foot or more above the ground. Large quantities of gas are also given off in most of the coal mines of the district, especially where minor faulting or folding has taken place. Moreover, a small quantity of oil of 45° Baumé gravity was collected during the past summer from the roof of No. 2 coal seam at Coleman, in the mine being operated by the International Coal and Coke Company. Whether this oil originated in the shale roof or was driven from the coal by dynamo-chemical action was not determined. It appears as if a certain amount of oily matter is indigenous in the coal seams of Crowsnest area, since numerous, small, circular, iridescent films or scales of what is thought to be an oil residue occur on closely spaced joint planes in the coals being mined both from No. 2 seam, Coleman, and No. "B" seam, Michel. This oily matter appears to have been part of the volatile constituent in the coal driven off during the metamorphism of the coal and lodged among the closely spaced joint planes developed at the same time.

Blairmore Formation

The Blairmore formation overlies the Kootenay, It consists of massive, crumbly, sandy shales of various colours, including green, grey, brown, red, and black, interbedded with minor amounts of massive, soft, greenish grey, coarse-grained and shaly sandstones. There are occasional thin beds of ironstone and at least one rather persistent bed, 10 to 15 feet thick, of bluish grey, shaly limestone which in places is fossiliferous. In the eastern part of the area it lies within a hundred feet of the base of the formation, but in the western part, the interval is much greater. The base of the formation is marked by a massive bed of cherty conglomerate or coarse, cherty sandstone. This conglomerate or its sandy equivalent is designated the Blairmore conglomerate. In the eastern part of Blairmore district, it is a massive, 20-foot bed of coarse, white, cherty sandstone. In the vicinity of Hillcrest and Bellevue, small lenses of chert pebbles appear. As the mountains are approached both the lenses and constituent pebbles become larger and more numerous until finally at Coleman the bed forms a prominent ridge of massive conglomerate with pebbles the size of hens' eggs. The thickness of the Blairmore formation ranges from 2,100 feet at the eastern outcrop to 3,000 feet at the outcrop west of Coleman. The Blairmore formation is represented in the Crowsnest coal basin of southeastern British Columbia by a series of conglomerates, sandstones, and shales designated the Elk River Conglomerate formation. This is estimated to have a thickness of over 6,000 feet.

The most complete section of the Blairmore formation obtained in Blairmore area was a partial section measured along Byron creek, reaching from the base of the formation up to within 200 feet of the top. The overlying concealed beds outcrop on the hill slope west of Hillcrest, and consist of green, shaly sandstones becoming coarse, gritty, and massive towards the top. North and east of Hillcrest the top of the formation is marked by a thick bed of conglomerate. A composite section of the formation at Hillcrest, where it has an estimated thickness of 2,316 feet, is as follows.

Byron Creek Section

	Thickness Feet
Overlying formation—Crowsnest volcanics	
Coarse, grey-green, massive sandstone becoming shaly towards base.....	180
Green sandstone, interbedded with buff-weathering, green shale..........	215
Green, sandy shale, massive bedded in places; in part concealed..........	211
Green, shaly sandstone and shale, in part concealed......................	130
Light brown, buff-weathering, sandy shale...............................	43
Interbedded green shale and sandstone, iron stained in places............	135

	Thickness Feet
Coarse, grey sandstone with bands of ironstone 18 feet from top	100
Green shale	15
Crumbly, green shale with a few bands of ironstone and green-grey sandstone	43
Green, sandy shale	21
Fine-grained, green sandstone	12
Green, crumbly shale in places heavily stained with iron	40
Green, shaly sandstone and shale, iron stained	27
Fine-bedded, green, shaly sandstone and some shale	36
Grey-green, shaly sandstone with some coarse, grey sandstone	27
Grey-green sandstone	17
Hard, black shale	1
Grey, shaly sandstone	14
Green sandstone and shale; contains a 4-foot bed of grey ironstone	250
Concealed	65
Green, sandy shale	15
Concealed	20
Grey-green, fine sandstone	20
Finely bedded, olive-green shale	43
Massive, grey-green sandstone	1
Green-weathering, grey, sandy shale	7
Light grey sandstone with layers of grey to black, sandy shale	10
Grey weathering, brown to black shale	7
Massive, green sandstone	10
Fine-grained, green sandstone with layers of green, sandy shale	70
Green sandstone with carbonaceous material, weathers buff	13
Compact, brown and green shales weathering red	29
Green, compact, sandy shale weathering rusty red	23
Green, shaly sandstone with ironstone concretions	10
Green, sandy shale	8
Grey to green, coarse sandstone	8
Green-grey, sandy shale	10
Fine-grained, green, sandy shale	5
Fine-grained, light buff-weathering, green sandstone	4
Green shale	29
Fine-grained, green sandstone, with ironstone concretions	8
Green weathering, black shale	8
Thin-bedded, green sandstone	4
Very compact, dark grey argillite; weathers red-brown	3
Fissile, green-weathering, grey shale	10
Coarse, green sandstone	4
Black shale with green sandstone lenses	20
Light grey, finely bedded, shaly sandstone	11
Compact, argillaceous limestone	10
Black shale	5
Concealed	69
Light grey, coarse sandstone	50
Concealed, largely green shale, 15-foot limestone bed	170
Massive, coarse, grey, cherty sandstone (Blairmore conglomerate)	20
Total thickness of formation	2,316

GENERAL REMARKS

No oil-stained sediments, or beds possessing a petroliferous odour or other suggestions of oil, were observed in the Blairmore sections examined. The beds that most likely would be source rocks of oil are the 5- to 15-foot argillaceous limestone beds in the lower part of the formation, but these beds appear to be of freshwater origin. One of them is persistent over a large part of Blairmore area and although not of a petroliferous character there, may prove to be so beyond the area examined. There are numerous thick beds of coarse sandstone throughout the Blairmore formation which would serve as reservoir sands should oil be present.

PALÆOZOIC-MESOZOIC CONTACT

Throughout most of Crowsnest district the base of the Fernie formation is marked by a conglomerate bed which lies upon quartzite beds of the Rocky Mountain Quartzite. The only observed section in which this was not the case was the Crowsnest Pass section at the phosphate mine, and there the age of the 350 feet of shales and sandstones immediately underlying the Fernie is in doubt. At Corbin a solitary outcrop of the basal Fernie conglomerate is exposed on the crest of the ridge 2,200 feet northeast of the townsite. The conglomerate there is composed of irregularly shaped boulders of quartzite, chert, and dolomitic limestone ranging up to 3 inches in diameter, firmly cemented in a quartzite base. The mantle of boulder clay which surrounds this small outcrop prevents a determination of the attitude and thickness of the bed, and the character of the contact. The conglomerate is approximately 10 feet thick and overlies quartzitic beds considered to be the top of the Rocky Mountain Quartzite which there has a thickness of 1,020 feet.

The basal conglomerate of the Fernie formation was observed also to outcrop on Rock creek north of Bellevue and on the north end of Bluff mountain. In both localities it is about 2 feet thick and is composed of angular pebbles and irregularly shaped fragments of quartzite, limestone, and chert, firmly cemented in a cherty base. The pebbles range up to 2 inches in diameter and show very little evidence of having been transported any great distance. The conglomerate resembles a breccia in which irregularly shaped fragments derived from a weathered surface of the Rocky Mountain Quartzite and the underlying Rundle limestone have been re-cemented by siliceous material derived from the weathered cherty beds. The Rocky Mountain Quartzite here has a thickness of 341 feet, and is believed to be of Pennsylvanian age. McLearn,[1] who made an exhaustive study of the Mesozoic fauna of Blairmore area, places the beds in the Lower, and possibly Middle, Jurassic. If this is so it means that a considerable hiatus exists between the lowermost Jurassic bed sand the underlying Palæozoic beds, the interval including part of the Lower Jurassic, all the Triassic. and possibly all of Permian times.

KOOTENAY-BLAIRMORE CONTACT

The top of the Kootenay in Blairmore district is drawn at the base of a massive, chert conglomerate represented in the eastern part of the area by a coarse, cherty sandstone, and designated the Blairmore conglomerate. This conglomerate normally lies directly upon the uppermost coal seam of the series, locally known as seam No. 1. Development work has shown, however, that in places the conglomerate is separated from the seam by a lens of sandstone ranging up to 4 feet in thickness. It was commonly thought that seam No. 1 was co-extensive with the Kootenay formation, but prospecting and mining development carried on over much of the district during the past twenty odd years have demonstrated that such is not the case, and that extensive Kootenay areas occur in which

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[1] McLearn, F. H.: Geol. Surv., Canada, Mus. Bull. 58, p. 101.

seam No. 1 is missing. In fact, within the Blairmore map-area, seam No. 1 is present in workable thicknesses on only three of the ten Kootenay segments that outcrop and along only a fraction of their lengths. The segments on which the seam is present are the two limbs of the Blairmore inlier and the western limb of the Livingstone Range fold. On the western limb of the Blairmore inlier the seam has been found to extend for a distance of only 2½ miles lying to the north of Blairmore. On the eastern or Hillcrest side of this inlier it is thought to extend for a maximum distance of about 5 miles and on the western limb of the Livingstone range it extends from Bellevue north to a little beyond Frank, a distance of 4 miles. Where the seam is present it varies in thickness from 3 to 17 feet. This variation in thickness may be attributable to variation of the vegetable accumulation in the original peat bog, but certain facts point to No. 1 seam as having been far more extensive than now and suggest that this variation in thickness and the absence of the seam in places are due to subsequent erosion. Thus, in prospecting for the seam, small, isolated patches of it were found at a number of localities immediately underlying the conglomerate. Such patches of No. 1 seam occur in the West Canadian Collieries property immediately to the north and south of Blairmore, on the Mutz segment 1 mile southwest of Blairmore, and at the Maple Leaf mine a mile east of Bellevue. The irregularities in the top of the Kootenay formation, combined with the occurrence of a massive conglomerate bed immediately overlying it, tend to support the view that an erosional unconformity representing a considerable interval of time occurs at the top of the Kootenay formation. This conglomerate has been observed to extend from this area northward to Bow river. The unconformity was referred to by McLearn[1] who is of the opinion that the hiatus represented by the disconformity between the Kootenay and Blairmore formations in Blairmore district may represent a large portion of Lower Cretaceous time.

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[1] McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1915, p. 112.

STRATIGRAPHY AND STRUCTURE OF THE EASTERN PORTION OF THE BLOOD INDIAN RESERVE, ALBERTA

By Loris S. Russell

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INTRODUCTION AND ACKNOWLEDGMENTS

An intensive program of test drilling by the Associated Securities, Limited, and the Commonwealth Petroleum, Limited, in the Blood Indian reserve near Lethbridge, Alberta, has resulted in the accumulation of important data on the stratigraphy and structure of this region. In co-operation with these investigations the writer undertook a survey of the sections exposed along Oldman and St. Mary rivers, which form the eastern boundary of the reserve. Six weeks were spent in the vicinity of Lethbridge, principally in making plane-table traverses of the rivers. In this work the writer was ably assisted by G. K. Lowther. The cores of a number of test-holes, preserved at Calgary, were studied with the permission of the Commonwealth Petroleum, Limited. Mr. C. E. Michener, of that company, kindly supplied data on the location and elevation of these holes. The logs of two test borings on the east side of Oldman river (designated A and B on the accompanying Figures 4 and 5) were furnished by the Texas Company of Canada, Limited. Col. F. M. Steel, of the Supervisory Mining Engineer's Office, Department of the Interior, Calgary, placed the facilities of his office at the writer's disposal.

The area under discussion occupies about 260 square miles, and may be defined as that portion of the Blood Indian reserve (No. 148) in tps. 5 to 9, ranges 21 to 23, W. 4th mer. It is bounded on the west by the west side of range 23, on the north by Belly river, and on the east by Oldman and St. Mary rivers, the latter stream closing the area on the south. In addition, a narrow strip bordering the reserve on the east and south is included, as well as a considerable area along Oldman river, north of the Belly. The district is treated in the general reports of Dawson[1] and of Williams and Dyer.[2] Recently the Alberta Society of Petroleum Geologists has published a series of papers dealing with the stratigraphy of southern Alberta. The most important of these in connexion with the present study is that by T. A. Link and A. J. Childerhose,[3] which describes the detailed stratigraphy of the Bearpaw formation near Lethbridge.

STRATIGRAPHY

BELLY RIVER SERIES

The only rocks of this subdivision outcropping within the area here discussed are those belonging to the so-called Pale beds, which form the upper part of the Belly River series. The "Pale" beds are of Upper Cretaceous age, belonging to the Montana group, and represent a portion of the Upper Senonian in the European standard section. The sediments of the "Pale" beds are mostly light grey, and greenish grey, argillaceous sandstones, with irregular horizons of brown concretions. The remains of freshwater molluscs, as well as an occasional dinosaur bone, may be found in these rocks. Toward the top, lenses of hard, massive sandstone occur, or there is a gradual transition upward to the Lethbridge coal member, which forms the upper part of the "Pale" beds. This coal-bearing zone, besides its importance as a source of good bituminous fuel, is of value as an horizon marker, because it underlies most of the region. The member contains numerous beds of coal and carbonaceous shale, at least one of which usually exceeds 3 feet in thickness. Passing upward through the coal member the interbedding material changes from sandstone and sandy shale to dark grey shales that appear indistinguishable from those of the overlying Bearpaw formation. Near the juncture of St. Mary and Oldman rivers the uppermost coal seam usually is overlain by a coquina bed, 0·3 to 11·5 feet in thickness, of *Ostrea subtrigonalis* Evans and Shumard. In legal subdivision 3, sec. 7, tp. 7, range 21, W. 4th mer., the same horizon is occupied by a small but rich lens of *Cyrena occidentalis* Meek and Hayden.

BEARPAW FORMATION

This is the most extensively developed and abundantly exposed formation in the area. The typical Bearpaw sediment is a rather dark grey, friable or fissile shale, with weather stains of red, blue, or yellow. Beds of sandy shale or true sandstone are not uncommon. Numerous bentonitic beds, varying in thickness from mere streaks to 2-foot zones, are distributed throughout the section. These have a surprisingly wide lateral distribution and make excellent horizon markers. Zones of reddish ferruginous concretions are common, but very lenticular. Numerous marine molluscs occur in the shale, the commonest in this area being the following.

Gervillia borealis Whiteaves; *Arctica ovata* (Whiteaves); *Placenticeras meeki* Boehm; *Baculites compressus* Say.

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[1] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1882–4, pt. C, pp. 1–169 (1884).
[2] Williams, M. Y., and Dyer, W. S.: Geol. Surv., Canada, Mem. 163 (1930).
[3] Bull. Am. Ass. Pet. Geol., vol. 15, pp. 1227–1242 (1931).

No macroscopic fossils were found to be restricted to any one horizon, although *Gervillia borealis* was observed to occur most abundantly in the lower 100 feet of the formation. A rich bed of *Arctica ovata* is present about 260 feet above the Lethbridge coal member. Remains of Foraminifera, Echinoidea, and Ostracoda also occur in the Bearpaw shale; the specimens collected by the writer are being studied by Mr. R. T. D. Wickenden.

The Bearpaw formation, like the underlying "Pale" beds, is of Montana and Upper Senonian age.

The detailed section of the formation in this area has been described by Link and Childerhose,[1] and the present writer's studies confirm in all essentials the work of these authors. Their section, however, is somewhat composite.

It is proposed here to describe in detail the excellent section exposed on St. Mary river, and to compare with it the various data obtained from other outcrops, and from well cores.

Section on St. Mary River, in Tps. 6 and 7, Ranges 22 and 23, W. 4th mer.

Remarks	Material	Thickness feet
Base of Blood Reserve sandstone	Interbedded sandstone and shale	4
Top of Bearpaw	Shale, somewhat sandy, grey and grey-brown	8
	Shale, fissile or friable, grey	10
	Shale, bentonitic, light greenish grey	0·1
	Shale, friable, grey	3
	Shale, sandy, soft, grey-brown	1·5
	Shale, friable, grey, with concretions	6·5
	Concealed	10
	Shale, somewhat carbonaceous, fissile, grey-brown	12
Ryegrass member	Shale, somewhat sandy, friable, grey-brown and grey, with calcite veins	11
	Shale, concretionary, grey-brown	0·5
	Shale, grey and brown, somewhat sandy, friable	8
	Shale, concretionary, grey-brown	0·5
	Shale, sandy, friable, grey-brown, with concretions	7
Bentonite No. 14	Shale, bentonitic, friable, grey-green	0·2
	Shale, friable, grey	12·5
Bentonite No. 13	Shale, bentonitic, friable, grey-green	0·3
	Shale, rather compact, dark grey	3
	Shale, yellow-streaked	0–0·1
	Shale, friable, grey, with thin concretionary bands	40
	Concretions, hard, crossbedded, grey-brown	0·5
	Shale, friable, grey	8
	Concretions, rusty brown	0–3
	Shale, grey, with concretions	55
Bentonite No. 12	Shale, bentonitic, friable, greenish grey	0·5
	Shale, fissile, grey	11
	Shale, bentonitic, greenish grey	0·04
	Shale, friable, grey	4
	Shale, somewhat sandy, friable, grey-brown, with concretions	5
	Shale, bentonitic, friable, pale yellow	0–0·1
	Shale, friable, grey-brown, somewhat sandy in places	8·5
	Concretions, grey-brown	0–2
	Shale, friable, grey and grey-brown	15·5

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[1] Bull. Am. Ass. Pet. Geol., vol. 15, pp. 1227–1241 (1931).

Section on St. Mary River, in Tps. 6 and 7, Ranges 22 and 23, W. 4th mer. —Continued

Remarks	Material	Thickness feet
Bentonite No. 11	Shale, very bentonitic, pale buff	0·2
	Shale, friable, grey and grey-brown	5
	Concretions, grey-brown	0–2
	Shale, friable, grey and grey-brown	21
	Shale, bentonitic, light grey	0–0·05
	Shale, sandy, soft, friable, grey-brown	3–4
	Shale, friable, grey and grey-brown, somewhat sandy at top	5
	Shale, bentonitic, pale buff	0–0·1
	Shale, friable, grey, somewhat sandy and brown in places.	14
Bentonite No. 10	Shale, bentonitic, light greenish grey	0·2
	Shale, grey, friable	1·5
	Shale, somewhat bentonitic, grey-green	0–0·2
	Shale, friable, grey	4
Bentonite No. 9	Shale, bentonitic, friable, light greenish grey	0·5
	Shale, rather sandy, grey and brownish grey, with fossiliferous concretions	12
Bentonite No. 8	Bentonite, friable, light greenish grey	0·7
	Shale, friable or fissile, fossiliferous, grey	15
Bentonite No. 7	Bentonite, pale greenish grey	0·5
	Shale, fissile, grey, with fossils and concretions	5
Kipp member	Shale, sandy, friable, grey-brown	2·5
	Concretions, rusty brown	0·5
	Shale, sandy, friable, grey-brown	5
	Concretions, rusty brown	1–2
	Shale, sandy, rather soft, friable, brownish grey, with fossiliferous concretions and scattered nodules; transitional below	20
	Shale, friable, brownish grey to grey, somewhat sandy in places; fossiliferous concretions	62
Bentonite No. 6; "D" of Link and Childerhose.	Bentonite, light greenish grey	0·3
	Shale, friable, grey	1
	Bentonite, light greenish grey	0·2
	Shale, fissile or friable, grey, with concretions	22
	Shale, bentonitic, light grey	0–0·2
	Shale, fissile, grey, with concretions	13
	Fossil bed, *Artica ovata*	0·1
	Shale, fissile, grey, fossiliferous	15
Magrath member	Shale, sandy, soft, grey-brown	3·5
	Concretions, rusty brown, fossiliferous	0–0·5
	Shale, sandy, soft, grey-brown	3
Bentonite No. 5	Shale, bentonitic, especially in lower portion, light greenish grey	2
	Shale, fissile or friable, grey, fossiliferous, with concretions.	55
	Concretions, rusty brown	0–2
	Shale, fissile or friable, grey, with concretions	18
	Concretions, rusty brown	0–1
	Shale, sandy, grey, friable	2
Bentonite No. 4; "B" of Link and Childerhose.	Shale, bentonitic, pale greenish grey	0·5
	Shale, fissile or friable, grey	12
	Concretions	0–1
	Shale, bentonitic, pale grey-buff	0·1
	Shale, grey	7
	Concretions	0–1
	Shale, fissile, grey	5
Bentonite No. 3	Bentonite, pale greenish grey, usually with shale parting in lower portion	0·2
	Shale, friable, grey	3
	Shale, bentonitic, grey and yellow	0·05
	Shale, fissile or friable, grey, with concretions	7
	Shale, bentonitic, light greenish grey	0·1

Section on St. Mary River, in Tps. 6 and 7, Ranges 22 and 23, W. 4th mer. —Concluded

Remarks	Material	Thickness feet
	Shale, fissile or friable, grey, with concretions and fossils...	38
	Concretions, rusty yellow	0-2
	Shale, grey	1
Bentonite No. 2	Bentonite, light grey	0·1
	Shale, fissile or friable, grey	19
	Concretions, dark reddish brown	0-1
	Shale, fissile, grey	7
	Shale, bentonitic, yellowish	0·05
	Shale, fissile, grey	3
Bentonite No. 1; "A" of Link and Childerhose.	Bentonite, pale greenish grey	0·7
	Shale, fissile, grey	10
	Concretions, rusty brown	0-1
	Shale, fissile, grey	11
	Concretions	0-1
	Shale, fissile, grey, with concretions	10
	Concretions, dark reddish brown	0-1
	Shale, grey	6·5
	Shale, friable, brownish grey, with thin, rusty, concretionary bands	5
	Shale, friable, grey	1·5
	Shale, sandy, friable, brownish grey	1·5
Base of Bearpaw	Shale, fissile, grey	4·5
Top of Belly River	Coal	0·3

The total thickness of the Bearpaw formation in this section is about 731 feet. It should be noted that the three members, Ryegrass, Kipp, and Magrath, which are called sandstones by Link and Childerhose, are represented here only by zones of sandy shale.

The Bearpaw section on Oldman river is incompletely exposed, but the presence of bentonite beds enables most of the outcrops to be placed in the stratigraphic column. The principal difference to be noted here, in comparison with the section on St. Mary river, is the better development of the sandy members. The Ryegrass member appears in a small fold near the quarter corner east of sec. 33, tp. 9, range 23, W. 4th mer. About 20 feet of grey, massive, clayey sandstone is exposed, overlain by somewhat sandy shale. A partial exposure of the Kipp sandstone may be seen in legal subdivision 2, sec. 24, tp. 9, range 23, W. 4th mer. The following complete section of the same zone is visible 4½ miles to the south.

Section of the Kipp Member on Oldman River, Sec. 25, Tp. 8, Range 23, W. 4th Mer.

Remarks	Material	Thickness feet
Bentonite No. 8	Shale, bentonitic, grey-green	0·5
	Shale, somewhat sandy, grey-brown, friable	5
	Shale, fissile, grey	5
Kipp member	Shale, sandy, friable, grey-brown	4
	Concretions	0-1
	Sandstone, clayey, soft or concretionary, grey-brown, with marine fossils	15
	Shale, sandy, friable, grey-brown, with concretions and fossils	27
	Shale, friable or fissile, grey, with concretions	31

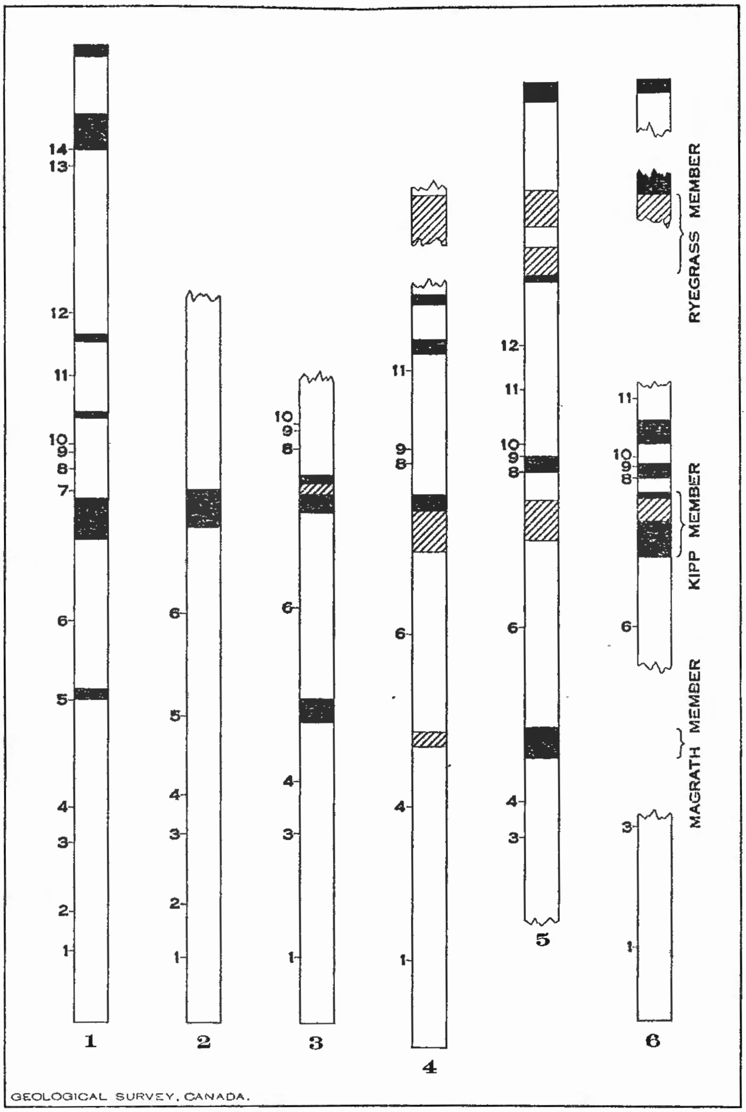

Figure 3. Columnar sections of Bearpaw formation, east part of Blood Indian reserve (west of 4th meridian), Alberta. Numbers attached to sections designate the various bentonitic horizons; sandy shale shown by solid black; sandstone by ruling, and the remaining portions of sections are shale. 1, St. Mary river, sec. 24, tp. 6, range 23, to sec. 2, tp. 7, range 22; 2, Commonwealth Petroleum, Limited, test hole No. 2; 3, Commonwealth Petroleum, Limited, test hole No. 8; 4, Commonwealth Petroleum, Limited, test hole No. 10; 5, Commonwealth Petroleum, Limited, test hole No. 11; 6, Oldman river, sec. 31, tp. 10, range 23, to sec. 11, tp. 8, range 22.

The total thickness of the Kipp member in the above section is 47 feet. Bentonite No. 7 is cut out by the 15-foot sandstone bed. The remaining sandstone zone, the Magrath member, was not observed by the writer on Oldman river.

Other sections of the Bearpaw beds within the area were obtained from the cores of test-holes. These give excellent data on the sandy members, and show many of the bentonite horizons. The absence of a certain bentonitic bed from a core is not conclusive evidence that the horizon is undeveloped at the site of the test-hole. In standard rig drills it probably will be even more difficult to record the presence of these beds. Small-scale normal faulting, which is very prevalent in the area, may be another source of discrepancy in well-log correlation.

The more important of these test-hole sections are shown in Figure 3, in comparison with the sections on St. Mary and Oldman rivers. It may be noted that the Magrath member is not usually well developed as a sandstone. The Kipp and Ryegrass members vary from sandy shale to thick beds of true sandstone. This change to more arenaceous sediments takes place from south to north, and there is also some suggestion of an increase in sandstone toward the west.

BLOOD RESERVE SANDSTONE

Throughout most of southwestern Alberta the Bearpaw formation is overlain by a thick sandstone zone called Fox Hills by various authors. The present writer intends to show, in a forthcoming paper, that this sandstone, if of Fox Hills age at all, represents only a portion of that stage in southern Alberta. In Glacier county, Montana, Dr. Eugene Stebinger[1] applied the name Horsethief to the sandstone overlying the Bearpaw. These Horsethief beds may be traced northward into Alberta, where they form the subdivision here under discussion. Stebinger's name, Horsethief, therefore, may be used with propriety for the "Fox Hills" sandstone of southwestern Alberta. However, it has been customary to apply local Canadian names to most of the Cretaceous formations that cross the International Boundary, and for this reason the name Blood Reserve sandstone is proposed here. The type section is located on St. Mary river, in secs. 23 and 24, tp. 6, range 23, W. 4th mer.

The Blood Reserve formation is composed of very massive, rather medium-grained sandstone, light grey or grey-buff in colour. It commonly weathers to a buff, yellow, or greenish tinge. The cement is in places calcareous, in others argillaceous. Crossbedding and irregular concretions commonly are developed, and the sandstone varies from hard to rather soft.

Throughout most of the area the sandstone is about 80 feet thick. This figure may be compared with the 225 to 375 feet given by Stebinger[2] as the thickness of the Horsethief sandstone in Montana. An anomalous thickness is seen in the core of Commonwealth Petroleum test-hole No. 11, where 125 feet of uninterrupted sandstone is present. This is in striking contrast with the section in Rattlesnake coulée, less than a mile to the north, where only 77 feet of sandstone was measured by the writer. The increase in thickness may be due to the lensing out of shale beds in the basal

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[1] U.S. Geol. Surv., Prof. Paper 90-G, pp. 62, 63 (1914).
[2] U.S. Geol. Surv., Bull. 621, pt. K, p. 124 (1916).

St. Mary River, which would allow lower sandstones of that formation to be included in the Blood Reserve. It is quite probable, however, that the abrupt thickening takes place entirely within the Blood Reserve formation.

In the northern part of the area the sandstone thins rapidly, and on Oldman river only 40 feet could be identified with confidence as Blood Reserve. In central Alberta various authors have attempted to recognize "Fox Hills" beds, but the writer would assign the rocks so designated, in some cases to the Bearpaw, in others to the base of the Edmonton.

The "Fox Hills" sandstone of southwestern Alberta generally has been described as of marine deposition. The principal evidence for this is the presence of obscure structures called *Halymenites major*, regarded as the remains of seaweeds. Fossil molluscs found by the writer in the upper part of the Blood Reserve sandstone all belong to brackish-water or freshwater genera. The following species have been identified.

> *Ostrea glabra* Meek and Hayden; *Unio consuetus* Whiteaves; *Corbula perangulata* Whiteaves; *Viviparus raynoldsanus* Meek and Hayden?; *Melania wyomingensis* Meek.

ST. MARY RIVER FORMATION

This is a thick series of alternating sandstones and shales, overlying the Blood Reserve (Horsethief) sandstone throughout southwestern Alberta and adjacent Montana. The sandstones are usually hard, massive, medium grained, and light grey. The proportion of calcium carbonate present is relatively high. These sandstone beds are very lenticular. The shales are friable and poorly bedded, and commonly have an appreciable content of sand. Greenish grey is the usual colour, but grey and brown shales also occur. Thin beds of lignite are present in places, especially toward the base of the formation. The repeated alternation of sandstone and shale, and the prevailing light colour of the sediments give a characteristic appearance to outcrops of St. Mary River beds.

Freshwater molluscs are found at various horizons in the formation, and make up a rather characteristic fauna. The following species are known to occur within or near the area under discussion.

> *Unio danae* Meek and Hayden; *Unio albertensis* Whiteaves; *Sphaerium heskethense* Warren; *Viviparus raynoldsanus* Meek and Hayden; *Viviparus prudentius* White; *Valvata subumbilicata* (Meek and Hayden); *Goniobasis whiteavesi* Russell; *Physa canadensis* Whiteaves.

Brackish-water species occur abundantly in the basal strata of the formation. The following have been collected within this area.

> *Ostrea glabra* Meek and Hayden; *Ostrea arcuatilis* Meek; *Cyrena occidentalis* Meek and Hayden; *Corbula perangulata* Whiteaves.

The age of the formation is late Cretaceous, corresponding approximately to that of the Edmonton formation farther north.

Determination of the thickness on St. Mary river would be difficult, owing to the presence of folds. A little to the northwest of the area, on Oldman river, an excellent section of the St. Mary River formation was surveyed. A conservative estimate based on the data so obtained, gives 1,500 feet as the thickness here. The preparation of columnar sections of the St. Mary River beds usually is impracticable, due to the lenticular nature of the strata. The basal portion of the formation, however, contains some important horizons, which are described in the following detailed sections.

Section on St. Mary River, in Secs. 23 and 24, Tp. 6, Range 23, W. 4th Mer.

Remarks	Material	Thickness feet
	Sandstone, hard, crossbedded, grey-buff	3
	Shale, sandy, very friable, grey and grey-buff	7
	Shell fragments, *Unio* sp.	
	Shale, somewhat carbonaceous, friable, grey-brown, with dinosaur bones	1·5
	Shale, sandy, friable, grey-brown	2
	Sandstone, clayey, soft, friable, grey-buff, with hard lenses; *Unio* sp	5
	Shale, sandy, very friable, grey and grey-buff	3·5
	Sandstone, hard, somewhat concretionary, grey-buff	1·5
	Shale, sandy, very friable, grey	1
	Shale, sandy, very friable, grey, with greenish grey concretions	3
	Sandstone, hard, massive, grey-buff	3
	Shale, sandy, friable, grey and grey-buff	18
	Sandstone, clayey, grey-buff	3·5
	Shale, bentonitic, light grey-green to whitish	±0·2
	Shale, sandy, and sandstone, clayey, friable, grey-buff	3
	Sandstone, moderately hard, somewhat concretionary, clayey, grey-buff	2
	Shale, carbonaceous, dark grey-brown	1·5
	Shale, sandy, friable, grey-brown	2·5
	Sandstone, clayey, grey-buff	1·5
	Shale, sandy, friable, grey-brown	0·5
	Shale, sandy, friable, grey-buff	4
	Shale, sandy, somewhat concretionary, bluish grey, with shell fragments	0·5
	Shale, sandy, friable, grey-brown	2·5
	Sandstone, clayey, rather hard, massive, light grey and grey-buff	±4
	Shale, sandy, friable, grey-brown; fragments of freshwater shells	3·2
	Concretions, grey-brown, hard	1
	Shale, coaly	±1
	Shale, sandy, friable, grey-brown	2
	Sandstone, hard, grey-buff, irregularly bedded	2
	Shale, coaly, black and dark brown	2·5
	Shale, sandy, friable, brown	2·5
	Shale, very fissile, dark grey-brown	1
	Shale, friable, grey-brown	2
	Shale, sandy, soft, friable, grey-brown	1·5
	Sandstone, clayey, soft, light grey-brown; concretionary in upper part	3
	Shale, sandy, brown, with coquina of *Ostrea glabra* (lenses out laterally)	3·5
	Shale, sandy, soft, grey-brown	2
Base of St. Mary River	Shale, friable, grey-brown	3
Top of Blood Reserve	Sandstone, carbonaceous, somewhat concretionary, dark grey-brown	1
	Sandstone, hard, massive, calcareous or argillaceous, grey-buff and grey, with concretions	85

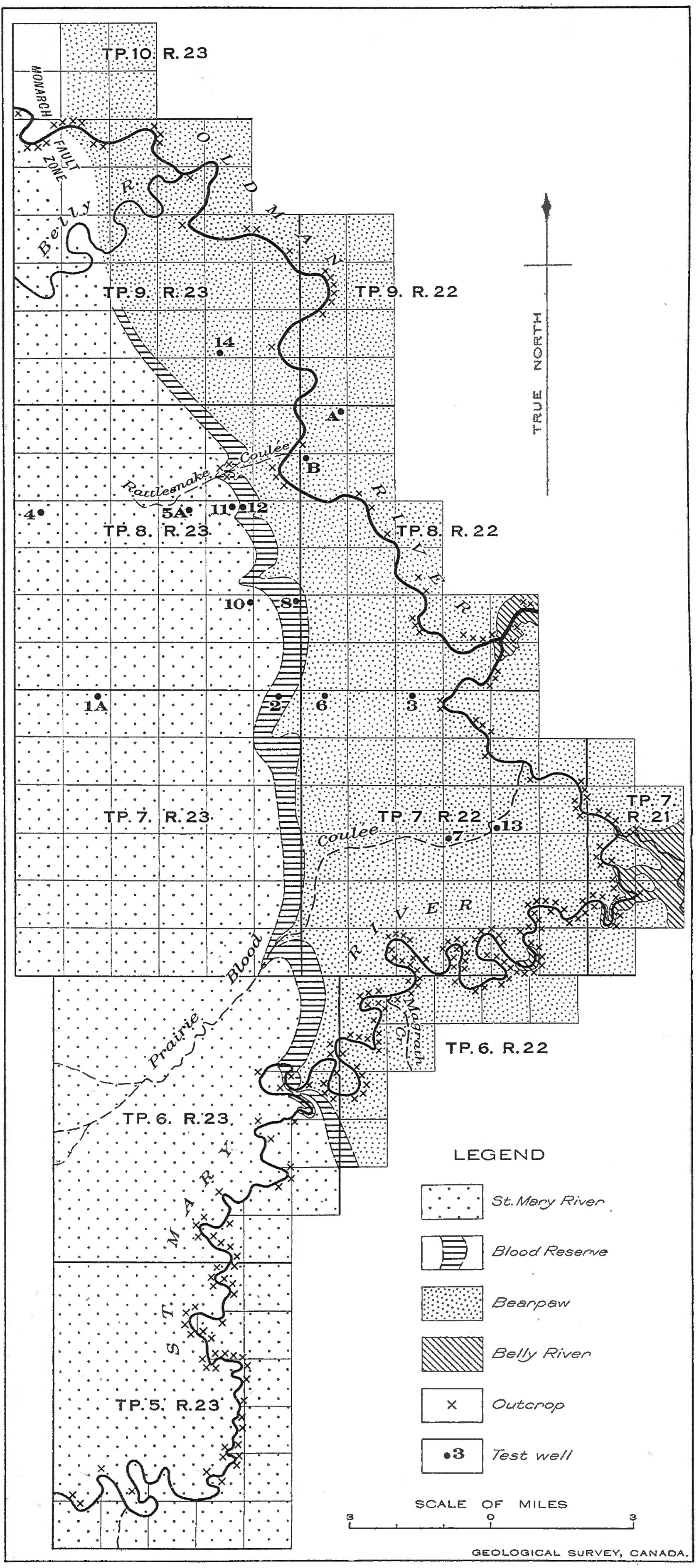

Figure 4. East part of Blood Indian reserve (west of 4th meridian), Alberta, showing distribution of formations.

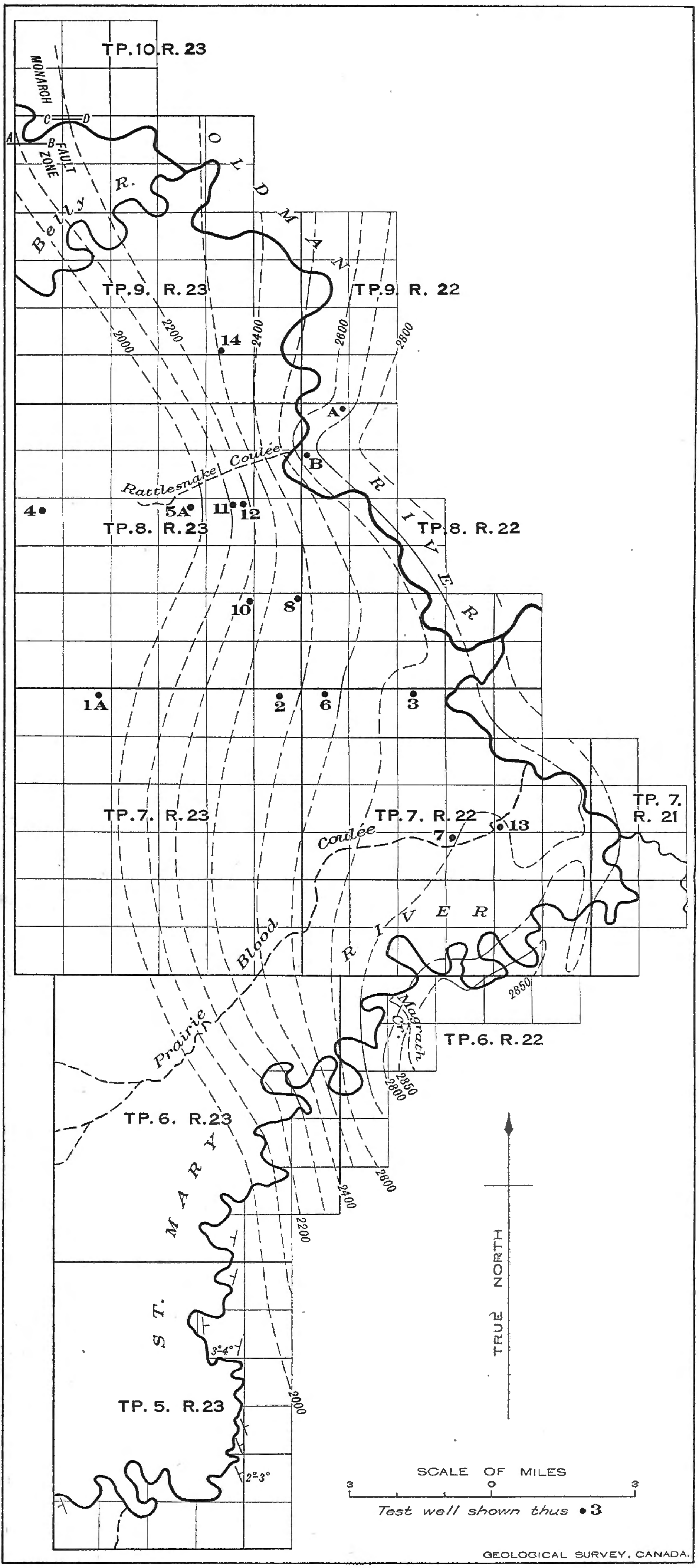

Figure 5. East part of Blood Indian reserve (west of 4th meridian), Alberta, showing structure contours on top of Belly River formation, datum sea-level.

Section on Oldman River, at Monarch Fault Zone, Legal Subdivision 12, Sec. 31, Tp. 9, Range 23, W. 4th Mer.

Remarks	Material	Thickness feet
	Shale, carbonaceous	?
	Sandstone, clayey, soft, grey, with hard brown bands	2
	Sandstone, rather soft, ochre-yellow	0·5
	Sandstone, soft, grey, with fine, dark streaks	1·5
	Shale, hard, friable, dark grey	3
	Hard coquina of *Corbula perangulata*	0·5
	Shale, hard, friable, dark grey, with scattered shells of *Corbula*	3
	Shale, sandy, soft, friable, grey	2
	Hard coquina of *Corbula perangulata* and *Ostrea* sp	0·7
	Sandstone, clayey, moderately hard, light grey, with carbonaceous and rusty streaks; some shell fragments	20
	Sandstone, hard, with numerous *Ostrea glabra*	2
	Shale, dark grey, friable or fissile	6
	Coquina, very hard, rusty-weathering; *Ostrea arcuatilis*, *Cyrena occidentalis*	3
	Sandstone, clayey, soft, grey	2
	Shale, dark, with *Ostrea* sp	1
	Bentonite, light yellow	0·2
	Shale, friable, brown	3
	Shale, fissile and friable, dark grey; *Corbula* sp	1·5
Base of St. Mary River	Shale, sandy, friable, brown	15
Blood Reserve sandstone	Sandstone, clayey, rather soft, massive, light grey and brown, with carbonaceous and rusty streaks	40
Top of Bearpaw	Shale, sandy, friable, brown	10

STRUCTURE

The eastern portion of the Blood Indian reserve is situated on the east limb of the Alberta syncline and the west limb of the Sweetgrass anticline. Hence the general structure of the area is monoclinal, with a prevailing westward dip of several degrees. Under these conditions the search for possible reservoirs of petroleum and natural gas becomes directed principally toward the discovery of easterly or reverse dips. The magnitude of such reservoirs will be proportional to the degree of easterly dip and to the area of strata so inclined.

The detailed structure of the area will be described from south to north. Structure contours are not shown on the southernmost portion of the accompanying Figure 5. This part of the area is underlain by the St. Mary River formation, in which reliable horizons are yet to be determined, and where the writer's data were obtained by compass and clinometer observations. No doubt large-scale instrumental traverses, such as were made in other parts of the area, would have yielded somewhat more definite results.

It will be observed from the figure that an anticlinal axis crosses St. Mary river somewhere between secs. 7 and 10, tp. 5, range 23, W. 4th mer. Outcrops are small and few in number here, so that the exact position and magnitude of the structure were not determined. Presumably it is the southward continuation of this fold that has been tested by the Spring Coulée well of the Alberta Pacific Consolidated Oils, Limited, in sec. 15, tp. 4, range 23, W. 4th mer.

Eastward-dipping St. Mary River beds may be observed in secs. 10, 15, and 27, tp. 5, range 23, W. 4th mer., forming the west limb of a low syncline, which is seen to cross St. Mary river near the quarter corner north of section 22. The east limb of this structure outcrops in secs. 22 and 34, tp. 5, range 23, W. 4th mer., and the westerly dip apparently persists in the remaining St. Mary River strata traversed by the river.

In sec. 24, tp. 6, range 23, W. 4th mer., the Blood Reserve sandstone and the upper part of the Bearpaw formation appear, and from here to the mouth of Pothole creek the exposure is almost continuous. This condition, together with the presence of numerous determined horizons in the Bearpaw beds, permits a very detailed determination of the structure. Normal faults are very numerous here, but as they seldom exceed 10 feet in throw, they are not recorded.

The structure contours show a relatively steep westward dip in sec. 24, tp. 6, range 23, and secs. 19 and 30, tp. 6, range 22, W. 4th mer. There is evidence of a slight reverse dip in sec. 33, tp. 6, range 22, W. 4th mer., and the direction of strike changes to considerably east of north. In sec. 12, tp. 7, range 22, W. 4th mer., a distinct eastward dip may be measured, but this changes to westward in the adjacent sec. 7, tp. 7, range 21,W. 4th mer. These observations are interpreted as indicating an anticlinal axis crossing the river in sec. 12, tp. 7, range 22, W. 4th mer., and a synclinal axis crossing near the west boundary of range 21.

In the general vicinity of Pothole creek the base of the Bearpaw formation is well exposed, and shows a persistent westerly dip. To the west of here, in the central part of tp. 7, range 22, W. 4th mer., the beds are nearly horizontal, as shown by test borings. On the accompanying Figure 5 an attempt is made to show how the structures observed on St. Mary river may disappear within such a short distance to the north.

From Pothole creek to the mouth of St. Mary river the principal feature to be observed is the northwesterly direction of the strike. A low anticline may be observed in sec. 24, tp. 7, range 22, W. 4th mer., and there is probably a very shallow syncline in the NW. ¼ sec. 34, tp. 7, range 22, W. 4th mer., suggested by the log of Commonwealth Petroleum test-hole No. 3.

The structure of the remaining part of the area is determined from scattered outcrops on Oldman river, and from the logs of test-holes. Data from these sources indicate a general westerly dip, which is quite pronounced in the northern part of township 8, but which becomes gentler toward the north. The very strong westward dip in the NE. ¼ sec. 25, tp. 8, range 23, W. 4th mer., and the pronounced nose in secs. 30 and 31, tp. 8, range 22, W. 4th mer., are noteworthy. These features may indicate large-scale faulting, but no evidence of this was observed. It is quite possible that easterly dips are present in the northern part of the area, but, if so, they must be of rather limited extent. This will be determined by further drilling.

The most striking structural feature of the area appears in the northwest corner, 3 miles north of the Indian Reserve boundary. This is here designated as the Monarch fault zone. It is well exposed in two large outcrops and a number of smaller ones on Oldman river, in secs. 31 and 32, tp. 9, range 23, and sec. 6, tp. 10, range 23, W. 4th mer. The writer's

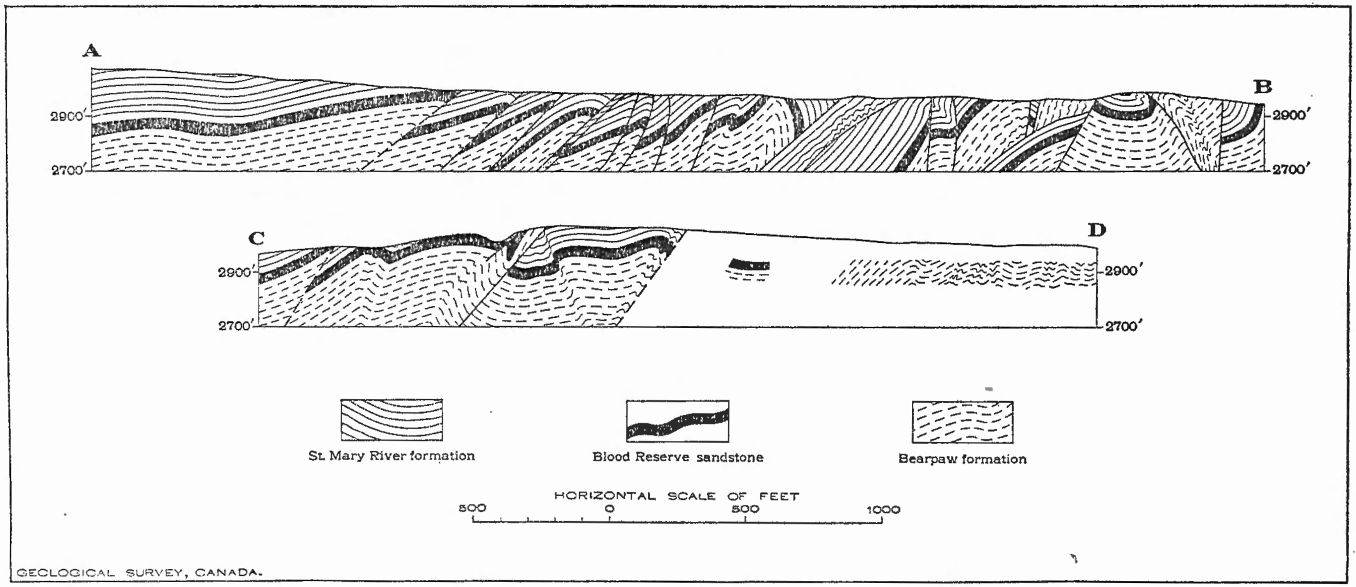

Figure 6. Cross-sections of the Monarch fault zone, east part of Blood Indian reserve (west of 4th meridian), Alberta. *See* Figure 3 for positions of lines of sections.

interpretation of the structure here appears in the two sections of Figure 6. Essentially, the Monarch fault zone consists of a series of blocks, separated by thrust faults of rather steep inclination, and involving, in almost every case, portions of the St. Mary River, Blood Reserve, and Bearpaw formations.

In spite of the intense deformation visible in this zone, it does not seem to be a major structural feature. This is suggested by the apparent lack of continuity along the strike. No fault zone is visible in sec. 26, tp. 8, range 23, W. 4th mer., where the same horizons outcrop. Furthermore, in the fault zone itself the stratigraphic displacement is not great. In only one case was it observed to exceed 100 feet, and it is usually much less. The horizons exposed at river-level in the most westerly of the visible fault blocks are the same as those seen in the most easterly block. If we assume that the faults disappear in the more competent rocks at depth, their place must be taken, not by one or more large folds, but by a series of small undulations.

The localization of this zone of intensive deformation probably is dependent on the stratigraphic relationships. As noted above, almost every fault block consists of relatively hard, sandy beds (St. Mary River, Blood Reserve), overlying softer, more argillaceous strata (Bearpaw). In reconstructing the history of the deformation, we may postulate a slight dip to the west prior to the development of faults. This dip would bring the Bearpaw-Blood Reserve contact to the surface near the present site of the fault zone. Further stresses from the west, transmitted by the relatively competent St. Mary River formation, found expression in the development of shear zones and faults along the top of the less competent Bearpaw shale. This release would be most pronounced near the surface. Continued pressure steepened the earlier breaks and developed additional thrusts. This would account for the different inclination of various existing fault planes. Cessation of pressure was followed by relaxation, developing a few normal faults, as in other parts of the area. As a corollary of this interpretation, we may imagine that the fault zone is not continuous for any great distance downward, but that it may extend somewhat westward beneath the rather gently dipping St. Mary River formation.

OIL PROSPECTS OF THE FISHER CREEK, TWO PINE, AND BIRCH RIDGE STRUCTURES, EASTERN FOOTHILLS OF ALBERTA[1]

By G. S. Hume

CONTENTS

Illustrations

INTRODUCTION

From 1926 to 1930 geological mapping on a scale of 2 inches to 1 mile has been carried on over an area in the eastern foothills between Highwood and Bow rivers. The maps (Nos. 261A to 265A) now published delimit the various formations and indicate the favourable and unfavourable areas for oil and gas accumulations. From the results of this work and from information obtained from various wells drilled in the foothills, it was thought that the Fisher Creek area, 12 miles west of the north end of Turner valley, and the Two Pine area between Elbow river and Jumpingpound creek north and east of Bragg Creek post office, were most likely to yield the maximum amount of information concerning the type of structure within the most favourable prospecting area. Consequently, these two areas were mapped in 1931 on a scale of 10 inches to 1 mile. In order to do this detailed mapping it was necessary to know the exact succession of the strata which outcrop within these areas, so that as far as possible individual beds could be recognized and used as a basis for the interpretation of structure. Consequently, a detailed section was made from the eastern boundary of the Rocky Mountain forest reserve on Elbow river westward to Canyon creek and up Canyon creek to the west side of Moose mountain. This area was chosen on account of its proximity to the prospective oil and gas fields and because the formations there outcropping are less involved in complicated folding and faulting than in most foothills areas. Also, since the Palæozoic limestone that contains the principal oil and gas-producing horizon of Turner valley outcrops in Moose mountain, this study provided data on the porosity of probably productive zones and also gave some information on the possible origin of the oil and gas.

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[1] Geological maps with cross-sections on the scale of ~~10~~ 5 inches to 1 mile have been prepared of the Fisher Creek and Two Pine structures. These maps are very large and cannot be issued in the ordinary way, but copies will be supplied at cost to those applying for them to the Director, Geological Survey, Ottawa. Copies can be provided either coloured by hand or uncoloured. The latter will be cheaper and can readily be coloured with crayons by the recipient.

The detailed mapping of Fisher Creek and Two Pine areas indicates the presence of overthrust faults which, although steeply inclined westward at the surface, may become lower-angled faults at depth. Eastward-dipping faults or underthrusts are prominent in both areas and give a type of structure hitherto not recognized in this part of the foothills. In both areas it is probable that Palæozoic limestones are included in the folding above the planes of overthrusting and in them and possibly in at least one higher horizon the prospects for gas and oil are thought to be favourable. Seepages of gas occur in both areas and the porosity of prospective productive horizons may be much the same as in Turner valley, which has yielded large quantities of gas and oil. A new structure previously mapped but not described in detail occurs northwest of Fisher Creek area and southeast of Two Pine area. It is here called the Birch Ridge structure, and is believed to be a simple anticline, thrust-faulted along the original axial plane of the fold. It is concluded that this structure favours oil and gas accumulations and that wells drilled on it can reach the Palæozoic limestone at depths ranging from 4,500 to 5,000 feet.

During the field season, C. O. Hage, N. R. Jennejohn, and J. C. Pratt acted as assistants. Dr. T. A. Link, geologist, Imperial Oil Company, Limited, spent one day with the writer in Fisher Creek area examining the salient features of the structure and Dr. Link with Dr. Robin Willis, of the Nordon Oil Corporation, joined the writer in a field trip over the Two Pine anticline. The trips were exceedingly helpful and thanks are due to these geologists for suggestions regarding the interpretation of these complex structures.

STRATIGRAPHY

The stratigraphic succession of the formations within Fisher Creek and Two Pine areas is given in the following table.

Table of Formations

Age	Formation	Thickness in feet
Upper Cretaceous..........	Belly River....................................	2,000 to 2,700
	Upper Alberta ("Benton") shales with Cardium bands..	1,900 to 1,950
	Lower Alberta ("Benton") shale................	850 to 900
Lower Cretaceous..........	Blairmore....................................	1,500 to 1,630
	Kootenay....................................	350
Jurassic....................	Fernie..	220
Pennsylvanian? and Mississippian............	Rundle..	1,400
Mississippian..............	Banff shale....................................	650 to 700
Devonian..................	?	?

PALÆOZOIC LIMESTONES

Palæozoic limestones outcrop in Moose mountain and have been encountered in many wells drilled in Turner valley and elsewhere in the foothills. In Moose mountain, Fernie shales of Jurassic age conformably overlie heavy-bedded limestones the top of which in many places is a chert breccia usually less than 1 foot in thickness. The age of the upper part of this limestone series is not definitely known as no fossils have been found in it, but it continues downward without any apparent break into other limestones which carry, according to Miss A. E. Wilson, of the Geological Survey, fossils having "definite affinities with the Pennsylvanian as well as some forms which have their origin in the Upper Mississippian" and represent a fauna believed to be Rundle in age. In Lake Minnewanka area Shimer[1] believed that the upper two-thirds of the Rundle formation was Pennsylvanian and the lower third Mississippian. In Banff area, however, Warren[2] considers the whole of the Rundle formation to be Mississippian. The thickness of the Rundle formation in Moose mountain is 1,400 feet, whereas at Banff Warren measured 2,400 feet, and in Lake Minnewanka area Shimer included in it 1,500 feet of Pennsylvanian and 600 feet of Mississippian strata. In Banff area, according to Warren[3], the Rundle formation is overlain by 700 feet of Rocky Mountain quartzite (Pennsylvanian) and this in turn by approximately 3,400 feet of the Spray River formation (Triassic). As far as known neither the Rocky Mountain quartzite nor the Spray River formation are present in Moose Mountain area where Fernie shales conformably overlie the Rundle formation and, therefore, are separated by an erosional interval represented by 4,100 feet of strata in Banff area. The section of the Rundle formation on the west flank of Moose mountain is as follows.

	Thickness Feet
Shales (Fernie shale contact)	
Grey limestone with some argillaceous layers and containing brecciated, porous beds	230
Light grey, argillaceous limestone with small amount of chert in nodules, underlain by hard, white limestone with thin layers and nodules of chert	210
Massive, crystalline and fine-grained limestone	200
Massive, brownish, crystalline limestone alternating with argillaceous limestone containing chert nodules	180
Massive, crystalline limestone in part soft, underlain by thinner bedded, slightly argillaceous limestone	230
Massive, crystalline limestone containing many cup corals at base	60
Dark, massive limestone with a few crystalline beds, becoming very cherty toward the base	290
Brown shale (Banff shale contact)	.....
Total thickness of Rundle formation	1,400

The above section is generalized somewhat and there are intervals in it where exposures are not complete. Roughly it is divisible into three parts: (1) an upper part containing massive and argillaceous limestones with porous brecciated beds; (2) a middle part mostly of crystalline limestones; and (3) a lower part of very hard, massive limestones containing an abundance of chert in small nodules and discontinuous layers.

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[1] Shimer, H. W.: Geol. Surv., Canada, Mus. Bull. No. 42, p. 5.
[2] Warren, P. S.: Geol. Surv., Canada, Mem. 153, p. 34.
[3] Warren, P. S.: Geol. Surv., Canada, Mem. 153, p. 34.

The upper part is well exposed on the east side of Moose mountain in Canyon creek and the section in detail is as follows.

	Thickness Feet
At one place where the contact of the Fernie and underlying limestone was observed, the basal part of the Fernie consists of 6 inches of yellow-weathered shales overlain by dark fissile shales and underlain by 4 inches of chert on top of massive limestones. At other places the upper limestone bed is capped by a chert breccia only a few inches thick and underlain by massive, grey limestones.	
Hard, grey limestone with a small amount of argillaceous material.......	50
Argillaceous, hard limestone showing ripple-marks, mud balls, intraformational breccia, and mud-cracks, the edges of which are purplish grading into white limestone. Small pieces of pyrobituminous substance at base..	30
Highly crystalline, dark limestone which emits a fetid odour when struck with the hammer..	1
Concealed interval (estimated)..	50
Non-bedded limestone showing many small pores or cavities and a brecciated character, separated by thin beds of limestone.................	25
Hard limestone with some large, oval cavities up to 2 feet in diameter.....	10
Non-bedded, porous, brecciated limestone............................	5
Massive limestone (in part concealed)..................................	30
Purplish, argillaceous limestone underlain by porous, brecciated limestone (2 feet)..	10
Green, shaly limestone..	2
Brecciated, porous limestone..	2
Hard, massive, grey limestone	

The interesting feature of this section is the brecciated porous zones, of which several occur as noted above. The individual fragments of the breccia vary in size up to 6 inches and since in part they have fine bedding laminations it can be shown that the fragments now occur in various attitudes with reference to the planes of bedding above and below. In a few places the breccias contain argillaceous materials and near the top of the section the argillaceous beds that show ripple-marks, mud balls, and mud-cracks are clearly of shallow water deposition. The purplish colour of some of the argillaceous beds and the purplish tinge around the edges of the mud-cracks suggest oxidation during exposure, possibly on a tidal flat. It is not unreasonable to assume, therefore, that the breccias were formed at the time of deposition as a result of the breaking of the beds by wave action in a shallow sea, and that the porosity which they now exhibit is the result of imperfect consolidation subsequent to fragmentation. The upper part of the Palæozoic limestones has been found to be porous in Turner valley where it produces gas and oil. Porosity has also been observed at various places in limestone exposures along the front range from Highwood to Red Deer river. As a result of investigations[1] on the porosity of limestone in other parts of the world the writer formerly considered that the porosity in the upper part of the Palæozoic limestones might be due to solution and leaching during the period of erosion prior to the deposition of the Fernie shales and now represented by the erosional unconformity at the top of the Palæozoic. It is known that the erosional unconformity at the top of the Palæozoic is widespread in the foothills and that erosion had proceeded to different depths in different places. The development of porosity in the beds forming the eroded surface did not, therefore, appear to have any relationship to the age of the limestone. The only thing necessary was that the

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[1] *See* papers by Howard, W. V., Murray, A. N., and Love, W. W.: Bull. Am. Ass. Pet. Geol., vol. 12, No. 12, vol. 13, No. 11, and Ec. Geol., vol. 25, Nos. 5 and 7.

beds should be such that they could be dissolved by circulating groundwaters carrying weak acids. In Moose Mountain area no field data were secured that would support the theory of porosity having been developed by solution during the period of erosion represented by the erosional unconformity at the top of the Palæozoic. For instance, a bed of pure crystalline limestone one foot thick between the brecciated porous zone and the top of the limestone is no more porous than its crystalline character would allow, although its composition is such as would seem to be readily soluble by weak, acidic waters. It is, therefore, problematical to what extent, if any, the upper part of the limestone was rendered porous during the period of erosion prior to the deposition of the Fernie shales and yet, if the porosity in the upper part of the Palæozoic limestones in various foothills localities is found to have developed at different stratigraphic horizons, as is probable, it is extremely difficult to otherwise account for this condition.

No very detailed study was made of the central part of the Rundle formation in Moose Mountain area, but fossils were collected from the various horizons and these show definite Pennsylvanian affinities as well as some forms that have their origin in Upper Mississippian.

This part of the section is characterized by an abundance of crystalline limestone beds, some of which are white and show a considerable porosity and others of which are brownish and emit a fetid odour when struck by a hammer. There is no doubt that this part of the section would provide sufficient porosity for gas and oil reservoirs.

The lower part of the section is very easily recognized in the field because it contains an abundance of chert in nodules and discontinuous thin layers. The limestones are massive and very hard and consequently are cliff-forming. They are commonly, however, quite crystalline and many are brownish in colour. The lower 100 feet consists of the following succession:

	Thickness Feet
Thin-bedded, crystalline limestone	13
Crystalline limestone with a few chert nodules, beds very massive	35
Cherty, nodular limestone	5
Crystalline limestone	6
Cherty limestone	18
Crystalline limestone	9
Cherty limestone (50 per cent chert), chert in flat nodules up to 6 inches in diameter or in discontinuous layers up to 2 inches thick	10
Massive, crystalline, brown limestone	9
Brown shale (Banff shale contact)	

BANFF SHALE

The contact between the Rundle limestone and the underlying Banff shale has been drawn at an horizon of brown shale 4 to 6 inches thick. The cherty limestones of the Rundle formation are very massive and hard, and, as already stated, frequently form cliffs. The Banff formation is softer than the Rundle limestones, but harder than the thin band of shale at the contact. The result is that the thin band of shale weathers out, leaving a distinct notch at the base of the cliffs of Rundle limestone. For this reason the contact between the Rundle and Banff formations can be easily found and traced around the dome which occupies the central part of Moose mountain on Canyon creek. The top of the Banff shale formation contains some massive crystalline beds, but invariably these alternate with strata that are somewhat argillaceous. In fact, shaly limestones and limy shales are found throughout the whole formation and fossils are quite abundant at certain horizons, a condition which is quite in contrast with the massive and sparingly fossiliferous characters of the Rundle beds. The base of the Banff shales is not exposed on Canyon creek. The Moose Dome well, drilled in the central part of the dome in Moose mountain, encountered black shales between depths of 60 and 140 feet and below this entered limestones that probably are Devonian. The age of the black shales is not definitely known, and considering only this locality it might be inferred on lithological grounds that the black shales should be included with the Banff shales rather than with the underlying limestones. In the plains area, however, it has been shown[1] that under Carboniferous limestones there are 20 to 30 feet of black, highly bituminous shales that carry Devonian fossils and overlie Devonian limestones. It would be reasonable to expect a thicker zone of black shales to the west of the plains areas and hence it is possible that the black shales in the Moose Dome well are also Devonian. In the absence of fossils, however, a definite determination is not possible.

The thickness of the Banff shale formation was not accurately measured but is estimated to be 650 to 700 feet.

FERNIE

The following section of the Fernie formation is exposed on Canyon creek on the east flank of Moose mountain in the Bow River forest reserve.

Kootenay: Erosional Contact with the Fernie Formation

	Thickness Feet
Fernie	
Yellow weathering sandstone. In places this is completely eroded......	0–8
Brown, fairly massive but soft sandstone separated by small amount of black shale..........	22
Dark shale with thin layers of brown sandstone..........	7
Dark shale with thin layers of sandstone, grading upwards into fairly massive beds of brown sandstone..........	24
Dark grey, sandy shale grading upwards into brown, crossbedded, thinly laminated sandstones..........	15
Sandy shale with flat pyrite nodules in abundance, overlain by dark grey shale..........	20
Dark shale weathering sulphur yellow..........	17
Grey bentonite layer..........	0·2
Dark shale weathering to a bright sulphur yellow. Many pyrite nodules 1 to 2 inches in diameter with other flat pyrite nodules up to 6 inches in diameter. White alum coating..........	7·5
Rusty weathering shale with a layer containing Belemnites in great abundance below a 1-inch limy layer..........	3
Lime nodules up to..........	1
Black shale with a few Belemnites..........	10
Thin, limy nodules showing a tendency to form a continuous layer......	0·3
Grey shale with Belemnites..........	5
Greenish yellow-weathering shale with many Belemnites and Stephanoceratids of lower Middle Jurassic age (McLearn, F. H.)..........	5·5
Grey lime band..........	0·5 to 1
Black shale, many Belemnites..........	4
Grey lime band..........	0·5
Black shales with *Gryphœa* sp..........	24
Black lime band..........	1·5
Black, thin-bedded shales containing a *Dactylioceratid*-like genus of Ammonite in abundance in thin layers. According to McLearn this is about late Lower Jurassic in age. These are the "Poker chip" shales of Turner valley..........	45
Chert breccia of top of Palæozoic limestone.	

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[1] Moore, P. D.: Am. Ass. Pet. Geol., vol. 15, No. 10.

The total thickness of the Fernie, as thus described, is about 220 feet. This includes 8 feet of yellow-weathering sandstone which may or may not be present on the top on account of an erosional unconformity with the overlying brown sandstones which are here considered to be basal Kootenay in age. It will be noted that F. H. McLearn reports that such fossils as could be obtained indicate a late lower and a lower Middle Jurassic age. It is not possible to state the exact age of the upper part of the section as no fossils could be obtained from it.

The Fernie on Canyon creek on the west flank of Moose mountain is not well exposed. The yellow-weathering sandstone at the top of the formation is present and has the same character as on the east flank of Moose mountain. The section, however, appears to contain more lime bands than on the east flank, but no continuous section was examined.

KOOTENAY

The Kootenay is divisible into an upper part consisting of coal seams, coaly shales, and sandstones, and a lower part of prominent sandstones with shale layers. The upper part has been considerably folded even where the beds above and below it show a fairly uniform dip. For this reason the width of the outcrop varies considerably and as the coal and coaly shales are rarely well exposed it is not easy to make an accurate measurement of thickness. The thickness is given by Cairnes[1] as 345 feet for a section exposed on the east flank of Moose mountain at the head of Bragg creek on NE. ¼ sec. 8, tp. 23, range 6, W. 5th mer. The section is as follows.

	Feet	Inches
Dark brown shale	1	0
Coal	1	6
Brown shale	42	0
Sandstone	7	3
Brown shale	3	6
Dark, coarse sandstone	22	0
Sandstone and shale	15	6
Coal	1	6
Grey, sandy shales	2	3
Coal	3	7
Dark grey shales	8	3
Coal	1	10
Dark brown sandstones and shales	21	0
Coal	2	3
Dark sandstones and shales	73	0
Coal	8	2
Brown, coarse sandstones	24	0
Coal	6	10
Dark, coarse shales	4	3
Dark blue shales	9	0
Shales and sandstones	23	0
Brown, prominent sandstone beds	63	
Total thickness	344	8

The prominent brown sandstone beds outcrop in many places both on the east and west flanks of Moose mountain. The coal and coaly shales outcrop at the mouth of the canyon on Elbow river, east of the mouth of Canyon creek, where the section is as follows.

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[1] Cairnes, D. D.: Geol. Surv., Canada, Mem. 61, p. 3 (1914).

	Feet
Basal Blairmore conglomerate and sandstone	
Coal and coaly shale	5
Black, sandy shale with 1 foot of coaly shale at base	10
Dark sandstone	4
Dark, sandy shale with sandstone layers and small, flat nodules	8·5
Dark brown, micaceous sandstone	3
Dark shale	2
Coal and dark shale	2
Dark shale with stringers of coal	6
Dark brown sandstone	4
Coaly shale	2
Black, sandy shale and sandstone	9
Black shale	4
Coal and coaly shale	1
Sandstone and dark shale	6
Black, coaly shale	4
Sandy, grey shales with thin streaks of black, coaly shale	16

Below this the beds are too highly contorted and faulted for measurement. It will be noted that there is much less coal in this section than in that given by Cairnes. The coal seam that has been mined near the mouth of Canyon creek is the seam immediately underlying the basal Blairmore conglomerate and sandstone with which the contact is exceedingly sharp.

BLAIRMORE

The contact between the Blairmore and the overlying Lower Alberta ("Benton") shales is drawn at a finely conglomeratic bed a few inches to several feet thick at the base of a group of dark shales carrying Colorado fossils. This bed has become known as the "grit" bed and is easily recognized in drill samples. In reality the "grit" bed belongs to the Lower Alberta ("Benton") shales, as in a few instances dark shales occur immediately below it. The Blairmore strata below the "grit" bed consist of an alternation of greenish sandstones and shales and near the top of the formation there are fairly massive sandstones that have in Turner valley received local names. The first or uppermost of these is the Stockmens sandstone which in Turner valley occurs about 100 feet below the top of the formation. It is a coarse, in many cases conglomeratic, sandstone composed mainly of quartz grains. In Two Pine area its stratigraphic position is approximately 200 feet below the "grit" bed, but in reality there are several sandstone beds which compose the Stockmens group with a stratigraphic range of 150 to 200 feet below the "grit." Where only one of these beds is seen in outcrop it is not usually possible to define the stratigraphic position except within the limits as given above. Below the Stockmens sandstone the top of the McDougal-Segur sandstone is in Turner valley approximately 220 feet below the "grit" bed. In Two Pine and Fisher Creek areas the outcrops of McDougal-Segur sandstones comprise a group of somewhat varying thickness. In places these sandstones are very massive with much carbonaceous material and thin stringers of coal and lenses of coaly materials. They weather grey to whitish, but on fresh surfaces show a greenish tinge. In other places sandstones believed to represent the same horizon are separated by thin amounts of sandy shale and the group is at least 100 feet thick. Between the Stockmens and the top of the McDougal-Segur sandstones in Two Pine area there are believed to be about 200 feet of green, sandy shales, thin-bedded sandstones, and maroon shales in thin layers or lenses. Below the McDougal-Segur sandstone group are greenish shales and sandy shales and in some localities thin layers of maroon shales. This part of the section can best be studied on Elbow river east of Bragg creek on the south end of the Two Pine anticline. The lower part of the section is best exposed on Elbow river in the Rocky Mountain forest reserve west of Herron Petroleums well and east of Canyon creek. The lower part of the section on Elbow river within the forest reserve is as follows. The section commences at an horizon estimated to be 450 feet below the "grit" bed.

	Thickness Feet
Hard, green sandstones	7
Shaly, green sandstones	5
Sandstone with shale partings	10
Shale with plant material	10
Green shale	10
Massive sandstone with large nodules	5
Green, sandy shales with a little dark shale and coal stringers	11
Green shales and shaly sandstone	10
Green, shaly sandstone with nodules up to 6 to 8 inches in diameter	7
Green shale	5
Green sandstone	2
Green shale	12
Green sandstone	12
Platy, green sandstone	8
Massive, green, coarse sandstone	28
Hard, green sandstone with ironstone cement and large nodules	20
Covered interval—at base of which are very hard sandstones, weathering brown due to ironstone cement	105
Thin-bedded sandstone	4·7
Massive sandstone with ironstone cement	5·4
Platy sandstone	19·4
Green shale	6·5
Grey and greenish sandstone	3·5
Dark, sandy shale	6
Massive sandstone with ironstone cement	17
Green, sandy shale	3·8
Hard, green sandstone, in part shaly	7·8
Dark, sandy shales	7·5
Coaly shales and coal	0·8
Green shale	15
Maroon and green shale	2
Green shale with nodules up to 2 feet in diameter	15
Sandstone	3
Green, sandy shale	25
Massive sandstone weathering brownish	5
Green shale with dark shale and carbonaceous materials	5
Dark shale and green, sandy shale	10
Grey sandstone, weathering brownish	7·5
Dark greenish sandstone	7
Dark green, splintery shale	9
Green shale and shaly sandstone	8
Grey to greenish sandstone	24
Green shale and thin beds of sandstone	5
Very green shale	3
Dark green sandstone	11
Massive sandstone with ironstone cement	12
Shaly sandstone and shale	6
Green shale with a small amount of sandstone	9
Sandstone and shale interbedded with large ironstone concretions	10
Shaly, green sandstone	10
Thin-bedded sandstone with carbonaceous partings	9
Black, splintery shale and drab-greenish shale	11
Grey to greenish, thin-bedded sandstone	19
Sandstone alternating with dark shale	4
Black shale with fern-like plants, etc	2
Sandstone underlain by sandy, dark green shale with nodules 1 foot in diameter	15

	Thickness Feet
Light green shale underlain by dark green sandstone	8
Greenish sandstone	24
Massive sandstone weathering brownish	8·5
Massive sandstone with very thin conglomeratic layer at top	15
Shaly sandstone	20
Massive sandstone with ironstone nodules	8
Thin, platy sandstone	10
Massive, green sandstone	16
Dark, splintery shale	10
Brownish weathering (ironstone) sandstone	6
Dark shale	12
Siliceous, dark, limy band	2
The top of the limy series in this section is thus about 1,200 feet below the top of the formation.	
Thin-bedded, dark shale	9
Massive sandstone with ironstone	6
Thinly laminated, sandy, limy beds	15
Siliceous sandstone weathering brownish (ironstone) overlain by one inch of coal and coaly shale; the beds that contain an ironstone cement are very hard	4
Dark, limy beds with dark shales	10
Dark shale	7
Hard, siliceous ironstone and limy beds	6
Dark shale and thin, limy beds	4·5
Shaly, limy beds	9
Massive, siliceous, ironstone sandstone separated by thin layers of very black shale	30
Ironstone sandstone, fine grained	4
Black shale	1
Siliceous ironstone	2
Coarse sandstone and limy beds with some dark shale	35
Dark shale	3
Massive, coarse sandstone	20
Covered interval	65
Crossbedded, siliceous sandstone	7
Covered interval	30
Siliceous, ironstone sandstone weathering yellowish	4
Dark shale	2
Ironstone sandstone weathering yellowish	5
Covered interval	8
Dark shale	30
Greenish sandstone and shale; nodular	20
Hard, grey sandstone	10
Hard, siliceous sandstone in part grey and in part thin bedded and dark	15
Hard, white sandstone and conglomerate	70
Base of Blairmore formation	
Total thickness	1,630

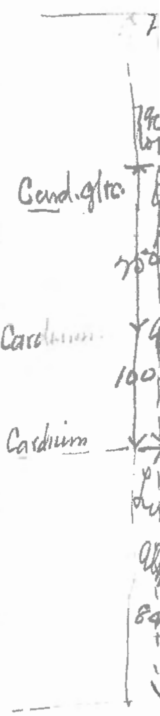
In Turner valley the Blairmore is now defined as a series of strata between the "grit" bed and the base of the "Dalhousie sandstone" and the thickness is believed to be about 1,200 feet. The Dalhousie sandstone of Turner valley shows some fine conglomerate which is believed to be the basal Blairmore conglomerate. It is possible that the Blairmore in both Fisher Creek and Two Pine areas is somewhat thinner than the section given above; in fact drilling in the Cottonbelt well on the Fisher Creek structure seems to indicate a thickness of approximately 1,500 feet. This is quite in harmony with the known eastward thinning of the Blairmore formation.

LOWER ALBERTA ("BENTON") SHALES

The Lower Alberta ("Benton") shales, as exposed on the east side of the Two Pine anticline on Elbow river, show the following succession of strata.

	Thickness Feet	
Cardium conglomerate (basal band)	16	lower Cardium
Shaly sandstones of Cardium band	48	
Sandy shales	45	
Black shale with large ironstone concretions	121	
Thin-bedded, sandy shales—nodules few and not large	76	
Covered interval	25	
Dark shales with thin, ironstone nodule bands	47	
Rusty weathering shale	50	
Dark shale with thin, sandstone bands	36	
Very thin-bedded shales	84	
Limy, ironstone band weathering yellow	1	
Thinly bedded, black shale	90	
Paper-thin, black shales	12	
Thin-bedded shales with small sandstone beds	105	
Thinly bedded, sandy shales	32	
Thinly bedded sandstone	1	
Thinly bedded, sandy shales	22	
Sandstone	1	
Thinly bedded, sandy shales	14	
Brown, finely crossbedded sandstones and shales	9	
Sandy shales	16	
Black shales	53	
"Grit"	2	base

The thickness from the base of the Cardium sandstone to the base of the "grit" is thus 842 feet. This is quite in harmony with other sections in this part of the eastern foothills where the thickness of the Lower Alberta ("Benton") shales is thought to be 850 feet.



CARDIUM BANDS AND UPPER ALBERTA ("BENTON") SHALES

Within the eastern foothills the Cardium is somewhat variable, but in the vicinity of Fisher Creek and Two Pine areas consists of three bands of conglomerate and sandstones separated by dark shales. No band is uniform over the whole area, the greatest variation being shown in the thickness of the conglomerates which may in certain places be absent from some of the bands. In other places, as in the lower band exposed on the east flank of the Two Pine anticline, the conglomerate is 16 feet thick. The upper band frequently shows the conglomerate in an ironstone matrix, as on Jumpingpound creek in sec. 3, tp. 23, range 5, W. 5th mer. In other areas the intermediate band is very poorly developed. In general, however, the thickness from the top of the upper band to the intermediate is about 250 feet and from the intermediate to the bottom of the lower about 100 feet, making a total thickness of 350 feet. Between the different bands are dark shales and sandy shales which carry Upper Alberta ("Benton") fossils, so that in reality the Cardium zone belongs with the Upper Alberta ("Benton") shale group which has a total thickness of 1,900 to 1,950 feet and in the upper part carries marine Montana fossils, although mainly it is of Colorado age.

BELLY RIVER AND YOUNGER FORMATIONS

A description of the Belly River, Edmonton, and Paskapoo formations was published in Summary Report, 1929, part B. Belly River sandstones and shales occur on the flanks of the major anticlinal structure that extends from Highwood river to Jumpingpound creek. As both the Two Pine and Fisher Creek structures expose Blairmore strata bounded by Alberta

("Benton") shales, no younger formations were studied in detail in these areas since they are not likely to be encountered in drilling. The coal seam at the top of the Belly River formation occurs on Elbow river in the Sarcee Indian reserve, a short distance east of the Two Pine anticline. As the seam is 4 to 5 feet thick and contains good quality coal, its discovery was of considerable importance, since fuel can now be cheaply obtained for drilling on the Two Pine anticline. If, as now seems probable, new deep

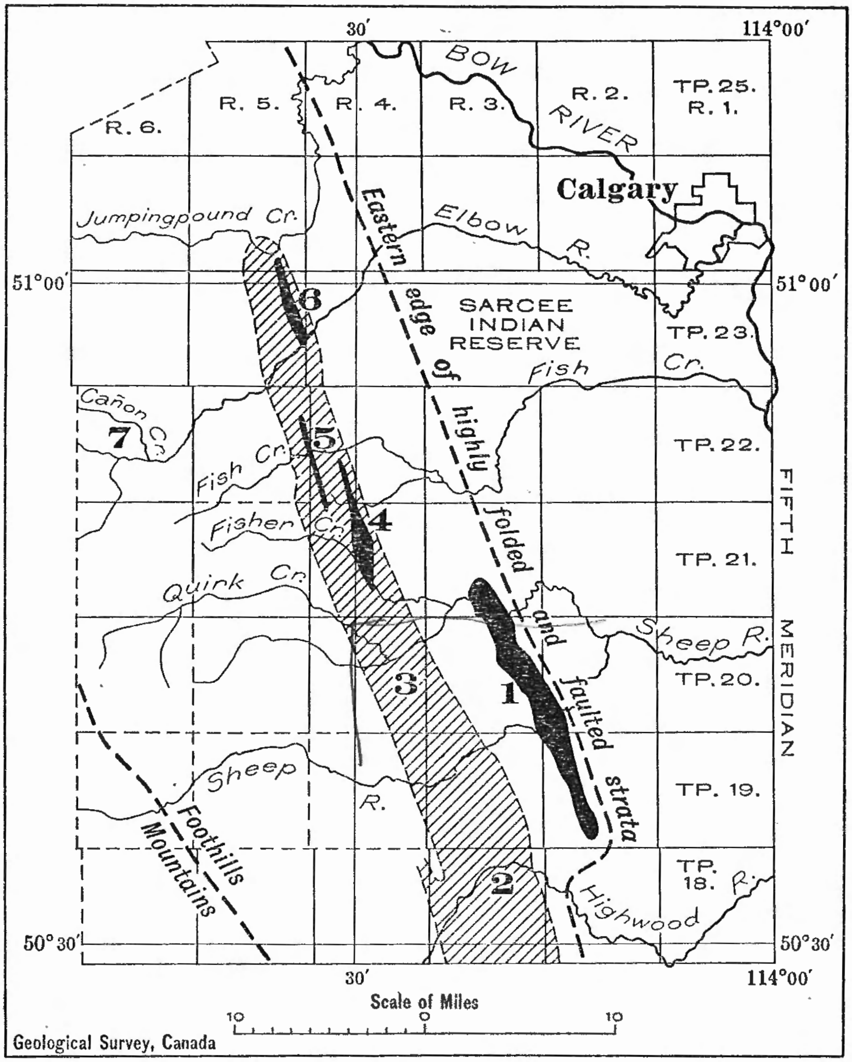


Figure 7. Showing location of Highwood-Jumpingpound anticline (by pattern of ruling) and: 1, Turner Valley area; 2, Highwood area; 3, Waite Valley area; 4, Fisher Creek structure; 5, Birch Ridge structure; 6, Two Pine structure; 7, Moose Mountain area.

wells for oil and gas are drilled on the Two Pine structure, the discovery of this coal seam will save many thousands of dollars for the operators. According to Mr. E. R. Fullerton of Bragg Creek, this coal seam was known many years ago, but its position was lost due to concealment by river gravels. Apparently the early summer floods of 1931 on Elbow river cut sufficiently deep into the north bank to again expose the coal, because on the writer's visit to this locality in 1927 no coal could be found.

STRUCTURE

As described in Summary Report, 1929, part B, a major anticlinal structure extends from Highwood river in the eastern foothills to Jumpingpound creek north of the village of Bragg Creek. This anticline is bounded on the east and west by ridges of Belly River strata dipping easterly and westerly, respectively. The anticline, however, is not a simple structure, but is broken into a series of thrust fault blocks mainly dipping westerly. Also, as a result of plunging within the anticline, structurally high and low areas occur along the strike. The structurally high areas are: (1) Highwood area; (2) Fisher Creek; (3) a narrow strip extending from the south of Whisky creek in range 4 to slightly north of Fish creek in range 5, and on account of including Birch hill, a prominent hill to the south of Fish creek, it is here designated the Birch Ridge structure; and (4) Two Pine anticline. The structurally low areas are intermediate between the structurally high (*See* Maps 261A to 265A) and are: (1) Waite valley and (2) an unnamed area north of the Birch Ridge structure and south of the Two Pine anticline (*See* Figure 7). As has already been mentioned, only two of these areas, namely Fisher Creek and Two Pine, were mapped in detail in 1931, but it is possible as a result of these studies to draw certain conclusions regarding the Birch Ridge structure which lies northwest of Fisher Creek area and southwest of Two Pine area.

The Fisher Creek and Two Pine structures differ greatly in detail, but it is believed that a certain type of faulting occurs in each. In the study of these structures three types of thrust faulting were considered, namely: (1) thrust faults of large displacement with a relatively narrow zone of contorted or disturbed strata west of the fault outcrop; (2) thrust faults of large displacement with a fairly wide zone of disturbed strata west of the fault outcrop; and (3) thrust faults of apparently small displacement with a relatively wide zone of disturbance west of the fault outcrop. Thrust faults belonging to group (1) are of common occurrence in the foothills belt and in some instances, as in Waite valley, drilling has proved that the faults have a steeply dipping fault plane from the surface to at least a very considerable depth. As has been pointed out above, these faults have only a relatively narrow disturbed zone in proximity to them. It is, therefore, believed that the narrow zone of disturbance close to thrust faults of large displacement is an indication that the faults continue to depth with steeply dipping planes. In the case of group (2), that is, thrust faults of large displacement showing a wide zone of disturbance west of the fault outcrop, it is believed the great width of the zone of disturbance is an indication that the strata so disturbed lie close to and above the fault plane which, therefore, though apparently steeply dipping at the surface, bends to a low angle at depth so as to underlie and thus influence the structure of the strata for a greater width than does a fault which remains steeply dipping to a great depth. The major overthrust faults to the east of the Fisher Creek and Two Pine anticlines are believed to be of this second type, as in each case, although the trace of the fault plane on the surface is fairly straight regardless of topography, indicating a relatively steeply dipping fault plane, there is a fairly wide zone of complicated structure to the west of the outcrop of the fault. In Fisher Creek area this disturbed zone affects the structure of the lower Blairmore strata on Fisher mountain. In the Two Pine anticline the disturbed zone is represented by the extremely complicated structure which causes numerous repetitions of the Cardium conglomerate and sandstone on the west side of the Sarcee reserve on Elbow river. In both of these structures the major overthrust has a large displacement. In Fisher Creek area Kootenay strata are overthrust onto Alberta ("Benton") shales, showing a stratigraphic break of as much as 2,500 feet and in the Two Pine anticline Upper Alberta ("Benton") shales are thrust onto the Edmonton or top of the Belly River formation, again giving a stratigraphic displacement of not less than 2,500 feet and possibly greater. The dip of the Alberta shales east of Fisher mountain is not definitely known on account of the lack of outcrops, but it is suspected to be westerly. In the case of the Two Pine anticline, however, it is known definitely that the dip of the strata east of the fault outcrop is westerly and hence in both cases it is suspected the faults approach bedding plane faults. Under such conditions with a large stratigraphic displacement it is obvious that the total displacement along the fault must be many times the stratigraphic displacement. It should be pointed out here that bedding plane faults of large total displacement, but very small stratigraphic break, can occur. The thrust fault underlying Turner valley and outcropping in Edmonton strata on Sheep creek is believed to be an example. For this reason this type of fault can be easily confused with type (3), that is, faults that apparently have only a very small displacement but have a relatively wide disturbed zone in proximity to them. Thus, on account of the small stratigraphic break in the fault that occurs east of Turner valley, it was originally thought to have a small displacement and its true character was not recognized until Sterling Pacific No. 1 well after drilling through about 1,400 feet of Palæozoic limestone passed through this fault into Lower Cretaceous strata, indicating that the fault was not only low-angled at depth but had a very large displacement. It is thought, however, that large, low-angled bedding plane faults, even those in which the stratigraphic break is small, can be distinguished from faults of small displacement, by a type of structure within the area affected by low-angled thrusting, namely the presence of underthrusts. In both the Fisher Creek and Two Pine structures there are eastward dipping thrust faults west of the outcrop of the major overthrusts. In these eastward dipping faults the west side has moved downwards relative to the east side and if the forces of deformation are considered to be derived from the west, as seems probable, these faults are underthrusts[1]. On the west flank

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[1] *See* Link, T. A.: "Relationship between Over and Under Thrusting Revealed by Experiments"; Am. Ass. Pet. Geol., vol. 12, No. 8, p. 826 (1928).

of Fisher mountain the McDougal-Segur sandstone group, which occurs about 300 feet or slightly more below the top of the Blairmore formation, has been underthrust into juxtaposition with a series of sandy limestone beds which occur in the basal part of this formation. The top of this series of limestone beds contains a heavy sandstone bed which on account of producing drilling difficulties has been called the "crooked hole" sandstone. Above the "crooked hole" sandstone are some calcareous shales and limy strata, but the main part of the lime series is below this horizon which is thought to be 1,100 to 1,200 feet below the top of the formation. Although the exact stratigraphic position of the limy beds that outcrop near the underthrust cannot be definitely recognized, the stratigraphic break appears to be at least 800 feet and may be considerably more. The conditions on the Two Pine anticline are somewhat similar, since in section 35, township 23, range 5, strata which immediately underlie the McDougal-Segur group are underthrust against lime beds of the basal Blairmore formation, thus indicating a displacement of several hundreds of feet. Other underthrusts are present on both the Fisher Creek and Two Pine structures and it has been suggested by Dr. Willis[1] that these underthrusts, probably, originate in the zone of maximum bending of a major overthrust, that is, where it changes from a steeply dipping fault near the surface to a less steeply dipping fault at depth (*See* Figure 8). If this is so, then the presence of these underthrusts may be taken as indicating the presence of faults dipping less steeply at depth than at the surface. This type of underthrust faulting has hitherto not been recognized in the foothills belt of this area. If the above deductions in regard to it are correct, and if the positions of the outcrops of both the overthrust and underthrust are known, then if these fault planes be projected downwards to their point of intersection, a method is provided whereby the depth to the zone

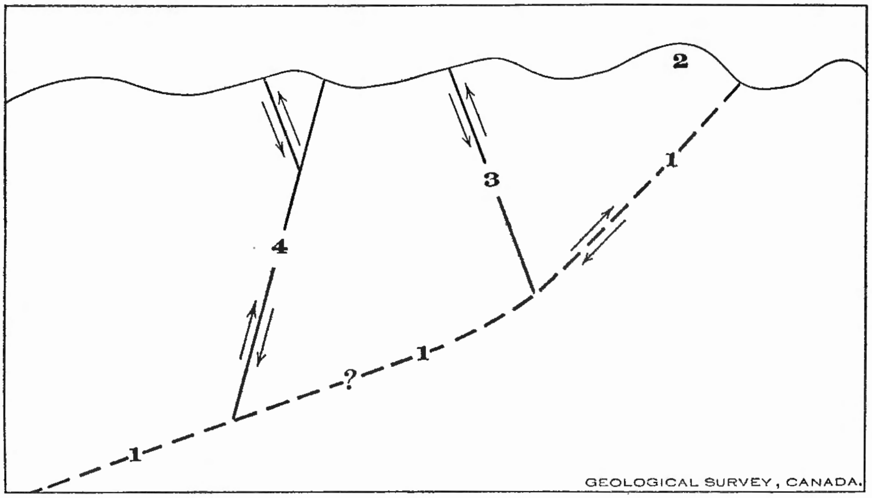

Figure 8. Type of faulting in the Fisher Creek and Two Pine structures: 1, major overthrust fault-dip of fault plane uncertain; 2, zone of complicated structure; 3, underthrust fault; 4, overthrust fault.

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[1] Personal communication.

of maximum curvature of the major overthrust fault may be predicted. The determination of this depth in both the Fisher Creek and Two Pine structures is, however, not a simple problem, for more than one underthrust is present and the angles of dip of the overthrust and underthrust fault planes at the surface are not known. The dip of the strata close to the underthrusts is steep and for this reason it is believed the underthrust fault plane probably dips at not less than 70 degrees. Information regarding the angle of dip of the major overthrust at the surface is more indefinite, but since the trace of the fault plane on the surface seems to follow a straight line regardless of topography, the angle must also be fairly steep. As the basis for a working hypothesis in constructing cross-sections the dip at the surface has been assumed to be 70 degrees for the underthrust fault plane and 50 degrees for the overthrust, and it has been assumed that the overthrust flattens to 20 degrees west of the intersection with the underthrust. These angles were suggested by Dr. Willis as they appear to be in conformity with information derived from surface studies and deep drilling on the New Black Diamond structure west of Turner valley. A section across the north end of Two Pine area in the vicinity of Graystone No. 1 (Signal Hill No. 2) well was constructed, using the above assumptions in regard to the dip of the fault planes. The positions of the faults are fairly accurately known in this area, since a number of horizons within the Blairmore are easily recognizable and the log of the Graystone well on the west flank of the structure gives an accurate succession of strata down to 4,200 feet, the present depth of the well. On constructing the cross-section and using the assumed dips for the fault planes as given above, it was found, however, that the Graystone well should have encountered the major overthrust at a depth of approximately 3,050 feet, whereas with the exception of one small, previously known thrust fault no marked repetition of strata had occurred down to 4,200 feet. It is evident that the assumed dip of one or both fault planes is too low, probably the dip of the overthrust fault plane is much steeper than assumed. By using the assumed values of dip of the fault planes and projecting observed surface dips of strata to depth, certain areas of both the Two Pine and Fisher Creek structures apparently should contain Palæozoic limestones above the major overthrust faults, because in certain areas the depth to the fault plane is great enough to accommodate the stratigraphic succession down to below the top of the limestones. If, however, immediately above the major overthrust a great amount of distortion took place in Fernie and Kootenay strata due to the relative ease with which these sediments might yield to compression in comparison with the harder Blairmore strata, then the total thickness to the fault plane would not be due to the presence of the limestones but to the increased thickness of the Fernie and Kootenay strata through which the fault would cut. If, however, the dip of the low-angled thrust is greater than assumed, as would seem to be indicated by the cross-section projected through Graystone No. 1 well, the probability of the limestone being involved in the structure above the major overthrust becomes progressively greater as the angle of this fault is increased. It is the writer's opinion, after a careful evaluation of the available data, that in all probability certain parts at least, of both the Fisher Creek and Two Pine structures, contain Palæozoic limestones and, therefore, both areas offer exceptionally good prospects for oil and gas production provided porous zones capable of acting as reservoir rocks exist in the limestone as in Turner valley. It is to be hoped that the drilling of Graystone No. 1 (Signal Hill No. 2) well will be continued, not only because greatly needed information regarding structure would be obtained, but also because if the assumed low-angled fault is not encountered above the Palæozoic limestone, this well will afford a good test of the west flank of the Two Pine anticline. The shows of oil so far encountered in the Graystone well, as indicative of a possible concentration of oil, have been very encouraging, especially since none of those lower horizons that might be expected to have a sufficient porosity for them to be productive has yet been reached by the drill.

The Birch Ridge structure extends from south of Whisky creek in range 4 to north of Fish creek in range 5. As far as can be deduced from present information the type of structure is quite different from that of either the Fisher Creek or Two Pine structures. The overthrust fault on the east side of Fisher Creek area appears to die out to the north and is replaced by a simple synclinal fold in the Cardium member of the Alberta ("Benton") shale group (*See* Maps Nos. 264A and 265A). There is a fault on the east side of the Birch Ridge structure along which Blairmore strata are overthrust onto the Alberta ("Benton") shales at about the Cardium horizon. As the strata close to the fault dip steeply it is assumed that the dip of the fault plane is also steep. There is no reason to believe this condition changes with depth. The Birch Ridge structure at its north end (*See* Map 265A) seems to be a simple anticline plunging northward and exposing Cardium sandstones on Elbow river in sec. 11, tp. 23, range 5. To the south, a thrust fault rather closely follows the axis of the anticline. The general structure accounts for the Blairmore strata outcropping in a long, narrow band from sec. 25, tp. 22, range 5, to sec. 31, tp. 21, range 4. The Birch Ridge structure seems, therefore, to be an anticline thrust faulted along its axis and is worthy of serious consideration as an oil and gas prospect. If wells are drilled they should commence sufficiently far west of the fault to reach the Palæozoic limestone before they are cut by the fault. In the case of a well so located a reasonable estimate of the depth to the Palæozoic limestone would be 4,500 to 5,000 feet, depending on the margin of safety allowed.

Elbow Oils, Limited, is drilling a well on sec. 35, tp. 22, range 5 (*See* Map 265A). This well commences in an area separated from the Birch Ridge structure by a fault which will undoubtedly be encountered as drilling proceeds. Below the fault the well will pass into the Birch Ridge structure, but at a very considerable distance down the west flank. The Palæozoic limestone in the well will be very deep, but should it be reached and production secured, the merits of the Birch Ridge structure will be proved. Much shallower tests of the Birch Ridge structure than the Elbow Oils well are, of course, possible.

OIL AND GAS PROSPECTS

The major anticlinal structure which extends from Highwood river to Jumpingpound creek has already been described.[1] Drilling on this struc-

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[1] Geol. Surv., Canada, Sum. Rept. 1929, pt. B, pp. 1-20.

ture has been done in Highwood area and shows of oil and gas with salt water were secured in some of the horizons where it was hoped there might be production. As shown on Map 261A the anticlinal structure in Highwood area is relatively broad and is broken by thrust faults into several, westerly dipping fault blocks. It is assumed that originally the Highwood anticline was a broad fold and that later, due to severe compression, it was broken into fault blocks. If this is so it seems probable that oil and gas would commence to accumulate in the early stages of folding, but because of the width of the original fold no marked concentration could result. Later when the fold was broken by faults each fault block would hold part of this oil and gas. No fault block so far drilled seems to have held a supply of oil and gas adequate for commercial production. It seems as if narrower folds where the oil and gas would concentrate in more limited areas, offer more favourable prospects. Both the Fisher Creek and Two Pine structures seem to fulfil these conditions, for not only is the main anticlinal structure much narrower than in Highwood area, but in each structure the structurally high part is concentrated into one compact group rather than into a series of fault blocks distributed over a considerable width. The same is true of the Birch Ridge structure, the character of which is best shown at the north end, north of Fish creek, where the structure is a simple anticline faulted along the axial plane of the fold.

It has already been shown[1] that many localities within the foothills contain oil and gas seepages. Turner Valley field has proved that there are porous zones capable of containing large volumes of gas and oil. It is reasonable to assume that these porous horizons will occur in other parts of the foothills where seepages indicate the petroliferous character of the strata. Seepages of gas occur in both Fisher Creek and Two Pine areas and although, in many cases, because of unfavourable structural conditions, seepages may not be of great significance as indicating possible reservoirs of gas and oil, yet seepages on favourable structures are important indicators that accumulations may exist. One of the largest gas seepages in this part of the eastern foothills occurs on Bull creek, a tributary of Highwood river, and yet the Hudson's Bay Oil and Gas Company's well drilled near it obtained no commercial production. On the other hand, however, the first well in Turner valley, Dingman No. 1, was drilled close to a seepage near Sheep creek. In choosing well sites, structural conditions should, therefore, receive more consideration than the mere presence of seepages, but where seepages occur in conjunction with favourable structures, the drilling of test wells is decidedly warranted.

Cottonbelt No. 1 well on the west side of sec. 21, tp. 21, range 4, in Fisher Creek area, has at the time of writing reached a depth of 2,620 feet. At a depth of about 300 feet the well encountered what is thought to be the McDougal-Segur group of sandstones, and although these sandstones outcrop a short distance east of the well and were expected to carry water only, some gas was found with the water. Several small oil and gas shows were encountered in the Blairmore formation and a slight show of oil was reported at the Blairmore-Kootenay contact at a depth of 2,258 feet. At present the well is drilling in lower Kootenay strata and has not reached the granular sandstone which in Turner valley is designated the "brown

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[1] Geol. Surv., Canada, Sum. Rept. 1929, pt. B, p. 18.

sand." In Turner valley only a very small thickness of Kootenay lies between the base of the Blairmore and the "brown sand," but since the Kootenay thickens westward to 350 feet in Moose Mountain area and a considerable thickness was found in the Calgary Development and Production well on sec. 20, tp. 19, range 3, which is approximately on the strike of the Cottonbelt location, but a number of miles southeast of it, therefore, a few hundred feet of Kootenay may be expected in the Cottonbelt well. This increase in the thickness of the Kootenay has no bearing on the prospects for oil and gas in lower horizons and it is considered that the drilling thickness from the "brown sand" to the top of the Palæozoic limestone will be much the same as in Turner Valley wells. The "brown sand" in Turner valley has produced oil in several wells, but it is not a persistent productive horizon. It offers prospects, however, in Fisher Creek area, although the upper part of the Palæozoic limestone is the more probable producing zone.

Graystone No. 1 (Signal Hill No. 2) well on the west flank of the Two Pine anticline has at present (December 1, 1931) reached a depth of 4,200 feet and drilling is being continued. The well at this depth is in the "lime series" of beds at the base of the Blairmore. It is probable that a considerable thickness of Kootenay will occur in this area, though because of the eastward thinning of the Kootenay this thickness may be somewhat less than in Herron Petrôleums No. 1 well where the base of the Blairmore was reached at 2,030 feet, the top of the "brown sand" at 2,440 feet, and the top of the Palæozoic limestone at 2,700 feet. The dip of the strata being drilled by Graystone No. 1 well is believed to be somewhat greater than in the Herron Petroleums well and due to this the drilling thickness will be somewhat increased for an equal amount of stratigraphic thickness.

THE DARMODY-RIVERHURST ARTESIAN WATER AREA, SOUTHERN SASKATCHEWAN

By D. C. Maddox

CONTENTS

Illustration

INTRODUCTION

During the field season of 1931 the writer, with the advice and assistance of Mr. R. T. D. Wickenden, investigated the artesian water area situated along the Canadian National railway between Darmody and Riverhurst. All available information on the deep wells was collected and their elevations were determined. Similar work was done to the north and west of the area, but time did not permit of its completion, so that the limits of the artesian water area have not been determined, but the area of artesian flow has been fairly well defined. The known area over which water is under pressure and rises part way or quite to the surface is at least 500 square miles, and practically everywhere in this area water can be obtained by drilling. The depth to which it is necessary to drill may be determined from the depths of existing wells as given in the accompanying table (*See also* Figure 9 for positions of wells) and from the elevation of the ground at any particular place (*See* Rush Lake sheet, Topographical Survey of Canada, Ottawa). Further work is necessary to determine the source of the water so as to get some idea of the amount available, but there is no doubt that the supply is large.

Most efficient assistance was given in the field by E. W. Shaw. Thanks are due to a large number of farmers who gave all information and assistance possible. The following well drillers gave much valuable information: Mr. Chris Olmen of Riverhurst; Mr. H. N. Williamson of the Dominion Drilling Company, Eston, Saskatchewan; Mr. J. D. McNeely of Moose Jaw; Mr. I. Wangle of Swiftcurrent; Messrs. R. R. Heal and R. Midgley of Elbow. The municipal clerks of several municipalities helped by giving information on well positions. Through the co-operation of Mr. R. H.

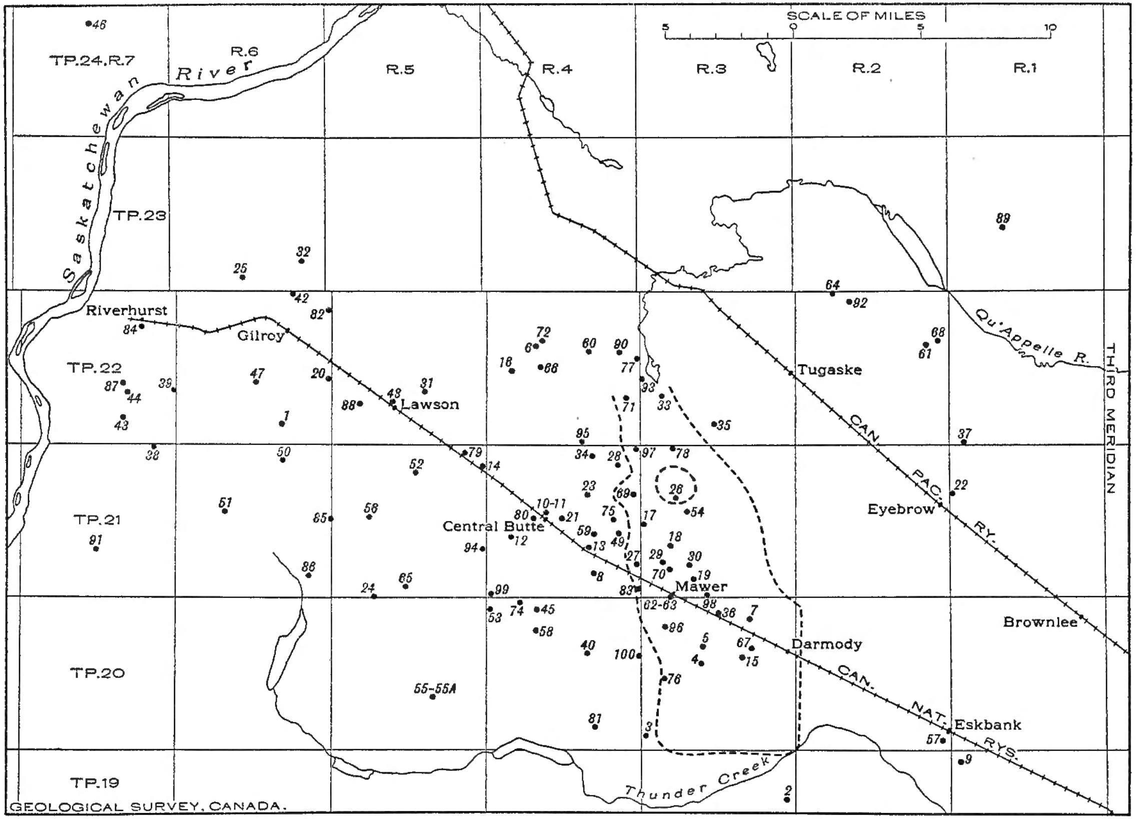

Figure 9. Index map showing positions of wells, Darmody-Riverhurst artesian water area, Saskatchewan. The approximate limit of the area of flowing wells is shown by a line of dashes.

Murray of the Division of Sanitation, Health Department, Regina, a number of analyses of water were made by that department and proved of considerable value in outlining the extent of the artesian area, as the water is unusual and fairly uniform in character.

The general water supply conditions in southern Saskatchewan have been described in some detail by H. E. Simpson.[1] The small rainfall, averaging at Regina for the twenty-year period 1910 to 1929, 14·8 inches, combined with a high rate of evaporation, renders the problem of water supply difficult. In most years water can be obtained for farm use from shallow wells or from dug-outs which conserve the rainfall of the earlier part of the year for use during the summer and autumn. In some areas both these sources of supply may seriously diminish or fail entirely in very dry seasons. The deeper wells in the surface deposits are in general less likely to be affected by drought than the shallower ones and the supply from the deep wells obtaining water from the bedrock formations does not seem to be affected to any appreciable extent by dry seasons.

The artesian area referred to in this report is located on the east half of the Rush Lake sectional sheet. No large towns or cities are included in the area, the population being distributed among villages and farms. The nearest city, Moose Jaw, is about 40 miles in a direct line east and south from the eastern limit of the area. Caron, from which Moose Jaw draws some of its water supply, is about 20 miles from this eastern limit. Topographically the area is fairly flat, the elevations in general ranging from 1,900 to 2,200 feet. Towards the south lies the valley of Thunder creek and beyond this Missouri côteau. The elevation of the eastern end of the area is about 1,960 to 1,970 feet, the elevation of Moose Jaw about 1,800 to 1,850 feet, and that of Regina about 1,900 feet.

GEOLOGY

With the exception of a few scattered outcrops of Cretaceous shales and sandstones the area is underlain by glacial deposits. Boulder clay of the ground moraine type is the dominant glacial deposit, although towards the southern limits some of the terminal or recessional type occurs. The Bearpaw formation of Cretaceous (Montana) age is known, from the work of P. S. Warren, to underlie the glacial drift over the greater part of the area. In Tugaske district a sandstone outcrops. Below the Bearpaw the sandy beds of the Belly River formation are considered to occur and below them marine shales probably Colorado in age. The water sand from which the deep wells draw their supply is considered to be a sandy bed in the Bearpaw shale or possibly in the upper part of the Belly River formation. Very few complete logs of the wells are available and very few samples other than a number from the water sand are to be had.

In the western part of the area one of the drillers, Mr. Chris Olmen, reports that about 200 feet above the water sand a dry sandstone was passed through in many of the wells, well No. 51 showing this sandstone at 310 feet to 326 feet, underlain by shale at 326 feet to 560 feet, at which point the water sand was found.

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[1] Simpson, H. E.: Geol. Surv., Canada, Sum. Rept. 1929, pt. B, pp. 69-82.

Information as to conditions below the water sand is rather uncertain as few wells have penetrated below it. In wells Nos. 8 and 55A, however, a second water sand was found about 100 feet below the first. Well No. 8 is producing water from this lower sand; well No. 55A was abandoned and another was drilled to the upper sand. In the Central Butte No. 1 well, now abandoned, 265 feet of shaly sandstone browner than the formations above it was reported as underlying the upper water sand. Well No. 54 showed, underlying the water sand, 110 feet of sand and shale, becoming browner at depth. Well No. 57, considered to lie outside the normal water area, is reported to have passed through shale from 300 to 750 feet, no water being found until the latter depth was reached. Information on well No. 22, also outside the central area, is not very reliable, but it seems probable that a second water sand was found 278 feet below the top of the first.

The thickness of the water sand is known only in a few cases as it is not generally necessary to drill through it. It is reported to be 20 feet thick at Riverhurst, 40 feet at Central Butte, 50 feet at well No. 86, and 21 feet at well No. 8. A hard layer, probably containing pyrite, is reported as occurring just above the water sand in wells Nos. 7, 15, 68, and 97, as well as in Elbow district north of this area. The water sand seems to be continuous over the whole area, because as far as known no dry holes have been drilled within its limits.

LIMITS OF THE ARTESIAN AREA

The limits of the area underlain by sand containing water of the type peculiar to the basin are difficult to define. Lacking a sufficient number of dry holes to define the boundaries, changes in the nature of the water as regards salinity may be used with caution in delimiting them. It has generally been considered that in the deeper, more stagnant, marginal parts of an artesian basin the water will, probably, contain a larger proportion of dissolved salts than in the more central parts. This is thought to be due to the retention of dissolved salts in the water at these points, where no flushing action of fresh or less saline water is likely to occur. In the case of the Darmody-Riverhurst area, some of the marginal wells yielding water high in salts seem to have reached an horizon deeper than that of the central area, but the fact that the normal water sand was not present in the upper part of such wells shows that they are located beyond the "normal" water limits.

On the north, the presence of sandy beds in the drift from which water may be obtained has obviated the necessity of drilling deep wells, and, therefore, direct evidence of the extent of the artesian area in that direction is lacking. Analysis of water from well No. 6 shows only a slight increase in total solids (117 grains a gallon). The water from well No. 31, however, showed 282·6 grains a gallon and it seems probable that the northern limit is about, or slightly to the south of, the north margin of township 22. North of township 24 a deep, soft-water horizon occurs and though work in this northern district is not completed, enough has been done to show that the water-level in the wells is generally lower than in the Darmody-Riverhurst area and the water of the town well at Loreburn shows a high saline content (190·2 grains a gallon).

On the east, the waters of all wells east of range 3 are very high in total solids (*See* analyses Nos. 61 and 89). No analyses of water from wells Nos. 22, 37, 64, 68, and 92 are available, but all are reported to be very salty, generally too much so for human use. No well records from townships 20 and 21, range 2, are available. The evidence shows that the eastern limit lies probably somewhere about the eastern boundary of range 3.

On the south lies the valley of Thunder creek and beyond this Missouri côteau. Analyses of water from wells Nos. 3 and 55 show normal conditions. Well No. 73 is not in use and no analysis is available. Well No. 2 yielded very salt water. The water of the Canadian Pacific Railway well at Chaplin contains 407·3 grains of total solids a gallon and is very hard. Several dry holes were drilled south of Mortlach, one to 650 feet. With this limited information it is difficult to draw a definite southern boundary, but it seems probable that the normal water area extends at least as far south as the northern limit of township 19, at least as far west as, and probably farther west than, range 5.

The western limits are not easily defined. A deep, soft-water horizon occurs west of Saskatchewan river and is probably continuous with the horizon east of the river. Although work west of the river has not been completed it seems safe to assume that the normal water sand extends to at least the western boundary of range 7 at least as far south as the northern limit of township 20.

These limits include fifteen townships, or 540 square miles. Eliminating the rather uncertain southwest corner a very conservative estimate of the area is 500 square miles.

ARTESIAN CONDITIONS

The conditions considered essential for an artesian basin of the normal type are as follows. Escape of water upwards or downwards from the water-bearing beds must be impossible and is commonly prevented by the presence of layers of relatively impervious rock such as shale. The water-bearing beds in the intake area must outcrop at an elevation sufficiently high above the ground-level at the well to permit of the water rising by hydrostatic pressure; and the height of outcrop must be sufficient to compensate for loss of head by friction during passage from the intake area to the well. Under these conditions a continuous supply of water is obtainable, the amount being dependent on the thickness and porosity of the water-bearing beds, on the amount of water entering at the intake area, and on the velocity of movement of water within water-bearing beds. The velocity of movement is governed by certain factors, the most important of which are the size and uniformity of size of the grains composing the water-bearing horizon, and the temperature of the water. The water may rise to the surface or only part way, depending upon the elevation of the ground at the well. In southern Alberta, Dowling[1] has described an artesian area in which the intake beds are supplied with water by Milk river where it flows over the porous Milk River sandstone,

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[1] Dowling, D. B.: Geol. Surv., Canada, Sum. Rept. 1922, pt. B, pp. 104-123.

which dips to the north under relatively impervious marine shale. In regions of comparatively small rainfall, such as southern Alberta and southern Saskatchewan, it would seem necessary, unless the intake beds outcrop over a large surface free from a more or less impervious cover of drift, that they should be in contact with a body of water such as a river or lake that represents the run-off from a comparatively large area. Russell[1] has suggested that an artesian basin may exist without the water-bearing horizon outcropping, the water existing in disconnected lenses or bodies of sandstone in which the pressure of the overlying rocks is thought to cause the rise of the water. Russell's conclusions, however, have been questioned so far as they apply to the Dakota artesian basin[2]. Ch. Terzaghi[3] has shown that such conditions have existed in the case of sand completely enclosed with unconsolidated clay, but concludes that they would not be applicable after the overlying rocks had reached complete consolidation. The question is of interest in the present discussion as offering an explanation of the pronounced rise in water-level towards the south where Missouri côteau lies. An alternative explanation for this rise is that the intake area lies towards the south or southwest and a general tendency of the water-level to rise to the south is noted in all parts of the area. A knowledge of the intake area is of great importance in estimating the amount of water supplied to the beds, and, in attempting to locate it in the present case, the rise of the water to an elevation of over 2,000 feet in the southern part of the area must be considered. Towards the intake area the elevation, both of the water-level and of the water-bearing horizon, would be expected to rise and the salinity of the water expected to decrease. This is the case in the southern Alberta artesian area.

In attempting to locate the intake area it is evident that neither the north nor the east are likely directions in which to look, the decline in surface elevations towards the east being also unfavourable. The conditions as regards the south are uncertain. The pronounced rise of the water-level towards the south is significant. The log of the Canadian Pacific Railway well at Chaplin shows as follows.

	Feet
Hard clay, light colour (probably shale)	272–500
Sandstone with water	500–585
Hard shale	585–675

The elevation of the top of the water sand is 1,710 feet and of the bottom of the well 1,535 feet. Of the 407·3 grains a gallon of total solids that the water contained, 148·4 were salts of calcium and magnesium. The casing set at 490 feet would exclude the hard surface waters. The nature of the water and of the rocks above makes it improbable that this water-bearing horizon is the same as the one found farther north. No outcrops of sandstone were seen on the road from Central Butte to Chaplin, though some sandy glacial outwash occurs. For the water-bearing horizon to outcrop in the Coteau between well No. 55 and Chaplin would require

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[1] Russell, W. L.: Econ. Geol., vol. 23, pp. 132–157 (1928).
[2] Piper, A. M.: Econ. Geol., vol. 23, pp. 683–696 (1928).
[3] Terzaghi, Ch.: Econ. Geol., vol. 24, pp. 94–100 and 211–213 (1929).

a rise of at least 300 feet in a few miles, whereas north of well No. 55 the rise to the south is only a few feet to the mile. Such a marked change in the rate of rise is improbable and, furthermore, the Côteau is not a probable source for the water. It is towards the west and southwest that the intake area is most likely to be found. Saskatchewan river within the limits of the Rush Lake sheet is excluded as a possible source because the elevation of the river water surface is too low to permit water to rise to over 2,000 feet, the elevation of the Saskatchewan being 1,788 feet at the west boundary of range 15 and 1,664 feet at the northern boundary of township 16. Swiftcurrent creek is a possible source. Within the limits of the Rush Lake sheet the creek has cut a deep valley, the elevation of the bottom of which ranges from about 2,350 feet to about 1,750 feet. A study of the water sand in the western half of the area of the sectional sheet shows a general rise to the south. In a group of wells south of Beechy, on which no levels have yet been run, a rise to the south is shown. Two wells on section 21, tp. 21, range 9, show water sand at elevations of 1,728 and 1,733 feet. In the Imperial Oil Company's Rush Lake well on the SE. ¼ sec. 30, tp. 19, range 11, a greenish sand was found at depths between 50 feet and 90 feet. The elevation of this well is not known, but it is probably about 1,775 feet, which would give an elevation of 1,725 feet for the top of the sandstone. At an abandoned deep well on the NE. ¼ of sec. 1, tp. 19, range 11, the water sand is at an elevation of about 1,775 feet. It seems probable that Swiftcurrent creek has cut down to the level of the water sand at some period and that the exposure has been covered with drift or alluvium. The chief difficulty in postulating Swiftcurrent creek as the source of the water lies in the fact that the water sand will have to rise from the Rush Lake well more than 300 feet in about 12 miles. West of Swiftcurrent creek several deep, soft water wells occur in which the water sand appears to be at a level of about 2,000 to 2,150 feet, but no work has been done on them and no analyses of water are available. Swiftcurrent creek appears to lose a good deal of water between Swift Current town and Saskatchewan river, but metering of the stream flow would be necessary to prove this, and the possibility of the escape of this water in springs must be considered. The extension of the water sand to the northwest seems limited by the fact that a dry hole 750 feet deep was drilled on the SW. ¼ sec. 18, tp. 21, range 11, and by the fact that Mr. Williamson of the Dominion Drilling Company reported a dry sand containing gas in Tyner and Cabri districts.

COMPOSITION OF THE WATER

The only complete available analysis of the water is one made by Cruikshank, of Regina, of the Canadian National Railways well at Mawer[1]; this follows, the figures referring to parts per million.

Calcium bicarbonate (as carbonate)................................	35
Magnesium bicarbonate (as carbonate)................................	10
Sodium carbonate..	498
" sulphate..	789

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[1] Johnston, W. A.: "The Water Supply Problem in Southern Saskatchewan"; Eng. Jour., Jan. 1931, p. 31. Geol. Surv., Canada, Sum. Rept. 1930, pt. B, p. 63.

Sodium chloride	163
Silica	2
Iron and alumina	2
Total solids by calculation	1,499
" " evaporation	1,560
Temporary hardness	5
Permanent "	0

This analysis shows that the artesian water differs markedly from the normally very hard water found in the drift. The water sand contains a considerable proportion of a green mineral apparently of the glauconite type, and it is considered probable that an exchange of bases occurs in the sand, the calcium of the calcium sulphate and bicarbonate being replaced by sodium. It has been thought that a change of this nature occurring in the Lance and Fort Union beds in Montana was due to leverrierite, a clay-like mineral contained in the rocks[1]; in that area it was considered that little further alteration in the water occurred below a depth of about 125 feet. In the case in question, however, the Bearpaw shale, the outcrops of which in many cases show crystals of selenite, the crystallized calcium sulphate, may well contribute more salts to the water at depth. The water in the wells of the southern Alberta artesian area differs in that it contains a much larger proportion of sodium carbonate relative to sodium sulphate, the sodium chloride content increasing as the distance from the intake area increases.

An analysis of the water from well No. 8 is of interest as it is the only one of water from the deeper water sand; it shows that sodium sulphate, sodium carbonate, and sodium chloride are in about equal proportions, whereas the analysis of the Canadian National Railways well at Mawer showed these proportions as approximately 5 : 3 : 1. Reference to the column headed "analysis" in the list of wells shows that the water in the central normal area is fairly uniform in composition, ranging from 90 to 115 grains a gallon of total solids. To the north, east, and south, the water becomes more saline, the analyses of the water from wells Nos. 61 and 68 showing practically all sodium chloride.

As regards the use of the water for drinking, all well owners consulted reported that it was very good and that at its usual temperature when pumped, 44 degrees to 48 degrees, it is preferable to the hard, drift water, and the taste of soda is not objectionable. As regards the use for irrigation and animals, Dole[2] states that of the alkaline salts the carbonate appears to be the most, and the sulphate the least, injurious. Perry[3] states that if water containing 84 grains or over to the gallon of total solids is used for irrigation purposes, the land irrigated must have good drainage conditions, causing the water to penetrate deeply into the ground, keeping it in motion, and preventing evaporation at the surface. Dr. F. T. Shutt of the Dominion Experimental Farm expressed the opinion that the water of the Canadian National Railways well at Mawer was too high in salts for irrigation pur-

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[1] Renick, B. C.: "Base Exchange in Ground Water by Silicates as Illustrated in Montana"; U.S. Geol. Surv., Water Supply Paper 520, pp. 69-71.

[2] Mendenhall, W. C., Dole, R. B., and Stabler, H.: "Ground Water in San Joaquin Valley, California"; U.S. Geol. Surv., Water Supply Paper 398, pp. 134-135.

[3] Perry, E. S.: "Ground Water in Eastern and Central Montana"; Montana Bur. of Mines and Geol., Mem. No. 2, p. 55.

poses. A little gas comes with the water in some of the wells. The owner of well No. 92 reports that for several years, for a period of about six weeks, sufficient gas came from the well to cause the water to flow, the last occasion being in February, 1930. The owners of wells Nos. 2 and 68 also report some gas. In the case of a deep well 4 miles north of Birsay, sufficient gas was present to cause effervescence in the water, yet the water-level remained 250 feet from the surface. The water in well No. 85 is reported as "oily" after standing, but this may be due to a film of iron oxide.

DESCRIPTIONS OF WELLS

The Canadian National Railways well at Mawer yielded the largest initial flow, reported at 115,000 gallons a day; it is now cut down to 4,800 gallons a day.

In well No. 85 the elevation of the water sand is more than 200 feet higher than in other wells in the vicinity, but the elevation of the water-level is about the same. The water is soft and sufficient to stand two weeks continuous pumping. The stratigraphic position of the water sand appears to correspond to that of the sandstone recorded about 200 feet above the water sand in the other wells. However, the driller of this well recorded 20 feet of sandstone, from the depths of 100 to 120 feet, and it seems peculiar that water was not found in this sand in other wells in the district.

A flowing well, owned by Mr. W. Griffith, on the NW. ¼ sec. 24, tp. 21, range 3, W. 3rd mer., was considered to be one of the normal water wells until an analysis showed only 41·2 grains a gallon of total solids, with much calcium and magnesium sulphate. The well, probably, is in the drift, the elevation of the water sand being 1,647 feet.

The group of wells in township 22, ranges 3 and 4, shows, apparently, the presence of two water sands, the sand in wells Nos. 33, 77, and 35 being 200 to 300 feet higher than the sand in other wells in the district. The possibility exists that the higher water sand is similar to that which outcrops at an elevation of about 2, 00 feet along the Canadian Pacific railway about 3 miles northwest of Tugaske, and at about the same elevation on the road north from Tugaske about a mile. If this is the case, there is a difference in elevation of over 200 feet in about 4 miles.

A certain amount of levelling work was done on wells located in the Elbow sheet to the north of the Rush Lake sheet and on some wells in the Rush Lake sheet west of Saskatchewan river. Considerable information was also collected in several districts in which no levelling was done. A brief summary of these results is given as bearing on the general question of artesian areas and on the possible source of the water.

ELBOW SHEET AREA

A deep, soft-water horizon extends from north of township 24 nearly to township 31. Some of the wells there are flowing. From the evidence of the twenty-four wells on which levels were run and from estimates of those on which no levels were taken, it appears that the water-level is generally lower than in Darmody-Riverhurst area. Elevations of the water sand and of the water-level show great differences in short distances, and it seems probable that several water sands occur.

Within a few miles of the Canadian National line from Dinsmore to Forgan, a number of soft-water wells 400 to 750 feet deep occur. A 1,003-foot well on the SW. ¼ sec. 20, tp. 27, range 9, found no water at depth.

MAIN CENTRE—BEAVER FLAT AREA

In the Main Centre district and in a district 4 to 6 miles south of Beaver Flat, a group of deep, soft-water wells occur. No levels were run on them, but the elevation of the water sand, 2,350 to 2,550 feet seems to be considerably higher than that in Darmody-Riverhurst area. Many of the wells yield water of a distinctly brown colour, probably due to lignite.

SOUTHWEST OF SWIFTCURRENT CREEK

In the area in the Rush Lake sheet bounded on the north by Saskatchewan river and on the east by Swiftcurrent creek, are several deep, soft-water wells. An estimate of depth to the water sand shows its elevation to be about 2,000 to 2,150 feet.

WEST OF SASKATCHEWAN RIVER, EAST OF RANGE 12, AND SOUTH OF TOWNSHIP 25

Many deep wells yielding soft water are found from Saskatchewan river to a few miles west of the Canadian National line from Birsay to Beechy. Some of the wells, especially those south of Beechy, appear to conform generally to the elevations of those east of the river, but many do not and it seems probable that several water sands occur in this area.

HERBERT

Information on four deep wells was collected. The depths range from 320 to 464 feet, corresponding to elevations of about 1,850 to 2,000 feet. The water is brown and soft, analysis of the town well showing 90·2 grains a gallon of sodium carbonate and sodium chloride.

AYLESBURY-CRAIK-HOLDFAST AREA

It is reported that several deep, soft-water wells occur in this area, but no work was done on them.

GENERAL STRUCTURAL CONDITIONS

On account of the very anomalous elevation figures no structure contours have been drawn on the map. The wells were drilled by several drillers, many of them years ago, and the ownership of the farms in some instances has changed. By eliminating the wells showing abnormal elevation figures, however, some fairly definite generalization may be made.

THE RISE OF THE WATER-BEARING HORIZON TO THE SOUTH

In the district south of Riverhurst wells Nos. 84, 87, 44, 43, and 91, all drilled by Mr. C. Olmen, show this rise between Nos. 84 and 91 to be 12 feet to the mile. In the district south of Gilroy, wells Nos. 47, 1, 50, and 86 show a rise of 14 feet to the mile. In the district east of Central Butte, the figures are so anomalous that it is difficult to draw conclusions; well No. 3 shows a rise of 9 feet to the mile from well No. 97; on this line, however, lies well No. 27 which shows a very high elevation of the water-bearing horizon. In the district north and south of Mawer, well No. 76 shows a rise of about 7 feet to the mile from well No. 78.

THE RISE OF THE WATER-BEARING HORIZON TO THE WEST

Although many exceptions occur, there seems to be a fairly definite indication of a westerly rise, the amount varies rather widely. On and near the northern boundary of township 21, wells Nos. 78, 97, 95, 1 and 50, and 38 show a fairly consistent rise of about 6 feet to the mile. On and near the north boundary of tp. 20, the rise from well No. 62 to the elevation of well No. 91 projected 2 miles south, shows a rise of about 5 feet to the mile. An abnormally high elevation of the water sand is shown by well No. 85, as previously mentioned. Wells Nos. 25 and 27 also show this. The well at Mawer is also considerably higher than the wells to the south and to the north.

WATER-LEVEL

In the flowing-well area, the elevation of the water-level has not generally been accurately determined. In well No. 98, however, its elevation is definitely known to be 1,990 feet. In well No. 100 the water rises exactly to the ground-level. As regards changes in water-level, information provided by well owners is rather conflicting. Data on changes of level in the water are of necessity rather indefinite. The wells are all closed in and are only opened for repairs to pumping apparatus or to clean them out. The water-level is often recorded when the pump rods are taken out, but it is probably not accurately measured. The owners of the following wells report no change in water-level in the periods specified: Nos. 23 and 79, 1916 to 1931; No. 80, 1915 to 1931; No. 8, 1914 to 1929. Owners of wells Nos. 92 and 64 report falls of 25 and 40 feet, respectively; these wells, however, are in the marginal parts of the area, in which gas is found. In well No. 59 a fall in level was recorded. Owners of wells Nos. 88 and 99 record rises of about 80 feet and 15 feet, respectively.

List of Wells

Serial No.	Name of owner	Location				Depth		Elevation of			Temperature of water, degrees F.	Driller	Year drilled	Yield in gallons a minute	Analysis total solids, grains a gallon
		West of 3rd meridian				Of well in feet	Surface to water, in feet	Surface, in feet	Top of water sand, in feet	Water-level, in feet					
		¼ Sec.	Sec.	Tp.	Range										
1	Andrews, J. R.	NW.	2	22	6	560	150	2,110	1,570	1,960	43	Collins	1916	....	....
2	Aske, J.	SE.	25	19	3	640	14	1,993	1,353	1,979	43	C. Olmen	1916	....	....
3	Averill, V. G.	NW.	6	20	3	400	2	2,024	1,636	2,022	45	J. D. McNeely	1928	....	137·2
4	Bach, H. M.	SW.	21	20	3	438	Flowing	1,984	1,558	....	....	J. D. McNeely	1918	2½	....
5	Bach, T.	SW.	28	20	3	437	"	1,977	1,552	....	48	J. D. McNeely	1917	16	....
6	Badger, T. M.	NE	20	22	4	414	50	1,970	1,556	1,921	43	C. Olmen	1914	....	117·0
7	Bruvold, O.	SW.	35	20	3	457	Flowing	1,970	1,525	....	49	J. D. McNeely	1919	47	....
8	Bourg, L.	NW.	2	21	4	512	35	2,040	1,528	2,005	....	C. Olmen	1914	....	104·8
9	Campbell, S. J.	NW.	31	19	1	1,140	....	1,997	1,630 857	....	....	R. Creelman	1919	....	....
10	Central Butte No. 1	SW.	21	21	4	800	....	2,061	1,566 1,261	....	....	Collins	1914–1915	....	....
11	Central Butte No. 2	SW.	21	21	4	500	60	2,061	1,566	2,001	50	R. Creelman	1925	....	115·8
12	Chapman, W.	SE.	18	21	4	573	160	2,160	1,587	2,000	....	C. Olmen	1917	....	....
13	Charlton, W.	NE.	10	21	4	528	28	2,027	1,511	1,999	....	J. D. McNeely	1919	....	....
14	Colwell, G.	SE.	36	21	5	540	90	2,073	1,542	1,983	....	C. Olmen	1923	....	....
15	Compton, M. E.	NE.	22	20	3	508	Flowing	1,971	1,475	....	48	J. D. McNeely	1925	1½	....
16	Cozark, G.	NE.	18	22	4	410	48	1,981	1,571	1,933	....	C. Olmen	1922	....	....
17	Currie, A.	NW.	18	21	3	418	Flowing	1,966	1,560	....	....	J. D. McNeely	1918	1	....
18	Dancy, C. M.	SW.	17	21	3	444	"	1,972	1,540	....	....	J. D. McNeely	1919	⅓	....
19	Dancy, R. S.	NW.	4	21	3	412	"	1,976	1,576	....	....	J. D. McNeely	1918	4	....
20	Dick, J.	NE.	13	22	6	540	140	2,090	1,550	1,950	....	C. Olmen	1919	....	....
21	Duffin, H.	SE.	21	21	4	501	60	2,037	1,548	1,977	....	J. D. McNeely and C. Olmen.	1916	....	....
22	Falkner, W. E.	SW.	30	21	1	690	200	2,083	1,671 1,393	1,883	....	Adams	1926	....	....
23	Fleenor, J. M.	SE.	27	21	4	450	12	1,988	1,558	1,976	....	Collins	1916	....	....
24	Ford, F.	SE.	5	21	5	538	160	2,152	1,625	1,992	44	Collins and Duff	1919	....	....
25	Gallaher	NE.	4	23	6	333	60	1,995	1,662	1,935	43	W. Coleman	1914	....	....
26	Gibbie, W. R.	NW.	20	21	3	495	10	1,986	1,503	1,976	....	J. D. McNeely	1922	....	....
27	Gibson, A.	SE.	12	21	4	330	Flowing	1,981	1,663	....	....	J. D. McNeely	1919	⅖	....
28	Gillespie, C.	SW.	36	21	4	404	....	1,962	1,578	....	....	Collins	1917	....	....
29	Grant, A. H.	SE.	7	21	3	444	Flowing	1,967	1,535	....	....	J. D. McNeely	1914	⅔	....
30	Grant, J. F.	SE.	8	21	3	450	"	1,976	1,538	....	47	J. D. McNeely	1916	½	....
31	Halladay, A. A.	NE.	10	22	5	470	58	2,034	1,564	1,976	....	C. Olmen	1923	....	282·6
32	Halladay, R.	SW.	12	23	6	505	80	2,084	1,579	2,004	45	C. Hopp	1929	....	....
33	Harley, G.	NE.	7	22	3	140	Flowing	1,912	1,772	....	....	C. Olmen	1916	....	....
34	Harris, P.	NW.	35	21	4	445	19	1,979	1,534	1,960	....	C. Olmen	1919	....	....
35	Harvey, E.	NE.	4	22	3	160	8	1,970	1,810	1,962	42	J. Foulston	1912	....	....
36	Hawkins, W.	SE.	33	20	3	425–440	Flowing	1,975	1,545	....	....	J. D. McNeely	1919	4½	....
37	Hill, E. J.	SE.	6	22	1	765	140±	2,110	1,345	1,970±	....	Adams	1920	....	....
38	Hudson, R.	NW.	36	21	7	382	36	2,026	1,644	1,990	....	C. Olmen	1927	....	....

List of Wells—Concluded

Serial No.	Name of owner	Location				Depth		Elevation of			Temperature of water, degrees F.	Driller	Year drilled	Yield in gallons a minute	Analysis total solids, grains a gallon
		West of 3rd meridian				Of well in feet	Surface to water, in feet	Surface, in feet	Top of water sand, in feet	Water-level, in feet					
		¼ Sec.	Sec.	Tp.	Range										
39	Jackson, N.	SE.	13	22	7	387	37	1,998	1,611	1,961	....	C. Olmen	1927	....	....
40	Johnson, R.	NE.	22	20	4	480	60	2,066	1,598	2,006	....	J. D. McNeely	....	....	....
42	Johnston, W. A.	NE.	35	22	6	640	100	2,139	1,499	2,039	....	Coleman	1916	....	....
43	Kent, T. A.	SE.	10	22	7	352	Flowing	1,963	1,611	1,965	....	C. Olmen	1925	⅛	....
44	Kent, W.	SW.	14	22	7	348	"	1,958	1,610	1,959	....	C. Olmen	1929	2	....
45	Kerr, Mrs. M.	NE.	32	20	4	527	104	2,088	1,561	1,984	....	C. Olmen	1915	....	....
46	Kinsman	SE.	28	24	7	410	160	1,889	1,491	1,729	....	Dom. Drillers	1927	....	150·6
47	Larson, E.	NW.	15	22	6	564	181	2,129	1,565	1,948	....	C. Olmen	1921	....	....
48	Lawson town	NW.	9	22	5	532	95	2,046	1,514	1,951	....	McLean	1916	....	137·4
49	Leslie, G. L.	NW.	13	21	4	....	....	1,978	....	....	....	R. Creelman	....	....	....
50	Lisell, O.	SW.	35	21	6	524	135	2,107	1,603	1,972	....	Collins	1914	....	....
51	McColl, D. T.	SE.	20	21	6	550	40	2,147	1,587	2,107	43	C. Olmen	....	....	....
52	McConnell, G.	NW.	27	21	5	640	180	2,127	1,537	1,947	....	Wheeler and Coleman	1915	....	....
53	McGillivray, S.	NW.	31	20	4	545	90	2,121	1,588	2,031	....	J. D. McNeely	1919	....	....
54	McGowan, J.	SE.	20	21	3	480?	Flowing	1,969	1,501	....	....	Collins	....	¼	....
55	McGregor, P.	SE.	15	20	5	400	120	2,165	1,765	2,045	....	Creelman and McNeely	1917	....	108·8
55A	McGregor, P.	SE.	15	20	5	507	....	....	1,765 1,658	....	....	....	....	....	....
56	McLachlan	SW.	20	21	5	517	100	2,115	1,598	2,015	....	Creelman	1919	....	....
57	McLaughlin Estate	SE.	1	20	2	1,050	60	1,984	946	1,924	....	J. D. McNeely	1920	....	....
58	McMillan, J. H.	NE.	29	20	4	520	75	2,099	1,609	2,024	46	R. Creelman	1922	....	....
59	Marjerison, J. A.	NW.	14	21	4	477	18	2,004	1,527	1,986	46½	R. Creelman	1922	....	....
60	Marshall	NE.	22	24	4	380	2½	1,912	1,532	1,909½	....	C. Olmen	1915	....	....
61	Marten, J.	NW.	24	22	2	564	50	1,887	1,337	1,837	43	R. Foulston	1919	....	495·8
62	Mawer, C.N.R.	SW.	5	21	3	392	Flowing	1,968	1,586	....	....	C. Olmen	1913	200	....
63	Mawer town	SW.	5	21	3	403	"	1,978	1,572	....	46	C. Olmen	1913	1½	....
64	Mess, H. B.	NE.	32	22	2	410	40	1,902	1,492	1,862	....	R. Creelman	....	....	....
65	Miller, P.	SE.	4	21	5	542	145	2,132	1,591	1,987	....	C. Olmen	1921	....	....
66	Moore, C. W.	SW.	21	22	4	420	48	1,974	1,554	1,926	....	C. Olmen	1920	....	....
67	Moore, H. J.	SW.	26	20	3	457	Flowing	1,967	1,522	....	....	J. D. McNeely	1926	36	113·8
68	Moore, W. J.	SE.	25	22	2	447	12	1,891	1,444	1,879	43	L. Adams	1920	....	....
69	Morrison, A.	SE.	25	21	4	419	Flowing	1,966	1,567	....	48	Collins	1916	1	....
70	Munroe, T. A.	SW.	8	21	3	435	"	1,971	1,548	....	47	J. D. McNeely	1913	1	....
71	Nelson, S.	NW.	12	22	4	460	"	1,920	1,460	....	....	R. Creelman	1914	⅛	....
72	Nicholson, R. G.	SW.	28	22	4	408	48	1,972	1,564	1,924	....	C. Olmen	1921	....	....
73	Olsen, C.	NW.	20	20	6	606	80	2,199	1,719	2,119	....	Collins	1918	....	....
74	Ouart, Theo.	NW.	32	20	4	528	106	2,100	1,593 1,572	1,994	....	C. Olmen and Trissel	1915	....	....

75	Perry, G..........	SE.	23	21	4	430	Flowing	1,978	1,560	1,978	....	R. Creelman and J. D. McNeely.	1922	1	....
76	Peterman, M........	NE.	18	20	3	425	"	1,989	1,576	....	48	J. D. McNeely....	1923	3	....
77	Pederson, G........	SE.	24	22	4	120	9	1,908	1,788	1,899	45	C. Olmen.........	1916	4	....
78	Pederson, F. G.....	NW.	32	21	3	418	Flowing	1,925	1,519	....	48	J. D. McNeely....	1917	1·2	....
79	Pollock, H..........	NW.	36	21	5	510	110	2,060	1,550	1,950	....	F. Hoyt..........	1916	....	....
80	Ratcliffe, W........	SE.	20	21	4	517	92	2,086	1,581	1,994	44	J. D. McNeely....	1915	....	....
81	Rehbein, I..........	NW.	2	20	4	476	50	2,068	1,604	2,018	46	J. D. McNeely....	1917	....	....
82	Richardson, F......	SE.	36	22	6	507	108	2,075	1,568	1,967	....	C. Hopp..........	1929	....	....
83	Ricketts, R.........	SE.	1	21	4	....	Flowing	1,987	....	....	49	J. D. McNeely....	....	½	....
84	Riverhurst town—														
	No. 1.............	NE.	26	22	7	386	27	1,953	1,567	1,926	....	C. Olmen.........	1926	....	....
	No. 2.............	NE.	26	22	7	406	....	....	....	....	....	....	....	....	....
85	Robertson, J........	SE.	24	21	6	297	240	2,181	1,884	1,941	43	C. Olmen.........	1918	....	....
86	Robinson, A........	NW.	1	21	6	400	60	2,072	1,672	2,012	....	Hartwick.........	1919	....	....
87	Rudd, N............	SE.	15	22	7	364	13	1,969	1,605	1,956	....	C. Olmen.........	1924	....	....
88	Slade Bros..........	NW.	8	22	5	480	70	2,056	1,576	1,986	47	Slade and Clark..	1911	....	....
89	Smith, Mrs. G. V...	SW.	16	23	1	512	48	1,904	1,392	1,856	....	Adams and Craik.	1919	....	424·4
90	Smith, J............	NW.	24	22	4	330	1	1,910	1,580	1,909	....	J. D. McNeely and C. Olmen.	1914	....	....
91	Stewart, R. R......	NE.	9	21	7	390	58	2,058	1,668	2,000	....	C. Olmen.........	1928	110·8	....
92	Stribble, L.........	NW.	33	22	2	414	25	1,898	1,484	1,873	44	R. Creelman......	1926	....	....
93	Voysey, A..........	NW.	18	22	3	312	2	1,918	1,606	1,916	43	C. Olmen.........	1920	....	....
94	Ward, A............	NE.	12	21	5	519	137 ft. 4 in.	2,120	1,601	1,982	....	....	....	....	....
95	Warren, F..........	SE.	3	22	4	435	27	1,976	1,541	1,949	43	R. Creelman......	1922	....	....
96	Watkins, S. R.......	NE.	30	20	3	435	Flowing	1,985	1,562	....	47	J. D. McNeely....	1919	1½	....
97	Westphal, O........	NE.	36	21	4	405	"	1,936	1,531	....	48	Westphal.........	1929	20	91·4
98	Wilson, J. B........	SE.	4	21	3	423	"	1,990	1,579	....	44	J. D. McNeely....	1928	2 at first	....
99	Wilson, J...........	SW.	6	21	4	554	100	2,114	1,560	2,014	....	R. Creelman......	1928	....	....
100	Young, G. V........	NE.	24	20	4	416	0·0	2,006	1,602	2,006	....	J. D. McNeely....	1919	½	....

DEEP BORINGS IN THE PRAIRIE PROVINCES

By W. A. Johnston

(Chief, Division of Pleistocene Geology, Water Supply, and Borings)

Collection of samples and records from wells drilled for oil, gas, and water was continued in 1931. Through an arrangement with the Department of Lands and Mines, of the Government of the Province of Alberta, samples and much information relative to well logs was received from the Petroleum and Natural Gas Division of that department. These samples numbered 12,853, only about one-half the number received in 1930, drilling operations having been greatly curtailed. Interest in the oil and gas possibilities of southern Alberta is still maintained, however, owing to the Sterling Pacific well in south Turner valley obtaining a good flow of wet gas, and to the interesting shows of crude oil obtained by the Hudson's Bay Oil and Gas Company in the Keho Lake well and Parco Oils No. 1 well at Twin River, 6 miles north of the International Boundary. Because of the interest in the boundary area the log of the Cameron Brook well in Waterton Lake area drilled in 1905 and of one other well west of Twin River and south of Cardston are given with this report. There is also considerable interest in the possibilities of the Cotton Belt well on Fisher creek.

In Saskatchewan, drilling for natural gas was done near East End, Herschel, Riverhurst, and Pilot Butte.

In Manitoba, the only deep test made was the Commonwealth No. 2 well in Pembina valley in the southern part of the province. This well has reached a depth of 1,090 feet and passed through the Dakota sandstone at 800 feet without finding any large supply of gas. It is proposed to continue the test to the Winnipeg sandstone which is estimated to lie at a depth of approximately 1,800 feet.

The results of ground water investigations in the area southeast of the elbow of the South Saskatchewan, by D. C. Maddox and R. T. D. Wickenden, are given in another part of this report. An investigation by R. T. D. Wickenden of the water possibilities in the Prairie River settlement in townships 46 and 47, ranges 13 to 15, southwest of Hudson Bay Junction, showed that deep drilling probably would result in the finding of salt water only, as wells to the southeast of the area indicated that the only water horizon at depth is the Dakota sandstone and that this contains saline water. Records of the water wells, furnished by the Canadian National and Canadian Pacific railways and by many drillers, have given information regarding ground water conditions in several areas that had not previously been tested. These results are given in Table I. A notable feature was the drilling of a well near Pleasant Valley, a few miles southwest of Melfort, Saskatchewan, which proved to be a flowing well that ran wild for some time. The general region is one in which it is difficult at many places to obtain good supplies of water by drilling, so that the occurrence is an interesting one. In many cases the presence of artesian water can be determined only by drilling, and records of successful wells such as this are of importance in indicating that other flowing wells probably can be obtained in the neighbourhood, although the extent of the artesian area may not be great. Such records, also, form valuable clues for the discovery of artesian basins in other areas and furnish information of value in directing future drilling in search of water. The necessity for the collection of records and their probable value in the future, especially in areas in which little is known regarding the ground water resources, is thus apparent.

Acknowledgments are due to officials of the Canadian Pacific and Canadian National railways and to well drillers and well owners, whose names are given in Table I, for co-operation in sending records of water wells.

The water wells at Bracken and Climax in southwestern Saskatchewan, in one of the driest parts of the province, furnished tests of a large area that had not previously been drilled. The driller's log of the Climax well is as follows:

	Feet
Topsoil	0- 40
Quicksand	40- 43
Blue shale (clay?)	43- 150
Gravel	150- 155
Blue shale	155- 870
Dry sand	870- 880
Blue shale	880- 990
Sandrock	990-1,005

The surface deposits, consisting of glacial drift, extend, probably, to 155 feet. The shale below is the Bearpaw and the sandrock probably Belly River. The water is soft and reported usable, but has to be pumped from a depth of 350 feet or somewhat more, the main water supply coming from the sandrock at the bottom of the well.

The Bracken well obtains its water from very fine sand at a depth of 608 feet. The water rises only to 450 feet from the surface. The yield is at least 3 gallons a minute, the capacity of the pump, but the water is too saline for human use.

The wells at Sceptre also are interesting, as the area is a difficult one in which to obtain good water. In the deeper well, water was obtained at three horizons, at 389 feet, at 500 to 600 feet, and at 695 feet. Analyses of these waters showed that the upper contained 197·6 grains of salts a gallon, the middle one 251·0 grains a gallon, and the lower one 193·0 grains a gallon, all being too salty for human use. The upper is a sodium sulphate water, the middle a sodium chloride water, and the lower is similar to the upper water. This well was plugged back to a depth of 389 feet and used solely as a cistern supply for horses and cattle. Another well, 206 feet, furnishes a supply of hard water for domestic use. A well drilled by the Canadian Pacific railway at Sceptre in 1917 was reported to have obtained a large supply of water at 198 feet in gravel at the base of the glacial drift.

Log of Western Oil and Fuel Company's Well (Drilled 1905), Sec. 23, Tp. 1, Range 30, W. 4th Mer., Cameron Brook, Southern Alberta

Standard drilling method. Samples examined by F. J. Fraser, 1931

Depth in feet	Lithology and colour	Notes
86	Shale, grey	
86- 639	Dolomite, grey and purple	
639- 646	" dark grey	Very siliceous
646- 677	" medium grey	"
677- 721	Shale, greenish grey	"
721- 730	" purple	"
730-1,205	Dolomite, light to dark grey	
1,205-1,208	Shale, medium grey	Yields oil by distillation
1,208-1,233	Dolomite, medium grey	
1,233-1,244	Shale, medium grey	
1,244-1,248	" light grey	
1,248-1,250	" medium grey	
1,250-1,256	" light grey	Slickensided
1,256-1,314	" medium grey	
1,314-1,325	" greenish grey	
1,325-1,356	" green	
1,356-1,365	" green-grey	
1,365-1,380	" light grey	
1,380-1,386	Sandstone, light grey	
1,386-1,394	Shale, green-grey	
1,394-1,431	Sandstone, light grey	
1,431-1,513	Shale, green-grey	
1,513-1,536	Sandstone, light grey	
1,536-1,577	" medium grey	
1,577-1,582	" dark grey	
1,582-1,597	" medium grey	
1,597-1,614	" brownish grey	
1,614-1,753	Shale, green-grey	Many slickensides

Two hundred and fifty-six samples taken at fairly regular intervals of a few feet were examined. The lithology of the samples has been deduced from texture, reaction to cold and hot acid, and micro-examination of insoluble residues. The samples recorded as dolomites are very fine grained, tough, and contain much silica. All samples contain carbonates. The samples recorded as sandstones are fine grained, and not easily distinguished from those recorded as shales. Micro-examination of the insoluble residues of the sandstones show dirty quartz, "cherty" grains with aggregate polarization, and in some cases fresh feldspar. The insoluble residues of the shales show a very dense material of indefinite character. The nature of the lower shale and sandstone samples is much obscured by slickensides.

It has long been known that Beltian (Precambrian) dolomites are overthrust on Cretaceous beds in Waterton Lake area in southern Alberta. The samples from the Cameron Brook well show this. Some of these samples were examined by R. A. Daly shortly after the well was drilled. He concluded that the samples from the lower part of the well are from Cretaceous, probably Benton, sediments[1]. Re-examination of the samples

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[1] Geol. Surv., Canada, Mem. 38, pp. 90 (1912).

has shown that the Beltian siliceous dolomite extends to 1,205 feet and occurs again at 1,208 to 1,233 feet, 3 feet of oil-shale intervening. The age of the oil-shale is not apparent, but it probably is much younger than the Beltian. The lower shales and sandstones do not resemble the Benton or Alberta shales, but do resemble the Crowsnest volcanics. G. S. Hume, who has examined the samples, agrees that they probably are of this age. The great number of samples showing slickensides shows that there has been considerable slicing of the lower beds by thrust faulting and it is possible that the volcanics are overthrust on younger beds.

Log of Boston Alberta Well, Sec. 5, Tp. 1, Range 25, W. 4th Mer.

Examined by F. J. Fraser and M. Mahoney

Depth in feet	Lithology and colour	Notes
20– 145	Sandstone, green-grey.........	Fine to medium grained, becoming shaly in lower part
145– 153	Shale, medium grey...........	
153– 293	Sandstone, green-grey.........	Medium to coarse grained
293– 350	Shale, green-grey.............	Reddish brown shale at 330 and 350 feet
350– 410	Sandstone, green-grey.........	Medium to coarse grained with shale at 400 feet
410– 450	Shale, green-grey.............	Coal fragments at 446 feet
450– 480	Sandstone, green-grey.........	
480– 510	Shale, green-grey.............	
510– 670	Sandstone, green-grey.........	Shale at 630 feet
670– 840	Sandy shale, green-grey.......	Sandstone at 700 feet
840– 920	Shale, dark grey..............	
920–1,390	Shale, very dark grey.........	Occasional fibrous calcite White calcite towards 1,390 feet
1,390–1,480	Sandstone, green-grey.........	Shale at 1,450 feet
1,480–1,510	Shale, “	Colour darkens at 1,510 feet
1,510–1,540	Sandstone, “	Shale at 1,530 feet
1,540–1,580	Shale, “	
1,580–1,610	Sandstone, “	Shaly towards 1,610 feet
1,610–1,720	Shale, “	
1,720–1,730	Sandstone, “	
1,730–1,750	Sandy shale, “	
1,750–1,760	Sandstone, “	
1,760–1,780	Shale, “	
1,780–1,800	Sandstone, “	
1,800–1,900	Sandy shale, “	
1,900–1,970	Sandstone, “	Shaly at 1,970 feet
1,970–1,990	Shale, “	
1,990–2,040	Sandstone, “	Shale at 2,030 feet
2,040–2,170	Shale, “	Brown shale at 2,070 and 2,150 to 2,170 feet
2,170–2,180	Shale, reddish brown.........	Mixed with green shale
2,180–2,270	Sandy shale, green- grey......	
2,270–2,290	Shaly sandstone, “	
2,290–2,600	Sandy shale, “	
2,600–2,610	Shaly sandstone, “	
2,610–2,750	Sandy shale, “	Sandstone at 2,640 and 2,660 feet
2,750–2,770	Sandstone, “	Fine grained
2,770–2,780	Shale, “	
2,780–2,790	Sandstone, “	Fine grained
2,790–2,870	Shale, “	Sandstone at 2,850 feet
2,870–2,930	Sandstone, “	Fine grained
2,930–3,070	Shale, “	Dark grey shale at 2,980 to 2,990 feet
3,070–3,100	Shale, dark grey.............	Mixed with green-grey shale
3,100–3,310	Shale, green-grey............	Sandy from 3,190 feet
3,310–3,330	Sandstone, “	Fine grained
3,330–3,340	Sandy shale, “	

The Boston Alberta well appears to have started in the Belly River beds, to have passed through a part of the Alberta (Benton) shales from 840 to 1,390 feet, and to have continued in Belly River beds to the bottom. Examination of the samples by R. T. D. Wickenden showed that the shale samples between 850 and 1,390 feet contain foraminifera similar to those that occur in the Upper Alberta shales of Red Coulée area. No typical Bearpaw species were found. The high degree of induration and the lithology also suggest that the shales are Upper Alberta in age. The dark shale at about 3,000 feet is readily disintegrated. It contains chara seeds and this suggests a freshwater origin and that it is part of the Belly River. Only parts of this formation appear to be represented; there probably is duplication by folding and thrust faulting. The sandstones and shales in the upper part of the well, down to 840 feet, probably are Belly River rather than St. Mary River as they are only slightly calcareous.

TABLE I

Water Wells, Records Received, 1931

Owner	¼ Sec.	Sec.	Tp.	Range	Mer.	Province	At or near	Depth in feet covered by records	Depth to bedrock Feet	Depth from surface to water Feet	Driller	Remarks
Smith, W. A.	....	15	18	9	1st	Manitoba	Amaranth	114	106	....	W. A. Smith	Water hard
Hogarth, M. E.	....	7	15	2	2nd	Saskatchewan	Whitewood	166	....	80	W. E. Clark	
Fraser, Colin	....	35?	19	15	"	"	Edgeley	550	....	30	"	Some water at 150 feet
Muscouquan Indian school	....	14	27	15	"	"	Lestock	225	....	28	S. Dempsey	A little water at 91 feet
Lemon, Ben	NE.	20	20	18	"	"	Zehner	252	....	157	"	Water hard
Can. Nat. rys	....	7	45	18	"	"	Melfort	246	....	....	A. Mainville	Water salty
Coombs, Jack	SE.	14	44	20	"	"	Pleasant Valley	154	....	Flow	S. Dempsey	Water hard
Downie, Bill	SW.	18	44	20	"	"	Ethelton	145	....	8	"	"
Can. Nat. rys	SE.	14	44	21A	"	"	"	236	....	114	Rahrick and Mainville	Stockyard well
"	SE.	14	44	21A	"	"	"	400	....	....	" "	Section House well
"	NE.	11	44	22	"	"	Meskanaw	450	175	....	" "	" "
"	NE.	11	44	22	"	"	"	600	205	....	" "	Stockyard well
"	NW.	11	43	23	"	"	Tarnopol	136	....	13	" "	"
Svendson, Sven	NE.	24	46	23	"	"	Weldon	80	....	4	....	Water hard, salty
Can. Nat. rys	SE.	19	42	24	"	"	Reynaud	206	....	50	Rahrick and Mainville	Stockyard well
"	SE.	19	42	24	"	"	"	264	120	127	"	Station well
Can. Pac. ry	....	29	17	5	3rd	"	Chaplin	675	....	70	....	Water very hard
"	....	23	28	5	"	"	Hawarden	148	....	....	....	
" No. 2	NE.	15	9	7	"	"	Vanguard-Meyronne Branch	200	138	....	....	Dry gravel 136 to 138 feet
" No. 3	NW.	4	10	7	"	"	" "	229	162	....	....	
" No. 1	SE.	9	10	7	"	"	" "	200	22	....	....	Water very hard
—	SE.	9	17	8	"	"	Morse	197	....	54	S. Dempsey	Water hard
Hubble, James H.	NE.	32	29	11	"	"	Milden	490	....	100	C. Fortier	Water soft
Uptigrove, J. E.	NE.	6	29	12	"	"	Sovereign	247	....	....	Dom. Drilling Co.	Water hard
Haddington Farms, Ltd.	SW.	23	29	12	"	"	"	320	....	....	P. Head	"
Whyte, R. O.	SE.	10	28	13	"	"	Glamis	228	200	72	Mr. Larson	"
Waite, A. G.	SE.	14	28	13	"	"	Sovereign	256	....	50	Dom. Drilling Co.	Water alkaline
Laurence, J. D.	NW.	32	28	13	"	"	"	256	....	40	"	Water hard
Barber, G. N.	NE.	35	28	13	"	"	"	360	....	100	C. Fortier	Water contains iron
Billet, C. W.	NW.	24	29	13	"	"	"	246	....	100	"	Water hard

Water Wells, Records Received, 1931—Concluded

Owner	¼ Sec.	Sec.	Tp.	Range	Mer.	Province	At or near	Depth in feet covered by records	Depth to bedrock Feet	Depth from surface to water Feet	'Driller	Remarks
Can. Nat. rys.	NW.	9	48	14	3rd	Saskatchewan	Sandwich	231	....	105	J. D. Cayle	Water hard
"	NW.	9	48	14	"	"	"	182	....	95	"	"
"	SW.	28	49	14	"	"	Glenbush	107	....	70	"	Stockyard well
"	NW.	28	49	14	"	"	"	111	....	75	"	Section House well
"	NE.	19	46	15	"	"	Iffley	132	....	....	"	Stockyard well
"	NE.	36	46	15	"	"	Hatherleigh	102	....	30	"	
Bracken	SE.	3	3	16	"	"	Bracken	608	....	450	S. O. Bingston	Water for stock and washing
Can. Nat. rys.	NW.	10	46	16	"	"	Hamlin	500	....	....	J. D. Cayle	Section House well Dry hole
"	NW.	10	46	16	"	"	"	283	....	30	"	Stockyard well
"	NW.	10	46	16	"	"	"	197	....	45	"	Section House No. 2
Climax village	SW.	17	3	18	"	"	Climax	1,005	....	650	S. O. Bingston	Water soft
Sceptre village	....	9	22	24	"	"	Sceptre	206	....	....	....	Water hard
"	....	9	22	24	"	"	"	779	....	....	....	Water at 389 feet, 500 to 600 feet, 695 feet

OTHER FIELD WORK

Geological

B. R. MacKay. Mr. MacKay made a detailed geological survey of the coal mining area at Hillcrest, Alberta. Information regarding the geological conditions affecting mining operations were supplied to the operating companies as the field work progressed. The companies have been supplied with hand-coloured copies of the geological maps and sections, and celluloid models showing the geological structure in three dimensions. A full report, now in course of preparation, is expected to be ready for publication in the Summary Report for 1932, or in separate form.

L. S. Russell. Mr. Russell remapped and restudied parts of the Calgary 8-mile map-area, Alberta. The results will be incorporated into a second edition of the Calgary sheet. A report is also being written.

R. T. D. Wickenden. Mr. Wickenden continued the study and mapping of the surface geology, including the soils, of the Regina 8-mile map-area (latitudes 49° to 52°; longitudes 102° to 109°), Saskatchewan. Further field work is required before a surface-geology edition of the Regina sheet can be published.

F. H. McLearn. Mr. McLearn completed the study and mapping of the bedrock geology of the Regina 8-mile map-area, Saskatchewan. The results will be issued in the form of a joint memoir by F. H. McLearn and P. S. Warren, dealing with their field work since 1928, a geological map (Regina sheet) on a scale of 1 inch to 8 miles, similar in character to the published Calgary sheet adjoining it on the west, and a sheet of geological sections representing the underground succession and structure.

S. R. Kirk. Mr. Kirk completed the study and mapping of the bedrock geology of the western part of the Winnipeg 8-mile map-area (latitudes 49° to 52°; longitudes 95° to 102°), Manitoba. A memoir, an 8-mile geological map (Winnipeg sheet), and a sheet of geological sections, similar to those above mentioned, by McLearn and Warren, are being prepared.

Topographical

A. C. Tuttle. Mr. Tuttle made a topographical survey of the Crowsnest 1-mile quadrangle (latitudes 49° 30′ to 49° 45′, longitudes 114° 30′ to 115°), Alberta and British Columbia. A 1-mile topographical map is being prepared for general map purposes and as a basis for geological work.

S. M. Steeves. Mr. Steeves completed the topographical survey of the Nordegg 1-mile quadrangle (latitudes 52° 15′ to 52° 30′; longitudes 116° to 116° 30′), Alberta. He also commenced the topographical survey of the Blackstone 1-mile quadrangle (latitudes 52° 30′ to 52° 45°; longitudes 116° to 116° 30′), Alberta. A 1-mile topographical sheet of the Nordegg quadrangle is being prepared.

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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 four parts, A, B, C, and D. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.